U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*

NUREG-1437, Volume 1
Revision 2

# Generic Environmental Impact Statement for License Renewal of Nuclear Plants

# Main Report

# Chapters 1 - 8

Draft Report for Comment

Office of Nuclear Material Safety and Safeguards

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## Draft Report for Comment

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Office of Nuclear Material Safety and Safeguards

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**Mail comments to:** Office of Administration, Mail Stop: TWFN-7-A60M, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001, ATTN: Division of Resource Management and Analysis.

For any questions about the material in this report, please contact: Jennifer Davis, Senior Environmental Project Manager, or Kevin Folk, Senior Environmental Project Manager, at 1-800-368-5642, extension 3835 or 6944 (respectively), or by e-mail at LicenseRenewalGEIS@nrc.gov.

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**Responsible Agency:** U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards

**Title**: Draft *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (NUREG-1437) Volumes 1 and 2, Revision 2

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# ABSTRACT

U.S. Nuclear Regulatory Commission (NRC) regulations allow for the renewal of commercial nuclear power plant operating licenses. There are no specific limitations in the Atomic Energy Act or the NRC's regulations restricting the number of times a license may be renewed. To support license renewal environmental reviews, the NRC published the first *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (LR GEIS) in 1996. Per NRC regulations, a review and update of the LR GEIS is conducted every 10 years, if necessary. The proposed action is the renewal of nuclear power plant operating licenses.

Since publication of the 1996 LR GEIS, 58 nuclear power plants (96 reactor units) have undergone license renewal environmental reviews and have received renewed licenses, the results of which were published as supplements to the LR GEIS. This revision evaluates the issues and findings of the 2013 LR GEIS (Revision 1). Lessons learned and knowledge gained from initial and subsequent license renewal environmental reviews provide major sources of new information for this assessment. In addition, new research, findings, public comments, changes in applicable laws and regulations, and other information were considered in evaluating the environmental impacts associated with license renewal. Additionally, this revision fully considers and evaluates the environmental impacts of subsequent license renewal as well as initial license renewal.

The purpose of the LR GEIS is to identify and evaluate environmental issues that could result in the same or similar impact at all nuclear power plants (or a distinct subset of plants) (i.e., generic issues) and determine which issues could result in different levels of impact, thus requiring nuclear power plant-specific environmental analyses for impact determination. The NRC has identified a total of 80 environmental issues for consideration in license renewal reviews, 59 of which have been evaluated in the LR GEIS and their impacts determined to be

applicable to license renewal for all nuclear power plants or a subset of plants. The LR GEIS also discusses a range of reasonable alternatives to the proposed action (initial license renewal or subsequent license renewal), which would be analyzed in detail in plant-specific supplements to the LR GEIS.

**Paperwork Reduction Act Statement**

This NUREG provides voluntary guidance for implementing the mandatory information collections in 10 CFR Part 51 that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.). These information collections were approved by the Office of Management and Budget (OMB) under control number 3150-0021. Send comments regarding these information collections to the FOIA, Library, and Information Collections Branch (T6A10M), U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001, or by email to Infocollects.Resource@nrc.gov, and to the OMB reviewer at: OMB Office of Information and Regulatory Affairs (3150-0021). Attn: Desk Officer for the Nuclear Regulatory Commission, 725 17th Street NW, Washington, DC 20503; email: oira_submission@omb.eop.gov.

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# ACRONYMS, ABBREVIATIONS, AND CHEMICAL NOMENCLATURE

| | |
|---|---|
| °C | degree(s) Celsius |
| °F | degree(s) Fahrenheit |
| ac | acre(s) |
| ADAMS | Agencywide Documents Access and Management System |
| AEA | Atomic Energy Act |
| AEC | U.S. Atomic Energy Commission |
| ALARA | as low as is reasonably achievable |
| APE | area of potential effect |
| BCG | Biota Concentration Guide |
| BEIR | Biological Effects of Ionizing Radiation (National Research Council Committee) |
| BMP | best management practice |
| BTA | best technology available |
| Btu | British thermal unit(s) |
| BWR | boiling water reactor |
| CAA | Clean Air Act |
| CCS | cooling canal system |
| CDC | Centers for Disease Control and Prevention |
| CDF | core damage frequency |
| CEQ | Council on Environmental Quality |
| CFR | *Code of Federal Regulations* |
| $CH_4$ | methane |
| cm | centimeter(s) |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| $CO_2e$ | carbon dioxide equivalent |
| CWA | Clean Water Act |
| dB | decibel(s) |
| dBA | A-weighted decibel(s) |
| DOE | U.S. Department of Energy |
| DPS | distinct population segment |
| EFH | essential fish habitat |
| EI | exposure index |
| EIA | Energy Information Administration |
| EIS | environmental impact statement |
| EMF | electromagnetic field |
| EPA | U.S. Environmental Protection Agency |
| ESA | Endangered Species Act |

| | |
|---|---|
| ESP | early site permit |
| Exelon | Exelon Generating Company LLC |
| | |
| F | Fujita (scale) |
| FCDF | fire core damage frequency |
| FES | final environmental statement |
| FLEX | flexible coping |
| FPRA | fire probabilistic risk assessment |
| FR | *Federal Register* |
| ft | foot (feet) |
| $ft^2$ | square foot (feet) |
| $ft^3$ | cubic foot (feet) |
| FWS | U.S. Fish and Wildlife Service |
| | |
| gal | gallon(s) |
| GEIS | generic environmental impact statement |
| GHG | greenhouse gas |
| gpm | gallon(s) per minute |
| GWd | gigawatt day(s) |
| GWd/MT | Gigawatt-days (units of energy) per metric tonne |
| Gy | gray(s) |
| | |
| $H_2O$ | water; water vapor |
| ha | hectare(s) |
| hr | hour(s) |
| Hz | hertz |
| | |
| IAEA | International Atomic Energy Agency |
| ICRP | International Commission on Radiological Protection |
| | |
| IM&E | impingement mortality and entrainment |
| in. | inch(es) |
| IPE | Individual Plant Examination |
| IPEEE | Individual Plant Examination of External Events |
| ISFSI | independent spent fuel storage installation |
| ITS | incidental take statement |
| | |
| Kd | partition coefficient |
| kg | kilogram(s) |
| km | kilometer(s) |
| kV | kilovolt(s) |
| kW | kilowatt(s) |
| kWh | kilowatt-hour(s) |
| | |
| L | liter(s) |
| LAR | license amendment request |

| | |
|---|---|
| lb | pound(s) |
| LCF | latent cancer fatality |
| LERF | large early release frequency |
| LLW | low-level (radioactive) waste |
| Ln | statistical sound level |
| LNT | linear no-threshold |
| LOA | letter of authorization |
| LOCA | loss-of-coolant accident |
| LOEL | lowest observed effects level |
| lpm | liter(s) per minute |
| LR GEIS | *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* |
| LWR | light water reactor |
| m | meter(s) |
| $m^2$ | square meter(s) |
| $m^3$ | cubic meter(s) |
| $m^3/s$ | cubic meter(s) per second |
| mA | milliampere(s) |
| MACCS | MELCOR Accident Consequence Code System |
| MCR | main cooling reservoir |
| MEI | maximally exposed individual |
| mG | milligauss |
| mg | milligram(s) |
| mg/L | milligram(s) per liter |
| Mgd | million gallons per day |
| mGy | milligray(s) |
| MHz | megahertz |
| mi | mile(s) |
| min | minute(s) |
| mL | milliliter(s) |
| MLd | million liters per day |
| MMBtu | million Btu |
| MPa | megapascal(s) |
| mph | mile(s) per hour |
| mrad | milliard(s) |
| mrem | millirem(s) |
| MSA | Magnuson-Stevens Fishery Conservation and Management Act |
| mSv | millisievert(s) |
| MT | metric tonne(s) |
| mT | millitesla(s) |
| MTHM | metric tonne(s) of heavy metal |
| MTU | metric tonne(s) of uranium |
| MW | megawatt(s) |
| MW(e) | megawatt(s) electric |
| MW(t) | megawatt(s) thermal |

| | |
|---|---|
| MWh | megawatt-hour(s) |
| NAAQS | National Ambient Air Quality Standards |
| NEPA | National Environmental Policy Act of 1969 |
| NGCC | natural gas combined cycle |
| NHPA | National Historic Preservation Act of 1966 |
| NMFS | National Marine Fisheries Service |
| NMSA | National Marine Sanctuaries Act |
| NO | nitrogen oxide |
| $NO_2$ | nitrogen dioxide |
| NOAA | National Oceanic and Atmospheric Administration |
| $NO_x$ | nitrogen oxides |
| NPDES | National Pollutant Discharge Elimination System |
| NRC | U.S. Nuclear Regulatory Commission |
| NREL | National Renewable Energy Laboratory |
| NRHP | National Register of Historic Places |
| NTTF | Near-Term Task Force |
| | |
| ODCM | Offsite Dose Calculation Manual |
| ONMS | Office of National Marine Sanctuaries |
| OSHA | Occupational Safety and Health Administration |
| | |
| pCi | picocurie(s) |
| pCi/L | picocuries per liter |
| PDR | Population dose risk |
| PM | particulate matter |
| $PM_{10}$ | particulate matter with a mean aerodynamic diameter of 10 μm or less |
| $PM_{2.5}$ | particulate matter with a mean aerodynamic diameter of 2.5 μm or less |
| ppm | part(s) per million |
| ppmv | parts per million by volume |
| ppt | part(s) per thousand |
| PRA | probabilistic risk assessment |
| PSD | prevention of significant deterioration |
| psi | pound(s) per square inch |
| PWR | pressurized water reactor |
| | |
| QHO | quantitative health objective |
| | |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| rem | roentgen-equivalent-man |
| REMP | Radiological Environmental Monitoring Program |
| ROW | right-of-way |
| | |
| s | second(s) |
| SAMA | severe accident mitigation alternative |
| SAMG | severe accident management guideline |
| SCDF | seismic core damage frequency |

| | |
|---|---|
| scf | standard cubic foot (feet) |
| SEIS | supplemental environmental impact statement |
| SFP | spent fuel pool |
| SGTR | steam generator tube rupture |
| SHPO | State Historic Preservation Office or Officer |
| SLR | subsequent license renewal |
| $SO_2$ | sulfur dioxide |
| SOARCA | state-of-the-art reactor consequence analysis |
| SPRA | seismic probabilistic risk assessment |
| SRM | Staff Requirements Memorandum |
| Sv | sievert(s) |
| TEDE | total effective dose equivalent |
| T/yr | ton (s) per year |
| UA | uncertainty analysis |
| UCB | upper confidence bound |
| $UF_6$ | uranium hexafluoride |
| USACE | U.S. Army Corps of Engineers |
| USGCRP | U.S. Global Change Research Program |
| VOC | volatile organic compound |
| yr | year(s) |
| µCi | microcurie(s) |
| µGy | microgray(s) |

# SHORTENED NUCLEAR POWER PLANT NAMES USED IN THIS REPORT

| | |
|---|---|
| Arkansas | Arkansas Nuclear One |
| Beaver Valley | Beaver Valley Power Station |
| Braidwood | Braidwood Station |
| Browns Ferry | Browns Ferry Nuclear Plant |
| Brunswick | Brunswick Steam Electric Plant |
| Byron | Byron Station |
| Callaway | Callaway Plant |
| Calvert Cliffs | Calvert Cliffs Nuclear Power Plant |
| Catawba | Catawba Nuclear Station |
| Clinton | Clinton Power Station |
| Columbia | Columbia Generating Station |
| Comanche Peak | Comanche Peak Steam Electric Station |
| Cooper | Cooper Nuclear Station |
| Crystal River | Crystal River Nuclear Power Plant |
| Davis-Besse | Davis-Besse Nuclear Power Station |
| Diablo Canyon | Diablo Canyon Power Plant |
| D.C. Cook | Donald C. Cook Nuclear Plant |
| Dresden | Dresden Nuclear Power Station |
| Duane Arnold | Duane Arnold Energy Center |
| Farley | Joseph M. Farley Nuclear Plant |
| Fermi | Enrico Fermi Atomic Power Plant |
| FitzPatrick | James A. FitzPatrick Nuclear Power Plant |
| Fort Calhoun | Fort Calhoun Station |
| Ginna | R.E. Ginna Nuclear Power Plant |
| Grand Gulf | Grand Gulf Nuclear Station |
| Harris | Shearon Harris Nuclear Power Plant |
| Hatch | Edwin I. Hatch Nuclear Plant |
| Hope Creek | Hope Creek Generating Station |
| Indian Point | Indian Point Energy Center |
| Kewaunee | Kewaunee Power Station |
| LaSalle | LaSalle County Station |
| Limerick | Limerick Generating Station |
| McGuire | McGuire Nuclear Station |
| Millstone | Millstone Power Station |
| Monticello | Monticello Nuclear Generating Plant |
| Nine Mile Point | Nine Mile Point Nuclear Station |
| North Anna | North Anna Power Station |
| Oconee | Oconee Nuclear Station |
| Oyster Creek | Oyster Creek Nuclear Generating Station |
| Palisades | Palisades Nuclear Plant |
| Palo Verde | Palo Verde Nuclear Generating Station |
| Peach Bottom | Peach Bottom Atomic Power Station |

Shortened Nuclear Power Plant Names Used In This Report

| | |
|---|---|
| Perry | Perry Nuclear Power Plant |
| Pilgrim | Pilgrim Nuclear Power Station |
| Point Beach | Point Beach Nuclear Plant |
| Prairie Island | Prairie Island Nuclear Generating Plant |
| Quad Cities | Quad Cities Nuclear Power Station |
| River Bend | River Bend Station |
| Robinson | H.B. Robinson Steam Electric Plant |
| St. Lucie | St. Lucie Nuclear Plant |
| Salem | Salem Nuclear Generating Station |
| San Onofre | San Onofre Nuclear Generating Station |
| Seabrook | Seabrook Station |
| Sequoyah | Sequoyah Nuclear Plant |
| South Texas | South Texas Project Electric Generating Station |
| Summer | Virgil C. Summer Nuclear Station |
| Surry | Surry Power Station |
| Susquehanna | Susquehanna Steam Electric Station |
| Three Mile Island | Three Mile Island, Unit 1 |
| Turkey Point | Turkey Point Nuclear Plant |
| Vermont Yankee | Vermont Yankee Nuclear Power Station |
| Vogtle | Vogtle Electric Generating Plant |
| Waterford | Waterford Steam Electric Station |
| Watts Bar | Watts Bar Nuclear Plant |
| Wolf Creek | Wolf Creek Generating Station |

# CONVERSION TABLE

| Multiply | By | To Obtain |
|---|---|---|
| ***To Convert English to Metric Equivalents*** | | |
| acres | 0.4047 | hectares (ha) |
| cubic feet (ft$^3$) | 0.02832 | cubic meters (m$^3$) |
| cubic yards (yd$^3$) | 0.7646 | cubic meters (m$^3$) |
| curies (Ci) | $3.7 \times 10^{10}$ | becquerels (Bq) |
| degrees Fahrenheit (°F) -32 | 0.5555 | degrees Celsius (°C) |
| feet (ft) | 0.3048 | meters (m) |
| gallons (gal) | 3.785 | liters (L) |
| gallons (gal) | 0.003785 | cubic meters (m$^3$) |
| inches (in.) | 2.540 | centimeters (cm) |
| miles (mi) | 1.609 | kilometers (km) |
| pounds (lb) | 0.4536 | kilograms (kg) |
| rads | 0.01 | grays (Gy) |
| rems | 0.01 | sieverts (Sv) |
| short tons (tons) | 907.2 | kilograms (kg) |
| short tons (tons) | 0.9072 | metric tons (t) |
| square feet (ft$^2$) | 0.09290 | square meters (m$^2$) |
| square yards (yd$^2$) | 0.8361 | square meters (m$^2$) |
| square miles (mi$^2$) | 2.590 | square kilometers (km$^2$) |
| yards (yd) | 0.9144 | meters (m) |
| ***To Convert Metric to English Equivalents*** | | |
| becquerels (Bq) | $2.7 \times 10^{-11}$ | curies (Ci) |
| centimeters (cm) | 0.3937 | inches (in.) |
| cubic meters (m$^3$) | 35.31 | cubic feet (ft$^3$) |
| cubic meters (m$^3$) | 1.308 | cubic yards (yd$^3$) |
| cubic meters (m$^3$) | 264.2 | gallons (gal) |
| degrees Celsius (°C) +17.78 | 1.8 | degrees Fahrenheit (°F) |
| grays (Gy) | 100 | rads |
| hectares (ha) | 2.471 | acres |
| kilograms (kg) | 2.205 | pounds (lb) |
| kilograms (kg) | 0.001102 | short tons (tons) |
| kilometers (km) | 0.6214 | miles (mi) |
| liters (L) | 0.2642 | gallons (gal) |
| meters (m) | 3.281 | feet (ft) |
| meters (m) | 1.094 | yards (yd) |
| metric tons (t) | 1.102 | short tons (tons) |
| sieverts (Sv) | 100 | rems |
| square kilometers (km$^2$) | 0.3861 | square miles (mi$^2$) |
| square meters (m$^2$) | 10.76 | square feet (ft$^2$) |
| square meters (m$^2$) | 1.196 | square yards (yd$^2$) |

# EXECUTIVE SUMMARY

The Atomic Energy Act of 1954 authorizes the U.S. Nuclear Regulatory Commission (NRC) to issue commercial nuclear power plant operating licenses for up to 40 years and permits the renewal of these licenses. By regulation, the NRC is allowed to renew these operating licenses for up to an additional 20 years, depending on the outcome of the safety and environmental reviews. There are no specific limitations in the Atomic Energy Act or the NRC's regulations restricting the number of times a license may be renewed.

NRC regulations in Title 10 of the *Code of Federal Regulations* Section 54.17(c) (10 CFR 54.17(c)) allow a license renewal application to be submitted within 20 years of license expiration, and NRC regulations at 10 CFR 54.31(b) specify that a renewed license will be for a term of up to 20 years plus the length of time remaining on the current license. As a result, renewed licenses may be for a term of up to 40 years.

The license renewal process is designed to ensure safe operation of the nuclear power plant and protection of the environment during the license renewal term. Under the NRC's environmental protection regulations in 10 CFR Part 51, which implements Section 102(2) of the National Environmental Policy Act (NEPA), the renewal of a nuclear power plant operating license requires an analysis of the environmental effects of the action and the preparation of an environmental impact statement (EIS).

To support the preparation of license renewal EISs, the NRC conducted a comprehensive review to identify the environmental effects of license renewal. The review determined which environmental effects could result in the same or similar (generic) impact at all nuclear power plants or a subset of plants and which effects could result in different levels of impact, requiring nuclear power plant-specific analyses for an impact determination. The review culminated in the issuance of the *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (LR GEIS), NUREG-1437, in May 1996, followed by the publication of the final rule that codified the LR GEIS findings on June 5, 1996 (61 *Federal Register* [FR] 28467).[1]

The LR GEIS[2] improved the efficiency of the license renewal environmental review process by (1) identifying and evaluating all of the environmental effects that may occur when renewing commercial nuclear power plant operating licenses, (2) identifying and evaluating the environmental effects that are expected to be generic (the same or similar) at all nuclear plants or a subset of plants, and (3) defining the number and scope of the environmental effects that need to be addressed in nuclear power plant-specific EISs. For the issues that cannot be evaluated generically, the NRC conducts nuclear power plant-specific (hereafter called plant-specific) environmental reviews and prepares plant-specific supplemental EISs (SEISs) to the LR GEIS. The generic environmental findings in the LR GEIS are applicable to the 20-year license renewal increment plus the number of years remaining on the current license, up to a maximum of 40 years, irrespective of the prior number of years of reactor operation (e.g., 40 years, 60 years, 80 years, etc.).

[1] Final rules were also issued in December 18, 1996 (61 FR 66537), and September 3, 1999 (64 FR 48496).
[2] Any reference to the 1996 LR GEIS includes the two-volume set published in May 1996 and Addendum 1 to the LR GEIS published in August 1999.

The 1996 final rule codified the findings of the 1996 LR GEIS into regulations at 10 CFR Part 51, Appendix B to Subpart A, "Environmental Effect of Renewing the Operating License of a Nuclear Power Plant," and Table B-1, "Summary of Findings on NEPA Issues for License Renewal of Nuclear Power Plants" (61 FR 28467, June 5, 1996). As stated in the final rule, the Commission recognized that environmental issues might change over time and that additional issues may need to be considered. Based on this recognition, and as further stated in the rule and in the introductory paragraph to Appendix B to Subpart A in Part 51 of the regulations, the Commission intends to review the material in Appendix B, including Table B-1 and the underlying LR GEIS, on a 10-year basis, and update it if necessary.

Subsequently, the NRC completed its first 10-year review of the 1996 LR GEIS and Table B-1 on June 20, 2013. That review of the LR GEIS considered lessons learned and knowledge gained from completed license renewal environmental reviews since 1996. The updated LR GEIS, Revision 1, and final rule (78 FR 37282), including Table B-1, redefined the number and scope of the NEPA issues that must be addressed in license renewal environmental reviews.

The NRC began the second 10-year review on August 4, 2020, by publishing a notice of intent to review and potentially update the LR GEIS (85 FR 47252), which contained the staff's preliminary analysis, including for subsequent license renewal. The notice invited public comments and proposals for specific environmental areas that should be updated. Pursuant to 10 CFR 51.29, the NRC conducted scoping and held a series of public meetings (see 85 FR 47252 for more details). The scoping period concluded on November 2, 2020.

In July 2021, the NRC staff submitted a rulemaking plan via SECY-21-0066 requesting Commission approval to initiate a rulemaking to amend Table B-1 and update the LR GEIS and associated guidance. In February 2022, the Commission issued Staff Requirements Memorandum (SRM)-SECY-21-0066, disapproving the staff's recommendation and directing the staff to develop a rulemaking plan that aligned with the Commission's adjudicatory Order CLI-22-03, and recent decisions in Orders CLI-22-02 and CLI-22-04, which concluded that the 2013 GEIS did not apply to subsequent license renewal (SLR) applications. The SRM also directed the NRC staff to include in the rulemaking plan a proposal to revise the LR GEIS, Table B-1, other regulations, and associated guidance, to fully support SLR.

The NRC staff submitted a revised rulemaking plan via SECY-22-0024 in March 2022 that requested Commission approval to initiate a rulemaking that aligned with the Commission's Order CLI-22-03 and recent decisions in Orders CLI-22-02 and CLI-22-04 regarding the NEPA analysis of SLR applications by updating NRC regulations and revising the LR GEIS, Table B-1, and associated guidance to fully support SLR. In April 2022, the Commission issued SRM-SECY-22-0024 approving the staff's recommendation to proceed with the rulemaking.

In April 2022, pursuant to SRM-SECY-21-0066, the staff also submitted a second paper to the Commission, SECY-22-0036, which concluded that no further updates to the LR GEIS were needed beyond those identified in SECY-22-0024 and that the rulemaking effort identified in SECY-22-0024 should constitute the agency's 10-year update to the LR GEIS. In June 2022, the Commission approved these recommendations in SRM-SECY-22-0036.

The proposed revisions to the LR GEIS are based on the consideration of (1) comments received from the public during the public scoping period, (2) a review of comments received on plant-specific SEISs, and (3) lessons learned and knowledge gained from previously completed and ongoing initial license renewal (initial LR) and SLR environmental reviews, (4) and Commission direction in SRM-SECY-22-0024. In addition, new scientific research, public comments, changes in environmental regulations and impacts methodology, and other new information were considered in evaluating the potential impacts associated with nuclear power plant continued operations and refurbishment during the license renewal term (initial LR or SLR).

Since development of the 2013 LR GEIS, 15 nuclear power plants have undergone initial LR environmental reviews. For the purposes of this review, the NRC also considered five SLR environmental reviews, including two environmental reviews (i.e., for North Anna and Point Beach plants) for which the NRC has issued a draft SEIS, but not a final SEIS. The purpose of the review for this LR GEIS is to determine if the findings presented in the 2013 LR GEIS remain valid for initial LR and support the scope of license renewal, consider whether those findings also apply to SLR, and to update or revise those findings as appropriate. When conducting a thorough update to the LR GEIS that reflects the “hard look” that is required for a NEPA document, the NRC considered changes in applicable laws and regulations, new data, collective experience, and lessons learned and knowledge gained from conducting initial LR and SLR environmental reviews since development of the 2013 LR GEIS. These developments and practical insights informed this LR GEIS revision. In doing so, the NRC considered the need to modify, add to, group, subdivide, or delete any of the 78 environmental issues evaluated in the 2013 LR GEIS.

## S.1 Purpose and Need for the Proposed Action

The proposed action is the renewal of commercial nuclear power plant operating licenses. A renewed license is just one of a number of conditions that licensees must meet to be allowed to continue to operate the nuclear power plant during the renewal term.

The purpose and need for the proposed action (license renewal) is to provide an option for the continued operation of the nuclear power plant beyond the current licensing term to meet future system power-generation needs, as such needs may be determined by State, utility, system, and, where authorized, Federal (other than NRC) decisionmakers. Unless there are findings in the safety review required by the Atomic Energy Act or in the NEPA environmental review that would lead the NRC to not renew the operating license, the NRC has no role in the energy-planning decisions of power plant owners, State regulators, system operators, and, in some cases, other Federal agencies as to whether the nuclear power plant should continue to operate.

In addition, the NRC has no authority or regulatory control over the ultimate selection of replacement energy alternatives. The NRC also cannot ensure the selection of environmentally preferable replacement power alternatives. While a range of reasonable replacement energy alternatives are discussed in the LR GEIS, and evaluated in detail in plant-specific supplements to the LR GEIS, the only alternative to license renewal within NRC’s decisionmaking authority is to not renew the operating license. The environmental impacts of not renewing the operating license are addressed under the no action alternative.

At some point, all nuclear power plants will terminate reactor operations and begin the decommissioning process. Under the no action alternative, reactor operations would be terminated at or before the end of the current operating license. The no action alternative, unlike the other alternatives, does not expressly meet the purpose and need of the proposed action (license renewal), because it does not provide an option for energy-planning decisionmakers in meeting future electric power system needs. No action, on its own, would likely create a need for replacement power, energy conservation and efficiency (demand-side management), purchasing power from outside the region, or some combination of these options. Thus, a range of reasonable replacement energy alternatives is described in the LR GEIS, including fossil fuel, new nuclear, and renewable energy sources. Conservation and power purchasing are also considered as replacement energy alternatives to license renewal because they represent other options for electric power system planners.

## S.2 Development of the Revised Generic Environmental Impact Statement

This LR GEIS documents the results of the systematic approach the NRC used to evaluate the environmental impacts of renewing the operating licenses of commercial nuclear power plants for an additional 20 years beyond the current license term, irrespective of the number of years of reactor operation (e.g., 40 years, 60 years, 80 years, etc.). The environmental consequences of both initial LR and SLR include (1) impacts associated with continued operations and any refurbishment activities similar to those that have occurred during the current license term; (2) impacts of various alternatives to the proposed action; (3) impacts from the termination of nuclear power plant operations and decommissioning after the license renewal term (with emphasis on the incremental effect caused by an additional 20 years of operation); (4) impacts associated with the uranium fuel cycle; (5) impacts of postulated accidents (design-basis accidents and severe accidents); (6) cumulative effects of the proposed action; and (7) resource commitments associated with the proposed action, including unavoidable adverse impacts, relationship between short-term use and long-term productivity, and irreversible and irretrievable commitment of resources. The LR GEIS also discusses the impacts of various reasonable alternatives to the proposed action (initial LR or SLR). The environmental consequences of these activities are discussed in the LR GEIS.

For this revision, the NRC staff reviewed and evaluated the 78 environmental issues and impact findings from the 2013 LR GEIS. Experience gained from license renewal reviews conducted since development of the 2013 LR GEIS provides a source of new information for the evaluation presented in this LR GEIS revision. In addition, new research, findings, and other information were considered in evaluating the significance of impacts associated with initial LR and SLR. The purpose of the evaluation was to determine if the 2013 LR GEIS findings remain valid and apply to SLR. In doing so, the NRC considered the need to modify, add to, group, subdivide, or delete any of the 78 issues evaluated in the 2013 LR GEIS.

In a notice of intent published in the *Federal Register* on August 4, 2020 (85 FR 47252), the NRC notified the public of its preliminary analysis and plan to review and potentially revise the LR GEIS, including to address SLR, and to provide an opportunity to participate in the environmental scoping process. This step was the initial opportunity for public participation in the LR GEIS revision. The NRC held four public webinars in August 2020 (August 19, 2020 and August 27, 2020, from 1:30 p.m. to 4:00 p.m. Eastern Daylight Time and 6:30 p.m. to 9:00 p.m. Eastern Daylight Time).

Participation in the scoping process by members of the public and local, State, Tribal, and Federal government agencies was encouraged and used to (1) determine whether to update the 2013 LR GEIS; (2) define the proposed action; (3) determine the scope of the update and identify whether there are any significant new issues to be analyzed in depth; (4) identify and eliminate from detailed study issues that are peripheral, are not significant, or have been covered by prior environmental review; (5) identify environmental assessments and other EISs under development or consideration related to the scope of the LR GEIS update; (6) identify other review and consultation requirements related to the proposed action; and (7) describe how the LR GEIS revision will be prepared. In addition, the NRC proposed to address SLRs in the LR GEIS revision.

The scoping period for this LR GEIS revision was from August 4, 2020 to November 2, 2020. The NRC staff reviewed the transcripts from the public meetings and all written material received during the scoping period and identified individual comments. All comments and suggestions received orally during the scoping meetings or in writing were considered. The NRC staff issued a scoping summary report in June 2021.

In evaluating the impacts of the proposed action (license renewal) and considering comments received during the scoping period, as well as the Commission's direction in SRM-SECY-22-0024, the NRC identified 80 environmental issues: 72 environmental issues were associated with continued operations, refurbishment, and other supporting activities; 2 with postulated accidents; 1 with termination of plant operations and decommissioning; 4 with the uranium fuel cycle; and 1 with cumulative effects (impacts). For all of these issues, the incremental effect of license renewal was the focus of the evaluation.

For each potential environmental issue, the revised LR GEIS (1) describes the nuclear power plant activity during the initial LR or SLR term that could affect the resource; (2) identifies the resource that is affected, (3) evaluates past license renewal reviews and other available information, including information related to impacts during a SLR term; (4) assesses the nature and magnitude of the environmental impact on the affected resource during initial LR or SLR; (5) characterizes the significance of the effect; (6) determines whether the results of the analysis apply to all nuclear power plants (whether the environmental issue is Category 1, Category 2, or uncategorized); and (7) considers additional mitigation measures for adverse impacts.

The scope of the revised LR GEIS also discusses a range of alternatives to license renewal, including replacement power generation (using fossil fuels, nuclear, and renewables), energy conservation and efficiency (demand-side management), and purchased power. It also evaluates the impacts from the no action alternative (not renewing the operating license). This LR GEIS includes the NRC's evaluation of construction, operation, postulated accidents, decommissioning, and fuel cycles for replacement energy alternatives.

## S.3 Impact Definitions and Categories

The NRC's environmental impact standard considers Council on Environmental Quality (CEQ) terminology, including CEQ revisions in Part 1501—NEPA and Agency Planning (40 CFR 1501).

In considering whether the effects of the proposed action are significant, the NRC analyzes the potentially affected environment and degree of the effects of the proposed action (initial LR or SLR). The potentially affected environment consists of the affected area and its resources, such as listed species and designated critical habitat under the Endangered Species Act (ESA). For nuclear power plant-specific environmental issues, significance would depend on the effects in the local area—including (1) both short- and long-term effects; (2) both beneficial and adverse effects; (3) effects on public health and safety; and (4) effects that would violate Federal, State, Tribal, or local law protecting the environment (40 CFR 1501.3(b)).

Based on this, the NRC has established three significance levels for potential impacts: SMALL, MODERATE, and LARGE. The three significance levels, presented in a footnote to Table B-1 of 10 CFR Part 51, Appendix B to Subpart A, are defined as follows:

- SMALL: Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered SMALL.
- MODERATE: Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.
- LARGE: Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

In addition to determining the impacts for each environmental issue, the NRC also determined whether the analysis in the LR GEIS could be applied to all nuclear power plants (or plants with specified design or site characteristics). Issues were assigned Category 1 or Category 2 as follows:

Category 1 issues are those that meet all of the following criteria:

- The environmental impacts associated with the issue have been determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics;
- A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts (except for offsite radiological impacts of spent nuclear fuel and high-level waste disposal and offsite radiological impacts—collective impacts from other than the disposal of spent fuel and high-level waste); and
- Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are not likely to be sufficiently beneficial to warrant implementation.

For issues that meet the three Category 1 criteria, no additional plant-specific analysis is required in future SEISs unless new and significant information is identified.

Category 2 issues are those that do not meet one or more of the criteria of Category 1, and therefore, require additional plant-specific review.

## S.4 Affected Environment

For purposes of the evaluation in this LR GEIS revision, the "affected environment" is the environment currently existing around operating commercial nuclear power plants. Current conditions in the affected environment are the result of past construction and operations at the plants. The NRC has considered the effects of these past and ongoing impacts and how they have shaped the environment. The NRC evaluated impacts of license renewal that are incremental to existing conditions. These existing conditions serve as the baseline for the evaluation and include the effects of past and present actions at the nuclear power plant sites and vicinity. This existing affected environment comprises the environmental baseline against which potential environmental impacts of license renewal are evaluated.

In the LR GEIS, the NRC describes the affected environment in terms of the following resource areas or subject matter areas: (1) description of nuclear power plant facilities and operations; (2) land use and visual resources; (3) meteorology, air quality, and noise; (4) geologic environment; (5) water resources (surface water and groundwater resources); (6) ecological resources (terrestrial resources, aquatic resources, and federally protected ecological resources); (7) historic and cultural resources; (8) socioeconomics; (9) human health (radiological and nonradiological hazards and postulated accidents); (10) environmental justice; (11) waste management and pollution prevention (radioactive and nonradioactive waste); and (12) greenhouse gas (GHG) emissions and climate change. The affected environments of the operating plant sites represent diverse environmental conditions.

## S.5 Impacts from Continued Operations and Refurbishment Activities Associated with License Renewal (Initial or Subsequent)

The NRC identified 80 environmental issues related to continued operations and refurbishment associated with both initial LR or SLR. Twenty of the issues were identified as Category 2 issues and would require plant-specific evaluations in future SEISs. Fifty-nine issues have been evaluated and determined to be generic to all nuclear power plants or to a subset of plants, and one issue is uncategorized. The conclusions for each issue are listed below by resource area.

**Land Use**

- The impacts of continued operations and refurbishment on onsite land use would be SMALL. Changes in onsite land use from continued operations and refurbishment associated with license renewal would be a small fraction of the nuclear power plant site and would only involve land that is controlled by the licensee. This is a Category 1 issue.
- The impacts of continued operations and refurbishment on offsite land use would be SMALL. Offsite land use would not be affected by continued operations and refurbishment associated with license renewal. This is a Category 1 issue.
- The impacts of continued operations and refurbishment on offsite land use in transmission line right-of-ways (ROWs) would be SMALL. Use of transmission line ROWs would continue with no change in offsite land use restrictions. This is a Category 1 issue.

**Visual Resources**

- The impacts of continued operations and refurbishment on the visual appearance (aesthetics) of plant structures or transmission lines from continued operations and refurbishment would be SMALL. No important changes to the aesthetics are expected from continued operations and refurbishment. This is a Category 1 issue.

**Air Quality**

- Air quality impacts from continued operations and refurbishment activities would be SMALL at all plants. Emissions from emergency diesel generators and fire pumps and routine operations of boilers used for space heating are minor. Impacts from cooling tower particulate emissions even under the worst-case situations have been small. Emissions resulting from refurbishment activities at locations in or near air quality nonattainment or maintenance areas would be short-lived and would cease after these activities are completed. Operating experience has shown that the scale of refurbishment activities has not resulted in exceedance of the *de minimis* thresholds for criteria pollutants, and best management practices (BMPs), including fugitive dust controls and the imposition of permit conditions in State and local air emissions permits, would ensure conformance with applicable State or Tribal implementation plans. This is a Category 1 issue.

- The impacts on air quality from continued operations of transmission lines would be SMALL. Production of ozone and oxides of nitrogen from transmission lines is insignificant and does not contribute measurably to ambient levels of these gases. This is a Category 1 issue.

**Noise**

- The impacts of continued operations and refurbishment on offsite noise levels would be SMALL. Noise levels would remain below regulatory guidelines for offsite receptors. This is a Category 1 issue.

**Geologic Environment**

- The impacts of continued operations and refurbishment activities on geology and soils would be SMALL for all nuclear plants and would not change appreciably during the license renewal term. This is a Category 1 issue.

**Surface Water Resources**

- The non-cooling system impacts of continued operations and refurbishment on surface water use and quality would be SMALL if BMPs are employed to control soil erosion and spills. Surface water use would not increase significantly or would be reduced if refurbishment occurs during a plant outage. This is a Category 1 issue.
- Altered current patterns would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been SMALL at operating nuclear power plants. This is a Category 1 issue.
- Effects on salinity gradients would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been SMALL at operating nuclear power plants. This is a Category 1 issue.
- Effects on thermal stratification in lakes would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been SMALL at operating nuclear power plants. This is a Category 1 issue.
- Scouring effects would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been SMALL at operating nuclear power plants. This is a Category 1 issue.
- The impacts from discharges of metals during continued operations and refurbishment would be SMALL. Discharges of metals in cooling system effluent have not been found to be a problem at operating nuclear power plants that have cooling-tower-based heat dissipation systems and have been mitigated at other plants. Discharges are monitored as part of the National Pollutant Discharge Elimination System (NPDES) permit process. This is a Category 1 issue.
- The discharge and effects of biocides, sanitary wastes, and minor chemical spills are regulated by State and Federal environmental agencies. Discharges are monitored and controlled as part of the NPDES permit process. These impacts have been SMALL at operating nuclear power plants. This is a Category 1 issue.
- Surface water use conflicts at plants with once-through cooling systems have not been found to be a problem at operating nuclear power plants that have once-through heat dissipation systems and the impacts would be SMALL. This is a Category 1 issue.

- Surface water use conflicts could occur at nuclear power plants that rely on cooling ponds or cooling towers using makeup water from a river. Impacts could be SMALL or MODERATE, depending on makeup water requirements, water availability, and competing water demands. This is a Category 2 issue.
- The effects of dredging on surface water quality would be SMALL. Dredging to remove accumulated sediments in the vicinity of intake and discharge structures and to maintain barge shipping has not been found to be a problem for surface water quality. Dredging is performed under permit from the U.S. Army Corps of Engineers, and possibly, from State or local agencies. This is a Category 1 issue.
- The impacts of temperature effects on sediment transport capacity would be SMALL. Temperature effects on sediment capacity have not been found to be a problem at operating nuclear power plants and are not expected to be a problem during the license renewal term. This is a Category 1 issue.

**Groundwater Resources**

- The non-cooling system impacts of continued operations and refurbishment on groundwater would be SMALL. Extensive dewatering is not anticipated during continued operations and refurbishment associated with license renewal. Industrial practices involving the use of solvents, hydrocarbons, heavy metals, or other chemicals and/or the use of wastewater ponds or lagoons have the potential to contaminate site groundwater, soil, and subsoil. Contamination is subject to State or U.S. Environmental Protection Agency (EPA)-regulated cleanup and monitoring programs. The application of BMPs for handling any materials produced or used during these activities would reduce impacts. This is a Category 1 issue.
- Groundwater use conflicts are not anticipated for nuclear power plants that withdraw less than 100 gallons per minute and the impacts would be SMALL. This is a Category 1 issue.
- Groundwater use conflicts with nearby groundwater users could occur at nuclear power plants that withdraw more than 100 gallons per minute. Impacts could be SMALL, MODERATE, or LARGE. This is a Category 2 issue.
- For plants that have closed-cycle cooling systems that withdraw makeup water from a river, groundwater use conflicts could result from water withdrawals from rivers during low-flow conditions, which may affect aquifer recharge. The significance of impacts would depend on makeup water requirements, water availability, and competing water demands. The impacts on groundwater quality could be SMALL, MODERATE, or LARGE. This is a Category 2 issue.
- The impacts of continued operations and refurbishment activities on groundwater quality resulting from water withdrawals would be SMALL. Groundwater withdrawals at operating nuclear power plants would not significantly degrade groundwater quality. This is a Category 1 issue.
- For plants that have cooling ponds, the impacts on groundwater quality could be SMALL or MODERATE. The significance of the impact would depend on cooling pond operation; water quality; site hydrogeologic conditions (including the interaction of surface water and groundwater); and the location, depth, and pump rate of water wells. This is a Category 2 issue.
- Radionuclides released to groundwater, particularly tritium, due to inadvertent leaks of radioactive liquids from plant components and pipes could result in SMALL or MODERATE groundwater quality impacts. Such leaks have occurred at numerous plants. Groundwater

protection programs have been established at all operating nuclear power plants to minimize the potential impact from any inadvertent releases. This is a Category 2 issue.

**Terrestrial Resources**

- Non-cooling system impacts on terrestrial resources may be SMALL, MODERATE, or LARGE. The magnitude of the effects of continued nuclear power plant operation and refurbishment, unrelated to operation of the cooling system, would depend on numerous site-specific factors, including ecological setting, planned activities during the license renewal term, and characteristics of the plants and animals present in the area. Application of BMPs and other conservation initiatives would reduce the potential for impacts. This is a Category 2 issue.
- Exposure of terrestrial organisms to radionuclides would be SMALL. Doses to terrestrial organisms from continued nuclear power plant operation and refurbishment during the license renewal term would be expected to remain well below U.S. Department of Energy exposure guidelines developed to protect these organisms. This is a Category 1 issue.
- Cooling system impacts on terrestrial resources for plants that have once-through cooling systems or cooling ponds would be SMALL. Continued operation of nuclear power plant cooling systems during license renewal could cause thermal effluent additions to receiving water bodies, chemical effluent additions to surface water or groundwater, impingement of waterfowl, disturbance of terrestrial plants and wetlands by maintenance dredging, and erosion of shoreline habitat. However, plants where these impacts have occurred successfully mitigated the impact, and it is no longer of concern. These impacts are not expected to be significant issues during the license renewal term. This is a Category 1 issue.
- Cooling tower impacts on terrestrial plants would be SMALL. Continued operation of nuclear power plant cooling towers could deposit particulates and water droplets or ice on vegetation and lead to structural damage or changes in terrestrial plant communities. However, plants where these impacts occurred successfully mitigated the impact. These impacts are not expected to be significant issues during the license renewal term. This is a Category 1 issue.
- The impacts of bird collisions with plant structures and transmission lines would be SMALL. Bird mortalities from collisions with nuclear power plant structures and in-scope transmission lines would be negligible for any species and are unlikely to threaten the stability of local or migratory bird populations or result in noticeable impairment of the function of a species within the ecosystem. These impacts are not expected to be significant issues during the license renewal term. This is a Category 1 issue.
- Nuclear power plants could consume water at rates that cause occasional or intermittent water use conflicts with nearby and downstream terrestrial and riparian communities. Such impacts could noticeably affect riparian or wetland species or alter characteristics of the ecological environment. The one plant where impacts have occurred successfully mitigated the impact. Impacts are expected to be SMALL at most nuclear power plants but could be MODERATE at some. This is a Category 2 issue.
- Transmission line ROW management impacts on terrestrial resources would be SMALL. In-scope transmission lines tend to occupy only industrial-use or other developed portions of nuclear power plant sites and, therefore, the effects of ROW maintenance on terrestrial plants and animals during the license renewal term would be negligible. Application of BMPs would reduce the potential for impacts. This is a Category 1 issue.

- Electromagnetic field (EMF) effects on terrestrial plants and animals would be SMALL. In-scope transmission lines tend to occupy only industrial-use or other developed portions of nuclear power plant sites and, therefore, the effects of EMFs on terrestrial plants and animals would be negligible. This is a Category 1 issue.

**Aquatic Resources**

- The impacts of impingement mortality and entrainment (IM&E) of aquatic organisms at nuclear power plants that have once-through cooling systems or cooling ponds may be SMALL, MODERATE, or LARGE. Impacts would generally be SMALL at nuclear power plants that have implemented best technology requirements for existing facilities under Clean Water Act (CWA) Section 316(b). For all other nuclear power plants that have once-through cooling systems or cooling ponds, impacts could be SMALL, MODERATE, or LARGE depending on characteristics of the cooling water intake system, results of impingement and entrainment studies performed at the plant, trends in local fish and shellfish populations, and implementation of mitigation measures. This is a Category 2 issue.
- The impacts of IM&E of aquatic organisms at nuclear power plants that have cooling towers would be SMALL. No significant impacts on aquatic populations associated with IM&E at nuclear power plants that have cooling towers have been reported, including effects on fish and shellfish from direct mortality, injury, or other sublethal effects. Impacts during the license renewal term would be similar and small. Further, the effects of these cooling water intake systems would be mitigated through adherence to NPDES permit conditions established pursuant to CWA Section 316(b). This is a Category 1 issue.
- Entrainment of phytoplankton and zooplankton would be SMALL at all nuclear power plants. Entrainment has not resulted in noticeable impacts on phytoplankton or zooplankton populations near operating nuclear power plants. Impacts during the license renewal term would be similar and small. Further, the effects would be mitigated through adherence to NPDES permit conditions established pursuant to CWA Section 316(b). This is a Category 1 issue.
- The effects of thermal effluents on aquatic organisms at nuclear power plants that have once-through cooling systems or cooling ponds may be SMALL, MODERATE, or LARGE. Effects would generally be SMALL at nuclear power plants that adhere to State water quality criteria or that have and maintain a valid CWA Section 316(a) variance. For all other nuclear power plants that have once-through cooling systems or cooling ponds, impacts could be SMALL, MODERATE, or LARGE depending on site-specific factors, including the ecological setting of the plant, characteristics of the cooling system and effluent discharges, and characteristics of the fish, shellfish, and other aquatic organisms present in the area. This is a Category 2 issue.
- The effects of thermal effluents on aquatic organisms at nuclear power plants that have cooling towers would be SMALL. Thermal effluents have not resulted in noticeable impacts on aquatic communities at nuclear power plants that have cooling towers. Impacts during the license renewal term would be similar and small. Further, effects would be mitigated through adherence to State water quality criteria or CWA Section 316(a) variances. This is a Category 1 issue.
- Infrequently reported effects of thermal effluents would be SMALL at all nuclear power plants. Continued operation of nuclear power plant cooling systems could result in certain infrequently reported thermal impacts, including cold shock, thermal migration barriers,

accelerated maturation of aquatic insects, proliferation of aquatic nuisance organisms, depletion of dissolved oxygen, gas supersaturation, eutrophication, and increased susceptibility of exposed fish and shellfish to predation, parasitism, and disease. Most of these effects have not been reported at operating nuclear power plants. Plants that have experienced these impacts successfully mitigated the impact, and it is no longer of concern. Infrequently reported thermal impacts are not expected to be significant issues during the license renewal term. This is a Category 1 issue.

- The effects of nonradiological contaminants on aquatic organisms would be SMALL. Heavy metal leaching from condenser tubes was an issue at several operating nuclear power plants. These plants successfully mitigated the issue, and it is no longer of concern. Cooling system effluents would be the primary source of nonradiological contaminants during the license renewal term. Implementation of BMPs and adherence to NPDES permit limitations would minimize the effects of these contaminants on the aquatic environment. This is a Category 1 issue.
- Exposure of aquatic organisms to radionuclides would be SMALL. Doses to aquatic organisms from continued nuclear power plant operation and refurbishment during license renewal would be expected to remain well below U.S. Department of Energy exposure guidelines developed to protect these organisms. This is a Category 1 issue.
- The effects of dredging on aquatic resources would be SMALL. Dredging at nuclear power plants is expected to occur infrequently, would be of relatively short duration, and would affect relatively small areas. Continued operation of many plants may not require any dredging. Adherence to BMPs and CWA Section 404 permit conditions would mitigate potential impacts at plants where dredging is necessary to maintain the function or reliability of cooling systems. Dredging is not expected to be a significant issue during the license renewal term. This is a Category 1 issue.
- Water use conflicts with aquatic resources at nuclear power plants that have cooling ponds or cooling towers using makeup water from a river may be SMALL or MODERATE. Nuclear power plants could consume water at rates that cause occasional or intermittent water use conflicts with nearby and downstream aquatic communities. Such impacts could noticeably affect aquatic plants or animals or alter characteristics of the ecological environment during the license renewal term. The one plant where impacts have occurred successfully mitigated the impact. Impacts are expected to be SMALL at most nuclear power plants but could be MODERATE at some. This is a Category 2 issue.
- Non-cooling system impacts on aquatic resources would be SMALL. No significant impacts on aquatic resources associated with landscape and grounds maintenance, stormwater management, or ground-disturbing activities at operating nuclear power plants have been reported. Impacts from continued operation and refurbishment during the license renewal term would be similar and small. Application of BMPs and other conservation initiatives would reduce the potential for impacts. This is a Category 1 issue.
- Impacts of transmission line ROW management on aquatic resources would be SMALL. In-scope transmission lines tend to occupy only industrial-use or other developed portions of nuclear power plant sites and, therefore, the effects of ROW maintenance on aquatic plants and animals during the license renewal term would be negligible. Application of BMPs would reduce the potential for impacts. This is a Category 1 issue.

**Federally Protected Ecological Resources**

- The potential effects of continued nuclear power plant operation and refurbishment on federally listed species and critical habitats under U.S. Fish and Wildlife Service jurisdiction would depend on numerous site-specific factors, including the ecological setting; listed species and critical habitats present in the action area; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and other ground-disturbing activities. Consultation with the U.S. Fish and Wildlife Service under ESA Section 7(a)(2) would be required if license renewal may affect listed species or critical habitats under this agency's jurisdiction. This is a Category 2 issue.
- The potential effects of continued nuclear power plant operation and refurbishment on federally listed species and critical habitats under National Marine Fisheries Service jurisdiction would depend on numerous site-specific factors, including the ecological setting; listed species and critical habitats present in the action area; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and other ground-disturbing activities. Consultation with the National Marine Fisheries Service under ESA Section 7(a)(2) would be required if license renewal may affect listed species or critical habitats under this agency's jurisdiction. This is a Category 2 issue.
- The potential effects of continued nuclear power plant operation and refurbishment on essential fish habitat (EFH) would depend on numerous site-specific factors, including the ecological setting; EFH present in the area, including habitats of particular concern; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and other activities that may affect aquatic habitats. Consultation with the National Marine Fisheries Service under Magnuson-Stevens Act Section 305(b) would be required if license renewal could result in adverse effects to EFH. This is a Category 2 issue.
- The potential effects of continued nuclear power plant operation and refurbishment on sanctuary resources would depend on numerous site-specific factors, including the ecological setting; national marine sanctuaries present in the area; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and other activities that may affect aquatic habitats. Consultation with the Office of National Marine Sanctuaries under National Marine Sanctuaries Act Section 304(d) would be required if license renewal could destroy, cause the loss of, or injure sanctuary resources. This is a Category 2 issue.

**Historic and Cultural Resources**

- Impacts from continued operations and refurbishment on historic and cultural resources located onsite and in the transmission line ROW are analyzed on a plant-specific basis. The NRC will perform a NEPA and National Historic Preservation Act (NHPA) Section 106 analysis, in accordance with 36 CFR Part 800, in its preparation of the SEIS. The NHPA Section 106 analysis includes consultation with the State and Tribal Historic Preservation Officers, Indian Tribes, and other interested parties. This is a Category 2 issue.

**Socioeconomics**

- Although most nuclear power plants have large numbers of employees with higher than average wages and salaries, employment, income, recreation, and tourism, impacts from continued operations and refurbishment associated with license renewal are expected to be SMALL. This is a Category 1 issue.
- Impacts on tax revenue would be SMALL. Nuclear plants provide tax revenue to local jurisdictions in the form of property tax payments, payments in lieu of tax (PILOT) payments,

or tax payments on energy production. The amount of tax revenue paid during the license renewal term as a result of continued operations and refurbishment associated with license renewal is not expected to change. This is a Category 1 issue.

- Changes to community services and education resulting from continued operations and refurbishment associated with license renewal would be SMALL. With little or no change in (1) employment at the licensee's plant, (2) value of the power plant, (3) payments on energy production, and (4) PILOT payments expected during the renewal term, community and educational services would not be affected by continued power plant operations. This is a Category 1 issue.
- Population and housing impacts would be SMALL because changes resulting from continued operations and refurbishment associated with license renewal to regional population and housing availability and value would be small. With little or no change in employment at the licensee's plant expected during the license renewal term, population and housing availability and values would not be affected by continued power plant operations. This is a Category 1 issue.
- Transportation impacts would be SMALL because changes resulting from continued operations and refurbishment associated with license renewal to traffic volumes would be small. This is a Category 1 issue.

**Human Health**

- Radiation doses to plant workers from continued operations and refurbishment associated with license renewal are expected to be within the range of doses experienced during the current license term and would continue to be well below regulatory limits. The impacts from radiation doses to plant workers would be SMALL. This is a Category 1 issue.
- Radiation doses to the public from continued operations and refurbishment associated with the license renewal term are expected to continue at current levels and would be well below regulatory limits. The impacts from radiation doses to the public would be SMALL. This is a Category 1 issue.
- Chemical hazards to plant workers resulting from continued operations and refurbishment associated with license renewal are expected to be minimized by the licensee implementing good industrial hygiene practices as required by permits and Federal and State regulations. Chemical releases to the environment and the potential for impacts on the public are expected to be minimized by adherence to discharge limitations of NPDES and other permits. The impacts from chemical hazards to plant workers would be SMALL. This is a Category 1 issue.
- Microbiological hazards to plant workers would be SMALL. Occupational health impacts are expected to be controlled by continued application of accepted industrial hygiene practices to minimize worker exposures as required by permits and Federal and State regulations. This is a Category 1 issue.
- Microbiological hazards to the public are not expected to be a problem at most operating plants but could result in SMALL, MODERATE, or LARGE impacts at plants that have cooling ponds, lakes, canals, or that discharge to waters of the United States accessible to the public. Impacts would depend on site-specific characteristics. This is a Category 2 issue.
- The effects of EMFs associated with nuclear plants and associated transmission lines on human health are uncertain. Studies of 60-hertz (Hz) EMFs have not uncovered consistent

evidence linking harmful effects with field exposures. EMFs are unlike other agents that have a toxic effect (e.g., toxic chemicals and ionizing radiation) in that dramatic acute effects cannot be forced and longer-term effects, if real, are subtle. Because the state of the science is currently inadequate, no generic conclusion on human health impacts is possible. This issue has not been categorized.

- Impacts from continued operations and refurbishment on worker safety would be SMALL. Physical occupational safety and health hazards are generic to all types of electrical generating stations, including nuclear power plants, and are of small significance if the workers adhere to safety standards and use personal protective equipment as required by Federal and State regulations. This is a Category 1 issue.
- Electric shock hazards could result in SMALL, MODERATE, or LARGE impacts. Electrical shock potential is of small significance for transmission lines that are operated in adherence with the National Electrical Safety Code (NESC). Without a review of conformance with NESC criteria of each nuclear power plant's in-scope transmission lines, it is not possible to determine the generic significance of the electrical shock potential. This is a Category 2 issue.

**Postulated Accidents**

- The environmental impacts of design-basis accidents are SMALL for all nuclear plants. Due to the requirements for nuclear plants to maintain their licensing basis and implement aging management programs during the license renewal term, the environmental impacts from design-basis accident risk during an initial license renewal or SLR term should not differ significantly from those calculated for the design-basis accident assessments conducted as part of the initial plant licensing process. This is a Category 1 issue.
- For severe accidents, the probability-weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to groundwater, and societal and economic impacts from severe accidents are SMALL for all plants. Severe accident mitigation alternatives do not warrant further plant-specific analysis because the demonstrated reductions in population dose risk and continued severe accident regulatory improvements substantially reduce the likelihood of finding cost-effective significant plant improvements. Additionally, all license renewal applicants expected to reference this LR GEIS have already considered severe accident mitigation and therefore would not need to do so again under Commission policy. This is a Category 1 issue.

**Environmental Justice**

- Impacts on minority populations, low-income populations, Indian Tribes, and subsistence consumption resulting from continued operations and refurbishment associated with license renewal will be addressed in nuclear plant-specific reviews. See "Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions" (69 FR 52040). This is a Category 2 issue.

**Waste Management**

- The impacts from low-level waste (LLW) storage and disposal would be SMALL. The comprehensive regulatory controls that are in place and the low public doses being achieved at reactors ensure that the radiological impacts on the environment would remain SMALL during the license renewal term. This is a Category 1 issue.

- The impacts from onsite storage of spent nuclear fuel would be SMALL during the license renewal term, as defined as the licensed life for operation of a reactor evaluated in NUREG-2157. The expected increase in the volume of spent fuel from an additional 20 years of operation can be safely accommodated onsite during the license renewal term with small environmental effects through dry or pool storage at all plants. This is a Category 1 issue. For the period after the licensed life for reactor operations, the impacts of onsite storage of spent nuclear fuel during the continued storage period are discussed in NUREG–2157 and as stated in [10 CFR] § 51.23(b), shall be deemed incorporated into this issue.
- For the impacts from offsite radiological impacts of spent nuclear fuel and high-level waste disposal, the Commission has not assigned a single significance level. The EPA dose limits established for the proposed repository at Yucca Mountain, Nevada apply. The Commission concludes that the impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR Part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the impacts of spent fuel and high-level waste disposal, this issue is considered Category 1.
- The radiological and nonradiological environmental impacts of storage and long-term disposal of mixed waste from any individual plant at licensed sites are SMALL. The comprehensive regulatory controls and the facilities and procedures that are in place ensure proper handling and storage, as well as negligible doses and exposure to toxic materials for the public and the environment at all plants. License renewal would not increase the small continuing risk to human health and the environment posed by mixed waste at all plants. This is a Category 1 issue.
- The impacts from nonradioactive waste storage and disposal would be SMALL. No changes to systems that generate nonradioactive waste are anticipated during the license renewal term. Facilities and procedures are in place to ensure continued proper handling, storage, and disposal, as well as negligible exposure to toxic materials for the public and the environment at all plants. This is a Category 1 issue.

**Greenhouse Gas Emissions and Climate Change**

- GHG impacts on climate change from continued operation and refurbishment associated with license renewal are expected to be SMALL. GHG emissions from routine operations at nuclear power plants are typically very minor because such plants, by their very nature, do not normally combust fossil fuel to generate electricity. GHG emissions from construction vehicles and other motorized equipment for refurbishment activities would be intermittent and temporary, restricted to the refurbishment period. Worker vehicle GHG emissions for refurbishment would be similar to worker vehicle emissions from normal nuclear power plant operations. This is a Category 1 issue.
- Climate change can have additive effects on environmental resource conditions that may also be directly impacted by continued operations and refurbishment during the license renewal term. The effects of climate change can vary regionally and climate change information at the regional and local scale is necessary to assess trends and the impacts on the human environment for a specific location. The impacts of climate change on environmental resources are location-specific and cannot be evaluated generically. This is a Category 2 issue.

**Cumulative Effects**

- Cumulative effects or impacts are those effects that result from the incremental effects of the proposed license renewal action when added to the effects of other past, present, and reasonably foreseeable actions, regardless of what agency (Federal or non-Federal) or person undertakes such actions. The cumulative effects of continued operations and refurbishment associated with license renewal must be considered on a nuclear plant-specific basis. The effects depend on regional resource characteristics, the incremental resource-specific effects of license renewal, and the cumulative significance of other factors affecting the environmental resource. This is a Category 2 issue.

**Uranium Fuel Cycle**

- The individual offsite radiological impacts resulting from portions of the uranium fuel cycle, other than the disposal of spent fuel and high-level waste, would be SMALL. The impacts on individuals from radioactive gaseous and liquid releases during the license renewal term would remain at or below the NRC's regulatory limits. This is a Category 1 issue.
- For the collective offsite radiological impacts from the uranium fuel cycle other than the disposal of spent fuel and high-level waste, there are no regulatory limits applicable to collective doses to the general public from fuel-cycle facilities. The practice of estimating health effects based on collective doses may not be meaningful. All fuel-cycle facilities are designed and operated to meet the applicable regulatory dose limits and standards. Accordingly, the Commission concludes that the collective impacts are acceptable. This is a Category 1 issue.
- The nonradiological impacts of the uranium fuel cycle resulting from the renewal of an operating license for any plant would be SMALL. This is a Category 1 issue.
- The impacts of transporting materials to and from uranium-fuel-cycle facilities on workers, the public, and the environment are expected to be SMALL. This is a Category 1 issue.

**Termination of Nuclear Power Plant Operations and Decommissioning**

- Termination of plant operations and decommissioning would occur eventually regardless of license renewal. The additional 20-year period of operation under the license renewal term would not affect the impacts of shutdown and decommissioning on any resource or at any plant. This is a Category 1 issue.

## S.6 Comparison of Alternatives

This LR GEIS also evaluates the impacts of the proposed action (license renewal) and describes a range of alternatives to license renewal, including the no action alternative (not renewing the operating license). It also evaluates the impacts of replacement energy alternatives (fossil fuel, nuclear, and renewables), energy conservation and efficiency (demand-side management), and purchased power. The impacts of renewing the operating license of a nuclear power plant are comparable to the impacts of replacement energy alternatives. Replacement energy alternatives could require the construction of a new power plant and/or modification of the electric transmission grid. New power plants would also have operational impacts. Conversely, license renewal does not require new construction and operational impacts beyond what is already being experienced. Other alternatives not requiring construction or causing operational impacts include energy conservation and efficiency (demand-side management), delayed retirement, repowering, and purchased power.

The operational impacts of license renewal are comparable to the operational impacts of replacement energy alternatives in some resource areas (socioeconomics) but are different in other resource areas (air emissions, fuel cycles, land use, and water consumption). Renewable energy alternatives (wind, ocean wave, and current power generation) have very few operational impacts, while others (biomass combustion and conventional hydropower) can have considerable impacts. In addition, some renewable energy alternatives (wind and solar) have relatively low but regionally variable capacity factors.

License renewal and replacement energy alternatives differ in other respects, including accident consequences and fuel-cycle impacts. A severe accident under the license renewal and the new nuclear alternative may have a low probability but potentially high consequence, and, compared to renewables, fossil fuel power generation may require large amounts of land for fuel extraction and storage.

In addition, impacts from terminating power plant operations and decommissioning also differ. License renewal delays the date of terminating reactor operations and decommissioning but generally does not alter the level of impact. In comparison, impacts from terminating operations and decommissioning of some replacement energy alternatives could be greater than those from license renewal.

Under NEPA, the NRC has an obligation to consider reasonable alternatives to the proposed action (license renewal). The LR GEIS facilitates that analysis by providing NRC review teams with environmental information related to the range of reasonable replacement energy alternatives as of the time this LR GEIS was prepared. A plant-specific analysis of replacement energy alternatives will be performed for each SEIS, taking into account changes in technology and science since the preparation of this LR GEIS.

# 1.0 INTRODUCTION

The Atomic Energy Act (AEA) of 1954 (42 U.S.C. § 2011 et seq.) authorizes the U.S. Nuclear Regulatory Commission (NRC) to issue commercial nuclear power plant operating licenses for up to 40 years. The 40-year length of the original license period was imposed for economic and antitrust reasons rather than the technical limitations of the nuclear power plant. NRC regulations allow for the renewal of these operating licenses for up to an additional 20 years, depending on the outcome of an assessment determining whether the nuclear power plant can continue to operate safely and protect the environment during the 20-year period of extended operation. There are no specific limitations in the AEA or the NRC's regulations restricting the number of times a license may be renewed.

The NRC's regulations in Title 10 of the *Code of Federal Regulations* (10 CFR) Section 54.17(c) allow a license renewal application to be submitted within 20 years of license expiration, and the NRC's regulations at 10 CFR 54.31(b) specify that a renewed license will be for a term of up to 20 years plus the length of time remaining on the current license. As a result, renewed licenses may be for a term of up to 40 years.

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The license renewal process is designed to ensure the safe operation of the nuclear power plant and protection of the environment during the license renewal term. Under the NRC's regulations in 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions", which implement Section 102(2) of the National Environmental Policy Act (NEPA; 42 U.S.C. § 4321 et seq.), the renewal of a nuclear power plant operating license requires an analysis of the environmental effects of the proposed action and the preparation of an environmental impact statement (EIS).

To support the preparation of license renewal EISs, the NRC conducted a comprehensive review to identify the environmental effects of license renewal. The review determined which environmental effects could result in the same or similar (generic) impact at all nuclear power plants or a subset of plants and which effects could result in different levels of impact, requiring nuclear plant-specific analyses for an impact determination. The review culminated in the issuance of NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (LR GEIS), in May 1996, followed by the publication of the final rule that codified the LR GEIS findings on June 5, 1996 (61 *Federal Register* [FR] 28467[1]; NRC 1996, NRC 1999b).

The 1996 LR GEIS[2] improved the efficiency of the license renewal environmental review process by (1) identifying and evaluating all of the environmental effects that may occur when renewing commercial nuclear power plant operating licenses, (2) identifying and evaluating the environmental effects that are expected to be generic (the same or similar) at all nuclear power plants or a subset of plants, and (3) defining the number and scope of the environmental effects that need to be addressed in nuclear power plant-specific EISs. For the issues that could not be evaluated generically, the NRC would conduct nuclear power plant-specific (hereafter called plant-specific) environmental reviews and prepare plant-specific supplemental EISs (SEISs) to the LR GEIS. The generic environmental findings in this LR GEIS are applicable to the 20-year license renewal increment plus the number of years remaining on the current license, up to a maximum of 40 years, irrespective of the prior number of years of reactor operation (e.g., 40 years, 60 years, 80 years, etc.).

> **Generic Environmental Impact Statement**
>
> A GEIS is an EIS that assesses the scope and impact of the environmental effects that would be associated with an action (such as license renewal) at numerous sites.

## 1.1 Purpose of the LR GEIS

This LR GEIS documents the results of the systematic approach the NRC used to evaluate the incremental environmental impacts of renewing the operating licenses of commercial nuclear power plants for an additional 20 years beyond the current license term, irrespective of the number of years of prior reactor operation (e.g., 40 years, 60 years, 80 years, etc.). The LR GEIS also provides the technical basis for the Commission's license renewal regulations in 10 CFR Part 51. In the 1996 LR GEIS and related rulemaking, the Commission determined that certain impacts associated with the renewal of a nuclear power plant operating license were the same or similar for all plants or subset of plants and could be treated on a generic basis. In this way, repetitive reviews of these impacts could be avoided. The Commission based its generic assessment of certain environmental impacts on the following factors:

- License renewal will involve nuclear power plants for which the environmental impacts of operation are well understood as a result of lessons learned and knowledge gained from operating experience and completed license renewals.
- Activities associated with license renewal are expected to be within this range of operating experience; thus, environmental impacts can be reasonably predicted.
- Changes in the environment around nuclear power plants are gradual and predictable.

[1] Final rules were also issued on December 18, 1996 (61 FR 66537) and September 3, 1999 (64 FR 48496).
[2] Any reference in this document to the 1996 LR GEIS includes the two-volume set published in May 1996 (NRC 1996) and Addendum 1 to the LR GEIS published in August 1999 (NRC 1999b).

The LR GEIS is intended to improve the efficiency of the license renewal environmental review process by (1) providing an evaluation of the types of environmental impacts that may occur by an initial license renewal (initial LR) of commercial nuclear power plant operating licenses or subsequent license renewal (SLR), (2) identifying and assessing impacts that are expected to be generic (the same or similar) at all nuclear plants (or plants with specified plant or site characteristics), and (3) defining the number and scope of environmental issues that need to be addressed in plant-specific SEISs. The LR GEIS also provides information that aids in the preparation of plant-specific EISs.

## 1.2 Description of the Proposed Action

The NRC's environmental regulations in 10 CFR 51.20, require the preparation of an EIS to address the impacts of renewing a plant's operating license. The EIS requirements for a plant-specific license renewal review are specified in 10 CFR 51.71 and 51.95. The NRC's public health and safety and other technical requirements for the renewal of operating licenses are found in 10 CFR Part 54. Part 54 requires applicants to perform safety evaluations and assessments of nuclear power plants and provide the NRC with sufficient information to analyze the impacts of continued operation for the requested license renewal term. Applicants are required to assess the effects of aging on passive and long-lived systems, structures, and components.

**The Proposed Action**

To renew commercial nuclear power plant operating licenses.

**Purpose and Need for the Proposed Action**

To provide an option to continue nuclear power plant operations beyond the current licensing term to meet future system generating needs.

Most nuclear power plant licensees (either a public utility or non-utility plant owner) are expected to begin preparation for license renewal about 10 to 20 years before expiration of their current operating licenses. Inspection, surveillance, testing, and maintenance programs to support continued nuclear power plant operations during the license renewal term would be integrated gradually over a period of years. Any refurbishment-type activities undertaken for the purposes of license renewal have generally been completed during normal plant refueling or maintenance outages before the original license expires. Activities associated with license renewal and operation of a nuclear power plant for an additional 20 years are discussed in Chapter 2.0.

## 1.3 Purpose and Need for the Proposed Action

The Commission acts on each application submitted by a licensee for the renewal of commercial nuclear power plant operating licenses per Section 103 of the AEA. A renewed license is just one of several conditions that each licensee must meet to operate its nuclear power plant during the license renewal term. State regulators, system operators, and in some cases, other Federal agencies, ultimately decide whether the nuclear power plant will continue to operate based on factors such as need for power or other factors within the State's jurisdiction or owner's control. Economic considerations play a primary role in this decision.

The purpose and need for the proposed action (issuance of a renewed license) is to provide an option that allows for baseload power generation capability beyond the term of the current nuclear power plant operating license to meet future system generating needs. Such needs may be determined by other energy-planning decisionmakers, such as State, utility, and, where authorized, Federal agencies (other than the NRC). Unless there are findings in the safety review required by the AEA or the NEPA environmental review that would lead the NRC to reject a license renewal application, the NRC does not have a role in the energy-planning decisions about whether a particular nuclear power plant should continue to operate.

From the perspective of the licensee and the State regulatory authority, the purpose of renewing an operating license is to maintain the availability of the nuclear power plant to meet system energy requirements beyond the term of the plant's current license. In cases of interstate generation or other special circumstances, Federal agencies such as the Federal Energy Regulatory Commission or the Tennessee Valley Authority may be involved in making these decisions.

## 1.4 Alternatives to the Proposed Action

In plant-specific license renewal environmental reviews, the NRC considers the environmental consequences of the proposed action, the no action alternative (i.e., not renewing the operating license), and the environmental consequences of various alternatives for replacing or offsetting the nuclear power plant's generating capacity. No conclusions are made in the LR GEIS about the relative environmental consequences of license renewal, the no action alternative, and the construction and operation of alternative facilities for generating electric energy. However, information presented in the LR GEIS can be used by the NRC and applicants in performing the plant-specific analysis of alternatives.

In plant-specific environmental reviews, the NRC compares the environmental impacts of license renewal with those of the no action alternative and replacement energy alternatives to determine whether or not the adverse environmental impacts of license renewal are so great that preserving the option of license renewal for energy planning decisionmakers would be unreasonable (10 CFR 51.95(c)(4)).

## 1.5 Analytical Approach Used in the LR GEIS

### 1.5.1 Objectives

The LR GEIS serves to facilitate the NRC's environmental review process by identifying and evaluating environmental impacts that are considered generic and common to all, or a subset of, nuclear power plants. Plant-specific environmental issues will be addressed in separate SEISs to the LR GEIS. Generic impacts will be reconsidered in plant-specific SEISs only if there is new and potentially significant information with respect to the conclusions in this LR GEIS.

### 1.5.2 Methodology

Environmental impacts of license renewal and the resources that could be affected by continued operation and any refurbishment undertaken for the purposes of license renewal were identified. The general analytical approach for identifying environmental impacts was to (1) describe the nuclear power plant activity that could affect the resource, (2) identify the resource that is affected, (3) evaluate past license renewal reviews and other available information, (4) assess the nature and magnitude of the environmental impact from initial LR or SLR on the affected resource, (5) characterize the significance of the effects, and (6) determine whether the results of the analysis apply to all, or a subset of, nuclear power plants (whether the environmental issue is Category 1 or Category 2, as described below). Identifying environmental impacts (or issues) was done in an iterative rather than a stepwise manner. For example, after information was collected and levels of significance were reviewed, impacts were reexamined to determine if any should be removed, added, consolidated, or divided.

#### *1.5.2.1 Defining Environmental Issues*

The NRC updated the LR GEIS in 2013. The 2013 LR GEIS presents the findings of a systematic inquiry into the environmental impacts of license renewal resulting in the identification of 78 environmental issues (or impacts). Public and stakeholder comments on previous plant-specific license renewal reviews were analyzed in an effort to reevaluate the existing environmental issues and identify new issues. As a result, the NRC considered the need to modify, add to, group, subdivide, or delete any of the 78 environmental issues evaluated in the 2013 LR GEIS. In this revised LR GEIS, the NRC has evaluated 80 environmental issues.

#### *1.5.2.2 Collecting Information*

Information from license renewal environmental reviews performed since development of the 2013 LR GEIS was collected and reviewed. Searches of the open scientific literature, databases, and websites were conducted for each resource area. This information was collected and evaluated to determine if the environmental issues and findings in the 2013 LR GEIS needed to be revised for initial LR and to update those findings to apply to SLR.

#### *1.5.2.3 Impact Definitions and Categories*

The NRC's environmental impact standard considers Council on Environmental Quality (CEQ) terminology, including CEQ revisions in Part 1501—NEPA and Agency Planning (40 CFR 1501).

In considering whether the effects of the proposed action are significant, the NRC analyzes the potentially affected environment and degree of the effects of the proposed action (license renewal – either initial LR or SLR). The potentially affected environment consists of the affected area and its resources, such as listed species and designated critical habitat under the Endangered Species Act of 1973 (16 U.S.C. § 1531 et seq.). For plant-specific environmental issues, significance would depend on the effects in the local area, including (1) short- and long-term effects, (2) beneficial and adverse effects, (3) effects on public health and safety, and (4) effects that would violate Federal, State, Tribal, or local law protecting the environment (40 CFR 1501.3(b)).

Based on this, the NRC has established three significance levels for potential impacts: SMALL, MODERATE, and LARGE. The three significance levels, presented in a footnote to Table B–1 in Appendix B to Subpart A of 10 CFR Part 51, are defined as follows:

- SMALL – environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered SMALL.

- MODERATE – environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.
- LARGE – environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

These levels are used for describing the environmental impacts of the proposed action as well as the impacts of a range of reasonable alternatives to the proposed action. Resource-specific effects or impact definitions from applicable environmental laws and executive orders, other than SMALL, MODERATE, and LARGE, are provided where appropriate.

For issues in which the probability of occurrence is a key consideration (i.e., postulated accidents), the probability of occurrence has been factored into the impact determination. Mitigation measures that could be used to avoid, minimize, rectify, reduce, eliminate, or compensate for adverse impacts are discussed where appropriate.

In addition to determining the impacts for each environmental issue, a determination is also made for each issue about whether the environmental analysis in the LR GEIS could be applied to all nuclear power plants (or plants with specified design or site characteristics). Based on the applicability of the impact analysis, each issue is assigned either Category 1 or Category 2. These categories are defined below.

- **Category 1** – the analysis reported in the LR GEIS has shown the following:
    - The environmental impacts associated with the issue have been determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics;
    - A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts (except for offsite radiological impacts of spent nuclear fuel and high-level waste disposal and offsite radiological impacts – collective impacts from other than the disposal of spent fuel and high-level waste); and
    - Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are not likely to be sufficiently beneficial to warrant implementation.
- **Category 2** – the analysis reported in the LR GEIS has shown that one or more of the criteria of Category 1 cannot be met and therefore, additional plant-specific review is required.

If all three Category 1 criteria apply to an issue, the NRC relies on the generic finding and analysis in this LR GEIS when conducting license renewal environmental reviews as documented in plant-specific SEISs, provided no new and significant information is identified requiring additional analysis. For issues that do not meet all three Category 1 criteria, the issue is considered Category 2, and a plant-specific impact analysis is required for that issue in the SEIS.

## 1.6 Scope of the LR GEIS Revision

The introduction in Appendix B to Subpart A of 10 CFR Part 51 states that, on a 10-year cycle, the Commission intends to review the material in Appendix B, including Table B-1, and update it, if necessary (61 FR 28467). Therefore, the NRC began the latest review in April 2020, approximately 7 years after the completion of the previous revision cycle in June 2013.

Subsequently, the NRC published a notice of intent in the *Federal Register* on August 4, 2020 (85 FR 47252), that notified the public of the NRC's intent to review and potentially update Table B-1 and the 2013 LR GEIS; indicated the results of the NRC staff's preliminary review, including consideration of SLR; and invited public comments and proposals for other areas that should be updated.

At the conclusion of the scoping period, the staff began drafting a rulemaking plan. In July 2021, the NRC staff submitted SECY-21-0066, "Rulemaking Plan for Renewing Nuclear Power Plant Operating Licenses – Environmental Review (RIN 3150-AK32; NRC-2018-0296)" (NRC 2021l), to request Commission approval to initiate a rulemaking to amend Table B-1 and update the LR GEIS and associated guidance. The rulemaking plan also proposed to remove the word "initial" from 10 CFR 51.53(c)(3), which details when license renewal applicants may rely on the LR GEIS's findings for Category 1 issues in preparing environmental reports in support of those applications. These changes would have enabled SLR applicants to also rely on the LR GEIS for Category 1 issues. The rulemaking plan would also have made corresponding changes to the LR GEIS and the associated guidance, to indicate their applicability to SLRs.

In February 2022, the Commission issued Staff Requirements Memorandum (SRM)-SECY-21-0066, "Rulemaking Plan for Renewing Nuclear Power Plant Operating Licenses – Environmental Review (RIN 3150-AK32; NRC-2018-0296)" (NRC 2022c), disapproving the staff's recommendation and directing the staff to develop a rulemaking plan that aligned with the Commission's adjudicatory orders in CLI-22-03, CLI-22-02, and CLI-22-04, which concluded that the 2013 LR GEIS did not apply to SLR applications. The SRM also directed the NRC staff to include in the rulemaking plan a proposal to remove the word "initial" from 10 CFR 51.53(c)(3) and to revise the LR GEIS, Table B-1, and associated guidance, to fully support SLR.

The NRC staff submitted SECY-22-0024, "Rulemaking Plan for Renewing Nuclear Power Plant Operating Licenses – Environmental Review (RIN 3150-AK32; NRC-2018-0296)" (NRC 2022b), in March 2022 requesting Commission approval to initiate a rulemaking that would align with the Commission's orders CLI-22-02, CLI-22-03, and CLI-22-04 regarding the NEPA analysis of subsequent license renewal applications by removing the word "initial" from 10 CFR 51.53(c)(3) and revising the LR GEIS, Table B-1 and associated guidance to fully support subsequent license renewal. In April 2022, the Commission issued SRM-SECY-22-0024, "Rulemaking Plan for Renewing Nuclear Power Plant Operating Licenses – Environmental Review (RIN 3150-AK32; NRC-2018-0296)" (NRC 2022d), approving the staff's recommendation to proceed with the rulemaking.

In April 2022, pursuant to SRM-SECY-21-0066, the staff also submitted a second paper to the Commission, SECY-22-0036, which concluded that no further updates to the LR GEIS were needed beyond those identified in SECY-22-0024 and that the rulemaking effort identified in SECY-22-0024 should constitute the agency's 10-year update to the LR GEIS. In June 2022, the Commission approved these recommendations in SRM-SECY-22-0036.

To support this review, the NRC staff reviewed and evaluated the environmental issues and impact findings in the 2013 LR GEIS for both initial LR and SLR. Lessons learned and knowledge gained during previous license renewal environmental reviews provided a major source of new information for this review. Public comments received during license renewal environmental reviews were reexamined to validate existing environmental issues and identify new ones. Since 2013, 15 commercial nuclear power plants have undergone an initial LR environmental review. For the purposes of this review, the NRC also considered five SLR environmental reviews including two reviews (i.e., North Anna and Point Beach) where the NRC has issued a draft SEIS, but not a final SEIS. The purpose of the review for this LR GEIS was to determine if the findings presented in the 2013 LR GEIS support the scope of license renewal including initial LR and SLR. In doing so, the NRC considered the need to modify, add to, group, subdivide, or delete any of the 78 environmental issues evaluated in the 2013 LR GEIS. In summary, new research, findings, public comments, changes in applicable laws and regulations, and other information were considered in evaluating the environmental impacts associated with license renewal. As a result of this review, the NRC proposes 80 environmental issues for detailed consideration in this LR GEIS.

## 1.7 Decisions to Be Supported by the LR GEIS

The decisions to be supported by the LR GEIS are whether or not to renew the operating licenses of individual commercial nuclear power plants for an additional 20 years. The LR GEIS was developed to support these decisions and to serve as a basis from which future NEPA analyses for the license renewal of individual nuclear power plants would tier. According to CEQ guidelines (CEQ 2022), tiering refers to "… the coverage of general matters in broader environmental impact statements or environmental assessments (such as national program or policy statements) with subsequent narrower statements or environmental analyses (such as regional or basin-wide program statements or ultimately site-specific statements) incorporating by reference the general discussions and concentrating solely on the issues specific to the statement subsequently prepared." CEQ also states that, "Tiering in such cases is appropriate when it helps the lead agency focus on the issues [that] are ripe for decision and exclude from consideration issues already decided or not yet ripe." The LR GEIS provides the NRC decisionmaker with important environmental information considered common to all (or a subset of) nuclear power plants and allows greater focus to be placed on plant-specific (i.e., Category 2) issues.

The scope of the environmental review for license renewal consists of the range of actions, alternatives, and impacts to be considered in an EIS. The purpose of scoping is to identify significant issues related to the proposed action. Scoping also identifies and eliminates from detailed study issues that are not significant or have been covered by a prior environmental review. Having a defined scope for the environmental review allows the NRC to concentrate on the essential issues resulting from the actions being considered rather than on issues that may have been or are being evaluated in different regulatory review processes, such as the license renewal safety review (NRC 2006a).

**Environmental Impact Statements**

10 CFR 51.70(b): The draft environmental impact statement … will state how alternatives considered in it and decisions based on it will or will not achieve the requirements of Sections 101 and 102(1) of NEPA. (See also the Council on Environmental Quality (CEQ) Regulations for Implementing NEPA, 40 CFR 1502.2(d))

The NEPA process for license renewal under 10 CFR Part 51 focuses on environmental impacts rather than on issues related to safety. Safety issues become important to the environmental review when they could result in environmental impacts, which is why the environmental effects of postulated accidents are considered in the LR GEIS and in plant-specific supplements to the LR GEIS. Under 10 CFR Part 54, the staff safety review considers nuclear power plant aging management of systems, structures, and components. The environmental issues are not considered as part of the safety review. Nuclear power plant safety issues are considered under 10 CFR Part 50. Safety issues that are raised during the environmental review are forwarded to the appropriate NRC organization for consideration and appropriate action (NRC 2006a).

The Commission determined that the NRC's regular ongoing oversight activities are sufficient to ensure the safety of active components during the period of extended operation, therefore the Commission determined to only consider aging for passive, long-lived components in license renewal reviews. Actions subject to NRC approval for license renewal are limited to the performance of specific activities and programs necessary to manage the effects of aging on the passive, long-lived structures and components identified in accordance with 10 CFR Part 54. Accordingly, the LR GEIS does not serve as the NEPA review for other activities or programs outside the scope of the NRC's 10 CFR Part 54 license renewal review.

For other actions, separate NEPA reviews must be conducted regardless of whether the action is necessary as a consequence of receiving a renewed license, even if the activity was specifically addressed in the LR GEIS. For example, the environmental impacts of spent fuel pool expansion are addressed in the LR GEIS in the context of the environmental consequences of approving a renewed operating license. However, any plant-specific application submitted to the NRC to expand spent fuel pool capacity at a given facility would still require its own separate NEPA review. These separate NEPA reviews may reference and otherwise use applicable environmental information contained in the LR GEIS. For example, an environmental assessment prepared for a separate spent fuel pool expansion request may use the information in the LR GEIS to support a finding of no significant impact (see June 5, 1996 final rule [61 FR 28467]).

There are many factors that the NRC takes into consideration when deciding whether to renew the operating license of a nuclear power plant. The analyses of environmental impacts evaluated in this LR GEIS will provide the NRC's decisionmaker with important environmental information for use in the overall decision making process. There are also decisions outside the regulatory scope of license renewal that cannot be made on the basis of the final LR GEIS analysis. These decisions include the issues addressed in the following sections.

### 1.7.1 Changes to Nuclear Power Plant Cooling Systems

The NRC will not make a decision or any recommendations on the basis of information presented in this LR GEIS regarding changes to nuclear power plant cooling systems, other than those involving safety-related issues, to mitigate adverse impacts under the jurisdiction of State or other Federal agencies. Implementation of the provisions of the Clean Water Act (CWA; 33 U.S.C. § 1251 et seq.), including those regarding cooling system operations and design specifications, is the responsibility of the U.S. Environmental Protection Agency (EPA). In many cases, the EPA delegates such authority to the individual States. To operate a nuclear power plant, licensees must comply with the CWA, including associated requirements imposed by the EPA or the State, as part of the National Pollutant Discharge Elimination System (NPDES) permitting system under CWA Section 402 and State water quality certification requirements under CWA Section 401. The EPA or the State, not the NRC, sets the limits for effluents and operational parameters in plant-specific NPDES permits. Nuclear power plants cannot operate without a valid[1] NPDES permit and a Section 401 Water Quality Certification.

[1] A valid NPDES permit is considered to be one that is either current (i.e., within its current effective date) or one that has expired but has been "administratively continued" by the permitting authority upon the timely submission of an application for renewal pursuant to the provisions of 40 CFR 122.6.

### 1.7.2 Disposition of Spent Nuclear Fuel

The NRC will not make a decision or any recommendations on the basis of the information presented in this LR GEIS regarding the disposition of spent nuclear fuel at nuclear power plant sites. The scope of this LR GEIS with regard to the management and ultimate disposition of spent nuclear fuel for the timeframe after the period of extended operation is limited to the findings codified at 10 CFR 51.23 of the September 19, 2014 Continued Storage of Spent Nuclear Fuel, Final Rule (79 FR 56238) and associated NUREG-2157, *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel* (Continued Storage GEIS; NRC 2014c; 79 FR 56263).

In 1982, the Congress enacted the Nuclear Waste Policy Act (42 U.S.C. § 10101 et seq.), and on January 7, 1983, the President signed it into law. The Nuclear Waste Policy Act defined the Federal Government's responsibility to provide permanent disposal in a deep geologic repository for spent fuel and high-level radioactive waste from commercial and defense activities. Under amended provisions (1987) of this Act, the U.S. Department of Energy (DOE) has the responsibility to locate, build, and operate a repository for such wastes. The NRC has the responsibility to establish regulations governing the construction, operation, and closure of the repository, consistent with environmental standards established by the EPA.

The 1987 amendments required DOE to evaluate only the suitability of the site at Yucca Mountain, Nevada, for a geologic disposal facility. In addition, the amendments outlined a detailed approach for the disposal of high-level radioactive waste involving review by the President, Congress, State and Tribal governments, NRC, and other Federal agencies. In February 2002, after many years of studying the suitability of the site, DOE recommended to the President that the Yucca Mountain site be developed as a long-term geologic repository for high-level waste. In April 2002, the Governor of Nevada notified Congress of his State's objection to the proposed repository. Subsequently, Congress voted to override the objection of the State.

DOE submitted a license application to the NRC for construction authorization for a repository at Yucca Mountain in June 2008. Upon acceptance of the application, the NRC started its technical evaluation. However, on March 3, 2010, DOE filed a motion with the Atomic Safety and Licensing Board (Board) seeking permission to withdraw its application for authorization to construct a high-level waste geological repository at Yucca Mountain, Nevada. The Board denied that request on June 29, 2010, in LBP-10-11 (NRC 2010d), and the parties filed petitions asking the Commission to uphold or reverse this decision. On October 1, 2010, the Commission directed the staff to perform an orderly closure of its Yucca Mountain activities. As part of the orderly closure, the NRC staff prepared three technical evaluation reports documenting its work.

On September 9, 2011, the Commission issued Memorandum and Order CLI-11-07, stating that it found itself evenly divided about whether to take the affirmative action of overturning or upholding the Board's June 29, 2010 decision. Exercising its inherent supervisory authority, the Commission directed the Board to complete all necessary and appropriate case management activities by September 30, 2011. On September 30, 2011, the Board issued a Memorandum and Order suspending the proceeding (NRC 2011c).

In August 2013, the U.S. Court of Appeals for the District of Columbia Circuit issued a decision directing the NRC to resume its review of the DOE's license application (On Petition for Writ of Mandamus 2013). In November 2013, the Commission directed the NRC staff to complete the safety evaluation report and requested that DOE prepare the EIS supplement that the NRC staff had determined to be necessary. DOE informed the NRC that it would update a 2009 technical analysis it provided to the NRC, but that it would not prepare a supplement to its EISs. In January 2015, the NRC staff completed the five-volume safety evaluation report. In February 2015, the Commission directed the NRC staff to prepare the EIS supplement, which was completed in May 2016 as NUREG-2184 (NRC 2016a). Although the adjudicatory proceeding remains suspended, these materials along with other NRC nonsensitive Yucca Mountain-related documents are available to the public as part of the NRC staff's activities to retain the accumulated knowledge and experience gained as a result of its Yucca Mountain-related activities. These documents can be viewed on the NRC's public website (https://www.nrc.gov/waste/hlw-disposal.html).

Historically, the NRC's Waste Confidence Decision and Rule represented the Commission's determination that spent fuel could continue to be stored safely and without significant environmental impacts at reactor sites for a period of time after the end of the licensed life for operation. The Commission incorporated the generic determinations in a previous version of 10 CFR 51.23, which satisfied the NRC's obligations under NEPA for specific licensing actions that would foreseeably generate spent fuel and high-level waste. Because the Waste Confidence Rule was originally developed in 1984, the NRC updated the Rule; the last update was completed in 2010.

On December 23, 2010, the Commission published in the *Federal Register* a revision of the Waste Confidence Decision and Rule to reflect information gained from experience in the storage of spent nuclear fuel and the increased uncertainty in the siting and construction of a permanent geologic repository for the disposal of spent nuclear fuel and high-level waste (75 FR 81032 and 75 FR 81037). In response to the 2010 Waste Confidence Decision and Rule, the States of New York, New Jersey, Connecticut, and Vermont, along with several other parties challenged the Commission's NEPA analysis in the decision, which provided the regulatory basis for the rule. On June 8, 2012, the U.S. Court of Appeals, District of Columbia Circuit, in *New York v. NRC*, 681 F.3d 471 (New York v. NRC 2012), vacated the NRC's Waste Confidence Decision and Rule, after finding that it did not comply with NEPA.

In response to the court's ruling, the Commission issued CLI-12-16 (NRC 2012e) on August 7, 2012, in which the Commission determined that it would not issue licenses that rely upon the Waste Confidence Decision and Rule until the issues identified in the court's decision are appropriately addressed by the Commission. In SRM-COMSECY-12-0016 (dated September 6, 2012 [NRC 2012g]), the Commission directed the NRC staff to proceed with a rulemaking that included the development of a generic EIS to support a revised Waste Confidence Decision and Rule and to publish both the EIS and the revised decision and rule in the *Federal Register* within 24 months (by September 6, 2014).

Two LR GEIS issues in Table B-1 were affected by the court's decision. These issues which relied, wholly or in part, on the Waste Confidence Decision and Rule, were the "onsite storage of spent nuclear fuel" and "offsite radiological impacts of spent nuclear fuel and high-level waste disposal." Both of these issues were classified as Category 1 in the 1996 rule; the 2009 proposed rule continued the Category 1 classification for both of these issues. As part of its response to the *New York v. NRC* decision, the NRC revised these two issues accordingly in the 2013 LR GEIS and in the June 2013 Revisions to Environmental Review for Renewal of Nuclear Power Plant Operating License, Final Rule (78 FR 37282). Specifically, the NRC revised the Category 1 ''onsite storage of spent nuclear fuel'' issue to limit the period of time covered by the issue to only the license renewal term with an impact level of SMALL. Similarly, the NRC revised the Category 1 issue, ‘‘offsite radiological impacts of spent nuclear fuel and high-level waste disposal’’ by reclassifying the issue from Category 1 having an impact level of SMALL to uncategorized having an impact level of uncertain.

The Commission’s direction in SRM-COMSECY-12-0016 led to the 2014 Continued Storage Final Rule (79 FR 56238), which replaced the Waste Confidence Decision and Rule with a new regulation at 10 CFR 51.23 that codified the discussion of environmental impacts in NUREG-2157. In addition, the 2014 Continued Storage Final Rule made conforming changes to the two environmental issues in Table B-1 that were affected by the vacated 2010 Waste Confidence Rule: ‘‘onsite storage of spent nuclear fuel” and ‘‘offsite radiological impacts of spent nuclear fuel and high-level waste disposal.’’ The Commission revised the Table B-1 finding for “onsite storage of spent nuclear fuel” to add the phrase “during the license renewal term” to make clear that the SMALL impact is for the license renewal term only. In addition, a new paragraph was added for this issue in Table B-1 to address the impacts of onsite storage of spent fuel during the continued storage period. The second paragraph of the column entry was revised to read, “For the period after the licensed life for reactor operations, the impacts of onsite storage of spent nuclear fuel during the continued storage period are discussed in NUREG-2157 and as stated in § 51.23(b), shall be deemed incorporated into this issue.” As defined in the Continued Storage Final Rule, the phrase “licensed life for reactor operations” refers to the term of the license to operate a reactor and assumes an original licensed life of 40 years and up to two 20-year license extensions for each reactor. The changes reflect that the Category 1 findings for the issue of “onsite storage of spent nuclear fuel” cover the environmental impacts associated with the storage of spent nuclear fuel during the license renewal term as well as the period after the licensed life for reactor operations.

For the issue “offsite radiological impacts of spent nuclear fuel and high-level waste disposal,” the Continued Storage Final Rule revised the finding to reclassify the impact determination as a Category 1 issue with no impact level assigned. The finding column entry for this issue was also revised to reference EPA’s radiation protection standards for the high-level waste and spent nuclear fuel disposal components of the fuel cycle. As stated in the Continued Storage Final Rule (79 FR 56238), while the status of a geologic repository including a repository at Yucca Mountain, remains uncertain, the NRC believes that the current radiation standards for Yucca Mountain are protective of public health and safety and the environment. Further, the Continued Storage GEIS (NRC 2014c) concludes that deep geologic disposal remains technically feasible.

Lessons learned and knowledge gained from operating experience and license renewal environmental reviews completed since development of the 2013 LR GEIS regarding these issues are discussed in Section 4.11.1 of this LR GEIS.

### 1.7.3 Emergency Preparedness

The NRC will not make a decision or any recommendations on the basis of information presented in this LR GEIS regarding emergency preparedness at nuclear power plants. Nuclear power plant owners, government agencies, and State and local officials work together to create a system for emergency preparedness and response that will serve the public in the unlikely event of an emergency. The emergency plans for nuclear power plants cover preparations for evacuation, sheltering, and other actions to protect residents near plants in the event of a serious incident.

In the United States, 92 commercial nuclear power reactors are licensed to operate at 54 sites in 28 States. Each site has onsite and offsite emergency plans to assure that adequate protective measures can be taken to protect the public in the event of a radiological emergency. Federal oversight of emergency preparedness for licensed nuclear power plants is shared by the NRC and Federal Emergency Management Agency (FEMA). The NRC and FEMA have a Memorandum of Understanding (44 CFR Part 353 Appendix A), under which FEMA has the lead in overseeing offsite planning and response, and the NRC assists FEMA in carrying out this role. The NRC has statutory responsibility for the radiological health and safety of the public and retains the lead for oversight of onsite preparedness.

Before a nuclear power plant is licensed to operate, the NRC must have reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency. The NRC's decision of reasonable assurance is based on licensees complying with NRC regulations and guidance. In addition, licensees and area response organizations must demonstrate that they can effectively implement emergency plans and procedures during periodic evaluated exercises. As part of the reactor oversight process, the NRC reviews licensees' emergency planning procedures and training. These reviews include regular drills and exercises that assist licensees in identifying areas for improvement, such as the interface of security operations and emergency preparedness. Each nuclear power plant owner is required to exercise its emergency plan with the NRC, FEMA, and offsite authorities at least once every 2 years to ensure that State and local officials remain proficient in implementing their emergency plans. Licensees also self-test their emergency plans regularly by conducting drills.

FEMA findings and determinations about the adequacy and capability of implementing offsite plans are communicated to the NRC. The NRC reviews the FEMA findings and determinations as well as the onsite findings. The NRC then makes a determination about the overall state of emergency preparedness. The NRC uses the overall findings and determinations to make radiological health and safety decisions before issuing licenses and in its continuing oversight of operating reactors. The NRC has the authority to take action, including shutting down any reactor deemed not to provide reasonable assurance of the protection of public health and safety.

The Commission considered the need for a review of emergency planning issues in the context of license renewal during its rulemaking proceedings on 10 CFR Part 54, which included public notice and comment. As discussed in the statement of consideration for rulemaking (56 FR 64966), the programs for emergency preparedness at nuclear power facilities apply to all nuclear power facility licensees and require the specified levels of protection from each licensee regardless of nuclear power plant design, construction, or license date. Requirements related to emergency planning are in the regulations at 10 CFR 50.47 and Appendix E to 10 CFR Part 50. These requirements apply to all operating licenses and will continue to apply to facilities with renewed licenses. Through its standards and required exercises, the Commission reviews existing emergency preparedness plans throughout the life of any facility, keeping up with changing demographics and other site-related factors.

Therefore, the Commission has determined that there is no need for a special review of emergency planning issues in the context of an environmental review for license renewal (NRC 2006a). Thus, decisions and recommendations concerning emergency preparedness at nuclear power plants are ongoing and outside the regulatory scope of license renewal.

### 1.7.4 Safeguards and Security

The NRC requires that nuclear power plants be both safe and secure. Safety refers to operating the nuclear power plant in a manner that protects the public and the environment. Security refers to protecting the nuclear power plant (using people, equipment, and fortifications) from intruders who wish to damage or destroy it in order to harm people and the environment.

Security issues such as safeguards planning are not tied to a license renewal action but are considered to be issues that need to be dealt with continuously as a part of a nuclear power plant's current (and renewed) operating license. Security issues are periodically reviewed and updated at every operating nuclear power plant. These reviews continue throughout the period of an operating license, whether it is the original or renewed license. If issues related to security are discovered at a nuclear power plant, they are addressed immediately, and any necessary changes are reviewed and incorporated under the operating license (NRC 2006a). As such, decisions and recommendations concerning safeguards and security at nuclear power plants are ongoing and outside the regulatory scope of this LR GEIS.

### 1.7.5 Need for Power

The NRC will not make a decision or any recommendations on the basis of information presented in this LR GEIS regarding the need for power provided by nuclear power plants. The regulatory authority over licensee economics (including the need for power) falls within the jurisdiction of the States and, to some extent, within the jurisdiction of the Federal Energy Regulatory Commission. The proposed rule for license renewal published on September 17, 1991 (56 FR 47016), had originally included a cost-benefit analysis and consideration of licensee economics as part of the NEPA review. However, during the comment period, State, Federal, and licensee representatives expressed concern about the use of economic costs and cost-benefit balancing in the proposed rule and the 1996 LR GEIS. They noted that CEQ regulations interpret NEPA as requiring only an assessment of the cumulative effects of a proposed Federal action on the natural and human-made environment and that the determination of the need for generating capacity has always been a State responsibility. For this reason, the purpose and need for license renewal was defined by the Commission in the June 5, 1996 final rule as follows (61 FR 28467):

> The purpose and need for the proposed action (renewal of an operating license) is to provide an option that allows for power generation capability beyond the term of a current nuclear power plant operating license to meet future system generating needs, as such needs may be determined by State, utility, and, where authorized, Federal (other than NRC) decisionmakers.

10 CFR 51.95(c)(2) states, in part:

> The supplemental environmental impact statement for license renewal is not required to include discussion of need for power or the economic costs and economic benefits of the proposed action or of alternatives to the proposed action except insofar as such benefits and costs are either essential for a determination regarding the inclusion of an alternative in the range of alternatives considered or relevant to mitigation.

### 1.7.6 Seismicity, Flooding, and Other Natural Hazards

The NRC will not make a decision or any recommendations on the basis of information presented in this LR GEIS regarding seismic risk and flooding at nuclear power plants. The NRC's assessment of seismic and flood hazards for existing nuclear power plants is a separate and distinct process from license renewal reviews. Seismic and flood hazard issues are appropriately addressed by the NRC on an ongoing basis at all licensed nuclear facilities as part of its regulatory oversight activities. As such, decisions and recommendations concerning seismic risk and flooding at nuclear power plants are outside the regulatory scope of this LR GEIS. Following the accident at the Fukushima Dai-ichi nuclear power plant resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the NRC established the Near-Term Task Force as directed by the Commission on March 23, 2011, in COMGBJ-11-0002 (NRC 2011e). In consideration of the lessons learned following the Fukushima Dai-ichi accident, the NRC staff developed an enhanced process to make sure that there is an ongoing assessment of information on a range of natural hazards that could potentially pose a threat to nuclear power plants. The framework developed as part of this process provides a graded approach that allows the NRC to proactively, routinely, and systematically seek, evaluate, and respond to new hazard information (NRC 2016f). In 2017, the Commission approved the staff's process enhancements for an ongoing assessment of natural hazard information (NRC 2017).

## 1.8 Implementation of the Rule (10 CFR Part 51)

### 1.8.1 General Requirements

The regulatory requirements for conducting a NEPA review for license renewal are similar to the NEPA review requirements for other major nuclear plant licensing actions. Consistent with the current NEPA practice for nuclear plant licensing actions, an applicant is required to submit an environmental report that assesses the environmental impacts associated with the proposed action, considers alternatives to the proposed action, and evaluates any alternatives for reducing adverse environmental effects. For license renewal, the NRC prepares a draft SEIS to the LR GEIS for public comment and issues a final SEIS after considering public comments on the draft.

### 1.8.2 Applicant's Environmental Report

The applicant's environmental report must contain an assessment of the environmental impacts of renewing a license, the environmental impacts of alternatives, and mitigation alternatives. In assessing the environmental impacts of license renewal for the environmental report, the applicant should refer to the summary of findings on environmental issues for license renewal in Table B-1 of 10 CFR Part 51. The license renewal applicant is not required to assess the environmental impacts of Category 1 issues listed in Table B-1 unless the applicant is aware of new and significant information that would change the conclusions in the LR GEIS. For Category 2 issues listed in Table B-1, the applicant must provide a plant-specific assessment of the impacts. The NRC's regulation in 10 CFR 51.53(c)(3)(ii) specifies the areas that must be analyzed for the Category 2 issues in the environmental report.

The NRC's regulations in 10 CFR 51.45(c) and 10 CFR 51.53(c)(2) require license renewal applicants to consider alternatives for reducing or avoiding adverse environmental effects associated with the proposed action. Typically, this consideration is limited to the Category 2 NEPA issues listed in Table B-1. Pursuant to 10 CFR 51.45(d), the environmental report must also include a discussion of the status of compliance with applicable Federal, State, and local environmental standards. In addition, the NRC's regulation in 10 CFR 51.53(c)(2) specifically excludes the consideration of need for power, the economic costs and benefits of the proposed action, or alternatives to the proposed action in the environmental report for license renewal, except when such consideration is essential for determining whether to include an alternative in the range of alternatives or is relevant to mitigation. Other issues excluded from consideration in the environmental report include issues not related to the environmental effects of the proposed action (license renewal) and associated alternatives. The applicant should also demonstrate the consideration of a range (set) of reasonable alternatives to license renewal in the environmental report and is not limited to the alternatives and energy technologies presented in this LR GEIS. Information provided in the applicant's environmental report will be used in preparing the NRC's SEIS.

### 1.8.3 Supplemental Environmental Impact Statement

As required by 10 CFR 51.20(b)(2), the NRC is required to prepare a SEIS to the LR GEIS for each license renewal environmental review. The SEIS serves as the NRC's analysis of the environmental impacts of license renewal as well as a comparison of the impacts of alternatives. This document also presents the NRC's recommendation about the environmental impact of license renewal. SEISs for license renewal do not need to include a discussion of the need for power or the economic costs and economic benefits of the proposed action or of alternatives to the proposed action (10 CFR 51.95(c)(2)).

### 1.8.4 Public Scoping and Public Comments

The NRC conducts public scoping meetings to inform the public about the license renewal process and receive comments on the scope of the NRC's plant-specific environmental review. At the conclusion of the scoping period, NRC reviews and considers public comments in a scoping summary report. In addition, the draft SEIS is issued for public comment (see 10 CFR 51.73). In reviewing public scoping comments on the proposed action and comments on the draft SEIS, the NRC determines whether each comment provides any new and significant information compared to the information and conclusions presented in the LR GEIS (for Category 1 issues) as well as the information it provides on Category 2 issues considered in the SEIS. If comments are determined to provide new and significant information that could change the conclusions in the LR GEIS, these comments will be addressed in the SEIS.

### 1.8.5 Draft Supplemental Environmental Impact Statement

The NRC's draft SEIS presents an analysis of the environmental impacts of the proposed license renewal action and the environmental impacts of the alternatives to the proposed action. The NRC considers (1) the summary of findings on environmental issues for license renewal of nuclear power plants in Table B-1 of 10 CFR Part 51 for Category 1 issues, (2) plant-specific environmental impact analyses of Category 2 issues, and (3) any new and significant information from the applicant's environmental report or identified through public scoping and comment to reach a conclusion regarding the environmental impacts of license renewal. These impacts are then compared to the environmental impacts of replacement energy alternatives.

### 1.8.6 Final Supplemental Environmental Impact Statement

The NRC issues a final SEIS in accordance with 10 CFR 51.91 and 51.93 after considering (1) public comments, (2) the plant-specific environmental impact analysis of Category 2 issues, and (3) new and significant information involving Category 1 issues summarized in Table B-1.

The NRC provides a record of its decision regarding the environmental impacts of the proposed license renewal action (see 10 CFR 51.102 and 51.103). All comments on the draft SEIS are addressed by the NRC in the final SEIS in accordance with 10 CFR 51.91(a)(1). Comments regarding Category 1 issues are addressed in the following manner:

- The NRC's response to a comment regarding the applicability of the analysis of an impact codified in the rule (i.e., 10 CFR Part 51) to the plant in question may be a statement and explanation of its view that the analysis is adequate including, if applicable, consideration of the significance of any new information. A commenter dissatisfied with such a response may file a petition for rulemaking under 10 CFR 2.802. Procedures for the submission of petitions for rulemaking are explained in 10 CFR Part 2. If a commenter is successful in persuading the Commission that the new information does indicate that the analysis of an impact codified in the rule is incorrect in significant respects (either in general or with respect to the particular plant), then a rulemaking proceeding will be initiated.
- If a commenter provides new information that is relevant to the plant and is also relevant to other plants (i.e., generic information) and that information demonstrates that the analysis of an impact codified in the rule is incorrect, the NRC will seek Commission approval either to suspend the application of the rule on a generic basis with respect to the analysis or to delay granting the renewal application (and possibly other renewal applications) until the rule can be amended. This LR GEIS would reflect the corrected analysis and any additional consideration of alternatives as appropriate.
- If a commenter provides new, plant-specific information that demonstrates that the analysis of an impact codified in the rule is incorrect with respect to the particular plant, then the NRC staff will seek Commission approval to waive the application of the rule with respect to that analysis in that specific renewal proceeding. The SEIS would reflect the corrected analysis as appropriate.

The NRC will also consider comments on Category 2 issues and make any necessary changes to the SEIS or explain why no changes were needed.

## 1.9 Public Scoping Comments on the LR GEIS Update

In support of the proposed review and update of the LR GEIS, the NRC staff conducted a thorough environmental scoping process in 2020. The scoping process was conducted in accordance with Commission direction and the NRC's regulations in Appendix B, "Environmental Effect of Renewing the Operating License of a Nuclear Power Plant," to Subpart A, "National Environmental Policy Act – Regulations Implementing Section 102(2)," of 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions". The introduction in Appendix B to Subpart A of 10 CFR Part 51 states that, on a 10-year cycle, the Commission intends to review the material in Appendix B, including Table B-1, and update it, if necessary (61 FR 28467). Thus, the NRC began the latest review in April 2020, approximately 7 years after the completion of the previous revision cycle in June 2013.

On August 4, 2020, the NRC staff issued a *Federal Register* notice (85 FR 47252) initiating the scoping process to solicit public input to support the review to determine whether to update the LR GEIS, including updates to address SLR. It provided the public and other governmental entities with an opportunity to comment on the review and propose areas for updating, in accordance with 10 CFR 51.29. The NRC staff also directly contacted other Federal agencies, States, and Tribes to invite their participation.

The scoping process consisted of a 90-day public comment period and included four webinar meetings conducted on August 19, 2020, and August 27, 2020, from 1:30 p.m. to 4:00 p.m. and from 6:30 p.m. to 9:00 p.m. to receive comments from the public. Because of the COVID-19 public health emergency, no in-person meetings were held. The contents of each webinar meeting were transcribed by a court reporter. On August 19, approximately 40 people attended the two public webinar meetings, including representatives from the nuclear industry and Federal and State agencies. On August 27, approximately 20 people collectively attended the two webinar meetings, including representatives from the nuclear industry and Federal and State agencies. The official transcripts are available in NRC's Agencywide Documents Access and Management System (ADAMS) (NRC 2020j). The public scoping period ended on November 2, 2020.

At the conclusion of the scoping period, the NRC staff issued *Environmental Impact Statement Scoping Process Summary Report, Review and Update of the Generic Environmental Impact Statement for License Renewal of Nuclear Plants (NUREG-1437)*, dated June 2021 (NRC 2021e). The report contains (1) comments received during the public meeting, via email, and through Regulations.gov; (2) public comments grouped by subject area; and (3) NRC staff responses to those comments.

All comments received were considered as part of the staff's review and update and are referenced in Appendix A.

## 1.10 Lessons Learned

As previously discussed, the NRC reviewed and evaluated the impacts of license renewal. In conducting a thorough update to the LR GEIS that reflects the "hard look" that is required for a NEPA document, the NRC considered changes in applicable laws and regulations, new data in its possession, collective experience, and lessons learned and knowledge gained from conducting environmental reviews for initial LR and SLR since 2013. These developments and practical insights provided a significant source of new information for this LR GEIS revision.

The purpose of this review and evaluation was to determine if the findings presented in the 2013 LR GEIS support the scope of license renewal, including for initial LR and SLR. In doing so, the NRC considered the need to modify, add, group, subdivide, or delete any of the 78 issues in the 2013 LR GEIS. After this review and evaluation, the NRC identified 80 environmental issues for detailed consideration in this LR GEIS revision. The following summarizes the types of proposed changes to Table B-1. These changes are listed by order of appearance in Table B-1, not by order of significance:

- One Category 2 issue, "Groundwater quality degradation (cooling ponds at inland sites)," and a related Category 1 issue, "Groundwater quality degradation (cooling ponds in salt marshes)," were consolidated into a single Category 2 issue, "Groundwater quality degradation (plants with cooling ponds)."
- Two related Category 1 issues, "Infrequently reported thermal impacts (all plants)," and "Effects of cooling water discharge on dissolved oxygen, gas supersaturation, and eutrophication," and the thermal effluent component of the Category 1 issue, "Losses from predation, parasitism, and disease among organisms exposed to sublethal stresses," were consolidated into a single Category 1 issue, "Infrequently reported effects of thermal effluents."
- One Category 2 issue, "Impingement and entrainment of aquatic organisms (plants with once-through cooling systems or cooling ponds)," and the impingement component of a

Category 1 issue, "Losses from predation, parasitism, and disease among organisms exposed to sublethal stresses," were consolidated into a single Category 2 issue, "Impingement mortality and entrainment of aquatic organisms (plants with once-through cooling systems or cooling ponds)."

- One Category 1 issue, "Impingement and entrainment of aquatic organisms (plants with cooling towers)," and the impingement component of the Category 1 issue, "Losses from predation, parasitism, and disease among organisms exposed to sublethal stresses," were consolidated into a single Category 1 issue, "Impingement mortality and entrainment of aquatic organisms (plants with cooling towers)."
- One Category 2 issue, "Threatened, endangered, and protected species and essential fish habitat," was divided into three Category 2 issues: (1) "Endangered Species Act: federally listed species and critical habitats under U.S. Fish and Wildlife jurisdiction," (2) "Endangered Species Act: federally listed species and critical habitats under National Marine Fisheries Service jurisdiction," and (3) "Magnuson-Stevens Act: essential fish habitat."
- Two new Category 2 issues, "National Marine Sanctuaries Act: sanctuary resources" and "Climate change impacts on environmental resources," were added.
- One Category 2 issue, "Severe accidents," was changed to a Category 1 issue.
- One new Category 1 issue, "Greenhouse gas impacts on climate change," was added.
- Several issue titles and findings were revised for clarity.

Historically, the issues identified in the LR GEIS have served to accurately categorize most environmental impacts associated with license renewal. While there have been a number of instances where new (but not significant) information was discovered during a license renewal environmental review for Category 1 issues since publication of the 2013 LR GEIS, the number of instances where information was determined to be both new and significant has been limited. Most notably, in the SEIS for second renewal of Turkey Point, the NRC found that new information for the Category 1 (generic) issue "Groundwater Quality Degradation (Plants with Cooling Ponds in Salt Marshes)" was both new and significant for the initial LR term (NRC 2019c). As noted above, that issue was consolidated with a Category 2 issue, "Groundwater quality degradation (cooling ponds at inland sites)," into a new Category 2 issue, "Groundwater quality degradation (plants with cooling ponds)."

## 1.11 Organization of the LR GEIS

Consistent with the 2013 LR GEIS, this LR GEIS revision adopts the NRC's standard format for EISs as established in 10 CFR Part 51, Subpart A, Appendix A. This LR GEIS is organized according to a more typical NEPA resource-based approach to presenting impacts where all components of the proposed action and alternatives are presented for each resource area. The following list describes the contents of each chapter of the LR GEIS:

- **Chapter 2** presents brief descriptions of the proposed action (including nuclear plant operations, refurbishment, and termination of operations and decommissioning) during the license renewal term and a summary of impacts, the no action alternative, and energy alternatives.
- **Chapter 3** presents a general description of the affected environment in the vicinity of operating commercial nuclear power plants in the United States. Included are descriptions of nuclear power plant facilities and operations followed by general descriptions of existing conditions in the following topical areas: (1) land use and visual resources; (2) meteorology,

air quality, and noise; (3) geologic environment; (4) water resources (surface water resources and groundwater resources); (5) ecological resources (terrestrial resources, aquatic resources, and federally protected ecological resources); (6) historic and cultural resources; (7) socioeconomics; (8) human health (radiological and nonradiological hazards); (9) environmental justice; (10) waste management and pollution prevention; and (11) greenhouse gas emissions and climate change.

- **Chapter 4** presents the environmental consequences associated with the proposed action (license renewal) and energy alternatives (including the incremental effects of continued operations and refurbishment) on each of the topical areas presented in Chapter 3. Impacts common to all alternatives (including the environmental consequences of fuel cycles and terminating power plant operations), cumulative effects (impacts), and resource commitments associated with the proposed action are also discussed.
- **Chapter 5** presents the references for Chapters 1 through 4.
- **Chapter 6** presents a list of the preparers of this LR GEIS, their affiliations, authorship responsibilities, and qualifications.
- **Chapter 7** provides a list of the agencies, organizations, and persons receiving copies of the LR GEIS.
- **Chapter 8** provides for a glossary of terms used in the LR GEIS.

# 2.0 ALTERNATIVES INCLUDING THE PROPOSED ACTION

The proposed action is the renewal of a commercial nuclear power plant's operating license. The U.S. Nuclear Regulatory Commission's (NRC's) regulations in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 51, implementing Section 102(2) of the National Environmental Policy Act (NEPA; 42 U.S.C. § 4321 et seq.), requires the consideration of alternatives to renewing the nuclear power plant's operating license and the comparison of the impacts of renewing the operating license to the environmental impacts of reasonable alternatives. This allows the NRC to determine whether the environmental impacts of license renewal are so great that preserving the option of license renewal for energy-planning decisionmakers would be unreasonable. If the NRC decides not to renew the operating license of a nuclear power plant, energy-planning decisionmakers will then have to find alternative means of addressing energy needs. Alternatives to license renewal include other means of generating electricity, as well as offsetting demand using conservation and energy efficiency measures (demand-side management), delaying planned retirements of other existing plants, or purchasing sufficient power to replace the capacity supplied by the existing nuclear power plant.

**Contents of Chapter 2.0**



If the NRC renews the operating license, the decision about whether or not to continue nuclear power plant operations will be made by the licensee and State or other Federal (non-NRC) decisionmakers. This decision may be based on economic, reliability, operational, policy, and environmental objectives.

Section 2.1 below in this revision of NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (LR GEIS) describes the proposed action, including nuclear plant operations during the license renewal term (initial license renewal (initial LR) or subsequent license renewal (SLR)), refurbishment, and other activities associated with license renewal. Most of these activities would be the same as or similar to those already occurring at the nuclear plant. Termination of nuclear plant operations would occur at or before the end of the license renewal term, and decommissioning activities would commence after reactor operations have ceased.

The impacts of the proposed action and any refurbishment activities that may be undertaken in support of license renewal are summarized in Section 2.1.4, including each of the identified 80 environmental issues, their significance (SMALL, MODERATE, or LARGE, as defined in Section 1.5), and whether the impact designation would apply to all or a subset of nuclear plants. Section 2.2 describes the no action alternative (not renewing the operating license), and Section 2.3 presents alternatives for replacing existing nuclear generating capacity using other energy sources, including fossil fuel, new nuclear, renewable energy, and offsetting existing nuclear generating capacity, including demand-side management, delayed retirement, and purchased power. The potential environmental consequences (impacts) of the proposed action and alternatives to the proposed action are presented in Chapter 4.0.

The NRC does not reach a generic conclusion regarding the impacts of alternatives to license renewal and will consider these impacts in nuclear power plant-specific (hereafter called plant-specific) supplemental environmental impact statements (SEISs). However, Section 2.4 presents a summary comparison of the impacts of the proposed action to these alternatives.

**Alternatives to the Proposed Action Considered in the LR GEIS**

- Not renewing the operating licenses of commercial nuclear power plants (no action alternative).
- Replacing existing nuclear generating capacity using other energy sources (including fossil fuel, new nuclear, and renewable energy).
- Offsetting existing nuclear generation capacity using conservation and energy efficiency (demand-side management), delayed retirement, or purchased power.

## 2.1 Proposed Action

As stated in Section 1.2, the proposed action is the renewal of commercial nuclear power plant operating licenses. For the NRC to determine whether the license should be renewed, an applicant is required to perform certain safety analyses to demonstrate that the nuclear power plant and the licensee can effectively manage the effects of aging and continue safe reactor operations during the renewal term. These safety analyses include an assessment of the effects of potential age-related degradation of certain long-lived, passive systems, structures, and components (SSCs). This requires applicants to describe the conditions under which the plant would operate during the license renewal term. A description of nuclear plant operations during the license renewal term is provided in Section 2.1.1.

Applicants may also conduct refurbishment activities (replacement of major components and systems) necessary to continue reactor operation during the renewal term. These are described in Section 2.1.2. Section 2.1.3 presents an overview of the termination of nuclear plant operations and decommissioning process. Termination of operations and decommissioning impacts are addressed in Section 4.14.3.

### 2.1.1 Nuclear Plant Operations during the License Renewal Term

This section describes nuclear plant operations, maintenance, and refueling activities, including aging management reviews, required for license renewal. During the license renewal term, nuclear plants would continue to operate in the same manner as they do now. All nuclear reactors currently operating in the United States are light water reactors, of which there are two basic types—pressurized water reactors (PWRs) and boiling water reactors (BWRs). A brief description of these reactors and baseline conditions during their operation are presented in Chapter 3.0.

Activities conducted at nuclear plants include:

- reactor operations;
- waste management (processing, storage, packaging, and offsite shipment of wastes);

- security (includes site security personnel);
- office and clerical work (management, public relations, and support staff);
- laboratory analysis;
- surveillance, monitoring, and maintenance (e.g., equipment testing and inspections); and
- refueling and other outages (additional workers during outage).

These activities are expected to continue during the license renewal term. Certain SSCs such as the reactor pressure vessel, reactor containment building, and piping would continue to operate into the license renewal term. The regulations in 10 CFR Part 54 place certain requirements on licensees to make sure that such SSCs continue to operate safely. Incremental aging management activities implemented to allow operation of a nuclear power plant beyond the original 40-year license term are assumed to fall under one of two broad categories: (1) surveillance, monitoring, inspection, testing, trending, and recordkeeping actions, most of which are repeated at regular intervals, and (2) major refurbishment actions, which usually occur infrequently and possibly only once in the life of the plant for any given item. Refurbishment activities are discussed in Section 2.1.2.

The NRC finds that the approaches to environmental impacts from refurbishment activities contained in the previous LR GEISs are valid and conservative. The approaches yield environmental impacts that are likely greater than—or at least equal to—the actual impacts during the license renewal term.

### 2.1.2 Refurbishment and Other Activities Associated with License Renewal

The NRC assumes that licensees may need to conduct refurbishment activities to ensure the safe and economic operation of nuclear plants during the license renewal term. Refurbishment activities include replacement and repair of SSCs. Replacement activities include replacing steam generators and pressurizers for PWRs and recirculation piping systems for BWRs. It is assumed that some applicants may undertake construction projects to replace or improve power plant infrastructure. Such projects could include construction of new parking lots, roads, storage facilities, office buildings, structures, and other facilities.

The number of SSCs involved in refurbishment and the frequency and duration of each activity would vary. In many circumstances, refurbishment activities (e.g., steam generator and reactor vessel head replacement) have already taken place at a number of nuclear plants. These refurbishment-type activities were conducted for economic, reliability, or efficiency reasons during refueling or maintenance outages (i.e., not for license renewal). In addition, very few applications have identified any refurbishment activities associated with license renewal.

Impacts from refurbishment activities outside of license renewal are assumed to have been considered in annual site evaluation reports, environmental operating reports, and Radiological Environmental Monitoring Program reports. Detailed analyses of environmental impacts have not been performed for refurbishment actions in this LR GEIS revision because these actions would vary at each nuclear plant. Refurbishment activities proposed by license renewal applicants in their environmental report will be addressed in plant-specific environmental reviews. Chapter 4.0 of this LR GEIS considers the impacts of representative or bounding refurbishment activities in a number of resource areas.

### 2.1.3 Termination of Nuclear Plant Operations and Decommissioning after License Renewal

Environmental impacts caused by the licensee's decision to permanently cease nuclear plant operations and enter into decommissioning are outside the scope of the LR GEIS. This includes impacts from terminating reactor operations and the removal of fuel from the reactor vessel, regardless of when or why the decision is made. Decommissioning impacts are addressed in NUREG-0586, *Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, Supplement 1: Regarding the Decommissioning of Nuclear Power Reactors*, (Decommissioning GEIS) (NRC 2002c).

Most nuclear plant activities and systems dedicated to reactor operations would cease after reactor shutdown. Some activities (e.g., security and spent nuclear fuel management) would continue, while other activities (administration, laboratory analysis, and reactor surveillance, monitoring, and maintenance) may be reduced or eliminated. Shared systems at a nuclear power plant that have multiple units would continue to operate but at reduced capacity until all units cease operation. The cessation of activities needed to maintain and operate the reactor would reduce the need for workers at the nuclear power plant, but it would not lead to the immediate dismantlement of the reactor or its infrastructure.

The decommissioning process begins when the licensee informs the NRC that it has permanently ceased reactor operations, defueled, and intends to decommission the nuclear plant. Regulations in 10 CFR 50.82(a)(4)(i) and 10 CFR 52.110(d)(1) require licensees to submit a post-shutdown decommissioning activity report (PSDAR) to the NRC, and forward a copy to the affected State(s), no later than 2 years after the cessation of reactor operations.

The licensee must describe all planned activities in the PSDAR, including the schedule and estimated costs for radiological decommissioning (excluding site restoration and spent fuel management costs). The licensee also documents the evaluation of the environmental impacts of planned decommissioning activities at the nuclear plant and provides a basis for why impacts are bounded by previously issued environmental review documents (e.g., Decommissioning GEIS, NRC 2002c). The licensee must also describe any decommissioning activities whose impacts are not bounded and how the impacts will be addressed prior to conducting these activities at the nuclear plant (e.g., through regulatory exemption or license amendment requests). The licensee is required to update the PSDAR if there are any significant changes in decommissioning activity, costs, schedule, or environmental impact.

Once the NRC receives the PSDAR, the report is docketed and a notice of receipt is published in the *Federal Register* to solicit public comments. The NRC conducts a public meeting near the nuclear plant to discuss the licensee's decommissioning plans and schedule, answer questions, and solicit comments.

The licensee submits a License Termination Plan with final status survey strategy to the NRC near the end of decommissioning, at least 2 years before the operating license can be terminated. Prior to completing decommissioning, the licensee must conduct a survey demonstrating compliance with site release criteria established in the License Termination Plan. The NRC verifies the survey results by one or more of the following methods: a quality assurance/quality control review, side-by-side or split sampling of radiological surveys of selected areas, or independent confirmatory surveys. When the NRC confirms that the criteria in the License Termination Plan and all other NRC regulatory requirements have been met, the NRC either terminates or amends the operating license, depending on the licensee's decision on use of the licensed area. The former nuclear plant area and any remaining structures on the site can then be released for restricted or unrestricted use, as appropriate. The criteria for restricted use conditions and alternate criteria that the NRC may approve under certain conditions are listed in 10 CFR 20.1403 and 10 CFR 20.1404, respectively. The radiological criteria for releasing sites for unrestricted use are given in 10 CFR 20.1402.

### 2.1.4 Impacts of the Proposed Action

When evaluating the impacts of the proposed action, 80 environmental issues were identified: 72 issues associated with continued operations and any refurbishment during the initial LR and SLR terms; 2 with postulated accidents; 1 with the termination of nuclear power plant operations and decommissioning; 4 with the uranium fuel cycle; and 1 with cumulative effects. For all issues, the focus of the evaluation was on the incremental effects of license renewal (for the initial LR or SLR term) relative to the no action alternative. Impact significance levels and categories are defined in Section 1.5.

A summary of the environmental impacts of the proposed action is presented in Table 2.1-1. The technical basis for the impact determinations presented in this table is found in Chapter 4.0 of this LR GEIS in Sections 4.2 through 4.14.

**Table 2.1-1 Summary of Findings on Environmental Issues under the Proposed Action (Initial and Subsequent License Renewal)**

| Environmental Issue | Impact Finding[(a)(b)] |
|---|---|
| **Land Use** | |
| Onsite land use | **SMALL (Category 1).** Changes in onsite land use from continued operations and refurbishment associated with license renewal would be a small fraction of the nuclear power plant site and would involve only land that is controlled by the licensee. |
| Offsite land use | **SMALL (Category 1).** Offsite land use would not be affected by continued operations and refurbishment associated with license renewal. |
| Offsite land use in transmission line right-of-ways (ROWs)[(c)] | **SMALL (Category 1).** Use of transmission line ROWs from continued operations and refurbishment associated with license renewal would continue with no change in land use restrictions. |
| **Visual Resources** | |
| Aesthetic impacts | **SMALL (Category 1).** No important changes to the visual appearance of plant structures or transmission lines are expected from continued operations and refurbishment associated with license renewal. |

| Environmental Issue | Impact Finding[a][b] |
|---|---|
| **Air Quality** | |
| Air quality impacts | **SMALL (Category 1).** Air quality impacts from continued operations and refurbishment associated with license renewal are expected to be small at all plants. Emissions from emergency diesel generators and fire pumps and routine operations of boilers used for space heating are minor. Impacts from cooling tower particulate emissions have been small.<br><br>Emissions resulting from refurbishment activities at locations in or near air quality nonattainment or maintenance areas would be short-lived and would cease after these activities are completed. Operating experience has shown that the scale of refurbishment activities has not resulted in exceedance of the *de minimis* thresholds for criteria pollutants, and best management practices, including fugitive dust controls and the imposition of permit conditions in State and local air emissions permits, would ensure conformance with applicable State or Tribal implementation plans. |
| Air quality effects of transmission lines[c] | **SMALL (Category 1).** Production of ozone and oxides of nitrogen from transmission lines is insignificant and does not contribute measurably to ambient levels of these gases. |
| **Noise** | |
| Noise impacts | **SMALL (Category 1).** Noise levels would remain below regulatory guidelines for offsite receptors during continued operations and refurbishment associated with license renewal. |
| **Geologic Environment** | |
| Geology and soils | **SMALL (Category 1).** The impact of continued operations and refurbishment activities on geology and soils would be small for all nuclear power plants and would not change appreciably during the license renewal term. |
| **Surface Water Resources** | |
| Surface water use and quality (non-cooling system impacts) | **SMALL (Category 1).** Impacts are expected to be small if best management practices are employed to control soil erosion and spills. Surface water use associated with continued operations and refurbishment associated with license renewal would not increase significantly or would be reduced if refurbishment occurs during a plant outage. |
| Altered current patterns at intake and discharge structures | **SMALL (Category 1).** Altered current patterns would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been small at operating nuclear power plants. |
| Altered salinity gradients | **SMALL (Category 1).** Effects on salinity gradients would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been small at operating nuclear power plants. |
| Altered thermal stratification of lakes | **SMALL (Category 1).** Effects on thermal stratification would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been small at operating nuclear power plants. |
| Scouring caused by discharged cooling water | **SMALL (Category 1).** Scouring effects would be limited to the area in the vicinity of the intake and discharge structures. These impacts have been small at operating nuclear power plants. |

| Environmental Issue | Impact Finding[(a)(b)] |
|---|---|
| Discharge of metals in cooling system effluent | **SMALL (Category 1).** Discharges of metals have not been found to be a problem at operating nuclear power plants with cooling-tower-based heat dissipation systems and have been satisfactorily mitigated at other plants. Discharges are monitored and controlled as part of the National Pollutant Discharge Elimination System (NPDES) permit process. |
| Discharge of biocides, sanitary wastes, and minor chemical spills | **SMALL (Category 1).** The effects of these discharges are regulated by Federal and State environmental agencies. Discharges are monitored and controlled as part of the NPDES permit process. These impacts have been small at operating nuclear power plants. |
| Surface water use conflicts (plants with once-through cooling systems) | **SMALL (Category 1).** These conflicts have not been found to be a problem at operating nuclear power plants with once-through heat dissipation systems. |
| Surface water use conflicts (plants with cooling ponds or cooling towers using makeup water from a river) | **SMALL or MODERATE (Category 2).** Impacts could be of small or moderate significance, depending on makeup water requirements, water availability, and competing water demands. |
| Effects of dredging on surface water quality | **SMALL (Category 1).** Dredging to remove accumulated sediments in the vicinity of intake and discharge structures and to maintain barge shipping has not been found to be a problem for surface water quality. Dredging is performed under permit from the U.S. Army Corps of Engineers, and possibly, from other State or local agencies. |
| Temperature effects on sediment transport capacity | **SMALL (Category 1).** These effects have not been found to be a problem at operating nuclear power plants and are not expected to be a problem during the license renewal term. |
| **Groundwater Resources** | |
| Groundwater contamination and use (non-cooling system impacts) | **SMALL (Category 1).** Extensive dewatering is not anticipated from continued operations and refurbishment associated with license renewal. Industrial practices involving the use of solvents, hydrocarbons, heavy metals, or other chemicals, and/or the use of wastewater ponds or lagoons have the potential to contaminate site groundwater, soil, and subsoil. Contamination is subject to State or U.S. Environmental Protection Agency (EPA) regulated cleanup and monitoring programs. The application of best management practices for handling any materials produced or used during these activities would reduce impacts. |
| Groundwater use conflicts (plants that withdraw less than 100 gallons per minute [gpm]) | **SMALL (Category 1).** Plants that withdraw less than 100 gpm are not expected to cause any groundwater use conflicts. |
| Groundwater use conflicts (plants that withdraw more than 100 gallons per minute [gpm]) | **SMALL, MODERATE, or LARGE (Category 2).** Plants that withdraw more than 100 gpm could cause groundwater use conflicts with nearby groundwater users. |

| Environmental Issue | Impact Finding[(a)(b)] |
|---|---|
| Groundwater use conflicts (plants with closed-cycle cooling systems that withdraw makeup water from a river) | **SMALL, MODERATE, or LARGE (Category 2).** Water use conflicts could result from water withdrawals from rivers during low-flow conditions, which may affect aquifer recharge. The significance of impacts would depend on makeup water requirements, water availability, and competing water demands. |
| Groundwater quality degradation resulting from water withdrawals | **SMALL (Category 1).** Groundwater withdrawals at operating nuclear power plants would not contribute significantly to groundwater quality degradation. |
| Groundwater quality degradation (plants with cooling ponds) | **SMALL or MODERATE (Category 2).** Sites with cooling ponds could degrade groundwater quality. The significance of the impact would depend on site-specific conditions including cooling pond water quality, site hydrogeologic conditions (including the interaction of surface water and groundwater), and the location, depth, and pump rate of water wells. |
| Radionuclides released to groundwater | **SMALL or MODERATE (Category 2).** Leaks of radioactive liquids from plant components and pipes have occurred at numerous plants. Groundwater protection programs have been established at all operating nuclear power plants to minimize the potential impact from any inadvertent releases. The magnitude of impacts would depend on site-specific characteristics. |
| **Terrestrial Resources** | |
| Non-cooling system impacts on terrestrial resources | **SMALL, MODERATE, or LARGE (Category 2).** The magnitude of effects of continued nuclear power plant operation and refurbishment, unrelated to operation of the cooling system, would depend on numerous site-specific factors, including ecological setting, planned activities during the license renewal term, and characteristics of the plants and animals present in the area. Application of best management practices and other conservation initiatives would reduce the potential for impacts. |
| Exposure of terrestrial organisms to radionuclides | **SMALL (Category 1).** Doses to terrestrial organisms from continued nuclear power plant operation and refurbishment during the license renewal term would be expected to remain well below U.S. Department of Energy exposure guidelines developed to protect these organisms. |
| Cooling system impacts on terrestrial resources (plants with once-through cooling systems or cooling ponds) | **SMALL (Category 1).** Continued operation of nuclear power plant cooling systems during license renewal could cause thermal effluent additions to receiving water bodies, chemical effluent additions to surface water or groundwater, impingement of waterfowl, disturbance of terrestrial plants and wetlands from maintenance dredging, and erosion of shoreline habitat. However, plants where these impacts have occurred successfully mitigated the impact, and it is no longer of concern. These impacts are not expected to be significant issues during the license renewal term. |
| Cooling tower impacts on terrestrial plants | **SMALL (Category 1).** Continued operation of nuclear power plant cooling towers could deposit particulates and water droplets or ice on vegetation and lead to structural damage or changes in terrestrial plant communities. However, nuclear power plants where these impacts occurred have successfully mitigated the impact. These impacts are not expected to be significant issues during the license renewal term. |

| Environmental Issue | Impact Finding[a][b] |
| --- | --- |
| Bird collisions with plant structures and transmission lines[c] | **SMALL (Category 1).** Bird mortalities from collisions with nuclear power plant structures and in-scope transmission lines would be negligible for any species and are unlikely to threaten the stability of local or migratory bird populations or result in noticeable impairment of the function of a species within the ecosystem. These impacts are not expected to be significant issues during the license renewal term. |
| Water use conflicts with terrestrial resources (plants with cooling ponds or cooling towers using makeup water from a river) | **SMALL or MODERATE (Category 2).** Nuclear power plants could consume water at rates that cause occasional or intermittent water use conflicts with nearby and downstream terrestrial and riparian communities. Such impacts could noticeably affect riparian or wetland species or alter characteristics of the ecological environment during the license renewal term. The one plant where impacts have occurred successfully mitigated the impact. Impacts are expected to be small at most nuclear power plants but could be moderate at some. |
| Transmission line right-of-way (ROW) management impacts on terrestrial resources[c] | **SMALL (Category 1).** In-scope transmission lines tend to occupy only industrial-use or other developed portions of nuclear power plant sites and, therefore, effects of ROW maintenance on terrestrial plants and animals during the license renewal term would be negligible. Application of best management practices would reduce the potential for impacts. |
| Electromagnetic field effects on terrestrial plants and animals[c] | **SMALL (Category 1).** In-scope transmission lines tend to occupy only industrial-use or other developed portions of nuclear power plant sites and, therefore, the effects of electromagnetic fields on terrestrial plants and animals during the license renewal term would be negligible. |
| **Aquatic Resources** | |
| Impingement mortality and entrainment of aquatic organisms (plants with once-through cooling systems or cooling ponds) | **SMALL, MODERATE, or LARGE (Category 2).** The impacts of impingement mortality and entrainment would generally be small at nuclear power plants with once-through cooling systems or cooling ponds that have implemented best technology requirements for existing facilities under Clean Water Act (CWA) Section 316(b). For all other plants, impacts could be small, moderate, or large depending on characteristics of the cooling water intake system, results of impingement and entrainment studies performed at the plant, trends in local fish and shellfish populations, and implementation of mitigation measures. |
| Impingement mortality and entrainment of aquatic organisms (plants with cooling towers) | **SMALL (Category 1).** No significant impacts on aquatic populations associated with impingement mortality and entrainment at nuclear power plants with cooling towers have been reported, including effects on fish and shellfish from direct mortality, injury, or other sublethal effects. Impacts during the license renewal term would be similar and small. Further, the effects of these cooling water intake systems would be mitigated through adherence to NPDES permit conditions established pursuant to CWA Section 316(b). |
| Entrainment of phytoplankton and zooplankton | **SMALL (Category 1).** Entrainment has not resulted in noticeable impacts on phytoplankton or zooplankton populations near operating nuclear power plants. Impacts during the license renewal term would be similar and small. Further, effects would be mitigated through adherence to NPDES permit conditions established pursuant to CWA Section 316(b). |
| Effects of thermal effluents on aquatic organisms (plants with once-through | **SMALL, MODERATE, or LARGE (Category 2).** Acute, sublethal, and community-level effects of thermal effluents on aquatic organisms would generally be small at nuclear power plants with once-through cooling systems or cooling ponds that adhere to State water quality criteria or that |

| Environmental Issue | Impact Finding[(a)(b)] |
| --- | --- |
| cooling systems or cooling ponds) | have and maintain a valid CWA Section 316(a) variance. For all other plants, impacts could be small, moderate, or large depending on site-specific factors, including ecological setting of the plant; characteristics of the cooling system and effluent discharges; and characteristics of the fish, shellfish, and other aquatic organisms present in the area. |
| Effects of thermal effluents on aquatic organisms (plants with cooling towers) | **SMALL (Category 1).** Acute, sublethal, and community-level effects of thermal effluents have not resulted in noticeable impacts on aquatic communities at nuclear power plants with cooling towers. Impacts during the license renewal term would be similar and small. Further, effects would be mitigated through adherence to State water quality criteria or CWA Section 316(a) variances. |
| Infrequently reported effects of thermal effluents | **SMALL (Category 1).** Continued operation of nuclear power plant cooling systems could result in certain infrequently reported thermal impacts, including cold shock, thermal migration barriers, accelerated maturation of aquatic insects, proliferation of aquatic nuisance organisms, depletion of dissolved oxygen, gas supersaturation, eutrophication, and increased susceptibility of exposed fish and shellfish to predation, parasitism, and disease. Most of these effects have not been reported at operating nuclear power plants. Plants that have experienced these impacts successfully mitigated the impact, and it is no longer of concern. Infrequently reported thermal impacts are not expected to be significant issues during the license renewal term. |
| Effects of nonradiological contaminants on aquatic organisms | **SMALL (Category 1).** Heavy metal leaching from condenser tubes was an issue at several operating nuclear power plants. These plants successfully mitigated the issue, and it is no longer of concern. Cooling system effluents would be the primary source of nonradiological contaminants during the license renewal term. Implementation of best management practices and adherence to NPDES permit limitations would minimize the effects of these contaminants on the aquatic environment. |
| Exposure of aquatic organisms to radionuclides | **SMALL (Category 1).** Doses to aquatic organisms from continued nuclear power plant operation and refurbishment during the license renewal term would be expected to remain well below U.S. Department of Energy exposure guidelines developed to protect these organisms. |
| Effects of dredging on aquatic resources | **SMALL (Category 1).** Dredging at nuclear power plants is expected to occur infrequently, would be of relatively short duration, and would affect relatively small areas. Continued operation of many plants may not require any dredging. Adherence to best management practices and CWA Section 404 permit conditions would mitigate potential impacts at plants where dredging is necessary to maintain function or reliability of cooling systems. Dredging is not expected to be a significant issue during the license renewal term. |
| Water use conflicts with aquatic resources (plants with cooling ponds or cooling towers using makeup water from a river) | **SMALL or MODERATE (Category 2).** Nuclear power plants could consume water at rates that cause occasional or intermittent water use conflicts with nearby and downstream aquatic communities. Such impacts could noticeably affect aquatic plants or animals or alter characteristics of the ecological environment during the license renewal term. The one plant where impacts have occurred successfully mitigated the impact. Impacts are expected to be small at most nuclear power plants but could be moderate at some. |

| Environmental Issue | Impact Finding[(a)(b)] |
|---|---|
| Non-cooling system impacts on aquatic resources | **SMALL (Category 1).** No significant impacts on aquatic resources associated with landscape and grounds maintenance, stormwater management, or ground-disturbing activities at operating nuclear power plants have been reported. Impacts from continued operation and refurbishment during the license renewal term would be similar and small. Application of best management practices and other conservation initiatives would reduce the potential for impacts. |
| Impacts of transmission line right-of-way (ROW) management on aquatic resources[(c)] | **SMALL (Category 1).** In-scope transmission lines tend to occupy only industrial-use or other developed portions of nuclear power plant sites and, therefore, the effects of ROW maintenance on aquatic plants and animals during the license renewal term would be negligible. Application of best management practices would reduce the potential for impacts. |
| **Federally Protected Ecological Resources** | |
| Endangered Species Act: federally listed species and critical habitats under U.S. Fish and Wildlife jurisdiction | **(Category 2).** The potential effects of continued nuclear power plant operation and refurbishment on federally listed species and critical habitats would depend on numerous site-specific factors, including the ecological setting; listed species and critical habitats present in the action area; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and other ground-disturbing activities. Consultation with the U.S. Fish and Wildlife Service under Endangered Species Act Section 7(a)(2) would be required if license renewal may affect listed species or critical habitats under this agency's jurisdiction. |
| Endangered Species Act: federally listed species and critical habitats under National Marine Fisheries Service jurisdiction | **(Category 2).** The potential effects of continued nuclear power plant operation and refurbishment on federally listed species and critical habitats would depend on numerous site-specific factors, including the ecological setting; listed species and critical habitats present in the action area; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and other ground-disturbing activities. Consultation with the National Marine Fisheries Service under Endangered Species Act Section 7(a)(2) would be required if license renewal may affect listed species or critical habitats under this agency's jurisdiction. |
| Magnuson-Stevens Act: essential fish habitat | **(Category 2).** The potential effects of continued nuclear power plant operation and refurbishment on essential fish habitat would depend on numerous site-specific factors, including the ecological setting; essential fish habitat present in the area, including habitats of particular concern; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and other activities that may affect aquatic habitats. Consultation with the National Marine Fisheries Service under Magnuson-Stevens Act Section 305(b) would be required if license renewal could result in adverse effects to essential fish habitat. |
| National Marine Sanctuaries Act: sanctuary resources | **(Category 2).** The potential effects of continued nuclear power plant operation and refurbishment on sanctuary resources would depend on numerous site-specific factors, including the ecological setting; national marine sanctuaries present in the area; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and other activities that may affect aquatic habitats. Consultation with the Office of National Marine Sanctuaries under National Marine Sanctuaries Act Section 304(d) would be required if license renewal could destroy, cause the loss of, or injure sanctuary resources. |

| Environmental Issue | Impact Finding[(a)(b)] |
|---|---|
| **Historic and Cultural Resources** | |
| Historic and cultural resources[(c)] | **(Category 2).** Impacts from continued operations and refurbishment on historic and cultural resources located onsite and in the transmission line ROW are analyzed on a plant-specific basis. The NRC will perform a National Historic Preservation Act (NHPA) Section 106 review, in accordance with 36 CFR Part 800 which includes consultation with the State and Tribal Historic Preservation Officers, Indian Tribes, and other interested parties. |
| **Socioeconomics** | |
| Employment and income, recreation and tourism | **SMALL (Category 1).** Although most nuclear plants have large numbers of employees with higher than average wages and salaries, employment, income, recreation, and tourism impacts from continued operations and refurbishment associated with license renewal are expected to be small. |
| Tax revenue | **SMALL (Category 1).** Nuclear plants provide tax revenue to local jurisdictions in the form of property tax payments, payments in lieu of tax (PILOT), or tax payments on energy production. The amount of tax revenue paid during the license renewal term as a result of continued operations and refurbishment associated with license renewal is not expected to change. |
| Community services and education | **SMALL (Category 1).** Changes resulting from continued operations and refurbishment associated with license renewal to local community and educational services would be small. With little or no change in employment at the licensee's plant, value of the power plant, payments on energy production, and PILOT payments expected during the license renewal term, community and educational services would not be affected by continued power plant operations. |
| Population and housing | **SMALL (Category 1).** Changes resulting from continued operations and refurbishment associated with license renewal to regional population and housing availability and value would be small. With little or no change in employment at the licensee's plant expected during the license renewal term, population and housing availability and values would not be affected by continued power plant operations. |
| Transportation | **SMALL (Category 1).** Changes resulting from continued operations and refurbishment associated with license renewal to traffic volumes would be small. |
| **Human Health** | |
| Radiation exposures to plant workers | **SMALL (Category 1).** Occupational doses from continued operations and refurbishment associated with license renewal are expected to be within the range of doses experienced during the current license term, and would continue to be well below regulatory limits. |
| Radiation exposures to the public | **SMALL (Category 1).** Radiation doses to the public from continued operations and refurbishment associated with license renewal are expected to continue at current levels, and would be well below regulatory limits. |
| Chemical hazards | **SMALL (Category 1).** Chemical hazards to plant workers resulting from continued operations and refurbishment associated with license renewal are expected to be minimized by the licensee implementing good industrial hygiene practices as required by permits and Federal and State |

| Environmental Issue | Impact Finding[a][b] |
|---|---|
| | regulations. Chemical releases to the environment and the potential for impacts to the public are expected to be minimized by adherence to discharge limitations of NPDES and other permits. |
| Microbiological hazards to plant workers | **SMALL (Category 1).** Occupational health impacts are expected to be controlled by continued application of accepted industrial hygiene practices to minimize worker exposures as required by permits and Federal and State regulations. |
| Microbiological hazards to the public | **SMALL, MODERATE, or LARGE (Category 2).** These microorganisms are not expected to be a problem at most operating plants except possibly at plants using cooling ponds, lakes, canals, or that discharge to waters of the United States accessible to the public. Impacts would depend on site-specific characteristics. |
| Electromagnetic fields (EMFs)[c] | **Uncategorized (Uncertain impact).** Studies of 60-Hz EMFs have not uncovered consistent evidence linking harmful effects with field exposures. EMFs are unlike other agents that have a toxic effect (e.g., toxic chemicals and ionizing radiation) in that dramatic acute effects cannot be forced and longer-term effects, if real, are subtle. Because the state of the science is currently inadequate, no generic conclusion on human health impacts is possible. |
| Physical occupational hazards | **SMALL (Category 1).** Occupational safety and health hazards are generic to all types of electrical generating stations, including nuclear power plants, and are of small significance if the workers adhere to safety standards and use protective equipment as required by Federal and State regulations. |
| Electric shock hazards[c] | **SMALL, MODERATE, or LARGE (Category 2).** Electrical shock potential is of small significance for transmission lines that are operated in adherence with the National Electrical Safety Code (NESC). Without a review of conformance with NESC criteria of each nuclear power plant's in-scope transmission lines, it is not possible to determine the significance of the electrical shock potential. |
| **Postulated Accidents** | |
| Design-basis accidents | **SMALL (Category 1).** The NRC staff has concluded that the environmental impacts of design-basis accidents are of small significance for all plants. |
| Severe accidents[d] | **SMALL (Category 1).** The probability-weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to groundwater, and societal and economic impacts from severe accidents are small for all plants. Severe accident mitigation alternatives do not warrant further plant-specific analysis because the demonstrated reductions in population dose risk and continued severe accident regulatory improvements substantially reduce the likelihood of finding cost-effective significant plant improvements. |
| **Environmental Justice** | |
| Impacts on minority populations, low-income populations, and Indian Tribes | **(Category 2).** Impacts on minority populations, low-income populations, Indian Tribes, and subsistence consumption resulting from continued operations and refurbishment associated with license renewal will be addressed in nuclear plant-specific reviews. See "Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions" (69 FR 52040; August 24, 2004). |

| Environmental Issue | Impact Finding[(a)(b)] |
|---|---|
| **Waste Management** | |
| Low-level waste storage and disposal | **SMALL (Category 1).** The comprehensive regulatory controls that are in place and the low public doses being achieved at reactors ensure that the radiological impacts on the environment would remain small during the license renewal term. |
| Onsite storage of spent nuclear fuel | During the license renewal term, **Small (Category 1).** The expected increase in the volume of spent fuel from an additional 20 years of operation can be safely accommodated onsite during the license renewal term with small environmental impacts through dry or pool storage at all plants.<br><br>For the period after the licensed life for reactor operations, the impacts of onsite storage of spent nuclear fuel during the continued storage period are discussed in NUREG-2157 and as stated in § 51.23(b), shall be deemed incorporated into this issue. |
| Offsite radiological impacts of spent nuclear fuel and high-level waste disposal | **(Category 1).** For the high-level waste and spent fuel disposal component of the fuel cycle, the EPA established a dose limit of 0.15 mSv (15 millirem) per year for the first 10,000 years and 1.0 mSv (100 millirem) per year between 10,000 years and 1 million years for offsite releases of radionuclides at the proposed repository at Yucca Mountain, Nevada.<br><br>The Commission concludes that the impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the impacts of spent fuel and high level waste disposal, this issue is considered Category 1. |
| Mixed-waste storage and disposal | **SMALL (Category 1).** The comprehensive regulatory controls and the facilities and procedures that are in place ensure proper handling and storage, as well as negligible doses and exposure to toxic materials for the public and the environment at all plants. License renewal would not increase the small, continuing risk to human health and the environment posed by mixed waste at all plants. The radiological and nonradiological environmental impacts of long-term disposal of mixed waste from any individual plant at licensed sites are small. |
| Nonradioactive waste storage and disposal | **SMALL (Category 1).** No changes to systems that generate nonradioactive waste are anticipated during the license renewal term. Facilities and procedures are in place to ensure continued proper handling, storage, and disposal, as well as negligible exposure to toxic materials for the public and the environment at all plants. |
| **Greenhouse Gas Emissions and Climate Change** | |
| Greenhouse gas impacts on climate change | **SMALL (Category 1).** Greenhouse gas impacts on climate change from continued operations and refurbishment associated with license renewal are expected to be small at all plants. Greenhouse gas emissions from routine operations of nuclear power plants are typically very minor, because such plants, by their very nature, do not normally combust fossil fuels to generate electricity.<br><br>Greenhouse gas emissions from construction vehicles and other motorized equipment for refurbishment activities would be intermittent and temporary, |

| Environmental Issue | Impact Finding[(a)(b)] |
|---|---|
| | restricted to the refurbishment period. Worker vehicle greenhouse gas emissions for refurbishment would be similar to worker vehicle emissions from normal nuclear power plant operations. |
| Climate change impacts on environmental resources | **(Category 2).** Climate change can have additive effects on environmental resource conditions that may also be directly impacted by continued operations and refurbishment during the license renewal term. The effects of climate change can vary regionally and climate change information at the regional and local scale is necessary to assess trends and the impacts on the human environment for a specific location. The impacts of climate change on environmental resources during the license renewal term are location-specific and cannot be evaluated generically. |
| **Cumulative Effects** | |
| Cumulative effects | **(Category 2).** Cumulative effects or impacts of continued operations and refurbishment associated with license renewal must be considered on a plant-specific basis. The effects depend on regional resource characteristics, the incremental resource-specific effects of license renewal, and the cumulative significance of other factors affecting the environmental resource. |
| **Uranium Fuel Cycle** | |
| Offsite radiological impacts—individual impacts from other than the disposal of spent fuel and high-level waste | **SMALL (Category 1).** The impacts to the public from radiological exposures have been considered by the Commission in Table S-3 of this part. Based on information in the GEIS, impacts to individuals from radioactive gaseous and liquid releases, including radon-222 and technetium-99, would remain at or below the NRC's regulatory limits. |
| Offsite radiological impacts—collective impacts from other than the disposal of spent fuel and high-level waste | **(Category 1).** There are no regulatory limits applicable to collective doses to the general public from fuel-cycle facilities. The practice of estimating health effects on the basis of collective doses may not be meaningful. All fuel-cycle facilities are designed and operated to meet the applicable regulatory limits and standards. The Commission concludes that the collective impacts are acceptable.<br><br>The Commission concludes that the impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR Part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the collective impacts of the uranium fuel cycle, this issue is considered Category 1. |
| Nonradiological impacts of the uranium fuel cycle | **SMALL (Category 1).** The nonradiological impacts of the uranium fuel cycle resulting from the renewal of an operating license for any plant would be small. |
| Transportation | **SMALL (Category 1).** The impacts of transporting materials to and from uranium-fuel-cycle facilities on workers, the public, and the environment are expected to be small. |

| Environmental Issue | Impact Finding[(a)(b)] |
|---|---|
| **Termination of Nuclear Power Plant Operations and Decommissioning** | |
| Termination of plant operations and decommissioning | **SMALL (Category 1).** License renewal is expected to have a negligible effect on the impacts of terminating operations and decommissioning on all resources. |

(a) Supports the finding codified in Table B-1 of Appendix B to Subpart A of 10 CFR Part 51. Where appropriate, a single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts.
(b) The technical bases for these issues and findings in the LR GEIS have been revised to fully support the impacts of initial LR and SLR.
(c) This issue applies only to the in-scope portion of electric power transmission lines, which are defined as transmission lines that connect the nuclear power plant to the substation where electricity is fed into the regional power distribution system and transmission lines that supply power to the nuclear plant from the grid.
(d) Although the NRC does not anticipate any license renewal applications for nuclear power plants for which a previous severe accident mitigation design alternative (SAMDA) or severe accident mitigation alternative (SAMA) analysis has not been performed, alternatives to mitigate severe accidents must be considered for all plants that have not considered such alternatives.

## 2.2 No Action Alternative

The no action alternative represents a decision by the NRC not to renew the operating license of a nuclear power plant beyond the current operating license term. At some point, all nuclear plants will terminate operations and undergo decommissioning. Under the no action alternative, plant operations would terminate at or before the end of the current license term.

Not renewing the license and ceasing operation under the no action alternative may lead to a variety of potential outcomes, but these would be essentially the same regardless of whether operations cease at the expiration of the original operating license or at the expiration of a renewed license. Expiration of a license will require the reactor to ultimately undergo decommissioning, whether it be more immediate (as under DECON), or deferred (as under SAFSTOR). Termination of nuclear power plant operations would result in the total cessation of electrical power production. The no action alternative, unlike the other alternatives, does not expressly meet the purpose and need of the proposed action, because it does not provide a means of delivering baseload power to meet future electric system needs. No action on its own would likely create a need for replacement energy; that need could be met by installation of additional generating capacity, adoption or expansion of energy conservation and energy efficiency programs (including demand-side management), delayed retirements, purchased power, or some combination of these options.

## 2.3 Alternative Energy Sources

The following sections describe alternative energy sources identified by the NRC as being potentially capable of meeting the purpose and need of the proposed action (license renewal). Accordingly, these alternative energy sources could provide additional options that allow for baseload power-generation capability beyond the term of the current nuclear power plant operating license to meet future system power-generating needs, as such needs may be determined by State, utility, and, where authorized, Federal (other than NRC) decisionmakers. A reasonable alternative must be commercially viable on a utility scale and operational prior to the expiration of the reactor's operating license, or expected to become commercially viable on a utility scale and operational prior to the expiration of the reactor's operating license. The NRC has updated this LR GEIS to incorporate the latest information on alternative energy sources, but it is inevitable that rapidly evolving technologies will outpace the information presented. As technologies improve, the NRC expects that some alternative energy sources not currently viable for replacing or offsetting the power generated by a nuclear power plant may become viable at some time in the future. The NRC will make that determination during plant-specific license renewal reviews, as documented in plant-specific SEISs to this LR GEIS. The amount of replacement power generated or offset must equal the baseload capacity previously supplied by the nuclear plant and reliably operate at or near the nuclear plant's demonstrated capacity factor.[1]

If the need arises to replace or offset the generating capacity of a nuclear reactor, power could be provided by a suite of individual alternative energy sources. Power could also be provided using combinations of alternative energy sources, as well as by instituting demand-side management measures, delaying the scheduled retirement of one or more existing power plants, or purchasing an equivalent amount of power. The number of possible combinations of alternative energy sources that could replace or offset the generating capacity of a nuclear power plant is potentially unlimited. Based on this, the NRC has only evaluated individual energy sources rather than combinations of energy sources in this LR GEIS. However, combinations of energy sources may be considered during plant-specific license renewal reviews.

The following sections describe alternative means of generating electricity or otherwise addressing electrical loads that could serve to replace or offset the power produced by an existing nuclear power plant. As discussed in Chapter 1.0, the NRC does not engage in energy-planning decisions and makes no judgment about which alternative energy source(s) evaluated would be chosen in any given case.

The NRC relies on many sources of information to determine which alternatives are available and commercially viable. The U.S. Department of Energy's (DOE's) Energy Information Administration (EIA) maintains the official energy statistics of the Federal government. Along with information from other sources, the NRC commonly uses information from EIA reports, including the Electric Power Annual, Monthly Energy Review, Annual Energy Outlook, and Assumptions to the Annual Energy Outlook to identify energy trends and inform the staff's analysis of alternatives to the proposed action (initial LR or SLR). The NRC often considers the existing portfolio of electric generating technologies in the State or utility service area in which a nuclear plant is located, along with State and Federal policies that may promote or oppose certain alternatives. The NRC may also use the EIA's State Energy Profiles as well as State, regional, and, in some cases, utility- or system-level assessments of energy resources and projections (such as integrated resource plans) to identify alternatives for consideration.

The United States relies on a variety of energy sources and technologies to provide electrical power. Annual electric power generation has decreased from 4,125 million megawatt-hours (MMWh) in 2010 to 4,007 MMWh in 2020. Coal and petroleum (oil) generation decreased substantially between 2010 and 2020, while natural gas, wind, and solar increased. Table 2.3-1 includes the changes in values of net generation at utility-scale facilities between 2010 and 2020 (DOE/EIA 2022d).

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[1] The capacity factor is the ratio of the amount of electric energy produced by an electric generator over a given period of time to the amount of electric energy the same generator would have produced had it operated at its full, rated capacity over the same period of time.

**Table 2.3-1 Net Generation at Utility-Scale Facilities (million megawatt-hours [MMWh])**

| Utility-Scale Facility | Net Generation (in MMWh) in Year 2010 | Net Generation (in MMWh) in Year 2020 |
|---|---|---|
| Nuclear | 807 | 790 |
| Coal | 1,847 | 773 |
| Natural Gas | 988 | 1,624 |
| Oil | 37 | 17 |
| Hydroelectric | 260 | 285 |
| Geothermal | 15 | 16 |
| Wind | 95 | 338 |
| Biomass | 56 | 55 |
| Solar | 1 | 89 |
| Other[(a)] | 19 | 19 |
| Total | 4,125 | 4,007 |

MMWh = million megawatt-hours.
(a) Other includes blast furnace gas and other manufactured and waste gases derived from fossil fuels, non-biogenic municipal solid waste, batteries, hydrogen, purchased steam, sulfur, tire-derived fuel, and other miscellaneous energy sources, offset by savings associated with hydroelectric pumped storage.

In the EIA's *Annual Energy Outlook 2022 with Projections to 2050* (DOE/EIA 2022b), the EIA projects an increase in energy consumption and generating capacity throughout the 2050 forecast period because population and economic growth is expected to outweigh efficiency gains. Electricity demand is expected to grow slowly over the projection period, with renewable energy generation increasing more rapidly than overall electricity demand. Battery storage is expected to reduce natural gas- and oil-fired generation during peak hours. As coal and nuclear generating capacity retires, new capacity additions are likely to come largely from wind and solar generation (DOE/EIA 2022a).

In Sections 2.3.1 through 2.3.3 of this LR GEIS, the NRC presents a variety of energy sources (including fossil fuel, nuclear, and renewable energy technologies) that might be considered as alternatives for replacing the power generated by nuclear power plants being considered for initial LR or SLR. In Chapter 4.0, the NRC compares the environmental impacts of these alternatives to the environmental impacts of license renewal. In addition, Section 2.3.4 discusses non-power generating approaches that could also be considered for offsetting a nuclear power plant's existing capacity.

## 2.3.1 Fossil Fuel Energy Technologies

Fossil fuel energy technologies burn fuel derived from ancient organic matter such as natural gas, coal, or crude oil and as such are a source of greenhouse gases, including carbon dioxide ($CO_2$) (NRC 2013a). While the EIA indicates that renewable energy will be the fastest-growing category of U.S. energy source through 2050, fossil fuels such as natural gas will maintain a large market share, while coal and oil are likely to continue to decline.

### *2.3.1.1 Natural Gas*

The most common types of natural gas-fired plants are combustion turbine and combined-cycle plants. A schematic of a representative gas-fired power plant is provided in Figure 2.3-1. Combustion turbines use hot gases that drive a generator and are then used to run a compressor. In contrast, a combined-cycle power system typically uses a gas turbine to drive an electrical generator, recovering waste heat from the turbine exhaust to generate steam that drives a steam turbine generator. This two-cycle process has a high rate of efficiency because the natural gas combined-cycle system captures the exhaust heat that otherwise would be lost and reuses it. Baseload natural gas combined-cycle power plants have proven their reliability and can have capacity factors as high as 87 percent (DOE/EIA 2015a). Since 2016, 31 percent of new natural gas-powered plants constructed use advanced natural gas-fired combined-cycle units, increasing efficiency and decreasing capital construction costs (DOE/EIA 2019a).

As of 2021, natural gas technologies represented 37 percent of electricity generation, outpacing coal (23%), nuclear (19%), and renewables (21%). Based on reference case projections, natural gas generation as a proportion of U.S. electricity generation is expected to remain relatively constant (34% in 2050), with decreases in coal and nuclear generation being replaced by increases in renewables (DOE/EIA 2022h).

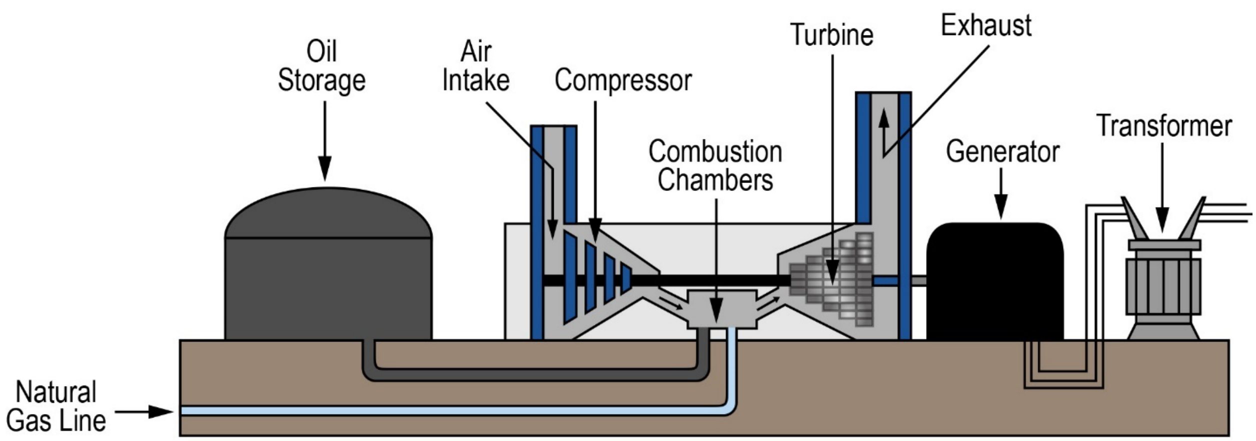



**Figure 2.3-1 Schematic of a Natural Gas-fired Plant**

*2.3.1.2 Coal*

Although coal has historically been the largest source of electricity generation in the United States, both natural gas and nuclear energy generation surpassed coal at the national level in 2020, before coal-fired generation rebounded after 2020. Overall, coal-fired electricity generation in the United States has continued to decrease as coal-fired generating units have been retired or converted to use other fuels and as the remaining coal-fired generating units have been used less often (DOE/EIA 2021c). Projections for the amount of electricity produced from coal in the future vary widely across planning scenarios, primarily due to cost uncertainties associated with anticipated future environmental regulations such as cap-and-trade regulations for nitrogen dioxide, sulfur dioxide and the regulation of greenhouse gases emissions, primarily carbon dioxide. The EIA projects that between 2021 and 2050, coal-fired generation will decrease from 23 percent to 10 percent of total U.S. electricity generation (DOE/EIA 2022h).

Baseload coal units have proven their reliability and can routinely sustain capacity factors as high as 85 percent. Among the technologies available, pulverized coal boilers producing supercritical steam (supercritical pulverized coal boilers) have become increasingly common at newer coal-fired plants given their generally high thermal efficiencies and overall reliability. A schematic of a representative coal-fired power plant is provided in Figure 2.3-2.

Supercritical pulverized coal facilities are more expensive than subcritical coal-fired plants to construct, but they consume less fuel per unit output, reducing environmental impacts. Integrated gasification combined cycle (IGCC) is another technology that generates electricity from coal. It combines modern coal gasification technology with both gas turbine and steam turbine power generation. The technology is cleaner than conventional pulverized coal plants because some of the major pollutants are removed from the gas stream before combustion. Although several smaller, IGCC power plants have been in operation since the mid-1990s, more recent large-scale projects using this technology have experienced setbacks and opposition that have hindered the technology from being fully integrated into the energy market.

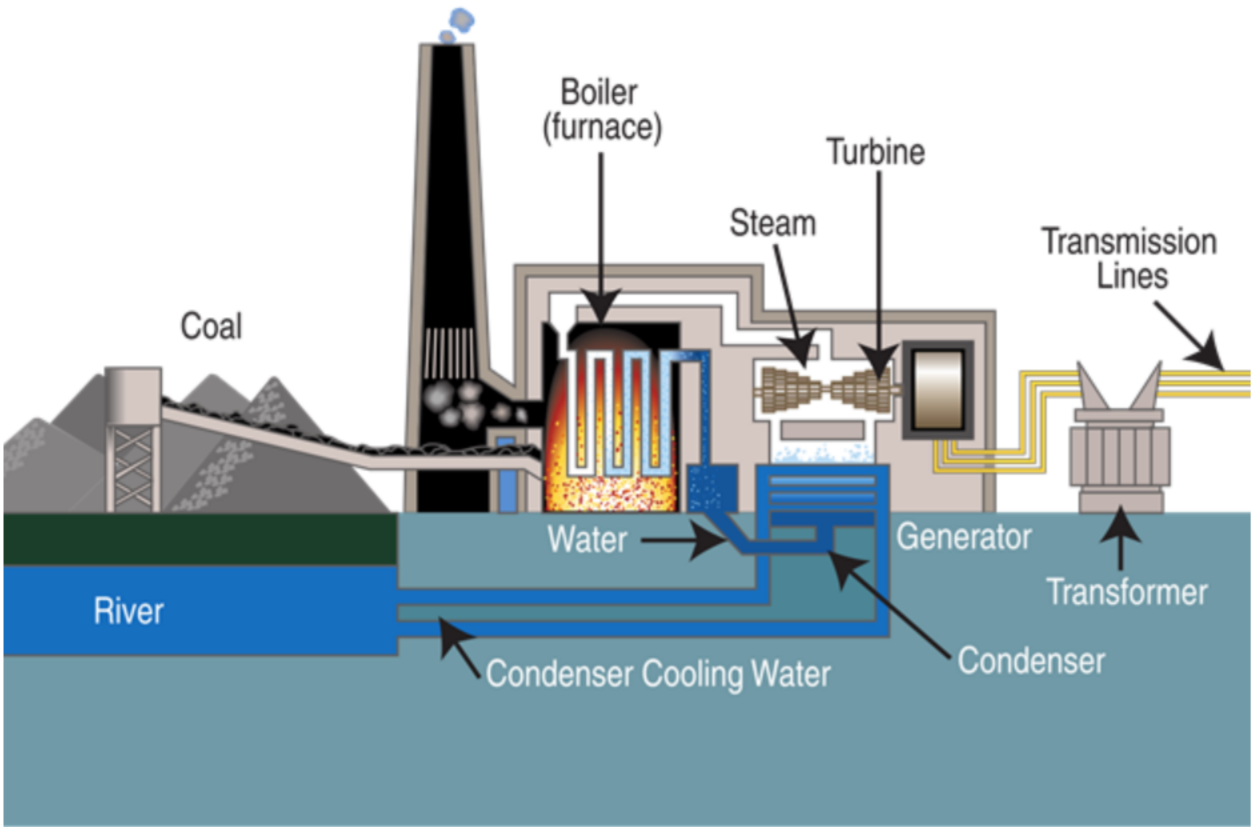



**Figure 2.3-2 Schematic of a Coal-fired Power Plant. Source: NETL Undated.**

Advanced coal technologies will likely become increasingly important as regulations on power plant emissions evolve, including under the Clean Air Act (42 U.S.C. § 701 et seq.) and the CWA (33 U.S. C. § 1251 et seq.). Technologies often referred to as “clean coal technologies,” which include coal cleaning processes, coal gasification technologies, improved combustion technologies, and enhanced devices for capturing pollutants, may reduce impacts associated with a coal-fired plant (NRC 2013a). The EIA assumes that by 2025, coal plants are expected to either invest in heat rate improvement technologies or be retired. Additionally, low natural gas prices are expected to contribute to the retirement of existing coal-fired plants (DOE/EIA 2020a).

#### *2.3.1.3 Oil*

Oil-fired energy technologies are conceptually similar to gas-fired technologies but use crude oil rather than natural gas fuel. According to the EIA, in 2016, only 3 percent of utility-scale generators used petroleum as a primary fuel and produced less than 1 percent of total electricity generation in the United States. In general, oil plants are located in coastal States where marine modes of oil transportation are competitive with transportation of coal by rail. These plants are on average nearly 40 years old, with roughly 70 percent of the capacity constructed prior to 1980. Since that time, oil-fired generation has become more expensive than other fossil fuel generation options. Accordingly, this high cost has contributed to the overall decline in the use of oil for electricity generation (DOE/EIA 2017).

### 2.3.2 New Nuclear Energy Technologies

Commercial nuclear power plants use fission to heat water and produce steam, which is then used to spin turbines that generate electricity. The newest nuclear power plant to enter service in the United States is Tennessee's Watts Bar Unit 2, which began operation in June 2016. Prior to then, the last new nuclear power reactor to come online was Watts Bar Unit 1 in 1996 (DOE/EIA 2022g). The EIA projects that nuclear power's contribution to total U.S. electrical generation will decrease from 19 percent in 2021 to 12 percent by 2050 (DOE/EIA 2022h). Currently, six light water nuclear reactor designs have been certified by the NRC. Certified designs include the 1,300 megawatt-electric (MWe) U.S. Advanced Boiling Water Reactor (10 CFR Part 52, Appendix A), the 1,300 MWe System 80+ Design (10 CFR Part 52, Appendix B), the 600 MWe AP600 Design (10 CFR Part 52 Appendix C), the 1,100 MWe AP1000 Design (10 CFR Part 52, Appendix D), the 1,500 MWe GE-Hitachi Economic Simplified Boiling Water Reactor (10 CFR Part 52 Appendix E), and the 1,400 MWe Korean Electric Power Corporation APR 1400 (10 CFR Part 52 Appendix F) (NRC 2020c).

Several companies are considering other advanced, non-light water reactor designs and technologies and are conducting preapplication activities with the NRC. These reactors may be cooled by liquid metals, molten salt mixtures, or inert gases. Advanced reactors can also consider fuel materials and designs that differ radically from standard uranium dioxide fuel types currently in use (NRC 2021c). Given the uncertainties associated with their technical viability and deployment timeframes, these emerging technologies are not evaluated further in this LR GEIS. Furthermore, the NRC is currently in the process of developing a Generic Environmental Impact Statement for Advanced Nuclear Reactors (ANR GEIS) to analyze the environmental impacts associated with the licensing of these reactors (85 FR 24040). In this LR GEIS, the NRC staff has evaluated the construction and operation of two types of new nuclear technologies as reasonable alternatives to license renewal: (1) large, advanced light water reactor (ALWR) plants and (2) small modular reactor (SMR) plants.

#### *2.3.2.1 Advanced Light Water Reactors*

ALWR designs feature advanced safety systems and evolutionary operating improvements over existing power reactors. The first large ALWR units to be built in the United States are expected to go into operation in 2023. When completed, Vogtle Units 3 and 4, in Waynesboro, Georgia, will become the first U.S. deployment of the Westinghouse AP1000 reactor, which was designed as a next-generation nuclear reactor that could provide a standardized design for the U.S. utilities market. In addition, the AP1000 has a smaller footprint, simpler design, and uses less piping, fewer valves, and fewer pumps than older designs (DOE/EIA 2022i, DOE Undated-d). A schematic of a large ALWR is depicted in Figure 2.3-3.

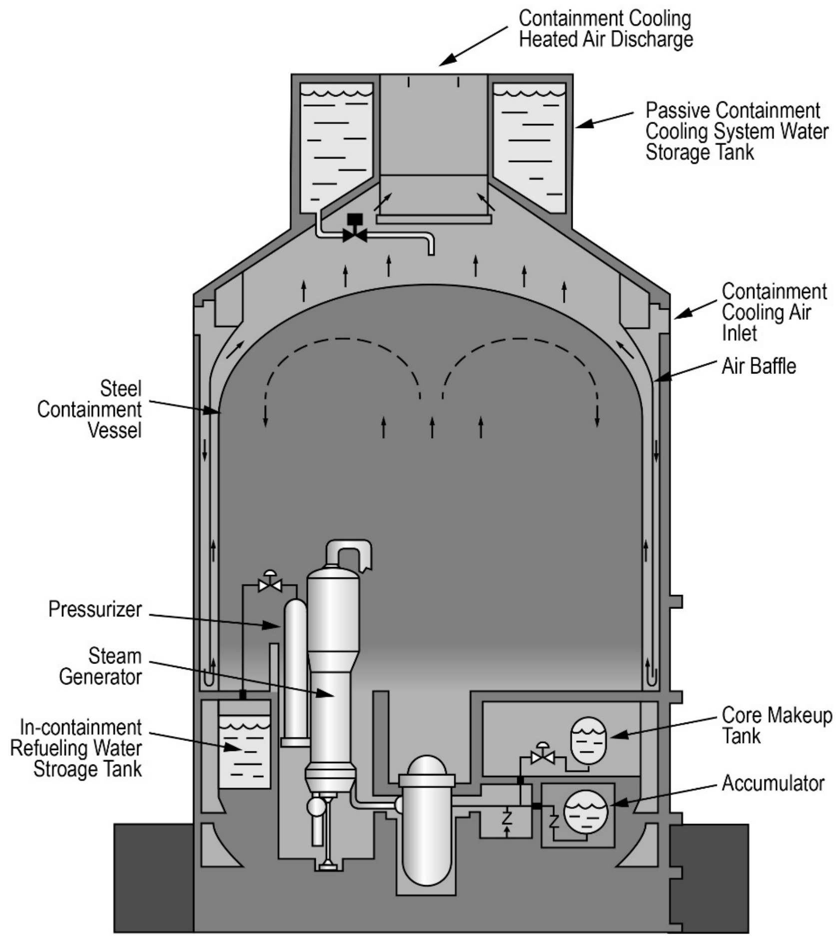
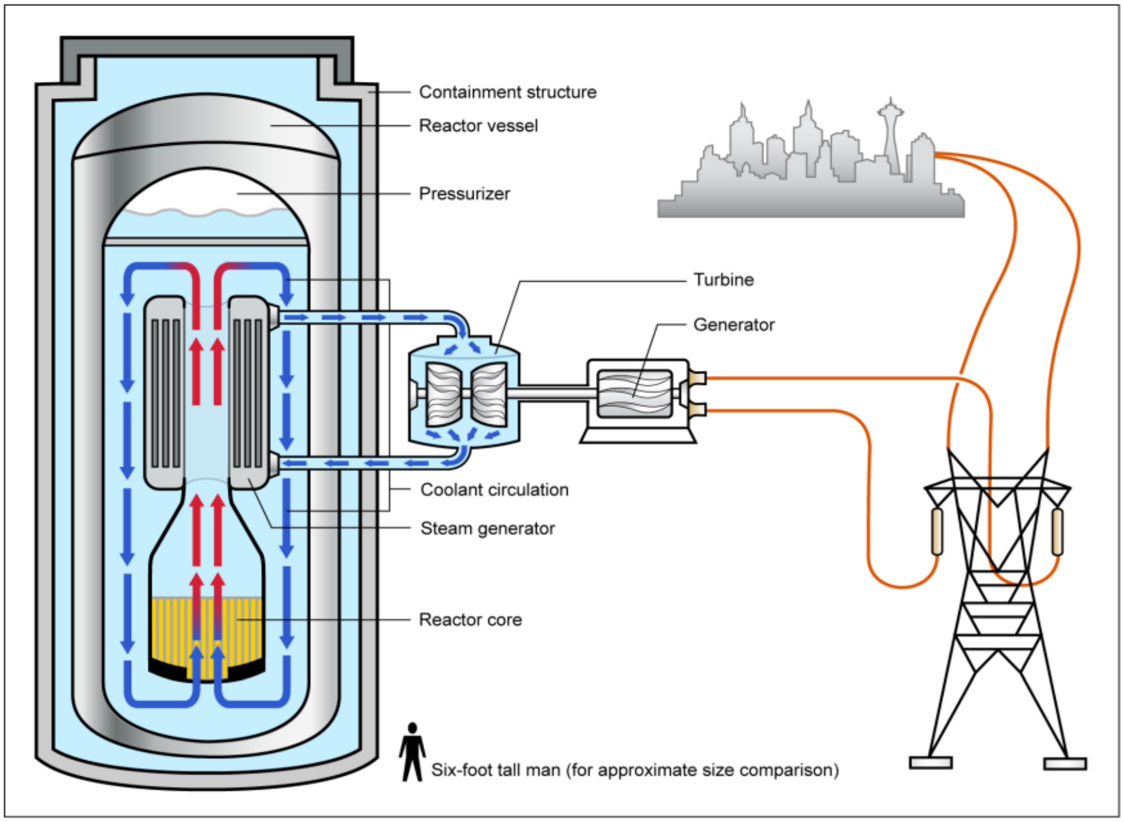



**Figure 2.3-3 Schematic of an Advanced Light Water Reactor. Adapted from: NRC 2004a.**

*2.3.2.2 Small Modular Reactors*

SMRs, in general, are light-water reactors that use water for cooling and enriched uranium for fuel in the same manner as the conventional, large light-water reactors currently operating in the United States. SMR modules typically generate 300 MWe or less, compared to today's larger nuclear reactor designs, which can generate 1,000 MWe or more per reactor. However, their smaller size means that several SMRs can be bundled together in a single containment. Smaller size also means greater siting flexibility because they can fit in locations not large enough to accommodate a conventional nuclear reactor (NRC 2018b, NRC 2020a, DOE 2022a). SMR design features can include below grade containment and inherent safe shutdown features, longer station blackout coping time without external intervention, and core and spent fuel pool cooling without the need for active heat removal. A representative SMR is illustrated in Figure 2.3-4. SMR power-generating facilities are also designed to be deployed in an incremental fashion to meet the power-generation needs of a service area, in which generating capacity can be added in increments to match load growth projections (NRC 2018b). Overall, the NRC staff assumes that the resource requirements, key characteristics, and impacts associated with constructing and operating SMRs would be bounded by the impacts of constructing and operating the large light-water reactor units that have been evaluated in NRC EISs since the 1970s. The NRC received the first design certification application for an SMR in

December 2016 (NRC 2022a). Following NRC certification, this design could potentially achieve operation on a commercial scale by 2027 (NuScale Power LLC 2022). Therefore, SMRs could be constructed and operational by the time many existing nuclear power plant licenses expire.




Source: GAO, based on Department of Energy documentation. | GAO-15-652

**Figure 2.3-4 Schematic of a Light Water Small Modular Nuclear Reactor. Source: GAO 2015.**

### 2.3.3 Renewable Energy Technologies

The NRC considers the following renewable energy technology alternatives for possible replacement power: solar (both photovoltaic and thermal), wind (both land-based and offshore), hydroelectric, biomass, geothermal, ocean wave and current, and fuel cells. Combinations of renewable energy alternatives may be considered during plant-specific license reviews.

Renewable energy sources accounted for approximately 20 percent of total U.S. electricity generation in 2020, and are projected to account for nearly 60 percent of cumulative generating capacity additions through 2050 (DOE/EIA 2021b, DOE/EIA 2022a). The past two decades have seen a dramatic increase in the commercial use of renewable energy alternatives, allowing for the increased likelihood that some of these technologies could individually or in combination provide total replacement power for a nuclear power plant. One of the major reasons for this is that energy storage technologies are rapidly gaining in importance. As the amounts of power from variable renewable energy sources such as wind and solar increase, energy storage capability has become an essential tool for temporally decoupling generation and demand (DOE/EIA 2021e).

Energy storage can enhance the overall efficiency and value of intermittent renewable energy technologies as sources of reliable baseload power. Some energy storage options can also help maintain grid stability through improved frequency management, and some may improve the use and integration of smart grid technologies. Energy storage technologies are not generation sources but rather complementary technologies that can take many forms, among them, electrochemical energy of batteries and capacitors, pumped storage hydropower, and compressed air.

Battery energy storage systems are increasingly being used to provide electric power-generation and backup capacity for times when nondispatchable renewable energy sources, such as wind and solar, are unavailable. These batteries can be used in a standalone manner or as components of a hybrid system coupled with intermittent generation sources. U.S. battery power capacity grew by 35 percent in 2020 and tripled over the last 5 years, and EIA expects this rapid growth to continue (DOE/EIA 2021e).

Pumped storage hydropower generates energy during peak load periods by using water previously pumped into an elevated storage reservoir and then released to turn a turbine-generator during off-peak periods, and in 2020 accounted for 93 percent of grid storage in the United States. In contrast, compressed air energy storage (CAES) systems use motor-driven air compressors to compress air into a suitable geological repository such as an underground salt cavern, a mine, or a porous rock formation. CAES systems have been limited, with only one such system developed in the United States in the 1990s (NPCC 2010).

The environmental impacts of the construction and operation of renewable energy alternatives are quite different from those of nonrenewable alternatives. The NRC presents these impacts in Chapter 4.0. In general, however, resource areas that have the greatest range of impacts include air quality, hydrology, and land use. Air quality impacts from hydroelectric, wind, solar, and ocean wave and ocean current generation methods would be negligible; however, biomass-fueled energy, for example, would emit air pollutants, some of them hazardous. Some geothermal technologies may also be sources of hazardous air pollutants. All renewable energy alternatives would rely on modest amounts of water, but those that would rely on conventional steam cycles to power turbine generators (biomass, geothermal, solar thermal) would have higher water demands, some of which are comparable to those of nonrenewable alternatives. All renewable energy alternatives would require land, although land requirements would be negligible for offshore wind and ocean wave and ocean current alternatives. Solar and conventional hydroelectric generators, for example, would require significant amounts of land.

The NRC has elected not to evaluate energy storage technologies as discrete alternatives to a nuclear reactor because they do not directly generate electricity. The NRC intends to consider the influence that energy storage technologies can have on its evaluations of the environmental impacts of alternative generating technologies in future license renewal reviews.

Brief overviews of renewable energy alternatives are provided in the following sections.

#### *2.3.3.1 Solar Energy*

Solar energy technologies generate power from sunlight. Solar technologies that are commercially viable for the production of electricity include solar photovoltaic (PV) and solar thermal, also referred to as concentrating solar power (CSP) (see Figure 2.3-5 and Figure 2.3-6).

Solar PV components convert sunlight directly into electricity using solar cells. Solar cells have been developed using silicon (single crystal, polycrystalline, and amorphous silicon) and a variety of compounds such as cadmium telluride, copper-indium-gallium-selenide, and gallium arsenide. Among the silicon-based solar cells, single crystals exhibit the highest efficiency, but polycrystalline cells now represent the majority of the PV market. Although more expensive to produce, high-performance, multi-junction cells offer greater energy-conversion efficiencies and are currently the subject of most research into utility-scale applications. Many solar cell materials are now being manufactured as thin films, which have lower efficiencies than other types of PV technologies but typically can be made at a lower cost. Unlike CSP technologies, PV systems do not require cooling water, although they may have substantial land requirements.

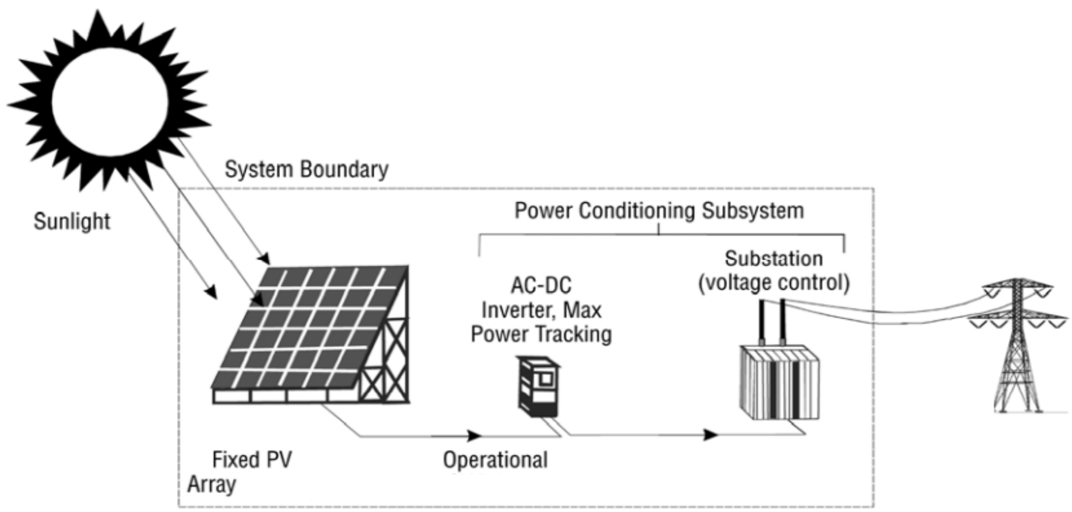



**Figure 2.3-5 Schematic of Solar Photovoltaic Power Plant. Adapted from: NRC 2013a.**

CSP systems use heat from the sun to boil water and produce steam. The steam then drives a turbine connected to a generator to ultimately produce electricity (NREL Undated). CSP facilities can use molten salt to store heat for steam production at night and during cloudy periods, but to do so and still maintain their nameplate capacities, such CSP facilities must increase the size of the solar field. CSP facilities use conventional steam cycles and thus have cooling demands similar to fossil fuel power plants of equivalent capacities and overall thermal efficiencies.

Solar generators are considered an intermittent resource because their availability depends on ambient exposure to the sun, also known as solar insolation. The highest-value solar resources in the United States exist in the desert regions of the Southwest. However, solar resources of adequate quality to support utility-scale solar energy facilities, particularly PV, are located—to varying extents—throughout the country.

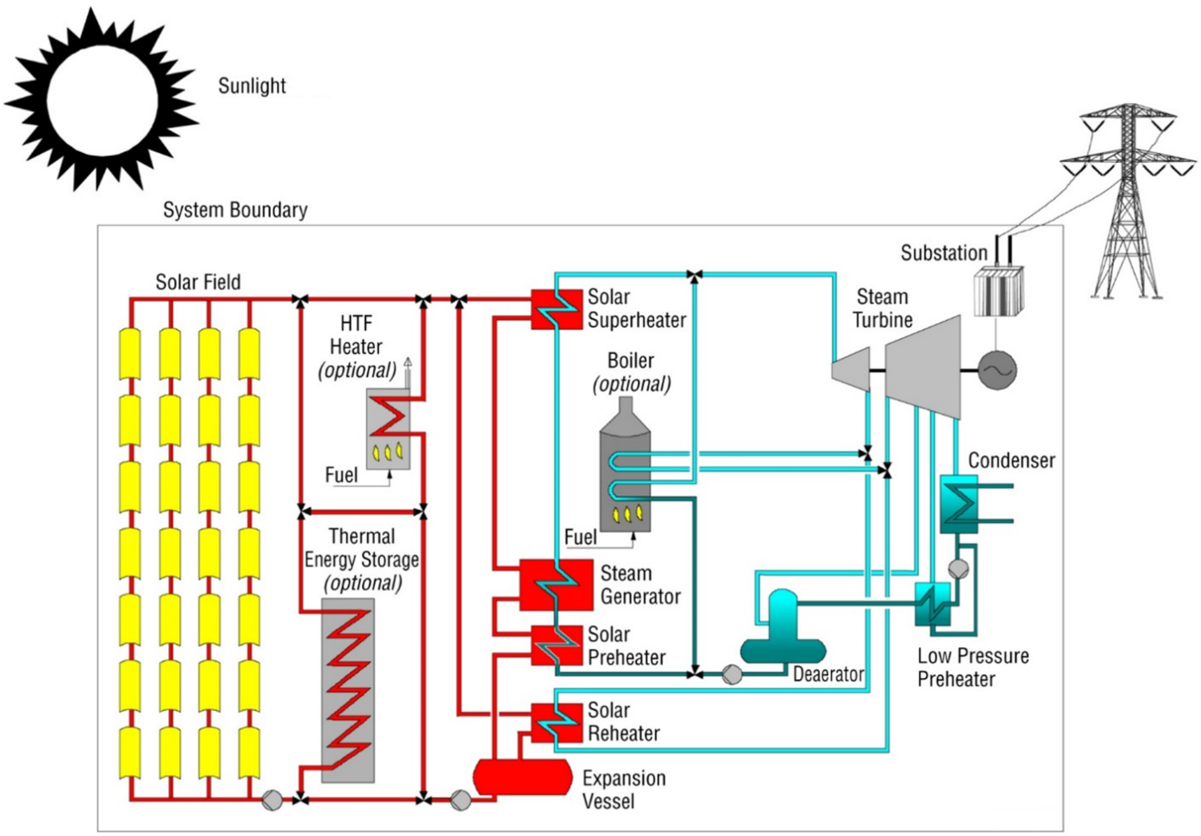



**Figure 2.3-6 Schematic of Concentrated Solar Power Plant. Adapted from: NRC 2013a.**

Solar energy technologies produced approximately 2.8 percent of total U.S. electricity generation in 2021, representing approximately 13.5 percent of total renewable generation (DOE/EIA 2022e). Nationwide, growth in utility-scale solar PV facilities (greater than 1 MW) has resulted in an increase from 145 MW in 2009 to over 35,000 MW of installed capacity in 2019 (DOE/EIA Undated-a). EIA projects that solar energy's contribution to total U.S. electrical generation will continue to increase and account for 20 percent by 2050 (DOE/EIA 2021d). EIA further projects that solar energy's share of total U.S. capacity will increase from 7 percent in 2020 to 29 percent in 2050. About 70 percent of these solar additions are anticipated to be from utility-scale PV power plants, and 30 percent from end-use PV such as residential and commercial rooftop solar installations (DOE/EIA 2022b).

#### *2.3.3.2 Wind Energy*

Onshore and offshore wind resources exist throughout the United States. The dominant technology for utility-scale applications is the horizontal-axis wind turbine. A typical wind turbine consists of rotor blades attached to a nacelle, which is mounted on a tower. Within the nacelle, a drive train connects to an electrical generator to produce electricity, which is then conveyed by cables to electronic conversion equipment situated at ground level within the tower (see Figure 2.3-7). As is the case with other renewable energy sources, the feasibility of wind energy serving as an alternative baseload power depends on the location (relative to expected electricity users), value, accessibility, and constancy of the resource. Wind energy must be converted to electricity at or near the point where it is extracted, and backup power sources or energy storage capabilities often need to be paired to overcome the intermittency and variability of wind resources.

The American Clean Power Association reports a total of more than 122,000 MW of installed wind energy capacity nationwide as of December 31, 2020 (DOE Undated-e). The average rated (nameplate) capacity of newly installed land-based wind turbines in the United States in 2018 was 2.4 MW (Wiser and Bolinger 2019).

Increasing attention has recently been focused on developing U.S. offshore wind resources, particularly along the Atlantic coast. In 2016, a 30 MWe project off the coast of Rhode Island became the first operating offshore wind farm in the United States (Orsted Undated). This was followed in 2020 with the construction and operation of the Mid-Atlantic's first offshore wind demonstration project in Federal waters, a 12 MWe demonstration project supporting the planned operation of a 2,600 MWe utility-scale wind farm off the coast of Virginia (BOEM 2021).

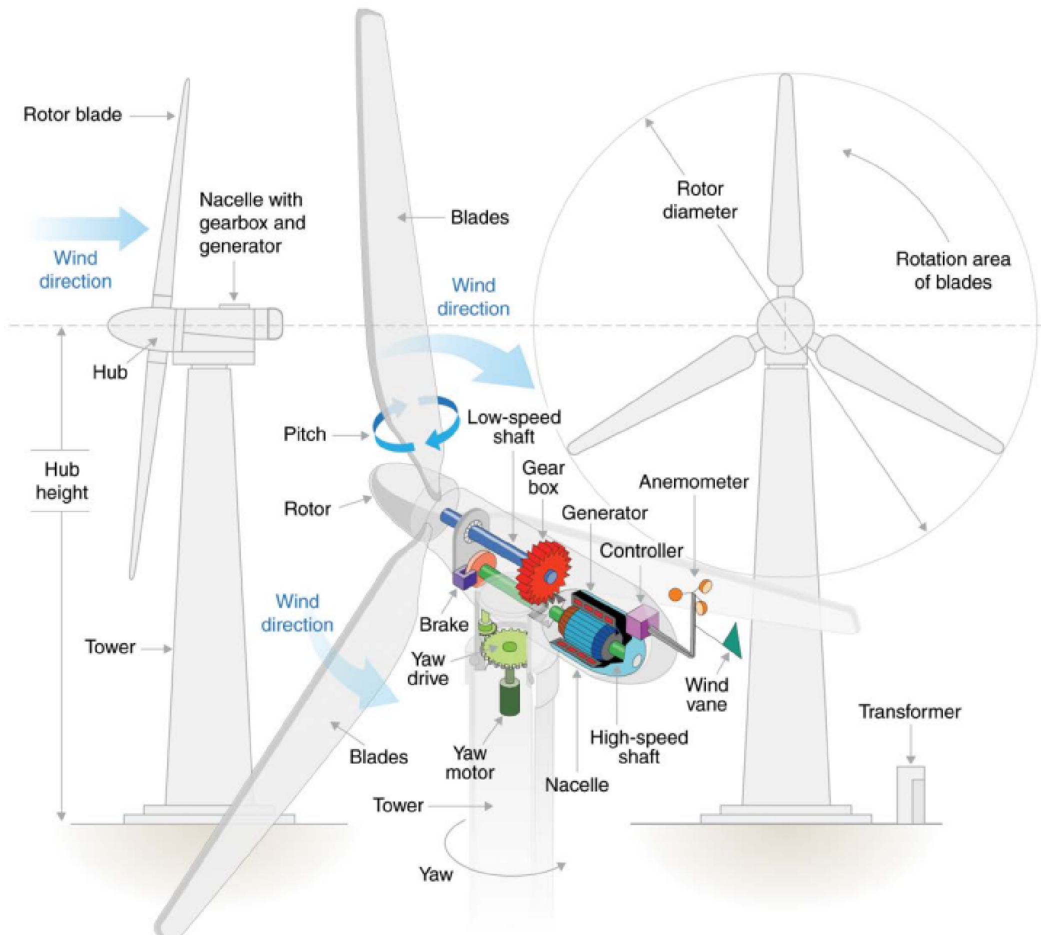



**Figure 2.3-7 Components of a Modern Horizontal-axis Wind Turbine. Source: NREL 2012.**

Modern offshore wind turbines are substantially larger than those constructed and operated on land. From 2000 to 2020, offshore wind turbine sizes have grown from an installed average of 2 MW per turbine to recent designs capable of generating 14 MW per turbine (BOEM 2020a). Offshore wind energy development activities have the potential to also affect onshore land use and coastal infrastructure, particularly due to onshore construction activities, port modifications, and cable landing facilities needed to connect the wind turbines to onshore electricity transmission infrastructure (BOEM 2019). A schematic of a representative offshore wind generating facility is illustrated in Figure 2.3-8.

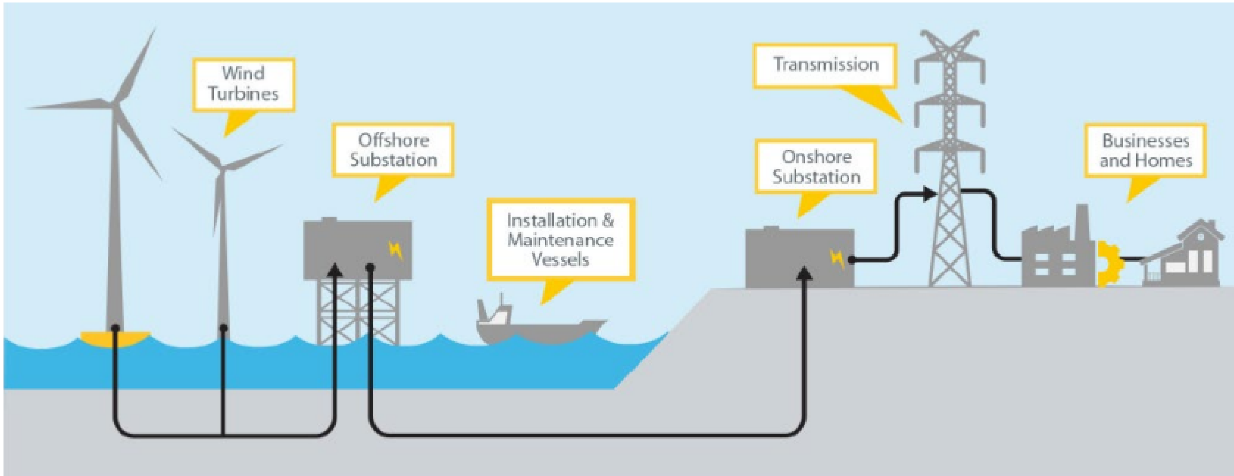



**Figure 2.3-8 Major Offshore Wind Power Plant and Transmission Elements. Source: DOE 2022b.**

The amount of wind electricity generation has grown significantly in the past 30 years. Wind energy was the source of approximately 9.2 percent of total U.S. electricity generation and about 46 percent of all renewable energy produced in 2021 (DOE/EIA 2022e). EIA forecasts that wind energy will account for approximately 10 percent of new U.S. generating capacity additions through 2050, exceeded only by solar and natural gas (DOE/EIA 2022b).

#### *2.3.3.3 Hydroelectric Energy*

Hydropower, which uses the flow of moving water to generate electricity, is one of the oldest and largest sources of renewable energy. As of 2020, there were approximately 2,300 operating hydroelectric facilities in the United States (DOE Undated-c). Hydroelectric technology operates by capturing the energy of flowing water and directing it to a turbine and generator to produce electricity. There are two fundamental hydropower facility designs: "run-of-the-river" facilities that simply redirect the natural flow of a river, stream, or canal through a hydroelectric facility and "store-and-release" facilities that block the flow of the river by using dams that cause the water to accumulate in an upstream reservoir (see Figure 2.3-9) (NRC 2013a).

Hydropower facilities generally have between a 40–50 percent capacity factor, higher than those of solar or wind, but lower than power plants operated for baseload power generation (DOE/EIA 2021a).

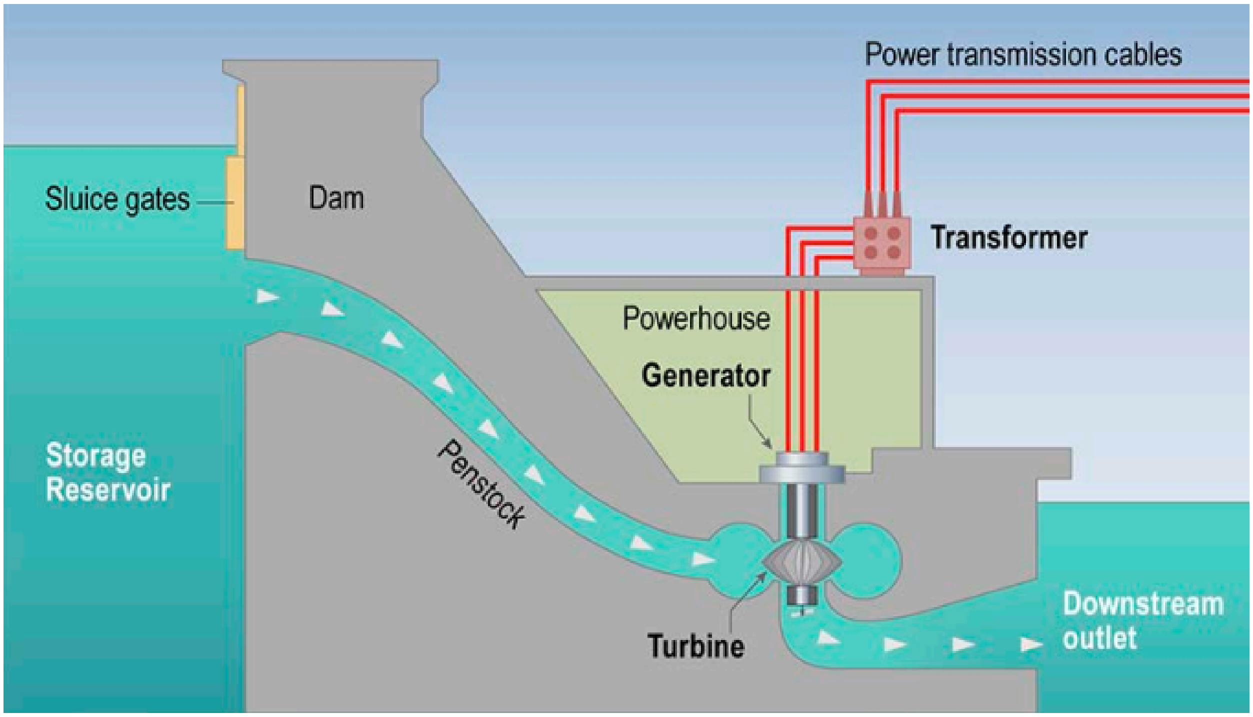



**Figure 2.3-9 Cross Section of a Large Hydroelectric Plant. Source: NREL 2012.**

Large hydroelectric facilities constructed on major rivers can have peak power capacities as high as 10,000 MW(e). However, river flow conditions and other circumstances and factors (e.g., spawning periods of anadromous fish) often require dam operators to divert river flow around power-generating turbines over various periods of time, thereby reducing the amount of power generated (NRC 2013a). In addition, hydroelectricity generation ultimately depends on precipitation levels that can vary seasonally and annually. As recently as 2019, hydroelectric energy was the leading source of U.S. renewable energy generation. In 2021, hydroelectricity accounted for approximately 6.3 percent of total U.S. utility-scale electricity generation and more than 31 percent of the total utility-scale renewable electricity generation (DOE/EIA 2022e). EIA projects that this level of generation will remain relatively steady through 2050 (DOE/EIA 2022b). However, the potential for future construction of large dams has diminished due to increased public concerns about flooding, habitat alteration and loss, and destruction of natural river courses. Additional demands for river water have also reduced water flow.

#### *2.3.3.4 Biomass Energy*

Biomass energy can be generated from a wide variety of fuels, including municipal solid waste (MSW), refuse-derived fuel, landfill gas, urban wood wastes, forest residues, agricultural crop residues and wastes, and energy crops. Definitions of materials that qualify as biomass may vary by State or region depending on regulatory schemes or renewable portfolio standards.

Biomass energy conversion is accomplished using a wide variety of technologies, some of which are similar in appearance and operation to fossil fuel plants, and include directly combusting biomass in a boiler or incinerator to produce steam, co-firing biomass along with fossil fuels (primarily coal) in boilers to produce steam, producing synthetic liquid fuels that are subsequently combusted, gasifying biomass to produce gaseous fuels that are subsequently combusted, and anaerobically digesting biomass to produce biogas. Accordingly, biomass generation is generally considered a carbon-emitting technology. Historically, wood has been the most widely used biomass fuel for electricity generation, while coal-biomass co-firing and MSW combustion are also commercially feasible. An example of a biomass-fired power plant is illustrated in Figure 2.3-10 (NRC 2013a).

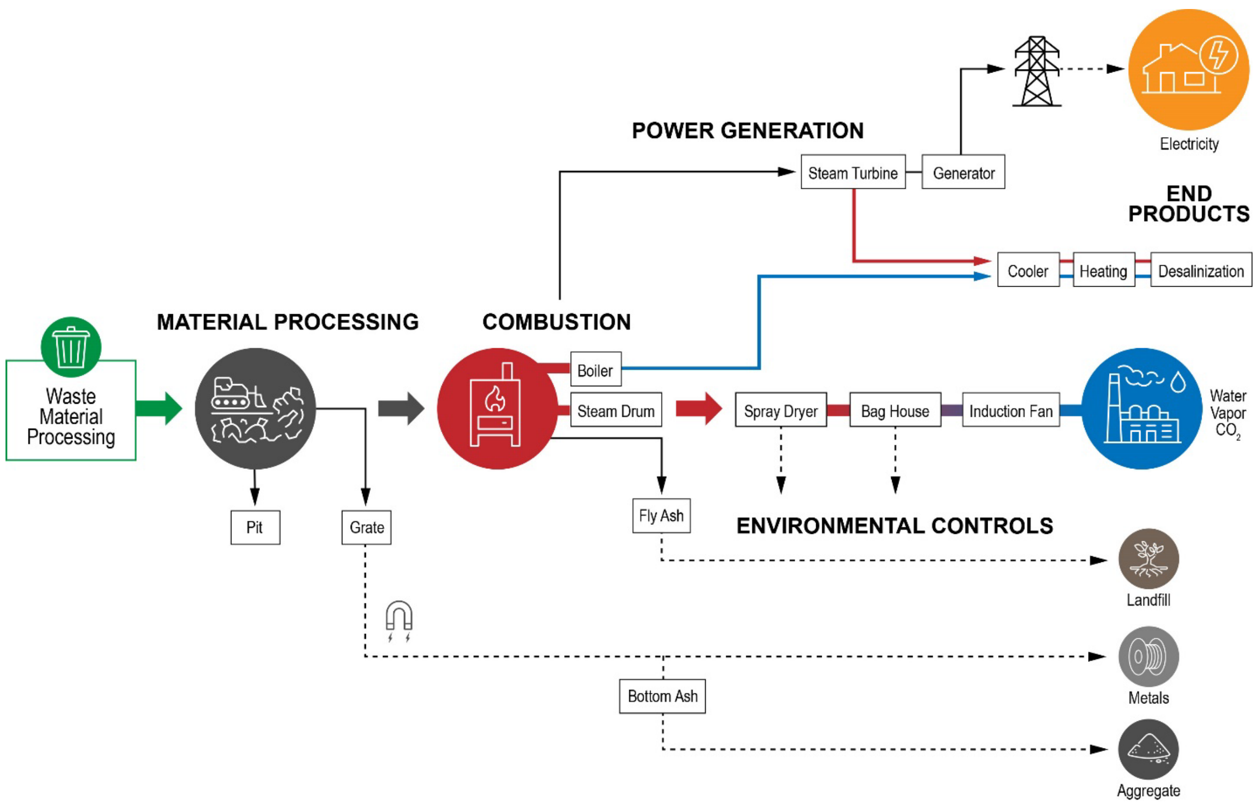



**Figure 2.3-10 Schematic of a Biomass/Waste-to-Energy Plant**

MSW combustors use one of three types of technologies: mass burn, modular, or refuse-derived fuel. Mass burning is currently the method used most frequently in the United States and involves no (or little) sorting, shredding, or separation. Consequently, toxic or hazardous components present in the waste stream are combusted, and toxic constituents are exhausted to the air or become part of the resulting solid wastes. As of 2019, the United States had 75 operational waste-to-energy plants in 21 States, processing approximately 29 million tons of waste per year. These waste-to-energy plants have an aggregate capacity of 2,725 MWe (Michaels and Krishnan 2019). Although some plants have expanded to handle additional waste and to produce more energy, only one new plant has been built in the United States since 1995 (Maize 2019).

Landfill gas is another potential source of biomass energy for electric power production. Landfills in which organic materials are disposed represent the largest source of methane in the United States. Landfill gas composition varies depending on the type of waste.

In 2021, biomass energy was the source of approximately 1.3 percent of total U.S. electrical generation and approximately 6.7 percent of the total generation derived from renewable energy sources (DOE/EIA 2022e). This contribution from biomass energy sources is projected to remain largely unchanged through 2050 (DOE/EIA 2022h).

#### *2.3.3.5 Geothermal Energy*

Geothermal energy is energy in the form of heat contained below the Earth's surface in hydrothermal zones (hot water or steam trapped in an aquifer), hot and dry geologic formations (referred to as hot dry rock or engineered geothermal systems [EGSs]), or in geopressurized resources (hot brine aquifers existing under pressure). The technical approaches to extracting geothermal energy resources involve drilling wells down into the heated resources to raise hot water or steam to the surface where the heat energy can be used to generate electricity. EGSs differ in that crews must first fracture a hot, dry rock formation and then inject a heat transfer fluid (typically water). They then recover the heated fluid from the formation through the well and then use the heated fluid to produce steam—and subsequently electricity—in a conventional steam turbine generator (NRC 2013a). A schematic of a representative geothermal generating facility is provided in Figure 2.3-11.

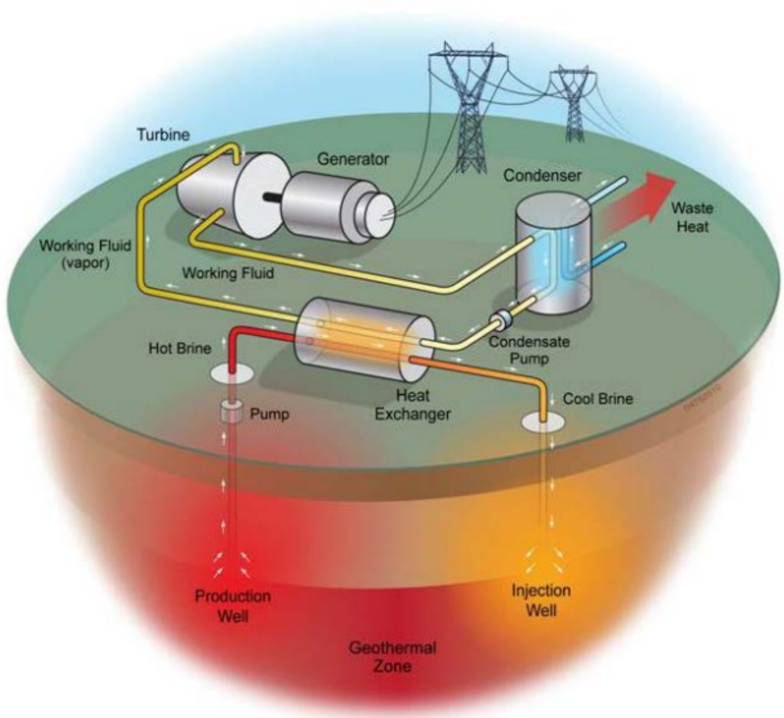



**Figure 2.3-11 Schematic of a Hydrothermal Binary Power Plant. Source: NREL 2012.**

Utility-scale geothermal energy generation requires geothermal reservoirs with a temperature above 200 degrees Fahrenheit (°F) (93 degrees Celsius [°C]). Known utility-scale geothermal resources are concentrated in the western United States, specifically Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. In general, most assessments of geothermal resources have concentrated on these Western States (DOE Undated-b, USGS 2008). In 2021, geothermal power plants produced approximately 1.3 percent of total U.S. electrical generation, equivalent to approximately 2.0 percent of total U.S. renewable electricity generation (DOE/EIA 2022e). This contribution from geothermal energy sources is projected to remain largely unchanged through 2050 (DOE/EIA 2022h).

### *2.3.3.6 Ocean Wave and Current Energy*

Waves, currents, and tides are often predictable and reliable, making them attractive candidates for potential renewable energy generation. Four major technologies may be suitable to harness wave energy: (1) point absorbers, (2) attenuators, (3) water column terminator devices, and (4) overtopping devices (see Figure 2.3-12) (BOEM Undated). Point absorbers and attenuators use floating buoys to convert wave motion into mechanical energy, driving a generator to produce electricity. Overtopping devices trap some portion of an incident wave at a higher elevation than the average height of the surrounding sea surface, while terminators allow waves to enter a tube, compressing air that is then used to drive a generator that produces electricity (2013 LR GEIS). Some of these technologies are undergoing demonstration testing at commercial scales, but none is currently used to provide baseload power (BOEM Undated).

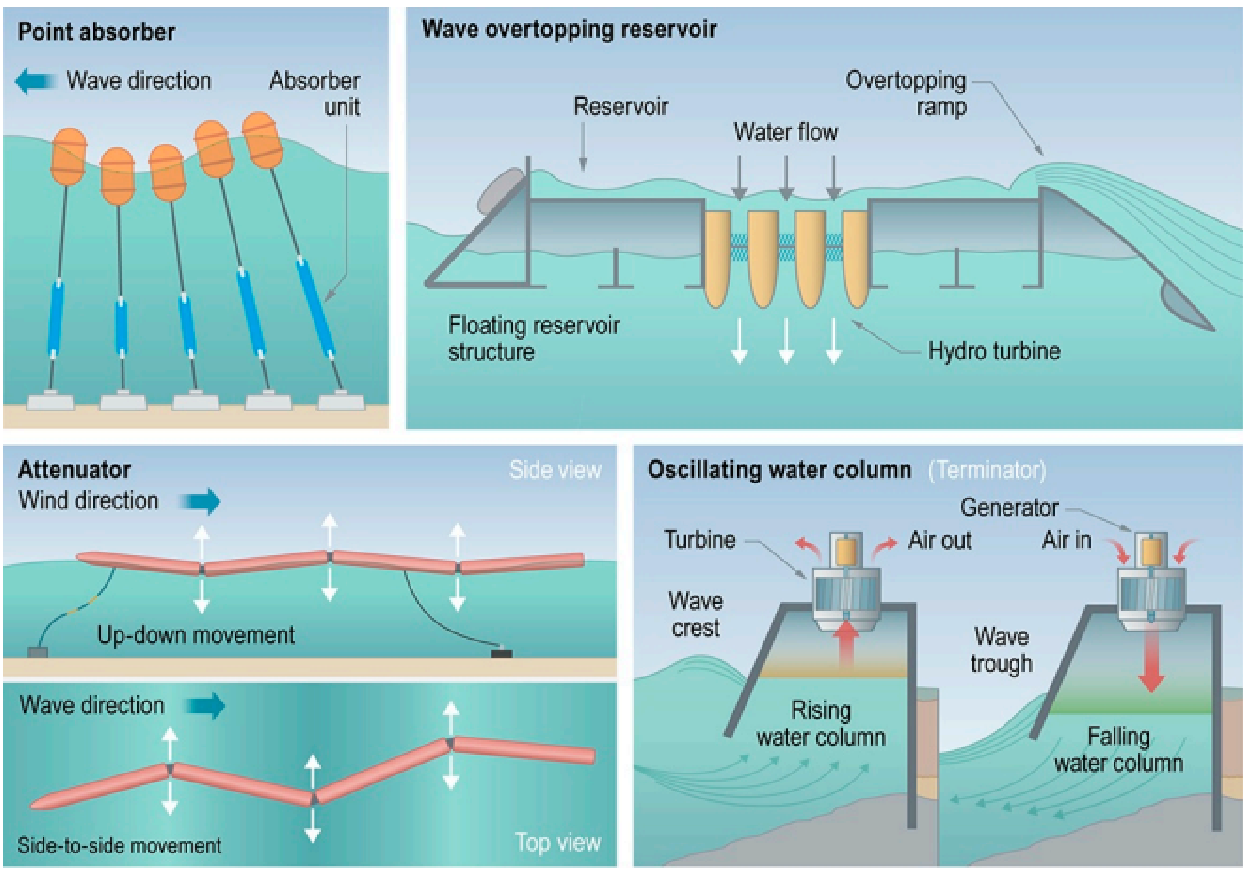



**Figure 2.3-12 Primary Types of Wave Energy Devices. Source: NREL 2012. Illustrations not to scale.**

In general, technologies that harness the energy of ocean waves are in their infancy and have not been used at utility scale. Feasibility studies and prototype tests for wave energy capture devices have been conducted for locations off the coasts of Hawaii, Oregon, California, Massachusetts, and Maine. Similarly, ocean current energy technology is also in its infancy. Existing prototypes capture ocean current energy with submerged turbines that are similar to wind turbines. Although the functions of ocean turbines and wind turbines are similar (both derive power from moving fluids), ocean turbines have substantially greater power-generating capacity because the energy contained in moving water is approximately 800 times greater than that contained in air (MMS 2007).

#### *2.3.3.7 Fuel Cells*

Fuel cells work without combustion and its associated environmental side effects. Power is produced electrochemically by passing a hydrogen-rich fuel over an anode, air over a cathode, and then separating the two by an electrolyte. The only byproducts are heat, water, and $CO_2$ (see Figure 2.3-13). Hydrogen fuel can come from a variety of hydrocarbon resources by subjecting them to steam under pressure. Natural gas is typically used as the source of hydrogen (DOE Undated-a). As of October 2020, the United States had a total of 250 MW of fuel cell generation capacity (DOE/EIA Undated-a).

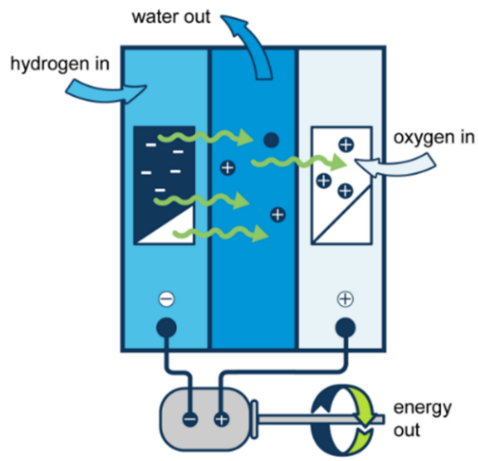



**Figure 2.3-13 Components of a Hydrogen Fuel Cell. Adapted from: DOE/EIA 2022f.**

Currently, fuel cells are not economically or technologically competitive with other alternatives for electricity generation. The EIA estimates that fuel cells may cost $6,866 per installed kilowatt (total overnight capital costs in 2020 dollars), which is high compared to other alternative technologies analyzed in this section (DOE/EIA 2022c). In 2021, the DOE launched an initiative to reduce the cost of hydrogen production to spur fuel cell and energy storage development over the next decade (DOE 2021b). However, it is unclear to what degree this initiative will lead to increased future development and deployment of fuel cell technologies.

### **2.3.4 Non-Power Generating Alternatives**

As discussed in Section 2.3, various electric power-generating technologies can be employed to replace the power provided by a nuclear power plant in a particular region of the country. The preceding sections have identified the technologies that the NRC considers to be viable candidates as alternatives. However, in addition to these power-generating options, alternatives that offset power needs and do not include the introduction of new electricity-generating capacity also exist. Three such alternatives are energy efficiency and demand response measures (collectively, part of a range of demand-side management measures), delayed retirement of existing non-nuclear plants, and purchased power from other electricity generators within or outside of a region.

#### *2.3.4.1 Demand-Side Management Programs*

The need for alternative or replacement power can precipitate or invigorate conservation and energy efficiency efforts designed to either reduce electricity demand at the retail level or alter the shape of the electricity load. All such efforts are broadly categorized as demand-side management (DSM), although DSM can also include other measures to influence energy consumer practices. Utility companies use DSM to reduce consumer energy usage, either through conservation and energy efficiency measures or through demand response (DOE/EIA 2019b). Energy efficiency measures consist of installations of more efficient devices or implementing more efficient processes that exceed current standards. Examples are replacing light bulbs with more efficient technology or replacing older heating, ventilation, and air conditioning systems with high-efficiency systems that exceed current codes and standards. Demand response programs are procedures that encourage a temporary reduction in demand for electricity at certain times in response to a signal from the grid operator or market conditions (DOE/EIA Undated-b). DSM measures may be championed by the same company that operates a nuclear power plant when that company also serves retail customers. In other cases, the measures may be offered by other load-serving entities, State-based programs, third-party service providers and aggregators, or even transmission operators. Programs include, but are not limited to, incentives for equipment upgrades, improved codes and standards, rebates or rate reductions in exchange for allowing a utility to control or curtail the use of high-consumption appliances (like air conditioners) or equipment, training in efficient operation of building heating and lighting systems, direct payments in consideration for avoided consumption, or use of price signals to shift consumption away from peak times.

Data contained in the latest EIA Electric Power Annual report showed that peak demand savings from energy efficiency and demand response activities totaled 16,674 MW in 2020 (DOE/EIA 2022d).

EIA data show that historically, residential electricity consumers have been responsible for the majority of peak load reductions achieved by conservation and energy efficiency programs. However, participation in most conservation programs is voluntary, and the existence of a program does not guarantee that reductions in electricity demand would occur. Nevertheless, energy conservation programs in general can result in significant reductions in demand. Recent legislative actions in some States requiring the establishment of programs such as “net metering” and technological advances in the electric transmission network (the “smart grid”) have facilitated greater degrees of participation in energy conservation programs, especially among residential customers.

Conservation and energy efficiency programs may reduce overall environmental impacts associated with energy production.

However, while the energy conservation or energy efficiency potential in the United States is substantial, the NRC staff is not aware of any cases where a DSM program has been implemented expressly to replace or offset a large, baseload generation station. While the potential to replace a large baseload generator may exist in some locations, it is more likely that DSM programs will not be evaluated in plant-specific license renewal environmental reviews as standalone alternatives but may play an important role in the evaluation of a combination of alternatives.

#### *2.3.4.2 Delayed Retirement of Other Generating Facilities*

Delayed retirement of other power-generating plants is another potential alternative to license renewal. Delaying the retirement of one or more power-generating facilities in a region could enable them to continue supplying sufficient electricity to offset that which a nuclear plant currently provides to its service area. Repowering existing facilities using new or different technologies could also provide a means for delaying their retirement.

Power plants retire for several reasons. Because generators are required to adhere to additional regulations that will require significant reductions in plant emissions, some power plant owners may opt for early retirement of older units (which often generate more pollutants and are less efficient) rather than incur the cost for compliance. Additional retirements may be driven by low competing commodity prices (such as low natural gas prices), slow growth in electricity demand, and the requirements of the EPA's Mercury and Air Toxics Standards (DOE/EIA 2015b). Impacts would occur in areas where delayed retirements of existing non-nuclear power plants occur, and the magnitude of these impacts would be reflective of the type of generating technology employed and the amount of power required.

#### *2.3.4.3 Purchased Power*

Bulk electricity purchases currently take place within geographic regions established by the North American Electric Reliability Corporation (NERC), the authorized Electric Reliability Organization for the United States. NERC is a regulatory organization that develops and enforces reliability standards; monitors the bulk power system; assesses future adequacy; audits owners, operators, and users for preparedness; and educates and trains industry personnel. NERC is composed of eight Regional Reliability Councils, each responsible for a specific geographic area. These entities account for virtually all bulk electricity (i.e., electricity provided at 100 kV or higher) supplied in the United States, Canada, and a portion of Baja California Norte, Mexico. Interconnections exist between NERC regions that allow for power exchanges between the regions when necessary to satisfy short-term demand. The NRC recognizes the possibility that replacement power may be imported from outside a nuclear power plant's service area, which may or may not require importing power from another region. In most instances, importing power from distant generating sources would have little or no measurable environmental impact in the vicinity of the nuclear power plant, but it could cause environmental impacts where the power is generated or anywhere along the transmission route. Similar to other approaches, the magnitude of these impacts would be reflective of the type of generating technology employed and the amount of power required.

Many factors influence power purchasing decisions, with respect to both technical feasibility and cost. The existing transmission grid may not support every possible power transfer agreement. Incremental power transfer capacities have been established between grid segments both within and across NERC regions, and modest amounts of power routinely transfer across those points. Such capabilities were established to make sure that overall grid stability and reliability under both routine and nonroutine conditions are maintained. In contrast, long-term transfers of utility-scale power from outside of a given power plant's region may require modification of one or more existing transmission grid segments (as well as modifications of substations and power synchronization equipment) and could require construction of new transmission line segments. New transmission lines may be required for long-term purchased power from within the same NERC region, but the need for new transmission lines is highly situation-dependent. Further, efforts by transmission operators to provide a price signal for transmission congestion through locational-marginal pricing would, over the long run, provide an incentive for power purchases closer to the existing power plant or construction of new capacity nearer the existing power plant. In general, the more geographically distant the exporting source, the greater the likelihood that new or modified interconnecting transmission line segments would be necessary.

## 2.4 Comparison of Alternatives

This section provides a summary comparison of the environmental impacts of the proposed action and alternatives. Table 2.4-1 through Table 2.4-5 provide an overview of the general findings of the impact analyses (presented in Chapter 4) for the proposed action and alternatives, including the no action alternative, and replacement energy alternatives (fossil fuel energy, nuclear energy, and renewable energy). Impacts related to construction (Table 2.4-1), operations (Table 2.4-2), postulated accidents (Table 2.4-3), termination of nuclear power plant operations and decommissioning (Table 2.4-4), and the fuel cycle (Table 2.4-5) are provided. In each of these tables, important aspects of each alternative that serve as the basis of the assessment are identified as well as the magnitude of the anticipated impact in each resource area. These tables also provide a summary of anticipated impacts from potential non-power generating approaches for offsetting a nuclear power plant's generating capacity (DSM, delayed retirement, and purchased power). Such non-power generating approaches are most likely to be considered only as components of plant-specific combination alternatives in plant-specific SEISs prepared to evaluate the environmental impacts of renewing a nuclear power plant's operating license. The non-power generating approaches would generally have impacts that will depend on the source used to compensate for the lost energy generation. Accordingly, these nongenerating approaches are not evaluated further in Chapter 4.0 of this LR GEIS. More detailed analyses incorporating relevant site-specific factors (as well as the future state of technology and, possibly, other reasonable alternatives) will be provided in each plant-specific SEIS.

Further, each plant-specific SEIS must analyze the impacts of the proposed action (license renewal) as well as a range of reasonable alternatives to provide replacement energy. According to the White House Council on Environmental Quality, reasonable alternatives comprise "those that are practical or feasible from the technical and economic standpoint and using common sense" (46 FR 18026). Replacement energy alternatives may require the construction of a new power plant and possibly the modification of the electric transmission grid. New power plants would also have operational impacts that may or may not be equivalent in nature and/or extent to the operational impacts of the nuclear plant. License renewal would not require major construction and operational impacts would not change beyond what is currently being experienced at the nuclear plant. Other alternatives that would not have construction or operational impacts include conservation and energy efficiency, delayed retirement, and purchased power.

The operational impacts of license renewal are comparable to replacement power alternatives and some renewable energy alternatives in some resource areas (e.g., socioeconomics), but quite different in other resource areas (e.g., air emissions, fuel cycle, land use, and water consumption). Some renewable energy alternatives (wind, ocean wave, and ocean current alternatives) have very few operational impacts, while others (biomass combustion and conventional hydropower) can have considerable operational impacts. Some renewable energy alternatives (wind and solar) have relatively low but regionally variable capacity factors while others (e.g., conventional hydropower and geothermal) can exhibit capacity factors at or near those of a nuclear power plant.

The proposed action and alternatives differ in other respects, including the consequences of accidents. The proposed action and new nuclear energy alternatives all may have low probability but potentially high-consequence accidents in comparison to non-nuclear alternatives.

**Table 2.4-1 Construction under the Proposed Action and Alternatives – Assessment Basis and Nature of Impacts**

| Proposed Action[(a)] | No Action Alternative | Fossil, New Nuclear, and Renewable Energy Alternatives | Demand-Side Management | Purchased Power and Delayed Retirement |
|---|---|---|---|---|
| Minor construction projects (refurbishment) associated with the proposed action. Original nuclear plant construction is not part of the proposed action. | No construction at nuclear plant sites if license renewal is denied. | Major construction projects would be required to build replacement fossil fuel, nuclear, or renewable energy generation capacity. Impacts would vary according to the specific alternative technology selected and site-specific resource conditions that would be reviewed under separate environmental review processes, depending on the activity’s location and proponent. Impacts at brownfield sites would be smaller than at greenfield sites. Power may also be replaced by a portfolio of alternative technologies; in such cases, impacts would be additive among portfolio components, occurring at each facility commensurate with the technology and the amount of replacement power it provides. | Little or no construction would be associated with DSM programs implemented to offset lost generation capacity. | No construction would occur from purchased power or delayed retirements of existing non-nuclear plants if available excess capacity is sufficient to offset losses. Construction could occur in instances where expansions of the capacity of the alternative generation source to meet power purchase agreements or modifications to the transmission grid were required to bring the imported power to the load centers affected by reactor retirement. |

DSM = demand-side management.

(a) Refer to Table 2.1-1 for a more detailed presentation of the impacts of construction (likely refurbishments) under the proposed action. These impacts are discussed in detail in Chapter 4.0.

**Table 2.4-2 Operations under the Proposed Action and Alternatives – Assessment Basis and Nature of Impacts**

| Proposed Action[(a)] | No Action Alternative | Fossil, New Nuclear, and Renewable Energy Alternatives | Demand-Side Management | Purchased Power and Delayed Retirement |
|---|---|---|---|---|
| Continued operations under the proposed action would be comparable to what is already occurring at the nuclear plant. | Termination of reactor operations would occur sooner than under the proposed action. After reactor shutdown, some systems would continue operating but at reduced levels. | Operation of a new fossil fuel energy, nuclear, or renewable energy facility would introduce new impacts to the facility site and vicinity. Impacts would vary according to site-specific resource conditions that would be reviewed under separate NEPA assessments. If lost power capacity is replaced with a portfolio of alternatives, impacts would be additive, occurring at each of the facilities within the portfolio based on the nature of the technology employed and commensurate with the amount of power produced. Impacts at brownfield sites may be less than at greenfield sites.<br><br>Fossil fuel energy alternatives would have similar operational impacts as the proposed action, nuclear, and some renewable alternatives (e.g., biomass), but would produce more air emissions. New nuclear energy alternatives would have operational impacts similar to those of fossil fuel and some renewable technologies but would produce fewer air emissions than fossil fuel and biomass technologies. Renewable technologies differ greatly in terms of operational impacts. | No new operational impacts are likely to result from DSM programs implemented to offset lost generation capacity. Existing operational impacts from current generation sources may be lessened if greater load reductions result. | Impacts would occur in areas where purchased power is produced or where delayed retirements of existing non-nuclear plants occur. Impact magnitude would be reflective of the type of generating technology employed and the amount of power required. |

DSM = demand-side management.
(a) Refer to Table 2.1-1 for a more detailed presentation of the impacts of operations under the proposed action. These impacts are discussed in detail in Chapter 4.0.

**Table 2.4-3 Postulated Accidents under the Proposed Action and Alternatives – Assessment Basis and Impact Magnitude**

| Proposed Action[(a)] | No Action Alternative | Fossil, New Nuclear, and Renewable Energy Alternatives | Demand-Side Management | Purchased Power and Delayed Retirement |
|---|---|---|---|---|
| Postulated accidents associated with continued operations under the license renewal term include design-basis accidents and severe accidents. The impacts take into consideration the low probability of an accident occurring. Design-basis accidents would have a small impact. Severe accidents would likely have larger consequences than design-basis accidents, but the probability-weighted consequences (i.e., the probability of occurrence of the accident multiplied by the consequence if the accident occurred) would be SMALL for all plants. | Plant shutdown would occur sooner than under the proposed action. A reduction in accident risk would occur sooner. | Accidents associated with fossil fuel energy facilities would have short-term, localized effects. Accidents associated with nuclear energy would be similar to those of the proposed action. Accidents associated with biomass facilities would be comparable to those of fossil fuel energy facilities. Accidents associated with hydropower (e.g., dam collapse) could have large, far-reaching effects. Accidents associated with coal combustion residue handling and storage could also have large, far-reaching effects. Impacts from accidents associated with other renewable energy technologies would be localized and generally inconsequential. | No accidents are associated with DSM measures aside from occupational hazards for those who install or implement them. | Impacts would occur in areas where purchased power is produced or where delayed retirements of existing non-nuclear plants occur. The nature and magnitude of the impact would depend on the technology used to produce the power and characteristics of the plant site. If power is purchased from existing generating facilities with excess capacity, little change in impact would be expected. Additional impacts may result from required expansions or modifications of transmission infrastructures. |

DSM = demand-side management.
(a) Refer to Table 2.1-1 for a more detailed presentation of the impacts of accidents under the proposed action. These impacts are discussed in detail in **Section 4.9.1.2**.

**Table 2.4-4 Termination of Nuclear Power Plant Operations and Decommissioning under the Proposed Action and Alternatives – Assessment Basis and Nature of Impacts**

| Proposed Action[(a)] | No Action Alternative | Fossil, New Nuclear, and Renewable Energy Alternatives | Demand-Side Management | Purchased Power and Delayed Retirement |
|---|---|---|---|---|
| Termination of reactor operations and decommissioning would occur regardless of the proposed action. The proposed action would not contribute substantially to the impacts from the termination of reactor operations and decommissioning. | The no action alternative would not contribute to the impacts of terminating reactor operations and decommissioning. | Termination of power plant operations and decommissioning of a fossil fuel, nuclear, or renewable energy facility would result in short-term impacts during facility dismantlement and longer-term waste management impacts. Impacts would vary according to site-specific resource conditions. The NRC staff’s analysis assumes that dams would remain in place for flood control after hydroelectric power generation ceases. Impacts at brownfield sites may be less than at greenfield sites. | No termination of operations and decommissioning impacts are anticipated to result from energy conservation programs implemented to offset lost generation capacity. Delaying retirements of existing non-nuclear plants would similarly delay impacts associated with termination of operations and decommissioning. | Because existing facilities would be used to produce purchased power, no termination of operations and decommissioning impacts would be associated with this alternative. |

(a) Refer to Table 2.1-1 for a more detailed presentation of the impacts of decommissioning under the proposed action. These impacts are discussed in detail in **Section 4.14.2.**

**Table 2.4-5 Fuel Cycle under the Proposed Action and Alternatives – Assessment Basis and Nature of Impacts**

| Proposed Action[(a)] | No Action Alternative | Fossil, Nuclear, and Renewable Energy Alternatives | Demand-Side Management | Purchased Power and Delayed Retirement |
|---|---|---|---|---|
| During the license renewal term, the proposed action would result in the need for continued mining and milling of uranium; fuel fabrication; and storage, transport, and disposal of radioactive and other wastes. | The no action alternative would reduce the need for nuclear fuel and reduce the environmental impacts associated with the uranium fuel cycle. | The fuel cycle of fossil fuel energy alternatives includes the extraction of coal (mining) or natural gas (drilling and fracking); fuel cleanup; transport of extracted fuel; and storage, transport, and disposal of combustion waste. Impacts would depend on characteristics of extraction sites and fuels. The new nuclear energy alternatives would have impacts similar to those of the proposed action. Of renewables, only certain biomass technologies (e.g., crop residues, forest products) have a well-defined fuel cycle. Biomass projects that involve growing, harvesting, and processing of plant materials would have impacts associated with producing and transporting biomass fuel and storage and disposal of combustion waste. Impacts would depend on the nature of the biomass being produced, the characteristics of areas used to produce fuel, and the technology used to convert the biomass to energy. | There is no fuel cycle associated with energy conservation. The fuel-cycle impacts associated with delayed retirement would depend on the specific fuel type associated with the existing non-nuclear plant. | The fuel-cycle impacts associated with power purchases would depend on the mix of generating sources that are used to produce purchased power. |

(a) Refer to Table 2.1-1 for a more detailed presentation of the impacts of operations under the proposed action. These impacts are discussed in detail in Section 4.14.1.

The termination of nuclear power plant operations and decommissioning impacts at nuclear plant sites would eventually occur regardless of a decision to renew their licenses. Thus, in this analysis, those impacts are not attributed to the proposed action, and the effects of the proposed action on the impacts from the termination of nuclear power plant operations and decommissioning would be SMALL in all resource areas. Impacts from the decommissioning of a new nuclear power reactor would be similar to that of the existing reactor.

Fuel-cycle impacts have been evaluated for license renewal and were found to be SMALL for all resource areas, except for offsite radiological impacts—collective impacts from other than the disposal of spent fuel and high-level waste, which are acceptable (see Section 4.14.1.1, "Uranium Fuel Cycle" for information about this issue). Fossil-fueled alternatives may have larger fuel-cycle impacts (mostly associated with land disturbance at fuel extraction sites), while other alternatives have no fuel-cycle impacts (renewable alternatives such as wind, wave, current, or solar alternatives do not require fuel).

# 3.0 AFFECTED ENVIRONMENT

For purposes of the evaluation in this revision of NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (LR GEIS), the "affected environment" is the environment that currently exists at and around operating U.S. commercial nuclear power plants. Because existing conditions are at least partially the result of past construction and operations at the nuclear plants, the impacts of these past and ongoing activities and how they have shaped the environment are summarized here. Thus, it is this existing environment that composes the environmental baseline against which potential environmental impacts of license renewal are evaluated. The impacts of continued operations and any refurbishment during the license renewal (initial license renewal [initial LR] or subsequent license renewal [SLR]) term that are presented in Chapter 4.0 are incremental to these baseline conditions, which include the effects of past and present actions at the plants.

**Contents of Chapter 3.0**



## 3.1 Description of Nuclear Power Plant Facilities and Operations

### 3.1.1 External Appearance and Settings

Nuclear power plants contain a number of buildings or structures. Among them are containment or reactor buildings, turbine buildings, auxiliary buildings, vent stacks, meteorological towers, and cooling systems, particularly cooling towers. A plant site layout also includes large parking areas, security fencing, switchyards, water intake and discharge facilities, and transmission lines (see Section 3.1.6.5). While reactor, turbine, and auxiliary buildings are often clad or painted in colors that are intended to reduce or mitigate their visual presence, the heights of many of the structures, coupled with red and/or white safety lights, make nuclear plants visible from many directions. Typical heights of nuclear plant facilities are as follows: reactor buildings are 300 ft (90 m), turbine buildings are 100 ft (30 m), stacks are 300 ft (90 m), meteorological towers are 200 ft (60 m), natural draft cooling towers are higher than 500 ft (150 m), and mechanical draft cooling towers are 100 ft (30 m) tall. In addition, condensation from cooling towers is generally visible for many miles. Transmission line towers are between 70 ft (20 m) and 170 ft (50 m) in height, depending on the voltage being carried.

There are two types of power reactors currently operating in the United States—boiling water reactors (BWRs) and pressurized water reactors (PWRs). All nuclear power plant sites are generally similar in terms of the types of facilities they contain. All plant sites contain a nuclear steam supply system. In addition, there are a number of common structures necessary for plant operation. However, the layout of buildings and structures varies considerably among the sites. For example, control rooms may be located in the auxiliary building, in a separate control building, or in a radwaste and control building. The following list describes typical structures located on most sites.

- **Containment or reactor building.** The containment or reactor building in a PWR is a massive concrete or steel structure that houses the reactor vessel, reactor coolant piping and pumps, steam generators, pressurizer, pumps, and associated piping. The reactor building structure of a BWR generally includes a containment structure and a shield building. The reactor containment building is a very large concrete or steel structure that houses the reactor vessel, the reactor coolant piping and pumps, and the suppression pool. It is located inside another structure called the shield building. The shield building for a BWR also generally contains the spent fuel pool and the new fuel pool.

  The reactor containment building for both PWRs and BWRs is designed to withstand natural disasters, such as tornados, hurricanes, and earthquakes. The containment building's ability to withstand such events and to contain the effects of accidents initiated by system failures constitutes a principal protection against releasing radioactive material to the environment.

- **Fuel building.** For PWRs, the fuel building has a fuel pool that is used to store and service spent fuel and prepare new fuel for insertion into the reactor. This building is connected to the reactor containment building by a transfer tube or channel that is used to move new fuel into the reactor and move spent fuel out of the reactor for storage.

- **Turbine building.** The turbine building houses the turbines, generators, condenser, feedwater heaters, condensate and feedwater pumps, waste-heat rejection system, pumps, and equipment that support those systems. In BWRs, primary coolant circulates through these systems, thereby causing them to become slightly contaminated. In PWRs, primary coolant is not circulated through the turbine building systems. However, it is not unusual for portions of the turbine building to become mildly contaminated because of leaks from the primary system into the secondary side during power generation at PWRs.

- **Auxiliary buildings.** Auxiliary buildings house support systems, such as the ventilation systems, emergency core cooling systems, laundry facilities, water treatment systems, and waste treatment systems. An auxiliary building may also contain the emergency diesel generators and, in some PWRs, the diesel fuel storage facility. The facility's control room is often located in the auxiliary building.

- **Diesel generator building.** Often a separate building houses the emergency diesel generators if they are not located in the auxiliary building. The emergency diesel generators do not become contaminated or activated.

- **Pump houses.** Various pump houses for circulating water, standby service water, diesel fuel, or makeup water may be onsite.

- **Cooling towers.** Cooling towers are structures designed to remove excess heat from the condenser without dumping the heat directly into water bodies, such as lakes or rivers. There are two principal types of cooling towers: mechanical draft towers and natural draft towers. Most nuclear power plants that have once-through cooling do not have cooling towers associated with them. However, several operating nuclear power plants with once-through cooling also have cooling towers that are used to reduce the temperature of the water before it is released to the environment.
- **Radioactive waste (radwaste) facilities.** Radioactive waste facilities may be contained in an auxiliary building or located in a separate solid radwaste building. For example, the radioactive waste storage facility may be a separate building.
- **Ventilation stack.** Many older nuclear power plants, particularly BWRs, have ventilation stacks to discharge gaseous waste effluents and ventilation air directly to the outside. These stacks can be 300 ft (90 m) tall or higher and contain monitoring systems to ensure that radioactive gaseous discharges are below fixed release limits. Radioactive gaseous effluents are treated and processed before being discharged out the stack.
- **Switchyard and transmission lines.** Plant sites also typically contain a large switchyard, where the electric voltage is stepped up and fed into the regional power distribution system. Electricity generated at the plant is carried offsite by transmission lines. Only those transmission lines that connect the plant to the switchyard where electricity is fed into the regional power distribution system (encompassing those lines that connect the plant to the first substation of the regional electric power grid) and power lines that feed the plant from the grid during outages are considered within the regulatory scope of license renewal environmental review and this LR GEIS. The transmission lines that comprise the regional power distribution system, and beyond the scope of the environmental review, would be expected to remain energized regardless of nuclear power plant license renewal.
- **Administrative, training, and security buildings.** Normally, the administrative, training, and security buildings are located outside the radiation protection zones; no radiological contamination is present; and radiation exposures are at general background levels.
- **Independent spent fuel storage installations (ISFSIs).** An ISFSI is designed and constructed for the interim storage of spent nuclear fuel and other radioactive materials associated with spent fuel storage. ISFSIs may be located at the site of a nuclear power plant or at another location. The most common design for an ISFSI, at this time, is a concrete pad with dry casks containing spent fuel bundles. ISFSIs are used by operating plants that require increased spent fuel storage capability because their spent fuel pools have reached capacity (see Section 3.11.1).

Nuclear power plant site areas range from 391 acres (ac) (158 hectares [ha]) to 14,000 ac (5,700 ha), with most sites encompassing 700 to 2,500 ac (283 to 1,000 ha). Larger land use areas are associated with plant cooling systems that include reservoirs, artificial lakes, and buffer areas.

Nuclear power plant sites are located in a range of political jurisdictions, including towns, townships, service districts, counties, parishes, and States. At 50 percent of the sites, the population density within a 50 mi (80 km) radius is fewer than 150 persons/mi$^2$ (58 persons/km$^2$), and for 75 percent of the sites, the density within 50 mi (80 km) is fewer than 325 persons/mi$^2$ (127 persons/km$^2$). Within the 50 mi (80 km) radius, Federal, State, and Tribal lands are present to various extents. Typically, inland nuclear power plant sites and their surrounding areas consist of flat to rolling countryside in wooded or agricultural areas. Coastal and Great Lakes nuclear power plant sites include riparian, wetland, beach, and other shoreline habitats. See Appendix C for summary descriptions of the characteristics of nuclear power plant sites and their surroundings.

### 3.1.2 Nuclear Reactor Systems

In the United States, all of the currently operating reactors used for commercial power generation are conventional (thermal) light water reactors (LWRs) that use water as a moderator and coolant. The two types of LWRs are PWRs and BWRs. Of the 92 operating LWRs, 61 are PWRs and 31 are BWRs (Figure 3.1-1 and Table 3.1-1). They are located at 54 sites in 28 States. Some of the reactors have sought and received power uprates, which allow these plants to operate at a higher licensed power level. Power uprates are a separate licensing action from license renewal and require separate U.S. Nuclear Regulatory Commission (NRC) review and approval. For the reactors that have been authorized to increase their power level, power uprate information is incorporated into Table 3.1-1. Additional reactors may seek power uprates in the future.

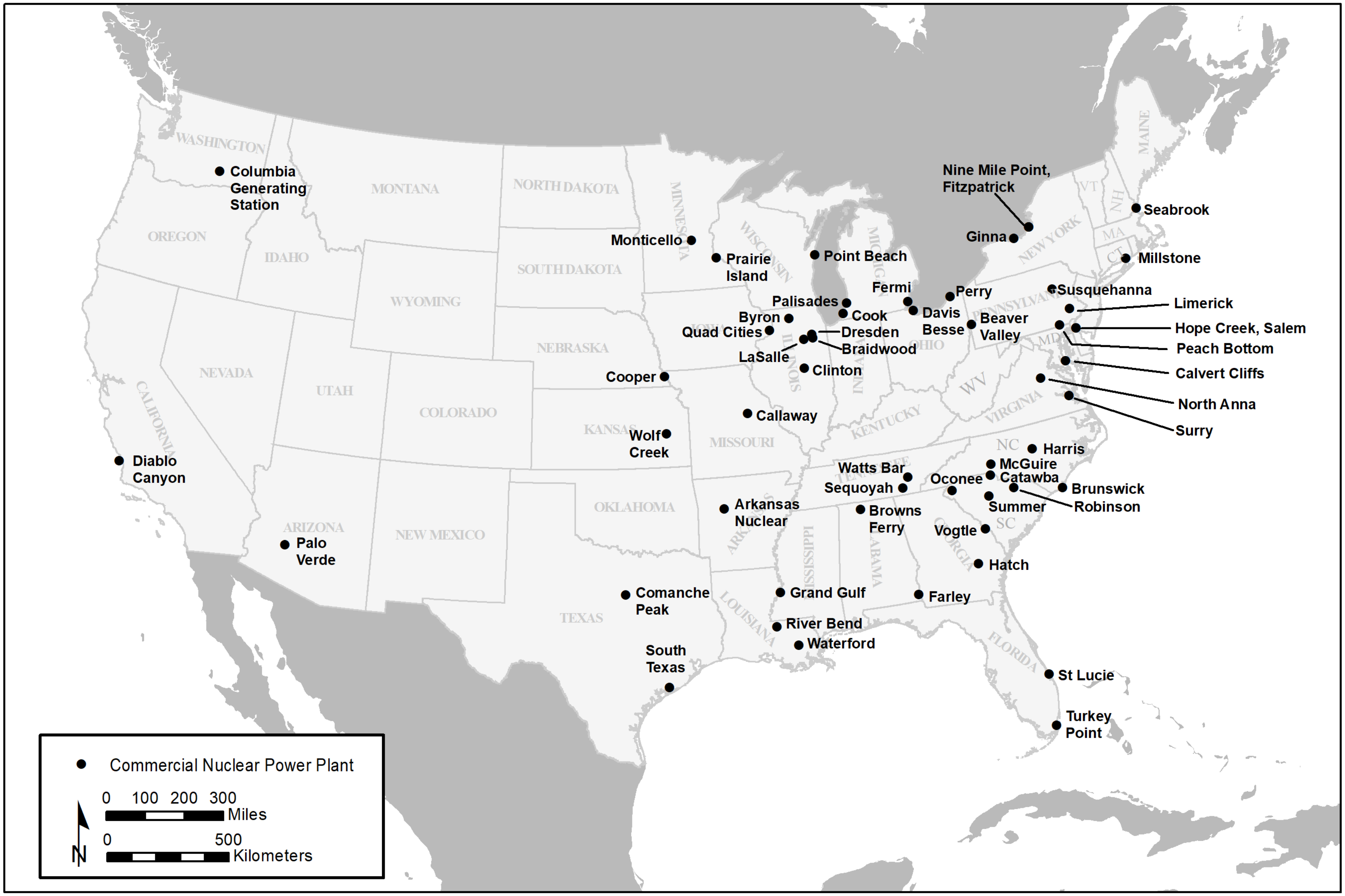



**Figure 3.1-1 Operating Commercial Nuclear Power Plants in the United States**

## Table 3.1-1 Characteristics of Operating U.S. Commercial Nuclear Power Plants[(a)]

| Nuclear Power Plant | Unit | Year Operating License Granted | Year License Expires | Net Capacity (MWe) | Reactor Type | Design Condenser Flow Rate ($10^3$ gpm) | Total Site Area (acres) | Nearest City | 2020 Population within 50 mi |
|---|---|---|---|---|---|---|---|---|---|
| Arkansas Nuclear One | 1 | 1974 | 2034 | 833 | PWR | 762 | 1,164 | Little Rock, AR | 312,591 |
| Arkansas Nuclear One | 2 | 1978 | 2038 | 985 | PWR | 422 | - | - | - |
| Beaver Valley Power Station | 1 | 1976 | 2036 | 892 | PWR | 480 | 453 | Pittsburgh, PA | 3,146,489 |
| Beaver Valley Power Station | 2 | 1987 | 2047 | 901 | PWR | 480 | - | - | - |
| Braidwood Station | 1 | 1987 | 2046 | 1,183 | PWR | 730 | 4,457 | Joliet, IL | 5,033,013 |
| Braidwood Station | 2 | 1988 | 2047 | 1,154 | PWR | 730 | - | - | - |
| Browns Ferry Nuclear Plant | 1 | 1973 | 2033 | 1,256 | BWR | 734 | 840 | Huntsville, AL | 1,081,319 |
| Browns Ferry Nuclear Plant | 2 | 1974 | 2034 | 1,259 | BWR | 734 | - | - | - |
| Browns Ferry Nuclear Plant | 3 | 1976 | 2036 | 1,260 | BWR | 734 | - | - | - |
| Brunswick Steam Electric Plant | 1 | 1976 | 2036 | 938 | BWR | 675 | 1,200 | Wilmington, NC | 548,758 |
| Brunswick Steam Electric Plant | 2 | 1974 | 2034 | 932 | BWR | 675 | - | - | - |
| Byron Station | 1 | 1985 | 2044 | 1,182 | PWR | 632 | 1,398 | Rockford, IL | 1,284,960 |
| Byron Station | 2 | 1987 | 2046 | 1,154 | PWR | 632 | - | - | - |
| Callaway Plant | 1 | 1984 | 2044 | 1,190 | PWR | 530 | 5,228 | Columbia, MO | 585,372 |
| Calvert Cliffs Nuclear Power Plant | 1 | 1974 | 2034 | 866 | PWR | 1,200 | 2,108 | Washington, D.C. | 3,962,475 |
| Calvert Cliffs Nuclear Power Plant | 2 | 1976 | 2036 | 842 | PWR | 1,200 | - | - | - |
| Catawba Nuclear Station | 1 | 1985 | 2043 | 1,160 | PWR | 660 | 391 | Charlotte, NC | 3,034,933 |
| Catawba Nuclear Station | 2 | 1986 | 2043 | 1,150 | PWR | 660 | - | - | - |
| Clinton Power Station | 1 | 1987 | 2027 | 1,065 | BWR | 569 | 14,000 | Decatur, IL | 815,617 |
| Columbia Generating Station | 1 | 1984 | 2043 | 1,163 | BWR | 550 | 1,089 | Spokane, WA | 517,245 |
| Comanche Peak Steam Electric Station | 1 | 1989 | 2030 | 1,205 | PWR | 1,030 | 7,669 | Fort Worth, TX | 2,077,599 |
| Comanche Peak Steam Electric Station | 2 | 1993 | 2033 | 1,195 | PWR | 1,030 | - | - | - |

| Nuclear Power Plant | Unit | Year Operating License Granted | Year License Expires | Net Capacity (MWe) | Reactor Type | Design Condenser Flow Rate ($10^3$ gpm) | Total Site Area (acres) | Nearest City | 2020 Population within 50 mi |
|---|---|---|---|---|---|---|---|---|---|
| Cooper Nuclear Station | 1 | 1974 | 2034 | 770 | BWR | 631 | 1,251 | Lincoln, NE | 153,581 |
| Donald C. Cook Nuclear Plant | 1 | 1974 | 2034 | 1,009 | PWR | 800 | 650 | South Bend, IN | 1,265,894 |
| Donald C. Cook Nuclear Plant | 2 | 1977 | 2037 | 1,060 | PWR | 800 | - | - | - |
| Davis-Besse Nuclear Power Station | 1 | 1977 | 2037 | 894 | PWR | 480 | 733 | Toledo, OH | 1,812,385 |
| Diablo Canyon Power Plant | 1 | 1984 | 2024 | 1,122 | PWR | 863 | 750 | Santa Barbara, CA | 499,952 |
| Diablo Canyon Power Plant | 2 | 1985 | 2025 | 1,118 | PWR | 863 | - | - | - |
| Dresden Nuclear Power Station | 2 | 1969 | 2029 | 902 | BWR | 940 | 2,500 | Joliet, IL | 7,525,651 |
| Dresden Nuclear Power Station | 3 | 1971 | 2031 | 895 | BWR | 940 | - | - | - |
| Joseph M. Farley Nuclear Plant | 1 | 1977 | 2037 | 874 | PWR | 635 | 1,850 | Columbus, GA | 425,394 |
| Joseph M. Farley Nuclear Plant | 2 | 1981 | 2041 | 877 | PWR | 635 | - | - | - |
| Enrico Fermi Atomic Power Plant | 2 | 1985 | 2045 | 1,141 | BWR | 836 | 1,120 | Detroit, MI | 4,908,826 |
| James A. FitzPatrick Nuclear Power Plant | 1 | 1974 | 2034 | 848 | BWR | 353 | 702 | Syracuse, NY | 932,913 |
| R.E. Ginna Nuclear Power Plant | 1 | 1969 | 2029 | 581 | PWR | 340 | 488 | Rochester, NY | 1,299,149 |
| Grand Gulf Nuclear Station | 1 | 1984 | 2044 | 1,401 | BWR | 572 | 2,100 | Jackson, MS | 323,744 |
| Shearon Harris Nuclear Power Plant | 1 | 1987 | 2046 | 964 | PWR | 483 | 10,744 | Raleigh, NC | 3,041,733 |
| Edwin I. Hatch Nuclear Plant | 1 | 1974 | 2034 | 876 | BWR | 556 | 2,240 | Savannah, GA | 464,024 |
| Edwin I. Hatch Nuclear Plant | 2 | 1978 | 2038 | 883 | BWR | 556 | - | - | - |
| Hope Creek Generating Station | 1 | 1986 | 2046 | 1,172 | BWR | 552 | 740 | Wilmington, DE | 5,946,917 |
| LaSalle County Station | 1 | 1982 | 2042 | 1,131 | BWR | 645 | 3,060 | Joliet, IL | 1,948,438 |

| Nuclear Power Plant | Unit | Year Operating License Granted | Year License Expires | Net Capacity (MWe) | Reactor Type | Design Condenser Flow Rate ($10^3$ gpm) | Total Site Area (acres) | Nearest City | 2020 Population within 50 mi |
|---|---|---|---|---|---|---|---|---|---|
| LaSalle County Station | 2 | 1984 | 2043 | 1,134 | BWR | 645 | - | - | - |
| Limerick Generating Station | 1 | 1985 | 2049 | 1,120 | BWR | 450 | 595 | Reading, PA | 8,594,665 |
| Limerick Generating Station | 2 | 1990 | 2049 | 1,122 | BWR | 450 | - | - | - |
| McGuire Nuclear Station | 1 | 1981 | 2041 | 1,159 | PWR | 675 | 577 | Charlotte, NC | 3,351,808 |
| McGuire Nuclear Station | 2 | 1983 | 2043 | 1,158 | PWR | 675 | - | - | - |
| Millstone Power Station | 2 | 1975 | 2035 | 853 | PWR | 523 | 500 | New Haven, CT | 3,071,351 |
| Millstone Power Station | 3 | 1986 | 2045 | 1,220 | PWR | 907 | - | - | - |
| Monticello Nuclear Generating Plant | 1 | 1970 | 2030 | 617 | BWR | 292 | 1,250 | Minneapolis, MN | 3,347,158 |
| Nine Mile Point Nuclear Station | 1 | 1968 | 2029 | 621 | BWR | 290 | 900 | Syracuse, NY | 927,862 |
| Nine Mile Point Nuclear Station | 2 | 1987 | 2046 | 1,292 | BWR | 580 | - | - | - |
| North Anna Power Station | 1 | 1978 | 2038 | 948 | PWR | 950 | 1,043 | Richmond, VA | 2,237,934 |
| North Anna Power Station | 2 | 1980 | 2040 | 944 | PWR | 950 | - | - | - |
| Oconee Nuclear Station | 1 | 1973 | 2033 | 847 | PWR | 680 | 510 | Greenville, SC | 1,577,801 |
| Oconee Nuclear Station | 2 | 1973 | 2033 | 848 | PWR | 680 | - | - | - |
| Oconee Nuclear Station | 3 | 1974 | 2034 | 859 | PWR | 680 | - | - | - |
| Palisades Nuclear Plant(b) | 1 | 1972 | 2031 | 769 | PWR | 98 | 432 | Kalamazoo, MI | 1,441,106 |
| Palo Verde Nuclear Generating Station | 1 | 1985 | 2045 | 1,211 | PWR | 560 | 4,050 | Phoenix, AZ | 2,350,442 |
| Palo Verde Nuclear Generating Station | 2 | 1986 | 2046 | 1,314 | PWR | 560 | - | - | - |
| Palo Verde Nuclear Generating Station | 3 | 1987 | 2047 | 1,312 | PWR | 560 | - | - | - |
| Peach Bottom Atomic Power Station | 2 | 1973 | 2053 | 1,265 | BWR | 750 | 620 | Lancaster, PA | 6,005,101 |
| Peach Bottom Atomic Power Station | 3 | 1974 | 2054 | 1,285 | BWR | 750 | - | - | - |
| Perry Nuclear Power Plant | 1 | 1986 | 2026 | 1,261 | BWR | 545 | 1,100 | Euclid, OH | 2,299,476 |
| Point Beach Nuclear Plant | 1 | 1970 | 2030 | 598 | PWR | 350 | 1,260 | Green Bay, WI | 826,680 |

| Nuclear Power Plant | Unit | Year Operating License Granted | Year License Expires | Net Capacity (MWe) | Reactor Type | Design Condenser Flow Rate ($10^3$ gpm) | Total Site Area (acres) | Nearest City | 2020 Population within 50 mi |
|---|---|---|---|---|---|---|---|---|---|
| Point Beach Nuclear Plant | 2 | 1972 | 2033 | 603 | PWR | 350 | - | - | - |
| Prairie Island Nuclear Generating Plant | 1 | 1973 | 2033 | 521 | PWR | 294 | 560 | Minneapolis, MN | 3,309,059 |
| Prairie Island Nuclear Generating Plant | 2 | 1974 | 2034 | 519 | PWR | 294 | - | - | - |
| Quad Cities Nuclear Power Station | 1 | 1972 | 2032 | 908 | BWR | 485 | 817 | Davenport, IA | 655,699 |
| Quad Cities Nuclear Power Station | 2 | 1972 | 2032 | 911 | BWR | 485 | - | - | - |
| River Bend Station | 1 | 1985 | 2045 | 968 | BWR | 508 | 3,300 | Baton Rouge, LA | 1,037,151 |
| H.B. Robinson Steam Electric Plant | 2 | 1970 | 2030 | 759 | PWR | 454 | 6,020 | Columbia, SC | 922,132 |
| St. Lucie Nuclear Plant | 1 | 1976 | 2036 | 981 | PWR | 484 | 1,130 | West Palm Beach, FL | 1,456,749 |
| St. Lucie Nuclear Plant | 2 | 1983 | 2043 | 987 | PWR | 484 | - | - | - |
| Salem Nuclear Generating Station | 1 | 1976 | 2036 | 1,174 | PWR | 1,100 | 700 | Wilmington, DE | 5,873,042 |
| Salem Nuclear Generating Station | 2 | 1981 | 2040 | 1,130 | PWR | 1,100 | - | - | - |
| Seabrook Station | 1 | 1990 | 2050 | 1,295 | PWR | 399 | 889 | Lawrence, MA | 4,693,723 |
| Sequoyah Nuclear Plant | 1 | 1980 | 2040 | 1,152 | PWR | 522 | 525 | Chattanooga, TN | 1,172,704 |
| Sequoyah Nuclear Plant | 2 | 1981 | 2041 | 1,126 | PWR | 522 | - | - | - |
| South Texas Project Electric Generating Station | 1 | 1988 | 2047 | 1,280 | PWR | 907 | 12,350 | Galveston, TX | 268,364 |
| South Texas Project Electric Generating Station | 2 | 1989 | 2048 | 1,280 | PWR | 907 | - | - | - |
| Virgil C. Summer Nuclear Station | 1 | 1982 | 2042 | 971 | PWR | 507 | 2,245 | Columbia, SC | 1,289,146 |
| Surry Power Station | 1 | 1972 | 2052 | 838 | PWR | 840 | 840 | Newport News, VA | 2,462,820 |
| Surry Power Station | 2 | 1973 | 2053 | 838 | PWR | 840 | 840 | - | - |

| Nuclear Power Plant | Unit | Year Operating License Granted | Year License Expires | Net Capacity (MWe) | Reactor Type | Design Condenser Flow Rate ($10^3$ gpm) | Total Site Area (acres) | Nearest City | 2020 Population within 50 mi |
|---|---|---|---|---|---|---|---|---|---|
| Susquehanna Steam Electric Station | 1 | 1982 | 2042 | 1,247 | BWR | 484 | 1,173 | Wilkes-Barre, PA | 1,829,035 |
| Susquehanna Steam Electric Station | 2 | 1984 | 2044 | 1,247 | BWR | 484 | - | - | - |
| Turkey Point Nuclear Plant | 3 | 1972 | 2052 | 837 | PWR | 650 | 2,400 | Miami, FL | 3,813,589 |
| Turkey Point Nuclear Plant | 4 | 1973 | 2053 | 861 | PWR | 650 | - | - | - |
| Vogtle Electric Generating Plant | 1 | 1987 | 2047 | 1,150 | PWR | 510 | 3,169 | Augusta, GA | 789,654 |
| Vogtle Electric Generating Plant | 2 | 1989 | 2049 | 1,152p | PWR | 510 | - | - | - |
| Waterford Steam Electric Station | 3 | 1985 | 2044 | 1,250 | PWR | 975 | 3,000 | New Orleans, LA | 2,171,180 |
| Watts Bar Nuclear Plant | 1 | 1996 | 2035 | 1,123 | PWR | 410 | 1,170 | Chattanooga, TN | 1,312,700 |
| Watts Bar Nuclear Plant | 2 | 2015 | 2055 | 1,122 | PWR | 410 | - | - | - |
| Wolf Creek Generating Station | 1 | 1985 | 2045 | 1,166 | PWR | 500 | 9,818 | Topeka, KS | 173,018 |

BWR = boiling water reactor, gpm = gallon(s) per minute; MWe = megawatts-electric; PWR = pressurized water reactor.

(a) The 2013 LR GEIS (NRC 2013a) included a number of nuclear power plants that are not being considered for license renewal and are not included in this table. They include the following plants:

- Bellefonte: Construction permits issued in 1974. Units 1 & 2 were never finished and mothballed in 1988. Currently under the NRC's Deferred Policy.
- Big Rock: Shutdown in 1997; decommissioning completed in August 2006. Stored spent fuel is still onsite.
- Crystal River Nuclear Power Plant (Crystal River) Unit 3: Shutdown in 2013. Decommissioning completion scheduled for 2026-2030.
- Duane Arnold Energy Center (Duane Arnold): Shutdown in 2020. Decommissioning completion scheduled for 2080.
- Fort Calhoun Station (Fort Calhoun): Shutdown in 2016. Decommissioning completion scheduled for 2026.
- Haddam (Connecticut Yankee): Shutdown in 1996; decommissioned in 2004. Stored spent fuel is still onsite.
- Indian Point Energy Center (Indian Point) Unit 2: Shutdown in 2020; Unit 3: Shutdown in 2021. Decommissioning completion scheduled for 2026 to 2033.
- Kewanee: Shutdown in 2013. Decommissioning completion scheduled for 2073.
- Maine Yankee: Closed in 1997; decommissioned completed in 2005. Stored spent fuel is still onsite.
- Millstone Power Station (Millstone), Unit 1: Shutdown in 1995; Decommissioning completion scheduled for 2056.
- Oyster Creek Nuclear Generating Station (Oyster Creek): Shutdown in 2018. Decommissioning completion scheduled for 2025.
- Pilgrim Nuclear Power Station (Pilgrim): Shutdown in 2019. Decommissioning completion scheduled for 2027.
- Rancho Seco: Shutdown in 1989; decommissioning completed and licensed terminated in 2018. Stored spent fuel is still onsite.
- San Onofre Nuclear Generating Station (San Onofre): Unit 1: Shutdown in 1992; Units 2 & 3: Shutdown in 2013. Decommissioning completion scheduled for 2030-2031.

- Shoreham: Fully decommissioned in 1994; it never produced power.
- Three Mile Island Unit 1: Shutdown in 2019. Decommissioning completion scheduled for 2079. Unit 2: Shutdown in 1979. Decommissioning completion scheduled for 2037.
- Trojan: Closed in 1992; decommissioning completed in 2006. Stored spent fuel is still onsite.
- Vermont Yankee Nuclear Power Station (Vermont Yankee): Shutdown in 2014. Decommissioning completion scheduled for 2026-2030.
- Yankee Rowe: Shutdown in 1992; decommissioning completed in 2006. Stored spent fuel is still onsite.
- Zion: Shutdown in 1998, decontamination and dismantlement began in 2011 and is scheduled to be completed by the end of 2022.

(b) Palisades Nuclear Plant (Palisades): Shutdown in May 2022. Status to be determined. The plant has been retained in this table for the purposes of this LR GEIS update.

No entry has been denoted by “-”.

Sources: Appendix C; NRC 2018f; NRC 2021r; Pacific Northwest National Laboratory calculations based on 2020 decennial census data.

The nuclear fuel used in all LWRs is uranium enriched to 2 to 5 percent in the uranium-235 isotope. The fuel is in the form of cylindrical uranium dioxide ($UO_2$) pellets, which are approximately 0.4 in. (1 centimeter [cm]) in diameter and 0.4 to 0.6 in. (1 to 1.5 cm) in height. The fuel pellets are stacked and sealed inside a hollow cylindrical zirconium alloy fuel rod. The fuel rods, also called fuel pins or fuel elements, are approximately 12 ft (3.6 m) long. They are bundled into fuel assemblies that generally consist of 15 × 15 or 17 × 17 rods for PWRs and 8 × 8 or 10 × 10 rods for BWRs. When new fuel is loaded into the reactors or spent fuel is removed from reactors, the fuel is handled as intact assemblies. Similarly, when spent fuel is stored onsite awaiting shipment offsite, the fuel assemblies remain intact.

Fission reactions that occur inside the fuel, primarily by the uranium-235 isotope, are the source of thermal energy in a nuclear reactor. This energy is transferred to the coolant, which is ordinary water, circulating in the primary coolant system in LWRs. The vessel, which encloses the reactor, is part of the primary coolant system.

In PWRs, water is heated to a high temperature under pressure inside the reactor vessel (Figure 3.1-2). The water flows in the primary circulation loop to the steam generator. Within the steam generator, water in the secondary circulation loop is converted to steam that drives the turbines. The turbines turn the generator to produce electricity. The steam leaving the turbines is condensed by water in the tertiary loop and returned to the steam generator. The tertiary loop water flows to cooling towers where it is cooled by evaporation, or it is discharged directly to a body of water, such as a river, lake, or other heat sink (see Section 3.1.3). The tertiary loop is open to the atmosphere, but the primary and secondary cooling loops are not.

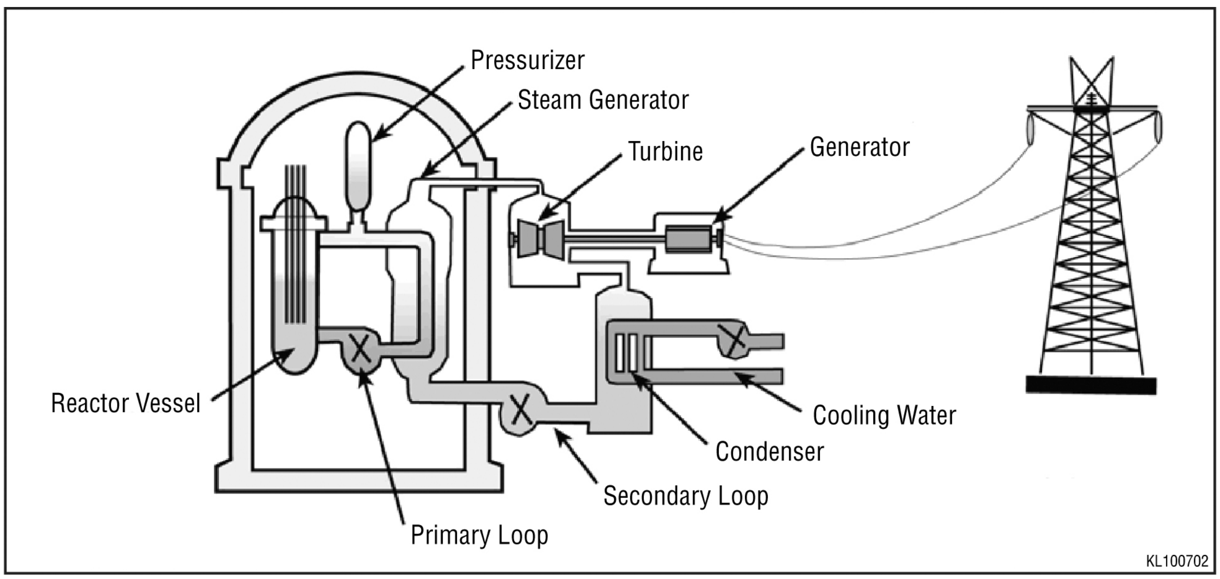



**Figure 3.1-2 Pressurized Water Reactor. Adapted from NRC 2002c.**

BWRs generate steam directly within the reactor vessel (Figure 3.1-3). The steam passes through moisture separators and steam dryers and then flows to the turbines. Because it generates steam directly in the reactor vessel, the power generation system contains only two heat transfer loops. The primary loop transports the steam from the reactor vessel directly to the turbines, which generate electricity. The secondary coolant loop removes excess heat from the primary loop in the condenser. From the condenser, the primary condensate proceeds into the feedwater stage, and the secondary coolant loop removes the excess heat and discharges it to the receiving water body. As is the case for PWRs, the coolant water from the condenser is pumped to cooling towers or it is discharged directly to a water body.

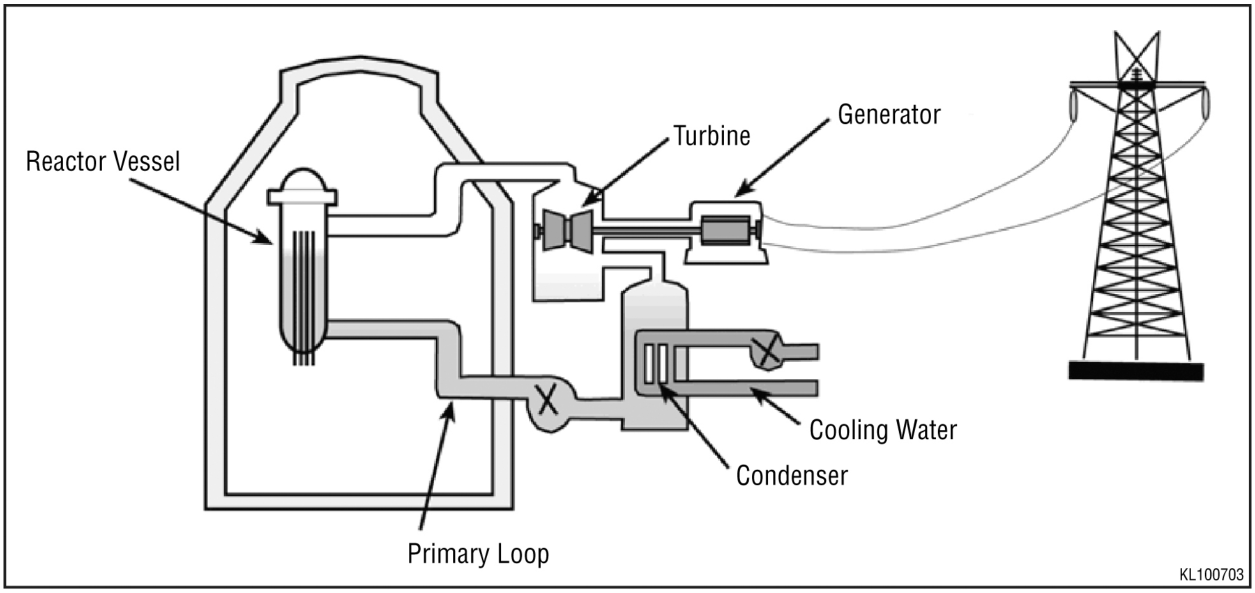



**Figure 3.1-3 Boiling Water Reactor. Adapted from NRC 2002c.**

### 3.1.3 Cooling Water Systems

In LWR designs, water is used to remove excess heat generated in reactor systems. The volume of water required and rate of flow is a function of several factors, including the licensed thermal power level of the reactor and the increase in cooling water temperature from the intake to the discharge. In general, larger nuclear power plants (i.e., more reactor units and/or higher licensed power levels) generate more waste heat and require more water for cooling.

Table 3.1-2 through Table 3.1-4 describe the configurations of the cooling systems used at existing nuclear power plant sites. There are two major types of cooling systems: once-through and closed-cycle. Once-through cooling systems withdraw water for condenser cooling from a nearby water body, such as a lake or river, circulate it through the condenser tubes, and return that water as heated effluent to the same water body (Figure 3.1-4a).

Average water withdrawal for nuclear power plants using once-through cooling is about 39,000 gal/MWh (148 $m^3$/MWh) of electricity generated (USGS 2019b). For comparison, using the dataset described by Marston et al. (2018) for operating nuclear power plants, most plants using once-through cooling withdraw between 28,000 and 52,000 gal/MWh (106 to 197 $m^3$/MWh) of water. In a once-through cooling system, waste heat is dissipated to the atmosphere mainly through evaporation, mixing with ambient water from the source water body, and, to a much smaller extent, by conduction, convection, and thermal radiation loss. Average consumptive water use for nuclear power plants using once-through cooling is about 400 gal/MWh (1.51 $m^3$/MWh) (USGS 2019b), with most plants estimated to consume between 290 and 570 gal/MWh (1.1 to 2.2 $m^3$/MWh) of water during electricity generation (based on the dataset described by Marston et al. [2018]).

**Table 3.1-2 Cooling Water System Source – Coastal or Estuarine Environment**

| Nuclear Power Plant | State | Cooling System | Cooling Water Source |
|---|---|---|---|
| Diablo Canyon | California | Once-through | Pacific Ocean |
| Millstone | Connecticut | Once-through | Long Island Sound |
| St. Lucie | Florida | Once-through | Atlantic Ocean |
| Turkey Point | Florida | Cooling canal | Biscayne Bay; Upper Floridan Aquifer (supplemental source) |
| Calvert Cliffs | Maryland | Once-through | Chesapeake Bay |
| Seabrook | New Hampshire | Once-through | Gulf of Maine |
| Hope Creek | New Jersey | Natural draft cooling towers | Delaware River |
| Salem | New Jersey | Once-through | Delaware River |
| Brunswick | North Carolina | Once-through | Cape Fear River |
| South Texas | Texas | Cooling pond | Colorado River |
| Surry | Virginia | Once-through | James River |

**Table 3.1-3 Cooling Water System Source – Great Lakes Environment**

| Nuclear Power Plant | State | Cooling System | Cooling Water Source |
|---|---|---|---|
| D.C. Cook | Michigan | Once-through | Lake Michigan |
| Fermi | Michigan | Natural draft cooling towers | Lake Erie |
| Palisades[(a)] | Michigan | Mechanical draft cooling towers | Lake Michigan |
| FitzPatrick | New York | Once-through | Lake Ontario |
| Ginna | New York | Once-through | Lake Ontario |
| Nine Mile Point | New York | Unit 1: Once-through<br>Unit 2: Natural draft cooling towers | Lake Ontario |
| Davis-Besse | Ohio | Natural draft cooling towers | Lake Erie |
| Perry | Ohio | Natural draft cooling towers | Lake Erie |
| Point Beach | Wisconsin | Once-through | Lake Michigan |

(a) Palisades shutdown in May 2022 but has been retained in this LR GEIS update.

**Table 3.1-4 Cooling Water System Source – Freshwater Riverine or Impoundment Environment**

| Nuclear Power Plant | State | Cooling System | Cooling Water Source |
|---|---|---|---|
| Browns Ferry | Alabama | Once-through (helper towers) | Wheeler Reservoir |
| Farley | Alabama | Mechanical draft cooling towers | Chattahoochee River |
| Palo Verde | Arizona | Mechanical draft cooling towers | Phoenix Wastewater Treatment Plant Effluent |
| Arkansas | Arkansas | Unit 1: once-through<br>Unit 2: natural draft cooling towers | Lake Dardanelle |
| Hatch | Georgia | Mechanical draft cooling towers | Altamaha River |
| Vogtle | Georgia | Natural draft cooling towers | Savannah River |
| Braidwood | Illinois | Cooling pond | Kankakee River |
| Byron | Illinois | Natural draft cooling towers | Rock River |
| Clinton | Illinois | Once-through (cooling pond) | Salt Creek |
| Dresden | Illinois | Cooling pond and optional mechanical draft cooling tower or once-through including residence time in pond and optional cooling towers | Kankakee River |
| LaSalle | Illinois | Cooling pond | Illinois River |
| Quad Cities | Illinois | Once-through | Mississippi River |
| Wolf Creek | Kansas | Cooling pond | Coffey County Lake |
| River Bend | Louisiana | Mechanical draft cooling towers | Mississippi River |
| Waterford | Louisiana | Once-through | Mississippi River |
| Monticello | Minnesota | Once-through and mechanical draft cooling towers | Mississippi River |
| Prairie Island | Minnesota | Once-through and mechanical draft cooling towers | Mississippi River |
| Grand Gulf | Mississippi | Natural draft cooling towers | Mississippi River |
| Callaway | Missouri | Natural draft cooling towers | Missouri River |
| Cooper | Nebraska | Once-through | Missouri River |
| Harris | North Carolina | Natural draft cooling towers | Harris Reservoir |
| McGuire | North Carolina | Once-through | Lake Norman |
| Beaver Valley | Pennsylvania | Natural draft cooling towers | Ohio River |
| Limerick | Pennsylvania | Natural draft cooling towers | Schuylkill River |
| Peach Bottom | Pennsylvania | Unit 2: Once-through<br>Unit 3: Once-through (mechanical draft cooling towers) | Conowingo Pond |
| Susquehanna | Pennsylvania | Natural draft cooling towers | Susquehanna River |

| Nuclear Power Plant | State | Cooling System | Cooling Water Source |
|---|---|---|---|
| Catawba | South Carolina | Mechanical draft cooling towers | Lake Wylie |
| Oconee | South Carolina | Once-through | Lake Keowee |
| H.B. Robinson | South Carolina | Once-through (Cooling pond) | Lake Robinson |
| Summer | South Carolina | Cooling pond | Monticello Reservoir |
| Sequoyah | Tennessee | Once-through and natural draft cooling towers | Chickamauga Lake |
| Watts Bar | Tennessee | Natural draft cooling towers | Chickamauga Lake |
| Comanche Peak | Texas | Once-through | Squaw Creek Reservoir |
| North Anna | Virginia | Once-through | Lake Anna |
| Columbia | Washington | Mechanical draft cooling towers | Columbia River |

Closed-cycle cooling systems typically use recirculated water from cooling towers to cool the condenser. Some nuclear power plants use cooling ponds, lakes, reservoirs, or canals (Figure 3.1-4b) that often function as closed-cycle systems. The average water withdrawal for nuclear power plants using closed-cycle cooling is 480 gal/MWh (1.82 $m^3$/MWh) for cooling ponds or lakes and 700 gal/MWh (2.65 $m^3$/MWh) for cooling towers (USGS 2019b). Because the predominant cooling mechanism associated with closed-cycle systems is evaporation, much of the water used for cooling is consumed and is not returned to the water source. The average consumptive water use for nuclear power plants using cooling towers is 500 gal/MWh (1.9 $m^3$/MWh) (USGS 2019b). Based on the dataset described by Marston et al. (2018), consumptive water use for most nuclear power plants using closed-cycle cooling ranges between 450 and 750 gal/MWh (1.7 to 2.8 $m^3$/MWh). Makeup water to account for these losses, as well as blowdown (water that is periodically rinsed from the cooling system to remove impurities and sediment that may degrade performance) is typically withdrawn from and released to a surface water body near the site.

Several nuclear plants use hybrid cooling systems that may be used in different configurations at different times of the year (Figure 3.1-4c). For instance, some once-through cooling system plants also operate cooling towers (sometimes referred to as “helper towers”) seasonally to reduce thermal load to the receiving water body, reduce entrainment during peak spawning periods, or reduce consumptive water use during periods of low river flow. The Peach Bottom Atomic Power Station (Peach Bottom) (NRC 2003b, NRC 2020g) has helper mechanical draft cooling towers that can process up to 60 percent of the plant’s heated effluent, while the remaining effluent is discharged as part of the once-through system. The Monticello Nuclear Generating Plant (Monticello) (NRC 2006c) uses once-through cooling in the winter but has mechanical draft cooling towers for closed-cycle cooling in the summer. The Dresden Nuclear Power Station (Dresden) (NRC 2004c) is similar in that it relies on a cooling pond system in the fall, winter, and spring, but in the summer, the plant operates as a once-through system that uses the cooling pond and helper mechanical draft cooling towers to reduce effluent temperatures before releasing the water to the Kankakee River (see Table 3.1-4). The Browns Ferry Nuclear Plant (Browns Ferry) (NRC 2005b) uses mechanical draft cooling towers in helper mode in accordance with conditions in its National Pollutant Discharge Elimination System (NPDES) permit to limit thermal impacts on Wheeler Reservoir.

All existing sites with two or three reactor units use the same cooling system for all units, except for two sites: the Arkansas Nuclear One (Arkansas) plant in Arkansas and Nine Mile Point Nuclear Station (Nine Mile Point) in New York. These two sites use once-through cooling for one unit and closed-cycle cooling for the other. The configuration of each nuclear power plant intake and discharge structure varies to accommodate the source water body and to minimize impacts on the hydrologic environment and aquatic ecosystem. Intake structures generally are located along the shoreline of the source water body. Most are equipped with devices that reduce impingement and entrainment of fish and other aquatic organisms. Some include fish return systems that return impinged organisms to the source water body. Discharge structures usually consist of pipes or canals that terminate in discharge jets or diffusers that promote rapid mixing of the effluent with the receiving body of water. Discharge of condenser cooling water (once-through systems) and blowdown water (closed-cycle systems) containing biocides and other chemicals used for corrosion control and other water treatment purposes are authorized by the Environmental Protection Agency (EPA), or authorized States and Tribes, under NPDES permits, which establish limits, as necessary, based on flow rates, chemical concentrations, and thermal criteria.

In addition to heat removal, nuclear power plants require cooling water for service water and auxiliary cooling water systems. Service water is special-purpose water that may not be treated for use. The auxiliary cooling water system typically includes the emergency core cooling system, the containment spray and cooling system, the emergency feedwater system, the component cooling water system, and the spent fuel pool water system. The volume of water required for these systems is usually less than 15 percent of the volume required for condenser cooling in once-through cooling systems. In closed-cycle cooling systems, the additional water needed for service water and auxiliary purposes is usually less than 5 percent of that needed for condenser cooling (NRC 1996).

In addition to surface water sources, some nuclear power plants use groundwater as a source for service, makeup, or potable water. The Grand Gulf Nuclear Station (Grand Gulf) uses groundwater as a source of makeup water to the condenser cooling system. This plant employs a radial collector well system (i.e., also known as Ranney® wells) to draw groundwater from the Mississippi River Alluvial aquifer (NRC 2014e). The Turkey Point Nuclear Plant (Turkey Point) also draws groundwater from the Upper Floridan Aquifer as a supplemental source of makeup water to the cooling canal system (CCS). These withdrawals primarily address salinity levels in the system and are part of a State-mandated mitigation program to restore salinity to a level similar to that of nearby surface waters (i.e., Biscayne Bay) (NRC 2019c).

### 3.1.4 Radioactive Waste Management Systems

During the fission process, a large inventory of radioactive fission products builds up within the fuel. Virtually all of the fission products are contained within the fuel pellets. The fuel pellets are enclosed in hollow metal rods (cladding), which are hermetically sealed to further prevent the release of fission products. However, a small fraction of the fission products escape from the fuel rods and contaminate the reactor coolant. The primary system coolant also has radioactive contaminants as a result of neutron activation. The radioactivity in the reactor coolant is the source of liquid, gaseous, and most of the solid radioactive wastes at LWRs. The following sections describe the basic design and operation of PWR and BWR radioactive waste treatment systems.

### *3.1.4.1 Liquid Radioactive Waste*

Radionuclide contaminants in the primary coolant are the source of liquid radioactive waste in LWRs. The specific sources of these wastes, their associated modes of collection and treatment, and the types and quantities of liquid radioactive wastes released to the environment are similar in many respects in BWRs and PWRs. Accordingly, the following discussion applies to both BWRs and PWRs; distinctions are made only when important differences exist.

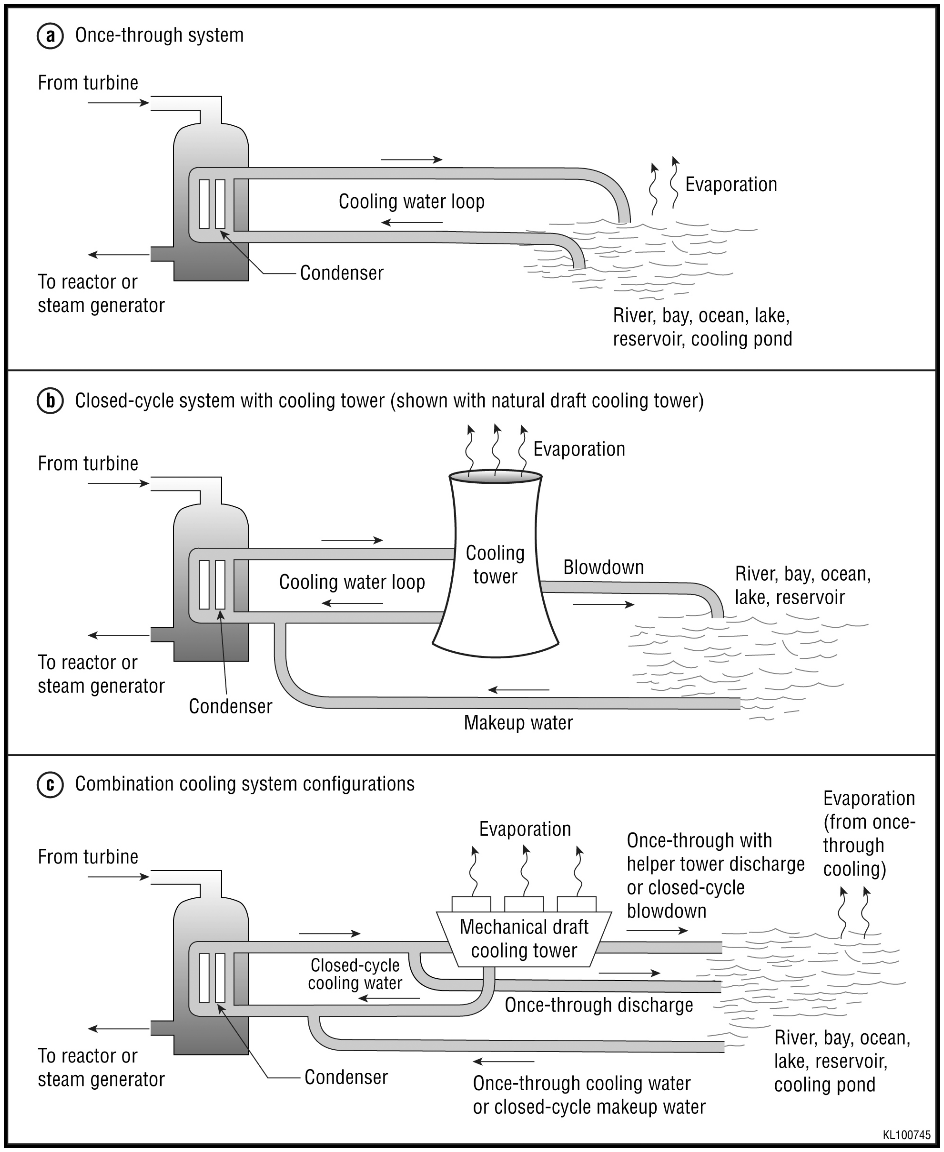



**Figure 3.1-4 Schematic Diagrams of Nuclear Power Plant Cooling Systems. Source: NRC 2013a.**

Liquid wastes resulting from LWR operation may be placed into the following categories: clean wastes, dirty wastes, detergent wastes, turbine building floor-drain water, and steam generator blowdown (PWRs only). Clean wastes include all liquid wastes with normally low conductivity and variable radioactivity. They consist of reactor-grade water, which is amenable to processing for reuse as reactor coolant makeup water. Clean wastes are collected from equipment leaks and drains, certain valve and pump seal leaks, and other aerated leakage sources. Dirty wastes include all liquid wastes with moderate chemical (ionic) conductivity and variable radioactivity that, after processing, may be used as reactor coolant makeup water. Dirty wastes consist of liquid wastes collected in the containment building sump, auxiliary building sumps and drains, laboratory drains, sample station drains, and other floor drains. Detergent wastes consist principally of laundry wastes and personnel and equipment decontamination wastes and normally have low radioactivity. Turbine building floor-drain wastes usually have high conductivity and a low radionuclide content. In PWRs, steam generator blowdown can have relatively high concentrations of radionuclides, depending on the amount of primary-to-secondary leakage. After processing, the water may be reused or discharged.

Each of these sources of liquid wastes receives varying degrees and types of treatment before being stored for reuse or discharged to the environment in accordance with applicable regulatory requirements and permit provisions (e.g., NPDES permit). The extent and types of treatment depend on the chemical content of the waste; to increase the efficiency of waste processing, wastes with similar characteristics are batched before treatment.

Controls for limiting the release of radiological liquid effluents at each nuclear power plant are described in the facility's Offsite Dose Calculation Manual (ODCM). Controls are based on (1) concentrations of radioactive materials in liquid effluents and (2) dose to a member of the public. Concentrations of radioactive material that are allowed to be released in liquid effluents to unrestricted areas are limited to the concentration specified in 10 *Code of Federal Regulations* (CFR) Part 20, Appendix B, Table 2.

The degree and effectiveness of processing, storing, and recycling of liquid radioactive waste has steadily increased among operating plants. For example, extensive recycling of steam generator blowdown in PWRs is now the typical mode of operation, and secondary side wastewater is routinely treated. In addition, the plant systems that process wastes are often augmented by commercial mobile processing systems. As a result, radionuclide releases in liquid effluent from LWRs have generally declined for most plants or remained the same over time.

#### *3.1.4.2 Gaseous Radioactive Waste*

The gaseous waste management system collects fission products, mainly noble gases, which accumulate in the primary coolant. A small portion of the primary coolant flow is continually diverted to the primary coolant purification, volume, and chemical control system to remove contaminants and adjust the coolant chemistry and volume. During this process, noncondensable gases are stripped and routed to the gaseous waste management system, which consists of a series of gas storage tanks. The storage tanks allow the short-half-life radioactive gases to decay, leaving only relatively small quantities of long-half-life radionuclides to be released to the atmosphere. Some LWRs may use charcoal delay systems rather than gas storage tanks.

For BWRs, the sources of routine radioactive gaseous emissions to the atmosphere are the air ejector, which removes noncondensable gases from the coolant to improve power conversion efficiency, and gaseous and vapor leakages, which, after monitoring and filtering, are discharged to the atmosphere via the building ventilation systems.

PWRs have three primary sources of gaseous radioactive emissions: (1) discharges from the gaseous waste management system; (2) discharges associated with the exhaust of noncondensable gases at the main condenser if a primary-to-secondary system leak exists; and (3) radioactive gaseous discharges from the building ventilation exhaust, including the reactor building, reactor auxiliary building, and fuel-handling building.

The quantities of gaseous effluents released from operating plants are controlled by the administrative limits that are defined in the ODCM, which is specific for each nuclear power plant. Controls are based on (1) the rate at which the gaseous effluent is released and (2) dose to a member of the public. The limits in the ODCM are designed to provide reasonable assurance that radioactive materials discharged in gaseous effluents are not in excess of the limits specified in 10 CFR Part 20, Appendix B, thereby limiting the exposure of a member of the public in an unrestricted area.

#### *3.1.4.3 Solid Radioactive Waste*

Solid low-level radioactive waste (LLW) from nuclear power plants is generated from the removal of radionuclides from liquid waste streams, filtration of airborne gaseous emissions, and removal of contaminated material from various reactor areas. Liquid contaminated with radionuclides comes from primary and secondary coolant systems, spent fuel pools, decontaminated wastewater, and laboratory operations.

Solid waste is packaged in containers to meet the applicable requirements of 49 CFR Parts 171 through 177. Disposal and transportation are performed in accordance with the applicable requirements of 10 CFR Part 61 and 10 CFR Part 71, respectively.

Solid radioactive waste generated during operations is shipped to a LLW processor or directly to a LLW disposal site. Volume reduction may occur both onsite and offsite. The most common onsite volume reduction techniques are high-pressure compacting in waste drums, dewatering and evaporating wet wastes, monitoring waste streams to segregate wastes, and sorting. Offsite waste management vendors compact wastes at ultra-high pressures, incinerate dry active waste, separate and incinerate oily and organic wastes, and concrete-solidify resins and sludges before the waste is sent to a LLW disposal site.

Spent fuel contains fission products and actinides produced when nuclear fuel is irradiated in reactors, as well as any unburned, unfissioned nuclear fuel remaining after the fuel rods have been removed from the reactor core. In the United States, the spent fuel is considered waste and is being stored at the reactor sites, either in spent fuel pools or dry storage facilities, called ISFSIs (see Section 3.11.1.2). While all spent fuel is currently stored at nuclear power plant sites, the NRC has licensed a consolidated interim storage facility ISFSI in Andrews, Texas (NRC 2021h), and has another application under review. Consolidated interim storage facilities are licensed under 10 CFR Part 72 and provide an option for away-from-reactor spent fuel storage.

Mixed wastes, which contain both radioactive and hazardous components, are generally accumulated in designated areas onsite and then shipped offsite for treatment and disposal. Mixed wastes are regulated both by the EPA or the State under authority granted by the Resource Conservation and Recovery Act (RCRA; 42 U.S.C. § 6901) and by the NRC or the State under authority granted by the Atomic Energy Act (AEA; 42 U.S.C. § 2011 et seq.) (see Section 3.11.3).

### 3.1.5 Nonradioactive Waste Management Systems

Nonradioactive wastes from nuclear power plants include both hazardous and nonhazardous wastes. Hazardous wastes, as defined by RCRA Subtitle C, may include organic materials, heavy metals, solvents, paints, cutting fluids, and lubricating oils that have been used at a nuclear power plant and, after use, have been declared to be waste. These wastes are generally accumulated in designated areas onsite and then shipped offsite for treatment and disposal. Certain hazardous waste streams may receive treatment at some sites. For example, waste oil is incinerated at some sites. Common treatment methods for these nonradioactive wastes include incineration, neutralization, biological treatment, and removal and recovery. All activities related to hazardous wastes—including storage, treatment, shipment, and disposal—are conducted pursuant to the regulations issued by the EPA or the State, if authorized, under RCRA (see Section 3.11.2).

There are also some routine or nonroutine releases from nuclear power plants that may have hazardous components, including boiler blowdown (continual or periodic purging of impurities from plant boilers), water treatment wastes (sludges and high-saline streams whose residues are disposed of as solid waste and biocides), boiler metal cleaning wastes, floor and yard drains, and stormwater runoff. With the exception of solid water treatment wastes, these releases would be regulated in accordance with each plant’s NPDES permit. Principal chemical and biocide waste sources include the following:

- Boric acid used to control reactor power and lithium hydroxide used to control pH in the coolant. These chemicals could be inadvertently released because of pipe or steam generator leakage.
- Sulfuric acid, which is added to the circulating water system to control scale.
- Hydrazine, which is used for corrosion control. It is released in steam generator blowdown.
- Sodium hydroxide and sulfuric acid, which are used to regenerate resins. These are discharged after neutralization.
- Phosphate in cleaning solutions.
- Biocides (e.g., chlorine and bromine compounds) used for condenser defouling.

Other small volumes of wastewater are released from other plant systems depending on the design of each plant. These volumes are discharged from sources such as the service water and auxiliary cooling systems, laboratory and sampling wastes, and metal treatment wastes. These waste streams are regulated and discharged in accordance with each plant’s NPDES permit as separate point sources or are combined with the cooling water discharges.

Nonradioactive and nonhazardous wastes such as office trash are picked up by a local waste hauler and sent to a local landfill without any treatment. Sanitary wastes are treated at a sewage treatment plant that is located either onsite or offsite. If the treatment plant is offsite, the sanitary waste is either collected in septic tanks, tested for radioactivity as necessary, and sent offsite periodically, or the sanitary waste may be tested for radioactivity and discharged directly to a publicly owned treatment works. Any effluent releases to surface water from onsite sewage plants are subject to NPDES permit limits.

### 3.1.6 Utility and Transportation Infrastructure

The utility and transportation infrastructure at nuclear power plants typically interfaces with public infrastructure systems available in the region. This infrastructure includes utilities, such as suppliers of electricity, fuel, and water, as well as roads and railroads used to gain access to the sites.

#### *3.1.6.1 Electricity*

Nuclear power plants generate electricity for other users and they also use electricity to operate. The amount of electrical power needed to run a 1,000 MWe nuclear power plant is relatively small compared to the amount it generates. Nuclear power plants must have at least two connections to the electrical distribution system to receive power from offsite sources. One serves as a primary source for power and a separate one serves as a backup to run the engineered safety features and emergency equipment in case of a loss of the first source. Each power plant has backup sources (e.g., diesel generators) to supply power if the power plant loses both offsite sources. The backup generators are tested periodically and power the emergency systems automatically in case external sources of electrical power are interrupted.

#### *3.1.6.2 Fuel*

An operating 1,000 MWe PWR contains approximately 220,000 lb (100 metric tons [MT]) of nuclear fuel in the form of uranium dioxide ($UO_2$) at any one time. Only about one-third of that fuel is replaced during every refueling. Assuming that the reactor is refueled once every 18 months, the amount of nuclear fuel needed (and spent fuel generated) would be roughly 44,000 lb (20 MT) per year. Fresh fuel is brought to the site and stored at the site until it is needed.

In addition to nuclear fuel, a nuclear power plant needs a certain amount of diesel fuel to operate the emergency diesel power generators. To meet emergency demands, a certain quantity of diesel fuel is stored onsite in fuel storage tanks. Fuel is also needed for space heating, ventilation, and air conditioning (i.e., HVAC) purposes. Plants use a variety of energy sources for heating, ventilation, and air conditioning, including electricity, natural gas, or fuel oil. Some plants have waste oil incinerators onsite to burn their used oil. The heat generated by such an incinerator is used to heat buildings during winter.

#### *3.1.6.3 Water*

Systems designed to provide cooling water at nuclear power plants are described in Section 3.1.3. In addition to needing water for cooling, plants need water for sanitary reasons and for everyday use by the personnel (e.g., drinking, showering, cleaning, laundry, toilets, and eye washes). Because most nuclear power plants are located in more rural areas away from population centers, they are typically not connected to community (public) water systems and need to be self-sufficient in meeting their water needs. Many plants continue to rely on onsite groundwater (e.g., the Palo Verde Nuclear Generating Station [Palo Verde], Limerick Generating Station [Limerick], South Texas Project Electric Generating Station [South Texas], Byron Station [Byron], Braidwood Station [Braidwood], LaSalle County Station [LaSalle], Surry Power Station [Surry], North Anna Power Station [North Anna], and Point Beach Nuclear Plant [Point Beach]) and some on surface water bodies (e.g., nearby rivers and lakes) (e.g., the Columbia Generating Station [Columbia] and Peach Bottom plant) to obtain potable water. An increasing number of plants obtain potable water from public water systems (e.g., the Seabrook

Station [Seabrook], Enrico Fermi Atomic Power Plant [Fermi], Sequoyah Nuclear Plant [Sequoyah], Waterford Steam Electric Station [Waterford], River Bend Station [River Bend], and Turkey Point plants).

The quantity of water needed for cooling purposes was discussed in Section 3.1.3. The amount of water needed for sanitary reasons is generally much smaller than the amount needed for cooling. After use, the potable water is processed as part of the sanitary wastewater treatment system. As described in Section 3.11.4, sanitary waste is either treated onsite, collected in septic tanks and then shipped offsite to be treated at a local sewage treatment plant, or discharged directly to a publicly owned treatment system.

#### *3.1.6.4 Transportation Systems*

All nuclear power plants are served by controlled access roads. In addition to the roads, many of the plants also have railroad connections for moving heavy equipment and other materials. Some of the plants that are located on navigable waters, such as rivers, the Great Lakes, or oceans, have facilities to receive and ship loads on barges.

Trucks are the most common mode of transportation for delivering materials to and from the sites. Deliveries are accepted at and shipments are made from designated areas on the sites under controlled conditions and by following established procedures. Workers generally use their personal vehicles to commute to work. Visitors use passenger cars or light pickup trucks to get to and from the sites. Parking areas are available on every site for workers and visitors. There is also a network of roads and sidewalks for vehicles and pedestrians on each site.

#### *3.1.6.5 Power Transmission Systems*

Each nuclear power plant is connected to an independent regional electrical power distribution grid. Power transmission systems consist of switching stations (or substations) and the transmission lines that transfer electricity from the nuclear power plant to the regional grid (see Section 3.1.1). Switching stations transfer electrical power from generating sources to transmission lines and regulate the operation of the power system. Transformers in switching stations convert the generated voltage to levels appropriate for the transmission lines based on the rating of the lines. Equipment for regulating system operation includes switches, power circuit breakers, meters, relays, microwave communication equipment, capacitors, and a variety of other electrical equipment. This equipment meters and controls power flow; improves the performance characteristics of the generated power; and protects generating equipment from short circuits, lightning strikes, and switching surges that may occur along the transmission lines. At nuclear power plant sites, switching stations generally occupy areas two to four times as large as areas occupied by the reactor and generator buildings, but they are typically not as visible as other plant structures.

Only those transmission lines that connect the nuclear power plant to the first substation where electricity is fed into the regional electric distribution system and power lines that provide power to the plant from the grid are considered within the regulatory scope of initial LR or SLR.

The original final environmental statements for the construction and operation of nuclear power plants also evaluated the impacts of constructing and operating transmission lines needed to connect nuclear power plants to the regional electric grid. Since construction, many of these transmission lines have been incorporated into the regional grid. In many cases, these transmission lines are no longer owned or managed by NRC licensees and would remain energized regardless of nuclear power plant license renewal. These transmission lines are outside of the scope of this LR GEIS.

### 3.1.7 Nuclear Power Plant Operations and Maintenance

Nuclear power reactors are capable of generating electricity continuously for long periods of time. However, they do not operate at maximum capacity or continuously for the entire term of their license. Plants can typically operate continuously for periods of time ranging from 1 year to 2 years on a single fuel load.

Maintenance activities are routinely performed on systems and components to help ensure the safe and reliable operation of the plant. In addition, inspection, testing, and surveillance activities are conducted throughout the operational life of a nuclear power plant to maintain the current licensing basis of the plant and ensure compliance with Federal, State, and local requirements regarding the environment and public safety.

Nuclear power plants must periodically discontinue the production of electricity for refueling, periodic in-service inspection (ISI), and scheduled maintenance. Refueling cycles occur approximately every 12 to 24 months. The duration of a refueling outage is typically about 1 to 2 months. These enhanced inspections are performed to comply with NRC and/or industry standards or requirements, such as the American Society of Mechanical Engineers Boiler and Pressure Vessel Code. ISIs are generally scheduled and performed during 10-year intervals as follows: the initial period of operation (the first 40 years) includes the 1st through 4th intervals, an initial period of extended operation (years 40 through 60) would include the 5th and 6th intervals, and a subsequent period of extended operation (years 60 through 80) would include the 7th and 8th intervals, and are subject to the requirements of 10 CFR 50.55(a), "Codes and Standards." For economic reasons and component accessibility, many of these activities are conducted simultaneously (e.g., refueling activities typically coincide with the ISI and maintenance activities).

Many plants also undertake various major refurbishment activities during their operational lives. These activities are performed to ensure both that the plant can be operated safely and that the capacity and reliability of the plant remain at acceptable levels. Typical major refurbishments that have occurred in the past include replacing PWR steam generators, reactor vessel heads, BWR recirculation piping, and rebuilding main steam turbine stages. The need to perform major refurbishments is plant-specific and depends on factors such as design features, operational history, and construction and fabrication details. The plants may remain out of service for extended periods of time (e.g., several months) while these major refurbishments are made. Outage durations vary considerably, depending on factors such as the scope of the repairs or modifications undertaken, the effectiveness of the outage planning, and the availability of replacement parts and components.

Each nuclear power plant may be part of a regulated utility system that may own several nuclear power plants, fossil fuel-fired plants, or other means of generating electricity for sale in a regulated market. Other nuclear power plants may be non-utility or independent power generators operating to produce and sell electricity at competitive wholesale power rates. An onsite staff is responsible for the actual operation of each plant, and an offsite staff may be headquartered at the plant site or some other location. Typically, 800 to 2,300 people are employed at nuclear power plant sites during periods of normal operation, depending on the number of operating reactors located at a particular site. The permanent onsite workforce is usually in the range of 600 to 800 people per reactor unit. However, during outage periods, the onsite workforce typically increases by 200 to 900 additional workers. The additional workers include engineering support staff, technicians, specialty crafts persons, and laborers called in both to perform specialized repairs, maintenance, tests, and inspections, and to assist the permanent staff with the more routine activities carried out during plant outages.

## 3.2 Land Use and Visual Resources

### 3.2.1 Land Use

Nuclear power plants are located on land zoned for industrial use in large complexes and land area requirements generally are 100 to 125 ac (40 to 50 ha) for the reactor containment building, auxiliary buildings, cooling system structures, administration and training offices, and other facilities (e.g., switchyards, security facilities, and parking lots). Land areas disturbed during construction of the power plant generally have been returned to prior uses or were ecologically restored when construction ended. Land area ranges from 391 ac (158 ha) for the Catawba Nuclear Station (Catawba) in North Carolina to 14,000 ac (5,700 ha) for the Clinton Power Station (Clinton) in Illinois (Table 3.1-1). Almost 58 percent of nuclear power plants encompass 500 to 2,000 ac (200 to 800 ha); 18 nuclear plants range from 500 to 1,000 ac (200 to 400 ha); and an additional 14 encompass 1,000 to 2,000 ac (400 to 800 ha). Larger land areas are often associated with human-made closed-cycle cooling systems that include cooling lagoons, spray canals, reservoirs, artificial lakes, and buffer areas.

In addition to generating electricity, other land uses can be found. Some nuclear plant licensees lease land for agricultural and forestry production, nature centers and conservation areas, recreational use, and cemetery and historic site access. Nuclear plants also have land set aside for onsite spent fuel storage facilities.

Land cover and land use percentages at each nuclear power plant depend on the total area and amount of land required for electric power generation. Land cover is generally designated within the land use “resource-oriented” classification system, which includes urban or built-up land, agricultural land (e.g., cropland, pasture, orchards, nurseries, fields, and fallow lands), rangeland, forest land, water, wetland (e.g., marshes and swamps), and barren land (e.g., beaches and gravel pits). Land cover designations can also use visually descriptive categories that include open areas (e.g., fields, cemeteries), forested areas, scrub forest, deciduous forest, hardwood forest, beach, wetlands, open water (e.g., ponds, streams, lakes, and canals), natural lands, recreational lands, and parking areas.

Land use within transmission line right-of-ways (ROWs) is restricted under easement rights acquired from private landowners or from Federal, State, Tribal, and local governments. Land use within ROWs may differ from adjacent land use. Land within the ROW is managed through a variety of oversight and maintenance procedures so that vegetation growth and building construction do not interfere with power line operation, maintenance, and access. Land use within ROWs is limited to activities that do not endanger line operation and may include recreation, off-road vehicle use, grazing, agricultural cultivation, irrigation, recreation, roads, environmental conservation, and wildlife areas.

Land cover within a 5 mi (8 km) radius of operating U.S. nuclear power plants, using the National Land Cover Database (USGS 2019a) classifications, is presented in Table 3.2-1. Land cover types near each nuclear plant site are also presented in Appendix C.

Section 307(c)(3)(A) of the Coastal Zone Management Act of 1972 (16 U.S.C. § 1456 et seq.) requires that license renewal applicants certify that the proposed Federal license renewal in a coastal zone or coastal watershed boundary, as defined by each State participating in the National Coastal Zone Management Program, is consistent with the enforceable policies of that State's Coastal Zone Management Program. States define their coastal zone boundaries by using a variety of parameters, such as the entire State, county or county-equivalent boundaries, political features (e.g., town boundaries), and geographic features (adjacency to tidal waters). Applicants must coordinate with the State agency that manages the State Coastal Zone Management Program to obtain a determination that the proposed nuclear plant license renewal is consistent with their program.

**Table 3.2-1 Percent of Land Cover Types within a 5-Mile Radius of Nuclear Power Plants**

| Land Cover Classes | Overall (%) |
|---|---|
| **Open water (total)** | **23.5** |
| **Undeveloped land (total)** | **43.1** |
| Barren land | 0.3 |
| Forest (deciduous, evergreen, and mixed) | 23.5 |
| Wetlands | 10.9 |
| Herbaceous | 4.2 |
| Shrub/scrub | 4.2 |
| **Developed land (total)** | **33.4** |
| Agriculture (cultivated crops and hay/pasture) | 22.2 |
| Developed open space | 4.5 |
| Low to high intensity developed land | 6.7 |
| **Total** | **100** |

Sources: USGS 2019a; Pacific Northwest National Laboratory calculations.

### 3.2.2 Visual Resources

Nuclear power plants—particularly those with tall natural draft cooling towers—stand out from the natural background. Power plant structures can be seen from a distance and across a wide area. Cooling towers can also draw attention because of their vapor plumes. These plumes, seen under certain meteorological and seasonal conditions, can extend the viewshed considerably beyond that of the cooling tower and power plant alone. After cooling towers and the containment building, transmission line towers are probably the most frequently observed power plant structure. However, nuclear plant transmission lines are generally indistinguishable from those from other power plants. In addition, nuclear power plant structures are often obscured by topography, other buildings, and vegetation.

Most nuclear plants have employed a variety of mitigation measures to decrease the visual intrusion, including cladding and paint colors used to blend in with the surroundings, nonreflective surfaces, and the placement of trees and other landscaping. Federal regulations require that tall structures, including the reactor containment building, cooling towers, stacks, and meteorological towers, be fitted with lights to alert aircraft of their presence. Often these structures can be visible at night from miles away.

Because nuclear power plants are frequently located near water bodies, views of the industrial facility and transmission lines intrude into recreational, historic, or scenic areas. Most of the visual impacts from transmission lines are associated with river crossings, wetlands, wildlife sanctuaries, open parks and athletic fields, roads, lakes, cemeteries, and historic battlefields.

## 3.3 Meteorology, Air Quality, and Noise

### 3.3.1 Meteorology and Climatology

The NRC requires that basic meteorological information be available for use in assessing (1) the environmental effects of radiological and nonradiological emissions and effluents resulting from the construction or operation of a nuclear power plant and (2) the benefits of design alternatives. All nuclear power plants in the United States have a required onsite meteorological monitoring program to provide the data needed to determine dispersion conditions in the vicinity of the plant for assessment of safety and environmental factors. These data are used with air dispersion models to assess and protect public health, safety, and property during plant operations (NRC 2007e).

The most recent update to NRC Regulatory Guide 1.23, *Meteorological Monitoring Programs for Nuclear Power Plants, Revision 1* (NRC 2007e), which covers meteorological monitoring programs for nuclear power plants, provides guidance for onsite meteorological measurements at licensed power reactors. The guidance covers the siting of instruments to provide representative measures at plant sites, the accuracy and range of specified measured parameters, and special considerations for plants located near influences of complex terrain (e.g., coastal areas, hills of significant grade or valleys), among other criteria and specifications.

Onsite meteorological conditions at commercial nuclear power plants are monitored at primary fixed meteorological towers with instrumentation at two levels (e.g., 10 and 60 m) and, if necessary, one additional higher level on the tower to better represent dispersion of elevated releases from stacks. A secondary onsite tower is typical at many installations as a backup if primary tower measures fail. Basic meteorological measurements from tower instruments typically include the following: (1) wind speed and direction from at least two levels; (2) temperature for an ambient reading at 33 ft (10 m) and to determine deltas or changes with height; and (3) precipitation, which is typically measured near ground level by the tower base. Supplemental measurements can include moisture at 33 ft (10 m) and, if applicable, incoming solar and net radiation, barometric pressure, soil temperature, and moisture at the top of the cooling tower. Atmospheric stability is determined from temperature differences at the two lowest levels on the tower. If a backup tower is present, measurements include wind speed and direction and horizontal wind direction variation, usually taken at one level.

Weather conditions at each of the plants can be quite variable depending on the year, season, time of day, and site-specific conditions, such as whether the site is near coastal zones or located in or near terrain with complex features (e.g., steep slopes, ravines, valleys). These conditions can be generally described by climate zones according to average temperatures. On the basis of temperature alone, there are three major climate zones: polar, temperate, and tropical. Within each of the three major climate zones, there are marine and continental climates. Areas near an ocean or other large body of water have a marine climate. Areas located within a large landmass have a continental climate. Typically, areas with a marine climate receive more precipitation and have a more moderate climate. A continental climate has less precipitation and a greater range in climate. Regional or localized refinements in climate descriptions and assessments can be made by considering other important climate variables and climate-influencing geographic variables, such as precipitation, humidity, surface roughness, proximity to oceans or large lakes, soil moisture, albedo, snow cover, and associated linkages and feedback mechanisms. Localized microclimates can be defined by considering factors such as urban latent and sensible heat flux and building-generated turbulence. Both national and regional maximum and minimum average annual temperature and precipitation climatologies over the 30 years from 1991 through 2020 are summarized in Section D.2 in Appendix D.

The National Climatic Data Center records and archives the occurrence of storms and weather phenomena. The National Climatic Data Center documents this information in a database that dates back to January 1950 (NOAA 2022b). Severe weather events recorded include floods, thunderstorms, hurricanes, and tornadoes. Table 3.3-1 provides the current enhanced Fujita (EF) scale next to the original Fujita (F) scale, adjusted to represent peak winds averaged over 3 seconds, which are used to identify a tornado event's intensity. The EF scale (WSEC 2006) is based on the highest wind speed estimated in the tornado path with maximum 3-second average wind gusts within the range specified for each EF intensity level. The range in damage to structures in the EF2 through EF5 range is described as considerable to incredible, and the damage depends highly on the building's structural design.

**Table 3.3-1 Fujita Tornado Intensity Scale**

| Intensity | Description of Damage | Original Fujita Scale (3-s gust) (mph) | Operational Enhanced Fujita Scale (3-s gust) (mph) |
|---|---|---|---|
| F0/EF0 | Light | 45 to 78 | 65 to 85 |
| F1/EF1 | Moderate | 79 to 117 | 86 to 110 |
| F2/EF2 | Considerable | 118 to 161 | 111 to 135 |
| F3/EF3 | Severe | 162 to 209 | 136 to 165 |
| F4/EF4 | Devastating | 210 to 261 | 166 to 200 |
| F5/EF5 | Incredible | 262 to 317 | >200 |

F = Fujita scale; EF = enhanced Fujita scale; mph = miles per hour; s = second.
Source: WSEC 2006.

### 3.3.2 Air Quality

Air emissions related to criteria air pollutants and volatile organic compounds (VOCs) (a precursor of ozone) are released to the atmosphere from ancillary non-nuclear facilities at nuclear power plants. These emissions include criteria air pollutants such as particulate matter (PM) with a mean aerodynamic diameter of 10 μm or less ($PM_{10}$), PM with a mean aerodynamic diameter of 2.5 μm or less ($PM_{2.5}$), sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$),[1] carbon monoxide (CO), and lead, and VOCs.

The EPA has set National Ambient Air Quality Standards (NAAQS) for six criteria pollutants, including $SO_2$, nitrogen dioxide ($NO_2$), CO, ozone, $PM_{10}$, $PM_{2.5}$, and lead, as shown in Table 3.3-2. Primary NAAQS specify maximum ambient (outdoor air) concentration levels of the criteria pollutants with the aim of protecting public health. Secondary NAAQS specify maximum concentration levels with the aim of protecting public welfare. The NAAQS specify different averaging times as well as maximum concentrations. Some of the NAAQS for

[1] NOx is not a criteria pollutant, but emissions are typically reported in terms of NOx. Nitrogen dioxide ($NO_2$) is the component of NOx that is a criteria pollutant, but emissions of $NO_2$ are not typically reported.

averaging times of 24 hours or less allow the standard values to be exceeded a limited number of times per year, and others specify other procedures for determining compliance. States can have their own State Ambient Air Quality Standards. State Ambient Air Quality Standards must be at least as stringent as the NAAQS and can include standards for additional pollutants. If a State has no standard corresponding to one of the NAAQS, the NAAQS apply.

An area where criteria air pollutants exceed NAAQS levels is called a nonattainment area. Previous nonattainment areas where air quality has improved to meet the NAAQS are redesignated maintenance areas and are subject to an air quality maintenance plan.

The currently designated nonattainment areas (as of February 2020)[1] for each criteria air pollutant (8-hour ozone, $PM_{10}$, $PM_{2.5}$, $SO_2$, $NO_2$, CO, and lead) and their relative locations with respect to operating nuclear power plants are shown on the map in Figure 3.3-1. There are currently more than 30 operating plants located within or adjacent to counties with designated nonattainment areas. There are no nonattainment areas designated for CO or $NO_2$.

**Table 3.3-2 National Ambient Air Quality Standards for Six Criteria Pollutants[(a)]**

| Pollutant | Averaging Time | NAAQS Value[(b)] | NAAQS Type[(c)] |
|---|---|---|---|
| $SO_2$ | 1-hour | 75 ppb | P |
| $SO_2$ | 3-hour | 0.5 ppm | S |
| $NO_2$ | 1-hour | 100 ppb | P |
| $NO_2$ | Annual | 0.053 ppm (53 ppb) | P, S |
| CO | 1-hour | 35 ppm | P |
| CO | 8-hour | 9 ppm | P |
| $O_3$ | 8-hour | 0.070 ppm | P, S |
| $PM_{10}$ | 24-hour | 150 $\mu g/m^3$ | P, S |
| $PM_{2.5}$ | 24-hour | 35 $\mu g/m^3$ | P, S |
| $PM_{2.5}$ | Annual | 15 $\mu g/m^3$ | S |
| $PM_{2.5}$ | Annual | 12 $\mu g/m^3$ | P |
| Pb | Rolling 3-month | 0.15 $\mu g/m^3$ | P, S |

(a) CO = carbon monoxide; NAAQS = National Ambient Air Quality Standards; $NO_2$ = nitrogen dioxide; $O_3$ = ozone; Pb =lead; $PM_{2.5}$ = particulate matter ≤ 2.5 μm; $PM_{10}$ = particulate matter ≤ 10 μm; and $SO_2$ = sulfur dioxide.
(b) Refer to 40 CFR Part 50 or EPA 2022f for detailed information about attainment determination and reference method for monitoring.
(c) P = Primary standard whose limits were set to protect public health; S = secondary standard whose limits were set to protect public welfare.
Source: EPA 2022f.

[1] Nonattainment area designations are ever-changing and redesignations may occur due to EPA's revisions for $PM_{10}$ and $PM_{2.5}$ (effective March 18, 2013), 8-hour ozone (effective October 26, 2015), Pb (effective January 12, 2009),1-hour $SO_2$ (effective August 23, 2010), and 1-hour $NO_2$ (effective April 12, 2010). Please refer to the latest EPA Green Book for the most updated nonattainment and maintenance area designations (Available URL: http://www.epa.gov//green-book/).

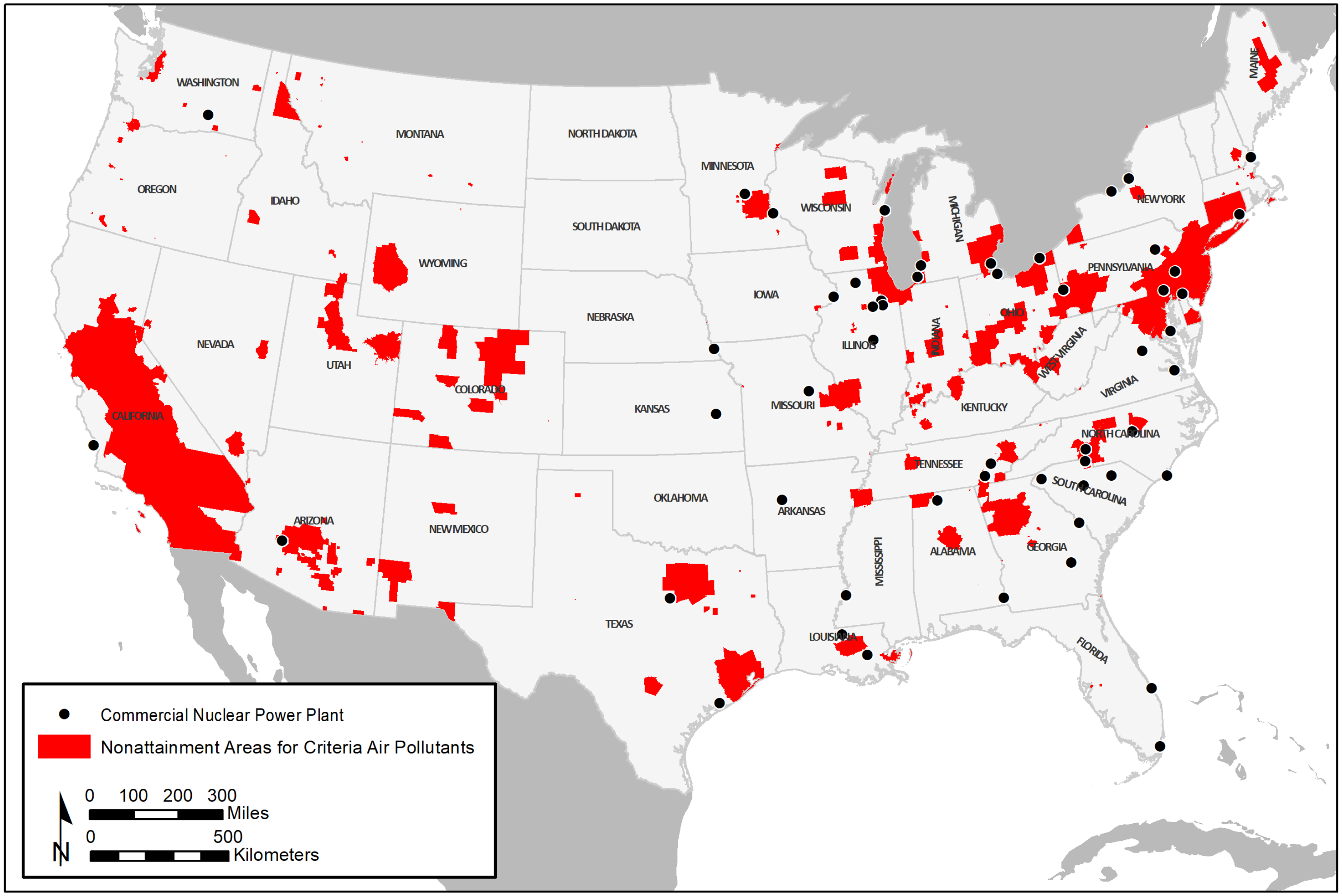



**Figure 3.3-1 Locations of Operating Nuclear Plants Relative to EPA-Nonattainment Areas, as of August 30, 2011. Adapted from EPA 2022e. Revoked 1-hour (1979) and 8-hour (1997) ozone are excluded.**

Sources at nuclear power plants that contribute to criteria air pollutants include backup diesel generators, boilers, fire pump engines, and cooling towers. The emissions from these sources (and, if applicable, emissions from the incineration of any waste products) must comply with State and local regulatory air quality permitting requirements. Because nuclear power plant ancillary facilities are generally low emitters of criteria air pollutants and VOCs, the impact on potential ambient air quality is minimal. However, special permit conditions may be applicable under various regulatory jurisdictions for facilities located in EPA designated nonattainment areas.

The operation of wet cooling towers results in the emission of salt and other inorganic and/or organic particles to the air. These releases are called drift emissions. Salt is the dominant drift component—being typically greater than 70 percent of the total suspended PM released—for coastal nuclear plants with wet towers that use seawater as the coolant. Drift emissions from cooling towers are also associated with deposits on downwind surfaces (e.g., vegetation, automobiles, and structures), known as drift deposition, and a resulting increase in downwind PM concentrations. The magnitude and pattern of these impacts could include both near-field and far-field receptors. The degree of impacts would depend on a number of factors, such as the size of the particles, the steam condenser flow rate or throughput, and the type and height of the cooling tower.

Cooling tower particulate emissions are formed entirely as secondary particles from evaporation of wet tower drift droplet releases to the atmosphere. Because the drift droplets generally contain the same chemical impurities (primarily dissolved solids) as those in the cooling water circulating through the tower, these impurities wind up in the drift that escapes the tower. Large drift droplets settle out of the tower's exhaust air stream and are deposited on surfaces near the tower. This process can lead to wetting, icing, and salt deposition and can cause related problems, such as damage to equipment or vegetation. Other drift droplets may evaporate and form mixed chemical particles from water-soluble materials (total dissolved solids or TDS), such as sea salt, and water-insoluble (total suspended solids) droplet-encapsulated particles (Pruppacher and Klett 1980) that are transported in the air as suspended PM before being deposited on surfaces downwind. Both $PM_{10}$ and $PM_{2.5}$ are generated when the drift droplets evaporate and leave fine PM formed by the crystallization of dissolved solids. Dissolved solids found in cooling tower drift can consist of salt compounds (e.g., sodium chloride, sodium nitrate, ammonium sulfate [$(NH_4)_2SO_4$] and other mineral matter, corrosion inhibitors, and biocides.

The magnitude of drift-related $PM_{10}$ and $PM_{2.5}$ emissions from wet towers depends on several conditions and parameters, such as the makeup water composition, concentrations of TDS (organic matter, biocides, corrosion inhibitors, sodium chloride), steam condenser flow rate, drift eliminator efficiency, number of cooling towers/cells, and annual hours of operation. In comparison, drift emissions from cooling tower systems using seawater are over 7 times greater than those from systems supplied with freshwater makeup feeds, if everything else is held constant. The Palo Verde plant in Arizona uses makeup water derived from the Phoenix City Sewage Treatment Plant. The associated drift emissions from the six mechanical draft cooling towers at the Palo Verde plant in 2017 were less than 32 and 20 tons for $PM_{10}$ and $PM_{2.5}$, respectively (MCAQD 2019). These emissions are relatively small and typical for a well-controlled cooling tower using a water supply with low TDS concentration levels. Palo Verde's air permit issued by the Maricopa County Air Quality Department requires that TDS concentration for each cooling tower be limited to 30,000 ppm (MCAQD 2010).

There is only one plant, Hope Creek Generating Station (Hope Creek) in New Jersey, that uses high-salinity water (from the Delaware River Estuary) as the reactor coolant in a natural draft cooling tower. An analysis of drift emissions and air impacts from Hope Creek's natural draft cooling tower was assessed with air quality modeling conducted in support of an extended power uprate from about 3,300 to about 3,800 megawatts-thermal (MWt) (NRC 2008b). The analysis showed that the uprate would increase the particulate cooling tower drift emissions from the current rate of 29.4 lb/hr (13.3 kg/hr) to an average rate of 35.6 lb/hr (16.1 kg/hr, with a maximum of 42.0 lb/hr [19.1 kg/hr]). Particulates (primarily salts) from the cooling tower are primarily $PM_{10}$. Although smaller suspended drift particles would also likely be generated from evaporation of cooling tower plume droplets, estimates of the size distribution of generated drift particles to determine the $PM_{2.5}$ fraction were not made. The NRC staff determined that the estimated increase in particulate emissions would exceed the New Jersey Department of Environmental Protection's (NJDEP's) regulatory maximum hourly emission limit of 30 lb/hr (13.6 kg/hr) for particulates (NJ Admin. Code 7:27-6). However, the NJDEP's Bureau of Technical Services reviewed the air quality modeling conducted in support of the proposed power uprate and determined that the cooling tower emissions would not exceed the NAAQS for $PM_{10}$ or New Jersey's Ambient Air Quality Standards for $PM_{10}$. On the basis of this determination, the NRC staff concluded that there would be no significant particulate emission impacts associated with the Hope Creek plant's cooling tower at the associated higher makeup water throughput necessary to sustain the higher requested plant operating loads (NRC 2008b). On June 13, 2007, NJDEP issued its final Title V air permit for the Hope Creek cooling tower, authorizing a variance to the plant's air operating permit with an hourly emission rate of 42 lb/hr (19.1 kg/hr) (State of New Jersey 2021). In addition, a prevention of significant deterioration (i.e., PSD) applicability determination by the EPA concluded that the requested power uprate would not result in a significant increase in emissions and would not be subject to prevention of significant deterioration review (State of New Jersey 2021). Further regulatory review was not required since the Hope Creek plant is located in an attainment area for $PM_{10}$.

Transmission lines have been associated with the production of minute amounts of ozone and $NO_x$. These pollutants are associated with corona—the breakdown of air that is very near high-voltage conductors. Corona is a phenomenon associated with all energized transmission lines. Under certain conditions, the localized electric field near an energized conductor can be sufficiently concentrated to produce a tiny electric discharge that can ionize air close to the conductors (EPRI 1982). This partial discharge of electrical energy is called corona discharge, or corona. Corona is most noticeable for higher-voltage lines during rain or fog conditions. In addition to the small quantities of ozone and $NO_x$ that form, other manifestations of corona events include energy loss, interference with radio or television transmission, and ambient noise (see Section 3.3.3). Typically, corona interference with radio and television reception is not a design problem. Interference levels in both fair and rainy weather are extremely low at the ROW edge for 230-kV and lower transmission lines, and they usually meet or exceed the reception guidelines of the Federal Communications Commission. As discussed in the 2013 LR GEIS, through the years, line designs that greatly reduce corona effects have been developed. Because transmission line emissions associated with corona discharge are so small when compared with emissions from other sources of air pollution (e.g., ozone precursors from automobiles, power plants, and large industrial boilers), these emissions are not a regulated source of air pollution in the United States.

Airborne radiological releases during normal plant operation and associated doses to downwind populations are discussed in Section 3.9.

### 3.3.3 Noise

Noise is unwanted sound that can be generated by many sources. Sound intensity is measured in logarithmic units called decibels (dB). A dB is the ratio of the measured sound pressure level to a reference level equal to a normal person's threshold of hearing. Another characteristic of sound is frequency or pitch. Noise may be comprised of many frequencies, but the human ear does not hear very low or very high frequencies. To represent noise as closely as possible to the noise levels people experience, sounds are measured using a frequency-weighting scheme known as the A-scale. Sound levels measured on this A-scale are given in units of A-weighted decibels (dBA). Levels can become very annoying at 85 dBA. To the human ear, an increase of 3 dBA is barely noticeable and an increase of 10 dBA sounds twice as loud (EPA 1981).

Several different terms are commonly used to describe sounds that vary in intensity over time. The equivalent sound intensity level represents the average sound intensity level over a specified interval, often 1 hour. The day-night sound intensity level is a single value calculated from hourly equivalent sound intensity level over a 24-hour period, with the addition of 10 dBA to sound levels from 10 p.m. to 7 a.m. This addition accounts for the greater sensitivity of most people to nighttime noise. Statistical sound level (Ln) is the sound level that is exceeded 'n' percent of the time during a given period. For example, L90, is the sound level exceeded 90 percent of the time and is considered the background level.

The principal sources of noise from nuclear power plant operations are natural draft and mechanical draft cooling towers, transmission lines, and transformers. Other occasional and intermittent noise sources may include auxiliary equipment (such as pumps to supply cooling water), mainsteam safety valves, corona discharge, firing range, and loudspeakers. In most cases, the sources of noise are far enough away from sensitive receptors outside plant boundaries that the noise is attenuated to nearly ambient levels and is scarcely noticeable.

There are no Federal regulations for public exposures to noise. When noise levels are below the levels that result in hearing loss, impacts have been judged primarily in terms of adverse public reactions to noise. The Department of Housing and Urban Development (24 CFR 51.101(a)(8)) uses day-night average sound levels of 55 dBA, recommended by EPA as guidelines or goals for outdoors in residential areas (EPA 1974). However, noise levels are considered acceptable if the day-night average sound level outside a residence is less than 65 dBA.

Natural draft and mechanical draft cooling towers emit noise of a broadband nature. Cooling tower noise is generated by fan equipment or falling water. At 164 ft (50 m) distance, noise level for a mechanical draft cooling tower can reach 60 dBA and at 230 ft (70 m) distance the noise level for a natural draft cooling tower can reach 66 dBA (Tetra Tech 2010; Neller and Snow 2003).

Transformers emit a humming noise of a specific tonal nature at twice the normal voltage or current cycle (core expansion and contraction twice its 60 hertz [Hz] cycle) with a vibration or noise harmonic of 120 Hz. This is called the fundamental noise frequency. Transformer noise originates almost entirely in the core as a result of the restrictive effects of steel on the generated magnetic field, a phenomenon called magnetostriction, which causes the core and its clamps to vibrate (Ellingson 1979). Since the core is not symmetrical and the magnetic effects do not behave in a simple way, the resultant noise is not pure in tone. This is the noise or vibration produced. The noise radiated by transformers is primarily composed of discrete tones at even harmonics of line frequency (e.g., 120, 240, 360 Hz) when the line frequency is 60 Hz

(Vér and Beranek 2005). Transformer noise is distinct because of its specific low frequencies. The low frequencies are not attenuated with distance and intervening materials as much as higher frequencies are; thus, low frequencies are more noticeable and obtrusive. However, at most sites employing cooling towers, transformer noise is masked by the broadband cooling tower noise. Sound levels from transformers varies depending on the capacity rating.

Transmission lines can generate a small amount of sound energy during corona activity. During corona events (see Section 3.3.2), the ionization of the air that surrounds conductors of the high-voltage transmission lines, which is caused by electrostatic fields in these lines, generates impulse corona currents. When the voltage on a particular phase is high enough, a corona burst occurs, and a noise is generated. This noise occurs primarily on the positive power line voltage wave and is referred to as positive corona noise (Maruvada 2000).

Although conductors are designed to minimize corona discharges, surface irregularities caused by damage, insects, raindrops, or contamination may locally enhance the electric field strength enough for corona discharges to occur (Cristina et al. 1985). This audible noise from the line can barely be heard in fair weather on higher-voltage lines. During wet weather, water drops collect on the conductor and increase corona activity so that a crackling or humming sound may be heard near the line. This noise is caused by small electrical discharges from the water drops. Measurements from a 765 kV transmission line during rain events found that the average sound levels at 50 ft (15 m) from the transmission line were 54.6 dBA, with sound levels as high as 64 dBA measured (Popeck and Knapp 1981).

Cooling tower and transformer noise from existing equipment does not change appreciably during the time when the plant is operating, nor does the crackling sound of transmission lines during storms. Increases or decreases in site noise levels can occur when equipment is upgraded or modified to meet life-cycle maintenance requirements or when the power level is uprated.

## 3.4 Geologic Environment

The geologic environment of a nuclear power plant site encompasses the physiographic or physical setting in which the plant has been constructed and the associated geologic strata and soils that comprise the site. Large-scale geologic hazards are a condition of the geologic environment and include geologic faulting and earthquakes that comprise a site's seismic setting.

Nuclear power plants are located in a variety of physiographic provinces, though most nuclear plants are located in the Atlantic Coastal Plain and Central Lowlands provinces. Each physiographic province consists of a regional geologic terrain with a broadly similar structure and character. However, within each province, the local geology may differ significantly from the regional conditions. The geologic setting of each nuclear plant is therefore more a reflection of the local geology rather than the physiographic province in which it is located. Nuclear power plants are located in a wide variety of settings, including uplands along rivers, glaciated till plains, Great Lakes shorelines, and coastal sites. As a result, the geologic strata on which plants have been sited and constructed range from variably textured, interbedded, unconsolidated to semi-consolidated sediments of relatively recent age (i.e., less than 11,700 years before present), to thick sequences of sedimentary rock (e.g., sandstone, shale, siltstone) of varying age, to massive crystalline igneous and metamorphic rocks (e.g., granitic and gneissic rocks) as old as Precambrian (i.e., greater than 540 million years before present). All safety-related structures (e.g., seismic Category 1 structures) at nuclear power plants are founded either on competent bedrock, engineered compacted strata, concrete fill, and/or structural backfill in order to make sure that no safety-related facilities are constructed in potentially unstable materials.

Soils across a plant site come from the disintegration of parent materials (i.e., bedrock or sediments) and interaction with the atmosphere and biological action, and can develop distinct horizons or layers with varying properties and uses. Soils and subsoils at nuclear plant sites vary in terms of the geotechnical properties relevant to site construction (e.g., shear-strength, shrink-swell potential, cut-slope stability, and erodibility) and the hydraulic properties related to the infiltration of water at the soil surface, the occurrence of groundwater, and the movement of contaminants. Depending on the nuclear plant's location and design, riverbanks or coastlines may need to be protected to prevent erosion, especially at water intake or discharge structures.

The soil resources available at each nuclear power plant are site-specific in terms of their potential erodibility and their potential use for agricultural activities and vary spatially on the basis of the distribution of different soil types on the site. Many of the nuclear plants in the Midwest, Great Plains, East, and Southeast (with the exception of plants in Florida) are located in areas with soils that are designated as prime farmland (see Figure 3.4-1). Prime farmland soil has the best combination of physical and chemical characteristics for growing crops and is potentially subject to the Farmland Protection Policy Act of 1981 (FPPA; 7 U.S.C. § 4201 et seq.) and its implementing regulations (7 CFR Part 657, 7 CFR Part 658). Other important farmland soils potentially subject to the FPPA include unique farmlands as well as farmlands designated as having statewide or local importance. Farmland subject to FPPA regulation does not have to be currently used for cropland. It can be forest land, pastureland, cropland, or other land, but not water or urban built-up land. Nuclear plants in Florida and in Western States are generally not located near prime or other important farmland. At some nuclear plant sites (e.g., Cooper Nuclear Station [Cooper] and Shearon Harris Nuclear Power Plant [Harris]), undeveloped or restored portions of the nuclear plant site have been leased for agricultural use including timber production. However, some land areas on plant sites may not be available for leasing if they are within a nuclear plant's security zone. Soil survey maps and data are available for most locations in the United States from the U.S. Department of Agriculture Natural Resources Conservation Service (USDA 2019).

The geologic resources in the vicinity of each nuclear plant, including rock, mineral, or energy rights and assets, vary with the location and may support extraction industries. These industries may include sand and gravel pit operations or quarrying for crushed stone. In general, there is little if any interaction between plant operations and local extraction industries, although some nuclear plants may purchase materials for landscaping and site construction from local sources. Commercial mining, quarrying, or drilling operations are not allowed within nuclear power plant site boundaries.

Another aspect of the geologic environment is the seismic setting. The NRC has well established design criteria and standards that are used as the basis for the construction of all commercial nuclear power plants in the United States. These include ensuring the ability to withstand environmental hazards, such as earthquakes and flooding, without loss of capacity to perform their safety functions. Specifically, the NRC requires that safety-related structures, systems, and components be designed to take into account the most severe natural phenomena historically reported for the site and surrounding area. With regard to earthquakes in particular, existing U.S. nuclear power plants were designed and built to withstand the ground-shaking level considered appropriate for the location, given the possible earthquake sources that may affect the site.

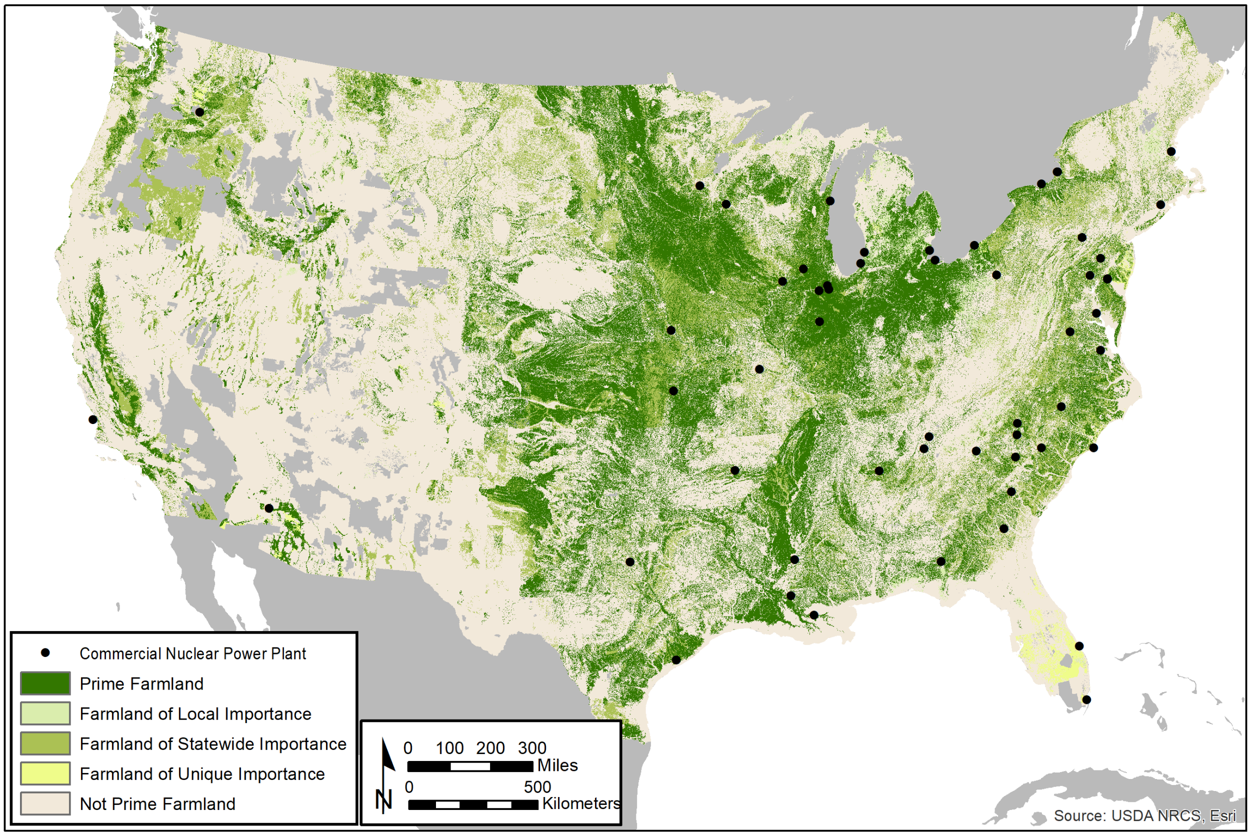



**Figure 3.4-1 Occurrence of Prime Farmland and Other Farmland of Importance, with Nuclear Power Plant Locations Shown. Source: USDA 2021.**

U.S. nuclear power plants were originally sited using geologic and seismic criteria set forth in 10 CFR 100.10(c)(1) and 10 CFR Part 100, Appendix A and, where applicable, designed and constructed in accordance with 10 CFR Part 50, Appendix A. The regulations require that plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena, including earthquakes and other natural phenomena, without loss of capability to perform safety functions. Plant-specific design bases for seismic protection are prescribed by a nuclear power plant's final safety analysis report/updated final safety analysis report and by applicable technical specifications. Detailed investigations of the proposed site and regional geologic environment are required to include an analysis of all historic earthquakes with the potential to affect the nuclear power plant site and power plant operations. Locations for nuclear power plants are also evaluated and characterized for the presence of geologic faults including those considered to be capable of generating earthquakes, predicted earthquake ground motions in order to establish the plant's safe shutdown earthquake, the potential for the nuclear plant to be exposed to seismically induced floods and water waves, and for the nature and behavior of the surficial geologic materials and subsurface materials and their engineering properties. In addition, spent fuel pools are designed with reinforced concrete so that they may remain operable through the largest historic earthquake that has or is expected to occur in the area.

The U.S. Geological Survey regularly updates its seismic hazard mapping products for the United States (see, for example, Rukstales and Petersen 2019; Petersen et al. 2020). Based on the 2018 seismic hazard maps, and as measured in terms of predicted earthquake-produced peak horizontal ground accelerations with a 2 percent probability of exceedance in 50 years (i.e., corresponding to a return time of about 2,500 years), most nuclear power plants are located in areas with peak horizontal acceleration less than 30 percent of gravity (0.3 g) (see Figure 3.4-2). Peak horizontal accelerations are related to earthquake intensity and the magnitude of shaking (Worden et al. 2020). Plants subject to a peak horizontal acceleration of 0.3 g could experience very strong shaking equivalent to Modified Mercalli Intensity VI, which indicates damage to buildings of good design would be expected to be negligible (Petersen et al. 2020; USGS 2021). In California, one operating nuclear power plant, Diablo Canyon Power Plant (Diablo Canyon), and one plant undergoing decommissioning (San Onofre, shut down in 2012) are in locations with predicted peak ground accelerations greater than 40 percent of gravity based on the 2018 seismic hazard map. Nuclear power plants, including Diablo Canyon, were designed to safely withstand the seismic hazards associated with earthquakes with epicenters at various locations and at various depths, magnitudes, and ground accelerations (AEC 1973; NRC 2020d).

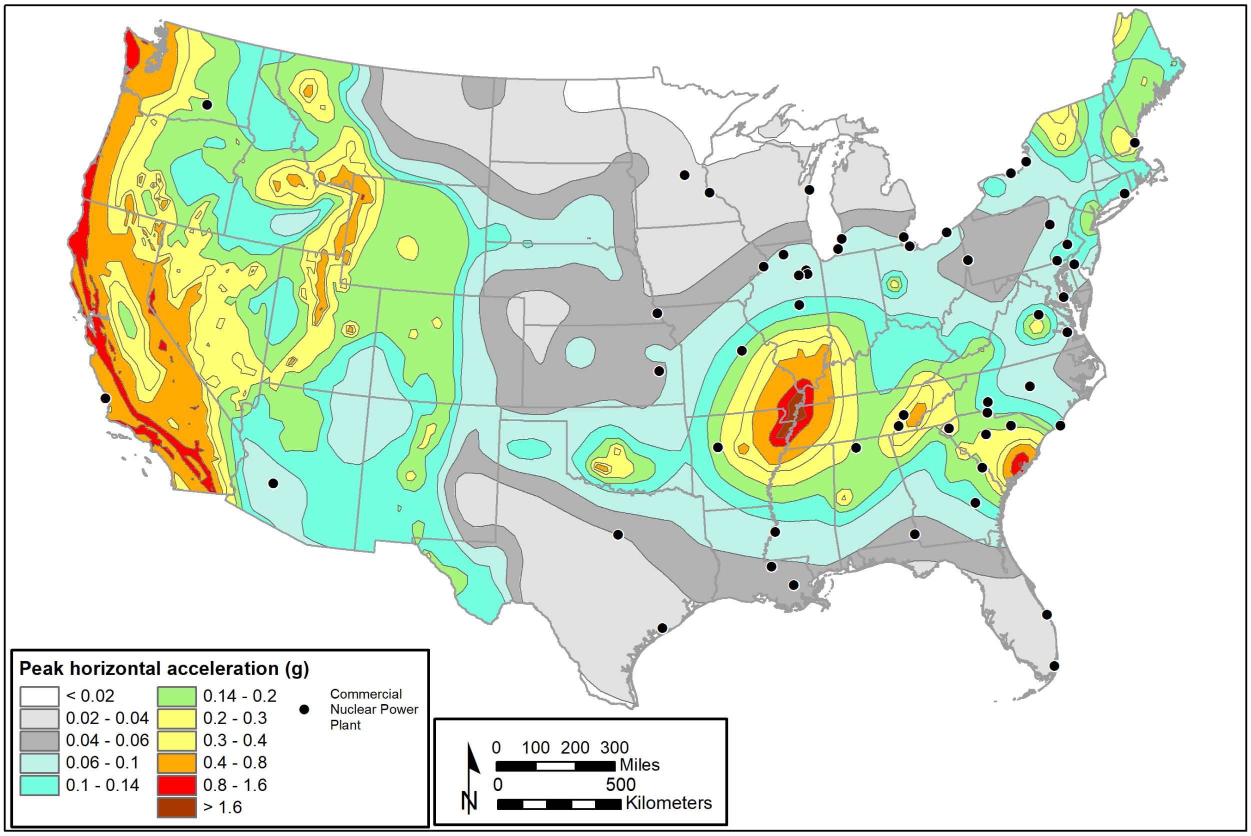



**Figure 3.4-2 2018 National Seismic Hazard Model Peak Horizontal Acceleration with a 2 Percent Probability of Exceedance in 50 Years (Site Class B/C) with Nuclear Power Plant Locations Shown. Seismic map source: Rukstales and Petersen 2019.**

The state of knowledge regarding geologic conditions and seismology and seismic hazards at a specific nuclear power plant site may have changed since construction. Although such discoveries are expected to be rare, new seismological conditions include the identification of previously unknown geologic faults. For example, a strike-slip fault was discovered approximately 1 km (0.6 mi) offshore of the Diablo Canyon Power Plant in 2009 (NRC 2009f). Moreover, the 2011 Tohoku earthquake and the resulting accident at the Fukushima Dai-ichi Nuclear Power Plant in Japan prompted a reevaluation of seismic hazards at U.S. nuclear power plants using present-day NRC requirements and guidance (NRC 2021q).

Changes in potential seismic hazards are not within the scope of the NRC's license renewal environmental review, except, where appropriate, during the analysis of severe accident mitigation alternatives, because any such changes would not be the result of continued operation of the nuclear power plant. Seismic design issues are considered during plant-specific safety reviews and, more specifically, are addressed on an ongoing basis through the reactor oversight process and other NRC safety programs, such as the Generic Issues Program, which are separate from the license renewal process. When new seismic hazard information becomes available, the NRC evaluates the new information, through the appropriate program, to determine if any changes are needed at one or more existing nuclear plants.

## 3.5 Water Resources

Water resources comprise all forms of surface water and groundwater occurring in the vicinity of nuclear power plants. Surface water encompasses all water bodies that occur above the ground surface, including rivers, streams, lakes, ponds, and other features, such as human-made reservoirs or other impoundments. Groundwater is water that is below the ground surface within a zone of saturation, with the uppermost groundwater surface comprising the water table. Groundwater comprises water that originated naturally as recharge from precipitation (e.g., rain or the melting of snow, sleet, or hail) or artificially as recharge from activities such as irrigation, industrial processing, and wastewater disposal. Groundwater returns to the surface through discharge to springs and baseflow into rivers and streams, evaporation from shallow water table areas, or human activity involving wells or excavations. Aquifers are subsurface formations capable of yielding a significant amount of groundwater to wells or springs. Lesser amounts of groundwater may also occur in areas above the saturated zone in the form of relatively small and isolated lenses of groundwater known as "perched" groundwater.

Potential water uses, from either surface water or groundwater sources, include uses for drinking and sanitary purposes, irrigation, maintenance of terrestrial and aquatic resources, recreation, and, of critical importance to all nuclear plants, industrial cooling and other applications. Demands for water are not restricted to freshwater (i.e., generally water with a TDS level of less than 1,000 mg/L), but can also be met, for certain uses, by brackish (i.e., TDS level of about 1,000 to 35,000 mg/L) and saltwater (saline) sources, including for industrial cooling applications. As such, nuclear power plants are located in a range of settings with respect to water resources availability. Specifically, 11 of the 55 currently licensed nuclear power plants are located in estuarine or coastal areas, 9 plants are located on or near the Great Lakes, and 35 plants are located on rivers and/or with associated impoundments (e.g., reservoirs) (see also Table 3.1-2 through Table 3.1-4 and Section 3.5.1.1).

Earth's water is always in movement, and the natural water cycle, also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the surface of the Earth. It is the movement of water from surface water, groundwater, and vegetation to the atmosphere and back to the Earth in the form of precipitation. Natural waters are normally replenished by precipitation. However, the availability of water resources is being reduced and their distribution is changing due to human activity and natural forces. This is further aggravated by global climate change and variations in natural conditions. Impacts within the hydrologic cycle can be observed in precipitation patterns, infiltration to groundwater, surface runoff, stream flow, and other natural features.

The water quality of surface water bodies and groundwater in the vicinity of and within the watersheds where nuclear power plant sites are located is influenced by a wide range of activities that are often unrelated to and far removed from plant operations. Urbanization and development increase the amount of impervious surface coverage, such as roads and sidewalks, and reduce the natural terrain and pervious surfaces, including woodlands, meadow, and prairie lands. These alterations result in higher runoff velocities while reducing or eliminating the ability for infiltration, which also reduces groundwater recharge. Pervious areas associated with urbanization and development, such as landscape and recreational areas, contribute to increased surface runoff because they are typically uniformly graded and sparsely vegetated. Increased runoff is also thermally warmer than precipitation falling on natural terrain, and can carry pollutants entrained from sources of contamination on the land surface and that may have otherwise been filtered through natural processes. As a result, changes in surface runoff velocities and volumes have the potential to result in surface water quality impacts, including changes in the chemical and thermal characteristics of the receiving waters. Additionally, increases in runoff lead to streamside erosion, loss of topsoil, and other hydrologic changes leading to increased flooding potential of downstream areas. These changes can occur in some watersheds despite design guidelines and regulations implemented by local, State, and Federal agencies to manage runoff rates associated with development.

Typical pollutants carried in stormwater runoff include sediment, nutrients, debris, bacteria, and common hazardous substances (e.g., fertilizers, pesticides, and petroleum products). Nutrient additions, whether from fertilizer additions to landscaped lawns in urban and suburban areas or from croplands in agricultural areas, add to the pollutant loading and can have negative effects on water quality, terrestrial communities, and aquatic life (see Section 3.6). Atmospheric deposition of pollutants is also a substantial contributor to water quality degradation in “downwind” regions and particularly in urbanized areas. Nuclear power plant operations can contribute to water quality and hydrologic changes by increasing stormwater runoff, adding to nutrient discharges from sewage treatment, and through effluent discharges from industrial cooling systems. The additional runoff volume results in a total increase in deposited pollutants from impervious surfaces and industrial yards. Cooling system discharges typically contain cooling water treatment chemicals (e.g., corrosion inhibitors and biocides) (see also Section 3.5.1.2). Such chemical constituents, when released to receiving water bodies, have the potential to affect aquatic organisms. Thermal pollution is an additional pollutant that warms a receiving water body through both stormwater runoff and industrial cooling discharges. Within a watershed, these conditions are exacerbated by basinwide deforestation and stripping of streamside vegetation in urban, suburban, and even in agricultural areas.

The collection of these pollutants from all sources in receiving waters can result in waters that are unable to meet the water quality standards and desired uses set by States, territories, or authorized Indian Tribes. The water bodies that do not meet the standard are included in the Clean Water Act (CWA) 303(d) list as impaired water bodies and require additional monitoring and more stringent effluent limits being imposed on industrial and other dischargers under Section 303(d). Each State is required to submit their impaired and threatened waters list (i.e., 303(d) list) for EPA approval every 2 years (EPA 2021c). For each water on the list, the State identifies the pollutant causing the impairment, when known. Based on the NRC’s license renewal environmental reviews performed since 2013, the range of pollutants identified as contributing to impairment of adjoining surface waters have included pathogens (e.g., coliform bacteria), sediment, various nutrients (e.g., phosphorus), polychlorinated biphenyls, and mercury contamination, none of which were attributable to nuclear power plant operations.

Finally, groundwater quality, whether in shallow, unconfined aquifers comprised of unconsolidated sediments or bedrock aquifers, may be affected by many of the sources previously described. Fertilizers, chemicals, and petroleum products can degrade groundwater quality by infiltration into soil, subsoils, and the water table. Subsurface sources of pollution may be from broken sewage pipelines, stormwater and/or combined sanitary sewers, as well as cracks in or failures of underground storage tanks. At nuclear power plant sites, groundwater quality has been affected by inadvertent releases of radionuclides, predominately tritium, from plant systems. Spills and leaks of petroleum products from industrial facilities (including nuclear facilities) also affect groundwater.

Within the context of the information discussed above, the following sections discuss the effects of past and current nuclear power plant operations on water resources, including relevant regulatory considerations.

### 3.5.1 Surface Water Resources

The dominant water requirement at most nuclear power plants is cooling water, which, in most cases, is obtained from surface water bodies. For this reason, most plants are located near suitable supplies of surface water, such as rivers, reservoirs, lakes, the Great Lakes, oceans, bays, or human-made impoundments, as described above. An exception is the Palo Verde plant in Arizona, which relies on treated municipal wastewater for cooling. Because of the interaction between power plants and surface water, issues arise in terms of both usage and quality. These are discussed in separate sections below.

#### *3.5.1.1 Surface Water Use*

Nuclear power plants withdraw large amounts of surface water to meet a variety of plant needs, especially for condenser cooling (see Section 3.1.3 for detailed analysis). The operating commercial nuclear power plants considered in this LR GEIS are compared in Table 3.5-1 in terms of their condenser flow rates, when normalized to energy production. Although nuclear plants in warmer geographical locations might be expected to have higher water requirements for cooling, a comparison of the locations of the plants and the normalized water use by their cooling systems suggests there is no correlation between high water use and warmer climate. Design factors are likely responsible for the overlapping ranges in condenser flow rates.

For closed-cycle cooling systems featuring cooling towers, the amount of water consumed equates approximately to the amount of water lost through evaporation and drift. In this type of cooling system, the condenser flow rate is much larger than the withdrawal rate from a surface water body, and this withdrawal rate is essentially the water consumption rate of the system. For once-through cooling systems, the condenser flow rate is nearly equal to the surface water withdrawal rate, and the consumption rate is much less because water is returned directly to the surface water body and undergoes less evaporative loss than in a cooling tower.

Cooling towers used at operating nuclear power plants consume water at a rate of about 9,400 to 10,000 gpm (0.59 to 0.63 $m^3/s$), normalized to 1,000 MWe, as a result of evaporation and drift (Table 3.5-1) (Marston et al. 2018). According to the National Renewable Energy Laboratory

(NREL 2011), the operational water consumption of nuclear plant cooling towers ranges from 9,700 to 14,000 gpm (0.61 to 0.88 $m^3$/s), normalized to 1,000 MWe. Additional water requirements offset the blowdown returned to the surface water body. Water withdrawal for plants with closed-cycle cooling systems is 5 to 10 percent of the withdrawal for plants with once-through cooling systems, with much of this water being used for makeup of water lost to evaporation (NRC 1996). An estimate of typical makeup water needs for nuclear plants having closed-cycle cooling, normalized to a 1,000 MWe reactor, is about 14,000 to 18,000 gpm (0.9 to 1.1 $m^3$/s) for all makeup needs (NRC 1996). This range of required makeup water includes not only the consumed water but also the offset of blowdown, which is returned to the surface water body. Variation in water use among plants results from the design of the cooling tower, concentration factor of recirculated water, climate at the site, plant operating conditions, and other plant-specific factors.

Once-through cooling systems are somewhat more common than closed-cycle systems (Table 3.5-1). For once-through systems used at operating nuclear plants, the water withdrawn is returned to the surface water body with less consumptive loss (about 6,600-6,700 gpm or 0.42 $m^3$/s) per 1,000 MWe because there is less evaporation than that associated with cooling towers (Marston et al. 2018). As indicated by National Renewable Energy Laboratory (NREL 2011), the operational water consumption of nuclear plant once-through cooling systems ranges between 2,000 to 7,000 gpm (0.13 to 0.44 $m^3$/s), normalized to 1,000 MWe. Marston et al. 2018 reports water consumption of once-through cooling systems at operating nuclear plants as ranging from 5,200 to 8,700 gpm (0.33 to 0.55 $m^3$/s) per 1,000 MWe. In all, the withdrawal rate from the surface water body, however, is much higher in a once-through cooling system than in a closed-cycle system. For example, in Table 3.5-1, compare the condenser flow rates needed for once-through systems, which correspond to their surface water withdrawals, with the consumptive losses of closed-cycle systems (e.g., cooling tower systems), which correspond to their surface water withdrawal or makeup water requirements. The thermal discharge from once-through cooling systems is generally higher than that from cooling towers, as discussed in Section 3.5.1.2 below.

**Table 3.5-1 Comparison of Cooling Water System Attributes for Operating Commercial Nuclear Power Plants**

| Cooling System[(a)] | Number of Sites[(a)] | Condenser Cooling Water Flow per Unit in gpm[(b)] | Average Reported Consumptive Water Loss per 1,000 MWe in gpm |
|---|---|---|---|
| Pond and/or canal | 9 | 454,000 to 907,000 | 10,200[(c)] |
| Mechanical draft cooling tower | 7 | 98,000 to 660,000 | 10,000[(d)] |
| Natural draft cooling tower | 13 | 410,000 to 836,000 | 9,400[(d)] |
| Once-through cooling (only) | 24 | 340,000 to 1,200,000 | 6,700[(d)] |
| Once-through cooling with tower | 4 | 292,000 to 750,000 | 6,600[(d)] |

gpm = gallons per minute.
(a) There are 54 operating commercial power reactor sites (2022) encompassing 92 nuclear generating units. For cases of multiple reactors per site, reactors using the same type of cooling system were counted only once. If multiple reactors at a site used different cooling systems (i.e., Nine Mile Point plant and Arkansas plant), they were tallied separately.
(b) Source: Appendix C of this LR GEIS.
(c) Source: National Renewable Energy Laboratory 2011 (NREL 2011).
(d) Source: Marston et al. 2018. Data for some plants were not reported by Marston et al. 2018.
Note: To convert gallons per minute (gpm) to liters per minute, multiply by 3.784. To convert gpm to cubic meters per second ($m^3$/s), multiply by 0.000063.

Additional operational surface-water-related needs at power plants include service water, auxiliary system supplies, and radioactive waste systems. These needs combined are small relative to the flow needed for condenser cooling (NRC 1996).

Nuclear plant water usage must comply with State, local, and regional regulations regarding water supply. Most States require permits regulating surface water usage.

For nuclear plants relying on river water, consumptive water losses reduce surface water supplies for other users downstream. In areas experiencing water availability problems, nuclear power plant consumption could conflict with other existing or potential uses (e.g., municipal and agricultural water withdrawals) and instream uses (e.g., adequate instream flows to protect aquatic biota, recreation, and riparian communities). Water availability issues have not been generally noted in past license renewal environmental reviews and are most likely to occur during times of extended drought.

Both water availability and water temperature are important factors in maintaining operations at power plants. As was previously described in the 2013 LR GEIS, in August 2007, a heat wave resulted in high river water temperatures at the Browns Ferry plant in Alabama. Because of the reduced capability of the river water to cool the condensers, one of the plant's three reactors was shut down, while operations at its other two reactors were cut by 25 percent. In summer 2006, the Quad Cities Nuclear Power Station (Quad Cities) in Illinois had to reduce operations because the Mississippi River was warm, and other plants in Illinois and Minnesota had to cut back as a result of drought effects.

More recently, a number of nuclear power plants have been affected by reduced water availability due to high temperatures. As relevant examples, in July 2012, Byron Units 1 and 2 had to reduce power due to degraded cooling tower performance during hot weather (NRC 2021o). In August 2014, Turkey Point Units 3 and 4 had to operate at reduced power due to excessive ultimate heat sink (CCS) temperature (NRC 2021m). In July 2016, the Perry Nuclear Power Plant (Perry) had to reduce power due to high ambient water temperature (NRC 2021p). In August 2018, the Clinton plant was forced to reduce power due to discharge temperature limitations (NRC 2021n).

In the report, *Water-Related Power Plant Curtailments: An Overview of Incidents and Contributing Factors*, National Renewable Energy Laboratory (NREL 2016) identifies 25 incidents at nuclear power plants between 2000 and 2015 where high water temperatures or water availability affected power generation. The operating nuclear power plants cited included Duane Arnold, Prairie Island Nuclear Generating Plant (Prairie Island), LaSalle, Dresden, Perry, Donald C. Cook Nuclear Plant (D.C. Cook), Quad Cities, Braidwood, Limerick, Vermont Yankee, Pilgrim Nuclear Power Station (Pilgrim), Millstone, Oyster Creek, Hope Creek, Riverbend, Browns Ferry, Turkey Point, and Monticello.

#### *3.5.1.2 Surface Water Quality*

Discharges from the circulating cooling water system account for the largest volumes of water and usually the greatest potential impacts on water quality and aquatic systems, although other systems may also contribute heat and chemical contaminants to the effluent. Provisions of the CWA regulate the discharge of pollutants into waters of the United States.

To operate a nuclear power plant, NRC licensees must comply with the CWA, including associated requirements imposed by EPA or the State. Specifically, Section 402 of the CWA requires that all facilities that discharge pollutants from any point source into waters of the United States obtain a NPDES permit. A NPDES permit is developed with two levels of controls: technology-based limits and water quality-based limits. NPDES permit terms may not exceed 5 years, and the applicant must reapply at least 180 days prior to the permit expiration date (EPA 2022g). Expired NPDES permits may be administratively extended and remain valid and in-force if the permit holder submits a complete NPDES renewal application as required. The EPA is authorized under the CWA to directly implement the NPDES program; however, the EPA has authorized most States and Tribes to implement all or parts of the national program. Conditions of discharge for each nuclear power plant are specified in its NPDES permit issued by the State or EPA.

CWA Section 401 requires an applicant for a Federal license whose activities may cause a discharge of regulated pollutants into navigable waters to provide the licensing agency with water quality certification from the State. This certification implies that discharges from the project to be licensed will comply with CWA requirements, as applicable, including that the project will not cause or contribute to a violation of State water quality standards. If the applicant has not received Section 401 certification, the NRC cannot issue a license unless that State has waived the requirement.

In July 2020, the EPA published a final rule revising the procedural requirements for CWA Section 401 certifications at 40 CFR 121 (85 FR 42210). The final rule became effective on September 11, 2020.[1] The revised regulations at 40 CFR 121.6 require that the Federal licensing agency establish the "reasonable period of time" and communicate that deadline to the appropriate certifying authority within 15 days of receiving notice of the applicant's certification request. Under the revised regulations, under no circumstances can the certifying authority take more than 1 year to issue the requested certification, deny certification, or waive its right to certify. The certifying authority's failure or refusal to act on a certification request within the reasonable period of time is considered a waiver. The NRC further recognizes that some NPDES-delegated States explicitly integrate their 401certification process with NPDES permit renewal and issuance.

Separate from permitting and associated regulatory requirements imposed on operating nuclear plants, the NRC considers new information and aspects of plant operations that could interact with the environment in a manner not previously recognized during the course of license renewal environmental reviews conducted for initial LRs and SLRs. For example, nuclear power plants with cooling ponds located in coastal areas have the potential to affect the water quality of adjacent water bodies via the groundwater pathway. This new, plant-specific aspect of continued operations was discovered during review of the second license renewal of Turkey Point Units 3 and 4 (NRC 2019c).

[1] In 2021, the EPA initiated a process to reconsider and revise the 2020 CWA Section 401 Certification Rule (86 FR 29541).

**Clean Water Act**

- Section 402 authorizes the NPDES permit program that controls water pollution by regulating point sources, including cooling water discharge from all facilities including thermoelectric power plants that discharge pollutants into waters of the United States.
- Section 401 requires applicants for Federal licenses or permits whose activities may cause a discharge of regulated pollutants into navigable waters of the United States to obtain a certification that their activities will not violate State water quality standards.
- Section 316(a) addresses the adverse environmental impacts associated with thermal discharges into waters of the United States. Under 316(b), the NPDES permitting authority can impose alternative, less-stringent, facility-specific effluent limits (called "variances") on the thermal component of individual point source discharges as long as the variances will assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the receiving body of water. Variances are good for the term of the NPDES permit (5 years), and the facility licensee must reapply for the variance each permit renewal term.
- Section 316(b) requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available (BTA) for minimizing impingement mortality and entrainment of aquatic organisms. Impingement mortality BTA compliance options are prescribed in regulations, while entrainment BTA is site-specific.

*3.5.1.2.1 Thermal Effluents and Withdrawal of Cooling Water from Surface Water Bodies*

NPDES permits for nuclear power plants impose temperature limits for effluents (which may vary by season) and/or a maximum temperature increase above the ambient water temperature (referred to as "delta-T," which also may vary by season). Other aspects of the permit may include the compliance measuring location and restrictions against plant shutdowns during winter to avoid drastic temperature changes in surface water bodies. Some NPDES permits also require nuclear power plants that operate a once-through cooling system with helper cooling towers to use the cooling towers seasonally to reduce thermal load to the receiving waterbody.

The area affected by heated releases to surface water bodies (the thermal plume) varies with site-specific conditions (e.g., discharge temperature, discharge rate, discharge structure location and design, flow of the surface water body, and temperature of the surface water body). Thermal plumes may be assessed in the field through computer modeling using thermal field data. Generally, the use of cooling towers decreases the thermal effluent discharged by a nuclear power plant (e.g., NRC 2006d).

Sections 316(a) and 316(b) of the CWA address thermal effects and impingement mortality and entrainment of aquatic organisms caused by operation of nuclear power plant cooling systems that withdraw and discharge to regulated waterbodies. The EPA, or authorized States and Tribes, impose the requirements of these CWA sections through NPDES permitting programs. Under CWA Section 316(a), nuclear power plants may apply for a thermal variance from State thermal surface water quality criteria. To do so, the facility must demonstrate that the requested variance is more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the receiving body of water (40 CFR Part 125 Subpart H). Variances are good for the NPDES permit term (5 years), and the licensee must reapply for the variance each permit renewal term. CWA Section 316(b) requires that the location, design, construction, and capacity of cooling water intake structures reflect the BTA for minimizing impingement mortality and entrainment of aquatic organisms. Impingement mortality BTA compliance options are prescribed in regulations, while entrainment BTA is plant-specific. Section 4.6.1.2 describes these sections of the CWA in detail, including the regulatory requirements relevant to nuclear power plants.

*3.5.1.2.2 Other Effluents*

Liquids containing chemicals and other constituents are discharged to surface water from nuclear power plants, as discussed in Section 3.1.4.1. The concentrations and flow rates of the liquids vary with activities involving the systems associated with floor drains, blowdown, laundries, decontamination, and other facilities. The liquids may also undergo treatment before reuse or discharge. These effluents are regulated under the plant's NPDES permit. As part of the permitting process, concentration limits are established, and monitoring takes place at specific outfalls or other monitoring locations. The frequency of sampling is also covered by the plant's NPDES permit. The EPA or authorized State or Tribal agencies also provide the reporting requirements, and they may post results on a publicly accessible website. Noncompliance issues may range from administrative matters to exceedances of concentration, temperature, or flow limits. The exceedance of a parameter limit will trigger the permitting agency to review the history and magnitude of exceedance recurrences. Actions may include reviewing the permit for appropriate parameter levels, setting a compliance schedule for the applicant, assessing fines, and, in a worst-case scenario, withdrawing a permit and disallowing the legal ability to discharge.

Sanitary sewage wastes are treated before their release to the environment to minimize environmental impacts. The treatment may be through discharge to a municipal wastewater treatment system, an onsite wastewater treatment plant, or an onsite septic system. In cases where nonradioactive sanitary or other wastes cannot be processed by onsite wastewater treatment systems, the wastes are collected by independent contractors and trucked to offsite treatment facilities. Waste collection and offsite disposal can occur during a planned outage, when portable toilets may be required to accommodate the additional workforce. Water quality issues related to sanitary waste treatment include the adequacy of the wastewater treatment system capacity for handling the increased flow and loading associated with operational changes to the plant, emission of phosphates from onsite laundries, suspended solids, coliform bacteria from sewage treatment discharges, and other effluents that cause excessive biochemical oxygen demand. State regulators are typically involved in site inspections, review of monitoring reports, and the handling of any violations.

The control of biological pests is critical to maintaining optimum system performance and minimizing operating costs. Consequently, many nuclear power plant cooling systems are periodically treated with molluscides to control the Asiatic clam (*Corbicula fluminea*) and the zebra mussel (*Dreissena polymorpha*), which are generally found in the portions of the cooling system where water temperatures are ambient rather than heated.

Biocides also are commonly used in cooling towers, although they may also be used in once-through systems or cooling ponds (DOE 1997a). Discharge of these chemicals to the receiving body of water can have toxic effects on aquatic organisms. Chlorine is commonly used as a biocide at nuclear power plants and represents the largest potential source of chemically toxic release to the aquatic environment. It may be injected at the intake or targeted at various points (such as the condensers) on an intermittent or continuous basis. Chlorine gas, which was commonly used in the past, has been replaced by many users with other forms, such as bleach (sodium hypochlorite) (DOE 1997a). At some plants, chemical biocides may be augmented with a non-chemical cleaning system that involves the injection of small spheres to control biofouling and buildup in condenser tubing. The spheres are injected into the water system and then collected upon discharge for reuse.

Bromide compounds have been used increasingly in recent years, either in place of or in addition to chlorine treatments. Dechlorination may occur prior to discharge. Non-oxidizing biocides used to control zebra mussels and other organisms include quaternary ammonia salts, triazine, glutaraldehyde, and other organic compounds.

Most nuclear power plants have a stormwater pollution prevention plan, with the parameter limits of the stormwater outfalls included in either an NPDES general permit or individual NPDES permit. Plants may also have a spill prevention, control, and countermeasures plan that contains information about potential liquid spill hazards and the appropriate absorbent materials to use if a spill occurs.

#### *3.5.1.3 Hydrologic Changes and Flooding*

As described in Section 3.5, urbanization of watersheds in which nuclear power plants operate increases the amount of impervious surface coverage resulting in water quality impacts and changes in the hydrologic characteristics of the watershed. Urbanization has a direct correlation to the degradation of natural receiving streams. The higher the percentage of the impervious surface coverage in a watershed, the higher the flow velocity and volume in receiving water bodies. Increases in stream flow erode natural stream banks and scour natural vegetation from littoral zones, while also adding to higher flow volume and increased potential for flooding. A flood is the occurrence when, under high water level and/or flow conditions, water overflows the natural or artificial bank of the water body. The floodplain or zone defines the extent of the land areas covered by the overflowing water. Floods can occur at any time, but weather patterns, terrain, land use coverage, and other factors influence when and where floods happen, as well as their frequency and severity. For example, the western United States can experience flooding due to cyclones in the winter and early spring; the streams in the southwest United States can experience flash flooding due to thunderstorms in late summer and fall; frontal storms in the northern and eastern United States can cause floods during the winter and spring; and the southeastern United States experiences flooding due to tropical storms, such as hurricanes, during the late summer and fall.

Flood zone boundaries are determined based on the predicted recurrence interval of flooding and the extent of the land area inundated through the use of analytical modeling and field observations. The recurrence interval is the average number of years between floods of a certain size. For instance, the 100-year flood, on average, is expected to occur once every 100 years. However, statistically there is a 1 in 100 chance that the 100-year flood will occur in any given year.

Flood zones are dynamic and change over time due to natural forces. Further, changes in urbanization increase runoff and changes in weather patterns increase the intensity of precipitation events. In some instances, land areas that were not previously within a flood zone have been reclassified as being in one after nearby river elevations and flood potential were reanalyzed. On large rivers, dams have been shown to reduce flooding. Flood-control dams, such as on multiuse reservoirs, are designed to release water flow at a controlled rate and allow water to back up in a reservoir when, typically under storm events, the inflows exceed the predetermined outflow rate. This prevents high flows from reaching streams that would otherwise flood and allows water flow to bypass communities without flooding them.

Currently operating nuclear power plants were originally sited in consideration of the hydrologic siting criteria set forth in 10 CFR Part 100 and designed and constructed in accordance with 10 CFR Part 50, Appendix A. The regulations require that plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena, including flooding, without loss of capability to perform safety functions. Plant-specific design bases for flood protection are prescribed by a nuclear power plant's updated safety analysis report and by applicable technical specifications. Acceptable protection for floods includes levees, seawalls, floodwalls, or breakwaters. If new information or plant operating experience related to flooding become available, the NRC evaluates the new information or plant data to determine whether any changes are needed at existing plants. Flood protection issues are considered during plant-specific safety reviews and, more specifically, are addressed on an ongoing basis through the reactor oversight process and other NRC safety programs, which are separate from the license renewal process.

### 3.5.2 Groundwater Resources

Some nuclear power plants also use groundwater as a source of water for some of their operational needs. The rate of usage varies greatly among the plants. Many plants use groundwater only for the potable water system and require less than 100 gpm (378 liters per minute or 0.006 $m^3$/s). At some plants, the original construction required dewatering of a shallow aquifer by using pumping wells or a drain system. Some plants operate dewatering systems to lower the water table near buildings. This is accomplished either by pumping or by having footing drains along foundations. Groundwater may also be used for sanitary uses or landscaping, and it may undergo processing to be used for makeup or service water systems. Groundwater usage regulations vary considerably from State to State, and State allocation permits are typically required.

At the Grand Gulf plant in Mississippi, large-diameter wells with radial collector arms (i.e., Ranney wells) are used to withdraw groundwater along the Mississippi River at relatively high rates. Radial collector wells are installed in alluvial aquifers along rivers to obtain a mixture of groundwater and surface water through induced infiltration. At Grand Gulf, the average groundwater pumping rate by their well systems is approximately 27,900 gpm (1.76 $m^3$/s) (NRC 2014e). Groundwater withdrawn at Grand Gulf is used for cooling, makeup, service, potable, sanitary, landscaping, and fire protection uses.

The quality of groundwater may be affected by operations at nuclear power plants. Water from cooling ponds may seep into the underlying surficial aquifer. Activities at power plants typically include general industrial practices, such as the storage and use of hydrocarbon fuels (diesel and/or gasoline), solvents, and other chemicals. These practices have the potential to contaminate soil and groundwater, and, at some plants, such contamination has occurred. Examples from plant-specific supplemental environmental impact statements (SEISs) include leakages or spills of gasoline (with methyl tertiary butyl ether or MTBE) at fuel tank storage areas, spills of fuel at transfer or filling stations, solvent leakages from storage area drums, spilled or sprayed solvents, and underground line leaks of hydraulic oil or diesel fuel (e.g., NRC 2006d, NRC 2007b, NRC 2016c). These incidents involved regulatory oversight under State regulations for hydrocarbons and under RCRA (42 U.S.C. § 6901 et seq.) for other chemicals, and offsite groundwater users were not affected.

Radionuclide releases from nuclear power plants have been identified as the source of radioactive materials in groundwater (or below-ground moisture) at many plant sites. These releases have been attributed to system leaks (e.g., from pipes, valves, or tanks), evaporation of liquids, condensation of vapors, and normal operations (routine, approved releases) (NRC 2021k). Detection of tritium has generally been the initial indicator of a release because it travels readily in groundwater. The issue of tritium (and other radionuclide) releases to groundwater rose to prominence as groundwater contamination was observed at an increasing number of plants, including the exceedance of drinking water standards in onsite groundwater at some plants.

The NRC formed a task force in 2006 in response to incidents at the Braidwood, Indian Point, Byron, and Dresden plants to examine the matter of liquid radionuclide releases from power plants (NRC 2006e). The task force report noted that the leaks were generally not observable because they occurred underground and because plants were not required to have onsite groundwater monitoring wells unless an onsite well was used for drinking water or irrigation water. The task force concluded that the available data on radionuclide releases did not identify any public health impacts, but the level of public concern warranted recommendations for enhanced regulations or regulatory guidance for unplanned, unmonitored releases; additional decommissioning funding and license renewal reviews; and enhanced public communications (NRC 2006e).

In response to the discoveries of underground radionuclide releases at nuclear power plants, the Nuclear Energy Institute, which represents the nuclear industry on policy issues, developed the Groundwater Protection Initiative, originally published in 2007 and revised most recently in 2019 (NEI 2019). Each Nuclear Energy Institute member company voluntarily committed to develop and implement a plant-specific groundwater protection program for operating or decommissioning nuclear power plants by July 31, 2006. These programs cover the assessment of plant systems and components, site hydrogeology, and implementation of groundwater monitoring programs. To monitor the actions of the nuclear industry, the NRC updated its inspection procedure to include this issue as part of its routine radiological inspection at all nuclear power plants.

In March 2010, the NRC formed a Groundwater Task Force to determine whether additional actions were needed to strengthen the NRC’s response to incidents of radionuclide releases to groundwater at nuclear power plant sites (NRC 2010e). This new task force was comprised of NRC management and technical staff charged with reevaluating the recommendations made in the 2006 lessons learned report and to consider more recent tritium releases to groundwater from nuclear power plants. On June 11, 2010, the task force issued its report that identified 16 conclusions and 4 recommendations (NRC 2010b).

Subsequently, the NRC’s Executive Director for Operations appointed a senior management review group to consider the Groundwater Task Force’s final report, identify the policy issues associated with the NRC’s groundwater protection regulatory framework, develop options for addressing the policy issues, and present options to the Commission (NRC 2010c). The outcome of the appointed senior management group’s review of the Groundwater Task Force Final Report was issued in February 2011 via SECY-11-0019 (NRC 2011f) along with a separate memorandum to the NRC Chairman. In summary, the group supported several ongoing staff actions, including evaluations of the long-term effectiveness of industry groundwater protection initiatives through onsite inspections, review of licensees’ root cause analyses, tracking of the frequency of leakage, and evaluation of industry performance metrics related to leakage and potential groundwater contamination.

In SRM-SECY-11-0019, dated August 15, 2011 (NRC 2011d), the Commission approved the senior management review group's recommendation to not incorporate the industry's voluntary initiative on groundwater protection into the NRC's regulatory framework and that the staff continue to monitor the effectiveness of the industry initiatives. The Commission also requested that the staff provide options for revising the agency's approach to groundwater protection.

On March 29, 2012, the staff submitted an options paper regarding the NRC's approach to groundwater protection (SECY-12-0046) to the Commission (NRC 2012h). The staff recommended an option that included continuing the agency's established regulatory approach under which the staff would continue inspecting and enforcing existing regulations using the system of dose limits and as low as is reasonably achievable (ALARA) principles. The staff would also implement the new regulatory requirements in 10 CFR 20.1406 for minimizing the introduction of residual radioactivity into the plant site and in 10 CFR 20.1501 for performing subsurface (i.e., soil and groundwater) monitoring.

The Commission in its SRM-SECY-12-0046, approved the staff's recommended option to continue the current regulatory approach to groundwater protection, including the additional requirements contained in the decommissioning planning rule. The Commission also directed the staff to provide a notation vote paper based on the result of comments solicited on the technical basis including the pros and cons of moving forward with a proposed prompt remediation rulemaking under consideration by the staff (NRC 2012f).

The NRC staff conducted a public meeting and webinar on June 4, 2013, to obtain stakeholder comments on the ongoing prompt remediation issue. In SECY-13-0108, dated October 7, 2013, the staff reported the results of its evaluation of stakeholder comments to the Commission (NRC 2013d). In SRM-SECY-13-0108, the Commission approved the NRC staff's recommendation to collect 2 years of additional data from the implementation of the decommissioning planning rule. Based on the staff's completion and evaluation of the data and stakeholder engagement, the Commission directed that the staff provide a paper with recommendations for addressing remediation of residual radioactivity at licensed facilities during facility operations (NRC 2013c).

In SECY-16-0121, dated October 16, 2016, the staff provided the Commission with its evaluation of options including the consideration of rulemaking to address the remediation of residual radioactivity at licensed facilities during operations (i.e., prompt remediation). The staff recommended no rulemaking, and cited existing NRC regulatory requirements and voluntary industry initiatives as providing adequate protection for public health and safety (NRC 2016g). In December 2016 (SRM-SECY-16-0121), the Commission approved the staff's recommended option (NRC 2016e).

The NRC has repeatedly determined that inadvertent releases at nuclear power plant sites either remain on power plant property or involve such low offsite levels of tritium that they do not affect public health and safety. The NRC has continued to review incidents of inadvertent releases to ensure that nuclear power plant operators take appropriate action.

Additionally, the NRC maintains an updated list of operating reactor sites that have experienced a leak or spill of liquids containing radioactive material to the onsite licensee (owner)-controlled area. The list includes plant sites where the concentration of tritium in the leak source, or in a groundwater sample, exceeded the EPA drinking water standard (20,000 pCi/L) at some time since initial startup (NRC 2021j). To date, tritium in excess of the drinking water standard has been observed in groundwater at 38 nuclear power plant sites as a result of leaks or spills, with 7 plants continuing to have tritium in groundwater above the drinking water standard as of

October 2021 (NRC 2021j). No site has reported tritium above the drinking water standard in offsite groundwater (NRC 2021j).

The NRC provides public access to all radioactive effluent and environmental monitoring data, including industry groundwater protection initiative monitoring results, reported to the NRC by nuclear power plant licensees at https://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html.

In summary, to protect groundwater quality during the period of operations and to minimize contamination during decommissioning, NRC licensees are required to conduct operations to minimize the introduction of residual radioactivity into the site, including the subsurface. NRC licensees are also required to survey, evaluate, document, and report the hazard of known spills or leaks of radioactive material. The NRC has reporting requirements based on the amount of radioactivity released, thus any large spills or leaks will be reported.

## 3.6 Ecological Resources

A variety of ecological resources exist at and in the vicinity of operating nuclear power plants across the United States. This section presents an overview of those resources. Sections 3.6.1, 3.6.2, and 3.6.3, discuss terrestrial resources, aquatic resources, and federally protected ecological resources, respectively. Wetlands and floodplains, which are transitional areas between terrestrial and aquatic systems, are described with terrestrial resources. This section summarizes the effects of past activities, including construction and current operations, at operating commercial nuclear power plant sites.

### 3.6.1 Terrestrial Resources

Operating commercial nuclear power plants are located in a variety of terrestrial habitat types. For the purposes of this analysis, terrestrial ecological resources in the vicinity of nuclear power plants are described in terms of upland vegetation and habitats, floodplain and wetland vegetation and habitats, and wildlife. Section 3.6.3.1 discusses federally protected terrestrial resources.

#### *3.6.1.1 Upland Vegetation and Habitats*

Terrestrial vegetation and habitats include forests, grasslands, and shrublands. These habitats have been affected by the initial construction of nuclear power plants, operation of those plants, and natural successional changes occurring within vegetation communities. In general, the level of land management varies by land use type at a nuclear power plant. See Section 3.2.1 for a general description of land use at a nuclear power plant.

Impacts on terrestrial vegetation and habitats can result from several activities or processes during normal operations at a nuclear power plant. Since startup of operations, industrial-use portions of nuclear power plant sites have typically been maintained as modified landscapes. These areas may also include disturbed early successional habitats or areas of relatively undisturbed habitat. Site maintenance, such as mowing and herbicide or pesticide application, generally keeps the diversity of plant species at a reduced level in these areas. Native plant species are often replaced by cultivated varieties or weedy species tolerant of disturbance. Non-industrial use portions of nuclear power plant sites may include natural areas, such as forest or shrubland, in various degrees of disturbance.

Terrestrial habitats near nuclear power plants can be subject to radiological releases under normal plant operations. These habitats are exposed to small amounts of radionuclides that result from the deposition of particulates released from nuclear power plant vents during normal operations. Releases typically include noble gases (which are not deposited), tritium, isotopes of iodine, and cesium, and they may also include carbon-14, strontium, cobalt, and chromium. Exposure to these radionuclides results in a dose rate to terrestrial plants of much less than 1.0 rad/d (0.1 Gy/d), which is the U.S. Department of Energy (DOE) guideline for adequate protection of terrestrial plant populations from the effects of ionizing radiation (DOE 2019) (see Section 4.6.1.1.2). Radionuclides, such as tritium, and other constituents in cooling water systems, such as biocides, that enter shallow groundwater from cooling ponds can be taken up by terrestrial plants.

Terrestrial habitats near nuclear power plants that have cooling towers are subject to the deposition of cooling tower drift particulates (including salt); the deposition of water droplets on vegetation from drift; structural damage from freezing vapor plumes; and increased humidity. Small amounts of particulates from cooling towers are dispersed over a wide area. Particulates from natural draft towers are typically dispersed over a larger area and at a lower deposition rate than those from mechanical draft towers (Roffman and Van Vleck 1974). However, most of the deposition from cooling towers occurs in relatively close proximity to the towers. Generally, deposition rates are below those that are known to result in measurable adverse effects on plants, and no deposition effects on agricultural crops or natural vegetative communities have been observed at most nuclear power plants. Some exceptions were observed at nuclear power plants in studies conducted in the 1980s (e.g., Palisades in Michigan and Prairie Island in Minnesota; NRC 1996); however, the NRC staff's review of recent license renewals did not identify any new issues. Impacts from icing, when they have occurred, have been minor and localized near cooling towers.

Effects of nuclear power plant operations on terrestrial habitats also include the effects of transmission line ROWs and their maintenance. ROW management typically includes the periodic cutting and removal of tall woody vegetation and the application of herbicides. Use of mechanized equipment can crush vegetation or injure or disturb insects and small animals. However, transmission lines and associated structures within the scope of license renewal reviews are expected to occur primarily on developed portions of sites and would include only the short lengths of transmission lines that run from the plant to the nearest substation (see Section 3.1.6.5).

#### *3.6.1.2 Floodplain and Wetland Vegetation and Habitats*

Floodplains are areas where the land is susceptible to flooding from any source and tend to occur along rivers and coastlines near many nuclear power plants (FEMA 2021). These areas attenuate the extent of flooding and often include wetlands, marshes, and riparian habitat. One-hundred year floodplains typically have at least a 1 percent chance of flooding in any given year. Many nuclear power plant cooling water intake systems and outfalls lie within floodplains. Some transmission lines may also cross through floodplains. Executive Order 11988, "Floodplain Management" (42 FR 26951), requires Federal agencies to restore and preserve the natural and beneficial values served by floodplains for activities undertaken in such areas.

Many wetland types occur near nuclear power plants. These include riverine, palustrine, lacustrine, estuarine, and marine wetlands, as described by the U.S. Fish and Wildlife Service (FWS) Cowardin classification for the National Wetlands Inventory (Cowardin et al. 1979). Most nuclear power plants have wetlands nearby (within a radius of 5 mi [8 km]), and wetlands cover an average of 9.3 percent of the land area near operating nuclear power plants, as mapped by the National Wetlands Inventory (FWS 2022b). The definition of wetlands traditionally excludes deep-water habitats, which are permanently flooded areas (Cowardin et al. 1979; FGDC 2013) and which occupy, on average, 21.2 percent of the area within 5 mi of operating nuclear power plants. The percentage of wetlands and deep-water habitats within 5 mi (8 km) of nuclear power plants is presented in Table D.5-3 in Appendix D.

**Wetland Types That Occur near Nuclear Power Plants**

- **Riverine wetlands** are contained within a channel that has moving water, at least periodically, and lack persistent vegetation.
- **Palustrine wetlands** are freshwater habitats that primarily support trees, shrubs, or persistent emergent plants, or they can be small (generally under 20 ac or 8 ha), shallow wetlands lacking such plant communities.
- **Lacustrine wetlands** are large or deep bodies of water that lack persistent vegetation.
- **Estuarine wetlands** occur near land with access to the ocean, are influenced by tides, and are diluted to a variable extent by freshwater.
- **Marine wetlands** are exposed to open ocean waves and currents and may be slightly diluted by freshwater.

Source: Cowardin et al. 1979.

At many nuclear power plant sites, initial plant construction and various aspects of plant operation have affected wetlands. These effects include those associated with facility construction, transmission line construction and maintenance, construction and operation of cooling systems, and stormwater management. Effects on wetlands from construction activities and stormwater runoff often include changes in vegetative plant community characteristics, altered hydrology, decreased water quality, and sedimentation (Wright et al. 2006; EPA 1996). Forested wetlands in ROWs are converted to scrub/shrub or emergent wetland types when trees are removed, and ROW management programs maintain ROWs in these habitat types. The operation of heavy equipment in wetlands during ROW maintenance or transmission line repairs can damage or compact wetland soils and vegetation and may promote the establishment of invasive species (DOE 2000). Executive Order 13112, “Invasive Species” (64 FR 6183), directs Federal agencies to prevent introduction of or to monitor and control invasive species.

Wetland losses or alterations occurred during the construction of many nuclear power plants. For example, during construction of the Oyster Creek plant (no longer operating) in New Jersey, the South Branch of Forked River and Oyster Creek were dredged and widened to accommodate operation of the cooling water system. As a result, most of the natural aquatic habitats that occurred within these portions of the river and creek were destroyed (NRC 2007b). Construction resulted in the loss of 200 ac of several types of wetlands (AEC 1974), and the resulting ecology of the river and creek is that they now function similar to Barnegat Bay. However, at nuclear power plants using cooling ponds, new wetland habitats may form along the margins of those ponds.

The operation of cooling water systems can expose wetland habitats to thermal impacts and contaminants in effluent discharged from the plant. Intake or discharge structure maintenance, periodic dredging, and the disposal of dredged sediments may also affect wetlands. Chemical or fuel spills on nuclear power plant sites can allow contaminants to enter nearby surface or groundwater, which could affect wetlands that interface with those water sources. Executive Order 11990, "Protection of Wetlands" (42 FR 26961), requires Federal agencies to not only minimize the destruction, loss, or degradation of wetlands while they are conducting their activities but also to preserve and enhance the natural and beneficial values of wetlands. Many activities that occur in wetlands are regulated under Section 404 of the CWA (Federal Water Pollution Control Act of 1972). Actions that result in the discharge of dredge or fill material into wetlands that are covered by the CWA require a permit from the U.S. Army Corps of Engineers. Additional permits may be required dependent upon the State and local jurisdictions.

#### *3.6.1.3 Wildlife*

Wildlife near nuclear power plants has also been affected by construction and operations. The initial construction of a nuclear power plant and transmission lines reduced the available terrestrial habitat at the site; habitat losses in many cases totaled hundreds of acres. Site maintenance of developed areas generally results in reduced wildlife diversity in these areas compared to surrounding habitats. Wildlife species occurring on industrial-use portions of nuclear power plant sites are typically limited by the low quality of the habitat and generally include common species adapted to industrial developments.

Because habitats along transmission line ROWs are maintained in a modified condition, the wildlife communities they support are different from those found in undisturbed habitats. Some predator species, such as skunks and raccoons, more readily use ROW habitats, and ROWs may therefore provide a means for new or easier access to some areas, thereby affecting populations of prey species (Evans and Gates 1997; Crooks and Soule 1999). Wildlife species in the vicinity of transformers or cooling towers are exposed to elevated noise levels that can disrupt behavior patterns. Wildlife near transmission lines are exposed to electromagnetic fields (EMFs). However, to date, there is no evidence that ecological resources are affected by EMFs. Atmospheric or surface water releases can result in the exposure of wildlife to contaminants. Wildlife is exposed to small amounts of radionuclides from the deposition of particulates released from nuclear power plant vents during normal operations. Exposure to these radionuclides results in a dose rate to terrestrial and riparian animals of much less than 0.1 rad/d (0.001 Gy/d), which is the DOE guideline for adequate protection from the effects of ionizing radiation (DOE 2019) (see Section 4.6.1.1.2).

Nuclear power plant structures, such as cooling towers, meteorological towers, and transmission lines, create collision hazards for birds. Some bird collisions could be considered unlawful take if the bird species are protected under the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. § 1531 et seq.), the Bald and Golden Eagle Protection Act of 1940, as amended (16 U.S.C. §§ 668–668d), or the Migratory Bird Treaty Act of 1918, as amended (16 U.S.C. § 703 et seq.). Several nuclear power plants with natural draft cooling towers have conducted studies to investigate the risk of bird collision hazard related to cooling towers and other site structures. The results of those monitoring efforts indicate that cooling towers at nuclear power plants do cause some collision mortality for migrating songbirds; however, these deaths represent only a fraction of the total annual bird collision mortality from all human-made sources. There are no reports of relatively high collision mortality, such as from electrocution, occurring from transmission lines associated with nuclear power plants in the United States. The length of these lines is considerably less than the total of transmission lines within the United States (Manville 2005). Although the data are not available, transmission lines associated with nuclear power plants are likely responsible for only a small fraction of total bird collision mortality associated with transmission lines nationwide. See Section 4.6.1.1 for a detailed description of bird collision mortality at nuclear power plants.

Cooling water systems can have both positive and negative impacts on prey of birds and other wildlife. Potential fish prey can be impinged or entrained by the cooling water intake system, while the fish return system, if present, or heated effluent discharge can provide areas of concentrated prey availability. Cooling system intakes can also create an impingement hazard for waterfowl, and water demands for cooling can create water use conflicts with wildlife. At the Nine Mile Point plant in New York, for example, approximately 100 greater scaup (*Aythya marila*) and lesser scaup (*Aythya affinis*) ducks were impinged at the cooling water intake structure in 2000 while feeding on zebra mussels (*Dreissena polymorpha*) during reverse flow conditions for de-icing of the structure (NRC 2006b). As a result of this incident, the licensee now cleans the Nine Mile Point intake structures annually to remove zebra mussels, and reverse flow conditions are scheduled during periods when diving duck feeding is limited (NRC 2006b). Water use conflicts at the Wolf Creek Generating Station (Wolf Creek) in Kansas can occur during drought conditions because makeup water for the cooling lake is withdrawn from the Neosho River, resulting in reduced flows (NRC 2008a). During such times, riparian communities along the Neosho River can be degraded or lost because of reduced flows, and wildlife can experience reduced habitat quantity or quality. For some nuclear power plants, State permits restrict water withdrawal to limit the adverse impacts of water withdrawals (e.g., the Byron [NRC 2015c] and River Bend plants [NRC 2018c]).

### 3.6.2 Aquatic Resources

Nuclear power plants are usually located near relatively large water bodies, such as major rivers and reservoirs, the Great Lakes, and estuarine and marine coastal areas, which provide a source of water to meet cooling system demands (Table 3.1-2, Table 3.1-3, Table 3.1-4). In the few cases where an operating nuclear power plant is located near only small streams (e.g., the Virgil C. Summer Nuclear Station [Summer] in South Carolina and Clinton plant in Illinois), the streams have been impounded to create cooling lakes. Aquatic resources associated with these water bodies may be affected by nuclear power plant operation. This discussion emphasizes the major ecosystem types (i.e., freshwater rivers, reservoirs, and lakes and coastal estuarine and marine systems) and major groups of aquatic biota (i.e., fish, other aquatic vertebrates, macroinvertebrates, zooplankton, phytoplankton, and macrophytes). Section 3.6.3.1 discusses federally protected aquatic resources.

#### *3.6.2.1 Aquatic Habitats*

The aquatic ecological communities that occur in the vicinity of operating nuclear power plants are diverse because of the differences in their geographies and habitat types and in the physical and chemical conditions of the water bodies located near them. The geographical setting, physical conditions (e.g., substrate type, temperature, turbidity, and light penetration), chemical factors (e.g., dissolved oxygen levels and nutrient concentrations), biological interactions (e.g., competition and predation), seasonal influences, and anthropogenic factors all interact to influence the types of species present and the nature of the aquatic community in a particular aquatic ecosystem. Nuclear power plants use freshwater, estuarine, and marine water bodies as sources of cooling water, except for the Palo Verde plant, which uses Phoenix City sewage effluent (Table 3.1-4).

Freshwater systems can be broadly categorized as lentic or lotic, depending on the degree of water movement. Lentic systems refer to water bodies that have standing or slow-flowing water, such as that found in ponds, lakes, reservoirs, and some canals. Lotic habitats generally have a measurable velocity and include natural rivers and streams and also some artificial waterways. Although some freshwater aquatic species occur in both lentic and lotic habitats, many species are adapted to the physical, chemical, and ecological characteristics of one system or the other, and the overall ecological communities present within these aquatic ecosystem types will differ for a given region of the country.

Species composition and ecological conditions within riverine environments are largely determined by the geographic area, gradient of the riverbed, velocity of the current, and source of nutrients and organic matter at the base of the food chain. Thus, ecological communities in rivers become altered if the river is impounded, with the degree of alteration depending on the degree to which various physical and chemical conditions are affected. These systems are sensitive to flow depletion or alteration, changes in temperature characteristics, blockages to the upstream or downstream movement of aquatic organisms, chemical pollution, and the introduction of non-native species.

**Aquatic Ecosystem Types**

- **Freshwater:** Waters with a salinity of 0.5 ppt or less.
  - **Lentic:** Standing or slow-flowing fresh water (e.g., lakes and ponds).
  - **Lotic:** Flowing freshwater with a measurable velocity (e.g., rivers and streams).
- **Marine:** Waters with a salinity of about 35–37 ppt (e.g., ocean overlying the continental shelf and associated shores).
- **Estuarine:** Coastal bodies of water, often semi-enclosed, that have a free connection with marine ecosystems (e.g., bays, inlets, lagoons, and ocean-flooded river valleys). In these areas, freshwater merges with marine waters; salinity concentrations vary spatially and temporally due to location and tidal activity.

Major rivers that serve as cooling water sources for operating nuclear power plants include the Mississippi River, Tennessee River, Missouri River, Susquehanna River, Delaware River, and Columbia River (see Table 3.1-4). Some nuclear power plants that use rivers for cooling are located on sections of rivers that have been impounded to slow the rate of flow and create pooled areas in the vicinity of cooling water withdrawal or discharge structures. These sections are not as clearly lentic in nature as the reservoirs.

The ecological communities that inhabit the aquatic environment differ, reflecting the preferences and tolerances of aquatic species at various life stages for the physical and chemical conditions that exist. A list of cooling water sources by operating nuclear power plant can be found in Table 3.1-3. Within the United States, nine operating nuclear power plants use water from natural lakes for cooling. These lakes are Lake Erie, Lake Michigan, and Lake Ontario.

Reservoirs differ from natural lakes and refer to areas of rivers or streams that are impounded by a dam or water control structure such that they have become physically, chemically, and ecologically more similar to lakes instead of the lotic system from which they are formed (Armantrout 1998). In the United States, 14 nuclear power plants use water from reservoirs for cooling. Fish species that thrive in the habitat conditions that exist within a given reservoir are often stocked and managed to support recreational fisheries (see Table 3.1-4).

Brackish to saltwater estuarine and marine ecosystems occur along the coastlines of the United States. General habitat types found within these ecosystems include the mouths of rivers, tidal streams, shorelines, salt marshes, beaches, mangroves, submerged aquatic vegetation, coral reefs, and open water. Estuaries are particularly important as staging points during the migration of certain fish species (e.g., salmon and eels) because these waterbodies give fish time to form schools and to physiologically adjust to changes in salinity. Many marine fish and invertebrate species use estuaries for spawning or as places where young fish can feed and grow before moving to other marine habitats. Estuarine and marine habitats support important commercial or recreational finfish and shellfish species. In the United States, 11 nuclear power plants use water from estuarine or marine environments (see Table 3.1-2).

#### *3.6.2.2 Aquatic Organisms*

Major groups of aquatic organisms include fish, other macroinvertebrates, aquatic macroinvertebrates, zooplankton, phytoplankton and aquatic macrophytes.

Fish can be characterized as freshwater, estuarine, marine, or diadromous (e.g., anadromous and catadromous) species. The first three categories are based on salinity regimes, whereas the diadromous category is composed of reproductively specialized fish that migrate between freshwater and saltwater to reproduce. Murdy et al. (1997) defined freshwater fish as those that usually inhabit waters with a salinity of less than 0.5 ppt; estuarine fish as those that inhabit tidal waters with salinities that range between 0 and 30 ppt; and marine fish as those that typically live and reproduce in coastal and oceanic waters with salinities that are 35 to 37 ppt. Anadromous species migrate from marine waters to freshwater to spawn, while catadromous species migrate from freshwater to marine waters to spawn. Anadromous species include sturgeons, clupeids, salmonids, smelts, striped bass (*Morone saxatilus*), and sea lamprey (*Petromyzon marinus*). Within the United States, the only catadromous species is the American eel (*Anguilla rostrata*). For some species, migratory movements may be confined within a freshwater system (e.g., species tend to move to upstream areas for spawning) or within the ocean (e.g., species tend to move northward as waters warm and southward as they cool). Many of the fish species that occur in the vicinity of the nuclear power plants are of commercial or recreational importance, while others serve as forage for those species.

Fish have various mechanisms to maintain health and fitness during large diurnal or seasonal changes in water temperature. The swimming performance of fish is influenced by temperature. A given species' swimming speed and endurance peak within a certain optimal temperature range but are reduced at lower or higher temperatures (Claireaux et al. 2006). Many marine fish have buoyant eggs while most stream fish have demersal eggs that are heavy and sink to the bottom of the water column. Most demersal eggs are also, at least temporarily, adhesive (Lagler et al. 1962). Newly hatched larvae undergo natural mortality rates of 5 to 30 percent per day as a result of predation, starvation, disease, pollution, and other causes (Batty and Blaxter 1992).

In addition to fish, other vertebrate species can be present in the aquatic ecosystems near nuclear power plants. These include marine reptiles, such as sea turtles, and marine mammals, such as whales, seals, and the West Indian manatee (*Trichechus manatus*).

Aquatic macroinvertebrates include a diverse range of taxa, including immature and adult insects, crustaceans, mollusks, and worms. These can occur on a variety of stable surfaces such as substrates, plants, debris, etc., and within the water. Macroinvertebrates control key ecosystem processes, such as primary production, decomposition, nutrient regeneration, water chemistry, and water clarity.

Nuisance or invasive species can be present in cooling water sources. For example, Asiatic clams (*Corbicula fluminea*) and zebra mussels can alter the trophic and nutrient dynamics of aquatic ecosystems and displace native mussels. Executive Order 13112, "Invasive Species" (64 FR 6183), directs Federal agencies to prevent introduction of or to monitor and control invasive species. Many nuclear power plants monitor for these species and periodically use physical or chemical methods to control biofouling of cooling system structures and components.

Zooplankton include protozoans, crustaceans, and the drifting larvae of fish and macroinvertebrates. Rotifers, cladocerans, and copepods are primary components of the zooplankton community in freshwater ecosystems. The zooplankton of estuarine and marine ecosystems include eggs, larvae, juveniles, and adults of anemones, jellyfish, bristleworms, sea urchins, starfish, copepods, isopods, amphipods, shrimp, crabs, lobsters, bryozoans, and mollusks. Ichthyoplankton, which are fish eggs and larvae, are a seasonal component of the zooplankton in all aquatic ecosystems. Zooplankton are an important link between phytoplankton and fish or other secondary consumers.

Phytoplankton are an important food source for some invertebrate and fish species and are important for converting carbon dioxide ($CO_2$) to organic materials via photosynthesis. Periphyton are algae attached to solid submerged objects and include species of diatoms and other algae that grow on natural or artificial substrates. These species can become planktonic as a result of scouring or other actions that separate individuals from their substrate. Components of phytoplankton include green algae (Chlorophyta), blue-green algae (Cyanophyta), and golden brown algae (Chrysophyta). Brown algae and kelp (Phaeophyta) and red algae (Rhodophyta) also occur in marine waters. Diatoms (Bacillariophyta) are a major component of the phytoplankton in many aquatic systems. Macrophytes can stabilize sediments, act as important links in nutrient cycling, provide shelter and protection for animal communities, and provide important nursery areas (Hall et al. 1978). Factors that affect the distribution and condition of submersed aquatic vascular plants include weather and hydrology, sedimentation, suspended solids and water clarity, and consumption and disturbance by fish and wildlife (USGS 1999).

#### *3.6.2.3 Effects of Existing Nuclear Plant Operations on Aquatic Resources*

The effects of nuclear power plant operations on aquatic resources include impingement and entrainment of aquatic organisms into the cooling water intake system, effects associated with thermal discharges, and chemical and radiological contamination.

Impingement occurs when organisms are trapped against the outer part of an intake structure's screening device (79 FR 48300). The force of the intake water traps the organisms against the screen, and individuals are unable to escape. Impingement can kill organisms immediately or cause exhaustion, suffocation, injury, and other physical stresses that contribute to later mortality. The potential for injury or death is generally related to the amount of time an organism is impinged, its fragility (susceptibility to injury), and the physical characteristics of the screen wash and fish return systems of the intake structure. Entrainment occurs when organisms pass through the screening device and travel through the entire cooling system, including the pumps, condenser or heat exchanger tubes, and discharge pipes (79 FR 48300). Organisms susceptible to entrainment are of smaller size, such as ichthyoplankton, meriplankton, zooplankton, and phytoplankton. Impingement and entrainment occurs at all nuclear power plants that withdraw water from a natural water body. The magnitude of impact that impingement and entrainment creates on the aquatic environment depends on the plant-specific characteristics of the cooling system as well as the characteristics of the local aquatic community.

Temperature can influence most biochemical, physiological, and life history activities of aquatic organisms (Beitinger et al. 2000). Thermal effects on aquatic biota can be lethal, sub-lethal, or community-level. These effects include heat shock; cold shock; interference with fish migration; accelerated maturation of aquatic insects; and proliferated growth of aquatic nuisance species.

Nuclear power plants also affect aquatic organisms through radiological and nonradiological chemical releases. Chemical effects on aquatic biota can occur from exposure to biocides and other contaminants (e.g., heavy metals such as copper, zinc, and chromium that may be leached from condenser tubing and other heat exchangers). Blowdown from closed-cycle cooling systems can contain concentrated levels of constituents present in the makeup water, residual biocides, process contaminants, and other chemicals added for controlling corrosion or deposits (DOE 1997a). Radionuclides are released to aquatic systems at or below permitted levels at nuclear power plants (10 CFR Part 20, Appendix B). Radionuclides can be environmentally significant because they have a strong tendency to adsorb onto particles (e.g., suspended and settled solids), can accumulate in biological organisms, or can be concentrated through trophic transfers (MDNR 2019). However, exposure to radionuclides results in a dose rate to aquatic organisms of much less than 1.0 rad/d (0.1 Gy/d), which is the DOE guideline for adequate protection from the effects of ionizing radiation (DOE 2019) (see Section 4.6.1.2.9). Radionuclides, such as tritium, and other constituents in cooling water systems, such as biocides, can enter aquatic systems and be taken up by aquatic plants and animals.

The impact of any type of nuclear power plant on aquatic resources can be difficult to determine because individual organisms and populations also respond to changes in environmental conditions (EPA 2002). Table 3.6-1 lists factors that influence the impacts of nuclear power plant operation on aquatic organisms, including characteristics of the nuclear power plant itself, as well as physical and biological ecosystem factors.

**Table 3.6-1 Factors That Influence the Impacts of Nuclear Power Plant Operation on Aquatic Organisms**

| Nuclear Power Plant Factors |
|---|
| • Volume of water withdrawn from source waterbody, which generally relates to type of cooling system (e.g., once-through, cooling tower, cooling pond, or hybrid) |
| • Cooling water intake velocity |
| • Intake and discharge location (e.g., distance from shoreline, depth of intake, biological richness of area, proximity to spawning and rearing habitat) |
| • Exclusion technologies (e.g., traveling screens and mesh size, screen wash characteristics, fish return system, capture and release programs) |
| • Thermal effluent temperature when entering receiving waterbody |
| • Thermal plume characteristics (e.g., surface area, depth, isotherm contours) |
| • Mitigation strategies (e.g., helper cooling tower operation, seasonal water withdrawal reductions, timing of outages, multiport or jet diffusers that promote rapid mixing of effluent) |
| • Radiological effluents |
| • Nonradiological chemical contaminants (e.g., chlorine, heavy metals, biocides) |
| • Dredging to improve intake flow and keep intake and discharge areas clear of sediment |

| |
|---|
| • Water use conflicts with aquatic resources |
| **Physical Ecosystem Factors** |
| • Waterbody type (e.g., riverine, lacustrine, estuarine, marine)<br>• Ambient water temperatures and seasonal regimes<br>• Ambient water quality (e.g., salinity, dissolved oxygen, pollutant levels)<br>• Stream flow and tidal influence<br>• Other human-induced stressors (e.g., dams, agricultural runoff, other industrial water users) |
| **Biological Ecosystem Factors** |
| • Spatial and temporal distribution of aquatic organisms and populations<br>• Species richness and evenness<br>• Population abundances and trends<br>• Habitat and sediment types present<br>• Seasonality of habitat use and migratory patterns of species<br>• Developmental stage of organism (e.g., egg, larvae, juvenile, adult)<br>• Body size of organism<br>• Condition and health of organism<br>• Ability of organism to detect or avoid flow of water into cooling water intake system<br>• Swimming capability of organism (e.g., burst, prolonged, and sustained swimming speeds)<br>• Physiological tolerance to abiotic factors (e.g., temperature, salinity, dissolved oxygen)<br>• Reproductive strategy and characteristics (e.g., location of spawning, mode of egg and larval dispersal)<br>• Predation pressures |

### 3.6.3 Federally Protected Ecological Resources

The NRC must consider the effects of its actions on ecological resources protected under several Federal statutes and must consult with the FWS or the National Oceanic and Atmospheric Administration (NOAA) prior to taking action in cases where an agency action may affect those resources. These statutes include the following:

- Endangered Species Act of 1973, as amended (ESA) (16 U.S.C. § 1531 et seq.)
- Magnuson-Stevens Fishery Conservation and Management Act (MSA), as amended by the Sustainable Fisheries Act of 1996 (16 U.S.C. § 1801 et seq.)
- National Marine Sanctuaries Act (NMSA) (16 U.S.C. § 1431 et seq.).

• The FWS and the NOAA's National Marine Fisheries Service (NMFS) (collectively, "the Services") promulgated regulations on interagency consultation under the ESA in 1986 (51 FR 19926). Depending on when a nuclear power plant was constructed and began operating, the NRC staff may have consulted with one or both Services under the ESA during initial permitting and licensing. NMFS promulgated regulations on interagency consultation under the MSA in 2002 (67 FR 2343). Congress amended the NMSA to require interagency coordination with NOAA's Office of National Marine Sanctuaries (ONMS) in 1992 (National Marine Sanctuaries Program Amendments Act of 1992). The NRC staff did not conduct essential fish habitat (EFH) and NMSA consultations during initial permitting and licensing of any current nuclear power plants, including those that have been decommissioned or are in decommissioning, because these statutes had either not been passed or had not been amended to require consultation;

however, rare species and unique ecological habitats were often considered in project planning. The NRC staff did not conduct EFH consultation for the first several initial LR reviews because these reviews were also conducted prior to the establishment of consultation requirements.

The sections below discuss species and habitats protected under each of the three statutes and how nuclear power plant operation during an initial LR or SLR term may affect these protected resources.

#### *3.6.3.1 Endangered Species Act*

Congress enacted the ESA in 1973 to protect and recover imperiled species and the ecosystems upon which they depend. The ESA provides a program for the conservation of endangered and threatened plants and animals (collectively, “listed species”) and the habitats in which they are found. The FWS and NMFS are the lead Federal agencies for implementing the ESA, and these agencies are charged with determining species that warrant listing.

Section 7 of the ESA establishes interagency consultation requirements for actions by Federal agencies. Section 7(a)(1) of the ESA charges Federal agencies to aid in the conservation of listed species. Section 7(a)(2) of the ESA requires that Federal agencies consult with the Services for actions that “may affect” federally listed species and critical habitats and to ensure that their actions do not jeopardize the continued existence of those species or destroy or adversely modify those habitats. Private actions with a Federal nexus, such as construction and operation of facilities that involve Federal licensing or approval, are also subject to consultation. Therefore, the NRC’s issuance of initial or subsequent renewed licenses may trigger consultation requirements. Consultation pursuant to ESA Section 7(a)(2) is commonly referred to as “Section 7 consultation.”

Section 9 of the ESA prohibits any action that causes a “take” of any listed species of endangered fish or wildlife by any person or entity. Take, as defined under the ESA, means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. Likewise, import, export, interstate, and foreign commerce of listed species are all generally prohibited.

Species listings and critical habitat designations require rulemakings and are codified at 50 CFR Part 17, “Endangered and Threatened Wildlife and Plants.” As of 2022, over 700 animals and 900 plants are listed as endangered or threatened, and the Services have designated critical habitat for many of these species. Given this large number, listed species are likely to occur near all operating nuclear power plants. However, the potential for a given species to occur in the action area of a specific nuclear power plant depends on the life history, habitat requirements, and distribution of that species and the ecological environment present on or near the power plant site. The “action area” is a regulatory term. It includes all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). The action area is not limited to the footprint of the action nor is it limited by the Federal action agency's authority; rather, it is a biological determination of the reach of the proposed action on the listed species.

In general, estuarine or marine listed species may occur in the action area of plants that draw directly from estuaries or the ocean. Examples of such species include listed species of sturgeon, sea turtles, whales, and salmon. Freshwater listed species, such as mussels and pallid sturgeon (*Scaphirhynchus albus*), may occur in the action area of plants that draw directly from freshwater sources, such as rivers or Great Lakes. Listed aquatic species are generally less likely to be present in constructed habitats, such as cooling ponds or canals, that do not hydrologically connect to natural surface waters from which colonization or immigration could occur. The presence of terrestrial listed species is highly dependent upon habitat availability and quality on or near the nuclear power plant site. Northern long-eared bats (*Myotis septentrionalis*) and Indiana bats (*M. sodalis*) are widely distributed across the eastern and north central United States and may be present at any site within their ranges whose habitat provides sufficient forage, roosting, or hibernating opportunities. Likewise, listed migratory birds may seasonally inhabit the action area of a nuclear power plant whose site provides even marginal stopover habitat, especially if that site is within one of the four major North American flyways.

Table 3.6-2 and Table 3.6-5 identify critical habitats and listed species that the NRC staff, in consultation with the Services, evaluated during initial LR or SLR environmental reviews conducted since development of the 2013 LR GEIS. As part of the 19 environmental reviews identified in the tables below, the NRC staff evaluated 107 listed species and designated critical habitat of 7 listed species. Many of the same species were present in the action area of multiple nuclear power plants. The most commonly evaluated terrestrial species were northern long-eared bats (11 license renewal reviews), Indiana bat (9 reviews), piping plover (*Charadrius melodus*) (6 reviews), eastern prairie fringed orchid (*Platanthera leucophaea*) (5 reviews), and rufa red knot (*Calidris canutus rufa*) (4 reviews). The most commonly evaluated aquatic species were Atlantic sturgeon (*Acipenser oxyrinchus*) (5 reviews), shortnose sturgeon (*A. brevirostrum*) (5 reviews), and pallid sturgeon (*Scaphirhynchus albus*) (4 reviews). Notably, the NRC staff evaluated the effects of nuclear power plant license renewal on all five of the listed Atlantic sturgeon distinct population segments (DPSs) among the five evaluations of this species. All other species listed in Table 3.6-5 were evaluated in three license renewal reviews or less.

Critical habitat represents the habitat that contains the physical or biological features essential to conservation of the listed species and that may require special management considerations or protection (78 FR 53058). Critical habitat may also include areas outside the geographical area occupied by the species if the Services determine that the area itself is essential for conservation. The NRC staff evaluated the critical habitat of seven listed species among six license renewal reviews since publication of the 2013 LR GEIS. Notably, the FWS has designated much of the Turkey Point site in Florida, including the plant's artificial cooling canal system (i.e., CCS), as critical habitat for the American crocodile (*Crocodylus acutus*). At the Surry plant in Virginia, the entirety of the James River in the action area of the plant is designated as critical habitat for the Chesapeake Bay DPS of Atlantic sturgeon. The Hudson River within the action area of the Indian Point plant (no longer operating) in New York is designated critical habitat for the New York Bight DPS of Atlantic sturgeon. At the Point Beach plant in Wisconsin, the FWS has designated critical habitat for the Great Lakes population of piping plover approximately 3 mi (5 km) south of the plant site along the shoreline of Lake Michigan.

As the Services continue to evaluate species for listing and delisting, new species may be relevant to license renewal reviews and additional critical habitat designations may occur near operating nuclear power plants. This means that for a given plant, the staff may be required to evaluate different or additional listed species and critical habitats during an SLR review than the staff evaluated during the initial LR review for that same plant.

**Table 3.6-2 Critical Habitats Evaluated in License Renewal Reviews, 2013–Present**

| Nuclear Power Plant | FWS Critical Habitat | Final Effect Determination[c] | NMFS Critical Habitat | Final Effect Determination[c] |
|---|---|---|---|---|
| Grand Gulf | Louisiana black bear | NE | - | - |
| Grand Gulf | rabbitsfoot mussel[d] | NE | - | - |
| LaSalle | Indiana bat | NE | - | - |
| Indian Point[a] | - | - | Atlantic sturgeon, New York Bight DPS | NLDM |
| Turkey Point[b] | American crocodile | LDM | - | - |
| Turkey Point[b] | West Indian manatee | NLDM | - | - |
| Surry[b] | Atlantic sturgeon, Chesapeake Bay DPS | NLDM | Atlantic sturgeon, Chesapeake Bay DPS | NLDM |
| Point Beach[b] | piping plover | NE | - | - |

FWS = U.S. Fish and Wildlife Service; NMFS = U.S. National Marine Fishery Services; NE = no effect; NLDM = may affect but is not likely to destroy or adversely modify; and LDM = likely to destroy or adversely modify; DPS = distinct population segment.

(a) The evaluation of this species was a part of a review that supplemented the NRC's Final Supplemental Environmental Impact Statement (final SEIS).
(b) This review evaluated an SLR term.
(c) The effect determinations provided here are the final determinations concerning each species that resulted from consultation with the Services. In some cases, the Service's letter of concurrence revised or amended the NRC staff's original effect determinations for a given species.
(d) At the time the NRC staff performed its review, critical habitat for this species was proposed for Federal listing. The Services have now issued a final rule designating this critical habitat.

No entry has been denoted by "-".

Sources: NRC 2014e, NRC 2016d, NRC 2018e, NRC 2019c, NRC 2020f, NRC 2021f.

Listed species and critical habitats can be adversely affected by the same factors described in Sections 3.6.1 and 3.6.2 relevant to terrestrial and aquatic resources. However, the magnitude and significance of such impacts can be greater for listed species because—by virtue of being eligible for Federal listing—these species are significantly more sensitive to environmental stressors as their populations are already in decline. Similarly, critical habitats are afforded special protections because they are critical to the preservation of the listed species.

In cases where adverse effects on listed species or critical habitats are possible, the NRC staff has engaged the Services in formal ESA Section 7 consultation as part of the license renewal review and obtained a biological opinion. A biological opinion evaluates the nature and extent of effects of the action on listed species and critical habitats. It is prepared by the FWS or NMFS and documents the Service's assessment of effects on listed species and critical habitat and whether the Federal action is likely to jeopardize the continued existence of those species or result in destruction or adverse modification of critical habitat. Biological opinions may include an incidental take statement (ITS) consisting of the level of anticipated take, reasonable and prudent measures, and terms and conditions. Any take that is subject to and in compliance with an ITS is not prohibited under the ESA. Biological opinions may also include discretionary conservation recommendations.

For consultations resulting in the Service's issuance of a biological opinion, the NRC requires its licensees to comply with the ITS of the biological opinion by incorporating environmental conditions into the relevant NRC facility license(s). As conditions of NRC-issued licenses, the NRC has a continuing duty to monitor compliance at facilities with valid biological opinions. This role is performed by the NRC's Interagency Consultation Coordinator. The NRC may exclude specific ITS requirements from its license(s) if another Federal agency will require those actions be taken.

Since the publication of the 2013 LR GEIS, the Services have issued six biological opinions in connection with continued operation of nuclear power plants during an initial LR or SLR term. These biological opinions are for the Indian Point (no longer operating), Salem Nuclear Generating Station (Salem) and Hope Creek, St. Lucie Nuclear Plant (St. Lucie), Columbia, Turkey Point, and Oyster Creek (no longer operating) plants. Each biological opinion includes an ITS that allows for a specified amount of take of these species that is incidental to, and not the purpose of, carrying out the Federal action of license renewal, as well as reasonable and prudent measures and terms and conditions to minimize such take. In accordance with these requirements, these plants monitor and report the effects of continued operation under the license renewal terms to the Services and the NRC. In total, NMFS has issued biological opinions to address take of listed fish and sea turtles resulting from impingement, entrainment, or entrapment at 10 nuclear power plants. Table 3.6-3 lists the nuclear plants and relevant species to which these opinions apply. The FWS has issued one biological opinion to address the effects of operation of the Turkey Point plant. Table 3.6-4 lists the species to which this opinion applies.

**Table 3.6-3 NMFS-Issued Biological Opinions for Nuclear Power Plant Operation**

| Nuclear Power Plant | Issue Date | Species Addressed in ITS | Opinion Reference |
|---|---|---|---|
| Brunswick | January 1, 2000 | green sea turtle<br>hawksbill sea turtle<br>Kemp's ridley sea turtle<br>leatherback sea turtle<br>loggerhead sea turtle | NRC 2000 |
| Columbia | March 10, 2017 | chinook salmon, Upper Columbia River spring run<br>steelhead, Upper Columbia River | NMFS 2017 |
| Crystal River[(a)] | August 8, 2002 | green sea turtle<br>hawksbill sea turtle<br>Kemp's ridley sea turtle<br>leatherback sea turtle<br>loggerhead sea turtle | NMFS 2002 |
| Diablo Canyon | September 18, 2006 | green sea turtle<br>leatherback sea turtle<br>loggerhead sea turtle<br>olive ridley sea turtle | NMFS 2006 |
| Hope Creek[(b)] | July 17, 2014, as clarified on November 23, 2018 | none[(c)] | NMFS 2014c NMFS 2018c |
| Indian Point[(d)] | January 30, 2013, as amended on April 10, 2018, and October 5, 2020 | Atlantic sturgeon<br>shortnose sturgeon | NMFS 2013 NMFS 2018a<br>NMFS 2020a |
| Oyster Creek[(e)] | May 29, 2020 | green sea turtle<br>Kemp's ridley sea turtle<br>loggerhead sea turtle | NRC 2020b |

| Nuclear Power Plant | Issue Date | Species Addressed in ITS | Opinion Reference |
|---|---|---|---|
| Salem[(b)] | July 17, 2014, as clarified on November 23, 2018 | Atlantic sturgeon<br>shortnose sturgeon<br>green sea turtle<br>Kemp's ridley sea turtle<br>loggerhead sea turtle | NMFS 2014c NMFS 2018c |
| San Onofre[(f)] | September 18, 2006 | green sea turtle<br>leatherback sea turtle<br>loggerhead sea turtle<br>olive ridley sea turtle | NMFS 2006 |
| St. Lucie[(g)] | March 24, 2016 | green sea turtle<br>hawksbill sea turtle<br>Kemp's ridley sea turtle<br>leatherback sea turtle<br>loggerhead sea turtle<br>smalltooth sawfish | NMFS 2016 |

ITS = incidental take statement.

(a) Crystal River plant shut down in February 2013. In a letter dated January 24, 2022, NMFS (2022) confirmed that the 2002 biological opinion is no longer applicable because the plant's cooling water intake system has been repurposed and modified for the Duke Energy Citrus Combined Cycle Station and is currently compliant with the 2014 programmatic biological opinion on the EPA's final regulations implementing Section 316(b) of the CWA (FWS/NMFS 2014).

(b) As of mid-2022, the NRC is in reinitiated consultation with NMFS to address incidental take of Atlantic sturgeon and Kemp's ridley sea turtles at Salem in excess of the levels established in the ITS. At the conclusion of this consultation, NMFS will issue a new biological opinion for continued operation of Salem and Hope Creek plants under the terms of the renewed operating licenses.

(c) In its biological opinion, NMFS evaluates the potential effects of Hope Creek operations on Atlantic and shortnose sturgeon and sea turtles but does not exempt incidental take at this plant because none is anticipated.

(d) Indian Point 2 ceased power operations in April 2020, and Indian Point 3 ceased in April 2021. Certain terms and conditions of the biological opinion continue to impose requirements during the decommissioning period.

(e) Oyster Creek plant ceased power operations in September 2018. The 2020 biological opinion addresses the effects of the last several years of operation as well as decommissioning. Although NMFS's prior biological opinion, issued on November 21, 2011, allowed for incidental take of sea turtles in the form of impingement into the cooling system intake system, the 2020 biological opinion does not exempt any additional take and does not include an ITS.

(f) San Onofre plant ceased power operations in June 2013. As of mid-2022, the NRC is in reinitiated consultation with NMFS to address the potential impacts of decommissioning on federally listed species. At the conclusion of consultation, NMFS may issue a new biological opinion if it determines that take is anticipated during the decommissioning period, or NMFS may not issue a new biological opinion and conclude consultation informally if take is not anticipated.

(g) As of mid-2022, the NRC is in reinitiated consultation with NMFS to address incidental take of smalltooth sawfish, green sea turtles, and Kemp's ridley sea turtles in excess of the levels established in the ITS. Additionally, the plant collected two giant manta rays in the intake canal in 2020. At the conclusion of this consultation, NMFS will issue a new biological opinion for continued operation of St. Lucie plant under the terms of the renewed operating licenses. The new biological opinion will also address scalloped hammerhead sharks, which were listed under the ESA in 2014 and have been historically captured at St. Lucie.

**Table 3.6-4 FWS-Issued Biological Opinions for Nuclear Power Plant Operation**

| Nuclear Power Plant | Issue Date | Species Addressed in ITS | Opinion Reference |
|---|---|---|---|
| Turkey Point | July 25, 2019, as amended on March 21, 2022 | American crocodile<br>eastern indigo snake | FWS 2019a<br>FWS 2022a |

ITS = incidental take statement.

The primary concern for listed aquatic species at operating nuclear power plants is the effects associated with operation of the cooling system. Listed fish, shellfish, and sea turtles are vulnerable to impingement, entrainment, and entrapment at plants that withdraw cooling water from natural water bodies, such as rivers, estuaries, and the ocean. Open-cycle cooling systems withdraw more water, and at a typically higher velocity, than cooling-tower-based closed-cycle systems. Therefore, risk of impingement, entrainment, and entrapment is greater at these facilities.

Sea turtles are susceptible to impingement or entrapment at numerous once-through oceanic plants. For instance, at the St. Lucie plant in Florida, marine organisms can enter one of three intake pipes located in the Atlantic Ocean and be drawn into the intake canal where they become entrapped. Since operations began in the late 1970s, St. Lucie plant has collected seven listed species in its intake canal: five species of sea turtles,[1] smalltooth sawfish (*Pristis pectinata*), and giant manta rays (*Mobula birostris*). Additionally, the plant collected two scalloped hammerhead sharks (*Sphyrna lewini*) prior to the NMFS's listing of this species in 2014. The NRC (2019a) most recently evaluated the impacts of St. Lucie plant operations on federally listed species in a 2019 biological assessment prepared to support reinitiated ESA Section 7 consultation. In that assessment, the NRC found that sea turtles could become injured or die from travel through the intake pipes or from entanglement in barrier nets within the intake canal. Turtles could suffer additional stress associated with capture and release. The NRC found that smalltooth sawfish may experience minor to moderate injury because of St. Lucie's cooling water intake system. As of mid-2022, the NRC and NMFS remain in reinitiated consultation, and NMFS has not yet made a final determination of effects. Sea turtle impingement or entrapment has also occurred at six other nuclear power plants: (1) Oyster Creek in New Jersey (no longer operating); (2) Salem in New Jersey; (3) Brunswick Steam Electric Plant (Brunswick) in North Carolina; (4) Crystal River Nuclear Power Plant (Crystal River) in Florida (no longer operating); (5) Diablo Canyon in California; and (6) San Onofre (no longer operating) in California. NMFS has issued biological opinions for each of these plants to address these effects (see Table 3.6-3).

At coastal northeast plants, Atlantic and shortnose sturgeon can become impinged or entrained on trash racks, traveling screens, or other components of the cooling water intake system. NMFS has issued biological opinions for both the Salem and Indian Point (no longer operating) plants to address these effects (Table 3.6-3). At other plants, although sturgeon are in the action area, the NRC and NMFS have determined that impingement and entrainment are not likely. For instance, at the Surry plant, the NRC (2020f) found that impingement of shortnose and Atlantic sturgeon is extremely unlikely to occur during the SLR term because the life stages of sturgeon in the action area would be of sufficient size and swimming capability to resist the flow of water into Surry's low-level intake structure. The NRC (2020f) found that entrainment does not pose a risk to sturgeon because entrainable life stages do not occur in the action area. NMFS (2020b) concurred with this determination and did not issue a biological opinion for this plant.

At the Columbia plant in Washington, Upper Columbia River spring run Chinook salmon (*Oncorhynchus tshawytscha*) and Upper Columbia River steelhead (*O. mykiss*) are susceptible to impingement on the intake screens or entrainment into the intake system because these species migrate past the plant seasonally as fry, which are only a few centimeters in length at this life stage. Notably, following the license renewal review, the licensee conducted fish

[1] The species of sea turtles are green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), and Kemp's ridley (*Lepidochelys kempii*).

entrainment characterization studies that showed that very few fish of any species are entrained into Columbia's cooling water intake system due to its design, which hydraulically deflects fish from becoming trapped on or passing through the intake screens. Neither of the two listed salmon species were collected during the study. Nonetheless, because Chinook salmon fry are small and seasonally abundant in the Hanford Reach of the Columbia River, researchers estimated that one to two Chinook salmon fry could have been entrained during the two-year study period (Anchor QEA, LLC 2020). Such take, if it occurred, is allowable under the NMFS's 2017 biological opinion (see Table 3.6-3).

Effects associated with thermal effluent discharge are another primary concern for aquatic listed species and their critical habitats. Cooling water discharges are regulated by the EPA, or authorized States or Tribes, under Section 316(a) of the CWA. Thermal effluent criteria and limitations are imposed on many plants through special conditions in the site NPDES permit. Under CWA Section 316(a), EPA or the States must establish thermal effluent limitations that assure the protection and propagation of the water body's balanced, indigenous population of shellfish, fish, and wildlife. Nonetheless, thermal discharges can affect habitat availability and fish behavior or migration. For instance, if a thermal plume extends across a river, it can affect fish migration by causing individuals to exert additional energy to avoid heated water, or it can block passage altogether. In general, the NRC has found thermal effects on listed species to be insignificant or discountable, and the NMFS has concurred on these findings during consultation.

Listed terrestrial species, including bats, birds, mammals, reptiles, amphibians, and invertebrates, can be affected by habitat loss, degradation, disturbance, or fragmentation resulting from construction, refurbishment, or other site activities, including site maintenance and infrastructure repairs, during the license renewal term. In general, the NRC staff has not found habitat alternation to be of concern in past NRC license renewal reviews. Nuclear power plant sites are already fully developed to support power operations, and neither initial LR nor SLRs generally require additional development that would affect natural habitats on or surrounding the site.

Noise and vibration and general human disturbance are stressors that can disrupt normal feeding, sheltering, and breeding activities. At low noise levels or farther distances, animals initially may be startled but would likely habituate to the low background noise levels. At louder noise levels and closer range, animals would likely be startled to the point of fleeing from the area. Fleeing individuals would expend increased levels of energy and would forgo the foraging, resting, or breeding opportunities that the action area may have otherwise provided. However, listed species that use the action area of operating nuclear power plants have likely become habituated to such disturbance because these plants have been consistently operating for several decades. For instance, the NRC (2021f) found that continued disturbances during the SLR term of the Point Beach plant in Wisconsin would not cause behavioral changes in piping plovers to a degree that would be able to be meaningfully measured, detected, or evaluated or that would reach the scale where a take might occur. The FWS (2021) concurred with this determination.

Listed bats can be vulnerable to mortality or injury from collisions with plant structures and vehicles. Bat collisions with human-made structures at nuclear power plants are not well documented but are likely rare based on the available information. In an assessment of the potential effects of operation of the Davis-Besse Nuclear Power Station (Davis-Besse) plant in Ohio, the NRC (2014a) noted that four dead bats were collected at the plant during bird mortality studies conducted from 1972 through 1979. Two red bats (*Lasiurus borealis*) were collected at the cooling tower, and one big brown bat (*Eptesicus fuscus*) and one tri-colored bat (*Perimyotis subflavus*) were collected near other plant structures. During the initial LR review, the NRC (2014a) found that future collisions of bats would be extremely unlikely and, therefore, discountable given the small number of bats collected during the study and the marginal suitable habitat that the plant site provides. The FWS (FWS 2014) concurred with this determination. In a 2015 assessment associated with the Indian Point plant in New York, the NRC (2015a) determined that bat collisions were less likely to occur at the Indian Point plant than at the Davis-Besse plant because Indian Point does not have cooling towers or similarly large obstructions. The tallest structures on the Indian Point site are 134 ft (40.8 m) tall turbine buildings and 250 ft (76.2 m) tall reactor containment structures. The NRC (2015a) concluded that the likelihood of bats colliding with these and other plant structures on the Indian Point site during the license renewal period was extremely unlikely and, therefore, discountable. The FWS (2015b) concurred with this determination. In 2018, the NRC (2018a) determined that the likelihood of bats colliding with site buildings or structures on the Seabrook site in New Hampshire would be extremely unlikely. The tallest structures on that site are a 199 ft (61 m) tall containment structure and 103 ft (31 m) tall turbine and heater bay building. The FWS (2018) concurred with the NRC's determination. In 2020, the NRC (2020f) determined that the likelihood of bats colliding with site buildings or structures on the Surry site in Virginia would be extremely unlikely. The FWS (2019b) again concurred with the NRC staff's determination on the basis that activities associated with the Surry plant SLR would be consistent with the activities analyzed in the FWS's January 5, 2016, programmatic biological opinion (FWS 2016). Most recently, the NRC (2021f) determined that the likelihood of bats colliding with site buildings or structures at the Point Beach plant in Wisconsin would be extremely unlikely based on structure height and operating experience. The FWS (2021) also concurred with this determination on the basis of the FWS's 2016 programmatic biological opinion (FWS 2016).

Unlike bat collision risk, the risk of bird collisions is more species-specific and depends on the particular life history, behaviors, and flight patterns of a species. For example, in 2014, the FWS (2014) used mortality data for blackpoll warbler (*Setophaga striata*), an unlisted species, to estimate future mortality of the Kirtland's warbler (*S. kirtlandii*)[1] at the Davis-Besse site during the license renewal term because the two species are similar. Because blackpoll warblers had been collected during past bird and bat mortality studies, the FWS determined that Kirtland's warbler mortality from collisions with the site's cooling tower or meteorological tower was possible. However, the FWS estimated the total Kirtland's warbler mortality during the seasonal migratory periods over the license renewal period to be less than 0.01 birds. Therefore, the FWS determined that no take was ultimately expected, and the FWS concurred with the NRC's (2014a) determination that the likelihood of this bird colliding with nuclear power plant buildings and structures is discountable or extremely unlikely to occur. In the same review, the FWS (2014) determined that red knot collisions were also a discountable effect due to the specific habitat needs of this species and the limited number that have been observed in Ohio, and the FWS did not calculate mortality for this species.

In 2016, the NRC (NRC 2016c) found that the risk of both red knots and piping plovers colliding with plant buildings or structures at the Fermi site in Michigan would be extremely unlikely to occur. The NRC made these determinations based on species-specific factors. For red knots, the NRC made this determination because this species is rare in the action area; the last red knot observed at the Fermi site was in 1973. For piping plovers, the NRC made this determination because individuals are not likely to inhabit inland developed portions of the site

[1] At the time of this review, the Kirtland's warbler was listed as endangered. The FWS has since delisted this species due to recovery (84 FR 54436).

that contain collision hazards. Factors relevant to both species included seasonal migration periods and the absence of the two species in bird mortality surveys conducted on the site. The FWS (2015a) concurred with the NRC's determination that Fermi license renewal was not likely to adversely affect these species.

In 2021, the NRC (2021f) evaluated the risk of piping plovers colliding with nuclear power plant buildings and structures as part of the Point Beach SLR review. The staff found that tall structures are unlikely to represent a unique collision hazard for this species based on its typical flight behavior. For instance, Stantial and Cohen (2015) assessed flight heights of piping plovers in New Jersey and Massachusetts during the 2012 and 2013 breeding seasons. The researchers found that flight heights ranged from 2.3 to 34.5 ft (0.7 to 10.5 m) with a mean of 8.5 ft (2.6 m). Visually estimated flight heights ranged from 0.25 to 131 ft (0.25 to 40 m). Because piping plovers fly relatively low to the ground, they are acclimated to navigating various natural and human-made flight hazards, and tall structures on nuclear power plant sites are unlikely to create an additional risk. Even in the case of wind turbines, which have moving components, researchers found that collision hazards at five wind facilities in New England during the piping plover breeding season—assuming constant turbine operation—ranged from 0.06 to 2.27 collisions per year for a single large turbine (41 m radius), 0.03 to 0.99 for a single medium turbine (22.5 m radius), and 0.01 to 0.29 for a single small turbine (9.6 m radius) (Stantial 2014). With respect to vehicle collision hazards, Stantial and Cohen (2015) determined the average calculated flight speed of piping plovers to be 30.5 fps (9.3 m/s). The high speed at which piping plovers can fly makes them unlikely to collide with nuclear power plant site vehicles, especially given that posted speed limits are generally low throughout these sites. The FWS (2021) concurred with these findings for Point Beach SLR.

**Table 3.6-5 ESA Listed Species Evaluated in License Renewal Reviews, 2013–Present**

| Nuclear Power Plant | FWS Species[c] | Final Effect Determination[d] | NMFS Species[c] | Final Effect Determination[d] |
|---|---|---|---|---|
| Seabrook | piping plover (*Charadrius melodus)* | NLAA | Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), Gulf of Maine DPS[g] | NLAA |
| Seabrook | roseate tern (*Sterna dougallii*) | NLAA | fin whale (*Balaenoptera physalus*) | NLAA |
| Seabrook | - | | humpback whale (*Megaptera novaeangliae*) | NLAA |
| Seabrook | - | | Kemp's ridley sea turtle (*Lepidochelys kempii*) | NLAA |
| Seabrook | - | | leatherback sea turtle (*Dermochelys coriacea*) | NLAA |
| Seabrook | - | | loggerhead sea turtle (*Caretta caretta*) | NLAA |
| Seabrook | - | | North Atlantic right whale (*Eubalaena glacialis*) | NLAA |
| Seabrook | - | | Shortnose sturgeon (*Acipenser brevirostrum*) | NLAA |
| South Texas | American alligator (*Alligator mississipiensis*) | N/A | green sea turtle (*Chelonia mydas*)[e] | NE |
| South Texas | Eskimo curlew (*Numenius borealis*) | NE | hawksbill sea turtle (*Eretmochelys imbricata*) | NE |
| South Texas | Louisiana black bear (*Ursus americanus luteolus*) | NE | Kemp's ridley sea turtle | NE |
| South Texas | northern aplomado falcon (*Falco femoralis septentrionalis*) | NLAA | leatherback sea turtle | NE |
| South Texas | ocelot (*Leopardus pardalis*) | NE | loggerhead sea turtle[e] | NE |
| South Texas | piping plover | NE | smalltooth sawfish (*Pristis pectinata*), U.S. DPS | NE |
| South Texas | Red wolf (*Canis rufus*) | NE | - | - |
| South Texas | smooth pimpleback (*Quadrula houstonensis*)[f] | NE | - | - |
| South Texas | Texas fawnsfoot (*Truncilla macrodon*)[f] | NE | - | - |
| South Texas | West Indian manatee (*Trichechus manatus*) | NE | - | - |

| Nuclear Power Plant | FWS Species(c) | Final Effect Determination(d) | NMFS Species(c) | Final Effect Determination(d) |
|---|---|---|---|---|
| South Texas | whooping crane (*Grus americana*) | NE | - | - |
| Limerick | bog turtle (*Clemmys muhlenbergii*) | NE | Atlantic sturgeon, New York Bight DPS | NE |
| Limerick | Dwarf wedgemussel (*Alasmidonta heterodon*) | NE | shortnose sturgeon | NE |
| Limerick | Indiana bat | NE | - | |
| Limerick | small whorled pogonia (*Isotria medeoloides*) | NE | - | - |
| Grand Gulf | American black bear (*Ursus americanus*) | NLAA | none | - |
| Grand Gulf | bayou darter (*Etheostoma rubrum*) | NLAA | - | - |
| Grand Gulf | fat pocketbook mussel (*Potamilus capax*) | NE | - | - |
| Grand Gulf | least tern (*Sterna antillarum*), Interior population | NE | - | - |
| Grand Gulf | Louisiana black bear | NLAA | - | - |
| Grand Gulf | pallid sturgeon (*Scaphirhynchus albus*) | NLAA | - | - |
| Grand Gulf | rabbitsfoot mussel (Quadrula cylindrica cylindrica)(g) | NE | - | - |
| Grand Gulf | red-cockaded woodpecker (*Picoides borealis*) | NE | - | - |
| Grand Gulf | wood stork (*Mycteria americana*) | NE | - | - |
| Callaway | gray bat (*Myotis grisescens*) | NE | none | - |
| Callaway | Indiana bat (*Myotis sodalis*) | NLAA | - | - |
| Callaway | Niangua darter (*Etheostoma nianguae*) | NE | - | - |
| Callaway | pallid sturgeon | NLAA | - | - |
| Callaway | pink mucket (*Lampsilis abrupta*) | NLAA | - | - |
| Callaway | running buffalo clover (*Trifolium stoloniferum*) | NE | - | - |
| Callaway | scaleshell (*Leptodea leptodon*) | NLAA | - | - |
| Callaway | spectaclecase (*Cumberlandia monodonta*) | NLAA | - | - |
| Callaway | Topeka shiner (*Notropis topeka*) | NE | - | - |

| Nuclear Power Plant | FWS Species[c] | Final Effect Determination[d] | NMFS Species[c] | Final Effect Determination[d] |
|---|---|---|---|---|
| Davis-Besse | eastern prairie fringed orchid (*Platanthera leucophaea*) | NE | none | - |
| Davis-Besse | Indiana bat | NLAA | - | - |
| Davis-Besse | Kirtland's warbler (*Setophaga kirtlandii*)[h] | NLAA | - | - |
| Davis-Besse | lakeside daisy (*Hymenopsis herbacea*) | NE | - | - |
| Davis-Besse | northern long-eared bat (*Myotis septentrionalis*) | NLAA | - | - |
| Davis-Besse | piping plover, Great Lakes watershed population | NLAA | - | - |
| Davis-Besse | rufa red knot (*Calidris canutus rufa*)[g] | NLAA | - | - |
| Sequoyah | dromedary pearlymussel (*Dromus dromas*) | NE | none | - |
| Sequoyah | gray bat | NE | - | - |
| Sequoyah | Indiana bat | NE | - | - |
| Sequoyah | large-flowered skullcap (*Scutellaria montana*) | NE | - | - |
| Sequoyah | northern long-eared bat | NE | - | - |
| Sequoyah | orangefoot pimpleback (*Plethobasus cooperianus*) | NE | - | - |
| Sequoyah | pink mucket | NE | - | - |
| Sequoyah | rough pigtoe (*Pleurobema plenum*) | NE | - | - |
| Sequoyah | small whorled pogonia | NE | - | - |
| Sequoyah | snail darter (*Percuba tanasi*) | NE | - | - |
| Sequoyah | Virginia spirarea (*Spiraea virginiana*) | NE | - | - |
| Byron | eastern prairie fringed orchid | NE | none | - |
| Byron | Indiana bat | NE | - | - |
| Byron | leafy prairie clover (*Dalea foliosa*) | NE | - | - |
| Byron | northern long-eared bat | NE | - | - |
| Byron | prairie bush clover (*Lespedeza leptostachya*) | NE | - | - |

| Nuclear Power Plant | FWS Species[c] | Final Effect Determination[d] | NMFS Species[c] | Final Effect Determination[d] |
|---|---|---|---|---|
| Braidwood | eastern massasauga (Sistrurus catenatus)[g] | NE | none | - |
| Braidwood | eastern prairie fringed orchid | NE | - | - |
| Braidwood | Hine's emerald dragonfly (*Somatochlora hineana*) | NE | - | - |
| Braidwood | lakeside daisy | NE | - | - |
| Braidwood | leafy prairie clover | NE | - | - |
| Braidwood | Mead's milkweed (*Asclepias meadii*) | NE | - | - |
| Braidwood | northern long-eared bat | NE | - | - |
| Braidwood | sheepnose mussel (*Plethobasus cyphyus*) | NLAA | - | - |
| Braidwood | snuffbox (*Epioblasma triquetra*) | NE | - | - |
| Fermi | eastern massasauga[g] | NE | none | - |
| Fermi | eastern prairie fringed orchid | NLAA | - | - |
| Fermi | Indiana bat | NLAA | - | - |
| Fermi | Karner blue butterfly (*Lycaeides melissa samuelis*) | NE | - | - |
| Fermi | northern long-eared bat | NLAA | - | - |
| Fermi | northern riffleshell (*Epioblasma torulosa rangiana*) | NE | - | - |
| Fermi | piping plover | NLAA | - | - |
| Fermi | rayed bean (*Villosa fabalis*) | NE | - | - |
| Fermi | rufa red knot | NLAA | - | - |
| Fermi | Snuffbox | NE | - | - |
| LaSalle | decurrent false aster (*Boltonia decurrens*) | NE | none | - |
| LaSalle | eastern prairie fringed orchid | NE | - | - |
| LaSalle | Indiana bat | NE | - | - |
| LaSalle | leafy prairie clover | NE | - | - |
| LaSalle | northern long-eared bat | NE | - | - |
| LaSalle | sheepnose mussel | NE | - | - |

| Nuclear Power Plant | FWS Species[c] | Final Effect Determination[d] | NMFS Species[c] | Final Effect Determination[d] |
|---|---|---|---|---|
| Indian Point[a] | bog turtle | NE | Atlantic sturgeon, New York Bight, Gulf of Maine, and Chesapeake Bay DPSs | LAA |
| Indian Point[a] | Indiana bat | NLAA | shortnose sturgeon | LAA |
| Indian Point[a] | northern long-eared bat | NLAA | - | |
| River Bend | pallid sturgeon | NLAA | none | |
| Waterford | gulf sturgeon (*Acipenser oxyrinchus desotoi*) | NE | none | - |
| Waterford | pallid sturgeon | NLAA | - | - |
| Waterford | West Indian manatee | NE | - | - |
| Turkey Point[b] | American alligator | N/A | green sea turtle, North Atlantic and South Atlantic DPSs | NLAA |
| Turkey Point[b] | American crocodile (*Crocodylus acutus*) | LAA | hawksbill sea turtle | NLAA |
| Turkey Point[b] | Bachman's warbler (*Vermivora bachmani*) | NE* | leatherback sea turtle | NLAA |
| Turkey Point[b] | Bartram's hairstreak butterfly (*Strymon acis bartrami*) | NE* | loggerhead sea turtle[e] | NLAA |
| Turkey Point[b] | beach jacquemontia (*Jacquemontia reclinata*) | NE* | smalltooth sawfish, U.S. DPS | NLAA |
| Turkey Point[b] | Blodgett's silverbush (*Argythamnia blodgettii*) | NLAA | - | - |
| Turkey Point[b] | Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) | NE* | - | - |
| Turkey Point[b] | Cape Sable thoroughwort (*Chromolaena frustrata*) | NLAA | - | - |
| Turkey Point[b] | Carter's mustard (*Warea carteri*) | NE* | - | - |
| Turkey Point[b] | Carter's small-flowered flax (*Linum carteri carteri*) | NE* | - | - |
| Turkey Point[b] | crenulate lead-plant (*Amorpha crenulata*) | NE* | - | - |
| Turkey Point[b] | deltoid spurge (*Chamaesyce deltoidea deltoidea*) | NE* | - | - |
| Turkey Point[b] | eastern indigo snake (*Drymarchon corais couperi*) | LAA | - | - |

| Nuclear Power Plant | FWS Species[c] | Final Effect Determination[d] | NMFS Species[c] | Final Effect Determination[d] |
|---|---|---|---|---|
| Turkey Point[b] | Everglades bully (*Sideroxylon reclinatum austrofloridense*) | NE* | - | - |
| Turkey Point[b] | Everglades snail kite (*Rostrhamus sociabilis*) | NLAA | - | - |
| Turkey Point[b] | Florida bonneted bat (*Eumops floridanus*) | NLAA | - | - |
| Turkey Point[b] | Florida brickell-bush (*Brickellia mosieri*) | NE* | - | - |
| Turkey Point[b] | Florida bristle fern (*Trichomanes punctatum floridanum*) | NLAA | - | - |
| Turkey Point[b] | Florida grasshopper sparrow (*Ammodramus savannarum*) | NE* | - | - |
| Turkey Point[b] | Florida leafwing butterfly (*Anaea troglodyta floridalis*) | NE* | - | - |
| Turkey Point[b] | Florida panther (*Puma concolor coryi*) | NLAA | - | - |
| Turkey Point[b] | Florida pinelands crabgrass (*Digitaria pauciflora*) | NE* | - | - |
| Turkey Point[b] | Florida prairie-clover (*Dalea carthagenensis floridana*) | NE* | - | - |
| Turkey Point[b] | Florida scrub-jay (*Aphelocoma coerulescens*) | NE* | - | - |
| Turkey Point[b] | Florida semaphore cactus (*Consolea corallicola*) | NLAA | - | - |
| Turkey Point[b] | Garber's spurge (*Chamaesyce garberi*) | NE* | - | - |
| Turkey Point[b] | ivory-billed woodpecker (*Campephilus principalis*) | NE* | - | - |
| Turkey Point[b] | Kirtland's warbler[h] | NLAA | - | - |
| Turkey Point[b] | Miami blue butterfly (*Cyclargus thomasi bethunebakeri*) | NE* | - | - |
| Turkey Point[b] | Okeechobee gourd (*Cucurbita okeechobeensis okeechobeensis*) | NE* | - | - |
| Turkey Point[b] | pineland sandmat (*Chamaesyce deltoidea pinetorum*) | NE* | - | - |
| Turkey Point[b] | piping plover | NLAA | - | - |

| Nuclear Power Plant | FWS Species(c) | Final Effect Determination(d) | NMFS Species(c) | Final Effect Determination(d) |
|---|---|---|---|---|
| Turkey Point(b) | puma (*Puma concolor*), all subspecies except *coryi* | N/A | - | - |
| Turkey Point(b) | red-cockaded woodpecker | NE* | - | - |
| Turkey Point(b) | rufa red knot | NLAA | - | - |
| Turkey Point(b) | sand flax (*Linum arenicola*) | NLAA | - | - |
| Turkey Point(b) | Schaus swallowtail butterfly (*Heraclides aristodemus ponceanus*) | NE* | - | - |
| Turkey Point(b) | Small's milkpea (*Galactia smallii*) | NE* | - | - |
| Turkey Point(b) | Stock Island tree snail (*Orthalicus reses*) | NE* | - | - |
| Turkey Point(b) | tiny polygala (*Polygala smallii*) | NE* | - | - |
| Turkey Point(b) | West Indian manatee | NLAA | - | - |
| Turkey Point(b) | wood stork | NLAA | - | - |
| Surry(b) | northern long-eared bat | NLAA | Atlantic sturgeon, Chesapeake Bay DPS | NLAA |
| Surry(b) | | | shortnose sturgeon | NLAA |
| Peach Bottom(b) | Atlantic sturgeon, Chesapeake Bay DPS | NE | *none* | - |
| Peach Bottom(b) | bog turtle | NE | - | - |
| Peach Bottom(b) | Chesapeake logperch (*Percina bimaculata*)(i) | LAA | - | - |
| Peach Bottom(b) | Indiana bat | NLAA | - | - |
| Peach Bottom(b) | northern long-eared bat | NLAA | - | - |
| Peach Bottom(b) | rufa red knot | NE | - | - |
| Peach Bottom(b) | shortnose sturgeon | NE | - | - |
| North Anna(b) | Atlantic pigtoe (*Fusconaia masoni*) | NE* | none | - |
| North Anna(b) | dwarf wedgemussel | NE* | - | - |
| North Anna(b) | green floater (*Lasmigona subviridis*) | NE* | - | - |

| Nuclear Power Plant | FWS Species[c] | Final Effect Determination[d] | NMFS Species[c] | Final Effect Determination[d] |
|---|---|---|---|---|
| North Anna[b] | James spineymussel (*Pleurobema collina*) | NE* | - | - |
| North Anna[b] | northern long-eared bat | NLAA | - | - |
| North Anna[b] | small whorled pogonia | NE* | - | - |
| Point Beach[b] | dwarf lake iris (*Iris lacustris*) | NE* | none | - |
| Point Beach[b] | Hine's emerald dragonfly | NE* | - | - |
| Point Beach[b] | northern long-eared bat | NLAA | - | - |
| Point Beach[b] | piping plover | NLAA | - | - |
| Point Beach[b] | Pitcher's thistle (*Cirsium pitcheri*) | NE* | - | - |
| Point Beach[b] | rusty patched bumblebee (*Bombus affinis*) | NE* | - | - |

FWS = U.S. Fish and Wildlife Service; NMFS = U.S. National Marine Fisheries Service; NE = no effect; NLAA = may affect but is not likely to adversely affect; and LAA = likely to adversely affect; DPS = distinct population segments.
(a) The evaluation of this species was a part of a review that supplemented the NRC's final SEIS.
(b) This review evaluated an SLR term.
(c) This table omits species that were candidates or proposed for Federal listing at the time of the NRC staff's review but for which the Services later determined that listing was not warranted.
(d) The effect determinations provided here are the final determinations concerning each species that resulted from consultation with the Services. In some cases, the Service's letter of concurrence revised or amended the NRC staff's original effect determinations for a given species. For certain species, the NRC staff determined that the species was not present in the action area. Accordingly, potential effects to these species were not evaluated in detail because there would be none. Effect determinations for these species are designated in this table as NE*.
(e) At the time the NRC staff performed its review, NMFS had not yet designated DPSs for this species.
(f) At the time the NRC staff performed its review, this species was a candidate for Federal listing. The Services have now issued a proposed rule to list the species.
(g) At the time the NRC staff performed its review, this species was a candidate species or was proposed for Federal listing. The Services have now issued a final rule listing the species.
(h) This species has been delisted since the NRC staff performed its review.
(i) At the time the NRC staff performed its review, this species was under review for Federal listing. It remains under review at this time.
No entry has been denoted by "-".
Sources: NRC 2015b, NRC 2013b, NRC 2014d, NRC 2014e, NRC 2014f, NRC 2015e, NRC 2015f, NRC 2015c, NRC 2015d, NRC 2016c, NRC 2016d, NRC 2018e, NRC 2018c, NRC 2018d, NRC 2019c, NRC 2020f, NRC 2020g, NRC 2021g, NRC 2021f

### *3.6.3.2 Magnuson-Stevens Fishery Conservation and Management Act*

Congress enacted the MSA in 1976 to foster long-term biological and economic sustainability of the Nation's marine fisheries. The MSA is a comprehensive, multi-purpose statute. Its key objectives include preventing overfishing, rebuilding overfished stocks, increasing long-term economic and social benefits, and ensuring a safe and sustainable supply of seafood. NOAA, together with eight regional Fishery Management Councils established under the act, implement the provisions of the MSA.

The MSA directs the Fishery Management Councils, in conjunction with NMFS, to designate areas of EFH and to manage marine resources within those areas. EFH is defined as the coastal and marine waters and substrate necessary for fish to spawn, breed, feed, or grow to maturity (50 CFR 600.10). The NMFS further defines "waters," "substrate," and "necessary" at 50 CFR 600.10. EFH applies to federally managed finfish and shellfish (herein referred to as "EFH species"). As of 2022, the Councils and NMFS have designated EFH for nearly 1,000 species at multiple life stages.

The Fishery Management Councils may also designate some EFH as habitat areas of particular concern (HAPC) if that habitat exhibits one or more of the following traits: rare, stressed by development, possessing important ecological functions for EFH species, or especially vulnerable to anthropogenic degradation. HAPCs can cover a specific location (e.g., an estuary bank or a single spawning location) or cover habitat type that is found at many locations (e.g., coral, nearshore nursery areas, or pupping grounds). HAPC designation does not convey additional restrictions or protections on an area. The designation simply focuses on increased scrutiny, study, or mitigation planning compared to surrounding areas because HAPCs represent high-priority areas for conservation, management, or research and are necessary for healthy ecosystems and sustainable fisheries. The Fishery Management Councils may, however, restrict the use or possession of fishing gear types within HAPCs. The geographic boundaries of HAPCs are subject to refinement through amendments, as research better informs management decisions (NOAA 2020).

Section 305(b) of the MSA contains interagency consultation requirements pertaining to Federal agencies and their actions. Under MSA Section 305(b)(2), Federal agencies must consult with NMFS for actions that may adversely affect EFH. Private actions with a Federal nexus, such as construction and operation of facilities that involve Federal licensing or approval, are also subject to consultation. Therefore, the NRC's issuance of initial or subsequent renewed licenses may trigger consultation requirements. Consultation pursuant to MSA Section 305(b) is commonly referred to as "EFH consultation."

EFH includes the substrate and benthic resources (e.g., submerged aquatic vegetation, shellfish beds, salt marsh wetlands, etc.), as well as the water column and prey species. NMFS defines "adverse effects" under the MSA as (50 CFR 600.810):

> …any impact that reduces quality and/or quantity of EFH. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH. Adverse effects to EFH may result from actions occurring within EFH or outside of EFH and may include site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions.

Further, in 50 CFR 600.815(a)(7), adverse effects on EFH resulting from prey loss are described as follows:

> Loss of prey may be an adverse effect on EFH and managed species because the presence of prey makes waters and substrate function as feeding habitat, and the definition of EFH includes waters and substrate necessary to fish for feeding. Therefore, actions that reduce the availability of a major prey species, either through direct harm or capture, or through adverse impacts to the prey species' habitat that are known to cause a reduction in the population of the prey species, may be considered adverse effects on EFH if such actions reduce the quality of EFH.

Notably, EFH is assessed in terms of impacts on the habitat of the EFH species rather than on the species itself. Therefore, the physical removal of habitat through cooling water withdrawals is an impact on EFH, whereas impingement and entrainment are not. Continued operation of a nuclear power plant during an initial LR or SLR term may cause the following adverse effects in the area:

- physical removal of habitat through cooling water withdrawals,
- physical alteration of habitat through heated effluent discharges,
- chemical alteration of habitat through radionuclides and other contaminants in heated effluent discharges,
- physical removal of habitat through maintenance dredging, and
- reduction in the prey base of the habitat.

EFH may occur at nuclear power plants located on or near estuaries, coastal inlets and bays, and the ocean. The MSA applies to marine and diadromous species. Therefore, EFH is generally not relevant for license renewal reviews of plants located on rivers well above the saltwater interface or confluence with marine waters; plants located on freshwater lakes, including the Great Lakes; or at plants that draw cooling water from human-made cooling ponds or canals that do not hydrologically connect to natural surface waters. One exception is in cases where a plant draws cooling water from the freshwater portion of a river that is inhabited by diadromous prey of EFH species with designated EFH downstream of the plant. By definition, adverse effects may occur outside of EFH, and loss of prey may be an adverse effect (see regulatory definitions above).

The Limerick plant in Pennsylvania is an example where prey loss was relevant to the license renewal review although the plant itself is not located near designated EFH. Limerick withdraws cooling water from the Schuylkill River and Perkiomen Creek and discharges heated effluent to the Schuylkill River. In cases where the natural flow of Perkiomen Creek is not adequate to supply cooling water to Limerick, the plant augments flow from the Delaware River to Perkiomen Creek. Although these waterways do not contain designated EFH, they provide habitat for anadromous fish consumed by several EFH species (bluefish [*Pomatomus saltatrix*], windowpane flounder [*Scophthalmus aquosus*], summer flounder [*Paralichthys dentatus*], and winter skate [*Leucoraja ocellata*]). These four species have designated EFH in the mixing zone of the Delaware River downstream from the Limerick plant. Prey of these species, such as *Alosa* species (e.g., American shad and river herring), spawn in freshwater and migrate to marine waters as juveniles. During migration, individuals pass through areas of designated EFH. Therefore, loss of *Alosa* individuals through impingement and entrainment at the Limerick plant has the potential to affect the abundance of prey downstream in the mixing zone, which could affect the quality of this EFH as feeding habitat. Based on this reasoning, NMFS recommended that the NRC engage in EFH consultation during the license renewal review. The NRC (2014b) prepared an EFH assessment that addressed these and other relevant effects. The NRC staff concluded that the Limerick license renewal would have minimal adverse effects on EFH for juveniles and adults of the four EFH species. Subsequently, NMFS (2014b) provided the NRC with EFH conservation recommendations, and the NRC (2014g) responded to these recommendations, which concluded EFH consultation.

The NRC staff also assessed prey loss for SLR of the Peach Bottom plant in Pennsylvania. During that review, the NRC (NRC 2020g) found that SLR would have no direct effects on the EFH of any species because no designated EFH is present in Conowingo Pond. All potential adverse impacts on EFH would be limited to loss of prey for those EFH species that consume anadromous prey species that migrate through Conowingo Pond. Anadromous prey fish, such as *Alosa* species, have been rare in collections associated with Conowingo Pond aquatic studies. None of the available studies or other information indicate that impingement, entrainment, thermal effects, or indirect impacts on the habitat of prey species would be noticeably affected as a result of SLR. Accordingly, no adverse effects on EFH would result from loss of prey, and the NRC staff concluded that the proposed action would have no adverse effects on the designated EFH for little skate, windowpane flounder, or winter skate.

Table 3.6-6 identifies EFH species and life stages whose EFH the NRC staff, in consultation with NMFS, evaluated during initial LR and SLR environmental reviews conducted since publication of the 2013 LR GEIS.[1] During this period, EFH was relevant to six reviews, and the NRC staff evaluated the EFH of 37 species among these reviews. Atlantic herring (*Clupea harengus*), Atlantic butterfish (*Peprilus triacanthus*), summer flounder, winter flounder (*Pleuronectes americanus*), and winter skate were the most prevalently evaluated EFH species.

In most cases, the NRC staff concluded that license renewal would result in no adverse effects or minimal adverse effects on EFH. For two EFH species, silver hake (*Merluccius bilinearis*) and winter flounder, the NRC concluded that license renewal would result in more than minimal but less than substantial adverse effects. The NRC (2015b) made this determination for all life stages of silver hake and larvae, juveniles, and adults of winter flounder as a result of the Seabrook plant license renewal. This was based on the effects of impingement, entrainment, and thermal effluents on these species' habitat.

[1] Prior to the 2013 LR GEIS, the NRC assessed EFH as part of seven license renewal environmental reviews: Oyster Creek (no longer operating); (2) Brunswick; (3) Pilgrim in Massachusetts (no longer operating); (4) Vermont Yankee in New York (no longer operating); (5) Indian Point (no longer operating); (6) Salem and Hope Creek; and (7) Crystal River in Florida (no longer operating). These are not described in detail in the 2013 LR GEIS. See the plant-specific SEISs for more information about these EFH consultations. The NRC has also prepared EFH assessments and conducted EFH consultation with NMFS for extended power uprates at the Hope Creek (NRC 2007a) and St. Lucie (NRC 2012c) plants.

1 **Table 3.6-6 EFH Evaluated in License Renewal Reviews, 2013–Present**

| Nuclear Power Plant | Species | Life Stage(s)[(b)] | Final Effect Determination[(c)] |
|---|---|---|---|
| Seabrook | American angler fish (*Lophius americanus*) | E, L, J | MAE |
| Seabrook | American angler fish | A | NAE |
| Seabrook | American plaice (*Hippoglossoides platessoides*) | J, A | NAE |
| Seabrook | Atlantic butterfish (*Peprilus triacanthus*) | E, L, J, A | NAE |
| Seabrook | Atlantic cod (*Gadus morhua*) | E | NAE |
| Seabrook | Atlantic cod | L, J, A | MAE |
| Seabrook | Atlantic halibut (*Hippoglossus hippoglossus*) | E, L | NAE |
| Seabrook | Atlantic halibut | J, A | MAE |
| Seabrook | Atlantic herring (*Clupea harengus*) | J, A | MAE |
| Seabrook | Atlantic mackerel (*Scomber scombrus*) | E, A | MAE |
| Seabrook | Atlantic mackerel | L, J | NAE |
| Seabrook | Atlantic sea scallop (*Placopecten magellanicus*) | E, L, A | NAE |
| Seabrook | Atlantic sea scallop | J | MAE |
| Seabrook | Atlantic surf clam (*Spisula solidissima*) | J, A | NAE |
| Seabrook | bluefin tuna (*Thunnus thynnus*) | A | NAE |
| Seabrook | haddock (*Melanogrammus aeglefinus*) | J | NAE |
| Seabrook | longfin inshore squid (*Loligo pealei*) | J, A | NAE |
| Seabrook | northern shortfin squid (*Illex illecebrosus*) | J, A | NAE |
| Seabrook | ocean pout (*Macrozoarces americanus*) | E, L, A | NAE |
| Seabrook | ocean pout | J | MAE |
| Seabrook | pollock (*Pollachius virens*) | J | MAE |
| Seabrook | red hake (*Urophycis chuss*) | E, L, J, A | MAE |
| Seabrook | redfish (*Sebastes fasciatus*) | L | NAE |
| Seabrook | Redfish | J, A | MAE |
| Seabrook | scup (*Stenotomus chrysops*) | J, A | NAE |
| Seabrook | silver hake (*Merluccius bilinearis*) | E, L, J, A | LSA |
| Seabrook | summer flounder (*Paralicthys dentatus*) | A | MAE |
| Seabrook | windowpane flounder (*Scopthalmus aquosus*) | J, A | MAE |
| Seabrook | winter flounder (*Pleuronectes americanus*) | E | NAE |
| Seabrook | winter flounder | L, J, A | LSA |
| Seabrook | yellowtail flounder *(Pleuronectes ferruginea*) | J, A | MAE |
| Columbia | coho salmon (*Oncorhynchus kisutch*) | - | MAE |
| Columbia | Upper Columbia River Chinook salmon (*Oncorhynchus tshawytscha*) | - | MAE |
| Limerick | American plaice | J | NAE |
| Limerick | Atlantic butterfish | J | NAE |
| Limerick | Atlantic herring | J | NAE |
| Limerick | black sea bass (*Centropristus striata*) | J | NAE |

| Nuclear Power Plant | Species | Life Stage(s)[b] | Final Effect Determination[c] |
|---|---|---|---|
| Limerick | bluefish (*Pomatomus saltatrix*) | J, A | MAE |
| Limerick | Scup | J | NAE |
| Limerick | summer flounder | J, A | MAE |
| Limerick | windowpane flounder | J, A | MAE |
| Limerick | winter flounder | J, A | MAE |
| Limerick | winter skate (*Leucoraja ocellata*) | J, A | MAE |
| Turkey Point[a] | gray snapper (*Lutjanus griseus*) | J, A | NE |
| Turkey Point[a] | mutton snapper (*Lutianus analis*) | J | NE |
| Turkey Point[a] | pink shrimp (*Farfantepenaeus duorarum*) | - | NE |
| Turkey Point[a] | spiny lobster (*Panulirus argus*) | - | NE |
| Turkey Point[a] | white grunt (*Haemulon plumieri*) | A | NE |
| Surry[a] | Atlantic butterfish | J, A | MAE |
| Surry[a] | Atlantic herring | - | NAE |
| Surry[a] | black sea bass | - | NAE |
| Surry[a] | Bluefish | J | MAE |
| Surry[a] | clearnose skate (*Raja eglanteria*) | - | NAE |
| Surry[a] | little skate (*Urophycis chuss*) | (P) | MAE |
| Surry[a] | red hake | - | NAE |
| Surry[a] | summer flounder | L, J, A | MAE |
| Surry[a] | windowpane flounder | J, A | MAE |
| Surry[a] | winter skate | (P) | MAE |
| Peach Bottom[a] | Atlantic herring | J, A | NE |
| Peach Bottom[a] | clearnose skate | J, A | NE |
| Peach Bottom[a] | little skate | E, L, J, A | NAE |
| Peach Bottom[a] | red hake | A | NE |
| Peach Bottom[a] | windowpane flounder | A | NAE |
| Peach Bottom[a] | winter skate | J, A | NAE |

(a) This review evaluated an SLR term.
(b) EFH is designated by life stage. E = eggs; L = larvae; J = juveniles; A = adults; (P) = prey of EFH species.
(c) The effect determinations provided here are the final determinations concerning each species that resulted from consultation with NMFS. NE = no effect; NAE = no adverse effects; MAE = minimal adverse effects; LSA = more than minimal but less than substantial adverse effects; and SAA = substantial adverse effects.
No entry has been denoted by "-".
Sources: NRC 2015b, NRC 2012a, NRC 2014b, NRC 2019c, NRC 2020f, NRC 2020g.

### *3.6.3.3 National Marine Sanctuaries Act*

Congress enacted the NMSA in 1972 to protect areas of the marine environment that have special national significance. The NMSA authorizes the Secretary of Commerce to establish the National Marine Sanctuary System and designate sanctuaries within that system. ONMS is charged with comprehensively managing this system, which includes 15 sanctuaries and the Papahānaumokuākea and Rose Atoll marine national monuments, encompassing more than 600,000 square miles of marine and Great Lakes waters from Washington State to the Florida

Keys, and from Lake Huron to American Samoa. Within these areas, sanctuary resources include any living or nonliving resource of a national marine sanctuary that contributes to the conservation, recreational, ecological, historical, educational, cultural, archaeological, scientific, or aesthetic value of the sanctuary. As of 2022, four additional sanctuaries are proposed for designation. Figure 3.6-1 depicts the locations of designated and proposed marine sanctuaries and marine national monuments. Maps of designated and proposed sanctuaries are available at: https://sanctuaries.noaa.gov/about/maps.html.


**Figure 3.6-1 National Marine Sanctuaries and Marine National Monuments. Source: NOAA 2022a.**

In 1992, Congress amended the NMSA to require interagency coordination. Pursuant to Section 304(d) of the NMSA, Federal agencies must consult with ONMS when their proposed actions are likely to destroy, cause the loss of, or injure a sanctuary resource. Private actions with a Federal nexus, such as construction and operation of facilities that involve Federal licensing or approval, are also subject to consultation. Therefore, the NRC's issuance of initial or subsequent renewed licenses may trigger consultation requirements. Consultation pursuant to NMSA Section 304(d) is commonly referred to as "NMSA consultation."

Currently, five operating nuclear power plants are located near designated or proposed national marine sanctuaries (see Table 3.6-7). Notably, this is a snapshot; the geographic extent of existing sanctuaries may change or expand in the future, and NOAA is likely to designate new sanctuaries as additional areas of conservation need are identified and assessed. National marine sanctuary advisory councils, which are community-based advisory groups, actively help ONMS determine whether additional areas warrant statutory protection. For instance, the advisory council for the Flower Garden Banks National Marine Sanctuary coordinated with ONMS to recommend expanding this sanctuary to include certain sensitive underwater features and marine biodiversity hotspots in the northwestern Gulf of Mexico. In 2021, NOAA published a final rule that added 14 additional shelf-edge reefs and banks off the coasts of Texas and Louisiana to this sanctuary (86 FR 4937). The Wisconsin Shipwreck Coast National Marine Sanctuary in western Lake Michigan is also a recent designation. NOAA designated this sanctuary in 2021 (86 FR 45860). As described further below, the Point Beach plant is located near this sanctuary.

**Table 3.6-7 National Marine Sanctuaries Near Operating Nuclear Power Plants**

| Sanctuary Name | Location | Nearby Nuclear Power Plants |
|---|---|---|
| Lake Ontario[(a)] | Eastern Lake Ontario and a segment of the Thousand Islands region of the St. Lawrence River | Ginna, Nine Mile Point, FitzPatrick |
| Wisconsin Shipwreck Coast | Western Lake Michigan bordering Wisconsin | Point Beach |
| Florida Keys | Florida Keys from south of Miami westward to encompass the Dry Tortugas, excluding Dry Tortugas National Park | Turkey Point |

(a) This sanctuary is currently proposed for designation.

The NRC staff has evaluated the potential impacts of license renewal on national marine sanctuaries in two environmental reviews conducted since publication of the 2013 LR GEIS: the Turkey Point and Point Beach plants, both of which were SLRs. These reviews are summarized below; neither ultimately required NMSA consultation with ONMS.

The Florida Keys National Marine Sanctuary encompasses 2,900 nautical $mi^2$ (5,370 nautical $km^2$) of coastal and ocean waters and submerged land surrounding the Florida Keys from south of Miami westward and encompassing the Dry Tortugas. The sanctuary includes several unique habitats, including the Nation's only coral reef that lies adjacent to the continent and one of the largest seagrass communities in the hemisphere. Card Sound, which lies adjacent and east of the Turkey Point site, is within the boundaries of the sanctuary. In 2019, the NRC staff determined that the Turkey Point SLR would not affect the resources of this sanctuary (NRC 2019c). Available monitoring data indicated no discernable impact of Turkey Point plant's CCS on the ecology of surrounding marsh and mangrove areas, Biscayne Bay, Card Sound, or any other nearby surface waters. The staff found that any potential future impacts would be addressed and mitigated through State and county requirements concerning the CCS and groundwater quality. Accordingly, the NRC staff concluded that SLR was not likely to destroy, cause the loss of, or injure any sanctuary resources and that consultation under the NMSA was not required.

The Wisconsin Shipwreck Coast National Marine Sanctuary encompasses a 962 $mi^2$ (1,550 $km^2$) area of western Lake Michigan along the Wisconsin coast. The sanctuary protects shipwrecks that possess exceptional historic, archaeological, and recreational value. Rock reefs and the structures of the shipwrecks provide shelter and foraging habitat for many species of commercially and recreationally important fish. The sanctuary also includes the State-managed Southern Refuge and the largest spawning population of lake trout (*Salvelinus namaycush*). The Point Beach plant lies on the coast of Lake Michigan within the region designated for this sanctuary. In 2021, the NRC staff determined that the Point Beach SLR would not affect the resources of this sanctuary (NRC 2021f). The NRC staff found that the sanctuary resources of concern (a nationally significant collection of maritime cultural heritage resources, including 36 known shipwrecks) are located at least 2 mi (3.2 km) from the Point Beach site and beyond the influence of either Point Beach's cooling water intake structure or the area affected by thermal effluent discharges and, thus, continued operation of Point Beach plant would not affect these resources. The licensee did not plan to conduct any shoreline stabilization or other in-water work during the proposed SLR term. Accordingly, the NRC staff concluded that subsequent license renewal was not likely to destroy, cause the loss of, or injure any sanctuary resources and that consultation under the NMSA was not required.

## 3.7 Historic and Cultural Resources

### 3.7.1 Scope of Review

Historic and cultural resources vary widely from site to site; there is no generic way of determining their existence or significance. Historic and cultural resource impacts must be analyzed on a plant-specific basis, and the NRC is required to complete a NEPA (42 U.S.C. § 4321 et seq.) and National Historic Preservation Act (NHPA) Section 106 review (54 U.S.C. § 300101 et seq.) prior to issuing a renewed license. This section presents an overview of these resources and the NEPA and NHPA Section 106 review and consultation processes. Historic and cultural resources are the remains of past human activities and include precontact (i.e., prehistoric) and historic era archaeological sites, districts, buildings, structures, and objects. Precontact era archaeological sites pre-date the arrival of Europeans in North America and may include small temporary camps, larger seasonal camps, large village sites, or specialized-use areas associated with fishing or hunting or with tool and pottery manufacture. Historic era archaeological sites post-date European contact with Indian Tribes[1] and may include farmsteads, mills, forts, residences, industrial sites, and shipwrecks. Architectural resources include buildings and structures. Historic and cultural resources also include elements of the cultural environment such as landscapes, sacred sites, and other resources that are of religious and cultural importance to Indian Tribes, such as traditional cultural properties (TCPs) important to a living community of people for maintaining its culture.[2]

A historic or a cultural resource is deemed to be historically significant, and thus, a "historic property" within the scope of the NHPA if it has been determined to be eligible for listing or is listed on the National Register of Historic Places (NRHP).[3] The NRHP is maintained by the U.S. National Park Service in accordance with its regulations in 36 CFR Part 60. The NRHP criteria to evaluate the eligibility of a property are set forth in 36 CFR 60.4.[4] In this regard, a historic property is at least 50 years old, although exceptions can be made for properties determined to be of "exceptional significance."[5]

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[1] Per 36 CFR 800.2(c)(2)(ii), the agency official will consult with any Indian Tribe or Native Hawaiian organization that attaches religious and cultural significance to historic properties that may be affected by an undertaking.

[2] According to U.S. National Park Service guidance, a "traditional cultural property" is associated "with the cultural practices or beliefs of a living community that (a) are rooted in that community's history and (b) are important in maintaining the continuing cultural identity of the community" (Parker and King 1998).

[3] Historic property is defined in 36 CFR 800.16(l)(1) as "... any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the [NRHP] maintained by the Secretary of Interior. This term includes artifacts, records, and remains that are related to and located within such properties." As defined in 36 CFR 800.16(l)(2), "The term eligible for inclusion in the National Register includes both properties formally determined as such in accordance with regulations of the Secretary of the Interior and all other properties that meet National Register listing criteria."

[4] The eligibility of a resource for listing in the NRHP is evaluated based on four criteria and is articulated in 36 CFR 60.4, as follows: Criterion a: Associated with events that have made a significant contribution to broad patterns of our history; Criterion b: Associated with the lives of persons significant in our past; or Criterion c: Embodies the distinctive characteristics of a type, period, or method of construction, or represents the work of a master, or that possesses high artistic values, or that represents a significant and distinguishable entity whose components may lack individual distinction; and Criterion d: Has yielded, or is likely to yield, information important to prehistory and history.

[5] 36 CFR 60.4(g).

### 3.7.2 NEPA and NHPA

NEPA requires Federal agencies to consider the potential effects of their actions on the affected human environment, which includes “aesthetic, historic, and cultural resources as these terms are commonly understood, including such resources as sacred sites” (CEQ and ACHP 2013). For NEPA compliance, impacts on cultural resources that are not eligible for or listed in the NRHP would also need to be considered (CEQ and ACHP 2013). The Advisory Council on Historic Preservation (ACHP) is an independent Federal agency that oversees the NHPA Section 106 review process in accordance with its implementing regulations in 36 CFR Part 800, “Protection of Historic Properties” (36 CFR Part 800). Section 106 of the NHPA requires Federal agencies to take into account the effects of their undertakings[1] on historic properties and consult with the appropriate parties as defined in 36 CFR 800.2. Consulting parties include the State Historic Preservation Officer (SHPO), ACHP, Tribal Historic Preservation Officer, and Indian Tribes that attach cultural and religious significance to historic properties on a government-to-government basis and other parties that have a demonstrated interest in the effects of the undertaking, including local governments and the public, as applicable. Issuing a renewed license (initial LR or SLR) is a Federal undertaking that requires compliance with the NHPA Section 106.

When preparing plant-specific supplements to this LR GEIS (see 36 CFR 800.8(c)), the NRC’s practice is to fulfill the requirements of NHPA Section 106 through the NEPA review process. For each application, the NRC would identify consulting parties and determine the scope of potential effects from the undertaking by defining the area of potential effect (APE). The license renewal (initial LR or SLR) APE includes lands within the nuclear power plant site boundary and the transmission lines up to the first substation that may be directly (e.g., physically) affected by land-disturbing or other operational activities associated with continued plant operations and maintenance and/or refurbishment activities. The APE may extend beyond the nuclear plant site when these activities may indirectly (e.g., visual and auditory) affect historic properties. This determination is made irrespective of land ownership or control.

The NRC will rely on historic and cultural resource investigations completed by qualified professionals, who meet the Secretary of Interior’s standards at 36 CFR Part 61, to identify historic and cultural resources located within the APE and complete NRHP eligibility determinations in consultation with the SHPO and other consulting parties to determine whether historic properties are present in the APE. The NHPA requires that information about the locations of some historic and cultural resources, as well as sensitive sacred and religious information, be withheld from the public to protect the resources (36 CFR 800.11(c)(1)). Other legal authorities regarding protection of information from public release may also apply.

Additional historic and cultural resource laws could apply if a proposed project is located on Federal lands (see Appendix F).

### 3.7.3 Historic and Cultural Resources at Nuclear Power Plant Sites

Nuclear power plant sites tend to be located in areas of focused past human activities (along waterways) and, as such, there is a potential for historic and cultural resources to be present

[1] An undertaking is “a project, activity, or program funded in whole or in part under the direct or indirect jurisdiction of a Federal agency, including those carried out by or on behalf of a Federal agency; those carried out with Federal financial assistance; and those requiring a Federal permit, license or approval” (see 36 CFR 800.16(y)).

within existing nuclear power plant site boundaries. A review of historic and cultural resources at various nuclear power plants that have undergone initial LR or SLR since 2013 indicates that there are a variety of historic and cultural resources (mainly archaeological resources) that have been identified that reflect land use throughout precontact and historic time periods. For example, at one nuclear power plant site there were 129 historic and cultural resources identified within the site boundaries. There are other examples of nuclear power plant sites that contain fewer or no historic and cultural resources identified. The number and diversity of resource types is dependent upon geographic location and prior site land use.

Based on experience from initial LR and SLR environmental reviews, ground-disturbing activities occurred during nuclear power plant construction resulting in extensive disturbance of much of the land in and immediately surrounding the power block. The term “power block” refers to the buildings and components directly involved in generating electricity at a power plant. At a nuclear power plant, the components of the power block vary with the reactor design, but always include the reactor and turbine building, and usually include several other buildings that include access, reactor auxiliary, safeguards, waste processing, or other nuclear generation support functions. Buildings within the power block require significant excavation of existing material, followed by placement of structural fill for a safe and stable base. Building excavations are extensive, and the area of excavation is larger than the as-built power block and reactor containment. There are also less-developed and undeveloped areas at nuclear power plant sites, including areas that were not extensively disturbed (e.g., construction laydown areas). Laydown areas are lands that were cleared, graded, and used to support fabrication and installation activities during initial power plant construction. Intact archaeological resources are unlikely to be present in heavily disturbed areas and do not require field investigation, whereas less disturbed areas could still contain unrecorded archaeological resources and should be investigated for the presence of historic and cultural resources.

Many nuclear power plant facilities were constructed prior to the implementation of NHPA Section 106 regulations located at 36 CFR Part 800; therefore, there were no formal standards for archaeological field investigations or requirements to identify and consult with Indian Tribes. A review of historic and cultural resources at various nuclear power plants that have undergone license renewal (initial LR or SLR) since 2013 indicates that most existing nuclear power plants in the United States were not investigated prior to initial construction for the presence of archaeological, architectural or TCP resources, nor have Indian Tribes been consulted regarding historic and cultural resources that may have significance to a Tribe’s history, culture, or religion. In some cases, archaeological and architectural resource investigations were completed prior to construction, but the methods used then are unlikely to meet the current Secretary of Interior’s standards for archaeological and architectural resource investigation. Historic and cultural resource field investigations may be necessary at the time of initial LR and SLR if none were completed previously or may need to be updated to meet current standards. In addition, identification of and consultation with Indian Tribes that have cultural and religious ties to nuclear power plant sites are required to identify all historic and cultural resources that may be located within the APE. Identification and consultation with Indian Tribes is the responsibility of the NRC.

For example during the license renewal review of the Sequoyah Nuclear Plant, Units 1 and 2, during the environmental audit, the NRC determined that a mound site that was thought to have been destroyed by initial facility construction was partially intact. The mound site was originally recorded in 1913 and excavated in 1936 and 1973. In 2010, Tennessee Valley Authority (TVA) conducted a cultural resources survey in preparation for its license renewal application. The survey was unable to locate the mound site and presumed that the site no longer existed.

TVA's environmental report stated that the mound was destroyed during the construction of Sequoyah Units 1 and 2. As a result of the NRC environmental audit and after further discussions, TVA reopened its NHPA Section 106 consultation with the Tennessee SHPO and submitted revisions to its previous cultural resource surveys and prepared an updated site form for the mound site. Additionally, TVA also reinitiated NHPA Section 106 consultation with Indian Tribes. There was no formal eligibility determination of the site for listing in the NRHP, although TVA believes the site is eligible (NRC 2015f).

Most license renewals are granted for a period of 20 years, so it is possible for historic and cultural resources, including the nuclear power plant facility itself, to fall within the 50-year threshold for inclusion in the NRHP and to have achieved historic significance during the license renewal period. For example, Fermi plant Unit 1, the Nation's first commercial-size nuclear power plant was determined eligible for listing in the NRHP in 2012 (NRC 2016c). Due to the passage of time since initial licensing, documentation and NRHP eligibility evaluation of all historic and cultural resources that fall within the 50-year threshold should be completed for initial LR and SLR.

## 3.8 Socioeconomics

This section describes socioeconomic factors that have the potential to be directly or indirectly affected by changes in nuclear power plant operations. The nuclear plant and the communities that support it can be described as a dynamic socioeconomic system. The communities provide the people, goods, and services needed to operate the nuclear power plant. Power plant operations, in turn, provide employment and income and pay for goods and services from the communities. The measure of a community's ability to support power plant operations depends on the ability of the community to respond to changing economic conditions.

The socioeconomics region of influence (ROI) is defined by the counties where nuclear power plant employees and their families reside, spend their income, and use their benefits, thereby affecting economic conditions in the region. Changes in power plant operation affects socioeconomic conditions in the ROI, including employment and income, recreation and tourism, tax revenue, community services and education, population and housing, and transportation.

### 3.8.1 Power Plant Employment and Expenditures

Nuclear power plants generate employment and income in the local economy. Wages, salaries, and expenditures generated by nuclear plant operation create demand for goods and services in the local economy, while wage and salary spending by workers creates additional demand for services and housing. Nuclear power plants also provide tax revenue for education, public safety, government services, and transportation.

Employment at nuclear power plants varies based on a number of factors, including the number of reactor units, energy production, and the type and age of the nuclear plant. The review of annual economic data on 15 nuclear power plants shows employment at these nuclear plants averaged about 800 workers, ranging from 506 workers at Point Beach to 941 workers at the Surry plant (Table 3.8-1).

**Table 3.8-1 Local Employment, and Tax Revenues at 15 Nuclear Plants from 2014 through 2020**

| Nuclear Power Plant | Data Year | Employment | Percent of Local Employment | Tax Revenues ($ million) | Percent of Local Tax Revenue |
|---|---|---|---|---|---|
| Byron | 2013 | 867 | 0.50 | 33.0 | 28.3 |
| Braidwood | 2014 | 885 | 0.22 | 24.5 | 1.4 |
| Comanche Peak | 2014 | 889 | N/A | 70.0 | N/A |
| Fermi | 2014 | 889 | 0.12 | 19.6 | 43.7 |
| Ginna | 2014 | 889 | N/A | 10.0 | N/A |
| South Texas | 2014 | 680 | N/A | 70.0 | N/A |
| LaSalle | 2015 | 889 | 0.22 | 22.5 | 31.1 |
| Cooper | 2016 | 641 | N/A | N/A | N/A |
| Waterford | 2016 | 641 | 0.27 | 22.4 | 15.2 |
| River Bend | 2017 | 680 | 0.31 | 14.2 | 63.1 |
| Turkey Point | 2018 | 679 | 0.05 | 36.6 | 0.4 |
| Surry | 2018 | 941 | 4.60 | 13.3 | 61.3 |
| Peach Bottom | 2019 | 919 | 0.19 | 1.4 | 0.8 |
| North Anna | 2020 | 903 | 2.69 | 11.6 | 4.8 |
| Point Beach | 2020 | 506 | 0.30 | 10.2 | 2.8 |

N/A = Not available.
Sources: NRC 2015c, NRC 2016d, NRC 2016c, NRC 2018c, NRC 2018d, NRC 2019c, NRC 2020g, NRC 2020f, NRC 2021f, NRC 2021g, NEI 2015b, NEI 2015c, NEI 2018, NEI 2015a.

Nuclear power plants provide tax revenue to State and local governments, and the 15 nuclear plants evaluated have tax characteristics similar to those in the 2013 LR GEIS. State and local tax payments ranged from $1.4 million at the Peach Bottom plant to $70.0 million at both the South Texas plant and Comanche Peak Steam Electric Station (Comanche Peak), averaging $25.3 million. Differences in tax revenue generated by the nuclear power plants are due to differences in State and local tax laws, electricity output, plant size, and plant employment.

Additional employment and expenditures occur during refueling and maintenance outages at each nuclear power plant, when additional workers and services are required for a 1- to 2-month period. Refueling outages generally occur on a 18- to 24-month cycle.

### 3.8.2 Regional Economic Characteristics

Regional economic characteristics can vary depending on the location of the nuclear power plant. Socioeconomic conditions in the county where the nuclear plant is located are directly affected by power plant operations as are the counties where the majority of power plant workers reside.

Many areas have changed since the nuclear power plant was constructed. Residential and commercial development and the diversification of economic activity in these areas have also changed the local and regional economic profile. Outdoor recreational activities have changed the focus of local and regional economic activity and the growth of retirement communities, in some instances, rivals the importance of traditional economic activities in the vicinity of a nuclear power plant.

As previously discussed, nuclear power plant operations generate employment, income, and expenditures in the local economy. These expenditures—payments for goods and services—create additional opportunities for employment and income in the regional economy. Nuclear plants are located in one of two regional economic settings: rural or urban.

#### *3.8.2.1 Rural Economies*

Most nuclear power plants are located in rural areas, where agriculture is the primary economic activity. Rural areas are considered to have relatively simple economies, without industries that provide the equipment and services needed to support nuclear plant operations, and with smaller, less diversified labor markets. A range of other industrial activities, including those associated with resource extraction, manufacturing, and transportation, provide employment and income.

Nuclear power plants located in rural economies include the Byron, River Bend, Waterford, Surry, North Anna, Point Beach, R.E. Ginna Nuclear Power Plant (Ginna), Comanche Peak, South Texas, and Cooper plants. Only 2 of the 10 nuclear plants, Surry and North Anna, provided 1 percent or more to regional employment.

#### *3.8.2.2 Urban Economies*

Some nuclear power plants are located in or near urban areas that have more complex economic activities, a wider range of industries, and larger and more diverse labor markets. Urban areas may also serve more specialized economic functions, including maritime shipping, fishing, and boatbuilding; recreation; and tourism. Many also have residential areas with second homes and retirement communities.

Nuclear power plants located in urban economies include the Braidwood, Fermi, LaSalle, Turkey Point, and Peach Bottom plants. None of the nuclear plants provided 1 percent or more to regional employment.

### **3.8.3 Demographic Characteristics**

Although most nuclear power plants are situated in rural areas, population densities within 20 mi (50 km) of most nuclear plant sites are generally high, and most are within 50 mi (80 km) of a city with a population of at least 100,000 (see Appendix C). Demographics vary around each nuclear power plant and many are affected by the remoteness of the nuclear plant to regional population centers.

Two measures of remoteness were developed for the LR GEIS—“sparseness” and “proximity”—which combine demographic data on population density and the distance to larger cities to place nuclear plants into three population classes (1996 LR GEIS). Population classifications of 15 representative nuclear power plant sites are presented in Table 3.8-2.

**Table 3.8-2 Population Classification of Regions around Selected Nuclear Power Plants**

| Population | Nuclear Power Plant | Population Density Within 20 miles | Sparseness Measure | Population Density Within 50 miles | Proximity Measure |
|---|---|---|---|---|---|
| Low | Cooper | 12.9 | 1 | 19.7 | 1 |
| Low | South Texas | 40.1 | 2 | 42.8 | 1 |
| Low | River Bend | 105.7 | 3 | 137.0 | 3 |
| Moderate | Comanche Peak | 70.5 | 3 | 269.4 | 4 |
| Moderate | Byron | 220.1 | 4 | 165.3 | 3 |
| High | North Anna | 149.1 | 4 | 296.3 | 4 |
| High | Point Beach | 226.9 | 4 | 298.0 | 4 |
| High | LaSalle | 253.2 | 4 | 250.9 | 4 |
| High | Waterford | 438.8 | 4 | 353.2 | 4 |
| High | Braidwood | 486.8 | 4 | 655.8 | 4 |
| High | Surry | 531.3 | 4 | 427.2 | 4 |
| High | Turkey Point | 937.3 | 4 | 685.4 | 4 |
| High | Peach Bottom | 1,268.5 | 4 | 874.8 | 4 |
| High | Fermi | 1,486.7 | 4 | 788.2 | 4 |
| High | Ginna | 3,339.3 | 4 | 335.7 | 4 |

Source: Pacific Northwest National Laboratory calculations based on 2020 decennial census data.

Many communities near a nuclear power plant have transient populations attracted to tourism and recreational activities, weekend and summer homes, and students attending full-time colleges and other educational institutions. Nuclear power plants located in coastal regions, notably D.C. Cook and Palisades plants on Lake Michigan and Brunswick plant on the North Carolina coast between Wilmington, North Carolina, and Myrtle Beach, South Carolina, have weekend, summer, and retirement populations and a range of recreational amenities that attract visitors from nearby metropolitan areas.

In addition to transient populations, farms and factories in rural communities often employ migrant workers on a seasonal basis. For example, berry production near the D.C. Cook and Palisades plants is a local agricultural activity that employs a sizable migrant labor force in the summer.

### 3.8.4 Housing and Community Services

Housing in the vicinity of nuclear power plants ranges in the number of housing units and the type and quality of available housing. Much of the difference is due to the local economy, population, and income; proximity to metropolitan areas; and recreation, tourism, second homes, and retirement communities. Although housing demand can be affected by changes in the number of workers at a nuclear power plant, demand for temporary rental housing increases during refueling and maintenance outages. This demand affects the availability and cost of housing. Some workers may occupy motel rooms and other temporary accommodations during refueling outages which include onsite temporary housing at some nuclear power plants.

Rural communities have smaller housing markets, stable prices for most types of housing, lower median house values, and stable vacancy rates. Housing markets in urban areas are generally less stable and feature more turnover, higher prices, and lower vacancy rates. Controls on housing development are more likely in urban areas, particularly where there is a transient seasonal population.

**Sparseness and Proximity Measures**

**Sparseness**

Most Sparse

1. There are fewer than 40 people/mi$^2$ (15 people/km$^2$) and there is no community with 25,000 or more people within 20 mi (32 km) of the plant.
2. There are 40 to 60 people/mi$^2$ (15 to 23 people/km$^2$) and there is no community with 25,000 or more people within 20 mi (32 km) of the plant.
3. There are 60 to 120 people/mi$^2$ (23 to 46 people/km$^2$) and there is at least one community with more than 25,000 people/mi$^2$ (10,000 people/km$^2$) within 20 mi (32 km) of the plant.

Least Sparse

4. There are more than 120 people/mi$^2$ (46 people/km$^2$) within 20 mi (32 km) of the plant.

**Proximity**

Not in Close Proximity

1. There are fewer than 50 people/mi$^2$ (19 people/km$^2$) and there is no city with more than 100,000 people within 50 mi (80 km) of the plant.
2. There are 50 to 190 people/mi$^2$ (19 to 73 people/km$^2$) and there is no city with 100,000 people within 50 mi (80 km) of the plant.
3. There are fewer than 190 people/mi$^2$ (73 people/km$^2$) and there are one or more cities with more than 100,000 people within 50 mi (80 km) of the plant.

In Close Proximity

4. There are more than 190 people/mi$^2$ (73 people/km$^2$) within 50 mi (80 km) of the plant.

Source: Adapted from NUREG/CR-2239.

### 3.8.5 Tax Revenue

Nuclear power plants provide tax revenue to State and local governments. Although property taxes are the most important source of revenue for most communities, other sources of revenue include taxes on energy production and direct funding from Federal and State governments for educational facilities and programs. Between 2014 and 2020, State and local taxes paid by the 15 nuclear power plants listed in Table 3.8-1 ranged from $1.4 million at the Peach Bottom plant to $70 million at the South Texas and Comanche Peak plants, averaging $24.1 million. Differences in tax revenue are due to variations in State and local tax laws, energy production, power plant size, and employment. Tax revenue is also used by State, regional, and local governments to fund education, public safety, services, and transportation networks. Property taxes paid by nuclear power plant owners contribute more than 50 percent of total property tax revenue in some rural communities (e.g., at the River Bend plant in Louisiana and the Surry plant in Virginia). Loss of tax revenue can affect the quality and availability of public services.

The deregulation of electricity markets in some States has led to changes in the methods used to estimate property values at some nuclear power plants. Any changes in tax revenues after utility deregulation would not occur as a direct result of license renewal (initial LR or SLR).

### 3.8.6 Local Transportation

Local and regional transportation networks in the vicinity of a nuclear power plant vary considerably depending on population density, the location and size of communities, economic development patterns, the power plant's location relative to interregional transportation corridors, and land surface features, such as mountains, rivers, and lakes. Commuting patterns in the vicinity of a nuclear power plant depend on the extent to which these factors limit or facilitate traffic movement and on the size of the workforce that uses the transportation network at any given time. Traffic volumes near a nuclear power plant depend on road network capacity, local traffic patterns, and the availability of alternate routes. Because most nuclear power plants have only one access road, congestion on this road may occur during shift changes.

## 3.9 Human Health

### 3.9.1 Radiological Exposure and Risk

Radiological exposures from nuclear power plants include offsite doses to members of the public and onsite doses to the workforce. Each of these impacts is common to all commercial U.S. reactors. The AEA requires the NRC to promulgate, inspect, and enforce standards that provide an adequate level of protection for public health and safety and the environment. The NRC continuously evaluates the latest radiation protection recommendations from international and national scientific bodies to establish the requirements for nuclear power plant licensees. The NRC has established multiple layers of radiation protection limits to protect the public against potential health risks from exposure to effluent discharges from nuclear power plant operations. If the licensees exceed a certain fraction of these dose levels in a calendar quarter, they are required to notify the NRC, investigate the cause, and initiate corrective actions within the specified time frame. Section 3.9.1.1 discusses regulatory requirements at nuclear power plants. Sections 3.9.1.2 and 3.9.1.3 discuss occupational and public exposure, respectively. These sections evaluate the performance of licensees in implementing these requirements, and they compare the doses and releases with permissible levels. Risk estimates are provided in Section 3.9.1.4.

#### *3.9.1.1 Regulatory Requirements*

Nuclear power reactors in the United States must be licensed by the NRC and must comply with NRC regulations and conditions specified in the license in order to operate. The licensees are required to comply with 10 CFR Part 20, Subpart C, "Occupational Dose Limits for Adults," and 10 CFR Part 20, Subpart D, "Radiation Dose Limits for Individual Members of the Public."

##### *3.9.1.1.1 Regulatory Requirements for Occupational Exposure*

10 CFR 20.1201 establishes occupational dose limits (see Table 3.9-1).

**Table 3.9-1 Occupational Dose Limits for Adults Established by 10 CFR Part 20**

| Tissue | Dose Limit[(a)] |
|---|---|
| Whole-body or any individual organ or tissue other than the lens of the eye | More limiting of 5 rem/yr TEDE to whole-body or 50 rem/yr sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye |
| Lens of the eye | 15 rem/yr dose equivalent |
| Extremities, including skin | 50 rem/yr shallow dose equivalent |

rem/yr = rem per year; TEDE = total effective dose equivalent.
(a) See table below for definitions.
Note: To convert rem to sievert, multiply by 0.01.
Source: 10 CFR Part 20

**Definitions of Dosimetry Terms**

- **Total effective dose equivalent (TEDE):** Sum of the dose equivalent (for external exposure) and the committed effective dose equivalent (for internal exposure).
- **Committed effective dose equivalent (CEDE):** Sum of the products of the weighting factors for body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.
- **Deep dose equivalent:** Applies to external whole-body exposure and is the dose equivalent at a tissue depth of 1 cm.
- **Committed dose equivalent:** Dose equivalent to organs or tissues from an intake of radioactive material for the 50-year period following the intake.
- **Dose equivalent:** Product of the absorbed dose in the tissue, quality factor, and all other necessary modifying factors at the location of interest.
- **Shallow dose equivalent:** Applies to the external exposure of the skin, as the dose equivalent at a tissue depth of 0.007 cm averaged over an area of 1 $cm^2$.
- **Organ dose:** Dose received as a result of radiation energy absorbed in a specific organ.
- **Total body dose or whole-body dose:** Sum of the dose received from external exposure to the total body, gonads, active blood-forming organs, head and trunk, or lens of the eye and the dose due to the intake of radionuclides by inhalation and ingestion, where a radioisotope is uniformly distributed throughout the body tissues rather than being concentrated in certain parts.

Under 10 CFR 20.2206, the NRC requires licensees to submit an annual report of the results of individual monitoring carried out by the licensee for each individual for whom monitoring was required by 10 CFR 20.1502 during that year.

Under 10 CFR 20.2202 and 10 CFR 20.2203, the NRC requires all licensees to submit reports of all occurrences involving personnel radiation exposures that exceed certain control levels. The control levels are used to investigate occurrences and to take corrective actions as necessary. Depending on the magnitude of the exposure, the occurrence reporting is required immediately, within 24 hours, or within 30 days. On the basis of the reporting requirement, the control levels can be placed in one of three categories (A, B, or C), as follows (NRC 2020i):

- Category A, immediate notification. A TEDE of 25 rem or more to any individual, an eye dose equivalent of 75 rem or more, or a shallow dose equivalent to the skin or extremities of 250 rad or more (10 CFR 20.2202(a)(1)).
- Category B, notification within 24 hours. A TEDE of 5 rem or more to any individual, an eye dose equivalent of 15 rem or more, or a shallow dose equivalent to the skin or extremities of 50 rem or more (10 CFR 20.2202(b)(1)).
- Category C, written report within 30 days. Any incident for which notification was required and doses or releases that exceed the limits in the license set by the NRC or EPA (10 CFR 20.2203).

*3.9.1.1.2 Regulatory Requirements for Public Exposure*

NRC regulations in 10 CFR Part 20 identify maximum allowable concentrations of radionuclides that can be released from a licensed facility into the air and water above background levels at the boundary of unrestricted areas to control radiation exposures of the public and releases of radioactivity. These concentrations are derived on the basis of an annual TEDE of 0.1 rem to individual members of the public. In addition, pursuant to 10 CFR 50.36a, nuclear power reactors have special license conditions called technical specifications for radioactive gaseous and liquid releases from the plant that are required to minimize the radiological impacts associated with plant operations to levels that are ALARA.

Appendix I to 10 CFR Part 50 provides numerical values on dose-design objectives for operation of LWRs to meet the ALARA requirement. The design objective doses for Appendix I are summarized here in Table 3.9-2.

In addition to keeping within NRC requirements, nuclear power plant releases to the environment must comply with EPA standards in 40 CFR Part 190, “Environmental Radiation Protection Standards for Nuclear Power Operations.” These standards specify limits on the annual dose equivalent from normal operations of uranium fuel-cycle facilities (except mining, waste disposal operations, transportation, and reuse of recovered non-uranium special nuclear and by-product materials). The standards are given in Table 3.9-3. Radon and its daughters are covered by Subpart D of 40 CFR Part 192 (the conforming NRC regulations are in Appendix A of 10 CFR Part 40.

**Table 3.9-2 Design Objectives and Annual Standards on Doses to the General Public from Nuclear Power Plants[(a)] from Appendix I to 10 CFR 50**

| Tissue | Gaseous Effluents | Liquid Effluents |
|---|---|---|
| Total body, mrem | 5[(b)] | 3 |
| Any organ (all pathways), mrem | N/A | 10 |
| Ground-level air dose,[(b)] mrad | 10 (gamma) and 20 (beta) | N/A |
| Any organ[(c)] (all pathways), mrem | 15 | N/A |
| Skin, mrem | 15 | N/A |

mrem = millirem; mrad = millirad; N/A = not applicable.
(a) Calculated doses.
(b) The ground-level air dose has always been limiting because an occupancy factor cannot be used. The 5-mrem total body objective could be limiting only in the case of high occupancy near the restricted area boundary.
(c) Particulates, radioiodines.
Source: 10 CFR Part 50.

**Table 3.9-3 Design Objectives and Annual Standards on Doses to the General Public from Nuclear Power Plants[(a)] from 40 CFR 190, Subpart B**

| Tissue | Gaseous Effluents | Liquid Effluents |
|---|---|---|
| Whole-body,[(b)] mrem | 25 | N/A |
| Thyroid,[(b)] mrem | 75 | N/A |
| Any other organ,[(b)] mrem | 25 | N/A |

mrem = millirem; N/A = not applicable.
(a) Calculated doses.
(b) All effluents and direct radiation except radon and its daughters.
Source: 40 CFR Part 190.

EPA standards in 40 CFR Part 61, "National Emission Standards for Hazardous Air Pollutants," apply only to airborne releases. The EPA specified an annual effective dose equivalent limit of 10 mrem for airborne releases from nuclear power plants; however, no more than 3 mrem can be caused by any isotope of iodine. However, the EPA later rescinded Subpart I of 40 CFR Part 61 as it applies to nuclear reactors based on the EPA's determination that the NRC's regulations provide an 'ample margin of safety' (60 FR 46206 1995).

Experience with the design, construction, and operation of nuclear power reactors indicates that compliance with the design objectives of Appendix I to 10 CFR Part 50 will keep average annual releases of radioactive material in effluents at small percentages of the limits specified in 10 CFR Part 20 and 40 CFR Part 190. At the same time, the licensee is given the flexibility in operations, compatible with considerations of health and safety, to ensure that the public is provided with a dependable source of power, even under unusual operating conditions that might temporarily result in releases that were higher than such small percentages but still well within the regulatory limits.

Another 10 CFR Part 20 requirement is that the sum of the external and internal doses (i.e., in TEDE) for a member of the public shall not exceed 100 mrem/yr. This value is an annual limit and is not intended to be applied as a long-term average goal. The dose limits in 10 CFR Part 20 are based on the methodology described in International Commission on Radiological Protection (ICRP) Publication 26 (ICRP 1977). The radiation levels at any unrestricted area should not exceed 2 mrem in any one hour. As stated in 10 CFR 20.1302(b), licensees comply with the 100-mrem limit for individual members of the public by (1) demonstrating by measurement or calculation that the dose to the individual likely to receive the highest dose from sources under the licensee's control does not exceed the annual dose limit or (2) that the annual average concentrations of radioactive material released in gaseous and liquid effluents at the boundary of the unrestricted area do not exceed the levels specified in Table 2 of 10 CFR Part 20, Appendix B; and at the unrestricted area boundary, the dose from external sources would not exceed 2 mrem in any given hour and 50 mrem in a single year. The concentration values given in Table 2 of Appendix B to 10 CFR Part 20 are equivalent to the radionuclide concentrations that, if inhaled or ingested continuously in a year, would produce a TEDE of 50 mrem. Nuclear power reactors, as discussed earlier in this section, are subject to additional regulatory controls which maintain doses to members of the public to the ALARA dose-design objectives in Appendix I to 10 CFR Part 50.

### *3.9.1.2 Occupational Radiological Exposures*

This section provides an evaluation of the radiological impacts on nuclear power plant workers. This evaluation extends to all nuclear power reactors. The data in this section are generally sourced from NUREG-0713 Volume 40 (NRC 2020i), which provides data through 2018. In 2018, there were 98 operating reactors in the United States, and all were LWRs; among them 33 are BWRs and 65 are PWRs. Currently (as of 2022), there are 92 operating reactors in the United States, and all are LWRs. Among them, 31 are BWRs and 61 are PWRs (NRC 2021c).

Plant workers conducting activities involving radioactively contaminated systems or working in radiation areas can be exposed to radiation. Individual occupational doses are measured by NRC licensees as required by the basic NRC radiation protection standard, 10 CFR Part 20 (see Section 3.9.1.1). Most of the occupational radiation dose to nuclear plant workers results from external radiation exposure rather than from internal exposure from inhaled or ingested radioactive materials. Workers also receive radiation exposure during the storage and handling of radioactive waste and during the inspection of stored radioactive waste. However, this source of exposure is small compared with other sources of exposure at operating nuclear plants.

Table 3.9-4 shows the radiation exposure data from all commercial U.S. nuclear power plants for the years 2006 through 2018. The year 2006 was chosen as a starting date because the dose data for years before 2006 were presented in the 2013 LR GEIS and the 1996 LR GEIS. For each year, the number of reactors, the number of workers receiving measurable exposures, the collective dose[1] for all reactors combined, and the number of individuals receiving a dose in the range of 4 to 5 rem are given. Data indicate that no worker received a dose in the range of 4 to 5 rem from 2006 to 2018. The collective dose has been about 11,000 person-rem or less since 2006 and shows a decreasing trend.

**Table 3.9-4 Occupational Whole-Body Dose Data at U.S. Commercial Nuclear Power Plants**

| Calendar Year | Number of Workers with Measurable Dose | Collective Dose (person-rem) | Number of Licensees | Number of Workers in the Range of 4 to 5 |
|---|---|---|---|---|
| 2006 | 80,265 | 11,021 | 104 | 0 |
| 2007 | 79,530 | 10,120 | 104 | 0 |
| 2008 | 79,450 | 9,196 | 104 | 0 |
| 2009 | 81,754 | 10,025 | 104 | 0 |
| 2010 | 75,010 | 8,631 | 104 | 0 |
| 2011 | 81,321 | 8,771 | 104 | 0 |
| 2012 | 79,549 | 8,035 | 104 | 0 |
| 2013 | 67,236 | 6,760 | 100 | 0 |
| 2014 | 70,847 | 7,125 | 100 | 0 |
| 2015 | 70,798 | 7,019 | 99 | 0 |
| 2016 | 59,353 | 5,366 | 99 | 0 |
| 2017 | 64,761 | 6,417 | 99 | 0 |

[1] The collective dose is the sum of all personal doses and is expressed as person-rem.

| Calendar Year | Number of Workers with Measurable Dose | Collective Dose (person-rem) | Number of Licensees | Number of Workers in the Range of 4 to 5 |
|---|---|---|---|---|
| 2018 | 61,014 | 5,829 | 98 | 0 |

Note: To convert rem to sievert (Sv), multiply by 0.01.
Source: NRC 2020i

Table 3.9-5 and Table 3.9-6 show the occupational dose history (2006 to 2018) for all commercial U.S. reactors. Average measurable occupational dose and annual collective occupational dose information are presented for plants that operated between 2006 and 2018. For the period from 2006 to 2018, the annual average measurable dose per plant worker has shown decreasing trends for both PWRs and BWRs. During 2018, at all operating nuclear power plants, the annual average individual dose was 0.1 rem compared with an exposure limit of 5 rem. The average collective occupational exposure for the year 2018 was roughly 1.11 person-Sv (111 person-rem) per plant at BWRs and about 0.34 person-Sv (34 person-rem) per plant at PWRs. For the years 2016 to 2018, the average collective occupational exposure for the BWRs was 1.09 person-Sv (109 person-rem) per plant, and for the PWRs, it was 0.34 person-Sv (34 person-rem) (Table 3.9-6).

Table 3.9-7 and Table 3.9-8 show the 3-year collective dose per reactor, number of workers with measurable doses, and average dose per worker for BWRs and PWRs, respectively, for the years 2016 to 2018.

**Table 3.9-5 Annual Average Measurable Occupational Dose per Individual for U.S. Commercial Nuclear Power Plants in rem**

| Year | BWR | PWR | LWR |
|---|---|---|---|
| 2006 | 0.15 | 0.13 | 0.14 |
| 2007 | 0.14 | 0.11 | 0.13 |
| 2008 | 0.13 | 0.10 | 0.12 |
| 2009 | 0.15 | 0.10 | 0.12 |
| 2010 | 0.13 | 0.10 | 0.12 |
| 2011 | 0.13 | 0.09 | 0.11 |
| 2012 | 0.11 | 0.09 | 0.10 |
| 2013 | 0.12 | 0.07 | 0.10 |
| 2014 | 0.11 | 0.09 | 0.10 |
| 2015 | 0.12 | 0.08 | 0.10 |
| 2016 | 0.11 | 0.07 | 0.09 |
| 2017 | 0.12 | 0.07 | 0.10 |
| 2018 | 0.12 | 0.07 | 0.10 |

BWR = boiling water reactor; PWR = pressurized water reactor; LWR = light water reactor.
Source: NRC 2020i

**Table 3.9-6 Annual Average Collective Occupational Dose for U.S. Commercial Nuclear Power Plants in person-rem**

| Year | BWR | PWR | LWR |
|---|---|---|---|
| 2006 | 143 | 87 | 106 |
| 2007 | 154 | 69 | 97 |
| 2008 | 129 | 68 | 88 |

| Year | BWR | PWR | LWR |
|---|---|---|---|
| 2009 | 151 | 69 | 96 |
| 2010 | 137 | 55 | 83 |
| 2011 | 142 | 55 | 84 |
| 2012 | 120 | 56 | 77 |
| 2013 | 127 | 35 | 68 |
| 2014 | 109 | 51 | 71 |
| 2015 | 122 | 44 | 71 |
| 2016 | 98 | 31 | 54 |
| 2017 | 118 | 37 | 65 |
| 2018 | 111 | 34 | 59 |

BWR = boiling water reactor; PWR = pressurized water reactor; LWR = light water reactor.
Source: NRC 2020i

Deviations higher than these averages in the table are routinely experienced, depending largely on whether a plant had an outage during a given year and the nature and extent of refurbishment or repair activities undertaken during outages.

**Table 3.9-7 Collective and Individual Worker Doses at Boiling Water Reactors from 2016 to 2018**

| Nuclear Power Plant | Reactor Years | Three-year Collective TEDE per Reactor Year 2016-2018 (person-rem) | Number of Workers with Measurable TEDE | Average TEDE per Worker (rem) |
|---|---|---|---|---|
| Browns Ferry 1, 2, 3 | 9 | 139.255 | 9,285 | 0.135 |
| Brunswick 1, 2 | 6 | 94.421 | 5,047 | 0.112 |
| Clinton | 3 | 88.537 | 2,958 | 0.090 |
| Columbia Generating | 3 | 83.386 | 2,804 | 0.089 |
| Cooper Station | 3 | 119.565 | 2,686 | 0.134 |
| Dresden 2, 3 | 6 | 64.987 | 5,689 | 0.069 |
| Duane Arnold | 3 | 68.644 | 2,053 | 0.100 |
| Fermi 2 | 3 | 216.286 | 5,377 | 0.121 |
| FitzPatrick | 3 | 140.683 | 2,969 | 0.142 |
| Grand Gulf | 3 | 133.971 | 3,282 | 0.122 |
| Hatch 1, 2 | 6 | 77.276 | 4,092 | 0.113 |
| Hope Creek 1 | 3 | 107.282 | 3,666 | 0.088 |
| Lasalle 1, 2 | 6 | 209.774 | 8,400 | 0.150 |
| Limerick 1, 2 | 6 | 71.931 | 5,110 | 0.084 |
| Monticello | 3 | 57.866 | 1,401 | 0.124 |
| Nine Mile Point 1, 2 | 6 | 130.573 | 4,985 | 0.157 |
| Peach Bottom 2, 3 | 6 | 96.229 | 5,593 | 0.103 |
| Perry | 3 | 131.318 | 2,017 | 0.195 |
| Pilgrim 1 | 3 | 82.006 | 2,966 | 0.083 |
| Quad Cities 1, 2 | 6 | 79.658 | 5,441 | 0.088 |
| River Bend 1 | 3 | 137.909 | 2,605 | 0.159 |

| Nuclear Power Plant | Reactor Years | Three-year Collective TEDE per Reactor Year 2016-2018 (person-rem) | Number of Workers with Measurable TEDE | Average TEDE per Worker (rem) |
|---|---|---|---|---|
| Susquehanna 1, 2 | 6 | 91.689 | 5,007 | 0.110 |

TEDE = total effective dose equivalent.
Source: NRC 2020i
Note: To convert rem to Sv, multiply by 0.01.

**Table 3.9-8 Collective and Individual Worker Doses at Pressurized Water Reactors from 2016 through 2018**

| Nuclear Power Plant[(a)] | Reactor Years | Three-year Collective TEDE per Reactor Year 2016-2018 (person-rem) | Number of Workers with Measurable TEDE | Average TEDE per Worker (rem) |
|---|---|---|---|---|
| Arkansas 1, 2 | 6 | 55.664 | 5,454 | 0.061 |
| Beaver Valley 1, 2 | 6 | 28.776 | 2,448 | 0.071 |
| Braidwood 1, 2 | 6 | 29.911 | 2,711 | 0.066 |
| Byron 1, 2 | 6 | 27.836 | 2,779 | 0.060 |
| Callaway 1 | 3 | 24.565 | 1,240 | 0.059 |
| Calvert Cliffs 1, 2 | 6 | 31.945 | 2,465 | 0.078 |
| Catawba 1, 2 | 6 | 32.773 | 2,853 | 0.069 |
| Comanche Peak 1, 2 | 6 | 33.220 | 2,240 | 0.089 |
| D.C. Cook 1, 2 | 6 | 32.038 | 2,990 | 0.064 |
| Davis-Besse 1 | 3 | 57.032 | 1,807 | 0.095 |
| Diablo Canyon 1, 2 | 6 | 19.610 | 2,312 | 0.051 |
| Farley 1, 2 | 6 | 21.258 | 2,124 | 0.060 |
| Ginna | 3 | 25.329 | 1,155 | 0.066 |
| Harris 1 | 3 | 25.276 | 1,295 | 0.059 |
| Indian Point 2, 3 | 6 | 43.977 | 4,580 | 0.058 |
| McGuire 1, 2 | 6 | 42.541 | 3,689 | 0.069 |
| Millstone 2, 3 | 6 | 40.472 | 2,751 | 0.088 |
| North Anna 1, 2 | 6 | 36.845 | 2,583 | 0.086 |
| Oconee 1, 2, 3 | 9 | 16.433 | 3,286 | 0.045 |
| Palisades | 3 | 122.031 | 1,927 | 0.190 |
| Palo Verde 1, 2, 3 | 9 | 17.754 | 3,390 | 0.047 |
| Point Beach 1, 2 | 6 | 31.334 | 1,791 | 0.105 |
| Prairie Island 1, 2 | 6 | 20.022 | 1,822 | 0.066 |
| Robinson 2 | 3 | 41.480 | 1,974 | 0.063 |
| Salem 1, 2 | 6 | 46.256 | 3,374 | 0.082 |
| Seabrook | 3 | 21.427 | 1,047 | 0.061 |
| Sequoyah 1, 2 | 6 | 45.732 | 3,331 | 0.082 |
| South Texas 1, 2 | 6 | 26.319 | 1,749 | 0.090 |
| St. Lucie 1, 2 | 6 | 43.445 | 3,204 | 0.081 |
| Summer 1 | 3 | 34.140 | 1,752 | 0.058 |
| Surry 1, 2 | 6 | 36.714 | 2,596 | 0.085 |
| Three Mile Island 1 | 3 | 34.047 | 1,396 | 0.073 |
| Turkey Point 3, 4 | 6 | 39.260 | 2,676 | 0.088 |
| Vogtle 1, 2 | 6 | 30.981 | 2,357 | 0.079 |
| Waterford 3 | 3 | 21.750 | 1,247 | 0.052 |

| Nuclear Power Plant[a] | Reactor Years | Three-year Collective TEDE per Reactor Year 2016-2018 (person-rem) | Number of Workers with Measurable TEDE | Average TEDE per Worker (rem) |
|---|---|---|---|---|
| Watts Bar 1, 2[b] | 5[b] | 23.416 | 2,042 | 0.057 |
| Wolf Creek 1 | 3 | 55.650 | 2,792 | 0.060 |
| Totals and Averages | 194 | - | 91,229 | 0.072 |
| Average per Reactor-Year | - | 33.992 | 470 | - |

TEDE = total effective dose equivalent.
(a) Sites where not all reactors had completed 3 full years of commercial operation as of December 31, 2018, are not included.
(b) Watts Bar Nuclear Plant (Watts Bar) 2 came online in October of 2016 and even though the unit has not completed 3 full years of commercial operation as of December 31, 2018, it is included in the total because Watts Bar 1 and 2 report together.
No entry has been denoted by "-".
Source: NRC 2020i.

To identify trends, Figure 3.9-1 and Figure 3.9-2 provide the average and median values of the annual collective dose per reactor for BWRs and PWRs for the years 1994 through 2018. The reported ranges of the values are shown by the vertical lines that extend to the minimum and maximum observed values. The rectangles indicate the range of values of the collective dose exhibited by those plants ranked in the 25th through the 75th percentiles. The median values do not normally fluctuate as much as the average values from year to year because they are not affected as much by the extreme values of the collective doses. The median collective dose was 28 person-rem for PWRs and 89 person-rem for BWRs in 2018. Figure 3.9-1 also shows that, in 2018, 50 percent of the PWRs reported collective doses between 19 and 44 person-rem, while 50 percent of the BWRs reported collective doses between 70 and 167 person-rem (NRC 2020i).

Table 3.9-9 and Table 3.9-10 presents the average, maximum, and minimum collective and individual occupational doses for all commercial nuclear power plants operating between 2006 and 2018.

For PWRs, the maximum variation in collective dose and annual average occupational dose was observed for Palisades. From 2006 to 2018, the collective dose varied from 6 to 486 person-rem, and the annual average occupational dose varied from 0.04 to 0.39 rem. The collective dose values were calculated per reactor rather than per site.

For BWRs, the maximum variation in collective dose and annual average occupational dose was observed for Perry. From 2006 to 2018, the collective dose varied from 30 to 615 person-rem and the annual average occupational dose was it varied from 0.10 to 0.34 rem. The collective dose values were calculated per reactor rather than per site.

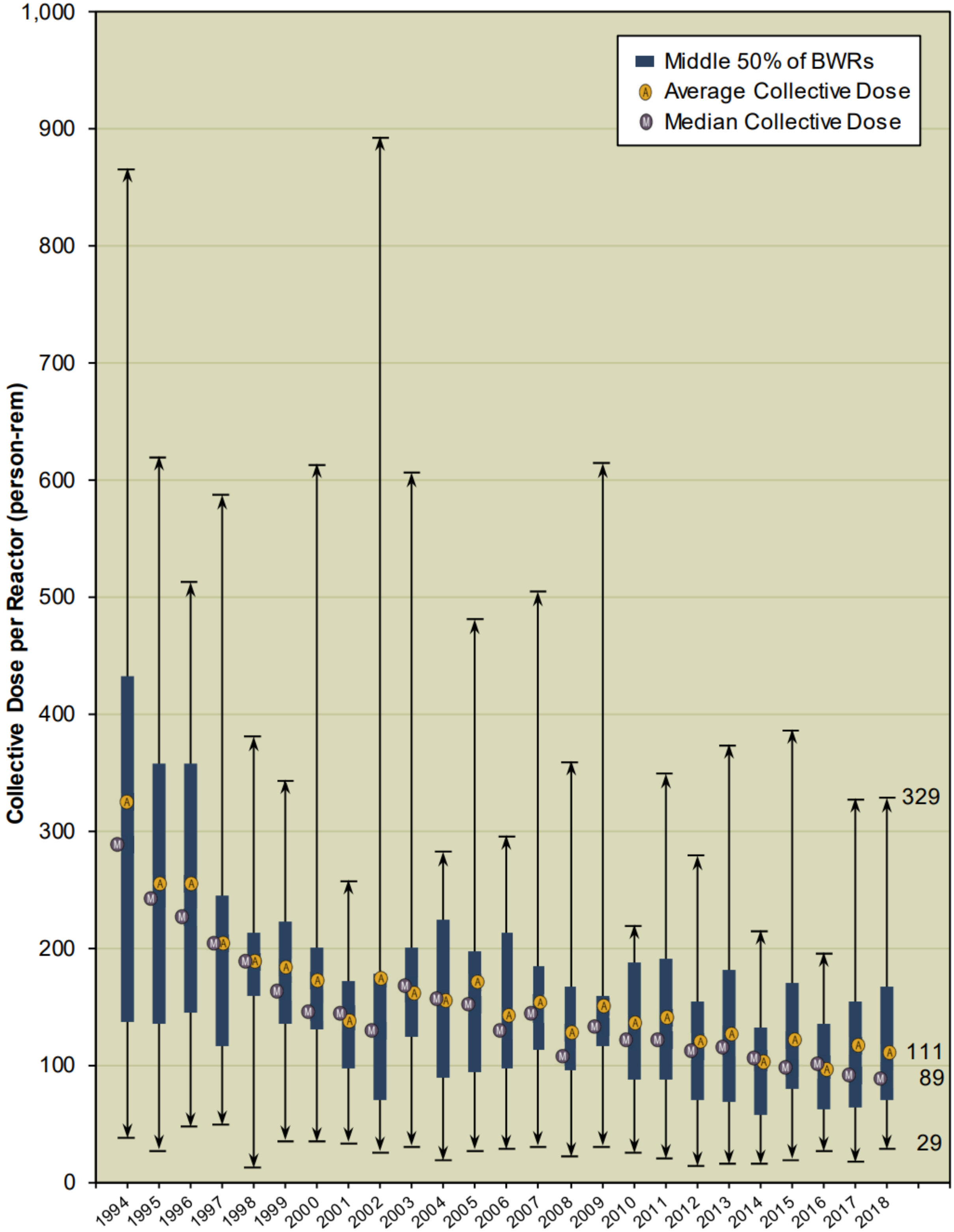



**Figure 3.9-1 Average, Median, and Extreme Values of the Collective Dose per Boiling Water Reactors Reactor from 1994 to 2018. Source: NRC 2020i.**

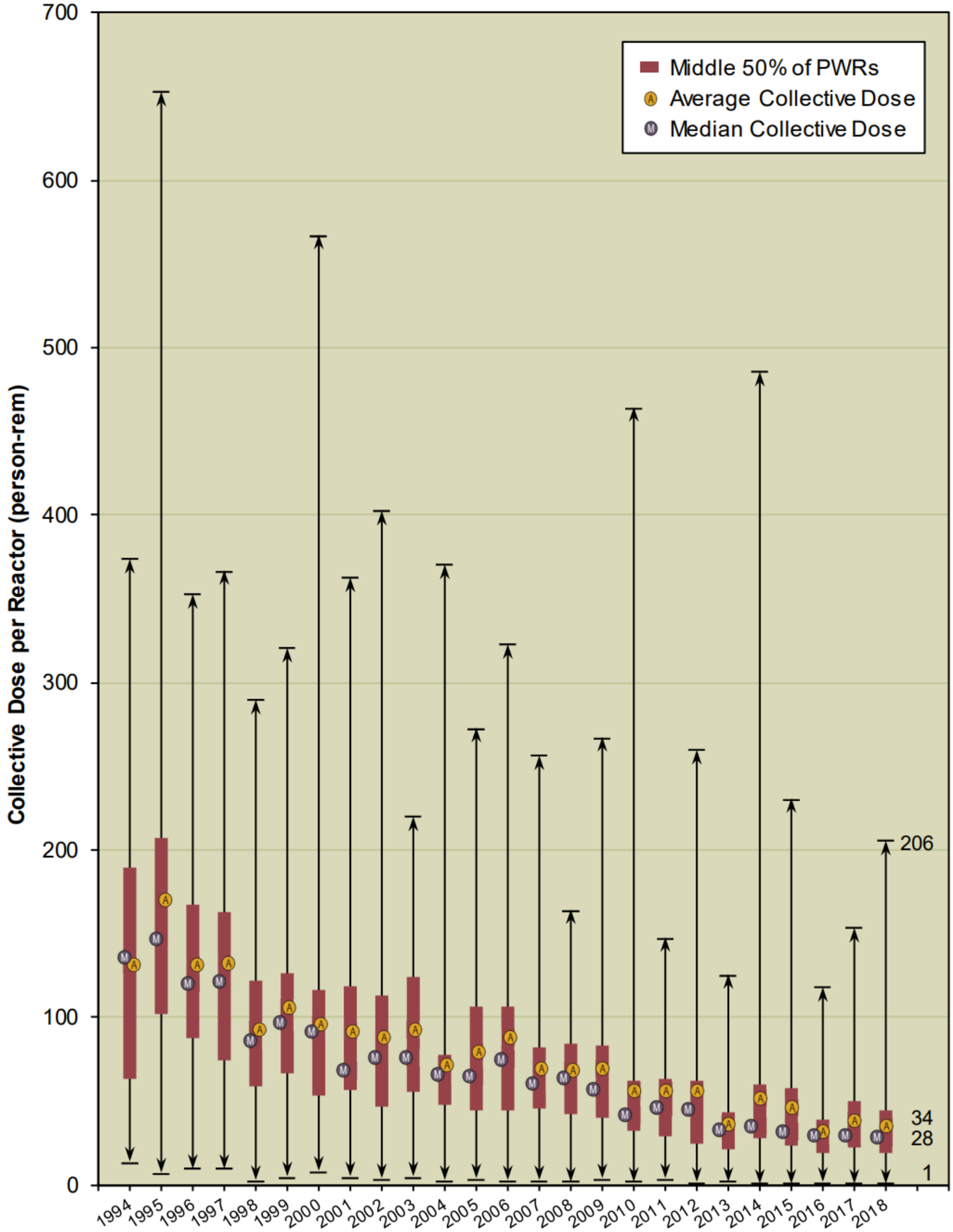



**Figure 3.9-2 Average, Median, and Extreme Values of the Collective Dose per Pressurized Water Reactor from 1994 to 2018. Source: NRC 2020i.**

**Table 3.9-9 Annual Collective Dose and Annual Occupational Dose for Pressurized Water Reactor Nuclear Power Plants from 2006 through 2018**

| PWR Plant | Average Collective Dose (person-rem/ reactor)[a] | Maximum Collective Dose (person-rem/ reactor)[a] | Minimum Collective Dose (person-rem/reactor)[a] | Annual Average Occupational Dose (rem) | Annual Maximum Occupational Dose (rem) | Annual Minimum Occupational Dose (rem) |
|---|---|---|---|---|---|---|
| Arkansas 1, 2 | 54 | 98 | 22 | 0.07 | 0.12 | 0.05 |
| Beaver Valley 1, 2 | 53 | 185 | 21 | 0.09 | 0.17 | 0.06 |
| Braidwood | 44 | 100 | 16 | 0.07 | 0.12 | 0.05 |
| Byron 1, 2 | 46 | 122 | 13 | 0.08 | 0.13 | 0.04 |
| Callaway 1 | 33 | 80 | 3 | 0.06 | 0.10 | 0.03 |
| Calvert Cliffs 1, 2 | 47 | 102 | 23 | 0.11 | 0.17 | 0.06 |
| Catawba 1, 2 | 49 | 106 | 16 | 0.08 | 0.12 | 0.05 |
| Comanche Peak 1, 2 | 47 | 110 | 18 | 0.09 | 0.16 | 0.05 |
| D.C. Cook 1, 2 | 48 | 156 | 15 | 0.09 | 0.18 | 0.05 |
| Crystal River 3[b] | 38 | 222 | 1 | 0.06 | 0.16 | 0.02 |
| Davis-Besse 1 | 98 | 464 | 1 | 0.09 | 0.28 | 0.02 |
| Diablo Canyon 1, 2 | 48 | 169 | 14 | 0.07 | 0.13 | 0.04 |
| Farley 1, 2 | 29 | 70 | 15 | 0.07 | 0.11 | 0.05 |
| Fort Calhoun[b] | 61 | 289 | 3 | 0.08 | 0.18 | 0.03 |
| Ginna | 39 | 102 | 2 | 0.07 | 0.11 | 0.02 |
| Harris 1 | 43 | 87 | 0 | 0.06 | 0.10 | 0.02 |
| Indian Point 2, 3[b] | 59 | 145 | 30 | 0.08 | 0.18 | 0.04 |
| Kewaunee[b] | 51 | 93 | 5 | 0.08 | 0.16 | 0.02 |
| McGuire 1, 2 | 51 | 83 | 20 | 0.07 | 0.11 | 0.05 |
| Millstone 2, 3 | 63 | 136 | 32 | 0.12 | 0.19 | 0.07 |
| North Anna 1, 2 | 53 | 155 | 22 | 0.11 | 0.20 | 0.07 |
| Oconee 1, 2, 3 | 46 | 84 | 12 | 0.08 | 0.13 | 0.04 |
| Palisades | 182 | 486 | 6 | 0.19 | 0.39 | 0.04 |
| Palo Verde 1, 2, 3 | 30 | 53 | 14 | 0.06 | 0.10 | 0.04 |
| Point Beach 1, 2 | 42 | 80 | 20 | 0.12 | 0.17 | 0.08 |
| Prairie Island 1, 2 | 36 | 69 | 3 | 0.09 | 0.13 | 0.05 |
| Robinson 2 | 46 | 86 | 3 | 0.06 | 0.09 | 0.03 |
| Salem 1, 2 | 53 | 164 | 17 | 0.07 | 0.10 | 0.04 |
| San Onofre[b] | 46 | 158 | 0 | 0.07 | 0.19 | 0.01 |
| Seabrook | 44 | 96 | 2 | 0.05 | 0.08 | 0.01 |
| Sequoyah 1, 2 | 62 | 145 | 22 | 0.09 | 0.14 | 0.06 |
| South Texas 1, 2 | 43 | 94 | 16 | 0.10 | 0.16 | 0.07 |
| St. Lucie 1, 2 | 81 | 205 | 36 | 0.11 | 0.17 | 0.08 |
| Summer 1 | 44 | 111 | 2 | 0.06 | 0.12 | 0.02 |
| Surry 1, 2 | 66 | 117 | 22 | 0.12 | 0.19 | 0.07 |
| Three Mile Island 1 | 74 | 242 | 2 | 0.07 | 0.12 | 0.03 |
| Turkey Point 3, 4 | 55 | 121 | 26 | 0.09 | 0.12 | 0.07 |
| Vogtle 1, 2 | 46 | 78 | 23 | 0.10 | 0.13 | 0.07 |
| Waterford 3 | 84 | 260 | 1 | 0.07 | 0.17 | 0.01 |
| Watts Bar 1, 2 | 31 | 161 | 1 | 0.06 | 0.16 | 0.02 |
| Wolf Creek 1 | 62 | 134 | 3 | 0.06 | 0.12 | 0.01 |

(a) The collective dose per reactor was calculated by dividing the "Collective Dose per Site" by the number of reactors on the site.
(b) Indicates nuclear power plants that have been shut down.
Note: To convert rem to Sv, multiply by 0.01.
Source: NRC 2020i.

**Table 3.9-10 Annual Collective Dose and Annual Occupational Dose for Boiling Water Reactor Nuclear Power Plants from 2006 through 2018**

| BWR Plant | Average Collective Dose (person-rem/ reactor)[(a)] | Maximum Collective Dose (person-rem/ reactor)[(a)] | Minimum Collective Dose (person-rem/ reactor)[(a)] | Annual Average Occupational Dose (rem) | Annual Maximum Occupational Dose (rem) | Annual Minimum Occupational Dose (rem) |
|---|---|---|---|---|---|---|
| Browns Ferry 1, 2, 3 | 145 | 214 | 96 | 0.16 | 0.20 | 0.12 |
| Brunswick 1, 2 | 148 | 204 | 84 | 0.12 | 0.14 | 0.07 |
| Clinton | 119 | 296 | 14 | 0.11 | 0.18 | 0.07 |
| Columbia | 150 | 336 | 27 | 0.10 | 0.16 | 0.04 |
| Cooper Station | 173 | 360 | 28 | 0.13 | 0.21 | 0.07 |
| Dresden 1, 2, 3 | 61 | 96 | 39 | 0.09 | 0.14 | 0.06 |
| Duane Arnold | 85 | 201 | 16 | 0.11 | 0.18 | 0.05 |
| Fermi 2 | 153 | 329 | 24 | 0.10 | 0.13 | 0.04 |
| FitzPatrick | 120 | 234 | 21 | 0.11 | 0.16 | 0.07 |
| Grand Gulf | 121 | 276 | 21 | 0.09 | 0.13 | 0.04 |
| Hatch 1, 2 | 87 | 130 | 42 | 0.12 | 0.18 | 0.05 |
| Hope Creek 1 | 119 | 191 | 25 | 0.07 | 0.09 | 0.03 |
| LaSalle 1, 2 | 171 | 285 | 109 | 0.15 | 0.20 | 0.09 |
| Limerick 1, 2 | 82 | 117 | 61 | 0.10 | 0.15 | 0.07 |
| Monticello | 101 | 237 | 29 | 0.13 | 0.18 | 0.07 |
| Nine Mile Point 1, 2 | 137 | 204 | 71 | 0.17 | 0.23 | 0.10 |
| Oyster Creek | 99 | 212 | 18 | 0.11 | 0.14 | 0.07 |
| Peach Bottom 2, 3 | 152 | 242 | 89 | 0.14 | 0.20 | 0.10 |
| Perry | 220 | 615 | 30 | 0.19 | 0.34 | 0.10 |
| Pilgrim 1 | 118 | 264 | 22 | 0.11 | 0.20 | 0.06 |
| Quad Cities 1, 2 | 120 | 280 | 71 | 0.11 | 0.24 | 0.08 |
| River Bend 1 | 147 | 312 | 16 | 0.11 | 0.18 | 0.05 |
| Susquehanna 1, 2 | 101 | 133 | 74 | 0.11 | 0.14 | 0.08 |
| Vermont Yankee | 101 | 214 | 13 | 0.14 | 0.19 | 0.10 |

(a) The collective dose per reactor was calculated by dividing the "Collective Dose per Site" by the number of reactors on the site.
Note: To convert rem to Sv, multiply by 0.01.
Source: NRC 2020i.

Table 3.9-11 and Table 3.9-12 show the annual collective occupational dose for all commercial nuclear power plants operating between 2006 to 2018 and Table 3.9-13 and Table 3.9-14 show the annual individual average occupational dose for PWR and BWR commercial nuclear power plants operating between 2006 to 2018. The year 2006 was chosen as a starting date because the dose data for years prior to 2006 were presented in the 2013 LR GEIS and the 1996 LR GEIS. From 2006 to 2018, operating nuclear power plants would have gone through many refueling outages, 5-year ISI, 10-year ISI, and also some refurbishment activities. To check for trends, data were divided into two time frames: from 2006 to 2012 and from 2013 to 2018. The averages for these two time frames were calculated and compared. The yearly average collective dose from 2013 to 2018 was lower than the dose from 2006 to 2012. For a few nuclear power plants, the average annual collective dose from 2013 to 2018 was higher, but in all cases, the yearly average occupational dose was less than 0.39 rem. The yearly average occupational dose was lower from 2013 to 2018 than from 2006 to 2012.

The data in Table 3.9-11, Table 3.9-12, Table 3.9-13, and Table 3.9-14 show that although there are variations from year to year, there is no consistent trend that shows that occupational doses are increasing over time. The average, maximum, and minimum collective occupational doses are presented in Table 3.9-15 and Table 3.9-16 for plants operated between 2014 to 2018. The average collective doses, however, are based on widely varying yearly doses. For example, between 2014 to 2018, annual collective doses for operating PWRs ranged from 1 to 486 person-rem; for operating BWRs, they ranged from 16 to 387 person-rem.

Average, maximum, and minimum individual occupational doses per reactor type are presented in Table 3.9-17 and Table 3.9-18 for plants that operated between 2006 and 2018. From 2006 through 2018, the annual dose per plant worker for operating PWRs ranged from 0.0 to 0.43 rem; for operating BWRs, it ranged from 0.03 to 0.34 rem.

Table 3.9-19 provides the distribution of individual whole-body doses for 2018. The dose distribution indicates that no worker received doses greater than 3 rem in 2018. Only 1 worker received a whole-body dose exceeding 2 rem during 2018. At BWRs, less than 0.003 percent of the workers received doses greater than 2 rem. At PWRs, no worker received a dose greater than 2 rem, and about 0.1 percent of the workers received a dose greater than 1 rem. Figure 3.9-3 shows the collective dose distribution by dose range for all commercial U.S. reactors from 2014 to 2018. The distribution of collective dose has been fairly constant over the past 5 years.

As mentioned in Section 3.9.1.1, under 10 CFR 20.2206, the NRC requires licensees to submit an annual report of the results of individual monitoring. In addition to reporting data on external exposures, licensees are required to report information about internal exposures. Licensees are required to list for each intake, the radionuclide, pulmonary clearance class, intake mode, and amount of the intake in microcuries. Eleven intakes by ingestion were reported by licensees during 2018 (5 for cobalt-60, 4 for manganese-54, and 2 for zinc-65). Fifty-five intakes were reported for the inhalation mode in 2018 (10 for cobalt-60, 10 for cobalt-58,1 for americium-241, 33 for iodine-131, and 1 niobium-95) (NRC 2020i). Table 3.9-20 lists the number of individuals with measurable CEDE, collective CEDE, and average measurable CEDE per individual as reported by different nuclear power reactor stations.

**Table 3.9-11 Annual Collective Dose for Pressurized Water Reactor (PWR) Nuclear Power Plants from 2006 through 2018 (person-rem/reactor)**

| No. of Reactors | Nuclear Power Plant | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Arkansas 1, 2 | 72 | 53 | 98 | 51 | 50 | 58 | 22 | 25 | 36 | 68 | 56 | 43 | 68 |
| 2 | Beaver Valley 1, 2 | 185 | 43 | 42 | 11 | 25 | 36 | 63 | 21 | 31 | 48 | 22 | 27 | 37 |
| 1 | Braidwood | 199 | 98 | 103 | 142 | 64 | 70 | 168 | 32 | 42 | 52 | 40 | 79 | 61 |
| 2 | Byron 1, 2 | 67 | 64 | 70 | 42 | 28 | 122 | 25 | 29 | 40 | 21 | 27 | 44 | 13 |
| 1 | Callaway 1 | 6 | 73 | 46 | 5 | 59 | 80 | 5 | 43 | 37 | 3 | 47 | 24 | 3 |
| 2 | Calvert Cliffs 1, 2 | 102 | 77 | 37 | 48 | 64 | 48 | 58 | 31 | 31 | 23 | 43 | 25 | 28 |
| 2 | Catawba 1, 2 | 106 | 72 | 43 | 85 | 49 | 26 | 47 | 41 | 25 | 49 | 39 | 16 | 44 |
| 2 | Comanche Peak 1, 2 | 30 | 110 | 84 | 26 | 35 | 77 | 33 | 23 | 70 | 21 | 18 | 60 | 21 |
| 2 | D.C. Cook 1, 2 | 156 | 119 | 38 | 20 | 42 | 29 | 25 | 52 | 27 | 15 | 47 | 29 | 20 |
| 1 | Crystal River 3 | 4 | 185 | 16 | 222 | 32 | 8 | 2 | 1 | 1 | 1 | 15 | 4 | 1 |
| 1 | Davis-Besse 1 | 204 | 7 | 107 | 4 | 464 | 73 | 43 | 3 | 200 | 1 | 118 | 2 | 51 |
| 2 | Diablo Canyon 1, 2 | 41 | 56 | 118 | 169 | 63 | 16 | 22 | 14 | 34 | 29 | 19 | 24 | 16 |
| 2 | Farley 1, 2 | 33 | 70 | 20 | 21 | 61 | 19 | 15 | 27 | 19 | 28 | 30 | 16 | 18 |
| 1 | Fort Calhoun | 289 | 4 | 96 | 111 | 10 | 79 | 39 | 64 | 5 | 76 | 11 | 3 | 7 |
| 1 | Ginna | 45 | 4 | 102 | 42 | 3 | 101 | 55 | 3 | 58 | 24 | 2 | 46 | 28 |
| 1 | Harris 1 | 87 | 65 | 10 | 41 | 83 | 5 | 80 | 55 | 1 | 58 | 44 | 0 | 32 |
| 2 | Indian Point 2, 3 | 145 | 55 | 71 | 40 | 100 | 32 | 55 | 37 | 71 | 30 | 36 | 51 | 44 |
| 1 | Kewaunee | 75 | 11 | 93 | 56 | 5 | 79 | 39 | 5 | 2 | 0 | 0 | 6 | 1 |
| 2 | McGuire 1, 2 | 54 | 78 | 83 | 40 | 41 | 60 | 31 | 55 | 69 | 25 | 34 | 74 | 20 |
| 2 | Millstone 2, 3 | 87 | 82 | 136 | 80 | 41 | 85 | 37 | 32 | 80 | 32 | 32 | 56 | 33 |
| 2 | North Anna 1, 2 | 41 | 155 | 31 | 39 | 91 | 45 | 53 | 61 | 36 | 22 | 60 | 22 | 28 |
| 3 | Oconee 1, 2, 3 | 74 | 84 | 62 | 60 | 64 | 61 | 44 | 35 | 36 | 23 | 18 | 12 | 19 |
| 1 | Palisades | 240 | 257 | 23 | 267 | 220 | 22 | 245 | 16 | 486 | 231 | 6 | 154 | 206 |
| 3 | Palo Verde 1, 2, 3 | 51 | 50 | 53 | 33 | 38 | 20 | 20 | 31 | 20 | 19 | 22 | 18 | 14 |
| 2 | Point Beach 1, 2 | 20 | 26 | 72 | 47 | 48 | 80 | 35 | 32 | 64 | 24 | 29 | 44 | 22 |
| 2 | Prairie Island 1, 2 | 69 | 3 | 63 | 27 | 27 | 29 | 60 | 65 | 35 | 31 | 24 | 17 | 19 |
| 1 | Robinson 2 | 3 | 81 | 68 | 7 | 86 | 4 | 65 | 81 | 29 | 56 | 4 | 59 | 62 |

| No. of Reactors | Nuclear Power Plant | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Salem 1, 2 | 45 | 59 | 164 | 51 | 39 | 63 | 24 | 30 | 55 | 17 | 47 | 68 | 25 |
| 2 | San Onofre | 158 | 46 | 63 | 89 | 100 | 15 | 111 | 3 | 1 | 1 | 1 | 0 | 12 |
| 1 | Seabrook | 77 | 4 | 75 | 87 | 4 | 66 | 54 | 2 | 40 | 96 | 2 | 29 | 33 |
| 2 | Sequoyah 1, 2 | 121 | 62 | 42 | 83 | 28 | 55 | 145 | 22 | 39 | 68 | 53 | 24 | 61 |
| 2 | South Texas 1, 2 | 75 | 46 | 94 | 40 | 40 | 70 | 25 | 30 | 17 | 42 | 16 | 28 | 35 |
| 2 | St. Lucie 1, 2 | 60 | 205 | 56 | 66 | 99 | 148 | 93 | 37 | 61 | 94 | 38 | 36 | 56 |
| 1 | Summer 1 | 61 | 3 | 49 | 56 | 2 | 32 | 82 | 5 | 111 | 65 | 3 | 50 | 49 |
| 2 | Surry 1, 2 | 117 | 104 | 75 | 97 | 56 | 57 | 84 | 34 | 29 | 91 | 22 | 29 | 59 |
| 1 | Three Mile Island 1 | 5 | 114 | 2 | 242 | 39 | 130 | 13 | 126 | 13 | 171 | 17 | 83 | 3 |
| 2 | Turkey Point 3, 4 | 75 | 54 | 49 | 83 | 43 | 31 | 121 | 41 | 57 | 40 | 38 | 54 | 26 |
| 2 | Vogtle 1, 2 | 58 | 60 | 69 | 40 | 45 | 59 | 30 | 39 | 78 | 30 | 29 | 40 | 23 |
| 1 | Waterford 3 | 110 | 20 | 134 | 255 | 5 | 100 | 260 | 3 | 69 | 66 | 3 | 61 | 1 |
| 2 | Watts Bar 1, 2 | 161 | 2 | 35 | 32 | 3 | 26 | 31 | 1 | 14 | 32 | 2 | 38 | 18 |
| 1 | Wolf Creek 1 | 97 | 4 | 95 | 74 | 11 | 134 | 8 | 111 | 28 | 75 | 91 | 3 | 73 |

Note: To convert rem to Sv, multiply by 0.01.
Source: NRC 2020i.

**Table 3.9-12 Annual Collective Dose for Boiling Water Reactor Nuclear Power Plants from 2006 through 2018 (person-rem/reactor)**

| No. of Reactors | Nuclear Power Plant | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Browns Ferry 1, 2, 3 | 214 | 185 | 161 | 116 | 186 | 99 | 155 | 128 | 130 | 96 | 135 | 117 | 166 |
| 2 | Brunswick 1, 2 | 140 | 145 | 177 | 175 | 204 | 191 | 185 | 181 | 131 | 115 | 84 | 108 | 92 |
| 1 | Clinton | 296 | 31 | 205 | 48 | 220 | 228 | 14 | 129 | 18 | 98 | 33 | 155 | 78 |
| 1 | Columbia | 56 | 306 | 55 | 305 | 55 | 336 | 45 | 224 | 34 | 289 | 27 | 180 | 43 |
| 1 | Cooper Station | 270 | 50 | 360 | 254 | 61 | 349 | 279 | 36 | 203 | 28 | 196 | 30 | 133 |
| 3 | Dresden 1, 2, 3 | 96 | 92 | 66 | 77 | 71 | 79 | 47 | 46 | 39 | 46 | 47 | 43 | 40 |
| 1 | Duane Arnold | 29 | 184 | 24 | 140 | 201 | 30 | 135 | 16 | 122 | 20 | 111 | 17 | 78 |
| 1 | Fermi 2 | 181 | 194 | 35 | 149 | 146 | 24 | 145 | 26 | 200 | 235 | 55 | 265 | 329 |
| 1 | FitzPatrick | 234 | 59 | 185 | 35 | 220 | 35 | 170 | 39 | 136 | 21 | 28 | 162 | 232 |
| 1 | Grand Gulf | 60 | 178 | 168 | 31 | 188 | 21 | 276 | 35 | 182 | 25 | 195 | 40 | 167 |

| No. of Reactors | Nuclear Power Plant | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Hatch 1, 2 | 130 | 69 | 95 | 93 | 123 | 88 | 96 | 70 | 95 | 42 | 111 | 51 | 70 |
| 1 | Hope Creek 1 | 134 | 191 | 35 | 169 | 161 | 25 | 154 | 151 | 37 | 170 | 140 | 32 | 150 |
| 2 | LaSalle 1, 2 | 124 | 114 | 109 | 148 | 192 | 170 | 112 | 192 | 183 | 251 | 169 | 285 | 175 |
| 2 | Limerick 1, 2 | 97 | 99 | 88 | 117 | 84 | 92 | 80 | 67 | 69 | 62 | 63 | 92 | 61 |
| 1 | Monticello | 33 | 191 | 44 | 174 | 56 | 237 | 39 | 199 | 35 | 130 | 29 | 116 | 29 |
| 2 | Nine Mile Point 1, 2 | 115 | 165 | 151 | 119 | 188 | 122 | 204 | 109 | 132 | 80 | 128 | 71 | 193 |
| 1 | Oyster Creek | 190 | 47 | 212 | 37 | 206 | 47 | 165 | 30 | 145 | 23 | 134 | 18 | 38 |
| 2 | Peach Bottom 2, 3 | 124 | 192 | 106 | 155 | 110 | 195 | 153 | 242 | 215 | 198 | 101 | 99 | 89 |
| 1 | Perry | 65 | 505 | 52 | 615 | 32 | 308 | 43 | 374 | 85 | 387 | 36 | 328 | 40 |
| 1 | Pilgrim 1 | 44 | 241 | 23 | 264 | 26 | 241 | 22 | 176 | 37 | 219 | 44 | 163 | 39 |
| 2 | Quad Cities 1, 2 | 280 | 125 | 137 | 159 | 121 | 144 | 97 | 96 | 78 | 85 | 71 | 87 | 81 |
| 1 | River Bend 1 | 214 | 131 | 312 | 219 | 40 | 211 | 34 | 188 | 16 | 128 | 71 | 273 | 70 |
| 2 | Susquehanna 1, 2 | 92 | 132 | 96 | 133 | 88 | 84 | 88 | 117 | 107 | 103 | 119 | 83 | 74 |
| 1 | Vermont Yankee | 50 | 171 | 214 | 61 | 206 | 176 | 45[(a)] | 170 | 21 | 50 | 13 | 14 | 18 |

Note: To convert rem to Sv, multiply by 0.01.
Sources: NRC 2020i.
(a) NRC 2019f, data missing from Vol 40.

**Table 3.9-13 Annual Average Measurable Occupational Doses at Pressurized Water Reactor Commercial Nuclear Power Plant Sites from 2006 through 2018 (in rem)**

| PWR Plants | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arkansas 1, 2 | 0.12 | 0.08 | 0.11 | 0.09 | 0.07 | 0.08 | 0.05 | 0.05 | 0.05 | 0.07 | 0.07 | 0.05 | 0.07 |
| Beaver Valley 1, 2 | 0.17 | 0.09 | 0.08 | 0.15 | 0.07 | 0.09 | 0.10 | 0.06 | 0.07 | 0.09 | 0.06 | 0.07 | 0.08 |
| Big Rock[a] | 0.01 | - | - | - | - | - | - | - | - | - | - | - | - |
| Braidwood 1, 2 | 0.12 | 0.08 | 0.08 | 0.10 | 0.07 | 0.07 | 0.09 | 0.05 | 0.05 | 0.05 | 0.05 | 0.07 | 0.07 |
| Byron 1, 2 | 0.12 | 0.10 | 0.09 | 0.08 | 0.06 | 0.13 | 0.06 | 0.06 | 0.07 | 0.05 | 0.06 | 0.07 | 0.04 |
| Callaway 1 | 0.03 | 0.07 | 0.06 | 0.03 | 0.07 | 0.10 | 0.03 | 0.06 | 0.06 | 0.03 | 0.07 | 0.05 | 0.04 |
| Calvert Cliffs 1, 2 | 0.17 | 0.13 | 0.10 | 0.11 | 0.15 | 0.14 | 0.16 | 0.11 | 0.11 | 0.08 | 0.10 | 0.07 | 0.06 |
| Catawba 1, 2 | 0.12 | 0.10 | 0.08 | 0.12 | 0.09 | 0.05 | 0.08 | 0.08 | 0.05 | 0.08 | 0.08 | 0.05 | 0.07 |
| Comanche Peak 1, 2 | 0.09 | 0.14 | 0.16 | 0.05 | 0.07 | 0.10 | 0.07 | 0.06 | 0.12 | 0.07 | 0.06 | 0.12 | 0.08 |
| D.C. Cook 1, 2 | 0.18 | 0.18 | 0.08 | 0.06 | 0.07 | 0.07 | 0.07 | 0.09 | 0.07 | 0.05 | 0.08 | 0.07 | 0.05 |
| Crystal River 3[b] | 0.03 | 0.16 | 0.06 | 0.13 | 0.05 | 0.03 | 0.02 | 0.02 | 0.03 | 0.04 | 0.16 | 0.06 | 0.05 |
| Davis-Besse 1 | 0.15 | 0.04 | 0.11 | 0.03 | 0.28 | 0.06 | 0.07 | 0.03 | 0.10 | 0.03 | 0.12 | 0.02 | 0.07 |
| Diablo Canyon 1, 2 | 0.08 | 0.09 | 0.11 | 0.13 | 0.09 | 0.04 | 0.05 | 0.04 | 0.07 | 0.07 | 0.05 | 0.06 | 0.04 |
| Farley 1, 2 | 0.09 | 0.11 | 0.06 | 0.06 | 0.09 | 0.05 | 0.05 | 0.07 | 0.05 | 0.06 | 0.06 | 0.05 | 0.06 |
| Fort Calhoun[c] | 0.18 | 0.04 | 0.11 | 0.13 | 0.06 | 0.08 | 0.08 | 0.09 | 0.03 | 0.10 | 0.07 | 0.04 | 0.09 |
| Ginna | 0.09 | 0.04 | 0.10 | 0.07 | 0.04 | 0.11 | 0.08 | 0.03 | 0.09 | 0.06 | 0.02 | 0.08 | 0.06 |
| Haddam Neck[d] | 0.10 | - | 0.01 | 0.01 | 0.01 | 0.06 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Harris 1 | 0.10 | 0.07 | 0.05 | 0.06 | 0.08 | 0.03 | 0.07 | 0.06 | 0.02 | 0.07 | 0.06 | 0.02 | 0.05 |
| Humbold T Bay[e] | 0.10 | 0.07 | 0.04 | 0.02 | 0.06 | 0.04 | 0.10 | 0.14 | 0.10 | 0.08 | - | - | - |
| Indian Point 1[f] | 0.04 | 0.01 | 0.02 | 0.00 | 0.01 | 0.00 | 0.00 | 0.09 | - | - | - | - | - |
| Indian Point 2, 3[g] | 0.18 | 0.06 | 0.10 | 0.04 | 0.10 | 0.05 | 0.09 | 0.06 | 0.11 | 0.05 | 0.08 | 0.05 | 0.05 |
| Kewaunee[h] | 0.14 | 0.08 | 0.16 | 0.09 | 0.03 | 0.10 | 0.07 | 0.04 | 0.03 | 0.02 | 0.02 | 0.10 | 0.13 |
| La Crosse[i] | - | 0.43 | 0.04 | 0.03 | 0.04 | 0.05 | 0.08 | 0.07 | 0.09 | 0.07 | 0.11 | 0.11 | 0.03 |
| Maine Yankee[j] | - | - | 0.01 | 0.05 | 0.08 | 0.03 | 0.04 | 0.05 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 |
| McGuire 1, 2 | 0.09 | 0.11 | 0.10 | 0.07 | 0.07 | 0.07 | 0.05 | 0.08 | 0.08 | 0.05 | 0.06 | 0.09 | 0.05 |
| Millstone 1[k] | 0.15 | 0.03 | - | - | - | - | - | - | - | - | - | - | - |
| Millstone 2, 3 | 0.15 | 0.14 | 0.19 | 0.16 | 0.11 | 0.16 | 0.10 | 0.09 | 0.13 | 0.08 | 0.07 | 0.10 | 0.09 |
| North Anna 1, 2 | 0.11 | 0.20 | 0.08 | 0.10 | 0.18 | 0.11 | 0.14 | 0.13 | 0.10 | 0.07 | 0.11 | 0.07 | 0.07 |
| Oconee 1, 2, 3 | 0.12 | 0.13 | 0.10 | 0.10 | 0.10 | 0.09 | 0.07 | 0.07 | 0.05 | 0.05 | 0.05 | 0.04 | 0.05 |
| Palisades | 0.27 | 0.24 | 0.09 | 0.27 | 0.24 | 0.06 | 0.22 | 0.05 | 0.39 | 0.25 | 0.04 | 0.19 | 0.22 |
| Palo Verde 1, 2, 3 | 0.10 | 0.06 | 0.09 | 0.06 | 0.07 | 0.05 | 0.05 | 0.08 | 0.06 | 0.05 | 0.06 | 0.05 | 0.04 |
| Point Beach 1, 2 | 0.09 | 0.10 | 0.15 | 0.12 | 0.11 | 0.16 | 0.12 | 0.12 | 0.17 | 0.11 | 0.11 | 0.12 | 0.08 |

| PWR Plants | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Prairie Island 1, 2 | 0.12 | 0.05 | 0.12 | 0.10 | 0.08 | 0.09 | 0.13 | 0.09 | 0.09 | 0.08 | 0.07 | 0.06 | 0.07 |
| Rancho Seco[(l)] | 0.22 | 0.10 | 0.03 | - | - | - | - | - | - | - | - | - | - |
| Robinson 2 | 0.04 | 0.09 | 0.09 | 0.05 | 0.09 | 0.03 | 0.06 | 0.07 | 0.06 | 0.06 | 0.03 | 0.07 | 0.06 |
| Salem 1, 2 | 0.06 | 0.09 | 0.10 | 0.08 | 0.08 | 0.06 | 0.07 | 0.07 | 0.04 | 0.06 | 0.08 | 0.08 | 0.09 |
| San Onofre 1[(m)] | 0.12 | 0.02 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| San Onofre 2, 3[(n)] | 0.19 | 0.09 | 0.12 | - | - | - | - | - | - | - | - | - | - |
| San Onofre 1[(m)], 2, 3[(n)] | - | - | - | 0.11 | 0.12 | 0.05 | 0.10 | 0.03 | 0.02 | 0.01 | 0.02 | 0.01 | 0.19 |
| Seabrook | 0.06 | 0.01 | 0.06 | 0.07 | 0.01 | 0.06 | 0.05 | 0.01 | 0.04 | 0.08 | 0.03 | 0.06 | 0.07 |
| Sequoyah 1, 2 | 0.14 | 0.10 | 0.09 | 0.12 | 0.07 | 0.08 | 0.11 | 0.07 | 0.09 | 0.09 | 0.09 | 0.06 | 0.09 |
| South Texas 1, 2 | 0.14 | 0.10 | 0.16 | 0.07 | 0.09 | 0.12 | 0.08 | 0.07 | 0.08 | 0.09 | 0.08 | 0.09 | 0.10 |
| St. Lucie 1, 2 | 0.10 | 0.17 | 0.10 | 0.12 | 0.15 | 0.14 | 0.11 | 0.08 | 0.11 | 0.13 | 0.08 | 0.08 | 0.10 |
| Summer 1 | 0.09 | 0.04 | 0.08 | 0.07 | 0.02 | 0.05 | 0.11 | 0.03 | 0.12 | 0.08 | 0.02 | 0.06 | 0.07 |
| Surry 1, 2 | 0.19 | 0.19 | 0.14 | 0.16 | 0.12 | 0.10 | 0.14 | 0.09 | 0.08 | 0.14 | 0.07 | 0.07 | 0.10 |
| Three Mile Island 1[(o)] | 0.04 | 0.09 | 0.03 | 0.12 | 0.05 | 0.11 | 0.05 | 0.10 | 0.06 | 0.12 | 0.05 | 0.08 | 0.03 |
| Turkey Point 3, 4 | 0.11 | 0.10 | 0.09 | 0.12 | 0.08 | 0.07 | 0.12 | 0.09 | 0.09 | 0.08 | 0.09 | 0.10 | 0.08 |
| Vogtle 1, 2 | 0.13 | 0.13 | 0.12 | 0.09 | 0.10 | 0.10 | 0.08 | 0.09 | 0.11 | 0.07 | 0.08 | 0.09 | 0.07 |
| Waterford 3 | 0.09 | 0.04 | 0.11 | 0.17 | 0.02 | 0.09 | 0.14 | 0.02 | 0.07 | 0.07 | 0.01 | 0.07 | 0.01 |
| Watts Bar 1, 2 | 0.16 | 0.03 | 0.08 | 0.07 | 0.05 | 0.06 | 0.06 | 0.03 | 0.05 | 0.07 | 0.02 | 0.07 | 0.05 |
| Wolf Creek 1 | 0.12 | 0.05 | 0.10 | 0.05 | 0.02 | 0.11 | 0.03 | 0.08 | 0.04 | 0.06 | 0.07 | 0.01 | 0.06 |
| Yankee Rowe[(p)] | 0.02 | - | 0.02 | 0.02 | 0.03 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 |
| Zion 1, 2[(q)] | 0.02 | 0.03 | 0.02 | - | 0.03 | 0.22 | 0.41 | 0.20 | 0.22 | 0.42 | 0.24 | 0.06 | 0.01 |

PWR = pressurized water reactor.

(a) Big Rock Point ceased operations in August 1997 and is no longer included in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.

(b) Crystal River ceased power generation in 2010 due to problems associated with containment building delamination. In June 2013, it was decided that it would not be put in commercial operation again and, therefore, it is no longer included in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.

(c) Fort Calhoun ceased power generation in October 2016 and is no longer included in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.

(d) Haddam Neck (also known as Connecticut Yankee) ceased operations on December 4, 1996, and is no longer in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.

(e) Humboldt Bay had been shut down since 1976, and in 1983, PG&E announced its intention to decommission the unit. Therefore, it is no longer included in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.

(f) Indian Point 1 was shut down October 31, 1974. All spent fuel was removed from the reactor vessel by January 1976. Therefore, it is no longer included in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.

(g) Indian Point 3 was purchased by a different utility in 1979 and subsequently reported its dose separately. Indian Point 1, 2, and 3 have been owned by the same utility since 2001 and report together.

(h) Kewaunee Power Station (Kewaunee) ceased operations in May 2013 and is no longer included in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.
(i) La Crosse ceased operations in 1987 and will not be put in commercial operation again. Therefore, it is no longer included in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.
(j) Maine Yankee ceased operations in August 1997 and is no longer included in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.
(k) Millstone 1 ceased operations in 1998 and is no longer included in the count of operating reactors. Parentheses indicate plant capacity when plant was operational. From 2008-2014, Millstone 1 voluntarily provided an estimate of the collective dose for Unit 1, but not the number of individuals with measurable dose.
(l) Rancho Seco ceased operations in June 1989 and is no longer in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.
(m) San Onofre 1 ceased operations in November 1992 and is no longer in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.
(n) San Onofre 2, 3 ceased power generation in January 2012, and in June 2013 it was decided that they would not be put back into commercial operation. Therefore, they are no longer included in the count of operating reactors. Parentheses indicate plant capacities when plants were operational.
(o) Three Mile Island, Unit 1 (Three Mile Island) resumed commercial power generation in October 1985 after being under regulatory restraint since 1979.
(p) Yankee Rowe ceased operations as of October 1991 and will not be put in commercial operation again. It is no longer in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.
(q) Zion 1, 2 ceased operations in 1997 and 1996, respectively, and are no longer included in the count of operating reactors.

No entry has been denoted by "-".

Source: NRC 2020i.

**Table 3.9-14 Annual Average Measurable Occupational Doses at Boiling Water Reactor Commercial Nuclear Power Plant Sites from 2006 through 2018 (in rem)**

| BWR Plants | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Browns Ferry[(a)] 1[(a)], 2, 3 | 0.18 | 0.18 | 0.18 | 0.16 | 0.2 | 0.14 | 0.15 | 0.15 | 0.16 | 0.13 | 0.13 | 0.12 | 0.15 |
| Brunswick 1, 2 | 0.13 | 0.13 | 0.14 | 0.13 | 0.13 | 0.14 | 0.11 | 0.09 | 0.07 | 0.09 | 0.10 | 0.12 | 0.12 |
| Clinton | 0.18 | 0.10 | 0.15 | 0.11 | 0.14 | 0.14 | 0.07 | 0.11 | 0.10 | 0.08 | 0.07 | 0.12 | 0.07 |
| Columbia Generating[(b)] | 0.09 | 0.14 | 0.08 | 0.16 | 0.07 | 0.15 | 0.04 | 0.13 | 0.04 | 0.14 | 0.05 | 0.10 | 0.09 |
| Cooper Station | 0.21 | 0.07 | 0.21 | 0.16 | 0.08 | 0.20 | 0.16 | 0.07 | 0.16 | 0.07 | 0.15 | 0.08 | 0.13 |
| Dresden 1[(c)], 2, 3 | 0.14 | 0.12 | 0.09 | 0.12 | 0.10 | 0.10 | 0.07 | 0.08 | 0.07 | 0.07 | 0.08 | 0.07 | 0.06 |
| Duane Arnold | 0.12 | 0.17 | 0.09 | 0.15 | 0.18 | 0.07 | 0.12 | 0.06 | 0.12 | 0.05 | 0.10 | 0.08 | 0.11 |
| Fermi 2 | 0.13 | 0.13 | 0.08 | 0.10 | 0.09 | 0.06 | 0.10 | 0.04 | 0.11 | 0.13 | 0.07 | 0.13 | 0.13 |
| FitzPatrick | 0.15 | 0.11 | 0.13 | 0.07 | 0.15 | 0.07 | 0.11 | 0.07 | 0.08 | 0.08 | 0.08 | 0.14 | 0.16 |
| Grand Gulf | 0.06 | 0.10 | 0.09 | 0.06 | 0.10 | 0.04 | 0.11 | 0.09 | 0.11 | 0.04 | 0.13 | 0.07 | 0.13 |
| Hatch 1, 2 | 0.18 | 0.10 | 0.14 | 0.14 | 0.14 | 0.11 | 0.12 | 0.10 | 0.12 | 0.05 | 0.13 | 0.09 | 0.11 |
| Hope Creek 1 | 0.06 | 0.09 | 0.03 | 0.08 | 0.08 | 0.06 | 0.07 | 0.07 | 0.04 | 0.06 | 0.08 | 0.08 | 0.09 |
| Lasalle 1, 2 | 0.12 | 0.12 | 0.09 | 0.15 | 0.16 | 0.12 | 0.11 | 0.20 | 0.17 | 0.20 | 0.13 | 0.20 | 0.12 |
| Limerick 1, 2 | 0.13 | 0.13 | 0.13 | 0.15 | 0.11 | 0.09 | 0.08 | 0.08 | 0.09 | 0.08 | 0.08 | 0.10 | 0.07 |
| Monticello | 0.12 | 0.18 | 0.12 | 0.14 | 0.11 | 0.12 | 0.07 | 0.16 | 0.13 | 0.15 | 0.09 | 0.14 | 0.11 |
| Nine Mile Point 1, 2 | 0.20 | 0.18 | 0.22 | 0.16 | 0.22 | 0.18 | 0.23 | 0.15 | 0.18 | 0.10 | 0.15 | 0.10 | 0.20 |
| Oyster Creek[(d)] | 0.13 | 0.10 | 0.14 | 0.10 | 0.12 | 0.11 | 0.12 | 0.10 | 0.13 | 0.08 | 0.10 | 0.07 | 0.11 |
| Peach Bottom 2, 3 | 0.16 | 0.20 | 0.12 | 0.15 | 0.13 | 0.14 | 0.12 | 0.17 | 0.14 | 0.13 | 0.10 | 0.11 | 0.10 |
| Perry | 0.13 | 0.31 | 0.10 | 0.34 | 0.12 | 0.19 | 0.11 | 0.23 | 0.19 | 0.24 | 0.10 | 0.23 | 0.14 |
| Pilgrim 1 | 0.07 | 0.17 | 0.06 | 0.20 | 0.08 | 0.20 | 0.08 | 0.15 | 0.09 | 0.16 | 0.07 | 0.10 | 0.06 |
| Quad Cities 1, 2 | 0.24 | 0.13 | 0.13 | 0.13 | 0.11 | 0.12 | 0.09 | 0.09 | 0.08 | 0.09 | 0.08 | 0.09 | 0.10 |
| River Bend 1 | 0.14 | 0.12 | 0.17 | 0.11 | 0.05 | 0.11 | 0.05 | 0.10 | 0.05 | 0.14 | 0.13 | 0.18 | 0.12 |
| Susquehanna 1, 2 | 0.10 | 0.11 | 0.10 | 0.14 | 0.09 | 0.09 | 0.08 | 0.13 | 0.11 | 0.12 | 0.11 | 0.11 | 0.11 |
| Vermont Yankee[(e)] | 0.13 | 0.14 | 0.15 | 0.16 | 0.19 | 0.17 | 0.16 | 0.11 | 0.12 | 0.10 | 0.11 | 0.10 | - |

BWR = boiling water reactor.
(a) All three Browns Ferry units were placed on administrative hold in 1985. Units 2 and 3 were restarted in 1991 and 1995, respectively. Browns Ferry Unit 1 was restarted during 2007.
(b) Energy Northwest changed the name of Washington Nuclear 2 to Columbia Generating Station in 2001.
(c) Dresden 1 ceased power generation in 1978, and in 1985, it was decided that it would not be put in commercial operation again. Therefore, it is no longer included in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.
(d) Oyster Creek ceased operations in September 2018 and is no longer included in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.
(e) Vermont Yankee ceased operations in December 2014 and is no longer in the count of operating reactors. Parentheses indicate plant capacity when plant was operational.
No entry has been denoted by "-".
Source: NRC 2020i.

**Table 3.9-15 Average, Maximum, and Minimum Annual Collective Occupational Dose per Plant for Pressurized Water Reactor Nuclear Power Plants in person-rem**

| Year | Average | Maximum | Minimum |
|---|---|---|---|
| 2014 | 51 | 486 | 1 |
| 2015 | 44 | 231 | 1 |
| 2016 | 31 | 118 | 2 |
| 2017 | 37 | 154 | 1 |
| 2018 | 34 | 206 | 1 |

Note: To convert rem to Sv, multiply by 0.01.
Source: NRC 2020i.

**Table 3.9-16 Average, Maximum, and Minimum Annual Collective Occupational Dose per Plant for Boiling Water Reactor Nuclear Power Plants in person-rem**

| Year | Average | Maximum | Minimum |
|---|---|---|---|
| 2014 | 109 | 215 | 16 |
| 2015 | 122 | 387 | 20 |
| 2016 | 98 | 196 | 27 |
| 2017 | 118 | 328 | 17 |
| 2018 | 111 | 329 | 29 |

Note: To convert rem to Sv, multiply by 0.01.
Source: NRC 2020i.

**Table 3.9-17 Average, Maximum, and Minimum Annual Individual Occupational Whole-Body Dose for Pressurized Water Reactor Nuclear Power Plants in rem**

| Year | Average Whole-Body Dose (rem) per Plant | Maximum Whole-Body Dose (rem) per Plant | Minimum Whole-Body Dose (rem) per Plant |
|---|---|---|---|
| 2006 | 0.11 | 0.27 | 0.01 |
| 2007 | 0.10 | 0.43 | 0.01 |
| 2008 | 0.09 | 0.19 | 0.01 |
| 2009 | 0.09 | 0.27 | 0.00 |
| 2010 | 0.08 | 0.28 | 0.01 |
| 2011 | 0.08 | 0.22 | 0.00 |
| 2012 | 0.09 | 0.41 | 0.00 |
| 2013 | 0.07 | 0.20 | 0.01 |
| 2014 | 0.08 | 0.39 | 0.01 |
| 2015 | 0.08 | 0.42 | 0.01 |
| 2016 | 0.07 | 0.24 | 0.01 |
| 2017 | 0.07 | 0.19 | 0.01 |
| 2018 | 0.07 | 0.22 | 0.01 |

Note: To convert rem to Sv, multiply by 0.01.
Source: NRC 2020i.

**Table 3.9-18 Average, Maximum, and Minimum Annual Individual Occupational Whole-Body Dose for Boiling Water Reactor Nuclear Power Plants in rem**

| Year | Average Whole-Body Dose (rem) per Plant | Maximum Whole-Body Dose (rem) per Plant | Minimum Whole-Body Dose (rem) per Plant |
|---|---|---|---|
| 2006 | 0.14 | 0.24 | 0.06 |
| 2007 | 0.14 | 0.31 | 0.07 |
| 2008 | 0.12 | 0.22 | 0.03 |
| 2009 | 0.14 | 0.34 | 0.06 |
| 2010 | 0.12 | 0.22 | 0.05 |
| 2011 | 0.12 | 0.20 | 0.04 |
| 2012 | 0.11 | 0.23 | 0.04 |
| 2013 | 0.11 | 0.23 | 0.04 |
| 2014 | 0.11 | 0.19 | 0.04 |
| 2015 | 0.11 | 0.24 | 0.04 |
| 2016 | 0.10 | 0.15 | 0.05 |
| 2017 | 0.11 | 0.23 | 0.07 |
| 2018 | 0.11 | 0.20 | 0.06 |

Note: To convert rem to Sv, multiply by 0.01.
Source: NRC 2020i.

**Table 3.9-19 Number of Workers at Boiling Water Reactors and Pressurized Water Reactors Who Received Whole-Body Doses within Specified Ranges during 2018**

| Whole Body Dose Range (rem)[(a)] | BWRs (33) | PWRs (65) | Total (98) |
|---|---|---|---|
| Meas. <0.025 | 9,354 | 11,145 | 20,499 |
| 0.025-0.10 | 11,320 | 12,387 | 23,707 |
| 0.10-0.25 | 6,258 | 4,772 | 11,030 |
| 0.25-0.50 | 3,021 | 1,186 | 4,207 |
| 0.50-0.75 | 831 | 255 | 1,086 |
| 0.75-1.0 | 250 | 66 | 316 |
| 1.0-2.0 | 134 | 34 | 168 |
| 2.0-3.0 | 1 | 0 | 1 |
| 3.0-4.0 | 0 | 0 | 0 |
| 4.0-5.0 | 0 | 0 | 0 |
| 5.0-6.0 | 0 | 0 | 0 |
| >6.0 | 0 | 0 | 0 |
| Total Number Monitored | 61,622 | 88,597 | 150,219 |
| Number with Measured Dose | 31,168 | 29,846 | 61,014 |
| Total Collective Dose (Whole Body) (person-rem) | 3,659.59 | 2,169.88 | 5,829.47 |

BWRs = boiling water reactors; PWRs = pressurized water reactors.
(a) Dose values exactly equal to the values separating ranges are reported in the next higher range.
Note: To convert rem to Sv, multiply by 0.01.
Source: NRC 2020i.

A portion of the total workforce can be defined as “transient.” These individuals are usually employed for special functions and may be employed at multiple reactor sites during a given year. Data for individual reactors described earlier include these people, but only for each power plant. Thus, some people are counted more than once, and some people receive greater annual doses than are reported by individual plants. In 2018, there were about 25,000 of these people (NRC 2020i). Over the years, doses to transient workers at nuclear power plants have been decreasing in the same way as doses to more permanent workers, going from an average of 0.32 rem in 2005 (NRC 2006f) to 0.20 rem in 2018 (NRC 2020i). In 2018, two transient workers received whole-body doses between 3 and 4 rem, and none received more than 4 rem (NRC 2020i).

Figure 3.9-3 shows the percentage of workers that received dose in five dose ranges for all commercial U.S. Reactors for 2014 through 2018 from NUREG-0713 (NRC 2020i). The data shows that the majority of the doses were less than 0.1 rem with much fewer dose contributions between 0.1 and 2 rem.

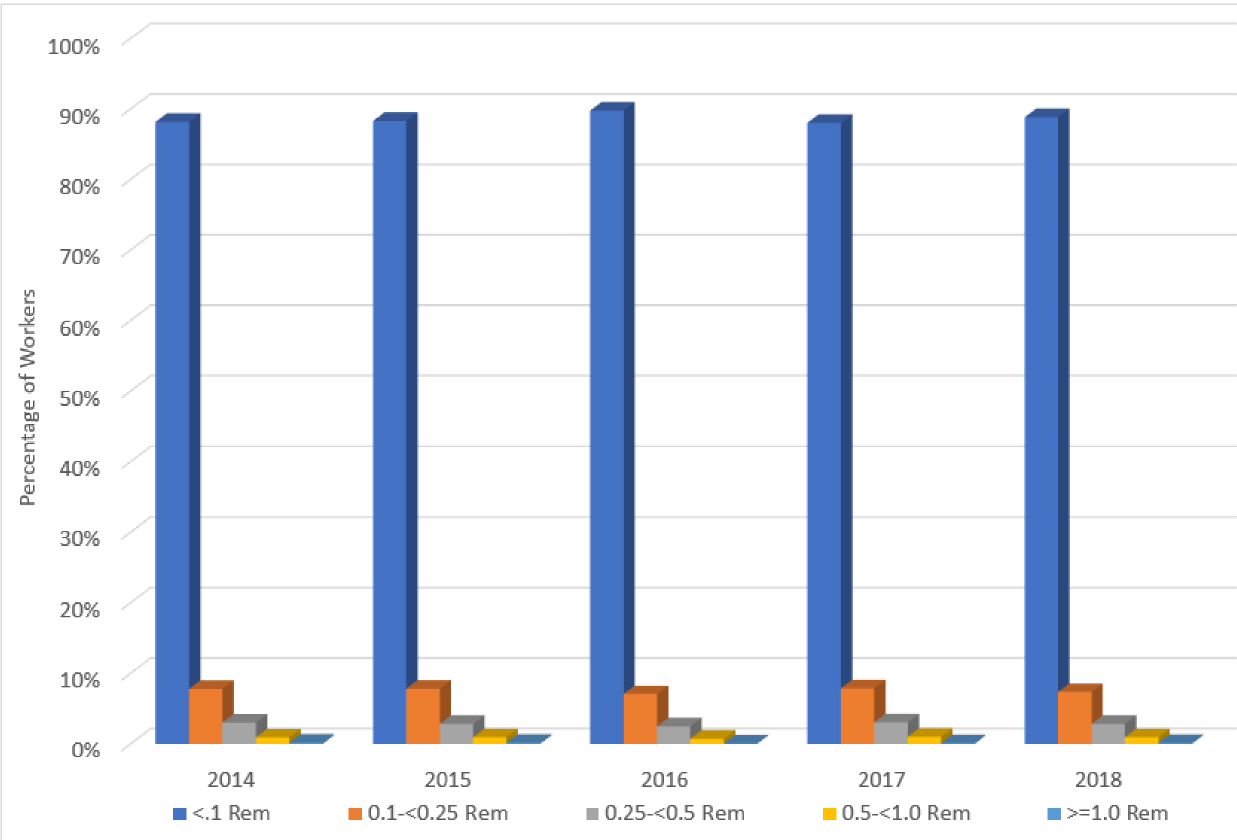



**Figure 3.9-3 Dose Distribution for All Commercial U.S. Reactors by Dose Range (rem), 2014 through 2018. Source: NRC 2020i.**

**Table 3.9-20 Collective and Average Committed Effective Dose Equivalent for Commercial U.S. Nuclear Power Plant Sites in 2018**

| Nuclear Power Plant | Number of Individuals with Measurable CEDE | Collective CEDE (person-rem) | Average Measurable CEDE (rem) |
|---|---|---|---|
| Diablo Canyon | 1 | 0.006 | 0.006 |
| Duane Arnold | 4 | 0.016 | 0.004 |
| Indian Point | 1 | 0.002 | 0.002 |
| Millstone | 1 | 0.001 | 0.001 |
| Wolf Creek | 96 | 0.194 | 0.002 |

CEDE = committed effective dose equivalent.
Note: To convert rem to Sv, multiply by 0.01.
Source: NRC 2020i.

As mentioned in Section 3.9.1.1, under 10 CFR 20.2202 and 10 CFR 20.2203, the NRC requires that all licensees submit reports of all occurrences involving personnel radiation exposures and releases of radioactive material that exceed certain control levels. For 2018, there was no occurrence reported for nuclear power reactors (NRC 2020i).

#### *3.9.1.3 Public Radiological Exposures*

Commercial nuclear power plants, under controlled conditions, release small amounts of radioactive materials to the environment during normal operation. Radioactive waste management systems are incorporated into each plant. They are designed to remove most of the fission product radioactivity that leaks from the fuel, as well as most of the activation- and corrosion-product radioactivity produced by neutrons in the vicinity of the reactor core. The amounts of radioactivity released through vents and discharge points to areas outside the plant boundaries are recorded and published annually in the radioactive effluent release reports for each facility. These reports are publicly available on the NRC's ADAMS. The effluent releases result in radiation doses to humans. Nuclear power plant licensees must comply with Federal regulations (e.g., 10 CFR Part 20, Appendix I to 10 CFR Part 50, 10 CFR 50.36a, and 40 CFR Part 190) and technical specifications in the operating license.

Potential environmental pathways through which persons may be exposed to radiation originating in a nuclear power plant include the atmospheric and water pathways. Radioactive materials released under controlled conditions include fission products and activation products. Fission product releases consist primarily of the noble gases and some of the more volatile materials like tritium, isotopes of iodine, and cesium. These materials are monitored before release to determine whether the limits on releases can be met. Releases to the aquatic pathways are similarly monitored. Radioactive materials in the liquid effluents are processed in radioactive waste treatment systems. The major radionuclides released to aquatic systems have been tritium, isotopes of cobalt, and cesium.

When an individual is exposed to radioactive materials released by the plant into air or water pathways, the dose is determined in part by the amount of time spent in the vicinity of the source or the amount of time the radionuclides inhaled or ingested are retained in the individual's body (exposure). The consequences associated with this exposure are evaluated by calculating the dose. The major exposure pathways include the following:

- inhalation of contaminated air;
- drinking milk or eating meat from animals that graze on open pasture on which radioactive contamination may be deposited;
- eating vegetables grown near the site; and
- drinking (untreated) water or eating fish caught near the point of discharge of liquid effluents.

Radiation doses are calculated for the maximally exposed individual (MEI) (that is, a hypothetical individual potentially subject to maximum exposure). Doses are calculated by using plant-specific data where available. For those cases in which plant-specific data are not readily available, conservative (overestimating) assumptions are used to estimate dose.

Members of the general public are also exposed when the low-level waste (LLW) is shipped offsite. The public radiation exposures from radioactive material transportation have been addressed in Table S-4 of 10 CFR Part 51. Table S-4 indicates that the cumulative dose to the exposed public from the transport of both LLW and spent fuel is estimated to be about 0.03 person-Sv (3 person-rem) per reactor year (see Table 4.14-2).

*3.9.1.3.1 Effluent Pathways for Calculations of Dose to the Public*

Radioactive effluents can be divided into several groups on the basis of their physical characteristics. Among the airborne effluents, the radioisotopes of the noble gases krypton, xenon, and argon neither deposit on the ground nor are absorbed and accumulated within living organisms; therefore, the noble gas effluents act primarily as a source of direct external radiation emanating from the effluent plume. For these effluents, dose calculations are performed for the site boundary where the highest external radiation doses to a member of the general public are estimated to occur.

A second group of airborne radioactive effluents—the fission product radioiodines and tritium—are also gaseous, but some of them can be deposited on the ground or inhaled during respiration. For this class of effluents, estimates are made of direct external radiation doses from ground deposits (as well as exposure to the plume). Estimates are also made of internal radiation doses to the total body, thyroid, bone, and other organs from inhalation and from vegetable, milk, and meat consumption.

A third group of airborne effluents consists of particulates and includes fission products, such as cesium and strontium, and activated corrosion products, such as cobalt and chromium. These effluents contribute to direct external radiation doses and to internal radiation doses through the same pathways as those described above for the radioiodine. Doses from the particulates are combined with those from the radioiodines and tritium for comparison with one of the design objectives of Appendix I to 10 CFR Part 50.

Liquid effluent constituents could include fission products such as strontium and iodine; activation and corrosion products, such as sodium, iron, and cobalt; and tritiated water. These radionuclides contribute to the internal doses through the pathways described above from fish consumption, water ingestion (as drinking water), and consumption of meat or vegetables raised near a nuclear plant and using irrigation water, as well as from any direct external radiation from recreational use of the water near the point of a plant’s discharge.

The release of each radioisotope and the site-specific meteorological and hydrological data serve as input to radiation dose models that estimate the maximum radiation dose that would be received outside the facility by way of a number of pathways for individual members of the public and for the general public as a whole. These models and the radiation dose calculations are discussed in Revision 1 of Regulatory Guide 1.109 (NRC 1977).

Doses from gaseous radioactive iodine and radioactive material in particulate form in gaseous effluents are calculated for individuals at the location or source point (e.g., site boundary, garden, residence, dairy animal, meat animal) where the highest radiation dose to a member of the public has been established from each applicable pathway (e.g., ground deposition, inhalation, vegetable consumption, milk consumption, meat consumption). Only those pathways associated with airborne effluents that are known to exist at a single location are combined to calculate the total maximum exposure to an exposed individual. Pathway doses associated with liquid effluents are conservatively combined without regard to any single location but are assumed to be associated with the maximum exposure of an individual.

A number of possible exposure pathways to humans are evaluated to determine the impact of routine releases from each nuclear facility on members of the general public living and working outside the site boundaries. A listing of these exposure pathways include external radiation exposure from gaseous effluents, inhalation of iodines and particulate contaminants in the air, consuming milk from dairy animals or eating meat from an animal that grazes on open pasture near the site on which iodines or particulates may be deposited, eating vegetables from a garden near the site (that may be contaminated by similar deposits), and drinking water or eating fish or invertebrates caught near the point of liquid effluent discharge. Other exposure pathways may include external irradiation from surface deposition; eating of animals and crops grown near the site and irrigated with water contaminated by liquid effluents; shoreline, boating, and swimming activities; drinking potentially contaminated water; and direct radiation being emitted from the plant itself. Calculations for most pathways are limited to a radius of 50 mi (80 km). For this study, effluent and MEI dose information was collected from a series of publicly available annual radioactive effluent release reports that licensees submit to the NRC every year.

*3.9.1.3.2 Radiological Monitoring*

Background radiation measurements at all reactor sites were obtained prior to operation of the nuclear reactor. Thus, each facility has characterized the natural background levels of radioactivity and radiation and their variations among the anticipated important exposure pathways in the areas surrounding the facilities. The operational, Radiological Environmental Monitoring Program (REMP) is conducted at each site to provide data on measurable levels of radiation and radioactive materials in the site environs in accordance with 10 CFR Parts 20 and 50. The REMP quantifies the environmental impacts associated with radioactive effluent releases from the plant. The REMP monitors the environment throughout the plant's operating lifetime to monitor radioactivity in the local environment. The REMP provides a mechanism for determining the levels of radioactivity in the environment to ensure that any accumulation of radionuclides released into the environment will not become significant as a result of plant operations. The REMP also measures radioactivity from other nuclear facilities that may be in the area (i.e., other nuclear power plants, hospitals using radioactive material, research facilities, or any other facility licensed to use radioactive material). Thus, the REMP monitors the cumulative impacts from all sources of radioactivity in the vicinity of the power plant. To obtain information on radioactivity around the plant, samples of environmental media (e.g., surface water; groundwater; drinking water; air; milk; locally grown crops; locally produced food products; river, ocean, or lake sediment; and fish and other aquatic biota) are collected from areas surrounding the plant for analysis to measure the amount of radioactivity, if any, in the samples. The media samples reflect the radiation exposure pathways (i.e., inhalation, ingestion, and physical location near the plant) to the public from radioactive effluents released by the nuclear power plant and from background radiation (i.e., cosmic sources, naturally occurring radioactive material, including radon, and global fallout). The NRC has standards for the amount of radioactivity in the sample media, which if exceeded, must be reported to the NRC, and the licensee must conduct an investigation. The REMP supplements the radioactive effluent monitoring program by verifying that measurable concentrations of radioactive materials and levels of radiation in the environment are not higher than expected when compared against data on the amount of radioactive effluent discharged.

The REMP can also identify the existence of effluents from unmonitored release points. A periodic land use survey identifies changes in the use of unrestricted areas to provide a basis for modifying the monitoring programs to reflect a new exposure pathway or a different plant-specific dose calculation parameter. The results of the REMP are documented by each licensee in the annual radiological environmental monitoring reports and submitted to NRC every year and are publicly available in NRC's ADAMS document system. The radiological environmental monitoring reports can also be accessed by navigating the reactor webpage for each site on the NRC website; effluent reports and environmental reports are available through the "Plant Environmental Report" section of the key documents.

*3.9.1.3.3 Public Radiation Doses*

Table 3.9-21 and Table 3.9-22 show the total body dose to the public, ground-level air dose, and dose to a critical organ for 3 years (2018 through 2020) from gaseous effluent releases for several PWRs and BWRs. The dose varies from year to year and also from reactor to reactor. The maximum total body dose is 0.47 mrem, maximum dose to a critical organ is 1.17 mrem, maximum ground-level air dose from gamma radiation is 0.99 mrad, and maximum ground-level dose from beta radiation is 0.011 mrad. All doses are much less than the design objectives of Appendix I of 10 CFR Part 50 provided in Table 3.9-2.

Table 3.9-23 and Table 3.9-24 show the total body dose to the public and dose to a critical organ for 3 years (2018 through 2020) from liquid effluent releases for the same PWRs and BWRs. The total body dose and dose to critical organ of the MEI from liquid effluent releases varies from year to year and also from reactor to reactor.

The doses from both gaseous and liquid effluents are much less than the design objectives of Appendix I of 10 CFR Part 50 provided in Table 3.9-2 and the EPA standards in 40 CFR 190, Subpart B provided in Table 3.9-3. Calculated MEI doses are also reported in annual effluent release reports based on the gaseous and liquid effluent releases for each plant. Under most circumstances, the dose calculations to the MEI, which are made by the plants, overestimate the calculated dose because of conservative assumptions. For most reactors, the annual MEI doses are a few millirem or less.

**Table 3.9-21 Doses from Gaseous Effluent Releases by select Pressurized Water Reactors from 2018 through 2020**

| Year | PWR | No. of Reactors | Total Body (mrem)[(a)] | Gamma (mrad)[(a)] | Beta (mrad)[(a)] | Critical Organ (mrem)[(a)] |
|---|---|---|---|---|---|---|
| 2018 | Comanche Peak | 2 | 9.00E-02 | 3.69E-04 | 1.38E-04 | 5.17E-04 |
| 2018 | D.C. Cook | 2 | 2.14E-03 | 4.01E-03 | 3.34E-03 | 9.57E-02 |
| 2018 | Palo Verde 1 | 1 | NR | 4.56E-04 | 1.62E-04 | 1.93E-01 |
| 2018 | Palo Verde 2 | 1 | NR | 1.53E-03 | 7.79E-04 | NR |
| 2018 | Palo Verde 3 | 1 | NR | 1.38E-04 | 4.87E-04 | 3.20E-01 |
| 2018 | Robinson | 1 | 3.31E-01 | 3.29E-03 | 1.67E-03 | 4.90E-01 |
| 2018 | Salem 1 | 1 | 2.49E-02 | 9.89E-05 | 4.14E-05 | 1.20E-01 |
| 2018 | Salem 2 | 1 | 2.17E-02 | 9.96E-05 | 5.20E-05 | 1.03E-01 |
| 2018 | Seabrook | 1 | NR | 1.40E-04 | 7.97E-05 | 3.49E-01 |
| 2018 | Surry | 2 | NR | 6.12E-04 | 1.81E-03 | 1.42E-01 |
| 2019 | Comanche Peak | 2 | 8.00E-02 | 3.12E-04 | 1.14E-04 | 4.35E-04 |
| 2019 | D.C. Cook | 2 | 1.33E-03 | 2.78E-03 | 2.06E-03 | 1.28E-01 |
| 2019 | Palo Verde 1 | 1 | NR | 5.02E-04 | 2.86E-04 | 1.69E-01 |
| 2019 | Palo Verde 2 | 1 | NR | 3.99E-04 | 1.41E-04 | 1.40E-01 |
| 2019 | Palo Verde 3 | 1 | NR | 1.46E-03 | 5.89E-04 | 3.12E-01 |
| 2019 | Robinson | 1 | 4.74E-01 | 3.12E-03 | 1.18E-03 | 5.79E-01 |
| 2019 | Salem 1 | 1 | 2.13E-02 | 1.01E-04 | 4.70E-05 | 9.35E-02 |
| 2019 | Salem 2 | 1 | 2.52E-02 | 1.33E-04 | 4.83E-05 | 1.17E-01 |

| Year | PWR | No. of Reactors | Total Body (mrem)[(a)] | Gamma (mrad)[(a)] | Beta (mrad)[(a)] | Critical Organ (mrem)[(a)] |
|---|---|---|---|---|---|---|
| 2019 | Seabrook | 1 | NR | 4.87E-05 | 3.17E-05 | 3.44E-01 |
| 2019 | Surry | 2 | NR | 7.14E-06 | 9.04E-06 | 9.40E-02 |
| 2020 | Comanche Peak | 2 | 8.00E-02 | 4.51E-04 | 1.65E-04 | 6.30E-04 |
| 2020 | D.C. Cook | 2 | 1.23E-03 | 2.26E-03 | 8.92E-04 | 1.02E-01 |
| 2020 | Palo Verde 1 | 1 | NR | 6.23E-04 | 2.49E-04 | 3.11E-03 |
| 2020 | Palo Verde 2 | 1 | NR | 9.90E-01 | 3.64E-04 | 1.95E-01 |
| 2020 | Palo Verde 3 | 1 | NR | 8.50E-04 | 3.13E-04 | 2.32E-01 |
| 2020 | Robinson | 1 | 2.57E-01 | 7.90E-03 | 2.90E-03 | 5.18E-01 |
| 2020 | Salem 1 | 1 | NR | 1.00E-04 | 4.61E-05 | 7.97E-02 |
| 2020 | Salem 2 | 1 | NR | 1.43E-04 | 5.31E-05 | 1.01E-01 |
| 2020 | Seabrook | 1 | NR | 5.61E-01 | 2.89E-04 | 3.29E-01 |
| 2020 | Surry | 2 | NR | 9.84E-05 | 3.68E-05 | 1.05E-01 |

PWR = pressurized water reactor; mrem = millirem; mrad = millirad; NR = not reported.
(a) Compare the values presented in this table with the design objectives presented in Table 3.9-2, Appendix I to 10 CFR 50 and Table 3.9-3, 40 CFR Part 190, Subpart B.
Note: To convert mrem to mSv, multiply by 0.01.
Sources: Annual effluent release reports. The radiological environmental monitoring reports can also be accessed by navigating the reactor webpage for each site on the NRC website; effluent reports and environmental reports are available through the "Plant Environmental Report" section of the key documents.

**Table 3.9-22 Doses from Gaseous Effluent Releases by select Boiling Water Reactors from 2018 through 2020**

| Year | BWR | No. of Reactors | Total Body (mrem)[(a)] | Gamma (mrad)[(a)] | Beta (mrad)[(a)] | Critical Organ (mrem)[(a)] |
|---|---|---|---|---|---|---|
| 2018 | Fermi 2 | 1 | 1.28E-01 | 6.72E-04 | 4.75E-04 | 1.17E+00 |
| 2018 | Hatch 1 | 1 | 5.07E-03 | 0.00E+00 | 0.00E+00 | 5.08E-03 |
| 2018 | Hatch 2 | 1 | 9.68E-03 | 0.00E+00 | 0.00E+00 | 9.85E-03 |
| 2018 | Hope Creek | 1 | 4.52E-02 | 4.78E-05 | 1.42E-04 | 1.69E-01 |
| 2018 | Limerick | 2 | 3.25E-03 | 3.45E-03 | 2.13E-03 | 5.35E-03 |
| 2018 | Columbia | 1 | NR | 3.13E-02 | 1.11E-02 | 2.97E-01 |
| 2019 | Fermi 2 | 1 | 1.40E-01 | 3.13E-06 | 1.23E-06 | 1.50E-01 |
| 2019 | Hatch 1 | 1 | 1.19E-02 | 0.00E+00 | 0.00E+00 | 1.19E-02 |
| 2019 | Hatch 2 | 1 | 1.39E-02 | 0.00E+00 | 0.00E+00 | 1.40E-02 |
| 2019 | Hope Creek | 1 | 4.11E-02 | 1.90E-03 | 3.21E-03 | 4.03E-02 |
| 2019 | Limerick | 2 | 9.79E-04 | 1.03E-03 | 6.12E-04 | 1.62E-03 |
| 2019 | Columbia | 1 | NR | 2.96E-02 | 1.04E-02 | 2.10E-01 |
| 2020 | Fermi 2 | 1 | 1.10E-01 | 1.15E-05 | 4.51E-06 | 4.14E-01 |
| 2020 | Hatch 1 | 1 | 2.09E-02 | 0.00E+00 | 0.00E+00 | 2.09E-02 |
| 2020 | Hatch 2 | 1 | 1.99E-02 | 0.00E+00 | 0.00E+00 | 2.02E-02 |
| 2020 | Hope Creek | 1 | NR | 1.90E-03 | 3.20E-03 | 2.37E-01 |
| 2020 | Limerick | 2 | 2.52E-03 | 2.66E-03 | 2.13E-03 | 4.39E-03 |
| 2020 | Columbia | 1 | NR | 2.85E-02 | 1.00E-02 | 1.67E-01 |

BWR = boiling water reactor; mrem = millirem; mrad = millirad; NR = not reported.
(a) Compare the values presented in this table with the design objectives presented in Table 3.9-2, Appendix I to 10 CFR 50 and Table 3.9-3, 40 CFR Part 190, Subpart B.
Note: To convert mrem to mSv, multiply by 0.01.
Sources: Annual effluent release reports. The radiological environmental monitoring reports can also be accessed by navigating the reactor webpage for each site on the NRC website; effluent reports and environmental reports are available through the "Plant Environmental Report" section of the key documents.

**Table 3.9-23 Dose from Liquid Effluent Releases by select Pressurized Water Reactor Nuclear Power Plants for 2018 through 2020**

| Year | PWR Name | No. of Reactors | Total Body (mrem)[(a)] | Critical Organ (mrem)[(a)] |
|---|---|---|---|---|
| 2018 | Comanche Peak | 2 | 1.14E-01 | 1.14E-01 |
| 2018 | D.C. Cook | 2 | 8.87E-02 | 4.80E-02 |
| 2018 | Palo Verde 1-3 | 3 | No Release | No Release |
| 2018 | Robinson | 1 | 1.43E-04 | 3.64E-04 |
| 2018 | Salem 1 | 1 | 1.06E-05 | 1.41E-04 |
| 2018 | Salem 2 | 1 | 4.33E-05 | 1.46E-04 |
| 2018 | Seabrook | 1 | 6.58E-04 | 1.62E-03 |
| 2018 | Surry | 2 | 5.61E-04 | 8.72E-04 |
| 2019 | Comanche Peak | 2 | 1.27E-01 | 1.27E-01 |
| 2019 | D.C. Cook | 2 | 8.43E-02 | 8.46E-02 |
| 2019 | Palo Verde 1-3 | 3 | No Release | No Release |
| 2019 | Robinson | 1 | 1.75E-06 | 1.83E-05 |
| 2019 | Salem 1 | 1 | 1.35E-02 | 1.67E-02 |
| 2019 | Salem 2 | 1 | 3.99E-03 | 2.60E-02 |
| 2019 | Seabrook | 1 | 1.86E-04 | 2.33E-04 |
| 2019 | Surry | 2 | 3.44E-04 | 4.08E-04 |
| 2020 | Comanche Peak | 2 | 1.14E-01 | 1.14E-01 |
| 2020 | D.C. Cook | 2 | 8.87E-02 | 4.80E-02 |
| 2020 | Palo Verde 1-3 | 3 | No Release | No Release |
| 2020 | Robinson | 1 | 2.01E-03 | 5.63E-03 |
| 2020 | Salem 1 | 1 | 1.36E-02 | 2.93E-02 |
| 2020 | Salem 2 | 1 | 4.67E-03 | 3.40E-02 |
| 2020 | Seabrook | 1 | 5.15E-04 | 8.42E-04 |
| 2020 | Surry | 2 | 1.77E-04 | 2.33E-04 |

PWR = pressurized water reactor; mrem = millirem.
(a) Compare the values presented in this table with the design objectives from Table 3.9-2, Appendix I to 10 CFR 50.
Note: To convert mrem to mSv, multiply by 0.01.
Sources: Annual effluent release reports. The radiological environmental monitoring reports can also be accessed by navigating the reactor webpage for each site on the NRC website; effluent reports and environmental reports are available through the "Plant Environmental Report" section of the key documents.

**Table 3.9-24 Dose from Liquid Effluent Releases from select Boiling Water Reactor Nuclear Power Plants for 2018 through 2020**

| Year | BWR Name | No. of Reactors | Total Body (mrem)[(a)] | Critical Organ (mrem)[(a)] |
|---|---|---|---|---|
| 2018 | Fermi 2 | 1 | No Release | No Release |
| 2018 | Hatch 1 | 1 | 3.53E-04 | 4.40E-04 |
| 2018 | Hatch 2 | 1 | 2.55E-04 | 3.33E-04 |
| 2018 | Hope Creek | 1 | 7.53E-03 | 2.07E-02 |
| 2018 | Limerick | 2 | 4.90E-04 | 6.59E-04 |
| 2018 | Columbia | 1 | No Release | No Release |
| 2019 | Fermi 2 | 1 | No Release | No Release |
| 2019 | Hatch 1 | 1 | 9.85E-04 | 8.01E-04 |
| 2019 | Hatch 2 | 1 | 3.88E-04 | 1.01E-03 |
| 2019 | Hope Creek | 1 | 7.92E-04 | 2.41E-03 |
| 2019 | Limerick | 2 | 9.63E-03 | 1.23E-02 |

| Year | BWR Name | No. of Reactors | Total Body (mrem)[(a)] | Critical Organ (mrem)[(a)] |
|---|---|---|---|---|
| 2019 | Columbia | 1 | No Release | No Release |
| 2020 | Fermi 2 | 1 | No Release | No Release |
| 2020 | Hatch 1 | 1 | 5.83E-04 | 7.56E-04 |
| 2020 | Hatch 2 | 1 | 6.99E-04 | 7.66E-04 |
| 2020 | Hope Creek | 1 | 1.65E-02 | 5.13E-02 |
| 2020 | Limerick | 2 | 2.83E-04 | 2.34E-03 |
| 2020 | Columbia | 1 | No Release | No Release |

BWR = boiling water reactor; mrem = millirem.
(a) Compare the values presented in this table with the design objectives from Table 3.9-2, Appendix I to 10 CFR 50.
Note: To convert mrem to mSv, multiply by 0.01.
Sources: Annual effluent release reports. The radiological environmental monitoring reports can also be accessed by navigating the reactor webpage for each site on the NRC website; effluent reports and environmental reports are available through the "Plant Environmental Report" section of the key documents.

*3.9.1.3.4 Radiological Exposure from Naturally Occurring and Artificial Sources*

Table 3.9-25 identifies background doses to a typical member of the U.S. population as summarized in National Council on Radiation Protection and Measurements Report 160 (2009) and National Council on Radiation Protection and Measurements Report 180 (2019). In the table, the annual values are rounded to the nearest 1 percent. A total average annual effective dose equivalent of 554 mrem/yr to members of the U.S. population is contributed by two primary sources: naturally occurring background radiation and medical exposure to patients.

Natural radiation sources other than radon result in 15 percent of the typical radiation dose received. The larger source of radiation dose in ubiquitous background (41 %) is from radon, particularly because of homes and other buildings that trap radon and significantly enhance its dose contribution over open-air living. The remaining 44 percent of the average annual effective dose equivalent consists of radiation mostly from medical procedures (computed tomography, 25 %; nuclear medicine, 7 %; interventional fluoroscopy, 5 percent; and conventional radiography and fluoroscopy, 4 %) and a small fraction from consumer products (2 %). The consumer product exposure category includes exposure to members of the public from building materials, commercial air travel, cigarette smoking, mining and agriculture products, combustion of fossil fuels, highway and road construction materials, and glass and ceramic. The industrial, security, medical, education, and research exposure category includes exposure to the members of the public from nuclear power generation; DOE installation; decommissioning and radioactive waste; industrial, medical, education, and research activities; contact with nuclear medicine patients; and security inspection systems. The occupational exposure category includes exposure to workers from medical, aviation, commercial nuclear power, industry and commerce, education and research, government, the DOE, and military installations. Radiation exposures from occupational activities, industrial, security, medical, educational and research contribute insignificantly to the total average effective dose equivalent.

**Table 3.9-25 Average Annual Effective Dose Equivalent of Ionizing Radiation to a Member of the U.S. Population for 2016**

| Source | EDE (mrem) | EDE Percent of Total |
|---|---|---|
| **Background (Total)** | **311** | **56** |
| **Ubiquitous background**[a] | | |
| Radon and thoron | 228 | 41 |
| **Natural**[a] | | |
| Cosmic | 33 | 6 |
| Terrestrial | 21 | 4 |
| Internal | 29 | 5 |
| **Medical**[b]**(Total)** | **229** | **41** |
| Computed tomography | 140 | 25 |
| Nuclear medicine | 41 | 7 |
| Interventional fluoroscopy | 26 | 5 |
| Conventional radiography and fluoroscopy | 22 | 4 |
| **Industrial, security, medical, educational and research**[a] | **0.3** | **0.05** |
| **Occupational**[a] | **0.5** | **0.09** |
| **Consumer products**[a] | **13** | **2** |
| **Total**[c] | **553.8** | **100** |

EDE = effective dose equivalent; mrem = millirem.
(a) NCRP 2009
(b) NCRP 2019. This NCRP updates the contribution from medical exposure due to changes in how procedures are conducted through the Image Wisely and Image Gently campaigns.
(c) Total includes background, medical, industrial, security, medical, and education research, occupational, and consumer products sources.

*3.9.1.3.5 Inadvertent Liquid Radioactive Releases*

As mentioned before, all commercial nuclear power plants routinely release radioactive material to the environment in the form of liquids and gases in accordance with regulations (Table 3.9-2). Each year, plant operators submit an effluent release report that documents the amount of radioactive material released to the environment during the year. This report also includes the public dose impact from the releases. Plant operators also conduct environmental monitoring in the vicinity and submit an environmental monitoring report every year to the NRC. All licensees must comply with the existing requirements to monitor and report effluents that are discharged, including abnormal discharges that may migrate offsite. A discussion of the historical inadvertent (unplanned) releases and the findings of the task force designated to conduct a lessons learned review following the inadvertent releases of tritium at the Braidwood, Indian Point, Byron, and Dresden sites is presented in Section 3.5.2.

*3.9.1.4 Radiation Health Effects Studies*

Radiation health effects have been the subject of published studies and a discussion of some of these studies and has been presented in the 2013 LR GEIS in Section 3.9.1.3.6 and is incorporated here by reference.

*3.9.1.4.1 Risk Estimates from Radiation Exposure*

In estimating the health effects resulting from both occupational and offsite radiation exposures as a result of operating nuclear power facilities, the normal probability coefficients for stochastic effects recommended by the ICRP (ICRP 1991) were used. The coefficients consider the most recent radiobiological and epidemiological information available and are consistent with the United Nations Scientific Committee on the Effects of Atomic Radiation. The coefficients used (Table 3.9-26) are the same as those published by ICRP in connection with a revision of its recommendations (ICRP 1991). Excess hereditary effects are listed separately because radiation-induced effects of this type have not been observed in any human population, as opposed to excess malignancies that have been identified among populations receiving instantaneous and near-uniform exposures in excess of 10 rem.

**Table 3.9-26 Nominal Probability Coefficients Used in ICRP (1991)[(a)]**

| Health Effect | Occupational | Public |
|---|---|---|
| Fatal cancer | 4 | 5 |
| Hereditary | 0.8 | 1.3 |

(a) Estimated number of excess effects among 10,000 people receiving 10,000 person-rem. Coefficients are based on “central” or “best” estimates.
Source: ICRP 1991.

In 2006, the National Research Council’s Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR) published BEIR VII, entitled *Health Risks from Exposure to Low Levels of Ionizing Radiation* (National Research Council 2006).

BEIR VII provides estimates of the risk of incidence and mortality for males and females. If the total fatal cancer risk is the sum of cancer deaths from all solid cancers and leukemia, then the fatal cancer risk coefficient for the general public would be $6 \times 10^{-4}$/person-rem. The fatal cancer risk for the general public based on ICRP is $5 \times 10^{-4}$/person-rem (Table 3.9-26). There is a difference of approximately 20 percent in the fatal cancer risk coefficient based on ICRP recommendation and the BEIR VII report. The difference of 20 percent is within the margin of uncertainty associated with these estimates.

The NRC completed a review of the BEIR VII report and documented its findings in the Commission paper SECY-05-0202, *Staff Review of the National Academies Study of the Health Risks from Exposure to Low Levels of Ionizing Radiation* (BEIR VII*)*, dated October 29, 2005 (NRC 2005g). In this paper, the NRC concluded that the findings presented in the BEIR VII report agree with the NRC’s current understanding of the health risks from exposure to ionizing radiation. The NRC agreed with the BEIR VII report’s major conclusion that current scientific evidence is consistent with the hypothesis that there is a linear, no-threshold dose response relationship between exposure to ionizing radiation and the development of cancer in humans. In addition to the BEIR VII paper, NCRP also published Commentary No. 27 in May 2018 providing a critical review of epidemiologic studies mostly published within the past ten years. NCRP concluded that the recent epidemiologic studies, along with judgements by other national and international scientific committees, support the continued use of the linear-non threshold model for radiation protection (NCRP 2018). The NRC has determined that the linear, no-threshold model continues to provide a sound regulatory basis for minimizing the risk to unnecessary radiation exposure to both members of the public and radiation workers; three petitions to move away from the linear, no-threshold model were denied in 2021 (86 FR 45923).

This conclusion is consistent with the process the NRC uses to develop its standards of radiological protection. Therefore, the NRC's regulations continue to be adequately protective of public health and safety and the environment.

If an occupational worker is exposed at 10 CFR Part 20 dose limits for 1 year, the probability of developing fatal cancer (on the basis of ICRP recommendations) from exposure due to an operating nuclear reactor is equal to $2 \times 10^{-3}$ on the basis of ICRP recommendations. However, the average individual worker doses are much less than the dose limits (see Table 3.9-5), and, at the doses observed between 2006 and 2018, the probability of developing fatal cancer would be in the range of $2.8 \times 10^{-5}$ to $6.0 \times 10^{-5}$.

If a member of the public is exposed at 40 CFR Part 190 dose limits, the probability of developing fatal cancer (on the basis of ICRP recommendations) from exposure resulting from operating a nuclear reactor is equal to $1.25 \times 10^{-5}$. However, the MEI doses are much less than the dose limits, and, at the doses observed between 2018 and 2020, the probability of developing fatal cancer would be in the range of $2.40 \times 10^{-10}$ to $1.3 \times 10^{-6}$.

#### *3.9.1.5 Conclusion*

Radiation doses to nuclear power plant workers and members of the public from the current operation of nuclear power plants have been examined, and the radiation doses were found to be well within design objectives and regulations in each instance.

### 3.9.2 Nonradiological Hazards

Nonradiological hazards, such as chemical, biological, EMFs, and physical hazards, are not unique to nuclear power plants and can occur in many types of industrial facilities. However, certain nonradiological hazards can be enhanced by physical plant elements or characteristics of nuclear power plants, which this section will discuss.

While nonradiological hazards can be minimized when workers adhere to safety standards and use appropriate protective equipment, fatalities and injuries from accidents can still occur. Risk to members of the public can also be minimized when adhering to safety standards. See Section 3.3 for information on meteorology, air quality, and noise, Section 3.5 for information on water resources, Section 3.11 for information on waste management and Appendix E for postulated accidents. The overall well-being of these resource areas is important to maintaining nonradiological public and occupational health.

The Occupational Safety and Health Administration (OSHA) is responsible for developing and enforcing workplace safety regulations. OSHA's mission is to ensure safe and healthful working conditions. OSHA was created by the Occupational Safety and Health Act of 1970 (29 USC 651 et seq.). With specific regard to nuclear power plants, hazards which result in an occupational risk, but do not affect the safety of licensed radioactive materials, are under the statutory authority of OSHA rather than the NRC as set forth in a Memorandum of Understanding (OSHA/NRC 2013) between the NRC and the OSHA. Additionally, the EPA, through multiple statutes, is responsible for the regulation of hazardous chemicals that can enter the environment and impact members of the public. As such, nuclear power plants have developed various programs and processes to show compliance with OSHA's regulations, including Chemical Safety Programs, Hazard Communication Programs, and/or an International Organization for Standardizations 9001 Certification of Approval. The approval is not required by OSHA or NRC but is a common industrial process that implements quality assurance by which safety requirements are met, hazards are identified, and risks are reduced. Additionally, nuclear power plants are required to have Federal, State, and/or local permits for releases to air (e.g., a Title V permit), surface or groundwater water (e.g., a NPDES permit), and other local permits and ordinances depending on the municipality.

#### *3.9.2.1 Chemical Hazards*

Chemical exposure can exist in the form of dust, fumes, fibers (solids), liquids, mists, gases, or vapors. Chemical exposure produces different effects on the body depending on the chemical and the amount of exposure. Chemicals can cause cancer, affect reproductive capability, disrupt the endocrine system, or have other health effects. Acute effects from chemical exposure occur immediately (e.g., when somebody inhales or ingests a poisonous substance such as cyanide). Chronic or delayed effects result in symptoms such as skin rashes, headaches, breathing difficulties, and nausea. There are multiple pathways by which humans can be exposed to chemicals. For example, a direct pathway would be a human breathing in a gaseous effluent or swimming in water that was contaminated by a liquid effluent. An indirect pathway would be a human eating a fish that had absorbed a pollutant into its body or eating crops that had been irrigated with water contaminated by a liquid effluent. In nuclear power plants, chemical exposure can result from discharges of chlorine or other biocides, small-volume discharges of sanitary and other liquid wastes, chemical spills, and heavy metals leached from cooling system piping and condenser tubing. Nuclear power plant backup diesel generators, boilers, fire pump engines, and cooling towers can also result in chemical exposure, but are generally low emitters of criteria air pollutants (e.g., $SO_2$, $NO_X$, and CO) and VOCs (e.g., such as components of petroleum fuels and hydraulic fluids [EPA 2022h]).

OSHA regulations in 29 CFR Part 1910 set enforceable permissible exposure limits for about 500 hazardous chemicals to protect workers against the health effects of exposure to hazardous substances, including limits on the airborne concentrations of hazardous chemicals in the air and skin contact. Most permissible exposure limits are 8-hour time-weighted averages, although there are also ceiling and peak limits.

The EPA is responsible for the regulation of hazardous chemicals that can enter the environment and impact members of the public. The EPA administers the following Federal acts related to chemical contamination: the Federal Insecticide, Fungicide, and Rodenticide Act (7 U.S.C. § 136 et seq.); Toxic Substances Control Act (15 U.S.C. § 2601 et seq.); RCRA (42 U.S.C. § 6901 et seq.); CWA (codified as the Federal Water Pollution Control Act of 1972; 33 U.S.C. § 1251 et seq.); Safe Drinking Water Act (SDWA; 42 U.S.C. § 300f et seq.); Clean Air Act (CAA; 42 U.S.C. § 7401 et seq.); and Comprehensive Environmental Response Compensation, and Liability Act (42 U.S.C. § 9601 et seq.). These Acts regulate the treatment, storage, disposal, and release of hazardous chemicals. Heavy metals (e.g., copper, zinc, and chromium) may be leached from condenser tubing and other heat exchangers and discharged by power plants as small-volume waste streams or corrosion products. Although all are found in small quantities in natural waters (and many are essential micronutrients), concentrations in the power plant discharge are controlled in the NPDES permit because excessive concentrations of heavy metals can be toxic to aquatic organisms (see Section 3.6). The ability of aquatic organisms to bioaccumulate heavy metals, even at low concentrations, has led to concerns about toxicity to both the humans and the biota that consume contaminated fish and shellfish. For example, the bioconcentration of copper discharged from the Chalk Point plant (a fossil fuel power plant on Chesapeake Bay) resulted in oyster “greening” (Roosenburg 1969). The bioaccumulation of copper released from the H.B. Robinson Steam Electric Plant (Robinson) resulted in malformations and decreased reproductive capacity among bluegill in the cooling reservoir (Harrison 1985). At the Diablo Canyon nuclear plant, it was observed that the concentration of soluble copper in effluent water was high during the startup of water circulation through the condenser system after a shutdown (Harrison 1985). In all three examples of excessive accumulation of copper (Diablo Canyon, Chalk Point, and Robinson), replacement of the copper alloy condenser tubes with another material (e.g., titanium) eliminated the problem.

#### *3.9.2.2 Microbiological Hazards*

Microbiological hazards occur when workers or members of the public come into contact with disease causing microorganisms, also known as etiological agents. Microbiological organisms of concern for public and occupational health, include enteric pathogens (bacteria that typically exists in the intestines of animals and humans (e.g., *Pseudomonas aeruginosa*), thermophilic fungi, bacteria (e.g., *Legionella* spp. and *Vibrio* spp.), free-living amoebae (e.g., *Naegleria fowleri* and *Acanthamoeba* spp.), as well as organisms that produce toxins that affect human health (e.g., dinoflagellates (*Karenia brevis*) and blue-green algae). Some of these disease causing organisms have been associated with the operation of nuclear power plant cooling systems (see Section 3.9.2.2.2). Etiological agents have been referred to as "thermophilic microorganisms" in previous NRC documents (e.g., NUREG-1555 [NRC 1999a]). Thermophilic microorganisms have an optimum growth at temperatures of 122 degrees Fahrenheit (°F) (50 degree Celsius [°C]) or more, a maximum temperature tolerance of up to 158 °F (70 °C), and a minimum tolerance of about 68 °F (20 °C) (Deacon 2006), which means improperly maintained cooling towers, hot water tanks, and thermal discharges could be optimal environments for microorganisms. Etiological agents associated with nuclear power stations also include more than just thermophilic microorganisms and may be present in elevated numbers in unheated and heated water systems as well as in cooling systems, receiving and source waterbodies, and site sewage treatment facilities.

Members of the public could be exposed to microorganisms in thermal effluents at nuclear plants that use cooling ponds, lakes, or canals that discharge to waters of the United States accessible to the public.

For this update of the LR GEIS, the SEISs published since 2013 were reviewed to determine the level of thermophilic microbiological organism enhancement. The SEISs note that health departments were contacted and that the health departments did not have any concerns. In all occurrences, with the exception of Turkey Point, the NRC staff concluded that impacts to the public from microbiological organism were SMALL. For Turkey Point, microbiological organisms impacts to members of the public was not discussed because Turkey Point discharges to a canal cooling system not accessible by the public with discharge to groundwater in a saline-water environment instead of a freshwater environment. See the 2013 LR GEIS for an additional discussion of reactor sites that were reviewed to predict the level of thermophilic microbiological organism enhancement. The 2013 LR GEIS review did not identify hazards to the public from enhancement of thermophilic microbiological organisms.

OSHA has information and guidance regarding how improperly maintained human-made water systems can serve as sources for a microbiological hazard, such as *Legionella* spp (OSHA Undated). *Legionella* causes Legionnaires' disease, which is an infection of the lungs. Legionella also causes Pontiac fever, which is a milder infection than Legionnaires' disease and includes fever and muscle aches but not an infection of the lungs. People get these diseases by breathing in droplets of water in the air that contain the hazard or by drinking contaminated water that accidentally goes into the lungs. The Centers for Disease Control and Prevention (CDC) also has general guidelines for preventing occupational exposure to *Legionella* and best practices for the control of *Legionella* (CDC 2021c). The American National Standards Institute/American Society of Heating, Refrigerating and Air Conditioning Engineers Standard 188-2018 documents a standard for Legionellosis and risk management for building water systems (ASHRAE 2021). A temperature range of 77–113 °F (25–45 °C) is best for *Legionella* spp. growth (CDC 2018).

*Acanthamoeba* and *Pseudomonas aeruginosa* are single-cell living organisms and much like *Legionella*, thrive in stagnant or untreated water and can enter the body through the eye, skin, or inhalation (OSHA 2015). *Pseudomonas aeruginosa* has an optimal growth temperature of 98.6 °F (37 °C) and can tolerate a temperature as high as 107.6 °F (42 °C) (Todar 2004). *Pseudomonas aeruginosa* can cause infections in the eye, blood, or lungs (CDC 2019a). *Acanthamoeba* can also cause infections of the eye, skin, and central nervous system.

*Naegleria fowleri*, is a single-celled living organism commonly found in warm freshwater. It thrives in warmer temperatures (up to 115 °F [46 °C]). *Naegleria fowleri* infections occur when people go swimming or diving in warm freshwater and the amoeba travels up the nose, across the blood-brain barrier, into the brain and destroys brain tissue. The disease is called primary amoebic meningoencephalitis. Infections do not occur by drinking contaminated water, nor through water vapor or aerosol droplets (CDC 2021d).

Toxins produced by some species of algae and cyanobacteria can cause harm to human health when they grow rapidly and create blooms. In low amounts, the cyanobacteria toxin is not a human health risk, but when the organisms cause a bloom, the toxin is harmful. Blooms occur when water is warm (e.g., like a thermal discharge from a nuclear power plant), slow-moving, and full of nutrients, such as phosphorus or nitrogen. An algae bloom can occur in freshwater or saltwater (CDC 2021a). Cyanobacteria, also called blue-green algae, are a kind of single-celled organism called phytoplankton. Exposure can be through skin contact, drinking water containing the cyanobacteria, breathing in droplets in the air that contain the algae, or eating shellfish or fish that are contaminated with the cyanobacteria. Symptoms of cyanobacteria exposure include stomach pain, headache, muscle weakness, dizziness, vomiting, diarrhea, and liver damage (CDC 2022). In saltwater, algal blooms are commonly caused by diatoms and dinoflagellates, which are another kind of phytoplankton. Breathing in sea spray or getting the contaminated seawater on skin can cause symptoms such as respiratory infection, shortness of breath, throat irritation, eye irritation, skin irritation, and asthma attacks. Eating seafood contaminated with the algae toxin can cause several illnesses, such as neurotoxic shellfish poisoning (CDC 2021b). Based on a review of SEISs to the LR GEIS published since 2013, the staff noted that the only occurrences of algal bloom occurred in Lake Anna in 2018, 2019, and 2020. In 2019, Dominion, the NRC-licensee for the North Anna Power Station, stated in a letter to the Virginia Department of Health that the bloom was located in an upper arm many miles from Outfall 001 (the primary discharge into Lake Anna) and outside the reach of the thermal plume. Dominion did develop its own cyanobacteria sampling plan in 2018 (NRC 2021g). The Fermi 2 SEIS (NRC 2016c) noted that the NRC received public comments regarding the role of Fermi's effluent on algal blooms. Fermi is located halfway between Toledo, Ohio, and Detroit, Michigan, on the lake basin where the algal blooms have been most prevalent. The SEIS also noted that the frequency and intensity of the blooms have been increasing and that the Fermi discharge is warmer and contains somewhat higher concentrations of nitrogen and phosphorus, than the ambient intake water of Lake Erie. The SEIS did conclude that the information did not contradict the conclusion of the LR GEIS which states, "Impacts of thermal discharge on the geographic distribution of aquatic organisms are considered to be of SMALL significance if populations in the overall region are not reduced. This is because heat is usually dissipated rapidly from power plant discharge plumes, and heated plumes are often small relative to the size of the receiving water body." Occupational worker exposure to biological hazards can be limited through proper maintenance of systems, processes, and machinery and through the use of personal protective equipment. Exposure of members of the public can also be limited through proper maintenance of systems, processes, and equipment and separation from thermal discharges.

*3.9.2.2.1 Studies of Microorganisms in Spent Fuel Pools*

During the scoping meeting for the Calvert Cliffs Nuclear Power Plant (Calvert Cliffs) license renewal SEIS in 1998, one member of the public raised an issue about the microorganisms that live in high radiation and extreme heat conditions (such as within the spent fuel pool) based on the article "Something's Bugging Nuclear Fuel" published in *Science News* (Raloff 1998). The commenter asked that consideration be given to these types of organisms, the possibility of their mutation, and consequences if they escaped from the plant into the natural aquatic environment. The NRC consulted specialists in the field; the following is a summary of their conclusions as presented in the SEIS (NRC 1999c):

- Many types of organisms can live in the temperature range of the spent fuel pools (100–150 °F [38–66 °C]).
- There is a potential for mutation in all living organisms, but microbes that have high levels of radiation resistance have also developed extremely efficient repair systems.
- Organisms that are associated with thermal waters of the spent fuel pool are likely to die if they are transferred into the relatively much lower water temperatures typical of surface waters. If the organisms are truly adapted to the high temperatures typical of the spent fuel pool, they probably would not be able to survive and compete with the indigenous microorganisms of the relatively cold waters of the natural water sources.

The NRC concluded that microorganisms that live in high radiation and extreme heat conditions typical of the spent fuel pool do not pose a risk to humans or the environment as discussed in the 2013 LR GEIS.

*3.9.2.2.2 Studies of Microorganisms In and Around Cooling Towers*

In 1981, cooling water systems at 11 nuclear power plants and associated control source waters were studied for the presence of thermophilic free-living amoebae, including *Naegleria fowleri*. The presence of pathogenic *Naegleria fowleri* in these waters was tested, and while all but one test site was positive for thermophilic free-living amoebae, only two test sites were positive for pathogenic *Naegleria fowleri*. Pathogenic *Naegleria fowleri* were not found in any control source waters (Tyndall 1982). In addition to testing for pathogenic amoebae in cooling water, testing for the presence of *Legionella* spp. was also done (Tyndall 1982). The concentrations of *Legionella* spp. in these waters were determined. In general, the artificially heated waters showed only a slight increase (i.e., no more than tenfold) in concentrations of *Legionella* spp. relative to source water. In a few cases, source waters had higher levels than did heated waters. Infectious *Legionella* spp. were found in 7 of 11 test waters and 5 of 11 control source waters.

Subsequently, a more detailed study of *Legionella* spp. in the environs of coal-fired power plants was undertaken to determine the distribution, abundance, infectivity, and aerosolization of *Legionella* spp. in power plant cooling systems (Tyndall 1983; Christensen et al. 1983; Tyndall 1985). This study found that positive air samples did not occur often at locations that were not next to cleaning operations, which suggests that aerosolized *Legionella* spp. associated with downtime procedures have minimal impact beyond these locations. Even within plant boundaries, detectable airborne *Legionella* spp. appear to be confined to very limited areas. In these areas, however, the more contact individuals have with the most concentrated *Legionella* spp. populations, particularly if they become aerosolized (as they do in some downtime operations), the more likely it is that workers are exposed.

Another study suggested that *Legionella*-like amoebal pathogens may be an unrecognized significant cause of respiratory disease (Berk et al. 2006). In this study, the occurrence of infected amoebae in water, biofilm, and sediment samples from 40 cooling towers (non-nuclear sites) and 40 natural aquatic environments were compared. The natural samples were collected from rivers, creeks, lakes, and ponds from Tennessee, Kentucky, New Jersey, Florida, and Texas. The cooling tower samples were collected from industries, hospitals, municipal buildings, universities, and other public sites from Tennessee, Kentucky, and Texas. The infected amoebae were found in 22 cooling tower samples and 3 natural samples. According to this study, the probability of infected amoebae occurring in cooling towers is 16 times higher than in natural environments.

#### *3.9.2.3 Electromagnetic Fields (EMFs)*

EMFs are generated by any electrical equipment. All nuclear power plants have electrical equipment and power transmission systems associated with them. Power transmission systems consist of switching stations (or substations) located on the plant site and the transmission lines needed to connect the plant to the regional electrical distribution grid. Transmission lines operate at a frequency of 60 Hz (60 cycles per second), which is low compared with the frequencies of 55 to 890 MHz for television transmitters and 1,000 MHz and greater for microwaves.

Electric and magnetic fields, collectively referred to as the EMF, are produced by operating transmission lines. Electric fields are produced by voltage, and their strength increases with increases in voltage. An electric field is present as long as equipment is connected to the source of electric power. The unit of electric field strength is V/m or kV/m (1 kV/m = 1,000 V/m). A magnetic field is produced from the flow of current through wires or electrical devices, and its strength increases as the current increases. The unit of magnetic field strength is gauss (G), milligauss (mG), or tesla (T). One tesla equals 10,000 G and 1 G equals 1,000 mG.

Occupational workers or members of the public near transmission lines may be exposed to the EMFs produced by the transmission lines. The EMF varies in time as the current and voltage change, so that the frequency of the EMF is the same (e.g., 60 Hz for standard alternating current, or AC). Electrical fields can be shielded by objects such as trees, buildings, and vehicles. Magnetic fields, however, penetrate most materials, but their strength decreases with increasing distance from the source.

Power lines associated with nuclear plants usually have voltages of 230 kV, 345 kV, 500 kV, or 765 kV (a voltage occurring primarily in the eastern United States). EMF strength at ground-level varies greatly under these lines, generally being stronger for higher-voltage lines, a flat configuration of conductors, relatively flat terrain, terrain with no shielding obstructions (e.g., trees or shrubs), and a closer approach of the lines to the ground. At locations where the field strength is at a maximum, the measured values under 500-kV lines often average about 4 kV/m but sometimes exceed 6 kV/m. Maximum electric field strengths at ground-level are 9 kV/m for 500-kV lines and 12 kV/m for 765-kV lines (Lee et al. 1989).

Measured magnetic field strengths at the location of maximum values beneath 500-kV lines often average about 70 mG. During peak electricity use, when line current is high, the field strength may peak at 140 mG (about 1 percent or less of the time) (Lee et al. 1989).

The EMFs resulting from 60-Hz power transmission lines fall under the category of non-ionizing radiation. Much of the general population has been exposed to power line fields since near the turn of the 20th century. There was little concern about health effects from such exposures until the 1960s. A series of events during the 1960s and 1970s heightened public interest in the possibility of health effects from non-ionizing radiation exposures and resulted in increased scientific investigation in this area (NRC 1996). Then, in 1979, results of an epidemiological study suggested a correlation between proximity to high-current wiring configurations and incidence of childhood leukemia (Wertheimer and Leeper 1979). This report resulted in additional interest and scientific research; however, no consistent evidence linking harmful effects with 60-Hz exposures has been presented. Additionally, many subsequent studies have been conducted on the exposure to EMF sources, and have concluded that current evidence does not support the existence of any health consequences from EMFs resulting from 60-Hz power transmission lines (WHO 2020, NIOSH 1996, NIEHS 2002).

There are no U.S. Federal standards limiting residential or occupational exposure to EMFs from power lines, but some States, such as Florida, Minnesota, Montana, New Jersey, New York, and Oregon, have set electric field and magnetic field standards for transmission lines (NIEHS 2002). A voluntary occupational standard has been set for EMFs by the International Commission on Non-Ionizing Radiation Protection. For occupational workers who are exposed to 60 Hz (power lines), the electric field standard is 8.3 kV/m and the magnetic field standard is 4,200 mG, while for the general public who are exposed to 60 Hz, the electrical field standard is 4.2 kV/m and the magnetic field standard is 833 mG (ICNIRP 1998). The National Institute of Occupational Safety and Health does not consider EMFs to be a proven health hazard (NIOSH 1996).

#### *3.9.2.4 Physical Hazards*

A physical hazard is an action, agent or condition that can cause harm upon contact. Physical actions could include slips, trips, and falls from height. Physical agents could include noise, vibration, and ionizing radiation. Physical conditions could include high heat, cold, pressure, confined space, or psychosocial issues, such as work-related stress. Power plant and maintenance workers could be working under potentially hazardous physical conditions (e.g., excessive heat, cold, and pressure), including electrical work, power line maintenance, and repair work.

Table 3.9-27 lists the total number of fatal occupational injuries that occurred in 2020 in different industry sectors. For the utility sector, of which the nuclear industry is a part, 19 workers suffered fatal occupational injuries. The rate of fatal injuries in the utility sector was less than the rate in the construction; transportation and warehousing; agriculture, forestry, fishing, and hunting; wholesale trade; and mining sectors. Table 3.9-28 lists the incidence rates of nonfatal occupational injuries and illnesses in different utilities for 2020. The incidence rate of nonfatal occupational injuries and illnesses is lowest for electric power generation, followed by electric power transmission control and distribution.

**Table 3.9-27 Number and Rate of Fatal Occupational Injuries by Industry Sector in 2020**

| Industry Sector | Number | Rate (per 100,000 employees) |
|---|---|---|
| Construction | 1,008 | 10.2 |
| Transportation and warehousing | 805 | 13.4 |
| Agriculture, forestry, fishing, and hunting | 511 | 21.5 |
| Government | 415 | 1.8 |
| Manufacturing | 340 | 2.3 |
| Retail trade | 275 | 2.0 |
| Leisure and hospitality | 219 | 2.5 |
| Other services (excluding Public Administration) | 188 | 3.3 |
| Wholesale trade | 155 | 4.6 |
| Educational and health services | 145 | 0.7 |
| Mining, quarrying, oil and gas extraction | 78 | N/A[d] |
| Financial activities | 93 | N/A |
| Information | 31 | N/A |
| Utilities[a] | 19 | N/A |
| Electric power generation, transmission, and distribution[b] | 14 | N/A |
| Electric power generation[c] | 4 | N/A |
| Electric power transmission, control, and distribution | 10 | N/A |
| Natural gas distribution | 1 | N/A |
| Water sewage and other system | 4 | N/A |
| All sectors | 4,764 | 3.4 |

(a) The numbers of fatalities from transportation, falls, and exposure to harmful substances or the environment were 10, 1, and 6, respectively.
(b) The numbers of fatalities from transportation, falls, and exposure to harmful substances or the environment were 7, 1, and 6, respectively.
(c) The numbers of fatalities from falls was 1.
(d) N/A = not available.
Sources: BLS 2021a; BLS 2020, BLS 2021d.

**Table 3.9-28 Incidence Rate of Nonfatal Occupational Injuries and Illnesses in Different Utilities in 2020**

| Utility | Rate (per 100 Employees) |
|---|---|
| Utilities | 8.4 |
| Electric power generation, transmission, and distribution | 5.7 |
| Electric power generation | 1.6 |
| Fossil Fuel electric power generation | 1.2 |
| Nuclear electric power generation | 0.1 |

| Utility | Rate (per 100 Employees) |
|---|---|
| Electric power transmission, control, and distribution | 6.0 |
| Natural gas distribution | 1.7 |
| Water, sewage, and other system | 1 |
| Overall | 2.7 |

Sources: BLS 2021b, BLS 2021c.

Table 3.9-29 lists the number and rate of fatal occupational injuries that occurred in 2020 for listed occupations. The occupational safety and health hazards issue is generic to all types of electrical generating stations, including nuclear power plants, and is of small significance if the workers adhere to safety standards and use protective equipment.

**Table 3.9-29 Number and Rate of Fatal Occupational Injuries for Selected Occupations in 2020**

| Occupation | Number | Rate per 100,000 Full-Time Equivalent Workers |
|---|---|---|
| Fishers and hunting workers | 42 | 132.14 |
| Aircraft pilots and flight engineers | 50 | 34.3 |
| Logging workers | 42 | 91.7 |
| Structural iron and steel workers | 16 | 32.5 |
| Refuse and recyclable material collectors | 30 | 33.1 |
| Farmers, ranchers, and other agricultural managers | 207 | 20.9 |
| Drivers/sales workers and truck drivers | 887 | 25.8 |
| Helpers, construction trades | 19 | 43.3 |

Source: BLS 2022.

#### *3.9.2.4.1 Electric Shock Hazards*

In-scope transmission lines are those lines that connect the plant to the first substation of the regional electric grid. This substation is frequently, but not always, located on the plant property. The greatest hazard from a transmission line is direct electrical contact with the conductors. The electrical contact can occur without physical contact between a grounded object and the conductor (e.g., when arcing occurs across an air gap) (BPA 2007). The electric field created by a high-voltage line extends from the energized conductors to other conducting objects, such as the ground, vegetation, buildings, vehicles, and persons. Potential field effects can include induced currents, steady-state current shocks, spark-discharge shocks, and, in some cases, field perception and neurobehavioral responses.

The shock hazard issue is evaluated by referring to the National Electric Safety Code (NESC). The purpose of the NESC is the practical safeguarding of persons during the installation, operation, or maintenance of electric supply and communication lines and associated equipment. The NESC contains the basic provisions that are considered necessary for the safety of employees and the public under the specified conditions (IEEE SA 2017).

Primary shock currents are produced mainly through direct contact with conductors and have effects ranging from a mild tingling sensation to death by electrocution. Tower designs preclude direct public access to the conductors. Secondary shock currents are produced when humans make contact with (1) capacitively charged bodies, such as a vehicle parked near a transmission line, or (2) magnetically linked metallic structures, such as fences near transmission lines. A person who contacts such an object could receive a shock and experience a painful sensation at the point of contact. The intensity of the shock depends on the EMF strength, the size of the object, and how well the object and the person are insulated from ground.

Design criteria that limit hazards from steady-state currents are based on the NESC, which requires that utility companies design transmission lines so that the short-circuit current to ground, produced from the largest anticipated vehicle or object, is limited to less than 5 milliamperes (mA) (IEEE SA 2017).

Historically, in the licensing process for the earlier licensed nuclear power plants, the issue of electrical shock safety was not addressed. Additionally, some nuclear power plants that received operating licenses with a stated transmission line voltage may have chosen to upgrade the line voltage for reasons of efficiency, possibly without reanalysis of induction effects. Also, since the initial NEPA review for those utilities that evaluated potential shock situations under the provision of the NESC, land use may have changed, resulting in the need for a reevaluation of this issue. Electrical shock potential is minimized for transmission lines that are operated in adherence with the NESC.

A review of the SEISs to the LR GEIS published since 2013, found that 3 transmission lines at South Texas did not meet the criteria defined by NESC (NRC 2013b), nor did nine transmission line spans at Sequoyah (NRC 2015f). Regarding South Texas, the staff concluded that the three transmission lines exceeded the NESC criterion by a small percentage. The locations where the lines exceed the standard are in remote locations or are on private property, and the applicant considered potential mitigation measures to reduce or avoid adverse impacts from electric shock. In the case of Sequoyah, TVA committed to upgrades to correct the deficiencies in transmission lines that did not meet the NESC criteria for induced current. The transmission lines discussed in South Texas and Sequoyah span areas beyond what was termed in the 2013 LR GEIS as in-scope transmission lines.

## 3.10 Environmental Justice

Under Executive Order 12898, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations” (59 FR 7629), Federal agencies are responsible for identifying and addressing, as appropriate, disproportionately high and adverse human health and environmental effects of its programs, policies, and activities on minority and low-income populations. Although independent agencies, like the NRC, were only requested, rather than directed, to comply with Executive Order 12898, the NRC Chairman, in a March 1994 letter to the President, committed the NRC to endeavoring to carry out its measures “ … as part of NRC’s efforts to comply with the requirements of NEPA” (NRC 1994). In 2004, the Commission issued its *Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions* (69 FR 52040), which states, “The Commission is committed to the general goals set forth in E.O. 12898, and strives to meet those goals as part of its NEPA review process.”

**Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations**

"Each Federal agency, whenever practicable and appropriate, shall collect, maintain, and analyze information assessing and comparing environmental and human health risks borne by populations identified by race, national origin, or income. To the extent practical and appropriate, Federal agencies shall use this information to determine whether their programs, policies, and activities have disproportionately high and adverse human health or environmental effects on minority populations and low-income populations."

The Council on Environmental Quality (CEQ) provides the following information in *Environmental Justice: Guidance Under the National Environmental Policy Act* (CEQ 1997b):

- **Disproportionately high and adverse human health effects.** In determining whether human health effects are disproportionately high and adverse, agencies should consider to the extent practicable: "(a) Whether the health effects, which may be measured in risks and rates, are significant (as employed by NEPA), or above generally accepted norms. Adverse health effects may include bodily impairment, infirmity, illness, or death; and (b) Whether the risk or rate of hazard exposure by a minority population, low-income population, or Indian Tribe to an environmental hazard is significant (as employed by NEPA) and appreciably exceeds or is likely to appreciably exceed the risk or rate to the general population or other appropriate comparison group; and (c) Whether health effects occur in a minority population, low-income population, or Indian Tribe affected by cumulative or multiple adverse exposures from environmental hazards."
- **Disproportionately high and adverse environmental effects.** In determining whether environmental effects are disproportionately high and adverse, agencies should consider to the extent practicable: "(a) Whether there is or will be an impact on the natural or physical environment that significantly (as employed by NEPA) and adversely affects a minority population, low-income population, or Indian Tribe. Such effects may include ecological, cultural, human health, economic, or social impacts on minority communities, low-income communities, or Indian Tribes when those impacts are interrelated to impacts on the natural or physical environment; and (b) Whether environmental effects are significant (as employed by NEPA) and are or may be having an adverse impact on minority populations, low-income populations, or Indian Tribes that appreciably exceeds or is likely to appreciably exceed those on the general population or other appropriate comparison group; and (c) Whether the environmental effects occur or would occur in a minority population, low-income population, or Indian Tribe affected by cumulative or multiple adverse exposures from environmental hazards."

The environmental justice analysis identifies minority populations, low-income populations, and Indian Tribes that could be affected by continued reactor operations and refurbishment activities at a nuclear power plant. The following CEQ definitions of minority individuals and populations and low-income populations are used:

- **Minority.** Individual(s) who identify themselves as members of the following population groups: Hispanic or Latino, American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Other Pacific Islander, or two or more races meaning individuals who identified themselves as being a member of two or more races, for example, Hispanic and Asian.

- **Minority population.** Minority populations are identified when (1) the minority population of an affected area exceeds 50 percent or (2) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. Minority populations may be communities of individuals living in close geographic proximity to one another or they may be a geographically dispersed or transient set of individuals, such as migrant workers or Native Americans, who, as a group, experience common conditions with regard to environmental exposure or environmental effects. The appropriate geographic unit of analysis may be a political jurisdiction, county, region, or State, or some other similar unit that is chosen so as not to artificially dilute or inflate the affected minority population.
- **Low-income population.** Low-income population is defined as individuals or families living below the annual statistical poverty threshold as defined by the U.S. Census Bureau's Current Population Reports, Series P-60 on Income and Poverty (CEQ 1997b). Low-income populations may be communities of individuals living in close geographic proximity to one another, or they may be a set of individuals, such as migrant workers or Native Americans, who, as a group, experience common conditions of environmental exposure or effect.

Consistent with the definitions used in the public and occupational health and safety analysis, affected populations are defined as minority and low-income populations who reside within a 50 mi (80 km) radius of a nuclear plant. Data on minority and low-income individuals are collected and analyzed at the census block group or tract level.[1]

The presence of minority populations, low-income populations, and Indian Tribes within 50 mi (80 km) of each nuclear power plant varies considerably depending on the location of Tribal lands, population trends, and regional economic activity. Nuclear power plants in southern and southwestern States have been found to have larger minority populations, including Browns Ferry, Brunswick, Catawba, Joseph M. Farley Nuclear Plant (Farley), North Anna, Robinson, Summer, and Surry nuclear plants. Nuclear power plants near metropolitan areas generally have larger minority and low-income populations, including Dresden and Ginna nuclear plants.

Section 4–4 of EO 12898 directs Federal agencies, whenever practical and appropriate, to collect and analyze information on the consumption patterns of populations who rely principally on fish and/or wildlife for subsistence and to communicate the risks of these consumption patterns to the public. Consideration is given to determine the means by which these populations could be disproportionately affected by the continued operation of a nuclear power plant. Consumption patterns (e.g., subsistence agriculture, hunting, and fishing) and certain resource dependencies often reflect the traditional or cultural practices of minority populations, low-income populations, and Indian Tribes.

In assessing human health effects, the NRC examines radiological risk from consumption of fish, wildlife, and local produce; exposure to radioactive material in water, soils, and vegetation; and the inhalation of airborne radioactive material during nuclear power plant operation. To assess the effect of nuclear reactor operations, licensees are required to collect samples from

[1] A census block group is a combination of census blocks, which are statistical subdivisions of a census tract. A census block is the smallest geographic entity for which the U.S. Census Bureau collects and tabulates decennial census information. A census tract is a small, relatively permanent statistical subdivision of counties delineated by local committees of census data users in accordance with U.S. Census Bureau guidelines for the purpose of collecting and presenting decennial census data. Census block groups are subsets of census tracts (USCB Undated).

the environment, as part of their REMP. These samples are analyzed annually for radioactivity to assess the impact of nuclear power plant operations.

## 3.11 Waste Management and Pollution Prevention

As part of their normal operations and as a result of equipment repairs and replacements due to normal maintenance activities, nuclear power plants routinely generate both radioactive and nonradioactive wastes. Nonradioactive wastes include hazardous and nonhazardous wastes. There is also a class of waste, called mixed waste, that is both radioactive and hazardous. The systems used to manage (i.e., treat, store, and dispose of) these wastes are described in Sections 3.1.4 and 3.1.5. The basic characteristics and current disposition paths for these waste streams are discussed in Section 3.11.1 for radioactive waste, 3.11.2 for hazardous waste, 3.11.3 for mixed waste, and 3.11.4 for nonradioactive nonhazardous waste. Waste minimization and pollution prevention measures commonly employed at nuclear power plants are reviewed in Section 3.11.5.

### 3.11.1 Radioactive Waste

There are two types of radiological wastes that could be associated with a commercial reactor: LLW and spent nuclear fuel. Regulations regarding how a licensee shall dispose of licensed materials is regulated in accordance with 10 CFR Part 20 Subpart K. The NRC requires that all licensees implement measures to minimize, to the extent practicable, the generation of radioactive waste (10 CFR 20.1406). These wastes are described in the sections below.

#### *3.11.1.1 Low-Level Radioactive Waste*

The Commission's licensing requirements for the land disposal of LLW are set forth in 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste." Part 61 defines LLW as "radioactive waste not classified as high-level radioactive waste [HLRW], transuranic [TRU] waste, spent nuclear fuel, or by-product material as defined in paragraphs (2), (3), and (4) of the definition of by-product material set forth in § 20.1003 of this chapter."[1] The NRC's definition of LLW is included in 10 CFR 61.55. Depending on the types and concentrations of radionuclides in the waste, the NRC classifies LLW as belonging to Class A, Class B, Class C, or greater-than-Class C (GTCC). Class A wastes generally contain short-lived radionuclides at relatively low concentrations, whereas the half-lives and concentrations of radionuclides in the Class B and C wastes are progressively higher. In addition, Class B wastes must meet more rigorous requirements with regard to their form to ensure they remain stable after disposal (e.g., by adding chemical stabilizing agents such as cement to the waste or placing the waste in a disposal container or structure that provides stability after disposal). Class C wastes must not only meet the more rigorous requirements above but also require the implementation of additional measures at the disposal facility to protect against inadvertent intrusion (e.g., by increasing the thickness and hardness of the cover over the waste disposal cell). Wastes containing radionuclides at concentrations that are higher than what is allowed for Class C wastes are classified as GTCC. GTCC is LLW with concentrations of radionuclides that exceed the limits established by the Commission for Class C LLW (NRC 2019e). Under the NRC's regulations, GTCC waste is considered to be generally unacceptable for near-surface disposal and must be disposed of in a geologic repository unless the Commission approves, on a case-by-case basis, disposal of such waste in a disposal site licensed pursuant to 10 CFR 61.55(a)(2)(iv). Disposal of GTCC waste is the responsibility of the DOE (Public Law 99-240).

[1] 10 CFR 61.2 (definition of "waste").

DOE prepared an EIS to evaluate the various alternatives for disposing of these wastes (DOE 2016) and presented the alternatives for disposal of GTCC LLW and GTCC-like waste (DOE 2017).

**Definitions of Radioactive Wastes Associated with Commercial Nuclear Power Plants**

- **Low-level waste:** Radioactive material that (1) is not high-level radioactive waste, spent nuclear fuel, or by-product material (as defined in Section 11e(2) of the AEA of 1954 [42 U.S.C. 2014(e)(2)]) and (2) is classified by the NRC, consistent with existing law, as low-level radioactive waste (as defined in the Low-Level Radioactive Waste Policy Act, as amended, Public Law 99 240; 42 U.S.C. § 2021b et seq.).
- **Spent nuclear fuel:** Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing (as included in the Nuclear Waste Policy Act of 1982, as amended, Public Law 97-425 [42 U.S.C. § 10101 et seq.]).

LLW generated at nuclear power plants generally consists of air filters, cleaning rags, protective tape, paper and plastic coverings, discarded contaminated clothing, tools, equipment parts, and solid laboratory wastes (all of these are collectively known as dry active waste) and wet wastes that result during the processing and recycling of contaminated liquids at the plants. Wet wastes generally consist of evaporator bottoms, spent demineralizer or ion exchange resins, and spent filter material from the equipment drain, floor drain, and water cleanup systems. The wet wastes are generally solidified, dried, or dewatered to make them acceptable at a disposal site. Some plants perform these operations onsite, while others ship their waste to a third-party vendor offsite for processing before it is sent to a disposal facility. The radioactivity can range from just above the background levels found in nature to very highly radioactive. LLW that contains radionuclides that have shorter decay times can be stored onsite by licensees until it can be released in accordance with 10 CFR Part 20, Subpart K. LLW that contains radionuclides that have longer decay times can be stored onsite until material inventory amounts are large enough for shipment to a LLW disposal site. The transportation and disposal of solid radioactive wastes are performed in accordance with the applicable requirements of 10 CFR Part 71 and 10 CFR Part 61, respectively.

LLW shipments from nuclear power plants to disposal facilities or waste processing centers and from waste processing centers to disposal facilities are generally made by trucks. Wastes are segregated and packaged by class. For load-leveling purposes, the wastes may be stored onsite at the plant temporarily before shipment offsite. Construction and operation of any LLW storage areas and any activities related to storage and processing of LLW onsite, including the preparation of waste for shipment and loading on vehicles before shipment, are carried out in accordance with the licensing requirements imposed by the NRC. All such operations are accounted for when the applicants prepare their annual radioactive effluent release reports to demonstrate compliance with the applicable Federal standards and requirements. The primary standards applicable to all the power plants are contained in 10 CFR Part 20, 40 CFR Part 190, and Appendix I to 10 CFR Part 50.

The Low-Level Radioactive Waste Policy Amendments Act of 1985 (Public Law 99-240)[1] gave States the responsibility for disposal of the LLW generated at commercial facilities within their

[1] The Low-Level Radioactive Waste Policy Amendments Act superseded, in its entirety, an earlier law, the Low-Level Radioactive Waste Policy Act of 1980 (Public Law 96-573).

states. As an incentive for States to manage waste on a regional basis, Congress consented to the formation of interstate agreements known as compacts, and it granted compact member States the authority to exclude LLW from States that are members of other compacts or unaffiliated with a compact. There are currently four operating disposal facilities in the United States that are licensed to accept LLW from commercial facilities (including nuclear power plants) (NRC 2020h). They are located in Clive, Utah; Andrews County, Texas; Barnwell, South Carolina; and near Richland, Washington. The Energy*Solutions* disposal facility in Clive, Utah, is licensed by the State of Utah to accept Class A LLW from all regions of the United States. The Waste Control Specialists, LLC site in Andrews County, Texas, is licensed by the State of Texas to accept Class A, B, and C LLW from the Texas Compact generators (Texas and Vermont) and from outside generators with permission from the Texas Compact. Energy*Solutions* Barnwell Operations located near Barnwell, South Carolina, accepts waste from the Atlantic Compact States (Connecticut, New Jersey, and South Carolina) and is licensed by the State of South Carolina to dispose of Class A, B, and C LLW. U.S. Ecology, located near Richland, Washington, accepts LLW from the Northwest and Rocky Mountain Compact States (Washington, Alaska, Hawaii, Idaho, Montana, Oregon, Utah, Wyoming, Colorado, Nevada, and New Mexico) and is licensed by the State of Washington to dispose of Class A, B, and C waste.

Annual quantities of LLW generated at the nuclear power plants vary from year to year depending on the number of maintenance activities undertaken and the number of unusual occurrences taking place in that year. However, on average, the volume and radioactivity of LLW generated at a PWR was approximately 10,600 $ft^3$ (300 $m^3$) and 1,000 Ci ($3.7 \times 10^{13}$ Bq) per year, respectively, according to the 1996 LR GEIS (Table 6.6 in NRC 1996). The annual volume and activity of LLW generated at a BWR are approximately twice the values indicated for a PWR. The total volume and activity of LLW generated at all the LWRs in the United States was approximately 706,000 $ft^3$ (20,000 $m^3$) and 60,000 Ci ($2.2 \times 10^{15}$ Bq), respectively, according to the 1996 LR GEIS (Table 6.6 in NRC 1996). Approximately 95 percent of this waste is Class A (NEI 2007b in the 2013 LR GEIS). Table 3.11-1 and Table 3.11-2 show the volume and activity of LLW shipped offsite per operating reactor unit from 11 power plant sites in 2020. For example, there are two operating units at the Comanche Peak site, and the volume and activity of LLW shipped from the Comanche Peak site in 2020 were 4,167 $ft^3$ (118 $m^3$) and 394 Ci ($1.46 \times 10^{13}$ Bq). The numbers in Table 3.11-1 and Table 3.11-2 were obtained from the annual radioactive effluent release reports issued by each plant for 2020.

Almost all of the LLW generated at the reactor sites is shipped offsite, either directly to a disposal facility or to a processing center for volume reduction or another type of treatment before being sent to a disposal site. The number of shipments leaving each reactor site varies but generally ranges from a few to about 100 per year. 10 CFR Part 20, Subpart K, discusses the various means by which the licensees may dispose of their radioactive waste.

**Table 3.11-1 Solid Low-Level Radioactive Waste Shipped Offsite per Reactor from Select Pressurized Water Reactor Power Plant Sites in 2020[(a)]**

| Nuclear Power Plant | Volume ($m^3$) | Activity (Ci) | Number of Shipments | Number of Reactors |
|---|---|---|---|---|
| Comanche Peak | 118 | 394 | 5 | 2 |
| D.C. Cook | 382.5 | 194.226 | 16 | 1 |
| Palo Verde 1-3 | 850 | 150 | 40 | 3 |

| Nuclear Power Plant | Volume ($m^3$) | Activity (Ci) | Number of Shipments | Number of Reactors |
|---|---|---|---|---|
| Robinson | 1,440 | 17,800 | 45 | 2 |
| Seabrook | 44.35 | 124.497 | 5 | 1 |
| Surry | 261.76 | 170.93075 | 13 | 2 |

Ci = curies; $m^3$= cubic meter.
(a) Annual effluent release reports. The radiological environmental monitoring reports can also be accessed by navigating the reactor webpage for each site on the NRC website; effluent reports and environmental reports are available through the "Plant Environmental Report" section of the key documents.

**Table 3.11-2 Solid Low-Level Radioactive Waste Shipped Offsite per Reactor from Select Boiling Water Reactor Power Plant Sites in 2020[a]**

| Nuclear Power Plant | Volume ($m^3$) | Activity (Ci) | Number of Shipments | Number of Reactors |
|---|---|---|---|---|
| Fermi 2 | 2,719.616 | 2,490.1 | 82 | 1 |
| Hatch | 625.1 | 534.351 | 67 | 2 |
| Hope Creek and Salem[b] | 770 | 180.8 | 37 | 3 |
| Limerick | 739.8 | 494 | 35 | 1 |
| Columbia | 303.9 | 892 | 48 | 1 |

Ci = curies; $m^3$= cubic meter.
(a) Annual effluent release reports. The radiological environmental monitoring reports can also be accessed by navigating the reactor webpage for each site on the NRC website; effluent reports and environmental reports are available through the "Plant Environmental Report" section of the key documents.
(b) Hope Creek is a BWR but is reported with the Salem Generating Station as a joint site, so it is included in this table.

#### *3.11.1.2 Spent Nuclear Fuel*

Spent nuclear fuel is fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated. When spent nuclear fuel is removed from a reactor, it is stored in racks placed in a pool (called the spent fuel pool) to isolate it from the environment and to allow the fuel rods to cool. Licensing plans contemplate disposal of spent fuel in a deep geological permanent repository. Siting and developing a permanent repository is required by the Nuclear Waste Policy Act of 1982. Delays in siting a permanent repository, coupled with rapidly filling spent fuel pools at some plants, have led utilities to seek means of continued onsite storage. These include (1) expanded pool storage, (2) aboveground dry storage, (3) longer fuel burnup to reduce the amount of spent nuclear fuel requiring interim storage, and (4) shipment of spent nuclear fuel to other plants. Any modification to the spent nuclear fuel storage configuration at a nuclear power plant is subject to NRC review and approval. Each review consists of a safety and environmental review. As part of the environmental review for such a modification, the NRC generally prepares an environmental assessment.

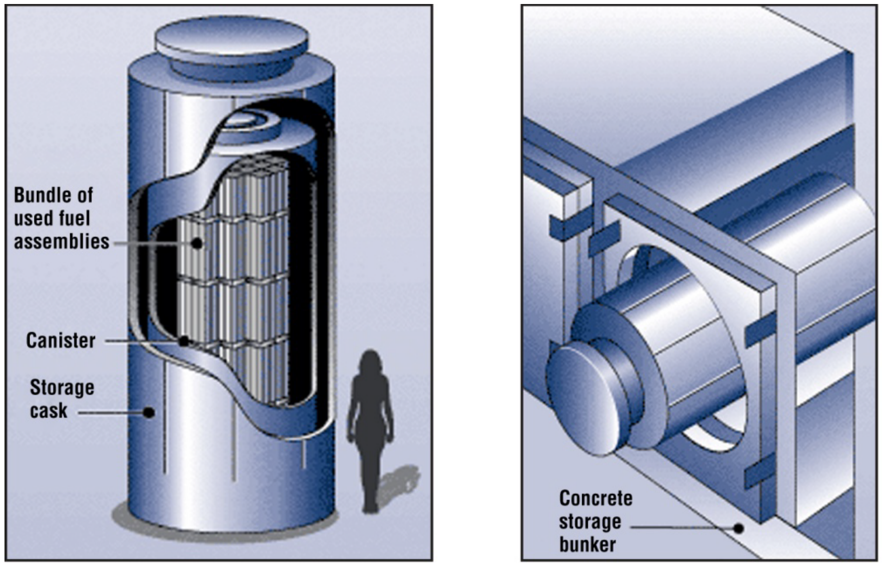
Expanded pool storage options include (1) enlarging the capacity of spent fuel racks, (2) adding racks to existing pool arrays ("dense-racking"), (3) reconfiguring spent fuel racks with neutron-absorbing racks, and (4) employing double-tiered storage (installing a second tier of racks above those on the spent fuel pool floor).

Aboveground dry storage involves moving the spent fuel assemblies, which have been stored in the spent fuel pool for a certain period of time, to aboveground, shielded enclosures that are air cooled (also known as dry storage). The spent nuclear fuel is stored in the spent fuel pool to cool, typically for several years, before it may be moved to a dry cask storage facility. In the late 1970s and early 1980s, the need for alternative storage grew when pools at many nuclear reactors filled with stored spent fuel. Utilities looked at options such as dry cask storage for increasing their storage capacity for spent nuclear fuel.

Dry cask storage allows spent nuclear fuel to be surrounded by inert gas inside a container called a cask. The casks are typically steel cylinders that are either welded or bolted closed. The steel cylinder provides a leak-proof containment for the spent nuclear fuel. Each cylinder is surrounded by additional steel, concrete, or other material to provide radiation shielding to workers and members of the public. Some of the cask designs can be used for both storage and transportation.

There are various dry storage cask system designs. With some designs, the steel cylinders containing the spent nuclear fuel are placed vertically in a concrete vault; other designs orient the cylinders horizontally. The concrete vaults provide the radiation shielding. Other cask designs orient the steel cylinder vertically on a concrete pad at a dry cask storage site and use both metal and concrete outer cylinders for radiation shielding. Figure 3.11-1 shows two of the typical dry cask storage designs. The location of the dry casks is in a facility known as an ISFSI. This is a facility designed and constructed for the interim storage of spent nuclear fuel, solid reactor-related GTCC, and other radioactive materials associated with spent nuclear fuel and reactor-related GTCC storage. The ISFSI is generally located within the same site where the nuclear fuel is used and are licensed by the NRC under either a general license or a site-specific license (see 10 CFR Part 72). Figure 3.11-2 shows the locations of currently licensed ISFSIs.

Longer-burnup fuel is fuel from which more energy can be obtained before it is taken out of the reactor and declared spent. As a result of using this fuel, less spent fuel is generated for the same amount of energy produced in a reactor.




Typical Vertical Storage System Typical Horizontal Storage System

**Figure 3.11-1 Typical Dry Cask Storage Systems. Source: NRC 2020k.**

**Definitions of Other Wastes Associated with Commercial Nuclear Power Plants**

- **Hazardous Waste:** A solid waste or combination of solid wastes that, because of its quantity, concentration, or physical, chemical, or infectious characteristics, may (1) cause or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness, or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed (as defined in the Resource Conservation and Recovery Act, as amended, Public Law 94-580 [42 U.S.C. § 6901 et seq.]).
- **Mixed Waste:** Waste that is both hazardous and radioactive.
- **Nonradioactive Nonhazardous Waste:** Waste that is neither radioactive nor hazardous.

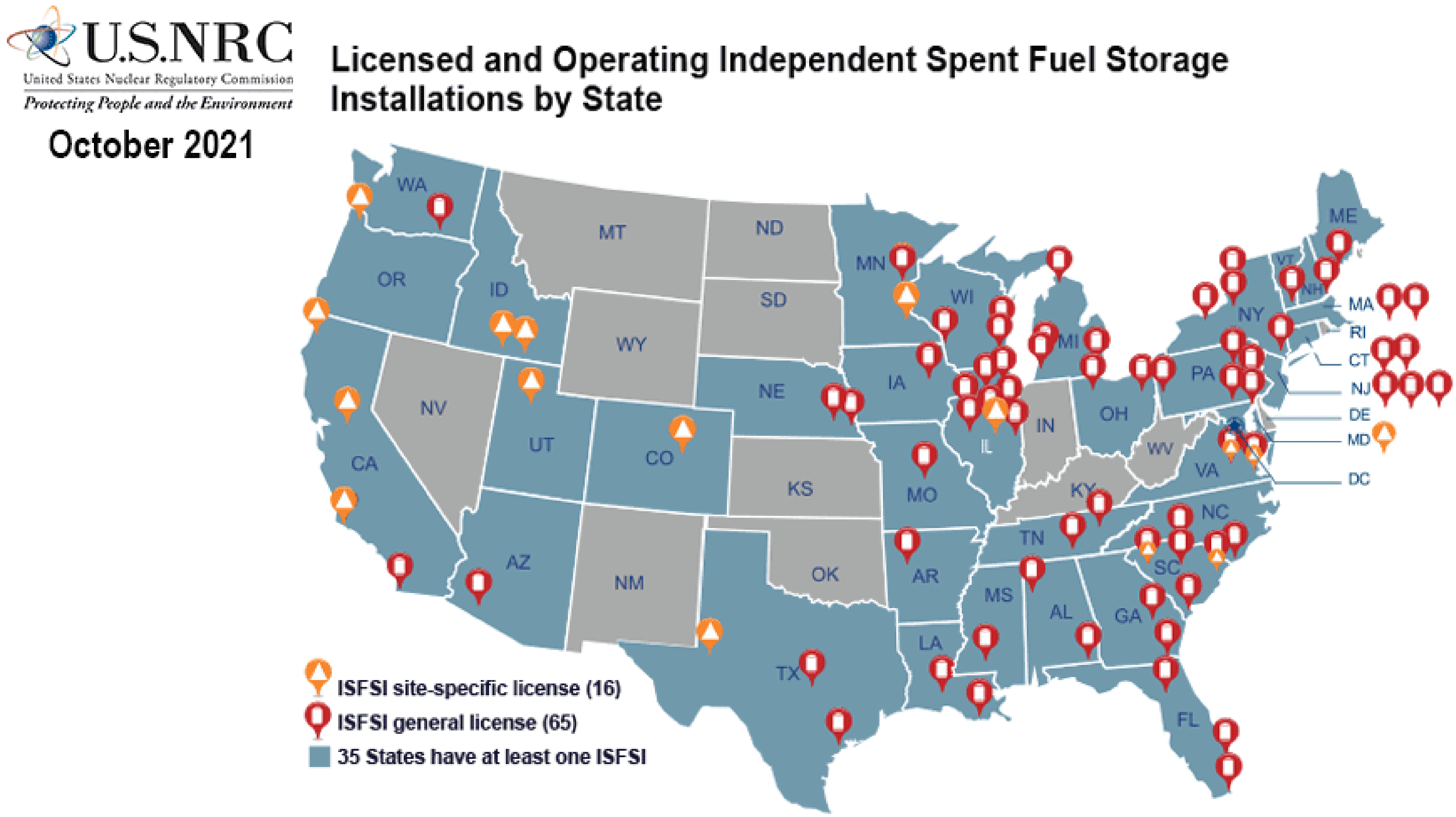



**Figure 3.11-2 Locations of Independent Spent Fuel Storage Installations Licensed by the NRC. Source: NRC 2021i.**

### 3.11.2 Hazardous Waste

Hazardous waste is defined by the EPA in 40 CFR Part 261, "Identification and Listing of Hazardous Waste" as solid waste that (1) is listed by the EPA as being hazardous; (2) exhibits one of the characteristics of ignitability, corrosivity, reactivity, or toxicity; or (3) is not excluded by the EPA from regulation as being hazardous.

All aspects of hazardous waste generation, treatment, transportation, and disposal are strictly regulated by the EPA or by the States under agreement with the EPA per the regulations promulgated under RCRA (Public Law 94-580 [42 U.S.C. § 6901 et seq.]).

The types of hazardous waste that nuclear power plants typically generate include waste paints, lab packs, and solvents. The quantities of these wastes generated at individual plants are highly variable but, generally, are relatively small compared to those at most other industrial facilities that generate hazardous waste. Most nuclear power plants accumulate their hazardous waste onsite as authorized under RCRA and transport it to a treatment facility for processing. The remaining residues are sent to a permanent disposal facility. There are quite a few RCRA-permitted treatment and disposal facilities throughout the United States that are used by the owners of nuclear power plants.

A class of hazardous waste called universal waste is handled differently than hazardous waste and includes batteries, pesticides, mercury-containing equipment, light bulbs, and aerosol cans. Federal universal waste regulations can be found in 40 CFR Part 273. All aspects of hazardous waste, such as generation, treatment, transportation, and disposal, are regulated by the EPA or by States under agreements with the EPA per the regulations set forth under RCRA. RCRA also defines categories of hazardous waste generators (EPA 2020a).

### 3.11.3 Mixed Waste

Mixed waste, regulated under RCRA and the AEA of 1954, as amended (42 U.S.C. § 2011 et seq.), is waste that is both radioactive and hazardous (EPA 2019). Mixed waste is subject to dual regulation: by the EPA or an authorized State for its hazardous component and by the NRC or an agreement state for its radioactivity. The types of mixed wastes generated at nuclear power plants include organics (e.g., liquid scintillation fluids, waste oils, halogenated organics), metals (e.g., lead, mercury, chromium, and cadmium), solvents, paints, and cutting fluids. The quantity of mixed waste generated varies considerably from plant to plant (NRC 1996). Overall, the quantities generated during operations are generally relatively small, but because of the added complexity of dual regulation, it is more problematic for plant owners to manage and dispose of mixed wastes than the other types of wastes. Similar to hazardous waste, mixed waste is generally accumulated onsite in designated areas as authorized under RCRA then shipped offsite for treatment as appropriate and for disposal. The only disposal facilities that are authorized to receive mixed LLW for disposal at present are the U.S. Ecology and the Waste Control Specialists facilities discussed under Section 3.11.1.1.

Occupational exposures and any releases from onsite treatment of these and any other types of wastes are considered when evaluating compliance with the applicable Federal standards and regulations: for example, 10 CFR Part 20, 40 CFR Part 190, and Appendix I to 10 CFR Part 50.

### 3.11.4 Nonhazardous Waste

Nonhazardous waste is waste that is not contaminated with either radionuclides or hazardous chemicals. These wastes include office trash, paper, wood, oils not mixed with hazardous waste or radiological waste, and sewage. Solid wastes defined as nonhazardous by 40 CFR Part 261 are collected and disposed of in a landfill. Sanitary wastes defined as nonhazardous by 40 CFR Part 261 are treated either at an onsite sewage treatment plant (as in the case of many large-scale industrial facilities), discharged directly to a municipal sewage system for treatment, or discharged to onsite septic tanks. The uncontaminated wastes and sewage are tested for radionuclides before being sent offsite to make sure that there is no inadvertent contamination. Any offsite releases from the onsite sewage treatment plants are conducted under NPDES permits. Most plants also collect and test the stormwater runoff from their sites before discharging it offsite. Large LWRs have nonradioactive waste management systems in place that manage both hazardous and nonhazardous wastes. For example, boiler blowdown, water treatment wastes, boiler metal cleaning wastes, laboratory and sampling wastes, floor and yard drains, and stormwater runoff are all managed by these systems and are regulated by an NPDES permit, with the exception of wastes in solid form (NRC 2013a).

### 3.11.5 Pollution Prevention and Waste Minimization

Waste minimization and pollution prevention are important elements of operations at all nuclear power plants. The licensees are required to consider pollution prevention measures as dictated by the Pollution Prevention Act (Public Law 101-508 [42 U.S.C. § 13101 et seq.]) and RCRA (Public Law 94-580 [42 U.S.C. § 6901 et seq.]).

In addition, licensees have waste minimization programs in place that are aimed at minimizing the quantities of waste sent offsite for treatment or disposal. Waste minimization techniques employed by the licensees may include (1) source reduction, which includes (a) changes in input materials (e.g., using materials that are not hazardous or are less hazardous), (b) changes in technology, and (c) changes in operating practices and (2) recycling of materials either onsite or offsite. For example, the licensees tend to reuse lead shielding components onsite until they have no further use for them. The establishment of a waste minimization program is also a requirement for managing hazardous wastes under RCRA.

## 3.12 Greenhouse Gas Emissions and Climate Change

### 3.12.1 Greenhouse Gas Emissions

Gases found in the Earth's atmosphere that trap heat and play a role in the Earth's climate are collectively termed greenhouse gases (GHGs). These GHGs include carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), water vapor ($H_2O$), and fluorinated gases, such as hydrofluorocarbons (HCFs), perfluorocarbons, and sulfur hexafluoride. Operations at nuclear power plants release GHGs from stationary combustion sources (e.g., diesel generators, pumps, diesel engines, boilers), refrigeration systems, electrical transmission and distribution systems, and mobile sources (worker vehicles and delivery vehicles).

The Earth's climate responds to changes in concentrations of GHGs in the atmosphere because these gases affect the amount of energy absorbed and heat trapped by the atmosphere. Increasing concentrations of GHGs in the atmosphere generally increase the Earth's surface temperature. Atmospheric concentrations of $CO_2$, $CH_4$, and $N_2O$ have significantly increased since 1750 (IPCC 2013, IPCC 2021). Long-lived GHGs—$CO_2$, $CH_4$, $N_2O$, and fluorinated gases—are well mixed throughout the Earth's atmosphere, and their impact on climate is long-lasting and cumulative in nature as a result of their long atmospheric lifetimes (EPA 2016). Therefore, the extent and nature of climate change is not specific to where GHGs are emitted. Carbon dioxide is of primary concern for global climate change because it is the primary gas emitted as a result of human activities. The most recent report from the Intergovernmental Panel on Climate Change (IPCC) states that "[i]t is unequivocal that human influence has warmed the global climate system since pre-industrial times" (IPCC 2021). The EPA has determined that GHGs "may reasonably be anticipated both to endanger public health and to endanger public welfare" (74 FR 66496).

In 2009, the EPA issued a final rule requiring the reporting of GHG emissions from facilities that directly emit 25,000 MT (27,557 tons) of $CO_2$ equivalents ($CO_2eq$[1]) or more per year (74 FR 56260). The 25,000 MT of $CO_2eq$ reporting threshold EPA established in the above final rule is not an indication of what EPA considers to be a significant (or insignificant) level of GHG emissions on a scientific basis, but a threshold chosen by EPA for policy evaluation purposes (74 FR 56260). The Greenhouse Gas Reporting Program captures approximately 90 percent of total U.S. GHG emissions from more than 8,000 facilities, because facilities that fall below the 25,000 MT of $CO_2eq$/yr are not required to report GHG emissions to the EPA. The EPA publishes GHG emission data from the Greenhouse Gas Reporting Program via the Facility Level Information on GreenHouse Gases Tool. The EPA also prepares an annual report, Inventory of U.S. Greenhouse Gas Emissions and Sinks (Inventory), that estimates total GHG emissions across all sectors of the U.S. economy by using national statistics (e.g., energy data, agricultural activities). EPA's Inventory is an essential tool for addressing climate change and participating in the United Nations Framework Convention on Climate Change to compare the relative global contribution of different emission sources and GHGs to climate change. In 2020, U.S. gross GHG emissions totaled 6,692 million tons (5,981 million MT) of $CO_2eq$ (EPA 2022a). Carbon dioxide represented 78.8 percent of total emissions, and the largest source of GHG emissions was fossil fuel combustion from transportation (e.g., passenger vehicles, freight trucks, light-duty trucks), followed by fossil fuel electric power generation (EPA 2022a). In 2020, the total amount of $CO_2eq$ emissions related to fossil fuel electricity generation was 1,586 million tons (1,439 million MT) (EPA 2022a). Table 3.12-1 presents annual GHG emissions by State.

**Table 3.12-1 Greenhouse Gas Emissions by State, 2020**

| State | Total GHG Emissions (tons) |
|---|---:|
| Alabama | 81,529,926 |
| Arkansas | 36,576,479 |
| Arizona | 48,145,971 |
| California | 101,817,155 |
| Colorado | 44,252,447 |
| Connecticut | 12,067,762 |
| District of Columbia | 331,144 |
| Delaware | 6,511,631 |

[1] Carbon dioxide equivalent ($CO_2eq$) is a metric used to compare the emissions of GHG based on their global warming potential—a measure used to compare how much heat a GHG traps in the atmosphere. The global warming potential is the total energy that a gas absorbs over a period of time, compared to $CO_2$. Carbon dioxide equivalent is obtained by multiplying the amount of the GHG by the associated GWP. For example, the global warming potential of $CH_4$ is estimated to be 21; therefore, one ton of $CH_4$ emission is equivalent to 21 tons of $CO_2$ emission.

| State | Total GHG Emissions (tons) |
|---|---|
| Florida | 132,460,532 |
| Georgia | 59,044,565 |
| Iowa | 44,492,715 |
| Idaho | 5,523,906 |
| Illinois | 85,500,581 |
| Indiana | 123,154,493 |
| Kansas | 36,175,597 |
| Kentucky | 73,303,670 |
| Louisiana | 149,745,938 |
| Massachusetts | 10,341,372 |
| Maryland | 17,607,838 |
| Maine | 3,190,240 |
| Michigan | 73,847,686 |
| Minnesota | 38,502,904 |
| Missouri | 75,413,377 |
| Mississippi | 45,465,248 |
| Montana | 16,042,590 |
| North Carolina | 51,036,623 |
| North Dakota | 39,668,230 |
| Nebraska | 29,625,029 |
| New Hampshire | 2,399,564 |
| New Jersey | 23,096,674 |
| New Mexico | 30,164,049 |
| Nevada | 18,545,886 |
| New York | 39,777,988 |
| Ohio | 113,959,613 |
| Oklahoma | 53,666,856 |
| Oregon | 14,961,597 |
| Pennsylvania | 115,362,063 |
| Rhode Island | 4,008,019 |
| South Carolina | 35,370,551 |
| South Dakota | 5,764,182 |
| Tennessee | 37,853,626 |
| Texas | 397,341,699 |
| Utah | 36,718,856 |
| Virginia | 48,514,702 |
| Vermont | 481,491 |
| Washington | 25,666,160 |
| Wisconsin | 44,591,776 |

GHG = greenhouse gas.
To convert to MT multiply by 0.907
Source: EPA 2022d.

GHG emissions from nuclear power plants are typically very minor because such plants, by their very nature, do not normally burn fossil fuels to generate electricity. Sources include stationary and mobile combustion sources, including diesel generators, pumps, diesel engines, boilers, worker vehicles, or delivery vehicles. Other GHG sources from nuclear power plants may include human-made fluorinated compounds. These include hydrofluorocarbons and perfluorocarbons contained in refrigerants. Sulfur hexafluoride is used in electric power transmission and distribution applications. Sulfur hexafluoride can be found in substations, circuit breakers, and other switchgear. The gas has replaced flammable insulating oils in many applications and allows for more compact substations. Fugitive emissions of sulfur hexafluoride can escape from gas-insulated substations and switchgear through seals, especially those in older equipment. The gas can also be released during equipment manufacturing, installation, servicing, and disposal (EPA 2022a).

Operations at nuclear power plants release GHGs (primarily $CO_2$) from stationary combustion sources (e.g., diesel generators, pumps, diesel engines, boilers), refrigeration systems, electrical transmission and distribution systems, and mobile sources (e.g., worker vehicles and delivery vehicles). GHG emissions generated can be categorized into direct and indirect emissions. The EPA has developed guidance to identify and scope sources to delineate, inventory, and account for GHG emissions. Direct GHG emissions include those that are owned or controlled by an organization (EPA 2021b). The EPA categorizes direct GHG emissions as Scope 1 emissions. This includes GHG emissions associated with stationary and mobile combustion sources at nuclear power plants, as well as fugitive emissions from refrigeration equipment and transmission lines. Indirect emissions are those associated with an organization's activities but are emitted from sources owned by other entities. The EPA's guidance categorizes indirect GHG emissions as Scope 2 and Scope 3 emissions. Scope 2 GHG emissions include emissions associated with the purchase of electricity consumed by the organization (EPA 2020b). Scope 3 emissions includes those from upstream and downstream activities such as transportation of purchased products, employee commuting, and end of-life treatment of sold products (EPA 2022c).

In 2009, the Commission issued a memorandum and order in CLI-09-21 (NRC 2009d) that stated the following:

> [B]ecause the Staff is currently addressing the emerging issues surrounding greenhouse gas emissions in environmental reviews required for the licensing of nuclear facilities, we believe it is prudent to provide the following guidance to the Staff. We expect the Staff to include consideration of carbon dioxide and other greenhouse gas emissions in its environmental reviews for major licensing actions under the National Environmental Policy Act.

Following the issuance of CLI-09-21 (NRC 2009d), the NRC began to evaluate the effects of GHG emissions and its implications for global climate change in its environmental reviews for license renewal applications. For the 2013 LR GEIS, direct GHG emissions data for facilities were not available to support an impact level determination for the license renewal term. Since publication of the 2013 LR GEIS, the NRC has included within each SEIS a plant-specific analysis of GHG emissions over the course of the license renewal term (initial and subsequent). Table 3.12-2 presents direct and indirect GHG emissions from representative operating nuclear power plants. The observed range and distribution of direct and indirect GHG emissions from site to site is a result of different sources and contributors, as well as differences in GHG data that nuclear power plant licensees inventory. Not all States have GHG emission reporting requirements, and EPA requires reporting only if the 25,000 MT threshold is met. In the absence of these reporting requirements, nuclear power plant licensees do not inventory GHG data uniformly.

**Table 3.12-2 Estimated Greenhouse Gas Emissions from Operations at Nuclear Power Plants**

| Nuclear Power Plant | Direct Greenhouse Gas Emissions (T/yr)[a] | Indirect Greenhouse Gas Emissions (T/yr)[a] |
|---|---|---|
| Braidwood[b] | 3,562—14,778 | 16,459—24,380 |
| Byron[b] | 4,761—7,638 | 6,307—7,638 |
| Callaway[c] | 845—5,042 | N/A |
| Columbia[d] | 650—856 | N/A |
| Davis-Besse[e] | 5,173 | N/A |
| Fermi[f] | 6,411—11,897 | 4,166 |
| Indian Point[g] | 540—7,188 | 4,928 |
| LaSalle[h] | 2,500 | 36,066 |
| North Anna[i] | 430—690 | 4,490 |
| Peach Bottom[j] | 29,705 | 10,090 |
| Point Beach[k] | 660—1,110 | 3,460 |
| River Bend[l] | 360—820 | 2,900 |
| Seabrook[m] | 7,893—47,778 | N/A |
| Surry[n] | 340—4,630 | 4,730 |
| Turkey Point[o] | 500—790 | 3,400 |
| Waterford[p] | 716—3,087 | 3,307 |

N/A = Not Available; T/yr = ton per year.
(a) To convert to MT multiply by 0.907.
(b) Data available for 2008–2012. Direct emissions include onsite combustion sources, refrigerants, and the $CO_2$ purge and fire protection system. Indirect emissions are from purchased electricity. Sources: NRC 2015c, NRC 2015d, Exelon Generation Company 2013, Exelon Generation Company 2014.
(c) Data available for 2007–2011. Direct emissions include onsite combustion sources. Source: NRC 2014f.
(d) Data available for 2006–2009. Direct emissions include onsite combustion sources. Source: NRC 2012b.
(e) Data available for 2010. Direct emissions include onsite combustion sources. Source: NRC 2015e.
(f) Data available for 2009–2013. Direct emissions include onsite combustion sources and refrigerants. Indirect emissions source include worker vehicles. Source: NRC 2016c.
(g) Data available for 2009–2013. Direct emissions include onsite combustion sources and electrical equipment related sources. Indirect emissions include worker vehicles. Source: NRC 2018e.
(h) Data available for 2010–2014. Direct emissions include onsite combustion sources, refrigerants, and fugitive emissions sources (from the $CO_2$ injection system, fire protection system, and condensers). Indirect emissions include purchased electricity. Source: NRC 2016d.
(i) Data available for 2013–2017. Direct emissions include onsite combustion sources. Indirect emissions from worker vehicles. Source: NRC 2021g.
(j) Direct emissions include onsite combustion sources. Direct emissions are based on maximum allowable fuel usage and hours as prescribed in Peach Bottom’s air permit, rather than actual fuel usage and run time. Therefore, the emissions are overestimates. Indirect emissions include worker vehicles. Source: NRC 2020g.
(k) Data available for 2014–2018. Direct emissions include onsite combustion sources. Indirect emissions from worker vehicles. Source: NRC 2021f.
(l) Data available for 2011–2015. Direct emissions include onsite combustion sources. Indirect emissions from worker vehicles. Source: NRC 2018c.
(m) Data available for 2005–2009. Direct emissions include onsite combustion sources and transmission substation. In 2007, higher than normal GHG emissions resulted from two equipment failures that contributed to 42,479 tons of $CO_2$eq (of the total 47, 778 total direct emissions). Sources: NRC 2015b and NextEra Energy 2010.
(n) Data available for 2011–2015. Direct emissions include onsite combustion sources. Indirect emissions from worker vehicles. Source: NRC 2019d.
(o) Data available for 2012–2016. Direct emissions include onsite combustion sources. Indirect emissions from worker vehicles. Source: NRC 2019c.

(p) Data available for 2010–2014. Direct emissions include onsite combustion sources. Indirect emissions from worker vehicles.
Source: NRC 2018d.

### 3.12.2 Observed Changes in Climate

Climate change is the decades or longer change in climate measurements (e.g., temperature and precipitation) that has been observed on a global, national, and regional level (IPCC 2007; EPA 2016; USGCRP 2014). Climate change research indicates that the cause of the Earth's warming over the last 50 to 100 years is due to the buildup of GHGs in the atmosphere resulting from human activities (IPCC 2013, IPCC 2021; USGCRP 2014, USGCRP 2017, USGCRP 2018). On a global level, from 1901 to 2016, the average temperature has increased by 1.8 °F (1.0 degree Celsius [°C]) (USGCRP 2018). Since 1901, precipitation has increased at an average rate of 0.1 in. (0.25 cm) per decade on a global level (EPA 2021a). The observed global change in average surface temperature and precipitation has been accompanied by an increase in sea surface temperatures, a decrease in global glacier ice, an increase in sea level, and changes in extreme weather events. Such extreme events include an increase in the frequency of heat waves, very heavy precipitation (defined as the heaviest 1 percent of all daily events), and recorded maximum daily high temperatures (IPCC 2007; EPA 2016; USGCRP 2009, USGCRP 2014). From 1880 to 2013, the global average sea level has risen at a rate of 0.06 in (0.15 cm) per year and from 1880 to 2020 global sea surface temperature has increased at a rate of 0.14 °F (0.07 °C) per decade (EPA 2021a).

The 2013 LR GEIS summarized the findings of the Second Annual Climate Assessment developed by the U.S. Global Change Research Program (USGCRP) (USGCRP 2009). The USGCRP is a Federal program mandated by Congress to coordinate Federal research conducted to better understand climate change. Since publication of the 2013 LR GEIS, Third and Fourth Annual Climate Assessments have been published (USGCRP 2014 and USGCRP 2018). The Fourth Annual Climate Assessment (USGCRP 2018) builds on the work of the previous assessments. The NRC uses consensus information from the USGCRP to evaluate the effects of climate change in its SEISs for license renewal of nuclear power plants. The USGCRP reports that from 1901 to 2016, average surface temperatures have increased by 1.8 °F (1.0 °C) across the contiguous United States (USGCRP 2018). Since 1901, average annual precipitation has increased by 4 percent across the United States (USGCRP 2018). Observed climate change indicators across the United States include increases in the frequency and intensity of heavy precipitation, earlier onset of spring snowmelt and runoff, rise of sea level and increased tidal flooding in coastal areas, an increased occurrence of heat waves, and a decrease in the occurrence of cold waves. Since the 1980s, data show an increase in the length of the frost-free season (i.e., the period between the last occurrence of 32 °F (0 °C) in the spring and first occurrence of 32 °F (0 °C) in the fall), across the contiguous United States. Over the period 1991 through 2011, the average frost-free season was 10 days longer (relative to the 1901 through 1960 time period) (USGCRP 2014). Over just the past two decades, the number of high-temperature records observed in the United States has far exceeded the number of low-temperature records (USGCRP 2018). Since the 1980s, the intensity, frequency, and duration of North Atlantic hurricanes have increased (USGCRP 2014).

Climate change and its impacts can vary regionally, spatially, and seasonally, depending on local, regional, and global factors. Observed climate changes and impacts have not been uniform across the United States. For instance, annual precipitation has increased across most of the northern and eastern States and decreased across the southern and western States. Sea level rise and coastal flooding have not been evenly distributed. Along the Atlantic coast, the U.S. Northeast has experienced a faster-than-global increase in sea level rise since the 1970s (USGCRP 2017). To provide localized information and greater granularity, USGCRP's Annual Climate Assessments (USGCRP 2014, USGCRP 2018) describe observed and projected changes in climate by U.S. geographic regions: Northeast, Southeast, Caribbean, Midwest, Northern Great Plains, Southern Great Plains, Northwest, Southwest, Midwest, Alaska, and Hawaii and U.S. Pacific Islands (see Figure 3.12-1). As can be seen in Figure 3.12-1, U.S. operating nuclear power plants are primarily located in the Northeast, Southeast, and Midwest regions. The discussions below provide a summary of the observed climate changes by the contiguous U.S. region, with a focus on regions where operating nuclear power plants are located.

#### *3.12.2.1 Northeast*

In the Northeast region of the United States, average annual air temperatures increased by 1.98 °F (1.1 °C) between 1895 and 2011 (USGCRP 2014). This observed warming has not been uniform; average temperatures increased less than 1 °F (0.6 °C) in West Virginia and 3 °F (1.6 °C) or more across New England (USGCRP 2018). The frost-free season has increased by 10 days across the Northeast during the 1986 to 2015 timeframe relative to 1901 to 1960 timeframe (USGCRP 2017). Between 1958 and 2016, the Northeast experienced a 55 percent increase in heavy precipitation events (i.e., the amount of annual precipitation falling in the heaviest 1 percent of events). This is the largest increase of any region in the United States (USGCRP 2018). Heavy precipitation events can lead to an increase in flooding because of greater runoff (USGCRP 2014, USGCRP 2018). Since the 1920s, the magnitude of river flooding has been increasing across the Northeast region by up 12 percent per decade (USGCRP 2014). Sea level rise along the Northeast coast has increased by 1 ft (0.3 m) since 1900, a rate that exceeds the global average of 8 in. (20 cm) (USGCRP 2014). From 1982 to 2006, sea surface temperatures in coastal waters of the Northeast warmed at almost twice the global rate of warming during this period (USGCRP 2014). Surface ocean temperatures in the Northeast have warmed faster than 99 percent of the global ocean since 2004, and a peak temperature in 2012 was part of a large "ocean heat wave" in the northwest Atlantic that persisted for nearly 18 months (USGCRP 2017). In the Indian Point initial LR SEIS, the NRC staff noted that sea level rise along the New York State coastline is 1.2 in. (3 cm) per decade since 1900, and a long-term warming trend in the Hudson River Estuary of 0.027 °F (0.015 °C) per year over the course of 63 years (1946 to 2008) (NRC 2018e). As discussed in the Indian Point and Seabrook license renewal SEISs, warming sea temperatures have shifted the distribution and abundance of aquatic species northward (NRC 2018e, NRC 2015b).

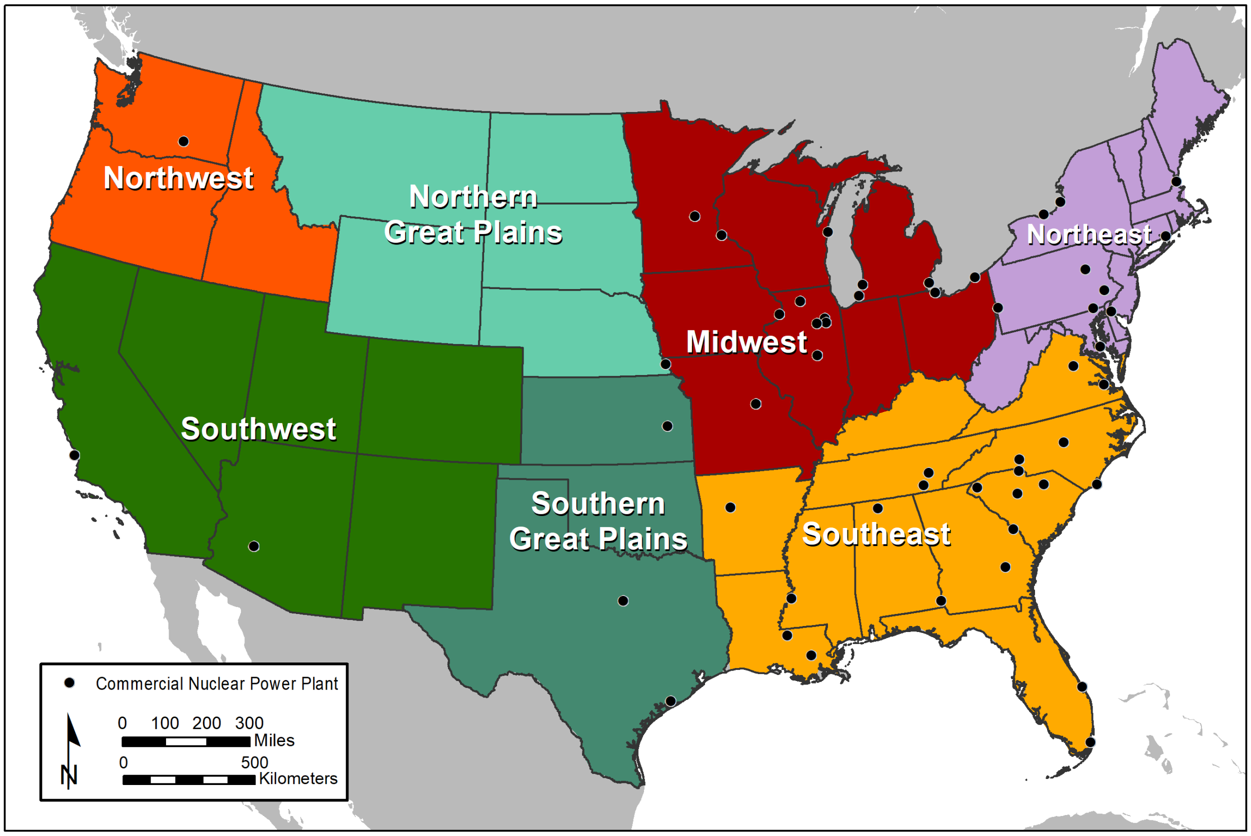



**Figure 3.12-1 Locations of Operating Nuclear Power Plants Relative to National Climate Assessment Geographic Regions**

#### *3.12.2.2 Southeast*

In the Southeast, ambient air temperature increases have generally been uneven across the region. It is one of the few regions in the world where there has not been an overall increase in surface temperatures (NOAA 2013a; USGCRP 2018). The overall lack of long-term warming in the Southeast has been termed "the warming hole" (NOAA 2013a, NOAA 2013d; USGCRP 2017; Partridge et al. 2018). Nonetheless, since the 1970s, average annual temperatures have steadily increased across the Southeast and have been accompanied by an increase in the number of hot days with maximum temperatures above 95 °F (35 °C) in the daytime and above 75 °F (23.9 °C) in the nighttime (NOAA 2013a; USGCRP 2009, USGCRP 2014, USGCRP 2018). Annual average temperatures have warmed by 0.46 °F (0.28 °C) between 1986–2016 (relative to 1901–1960) (USGCRP 2014, USGCRP 2017). The average annual number of hot days observed since the 1960s remains lower than the average number during the first half of the 20th century. In contrast, the number of warm nights above 75 °F (23.9 °C) has doubled on average in the Southeast region compared to the first half of the 20th century (USGCRP 2018). Average annual precipitation data for the Southeast region do not exhibit an increasing or decreasing trend overall for the long-term period (1895–2011) (NOAA 2013d). Precipitation in the Southeast region varies considerably throughout the seasons, and average precipitation has generally increased in the fall and decreased in the summer (NOAA 2013d; USGCRP 2009). Across parts of the Southeast region, decreases in annual average precipitation of up to 10 percent have occurred over the period 1986–2015 (relative to 1901–1960 for the contiguous United States) (USGCRP 2018). Between 1958 and 2016, heavy precipitation (i.e., the amount of annual precipitation falling in the heaviest 1 percent of events) has increased by an average of 27 percent across the Southeast region (USGCRP 2018).

Plant-specific environmental reviews of initial LR and SLR applications considered localized observed changes in sea level rise. The variability of sea level rise along U.S. coasts becomes apparent when comparing data presented in the NRC's license renewal SEISs. For instance, in the Waterford initial LR SEIS, the NRC noted that the relative sea level along the Louisiana coast increased by more than 8 in. (20 cm) between 1960 and 2015 (NRC 2018d). Sea level rise in coastal Louisiana is partially driven by land subsidence, both as a result of natural and anthropogenic processes (Jones et al. 2016). The Turkey Point SLR SEIS found that the relative sea level rise trend at Miami, Florida, is 0.09 in/yr (0.24 cm/yr), or about 9 in. (23 cm) per century (NRC 2019c). The Surry SLR SEIS found that the relative sea level rise trend at Sewells Point, Virginia, near the mouth of the James River, is 0.18 in./yr (0.46 cm/yr), or about 18 in. (46 cm) per century (NRC 2019d). Sea level rise is causing an increase in the frequency of high tide flood events in coastal areas of the Southeast region and saline water migrating upstream in estuaries (USGCRP 2018).

*3.12.2.3 Midwest*

Across the Midwest region, the annual average temperature from 1905–2012 has warmed by 1.5 °F (0.5 °C) (USGCRP 2014). The rate of warming over recent decades has accelerated, with average temperatures increasing twice as quickly between 1950 and 2010 relative to 1900-2010 (USGCRP 2014; NOAA 2013b). The frost-free season has increased by 9 days across the Midwest during the 1986 to 2015 timeframe relative to the 1901 to 1960 timeframe (USGCRP 2017). Precipitation in the Midwest from 1895–2011 has increased 0.31 in. (0.78 cm) per decade (NOAA 2013b). The Great Lakes have experienced increases in surface temperatures, declining lake ice cover, increasing summer evaporation rates, and earlier seasonal stratification of temperatures (USGCRP 2018). For instance, the NRC noted in the Point Beach SLR SEIS that for the 1995–2019 period, the average rate of warming in Lake Michigan has been 0.56–0.72 °F (0.31–0.40 °C), with the greatest warming occurring in October (NRC 2021f). In the Fermi initial LR SEIS, the NRC staff obtained modeled monthly Lake Erie surface water temperatures from the NOAA's Great Lakes Environmental Research Laboratory. For the 1950 to 2012 period, Lake Erie annual surface water temperatures increased at a rate of 0.067 °F (0.037 °C) per decade (NRC 2016c).

*3.12.2.4 Northern Great Plains*

Temperature data for the northern Great Plains region between 1986–2016 exhibit an increase of 1.69 °F (0.95 °C) (USGCRP 2017). The frost-free season has increased by 11 days across the northern Great Plains during the 1986 to 2015 timeframe relative to the 1901 to 1960 timeframe (USGCRP 2017). Annual precipitation between 1986–2015 showed differences featuring a general mixture of decreases in the western portion of the region and increases in the eastern portion of the region. Between 1958 and 2016, the northern Great Plains experienced a 29 percent increase in heavy precipitation events (USGCRP 2018).

*3.12.2.5 Southern Great Plains*

Temperature data for the southern Great Plains region between 1986–2016 exhibit an increase of 1.61 °F (0.9 °C) (USGCRP 2017). Long-term (1895 to 2012) average annual precipitation data for the southern Great Plains also exhibit an increasing trend. Since 1991, precipitation has increased by 8 percent in the southern Great Plains. Between 1958 and 2016, heavy precipitation events have increased by 12 percent (USGCRP 2014, USGCRP 2018). The frost-free season has increased by 7 days across the southern Great Plains during the 1986 to 2015 timeframe relative to the 1901 to 1960 timeframe (USGCRP 2017). Sea level rise along the Texas Gulf Coast is twice that of the global average (USGCRP 2018). The Gulf Coast of Texas has experienced several record-breaking floods and tropical cyclones, including Hurricane Harvey (USGCRP 2018).

*3.12.2.6 Northwest*

The Northwest region has warmed significantly. Temperature data for the Northwest region since 1900 exhibit an increase of 2 °F (1.1 °C) (USGCRP 2018). Warmer winters have resulted in a reduction in mountain snowpack and river streamflow. For instance, since 1950, the area-averaged snowpack in the Cascade Mountains has decreased by approximately 20 percent. The frost-free season has increased by 17 days across the Northwest during the 1986 to 2015 timeframe relative to the 1901–1960 timeframe (USGCRP 2017).

Precipitation has generally increased, but the trends are small compared to natural variability (USGCRP 2014). Between 1958 and 2016, the Northwest experienced an 8 percent increase in heavy precipitation events. This is the smallest increase of any region in the United States (USGCRP 2018). An increase in coastal and river water temperatures has been observed. Surface ocean temperatures along the Northwest coast have increased by 1.2 °F (0.64 °C) per century from 1900 to 2016 (USGCRP 2017). In July 2015, water temperature in the lower Columbia River and tributaries were higher than any year on record (USGCRP 2018). As noted in the Columbia initial LR SEIS, warmer water temperatures combined with less snowpack and lower stream flows have changed the balance of aquatic resources in the Columbia River Basin (NRC 2012b). The 2015 record temperatures led to a high rate of mortality for endangered sockeye and threatened Chinook in the Columbia River (USGCRP 2018).

*3.12.2.7 Southwest*

Across the Southwest region, annual average temperature between 1901 and 2016 has warmed by 1.6 °F (0.9 °C) (USGCRP 2017). Temperatures have increased across the entire region from 1901 to 2016, with the greatest increases occurring in California and western Colorado. Increased temperatures have decreased the snowpack and its water content and ultimately the water cycle across this region. The frost-free season increased by 17 days across the Southwest during the 1986 to 2015 timeframe relative to the 1901–1960 timeframe (USGCRP 2017).

While temperature increases have been relatively uniform throughout the region, that has not been the case for precipitation. For instance, precipitation since 1991 (relative to 1901–1960) increased across western California, but decreased in Arizona (USGCRP 2014). Unlike other regions of the United States, a trend in the frequency of extreme precipitation events in the Southwest is not evident (NOAA 2013c; USGCRP 2014). The Southwest region experienced the wettest conditions in the 1980s and 1990s, which coincide with El Niño-Southern Oscillation events (NOAA 2013c). El Niño-Southern Oscillation events involve periodic warming in sea surface temperatures in the central and eastern tropical Pacific Ocean that influences global and regional precipitation and is typically associated with heavy rainfall in the Southwest (USGCRP 2014). Over the last 50 years, there have been reductions in snowpack as a result of higher temperatures causing a shift from snow to rain, with early springtime warming resulting in earlier snowmelt-fed streamflow and less runoff throughout the summer season (USGCRP 2014; Thorne et al. 2012). Surface ocean temperatures along the Southwest coast have increased by 1.3 °F (0.73 °C) per century from 1900 to 2016 (USGCRP 2017). Sea level fluctuations along the California coast vary and result from a combination of factors, including tides, the El Niño-Southern Oscillation, and coastal winds (Bromirski et al. 2012). At the Golden Gate Bridge in San Francisco, sea level rose 9 in. (22 cm) between 1854 and 2016 and in San Diego, sea level rose 9.5 in. (24 cm) from 1906 to 2016 (USGCRP 2018).

# 4.0 ENVIRONMENTAL CONSEQUENCES AND MITIGATING ACTIONS

The U.S. Nuclear Regulatory Commission (NRC) evaluated the environmental consequences of the proposed action (i.e., license renewal) including the (1) impacts of continued reactor operations and refurbishment activities associated with initial license renewal (initial LR) and subsequent license renewal (SLR); (2) impacts of various reasonable alternatives to the proposed action; (3) impacts from the termination of nuclear power plant operations and decommissioning after the license renewal term (with emphasis on the incremental effect caused by an additional 20 years of subsequent operation); (4) impacts associated with the uranium fuel cycle; (5) impacts of postulated accidents (design-basis accidents and severe accidents); (6) cumulative impacts of the proposed action; and (7) resource commitments associated with the proposed action, including unavoidable adverse impacts, the relationship between short-term use and long-term productivity, and irreversible and irretrievable commitment of resources.

**Contents of Chapter 4.0**

## 4.1 Environmental Consequences and Mitigating Actions

### 4.1.1 Introduction

When considering whether the effects of the proposed action are significant, the NRC analyzes the potentially affected environment and degree of the effects of the proposed action (initial LR or SLR). The NRC has established three significance levels—SMALL, MODERATE, and LARGE—and uses these levels in nuclear power plant-specific (hereafter called plant-specific) supplemental environmental impact statements (SEISs) to the LR GEIS. As explained in Section 1.5.2.3, the three significance levels are defined as follows:

- SMALL: Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered SMALL.
- MODERATE: Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.
- LARGE: Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

These levels are used for describing the environmental impacts of the proposed action as well as the impacts of a range of reasonable alternatives to the proposed action. Resource-specific effects or impact definitions from applicable environmental laws and executive orders, other than SMALL, MODERATE, and LARGE, are provided where appropriate. In this *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (referred to in this document as the LR GEIS), the NRC's environmental impact levels are informed by Council on Environmental Quality (CEQ) terminology and guidance including revisions in Part 1501—NEPA and Agency Planning (see Title 40, Section 1501 in the *Code of Federal Regulations* [CEQ 2022]).

### 4.1.2 Environmental Consequences of the Proposed Action

As described in Section 2.1, activities associated with the proposed action could have environmental consequences at a nuclear power plant site. The proposed action includes activities associated with the normal operation of a nuclear power plant during the license renewal (initial LR or SLR) term, including (1) reactor operations; (2) surveillance, monitoring, and maintenance activities related to systems, structures, and components; (3) waste management; (4) refueling and other outages; (5) activities needed to support facility infrastructure requirements as part of routine operations and maintenance (e.g., road improvements and the installation or construction of new structures and other support facilities); and (6) any refurbishment activities needed to replace and/or repair critical portions of reactor systems.

The assessment includes a determination of the magnitude of the impact (SMALL, MODERATE, or LARGE) and whether or not the analysis of the environmental issue could be applied to all or a subset of nuclear plants, and whether plant-specific mitigation measures would be warranted. Environmental issues are assigned a Category 1 or a Category 2 designation as follows:

**Category 1** issues are those that meet all of the following criteria:

- The environmental impacts associated with the issue have been determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics.
- A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts (except for “Offsite radiological impacts of spent nuclear fuel and high-level waste disposal and “Offsite radiological impacts—collective impacts from other than the disposal of spent nuclear fuel and high-level waste”).
- The mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are not likely to be sufficiently beneficial to warrant implementation.

For environmental issues that meet the three Category 1 criteria, no additional plant-specific analysis is required in SEISs unless new and significant information is identified during the review (see Section 1.5.2.3).

**Category 2** issues are those that do not meet one or more of the criteria of Category 1 and for which, therefore, an additional plant-specific review is required.

A total of 80 environmental issues related to the proposed action were identified (summarized in Table 2.1-1). For each potential environmental issue identified, the NRC (1) describes the nuclear power plant activity during the initial LR or SLR term that could affect the resource, (2) identifies environmental resources that may be affected, (3) evaluates past license renewal reviews and other available information, including information related to impacts during a SLR term, (4) assesses the nature and magnitude of the environmental impact on the affected resource, (5) characterizes the significance of the effect, (6) determines whether the results of the analysis apply to all or a subset of nuclear power plants (i.e., whether the impact issue is Category 1 or Category 2), and (7) describes mitigation measures for adverse impacts.

### 4.1.3 Environmental Consequences of Continued Operations and Refurbishment Activities During the License Renewal Term (Initial or Subsequent)

Activities occurring during the initial LR or SLR term are the subject of this evaluation and are described in Section 2.1. The environmental impacts during the construction of a nuclear power plant and past operational impacts are not the focus of this evaluation. Construction impacts and the impacts of past operations have affected and, in many cases, shaped current environmental conditions at each nuclear plant and in its surroundings. These environmental conditions serve as the baseline for the impact analyses of continued operations and refurbishment activities during the license renewal term. Past environmental impacts are addressed in Chapter 3.0, Affected Environment. The impacts of continued operations and any refurbishment activities during the initial LR or SLR term are the same or similar to the impacts already occurring during the current license term. In most cases, impacts would remain the same and are SMALL. This is because initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. In other cases, impacts could change and may be MODERATE or LARGE. Further, in reviewing and updating the 2013 LR GEIS to account for SLR, the NRC also considered whether any feature of the analysis in the 2013 LR GEIS would be incompatible with SLR.

The NRC staff's review considered lessons learned, knowledge gained, and new information identified from license renewal environmental reviews performed since development of the 2013 LR GEIS (NRC 2013a). The environmental reviews included initial LR for the following 15 nuclear power plants: Seabrook Station (Seabrook; NRC 2015b), Columbia Generating Station (Columbia; NRC 2012a, NRC 2012b), South Texas Project Electric Generating Station (South Texas; NRC 2013b), Limerick Generating Station (Limerick; NRC 2014d), Grand Gulf Nuclear Station (Grand Gulf; NRC 2014e), Callaway Plant (Callaway; NRC 2014f), Davis-Besse Nuclear Power Station (Davis-Besse; NRC 2015e), Sequoyah Nuclear Plant (Sequoyah; NRC 2015f), Byron Station (Byron; NRC 2015c), Braidwood Station (Braidwood; NRC 2015d), Enrico Fermi Atomic Power Plant (Fermi; NRC 2016c), LaSalle County Station (LaSalle; NRC 2016d), Indian Point Energy Center (Indian Point; NRC 2018e), River Bend Station (River Bend; NRC 2018c), and Waterford Steam Electric Station (Waterford; NRC 2018d).

Additionally, the staff considered the results from SLR environmental reviews for the following 5 nuclear power plants: Turkey Point Nuclear Plant (Turkey Point; NRC 2019c), Peach Bottom Atomic Power Station (Peach Bottom; NRC 2020g), Surry Power Station (Surry; NRC 2020f), North Anna Power Station (North Anna; NRC 2021g), and Point Beach Nuclear Plant (Point Beach; NRC 2021f).

The NRC staff also considered new scientific research, public comments, changes in environmental regulations and impacts methodology, and other new information in evaluating the impacts associated with license renewal (initial LR or SLR).

Based on the NRC staff's review, a total of 80 environmental issues for the initial LR or SLR of nuclear power plants were identified and evaluated; they are summarized in Table 2.1-1. This revised LR GEIS provides the technical basis for the summary of findings on environmental issues in Table B-1 in Appendix B, Subpart A, of 10 CFR Part 51. The identified issues are discussed by resource area in this chapter. The assessment approaches specific to each resource area are described in Appendix D.

### 4.1.4 Environmental Consequences of the No Action Alternative

The no action alternative represents a decision where the NRC does not issue a renewed operating license. The licensee would then have to terminate reactor operations at the end of its current license and permanently shut down the nuclear power plant. At some point, all licensees will terminate nuclear plant operations and undergo decommissioning. Under the no action alternative, this would occur sooner than it would if the NRC issued a renewed operating license.

Not renewing the operating license and ceasing nuclear plant operation under the no action alternative would lead to a variety of potential outcomes. These outcomes would be the same as those that would occur after license renewal (see Section 4.14.3 for a discussion of these effects). Termination of reactor operations would result in a net reduction in power generating capacity. Power not generated by the nuclear plant during license renewal would likely be replaced by (1) replacement energy alternatives, (2) energy conservation and efficiency (demand-side management), (3) delayed retirements, (4) purchased power, or (5) some combination of these options. The consideration of the no action alternative does not involve the determination of whether replacement energy is needed or should be generated. The decision to generate electric power and the determination of how much power is needed are at the discretion of State, Federal (non-NRC), and utility officials.

### 4.1.5 Environmental Consequences of Alternative Energy Sources

Chapter 4 also considers the potential environmental impacts from the construction and operation of generating technologies using alternative energy sources (including fossil fuel, new nuclear, and renewable energy) to replace the amount of electric power generated by an existing nuclear power plant. For each resource area addressed in this chapter the range of possible environmental effects of constructing and operating various replacement energy alternatives is generically assessed. Alternatives were selected on the basis of energy technologies that are either currently commercially viable on a utility scale and operational or could become commercially viable on a utility scale and operational prior to the expiration of the original or renewed operating license. Other replacement energy technologies holding promise for becoming part of a bulk electricity portfolio sometime in the future are identified. Replacement energy is likely to be provided by a combination of electrical energy-producing technologies. The number of possible combinations of alternative energy sources that could replace or offset the generating capacity of a nuclear power plant is potentially unlimited. Based on this, the NRC has only evaluated individual energy sources rather than combinations of energy sources in this LR GEIS. However, combinations of energy sources may be considered during plant-specific license renewal reviews. The NRC does not engage in energy-planning decisions and makes no judgment as to which of the replacement energy alternatives evaluated in this LR GEIS would ultimately be chosen.

In addition to alternative electrical energy-generating technologies, power needs could also be offset by instituting demand-side management measures, delaying the scheduled retirement of one or more existing plants, or purchasing an equivalent amount of power from other energy suppliers. As summarized in Table 2.4-1 through Table 2.4-5, demand-side management initiatives are anticipated to result in negligible to no incremental environmental impacts. Delayed retirements and energy purchases would likely have characteristics similar to some of the replacement energy alternatives considered and would be dependent on their availability at the time they are needed. Historically, coal, natural gas, and nuclear-fueled power plants have been the most-prevalent sources of baseload purchased power, though an increasing number of renewable energy sources are emerging as viable options. As such, the effects of deploying offsetting alternatives such as purchased power and delayed retirement are likely to be similar to the effects of operating a combination of alternative electrical energy-generating technologies, and are therefore more effectively considered in plant-specific license renewal reviews.

### 4.1.6 Environmental Consequences of Terminating Nuclear Power Plant Operations and Decommissioning

All operating nuclear power plants will terminate operations and begin decommissioning either at the end of their operating license or after a decision is made to cease reactor operations. License renewal would delay this eventuality for up to an additional 20 years (yrs) beyond the current operating license period. The environmental impacts of decommissioning nuclear power plants were evaluated in the *Generic Environmental Impact Statement for Decommissioning Nuclear Facilities: Supplement 1, Regarding the Decommissioning of Nuclear Power Reactors* (NUREG-0586; NRC 2002c). The effects of renewing an operating license on the eventual impacts of terminating a nuclear power reactor license and the ensuing decommissioning are addressed as a single environmental issue. Because the impacts of license renewal on terminating plant operations and decommissioning are expected to be SMALL at all nuclear plants and for all environmental resources, it is considered a Category 1 issue. These impacts are discussed in Section 4.14.3.

## 4.2 <u>Land Use and Visual Resources</u>

### 4.2.1 Environmental Consequences of the Proposed Action – Continued Operations and Refurbishment Activities

Industrial land use at nuclear plants is not expected to change appreciably until after decommissioning is completed. Similarly, land use activity within transmission line right-of-ways (ROWs) would continue with few, if any, changes in land use restrictions and easements.

In addition, the visual appearance of nuclear power plants and transmission lines have been well established. These conditions are expected to remain unchanged during the initial LR or SLR term regardless of the prior number of years of nuclear plant operation.

#### *4.2.1.1 Land Use*

Environmental reviews have shown that license renewal and refurbishment have had little or no effect on land use at or near nuclear power plants. Land use impact issues evaluated in this LR GEIS revision include the impacts of continued plant operations and refurbishment activities on (1) onsite land use, (2) offsite land use, and (3) offsite land use in transmission line right-of-ways (ROWs).

##### *4.2.1.1.1 Onsite Land Use*

Operational activities during both the initial LR or SLR term would be similar to those already occurring at the nuclear plant. The industrial nature of onsite land use would remain unchanged. However, additional spent nuclear fuel and low-level radioactive waste would be generated during the license renewal term. This could require the construction of new or the expansion of existing onsite storage facilities. Future expanded installations would likely be located adjacent to existing storage facilities or otherwise in existing industrialized areas of the plant sites. This action would be addressed in separate environmental reviews. The NRC has not identified any information or situations during license renewal environmental reviews that would alter the conclusion that land use impacts from continued plant operations and refurbishment would be SMALL for all nuclear plants. Refurbishment activities, such as steam generator and vessel head replacement, have not permanently altered onsite land use.

Based on these considerations, the NRC concludes that impacts from continued nuclear plant operations during the initial LR and SLR terms and refurbishment on onsite land use would be the same—SMALL for all nuclear plants. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, onsite land use impacts would be SMALL for all nuclear plants, and it is a Category 1 issue for both initial LR and SLR.

##### *4.2.1.1.2 Offsite Land Use*

Environmental reviews have shown that initial LR or SLR and refurbishment activities have had little to no direct effect on development trends near nuclear power plants including changes in population or tax revenue in communities near nuclear power plants. Employment levels at nuclear plants remain the same or have decreased with no increased demand for housing, infrastructure improvements, or services. Operational activities during the license renewal term would be similar to those already occurring at the nuclear plant and would not affect offsite land use beyond what has already been affected. The NRC has not identified any information or situations, including in low-population areas or population and tax revenue changes resulting from initial LR or SLR that would alter the conclusion that impacts on offsite land use would be SMALL for all nuclear power plants.

For nuclear plants located in a coastal zone or coastal watershed, as defined by each State participating in the National Coastal Zone Management Program, applicants must submit to the affected State a certification that the proposed license renewal action is consistent with the State Coastal Zone Management Program. Applicants must receive a determination from the State agency that manages the State Coastal Zone Management Program that the proposed license renewal action would be consistent with the State program. Consistency with State Coastal Zone Management Programs further assures that impacts in State coastal zones will be small.

Based on these considerations, the NRC concludes that impacts from continued nuclear plant operations during the initial LR and SLR terms and refurbishment on offsite land use would be the same—SMALL for all nuclear plants. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue either for an initial LR or SLR term. Therefore, offsite land use impacts would be SMALL for all nuclear plants, and it is a Category 1 issue for both initial LR and SLR.

*4.2.1.1.3 Offsite Land Use in Transmission Line Right-of-Ways (ROWs)*

Transmission lines that connect the nuclear plant to the switchyard where electricity is fed into the regional power distribution system (the first substation of the regional electric power grid) and lines that feed electricity to the nuclear plant from the grid during outages are within the scope of license renewal environmental reviews. Operational activities in transmission line ROWs during the initial LR or SLR term would be the same or similar to those already occurring and would not affect offsite land use beyond what has already been affected.

Transmission lines do not preclude the use of the land in ROWs for other purposes, such as agriculture and recreation. Transmission lines connecting nuclear plants to the electrical grid are no different from transmission lines connecting any other power plant to the grid. However, certain land use activities in transmission line ROWs are restricted. Land cover is generally managed through a variety of maintenance procedures so that vegetation growth and building construction do not interfere with transmission line operation and access. Consequently, land use within transmission line ROWs is limited to activities that do not endanger power line operation; these activities include recreation, off-road vehicle use, grazing, agriculture, irrigation, roads, environmental conservation, and use as wildlife areas.

The impact of transmission lines on offsite land use during the license renewal term is considered to be SMALL for all nuclear plants and a Category 1 issue in the 2013 LR GEIS.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, impacts in offsite land use in transmission line ROWs would be SMALL for all nuclear plants, and it is a Category 1 issue for both initial LR and SLR.

#### *4.2.1.2 Visual Resources*

License renewal environmental reviews have shown that nuclear power plants and transmission lines do not change in appearance over time, so aesthetic impacts are not anticipated during the initial LR or SLR term.

##### *4.2.1.2.1 Aesthetic Impacts*

The NRC considered the visual impact of continued nuclear plant operations and refurbishment during the license renewal term in the 2013 LR GEIS. The NRC concluded aesthetic impacts would be SMALL for all nuclear plants and a Category 1 issue, because the visual appearance of nuclear power plants and transmission lines are not expected to change during the license renewal term.

Separately, a case study found a limited number of situations where nuclear power plants have had a negative effect on the public (NRC 1996). Negative perceptions were based on aesthetic considerations (for instance, the nuclear plant is out of character or scale with the community or the viewshed), physical environmental concerns, safety and perceived risk issues, an anti-nuclear plant attitude, or an anti-nuclear outlook. It is believed that these negative perceptions would persist regardless of any mitigation. Subsequently, license renewal environmental reviews have not revealed any new information that would change this perception.

After cooling towers and the containment building, transmission line towers are probably the most frequently observed structure associated with nuclear power plants. Transmission lines from nuclear plants are generally indistinguishable from those from other power plants. Because electrical transmission lines are common throughout the United States, they are generally perceived with less prejudice than the nuclear power plant itself. Also, the visual impact of transmission lines tends to wear off when viewed repeatedly. Replacing or moving towers or burying cables to reduce the visual impact would be impractical from both a cost and efficiency perspective. The visual impact of transmission lines during the license renewal term was also considered to be SMALL for all nuclear plants and a Category 1 issue in the 2013 LR GEIS. No new information or situations that would alter that conclusion has been identified in initial LR or SLR environmental reviews.

Based on these considerations, the NRC concludes the aesthetic impact of continued nuclear plant operations during initial LR and SLR terms and refurbishment would be the same—SMALL for all nuclear plants. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The visual appearance of nuclear plants would not change or have a different level of impact. Therefore, aesthetic impacts would be SMALL for all nuclear plants, and it is a Category 1 issue for both initial LR and SLR.

### **4.2.2 Environmental Consequences of Alternatives to the Proposed Action**

*Construction* – Various replacement energy alternatives would involve the permanent commitment of land for the construction of a new power plant along with support structures and other facilities. Other land use and visual impacts during construction would include land clearing, excavation, and the installation of temporary facilities, such as material laydown areas and concrete batch plants. Depending on the location, construction of an electrical substation, switchyards, transmission lines, railroad spurs, and access roads may also be required. Some of these facilities could affect offsite land use.

Construction of a new power plant at an existing nuclear plant or brownfield site would have less of a land use and visual impact than at a greenfield site. Installation of a replacement energy alternative at an existing nuclear plant site would require the least amount of land because the new power plant could make use of existing intake and discharge structures, substations, transmission lines, office buildings, parking lots, and access roads. Constructing a power plant at a greenfield site would convert land from other uses such as agriculture (including prime farmland) to industrial use. In addition, construction on a greenfield site could have a dramatic visual impact because the industrial appearance of a new power plant would be quite different from a surrounding rural landscape.

Increase in traffic to and from the construction site could require changes to existing transportation infrastructure and traffic patterns resulting in offsite land use and visual impacts.

*Operations* – Land would be in use throughout the period of power plant operation. Aesthetic impacts would be similar to those experienced at existing nuclear plants or industrial brownfield sites. Power plant structures, transmission lines, cooling and meteorological towers would add to the permanent visual impact. Vapor plumes during power plant operations may be visible for some distance in certain weather conditions.

#### *4.2.2.1 Fossil Energy Alternatives*

*Construction and Operations* – Land use impacts from constructing coal- or natural gas-fired power plants would be similar. However, a coal-fired power plant would need more land for coal fuel delivery and storage. A coal-fired power plant would likely have a greater visual impact than a natural gas-fired plant.

#### *4.2.2.2 New Nuclear Alternatives*

*Construction and Operations* – Land requirements for a new nuclear power plant would be the same as license renewal and similar to a coal-fired power plant. The appearance of the new nuclear power plant during operations would be the same as license renewal.

#### *4.2.2.3 Renewable Alternatives*

*Construction and Operation* – Land requirements for renewable energy facilities would vary greatly. Hydroelectric dams and reservoirs capable of generating utility-scale power would require a large land area resulting in a noticeable visual impact. Dams serving as flood control could affect land use both upstream and downstream of the reservoir.

Geothermal facilities, typically located in remote areas, would require a small land area and could generate vapor plumes in certain weather conditions. The appearance of wellheads, exposed piping, and power plant structures in remote settings would have a noticeable visual impact.

Land area required for biomass and municipal solid waste, refuse-derived and landfill gas-fired power plants would be similar to that required for other fossil fuel-fired facilities. Additional land would be required for biomass and municipal solid waste, refuse-derived and landfill gas-fuel handling facilities. Buildings, smokestacks, cooling towers, and condensate plumes would have a visual impact in open areas comparable to fossil fuel-fired facilities.

Utility-scale wind farms generally require large land or surface water areas. However, only a small percentage of land and water would be occupied by wind turbines and other support facilities. Land-based wind farms generally have a greater visual impact depending on the height and placement of the turbines (e.g., along ridgelines). Once construction is completed, the area between turbines can be used for other purposes (e.g., agriculture, grazing, boating, fishing, etc.). In addition, land would be required to support utility-scale offshore energy facilities for cable landings and substations. Distance from shore and the curvature of the Earth could attenuate some of the visual impacts of offshore wind turbines.

Utility-scale solar thermal power block and photovoltaic (PV) farms could require large areas of land. Visual impacts would depend on the size, location, and the amount of land needed for power generation—height of thermal power block, cooling towers, and condensate plume, and the array of solar collectors.

Offshore ocean wave and current energy-generating facilities would require a small land area for cable landing, substation, warehouse, and repair facilities. Existing piers and docks could also be used to support power generation. The relatively short height of above-water structures, distance from shore, and the curvature of the Earth may attenuate most, if not all, of the visual impacts.

## 4.3 Air Quality and Noise

### 4.3.1 Environmental Consequences of the Proposed Action – Continued Operations and Refurbishment Activities

Ambient air quality and noise conditions at all nuclear power plants and associated transmission lines have been well established during the current licensing term. These conditions are expected to remain unchanged during the license renewal term (initial LR or SLR term).

This section focuses on the impacts of continued operations and refurbishment activities associated with license renewal on air quality and noise. Refurbishment and associated construction activities can affect air quality (e.g., fugitive dust, vehicle and equipment exhaust emissions, and automobile exhaust from commuter traffic). Baseline meteorological, climatological, and ambient air quality and noise conditions at operating plants are discussed in Sections 3.3.1 and 3.3.2, respectively. License renewal is expected to result in a continuation of similar conditions for an extended period commensurate with the license renewal term (initial LR or SLR term). As a result, the criteria air pollutants emitted and the noise generated during normal continued nuclear plant operations during the initial LR or SLR term are not expected to change substantially and thus should remain SMALL.

#### *4.3.1.1 Air Quality*

Two issues related to impacts on air quality during the license renewal (initial LR or SLR) terms are considered in this section:

- air quality impacts – this issue encompasses impacts of continued operations and refurbishment activities on air quality, including nonattainment or maintenance area conformity; and

- air quality effects of transmission lines.

*4.3.1.1.1 Air Quality Impacts*

Impacts on air quality during normal plant operations can result from operations of fossil fuel-fired equipment needed for various plant functions (see Section 3.3.2). Each licensed plant typically employs emergency diesel generators for use as a backup power source. These generators provide a standby source of electric power for essential equipment required during plant upset or an emergency event. They also provide for safe reactor shutdown and for the maintenance of safe conditions at the power station during such an event. These diesel generators are typically tested once a month with several test burns of various durations (e.g., 1 to several hours). In addition to these maintenance tests, longer-running endurance tests are also typically conducted at each plant. Each generator is typically tested for 24 hours on a staggered test schedule (e.g., once every refueling outage). Plants with nonelectric fire pumps, typically also diesel-fired, usually employ test protocols identical or similar to those used for emergency generators. Maintenance procedures during these tests would include, for example, checks for leaks of lubricating oil or fuel from equipment, and pumps would be replaced as required.

In addition to the emergency diesel generators, fossil fuel (i.e., diesel-, oil-, or natural gas-fired) boilers are used primarily for evaporator heating, plant space heating, and/or feed water purification. These units typically operate at a variable load on a continuous basis throughout the year unless end use is restricted to one application, such as space heating. For example, the Peach Bottom plant uses two auxiliary boilers for space heating and to help with unit startups (NRC 2020g). Air emissions include carbon monoxide (CO), nitrogen oxides ($NO_x$), carbon dioxide ($CO_2$), methane, nitrous oxide, particulate matter (PM), and volatile organic compounds (VOCs) for diesel-, natural gas-, and oil-fired units. Natural gas-fired units emit only trace amounts of VOCs and PM that has an aerodynamic diameter of 10 $\mu$m or less ($PM_{10}$). The utility boilers at commercial plants are relatively small compared to most industrial boilers and are typically regulated through State-level operating permits.

Given the infrequency and short duration of maintenance testing of onsite combustion sources, annual air emissions are minor. For example, the contribution of air emissions from sources at the LaSalle, River Bend, Waterford, Peach Bottom, Turkey Point, Surry, Point Beach, and North Anna plants constitute anywhere from 0.2 to 2 percent of the County's (where the plant is located) annual air emissions (NRC 2016d, NRC 2018c, NRC 2018d, NRC 2019c, NRC 2020c, NRC 2020f, NRC 2021f, NRC 2021g). Therefore, annual air emissions from nuclear power plant sources would not be an air quality concern even at those plants located in or adjacent to nonattainment areas. The locations of the currently designated nonattainment areas near nuclear plants are shown in Section 3.3.2.

As discussed in Section 3.3.2, cooling tower drift can increase downwind PM concentrations, impair visibility, ice roadways, cause drift deposition, and damage vegetation and painted surfaces. Currently, 16 nuclear power plants use natural draft cooling towers and 11 nuclear power plants use mechanical draft cooling towers. Currently, no dry or hybrid (combinations incorporating elements of both dry and wet design) systems are being used at operating nuclear plants. The natural draft cooling tower at the Hope Creek Generating Station (Hope Creek) in New Jersey is the only operating tower at a plant that uses high-salinity water for cooling system makeup, which results in greater $PM_{10}$ concentrations (NRC 2011b). An air quality impact analysis performed in support of an extended power uprate request for Hope Creek assessed emissions related to cooling tower drift droplets for this situation. The analysis determined that cooling tower operations would result in average $PM_{10}$ emissions of 35.6 lb/hr, as summarized in Section 3.3.2, and the New Jersey Department of Environmental Protection determined that the $PM_{10}$ emissions would not exceed National Ambient Air Quality Standards. Thus, although there is the potential for some air quality impacts to occur as a result of equipment and cooling tower operations, as in the case with Hope Creek, the impacts have been small.

Diesel generators, pumps, fossil fuel boilers, and cooling towers typically require State or local operating permits. Operating permits specify conditions that limit air emissions, hours of operation, fuel content, or fuel consumption. Most State air pollution regulations provide air permit exemptions for air pollution sources that are not routinely operated, which can be defined as sources with insignificant activity meeting specified operating criteria (e.g., so many hours of continuous operation over specified periods or so many hours of operation per year). For example, the North Anna plant has one emergency generator, one diesel generator, and two fire pump diesel generators that are exempt from the site's State Operating Permit conditions because they are considered insignificant equipment emission units of minimal or no air quality concern (NRC 2021g). The Fermi plant uses two natural draft hyperbolic cooling towers that are exempt from Michigan's air permitting requirements. Particulate matter (with a diameter of 10 microns or less) emissions of each cooling tower are estimated to be 0.10 T/yr (NRC 2016c).

License renewal environmental reviews performed since publication of the 2013 LR GEIS (see Section 4.1.3) have not identified new information or situations that would result in air quality impacts that would differ from what was concluded in the 2013 LR GEIS for either an initial LR or SLR term. In the SEISs (for initial LRs and SLRs), the NRC concluded that fossil fuel-fired equipment is operated intermittently, primarily during testing or outages, annual air emissions are minor, and air emissions and sources would not be expected to change or have different impacts on air quality during the LR term. Therefore, the potential impact from onsite air emission sources on air quality would be expected to be SMALL for all nuclear plants, and it is a Category 1 issue for both initial LR and SLR.

Potential sources of impacts on air quality during refurbishment activities associated with continued operations during the license renewal term include (1) fugitive dust from site excavation and grading and (2) emissions from motorized equipment, construction vehicles, and workers' vehicles. With application of adequate controls or mitigation measures and best practices, the air quality impacts from these air pollution sources would be small and of relatively short duration.

During site excavation and grading, some PM in the form of fugitive dust would be released into the atmosphere. Construction vehicles and other motorized equipment would generate exhaust emissions that include small amounts of CO, $NO_x$, VOCs, and PM. These emissions would be temporary (restricted to the construction period) and localized (occurring only in the immediate vicinity of construction areas). For refurbishment occurring in geographical areas with poor or marginal air quality, the emissions generated from these activities could be cause for concern in a few cases (e.g., building demolition, debris removal, and new construction). However, the 1990 Clean Air Act Amendments include a provision that requires Federal actions conform to an applicable State Implementation Plan designed to achieve the National Ambient Air Quality Standards for criteria pollutants (sulfur dioxide [$SO_2$], nitrogen dioxide, CO, ozone, lead, $PM_{10}$, and PM with a mean aerodynamic diameter of 2.5 $\mu$m or less [$PM_{2.5}$]).

On April 5, 2010, the U.S. Environmental Protection Agency (EPA) issued its 40 CFR Part 51 and 93 revisions to the General Conformity Regulations in the *Federal Register* (75 FR 17254). General conformity requires Federal agencies to ensure that a proposed Federal action, such as initial LR or SLR, in air quality nonattainment or maintenance areas conforms to the applicable State Implementation Plan. A conformity analysis must be completed before the action is taken. A conformity analysis begins with an applicability analysis to determine whether the action is exempt or has total net direct and indirect emissions below the *de minimis* levels. The *de minimis* emission levels (40 CFR 93.153(b)) serve as screening values to determine whether a conformity determination must be undertaken for a proposed Federal action. The applicability analysis must be documented. If conformity applies, the agency must prepare a written conformity analysis and determination for each pollutant for which the emissions caused by a proposed Federal action would exceed the *de minimis* levels. An area is designated as nonattainment for a criteria pollutant if it does not meet National Ambient Air Quality Standards for the pollutant. A maintenance area is one that a State has redesignated from nonattainment to attainment. The current nationwide designations of nonattainment areas are identified in Section 3.3.2.

The *de minimis* levels for air emissions vary depending on air quality conditions in the area where the plant is located. In most cases, the *de minimis* levels are established at 100 T/yr. Exceptions include:

- $NO_x$ or VOC emissions of 10, 25, and 50 T/yr in extreme, severe, and serious ozone nonattainment areas, respectively;
- VOC emissions of 50 T/yr in ozone nonattainment areas inside an ozone transport region stretching from Virginia to Maine;
- Lead emissions of 25 T/yr in lead nonattainment areas;
- $PM_{10}$ emissions of 70 T/yr in serious $PM_{10}$ nonattainment areas; and
- $SO_2$, $NO_x$, VOC, and ammonia emissions of 70 T/yr in serious $PM_{2.5}$ nonattainment areas.

In maintenance areas, the *de minimis* levels are 100 T/yr for all pollutants, except for 50 T/yr for VOCs inside the ozone transport region and 25 T/yr for lead.

The EPA regulations require that direct construction emissions including construction vehicle and equipment exhaust and fugitive dust and indirect emissions, such as those from worker and delivery vehicles, be included in the conformity analysis. Emissions from construction equipment and vehicles are expected to be small for anticipated refurbishment projects on the basis of activities that have occurred to date. In the 1996 LR GEIS, the NRC concluded that the impacts from plant refurbishment associated with license renewal on air quality could range from SMALL to LARGE, although these impacts were expected to be SMALL for most plants. The 1996 LR GEIS determined that emissions from 2,300 vehicles over a 9-month refurbishment period may exceed the thresholds for CO, $NO_x$, and VOCs in nonattainment and maintenance areas. In the 2013 LR GEIS, the NRC concluded that the impact of refurbishment activities on air quality would be SMALL for most plants. The 2013 LR GEIS noted that findings from license renewal SEISs published since the 1996 LR GEIS have shown that refurbishment activities, such as steam generator and vessel head replacement, have not required the large numbers of workers, months of time, or the degree of land disturbance that was conservatively estimated in the 1996 LR GEIS. For example, refurbishment activities associated with license renewal for the Davis-Besse plant required an additional 1,400 workers for 90 days. It was estimated that the additional worker vehicles for this duration would result in 25 T of VOCs, 49 T of $NO_x$, 1.0 T of $SO_2$, and 1.5 T of $PM_{2.5}$ (direct emissions) being emitted, which would not exceed the *de minimis* levels of 100 T/yr of $NO_x$, 50 T/yr of VOCs for ozone maintenance areas, 100 T/yr of direct emissions of $PM_{2.5}$, 100 tons per year of $SO_2$, 100 T/yr for $PM_{2.5}$ maintenance areas and 100 T/yr for $SO_2$ nonattainment areas, as set forth in 40 CFR 93.153(b) (NRC 2015e). Additionally, Exelon Generating Company LLC (Exelon) estimated that steam generator replacement of Byron Unit 2 would require an additional 500 workers for 90 days (NRC 2015c). The NRC staff concluded that the additional workforce for steam generator replacement activities would be temporary and estimated to result in an additional 3.3 T (3.0 MT) of VOCs, 9.8 T(8.9 MT) of $NO_x$, 0.04 T (0.04 MT) of $SO_2$, and 0.40 T (0.36 MT) of $PM_{2.5}$ (direct emissions) being emitted, which do not exceed the *de minimis* levels of 100 T/yr set forth in 40 CFR 93.153(b). Therefore, the NRC concluded that the additional emissions resulting from these activities would be minor (NRC 2015c). For Indian Point vessel head replacement and control rod mechanism replacement, the NRC staff estimated that an additional 500 workers for 60 days would result in an additional 3.4 T (3.1 MT) of VOCs, 31.1 T (28.2 MT) of CO, 2.3 T (2.1 MT) of $NO_x$, 0.08 T (0.07 MT) of $SO_2$, and 0.01 T (0.01 MT) of $PM_{2.5}$ (NRC 2018e). These additional emissions would not exceed the *de minimis* levels for designated maintenance areas of 100 T (91 MT) for each pollutant.

The 1996 LR GEIS found that disturbed areas for refurbishment actions required 10 acres (ac) (4 hectares [ha]) or less for laydown areas and storage. Since publication of the 1996 LR GEIS and 2013 LR GEIS, the NRC has not identified refurbishment activities that would require disturbance of land that exceeds 10 ac (4 ha). For example, as part of refurbishment activities associated with license renewal for the Davis-Besse plant, temporary and permanent buildings were constructed and laydown areas were needed, which resulted in land disturbance of less than 10 ac (4 ha) (NRC 2015e). For Indian Point vessel head replacement and control rod mechanism replacement, storage would require construction of a permanent building requiring 0.12 ac (0.04 ha) (NRC 2010a). Because of the (1) small size of the disturbed area, (2) relatively short construction period, (3) availability of paved roadways at existing facilities, and (4) use of best management practices (BMPs) (such as watering, chemical stabilization, and seeding), fugitive dust resulting from these construction activities is minimal.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The NRC concludes that the impact of refurbishment activities on air quality during the initial LR or SLR terms would be SMALL. Impacts would be temporary and cease once projects were completed and implementation of BMPs, including fugitive dust controls and the imposition of new and/or revised conditions in State and local air emissions permits, would ensure conformance with applicable State or Tribal implementation plans.

The NRC also concludes that the air quality impacts of continued nuclear plant operations during the initial LR and SLR terms and refurbishment would be SMALL for all plants. The staff has identified no information that would lead to different impacts on air quality during the initial LR term or SLR term. Therefore, the impacts of initial LR and SLR on air quality is a Category 1 issue.

##### *4.3.1.1.2 Air Quality Effects of Transmission Lines*

Small amounts of ozone and substantially smaller amounts of oxides of nitrogen are produced by transmission lines during corona, a phenomenon that occurs when air ionizes near isolated irregularities on the conductor surface such as abrasions, dust particles, raindrops, and insects. Several studies have quantified the amount of ozone generated and concluded that the amount produced by even the largest lines in operation (765 kilovolt [kV]) is insignificant (SNYPSC 1978; Scott-Walton et al. 1979; Janes 1978; Varfalvy et al. 1985). Monitoring of ozone levels for

2 years near a Bonneville Power Administration 1,200 kV prototype line revealed no increase in ambient ozone levels caused by the line (Lee et al. 1989). Similarly, field tests conducted over a 19-month period concerning ozone levels adjacent to Sequoyah transmission lines concluded that high-voltage lines up to 765 kV do not generate ozone above ambient measurements made at locations remote from transmission lines (TVA 2013; NRC 2015f). The ozone concentrations generated by transmission lines are therefore too low to cause any significant effects. The minute amounts of oxides of nitrogen produced are similarly insignificant. On the basis of these considerations, the NRC concludes that the air quality impacts of transmission lines, within this scope of review (see Sections 3.1.1 and 3.1.6.5 in this LR GEIS), during the initial LR and SLR terms would be SMALL. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. This is supported by the evidence that production of ozone and nitrogen oxide are insignificant and does not measurably contribute to ambient levels of those gases. Potential mitigation measures (e.g., burying transmission lines) would be very costly and would not be warranted. Therefore, the issue of air quality impacts of transmission lines would be SMALL for all nuclear plants, and it is a Category 1 issue for both initial LR and SLR.

#### *4.3.1.2 Noise*

One issue related to noise impacts during the license renewal (initial LR or SLR) term is considered in this section:

- noise impacts of continued operations and refurbishment activities.

##### *4.3.1.2.1 Noise Impacts*

Noise from nuclear plant operations can often be detected offsite relatively close to the plant site boundary. Sources of noise and the relative magnitude of impacts during normal nuclear power plant operations are discussed in Section 3.3.3. Major sources of noise at operating nuclear power plants include cooling towers, turbines, transformers, large pumps, firing range, steam safety relief valves, and cooling water system motors. Nuclear plant operations have not changed appreciably with time, and no change in noise levels or noise-related impacts are expected during the initial LR or SLR term.

Given the industrial nature of the power plant and the number of years of plant operation, noise from a nuclear plant is generally nothing more than a continuous minor nuisance. However, noise levels may sometimes exceed the day-night average 55 A-weighted decibels (dBA) level that the EPA uses as a threshold level to protect against excess noise during outdoor activities (EPA 1974). For instance, continuous measurements at three noise-sensitive receptors from Fermi Unit 2 resulted in a day-night sound level of between 55 and 63 dBA (NRC 2016c). While the day-night sound levels measured are above EPA's recommended threshold, it does "not constitute a standard, specification, or regulation," rather it is intended to provide a basis for State and local governments establishing noise standards. Furthermore, the day-night sound levels measured at noise-sensitive receptors near Fermi Unit 2 were below the Federal Housing Administration guideline of a day-night average sound level of 65 dBA or less (NRC 2016c, 24 CFR Part 51). In 2008, an ambient noise-monitoring survey was performed in areas adjacent to the Turkey Point site. Measurements (equivalent sound intensity level) at monitoring locations offsite and beyond the site boundary (including nearest residence, day-care facility, and a park) ranged from 46 dBA to 67 dBA during the daytime and from 41 dBA to 56 dBA at nighttime. Audible noise sources contributing to noise levels included traffic, insects, and wind, indicating that audible sound from the Turkey Point site does not reach these noise-sensitive receptors (NRC 2016b). Ambient sound level surveys in the vicinity of nuclear power plants have not approached 80–85 dBA, which is the threshold at which noise levels can become very annoying (CDC 2019b).

In addition to EPA and U.S. Department of Housing and Urban Development noise threshold guidelines, local governments can establish noise ordinances. For example, Louisa County, VA, where the North Anna plant is located, has a noise ordinance that limits daytime sound levels to 75 decibels (dB) and nighttime sound levels to 65 dB for industrial zoning districts (NRC 2021g). Similarly, Waterford is located in a designated industrial land use area within a heavy manufacturing zoning district. St. Charles Parish (where Waterford is located) has a noise ordinance, but the ordinance does not set maximum permissible sounds levels for areas zoned as industrial (NRC 2018d).

Nuclear power plants have received noise complaints associated with operational activities. For instance, Braidwood received noise complaints related to the cooling water discharge system into the Kankakee River. Prior to 2011, this system produced noticeable noise at the discharge location. In 2011, Exelon installed a new diffuser for water discharge into the Kankakee River, which, among other environmental benefits, nearly eliminated noise from the discharge location (NRC 2015d). Furthermore, Exelon notifies the public about upcoming activities and the potential for noise via their notification system. The notification system alerts residences and other locations within 1 mi (1.6 km) of Braidwood prior to planned activities that may affect the surrounding area. Similarly, in response to complaints regarding activities associated with nighttime fire training at the range at Fermi, DTE Electric notifies the nearby municipalities of upcoming scheduled training at the range and provides information about upcoming activities (NRC 2016c).

Noise would also be generated by construction-related activities and equipment used during refurbishment. Noise attenuates rapidly with distance. As a rule of thumb, with a doubling in distance from a point source the sound level decreases by 6 dB. Additionally, this noise would occur for relatively short periods of time (several weeks) and is not expected to be distinguishable from other operational noises at the site boundary or create an adverse impact on nearby residents.

In the 1996 LR GEIS, the NRC noted that there have been few noise complaints at power plants, but that noise impacts have been found to be small. Because noise sources at power plants do not change appreciably during the aging process, the 1996 LR GEIS concluded that noise was not expected to be a problem at any nuclear plant during the license renewal term and given the few noise complaints no additional mitigation measures are warranted. The magnitude of noise impacts was therefore determined to be SMALL for all plants, and the issue was designated as Category 1. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The NRC has found that noise sources and levels are not expected to change from current operations and therefore would remain similar during the initial LR or SLR term.

On the basis of these considerations, the NRC concludes that the noise impact of continued nuclear plant operations during the initial LR and SLR terms and refurbishment would be SMALL for all plants. Therefore, this is a Category 1 issue.

### 4.3.2 Environmental Consequences of Alternatives to the Proposed Action

*Construction* – Construction of a replacement power alternative would result in temporary impacts on local air quality. Air emissions would include criteria pollutants (PM, $NO_x$, CO, and $SO_2$), hazardous air pollutants, and greenhouse gases (GHGs) from construction vehicles and equipment and dust from land clearing and grading. VOCs could be released from organic solvents used in cleaning, during the application of protective coatings, and the onsite storage and use of petroleum-based fuels. Air emissions would be intermittent and would vary depending on the level and duration of specific activities throughout the construction phase. Engine exhaust emissions would be from heavy construction equipment and commuter, delivery, and support vehicular traffic traveling to and from the facility as well as within the site. Fugitive dust emissions would be from soil disturbances by heavy construction equipment (e.g., earthmoving, excavating, and bulldozing), vehicle traffic on unpaved surfaces, concrete batch plant operations, and wind erosion to a lesser extent. Various mitigation techniques and BMPs (e.g., watering disturbed areas, reducing equipment idle times, and using ultra-low sulfur diesel fuel) could be used to minimize air emissions and reduce fugitive dust.

Construction of a replacement power alternative would be similar to the construction of any industrial facility in that they all involve many noise-generating activities. In general, noise emissions would vary during each phase of construction, depending on the level of activity, types of equipment and machinery used, and site-specific conditions. Typical construction equipment, such as dump trucks, loaders, bulldozers, graders, scrapers, air compressors, generators, and mobile cranes, would be used, and pile-driving and blasting activities could take place. Other noise sources include construction worker vehicle and truck delivery traffic. Impacts, however, would be temporary, and both air quality and noise impacts would return to preconstruction levels after construction was completed.

Air quality and noise impacts from construction activities would be similar whether occurring at a greenfield site, brownfield site, or at an existing nuclear power plant.

*Operations* – The impacts on air quality as a result of operation of a facility for a replacement power alternative would depend on the energy technology (e.g., fossil, new nuclear, or renewable). Air quality would be affected during operations by cooling tower drift, auxiliary power equipment, building heating, ventilation, and air conditioning (i.e., HVAC) systems, and vehicle emissions. Auxiliary power equipment could include standby diesel generators and power systems for emergency power and auxiliary steam.

Noise generated during operation would include noise from cooling towers (water pumps, cascading water, or fans), transformers, turbines, pumps, compressors, loudspeakers, other auxiliary equipment such as standby generators, and vehicles. Noise from vehicles would be intermittent.

#### *4.3.2.1 Fossil Energy Alternatives*

*Construction* – Air quality and noise impacts would be the same as described in Section 4.3.2.

*Operations* – Fossil fuel (coal, natural gas) power plants can have a significant impact on air quality. The burning of fossil fuels is a major source of criteria pollutants and GHGs, primarily $CO_2$, as well as other hazardous air pollutants. The exact nature of these pollutants and their quantity depends on many factors, including the chemical constituency of the fuel, combustion technology, air pollution control devices, and onsite management of fuel and waste material. Table 4.3-1 presents representative emission factors for various fossil fuel power plants. The values presented in Table 4.3-1 are not all inclusive of fossil fuel-burning technologies, but represent the possible range of operational emissions that could result from fossil fuel-fired power plants. In comparing these emission factors, it is apparent that air emissions from a natural gas combined cycle (NGCC) power plant would be less than those from operation of an integrated gasification combined cycle (IGCC) or supercritical pulverized coal (SCPC) plant.

**Table 4.3-1 Emission Factors of Representative Fossil Fuel Plants**

| Pollutant | Emission Factors[a] in kg/MWh (lb/MWh) for NGCC[b] | Emission Factors[a] in kg/MWh (lb/MWh) for SCPC[c] | Emission Factors[a] in kg/MWh (lb/MWh) for IGCC[d] |
|---|---|---|---|
| $SO_2$ | 0.003 (0.006) | 0.294 (0.648) | 0.059 (0.130) |
| $NO_x$ | 0.010 (0.022) | 0.318 (0.700) | 0.177 (0.390) |
| PM | 0.005 (0.012) | 0.041 (0.090) | 0.021 (0.047) |
| CO | 0.005 (0.012) | N/A | N/A |
| $CO_2$ | 336 (741) | 738 (1,627) | 602 (1,328) |

$SO_2$ = sulfur dioxide; $NO_x$ = nitrogen oxides; PM = particulate matter; CO = carbon monoxide; $CO_2$ = carbon dioxide; kg/MWh = kilograms per megawatt-hr; lb/MWh = pounds per megawatt-hr; NGCC = natural gas combined cycle; SCPC = supercritical pulverized coal; IGCC = integrated gasification combined cycle; N/A = not available.

(a) Values are based on gross output and no carbon capture technology.

(b) Emission factors are based on two combustion turbine-generators, a gross output of 740 MW, a capacity factor of 85 percent, $NO_x$ emissions control technology (selective catalytic reduction and dry low $NO_x$ burner), and low natural gas sulfur content.

(c) Emission factors are based on a gross output of 685 MW, a capacity factor of 85 percent, $SO_2$ emission control technology (wet limestone forced oxidation), $NO_x$ control technology (low $NO_x$ burner and selective catalytic reduction), and bituminous coal.

(d) Emission factors are based on two Shell gasifiers, a total gross output of 765 MW, a capacity factor of 80 percent, two carbon beds to remove mercury, and bituminous coal.

Source: NETL 2019.

Air quality and noise impacts from operations of a fossil fuel power plant would be the same as described in Section 4.3.2. Operation of a natural gas power plant would also include offsite mechanical noise from compressor stations and pipeline blowdowns. The Federal Energy Regulatory Commission requires that any new compressor station or any modification, upgrade, or update of an existing station must not exceed a day-night sound intensity level of 55 dBA at the closest noise-sensitive area (18 CFR 157.206).

#### *4.3.2.2 New Nuclear Alternatives*

*Construction* – Air quality and noise impacts for the construction of a new nuclear power plant would be the same as those described in Section 4.3.2. Air emissions from construction would be limited, local, and temporary. Noise impacts during construction would be limited to the immediate vicinity of the site.

*Operations* – Air quality and noise impacts would be the same as those described in Section 4.3.2. An operating nuclear plant would have minor air emissions associated with stationary combustion sources (e.g., diesel generators, auxiliary boilers, pumps) and mobile sources (e.g., worker vehicles, truck deliveries). Additional air emissions would result from the use of cooling towers and could contribute to the impacts associated with the formation of visible plumes, fogging, and subsequent icing downwind of the towers. Noise sources would include turbines, cooling towers, transformers, and vehicular traffic associated with worker and delivery vehicles.

#### *4.3.2.3 Renewable Alternatives*

*Construction* – Air quality and noise impacts for the construction of land-based alternative energy technologies would be the same as those described in Section 4.3.2. Air quality impacts associated with the construction of offshore power-generating facilities and support structures include the emission of criteria pollutants from construction barges and equipment (e.g., cranes, compressors) and vehicles delivering materials and crews to embarkation locations on the shore, and dust from the construction of onshore facilities (e.g., cable landings, substations).

Construction-related noise impacts would be substantially different offshore than those associated with onshore construction because these activities would be distant from most human receptors and because noise propagates much greater distances in water. Sources of noise would include crew vessels and construction and equipment barges; seismic technologies used to characterize the site; explosives or pile-driving to construct foundations for offshore wind turbines or anchoring devices for wave, tidal, and current energy capturing equipment; and excavation of sea bottoms for installation of buried power and communication cables. Construction-related impacts on air quality and noise would generally be temporary.

*Operations* – In general, air quality impacts associated with most renewable energy alternatives would be negligible because no burning of fossil fuels resulting in direct air emissions would be required to generate electricity. Emission sources associated with the operation of renewable energy alternatives could include engine exhaust from worker vehicles, heavy equipment associated with site inspections, onsite combustion sources (emergency diesel generators, pumps), and cooling towers. Biomass, geothermal, and refuse-derived fuel facilities, however, can emit significant air emissions, including criteria pollutants, polycyclic aromatic hydrocarbons, mercury, and hazardous air pollutants (Ciferno and Marano 2002; NREL 2003; Kagel et al. 2005; BLM 2008). Air emissions associated with the operation of offshore facilities will also result from engine exhaust of vessel traffic traveling to and from offshore sites for operation and maintenance activities.

Noise sources associated with operation of renewable energy alternatives can include transformers, transmission lines, cooling towers, pumps, and worker vehicles. Noise generated by onshore and offshore wind turbines includes aerodynamic noise from the blades and mechanical noise from turbine drivetrain components (generator, gearbox). Noise impacts would depend on the proximity of noise-sensitive receptors to noise sources.

## 4.4 Geologic Environment

### 4.4.1 Environmental Consequences of the Proposed Action – Continued Operations and Refurbishment Activities

#### *4.4.1.1 Geology and Soils*

This issue was added in the 2013 LR GEIS. Geologic and soil conditions at all nuclear power plants and associated transmission lines have been well established during the current licensing term. These conditions are expected to remain unchanged during the 20-year license renewal (initial LR or SLR) term.

The impact of continued operations and any refurbishment associated with license renewal on geologic and soil resources would consist of soil disturbance, including sediment and/or any associated bedrock, for projects, such as replacing or adding buildings, roads, parking lots, and belowground and aboveground utility structures. For such projects, a licensee may also need to obtain geologic resources (e.g., soil or sand borrow or backfill material, aggregate for road building or concrete production) from locations on the nuclear power plant site or from offsite borrow areas or quarries. However, it is more likely that these materials would be obtained from commercial vendors. Regardless, for onsite activities, implementation of BMPs by the plant licensee would reduce soil erosion and subsequent impacts on surface water quality. These practices include, but are not limited to, minimizing the amount of disturbed land, stockpiling topsoil before ground disturbance, mulching and seeding in disturbed areas, covering loose materials with temporary covers such as geotextiles, using sediment (silt) fences to reduce sediment loading to surface water, using check dams to minimize the erosive power of drainages, and installing proper culvert outlets to direct flows in streams or drainages.

Detailed geotechnical analyses would be required to address the stability of excavations, foundation footings, and slope cuts for building construction, road creation, or other refurbishment-related construction projects. Depending on the plant location and design, riverbank or coastline protection might need to be upgraded, especially at water intake or discharge structures, if natural flows, such as storm surges, cause an increase in erosion. For example, at the Point Beach plant, the bluffs along Lake Michigan are subject to erosion from storm action. The licensee performs necessary shoreline and bank stabilization activities in accordance with an authorization from the U.S. Army Corps of Engineers (USACE). In 2019, the licensee initiated a project to construct a new breakwater structure (wave barrier) along the plant boundary with Lake Michigan. The projected was completed in August 2020. The work included construction of a new breakwater structure extending north from near the midpoint of the Point Beach Unit 2 discharge flume for approximately 600 ft (185 m) to an existing breakwater structure. The second 600 ft (185 m) segment of the breakwater extends south from near the midpoint of the Point Beach Unit 1 flume and curves back to the existing shoreline. The breakwater structure consists of large armor stones (dolomite blocks) stacked on the lake bottom. The project also included installation of additional riprap protection along the shoreline, extending for 400 linear ft (120 m) and including the shoreline segment between the plant's two discharge flumes (NRC 2021f).

In addition, the Farmland Protection Policy Act of 1981 (7 USC 4201 et seq.) requires Federal agencies to take into account agency actions affecting the preservation of farmland, including prime and other important farmland soils, as described in Section 3.4. While the Farmland Protection Policy Act could apply in some circumstances at nuclear power plant sites (e.g., development of renewable energy resources as an alternative to license renewal, other projects completed with Federal assistance including funding), it does not apply to Federal permitting or licensing actions for activities on private or non-Federal lands (7 CFR Part 658).

Plant-specific environmental reviews conducted by the NRC to date have not identified any significant impact issues related to continued operations and refurbishment activities on geology and soils.

The impacts of natural phenomena, including geologic hazards, on nuclear power plant systems, structures, and components are outside the scope of the NRC's license renewal environmental review. Nonetheless, the environmental review documents the potential effects of continued nuclear power plant operation during the license renewal term, including any refurbishment activities, on the environment. As discussed in Section 3.4, nuclear power plants were originally sited, designed, and licensed in consideration of the geologic and seismic criteria set forth in 10 CFR 100.10(c)(1) and 10 CFR Part 100, Appendix A, and, where applicable, 10 CFR Part 50, Appendix A. In its license renewal environmental reviews, for instance, the NRC considers the risk to reactors from seismicity in the evaluation of severe accidents. Where appropriate, seismic issues are also assessed in the plant-specific safety review that is performed for license renewals. The NRC also conducts safety reviews prior to allowing licensees to make operational changes due to changing environmental conditions.

Further, the NRC requires all licensees to take seismic activity into account in order to maintain safe operating conditions at all nuclear power plants. When new seismic hazard information becomes available, the NRC evaluates the new information to determine if any changes are needed at existing plants, as discussed in Section 1.7.6 of this LR GEIS. This reactor oversight process, which considers seismic safety, is separate and distinct from the NRC staff's license renewal environmental review.

The impact of continued operations and refurbishment on geology and soils during the license renewal term was considered to be SMALL for all plants and a Category 1 issue in the 2013 LR GEIS. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The staff concludes that the impacts of continued nuclear plant operations during the initial LR or SLR terms and any refurbishment activities on geology and soils would be the same (SMALL) for all nuclear plants. As a result, geology and soils is a Category 1 issue.

### 4.4.2 Environmental Consequences of Alternatives to the Proposed Action

*Construction* – For all alternatives (including fossil energy, new nuclear, and renewable alternatives) discussed in this section, the impacts of construction on geology and soils would be similar in nature but would likely vary in intensity based on the land area required. Land would be cleared of any vegetation during construction. Clearing and grading activities over large land areas increases the risk of soil erosion, soil loss, and potential offsite water quality impacts due to stormwater runoff. Soils would be stored onsite for redistribution at the end of construction. Land clearing during construction and the installation of power plant structures and impervious surfaces (e.g., roads, parking lots, buildings) would alter surface drainage. Sources of engineered fill (e.g., compacted soil or other material) and aggregate such as crushed stone and sand and gravel would be required for construction of buildings, foundations, roads, and parking lots. Once facility construction is completed, areas disturbed during construction would be within the footprint of the completed facilities, overlain by other impervious surfaces (such as roadways and parking lots), or revegetated or stabilized as appropriate, so there would be no additional land disturbance and no direct operational impacts on geology and soils. Consumption of geologic resources (e.g., aggregate materials or topsoil) for maintenance purposes during operations would be negligible.

#### *4.4.2.1 Fossil Energy Alternatives*

*Operations* – Impacts on soil and geologic resources during power plant operations would be limited to the extraction of fossil fuel, typically at existing mining and drilling locations away from the power plant. Surface mining or underground mining for coal would result in various degrees of overburden clearing, soil stockpiling, waste rock disposal, re-routing of drainages, and management of any co-located geologic resources. Drilling for petroleum resources would involve clearing and grading for drill pads and construction of underground pipelines with associated soil disturbance. Proper design of surface water crossings would be needed to manage the potential for erosion at these locations. Eventual closure of extraction sites would require proper restoration of mines and other sites to reduce environmental impacts.

#### *4.4.2.2 New Nuclear Alternatives*

*Operations* – Impacts on soil and geologic resources during operations would be limited to the extraction of uranium ore material used to make nuclear fuel, typically at existing mining locations away from the power plant. The extraction could involve mining techniques similar to those used for fossil fuels, along with management of ore tailings. However, another method is solution mining (in situ leach uranium recovery), which involves the construction of drilling pads for injection and recovery wells to remove uranium from underground ore bodies.

#### *4.4.2.3 Renewable Alternatives*

*Operations* – For renewable energy facilities requiring large land areas (i.e., solar PV and solar thermal), vegetation maintenance during operations would increase the potential for soil erosion and loss by wind and precipitation runoff.

Other renewable technologies would entail potential operational impacts inherent to their design. The operation of hydroelectric dams would induce downstream impacts, including sediment transport and deposition patterns, and channel erosion or scouring. Geothermal energy facilities can induce land subsidence due to the removal of large quantities of ground-water. Farming to provide feedstock for biomass-fuel facilities would have the potential for increased soil erosion and the release of pesticides and fertilizers to nearby surface water bodies.

## **4.5 <u>Water Resources</u>**

Hydrologic and water quality conditions at all nuclear power plants and associated transmission lines have been well established during the current licensing terms. However, continued operations and any refurbishment activities could have an impact on water resources during the license renewal (initial LR or SLR) terms. This section describes the potential impact of these proposed activities and alternatives on surface water and groundwater resources.

### 4.5.1 Environmental Consequences of the Proposed Action – Continued Operations and Refurbishment Activities

Continued operations and any refurbishment activities during the license renewal term could affect surface water and groundwater resources in a manner similar to what has occurred during the current license term (see Sections 3.5.1 and 3.5.2, respectively).

#### *4.5.1.1 Surface Water Resources*

For the most part, no significant surface water impacts are anticipated during the license renewal terms that would be different from those occurring during the current license term. Certain operational changes (such as a power uprate) affecting surface water would be evaluated by the NRC in a separate environmental review. For potential impacts on water resources, the use of surface water is of greatest concern because of the high volumetric flow rates required for condenser cooling at nuclear power plants. Withdrawals from surface water bodies are high for both once-through and closed-cycle cooling systems. Consumptive water use occurs through evaporation and drift, especially from cooling towers, and may affect water availability downstream from nuclear power plants along rivers. Associated impacts on surface water quality may result from the discharge of thermal effluent containing chemical additives. Other potential impacts on surface water are the result of normal industrial plant activities during the license renewal term.

The following issues concern impacts on surface water that may occur during the initial LR or SLR term:

- surface water use and quality (non-cooling system impacts);
- altered current patterns at intake and discharge structures;
- altered salinity gradients;
- altered thermal stratification of lakes;
- scouring caused by discharged cooling water;
- discharge of metals in cooling system effluent;
- discharge of biocides, sanitary wastes, and minor chemical spills;
- surface water use conflicts (plants with once-through cooling systems);
- surface water use conflicts (plants with cooling ponds or cooling towers using makeup water from a river);
- effects of dredging on surface water quality; and
- temperature effects on sediment transport capacity.

##### *4.5.1.1.1 Surface Water Use and Quality (Non-Cooling System Impacts)*

Continued operations and refurbishment activities could result in the degradation of water quality within the receiving watershed. Power plant sites and land-disturbing activities can increase the variety and quantity of pollutants entering receiving water bodies such as streams, rivers, and lakes. Pollutants within stormwater runoff from plant sites can include suspended sediment; pesticides and nutrients from landscaped areas; petroleum products including oil and grease and toxic chemicals from motor vehicles; spills of hydrocarbon fuels; paints; road salts;

water treatment chemicals including acids and biocides; heavy metals from roof shingles and motor vehicles; and thermal pollution (i.e., heated stormwater runoff) from impervious surfaces. These pollutants could potentially harm aquatic and terrestrial species, contaminate recreational areas, and degrade drinking water supplies.

In an effort to minimize or eliminate impacts on the water quality of receiving water bodies, BMPs are typically included as conditions within National Pollutant Discharge Elimination System (NPDES) permits issued by the EPA, or, where delegated, by individual States. BMPs are measures used to control the adverse water quality-related effects of land disturbance and development or industrial activity. They include structural devices designed to remove pollutants, reduce runoff rates and volumes, and protect aquatic habitats. BMPs also include nonstructural or administrative approaches, such as training to educate staff in the proper handling and disposal of potential pollutants.

Permanent BMPs are designed to control pollutants to the maximum extent practicable during continued operations of the power plant. Extended detention and infiltration basins are examples of pollutant-removal features designed to remove pollutants based on volume. Hydrodynamic separator systems (hydrodynamic devices, baffle boxes, swirl concentrators, or cyclone separators) are examples of pollutant-removal devices that are typically designed based on flow rate.

Refurbishment activities involving construction-related land disturbance are expected to be managed by an approved Stormwater Pollution Prevention Plan (SWPPP). Development and implementation of a SWPPP is normally required as a condition of a NPDES permit. The SWPPP would indicate the structural and nonstructural BMPs that must be implemented for the duration of the refurbishment activity. Examples of construction BMPs include use of sediment (silt) fences, check dams, staked hay bales, sediment ponds, mulching, and geotextile matting of disturbed areas.

BMPs and conformance to plant site NPDES permits (individual sitewide or general permits), encompassing those covering stormwater discharges associated with construction and industrial activity, are expected to be followed during continued operations and refurbishment activities. Implementation of spill prevention and control plans would further reduce the likelihood of any liquid chemical spills.

Continued operations and refurbishment activities will require water for non-cooling-related purposes, including some consumptive use (i.e., water that is used but not returned to the source and effectively lost). The water source is dependent on the nuclear power plant site, water availability, and the nature of any refurbishment activities. Typical water sources at nuclear power plants are surface water, groundwater, and public domestic (potable) water.

Water may be used during refurbishment activities for concrete production, dust control, washing stations, facility and equipment cleaning, and soil compaction and excavation backfilling. However, the impacts due to the volume of water consumed from a surface water source would be insignificant when compared with that used or consumed by a plant’s cooling system (either once-through or closed-cycle cooling system).

The use of groundwater for non-cooling system uses would have a minimal impact on the surface water source similar to that of a direct surface water withdrawal, assuming an interconnection between the groundwater source and surface water body. Groundwater withdrawal near a water body with a disconnected groundwater table would have no effect on the surface water resource.

The use of public domestic water would reduce the direct consumptive use impacts on surface water resources. Still, domestic water runoff and water main breaks have the potential to introduce an additional pollutant (residual chlorine), which could impact water quality. It is expected that such occurrences would be rare and would be identified and corrected as piped domestic water is metered at the point of interconnection with a plant's water distribution system. Any such occurrences are not expected to present a significant water quality concern over the license renewal term.

Surface water consumption for non-cooling water-related operational activities is anticipated to be negligible and limited to uses such as facility and equipment cleaning. As a result, no surface water use conflicts would be expected.

The impacts of refurbishment on surface water use and quality during the license renewal term were considered to be SMALL for all plants and designated as a Category 1 issue in the 2013 LR GEIS. Further, non-cooling system operational impacts on water use and quality are expected to be SMALL, as described above. In addition, if refurbishment took place during a reactor shutdown, the overall water use by the facility would be greatly reduced. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On the basis of these considerations, the non-cooling system impacts of continued operations and refurbishment activities on surface water resources during the initial LR and SLR terms would be SMALL for all nuclear power plants. This is a Category 1 issue.

*4.5.1.1.2 Altered Current Patterns at Intake and Discharge Structures*

The large flow rates associated with cooling system water use have the potential to alter current patterns. The degree of influence depends on the design and location of the intake and discharge structures and the characteristics of the surface water body. The effect on currents near the intake and discharge locations is expected to be variable and localized, and any problems would have been mitigated during the early operational period of a nuclear power plant (NRC 1996). Most nuclear power plants are sited on large bodies of water to make use of the water for cooling purposes. The size of large rivers, lakes, or reservoirs precludes significant current alterations except in the vicinity of the structures. For ocean shore, bay, or tidally influenced river settings, the effect is further reduced when compared with the strong natural water movement patterns. For example, current patterns were modified at the Oyster Creek Nuclear Generating Station (Oyster Creek; which permanently shut down in September 2018). The plant site is located inland from Barnegat Bay in New Jersey. The once-through cooling system for this plant was created by modifying two small rivers originally flowing parallel into the bay. On the north side of the plant, the South Branch of the Forked River was enlarged between the plant and the bay to serve as an intake canal. On the south side of the plant, Oyster Creek was enlarged between the plant and the bay for use as a discharge canal. Near the plant, the two waterways were joined. Bay water was pulled from the bay through the intake canal to the plant, against the original flow direction of the lowest reach of the South Branch of the Forked River. Flow at the mouth of this river was both reversed and significantly increased, while flow at the mouth of the Oyster Creek discharge canal significantly increased during plant operations. While current patterns in Barnegat Bay in the immediate vicinity of the intake and discharge canals were affected by operations, the effect on the overall Barnegat Bay system was minor (NRC 1996; NRC 2007b).

This issue has no relevance to nuclear power plants relying on cooling ponds or canal systems because such structures are human-made (excavated earthworks or engineered impoundments) without natural currents.

Impacts from altered current patterns at intake and discharge structures during the license renewal term were considered to be SMALL for all plants and designated as Category 1 in the 2013 LR GEIS. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On the basis of these considerations, the impact of altered current patterns at intake and discharge structures would be SMALL during the initial LR and SLR terms for all nuclear plants. This is a Category 1 issue.

*4.5.1.1.3 Altered Salinity Gradients*

This issue relates to the few (operating) nuclear power plants (Table 3.1-2) located on estuaries and addresses changes in salinity caused by cooling system water withdrawals and discharges directly to receiving waters. Using the same example site as for the current patterns issue, construction of the Oyster Creek plant (no longer operating) included modification of the lower reaches of two creeks. These portions of the creeks were originally brackish, with a mix of freshwater from their upper reaches and tidally influenced bay water. Because of the cooling system operations, the water quality of these lower reaches had approached that of Barnegat Bay, with contributions of freshwater from their upper reaches being relatively minor. These lower reaches were also affected by occasional dredging activities, and the discharge canal received water to which heat and chemicals had been added. The salinity changes did not affect the upper portions of the creeks. In the 1996 LR GEIS, only minor effects had been noted in Barnegat Bay.

As documented in the 1996 LR GEIS and Calvert Cliffs Nuclear Power Plant (Calvert Cliffs) SEIS (NRC 1999c), the NRC found that operation of the Calvert Cliffs plant has not had significant effects on salinity in Chesapeake Bay. Altered salinity gradients are expected to be noticeable only in the immediate vicinity of the intake and discharge structures.

More recently, in the Surry SLR SEIS, the NRC evaluated the plant’s cooling water withdrawals and discharges to the tidally influenced James River in Virginia. The range in measured salinities in the James River for the period 1984 through 2018 indicated no significant effect from Surry’s operations, based on comparison to salinity data compiled prior to and immediately after plant startup in 1975. Higher salinity does occur within Surry’s engineered discharge canal due to the withdrawal of higher salinity water (NRC 2020f).

Impacts from altered salinity gradients at intake and discharge structures during the license renewal term were considered to be SMALL for all plants and designated as a Category 1 issue in the 2013 LR GEIS. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term.

On the basis of these considerations, the impact of altered salinity gradients would be SMALL during the initial LR and SLR terms for all nuclear plants. This is a Category 1 issue.

*4.5.1.1.4 Altered Thermal Stratification of Lakes*

Because cooling systems typically withdraw from the deeper, cooler portion of the water column of lakes or reservoirs and discharge to the surface, they have the ability to alter the thermal stratification of the surface water. This has not been shown to be an issue for rivers or oceans because of mixing caused by natural turbulence.

A thermal plume of discharge water loses heat to the atmosphere and to the receiving surface water body. It also undergoes mixing with the surface water. In the 1996 LR GEIS, examples included the Oconee Nuclear Station (Oconee) in South Carolina, where the withdrawal of cool, deep water for cooling purposes favors warmwater fish species at the expense of coolwater fish. Mitigation of this effect is possible by modifying the allowable discharge water temperature. In an example from the McGuire Nuclear Station (McGuire) in North Carolina, a modeling study indicated that increasing the permitted discharge temperature would reduce the withdrawal of cool, deep water and conserve coolwater species habitat.

Thermal plumes may be studied through field measurements and modeling studies. For plants on lakes or reservoirs, the thermal effect on stratification is examined periodically through the NPDES permit renewal process. For example, as documented in the Point Beach SLR SEIS, the plant's Wisconsin-issued NPDES permit imposes a heat-rejection limit on the plant's cooling water discharge. This limit accounts for operational changes implemented at Point Beach associated with the extended power uprate that the NRC approved in 2011 (NRC 2021f). Problems with thermal stratification due to nuclear power plant operations have not been encountered.

Impacts from altered thermal stratification of lakes and reservoirs during the license renewal term were considered to be SMALL for all plants and were designated as a Category 1 issue in the 2013 LR GEIS. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On the basis of these considerations, the impact of altered thermal stratification of lakes would be SMALL during the initial LR and SLR terms for all nuclear plants. This is a Category 1 issue.

*4.5.1.1.5 Scouring Caused by Discharged Cooling Water*

The high-flow rate of water from a cooling system discharge structure has the potential to scour sediments and redeposit them elsewhere. Scouring will remove fine-grained sediments, resulting in turbidity, and leave behind coarse-grained sediments.

The degree of scouring depends on the design of the discharge structure and the character of the sediments. Scouring is expected to occur only in the vicinity of the discharge structure where flow rates are high. While scouring is possible during reactor startup, operational periods would typically have negligible scouring. Natural sediment transport processes could bring fresh sediment into the discharge flow area. These processes include transport due to ocean currents, tides, river meandering, and storm events.

In the 1996 LR GEIS, scouring had not been noted as a problem at most plants and had been observed at only three nuclear power plants (Calvert Cliffs, Connecticut Yankee [no longer operating], and San Onofre Nuclear Generating Station [San Onofre; no longer operating]). The effects at these plants were localized and minor.

Impacts from scouring caused by discharged cooling water during the license renewal term were considered to be SMALL for all plants and were designated as a Category 1 issue in the 2013 LR GEIS. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On the basis of these considerations, the impact of scouring caused by discharged cooling water would be SMALL during the initial LR and SLR terms for all nuclear plants. This is a Category 1 issue.

*4.5.1.1.6 Discharge of Metals in Cooling System Effluent*

Heavy metals such as copper, zinc, and chromium can be leached from condenser tubing and other components of the heat exchange system by circulating cooling water. These metals are normally addressed in NPDES permits because high concentrations of them can be toxic to aquatic organisms. Operations at all nuclear power plants are subject to one or more NPDES permits that require licensees to conduct effluent monitoring and reporting for a wide range of pollutants that could potentially be discharged in cooling water and comingled effluents. For example, as described in the SEIS for initial LR of the Byron plant, the plant's Illinois-issued NPDES permit requires that the licensee monitor cooling system blowdown discharges to the Rock River for various parameters, including the metals zinc, iron, lead, copper, nickel, and chromium (NRC 2015c). During normal nuclear power plant operations, metal concentrations are normally below laboratory detection levels. However, plants occasionally undergo planned outages for refueling or unplanned maintenance, with stagnant water remaining in the heat exchange system. During an outage at the Diablo Canyon Power Plant (Diablo Canyon) in California, the longer residence time of water in the cooling system resulted in elevated copper levels in the discharge when operations resumed; abalone (*Haliotis* spp.) deaths were attributed to the increased copper (NRC 1996). At the H.B. Robinson Steam Electric Plant (Robinson) in South Carolina, the gradual accumulation of copper in its reservoir resulted in impacts on the bluegill (*Lepomis macrochirus*) population. In both cases, copper condenser tubes were replaced with titanium ones, and the problem was eliminated (NRC 1996).

Impacts from the discharge of metals in cooling system effluent during the license renewal term were considered to be SMALL for all nuclear power plants and were designated as a Category 1 issue in the 2013 LR GEIS. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On the basis of these considerations, the impact of the discharge of metals in cooling system effluent would be SMALL during the initial LR and SLR terms for all nuclear plants. This is a Category 1 issue.

*4.5.1.1.7 Discharge of Biocides, Sanitary Wastes, and Minor Chemical Spills*

The use of biocides and other water treatment chemicals is common and is required to control biofouling and nuisance organisms in plant cooling systems. However, the types of chemicals, their amounts or concentrations, and the frequency of their use may vary. The use of biocides at nuclear power plants is discussed generally in Section 3.5.1. Ultimately, any residual biocides used in the cooling system are discharged to surface water bodies. The discharge of treated sanitary waste also occurs at plants. Discharge may occur via onsite wastewater treatment facilities, via an onsite septic field, or through a connection to a municipal sewage system. Minor chemical spills collected in floor drains are associated with industry in general and are a possibility at all plants. Each of these factors represents a potential impact on surface water quality.

Discharges of cooling water and other plant wastewaters are monitored through the NPDES program administered by the EPA, or, where delegated, by individual States. The NPDES permit contains requirements that limit the flow rates and pollutant concentrations that may be discharged at permitted outfalls, including chemical residuals from biocides and other water treatment chemicals. For example, as described in the SEIS for initial LR of the Fermi plant, the plant's Michigan-issued NPDES imposes effluent limits and monitoring requirements for residual chlorine and other listed biocides (used for zebra mussel control) on the plant's primary outfall to Lake Erie (NRC 2016c). NPDES permits normally include special conditions such as requiring preapproval from the regulatory agency for the use of new water treatment chemicals, as well as requiring that onsite sanitary wastewater treatment facilities be attended by a licensed operator. The permit may also include biological monitoring parameters that are primarily associated with the discharge of cooling water. NPDES permits may also include biochemical monitoring parameters. Discharge from building drains is also addressed in the NPDES permit.

Because of Federal or State regulatory involvement, and the fact that no significant problems with outfall monitoring have been found, the impacts from the discharge of chlorine and other biocides and minor spills of sanitary wastes and chemicals during license renewal and refurbishment were considered to be SMALL for all nuclear power plants and designated as a Category 1 issue in the 2013 LR GEIS. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On the basis of these considerations, the discharge of biocides, sanitary wastes, and minor chemical spills would be SMALL during the initial LR and SLR terms for all nuclear plants. This is a Category 1 issue.

*4.5.1.1.8 Surface Water Use Conflicts (Plants with Once-Through Cooling Systems)*

Nuclear power plant cooling systems may compete with other users relying on surface water resources, including downstream municipal, agricultural, or industrial users. Once-through and closed-cycle cooling systems have different water consumption rates. As reported by Dieter et al. (2018), thermoelectric plant once-through cooling systems return most of their withdrawn water to the same surface water body, with evaporative losses of approximately 1 percent, compared to 57 percent for closed-cycle (recirculating) cooling systems. Consumptive use by plants with once-through cooling systems during the license renewal term is not expected to change unless power uprates, with associated increases in water use, are proposed. Because power uprates are a separate licensing action from license renewal, such uprates would normally require a separate environmental review by the NRC.

Future scenarios for water availability focus on climate change and associated changes in precipitation and temperature patterns. Since the beginning of the last century, annual precipitation has increased on average by 4 percent across the United States with increases in the Northeast, Midwest, and Great Plains and decreases over parts of the Southeast and Southwest. The frequency and intensity of heavy precipitation have increased average annual precipitation, with the highest observed changes occurring across the Northeast and Midwest. Climate models project that these trends will continue. Annual average temperature has increased by 1.2 degrees Fahrenheit (°F) (0.7 degree Celsius [°C]) across the contiguous United States for the period 1986–2016 relative to 1901–1960. In the coming decades, annual average temperatures are projected to increase by about 2.2 °F (1.2 °C) (USGCRP 2018). Increased temperatures and/or decreased rainfall would result in lower river flows, increased cooling pond evaporation, and lowered water levels in the Great Lakes or reservoirs. Climate change-induced impacts on water availability are less pronounced across large watersheds (large river systems and lakes). As a result, surface water withdrawals by nuclear power plants would be even less likely to affect water availability. While weather will vary from year to year, the results of climate change models and the projected changes to surface water runoff support increases in runoff across the eastern United States and decreases in runoff in the western United States, where water remains less available due to drought and decreases in winter snowpack. Regardless of overall climate change, droughts could result in problems with water supplies and allocations. Because future agricultural, municipal, and industrial users would continue to share their demands for surface water with power plants, conflicts might arise if the availability of this resource decreased. This situation would then necessitate decisions by local, State, and regional water-planning officials.

Population growth around nuclear power plants has caused increased demand on municipal water systems, including systems that rely on surface water. Municipal intakes located downstream of a nuclear power plant could experience water shortages, especially in times of drought. Water demands upstream of a plant could affect the water availability at the plant's intake.

In the 2013 LR GEIS, the impacts of continued operations and refurbishment on water use conflicts associated with once-through cooling systems were considered to be SMALL and were designated as a Category 1 issue. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue either for an initial LR or SLR term. On the basis of these considerations, the NRC concludes that the impact on water use conflicts from the continued operation and refurbishment activities would be SMALL during the initial LR and SLR terms for plants that use once-through cooling. This is a Category 1 issue.

##### *4.5.1.1.9 Surface Water Use Conflicts (Plants with Cooling Ponds or Cooling Towers Using Makeup Water from a River)*

Nuclear power plant cooling systems may compete with other users relying on surface water resources, including downstream municipal, agricultural, or industrial users. Closed-cycle cooling is not completely closed, because the system discharges blowdown water to a surface water body and withdraws water for makeup of both the consumptive water loss due to evaporation and drift (for cooling towers) and blowdown discharge. For plants using cooling towers, while the volume of surface water withdrawn is substantially less than once-through systems for a similarly sized nuclear power plant, the makeup water needed to replenish the consumptive loss of water to evaporation can be significant. As reported by the U.S. Geological Survey (USGS 2019b), consumptive water use in thermoelectric power plants with recirculating cooling systems can be up to 74 percent of the withdrawal flow rate. Cooling ponds also require makeup water as a result of naturally occurring evaporation, evaporation of the warm effluent, the potential need for periodic blowdown to maintain pond chemistry, and possible seepage to groundwater.

Consumptive use by plants with cooling ponds or cooling towers using makeup water from a river during the license renewal term is not expected to change unless power uprates, with associated increases in water use, occur. Such uprates would normally require a separate environmental review by the NRC. Any river, regardless of size, can experience low-flow conditions of varying severity during periods of drought and changing conditions in the affected watershed such as upstream diversions and use of river water. However, the potential for direct impacts on instream flow and potential water availability for other users from nuclear power plant surface water withdrawals are greater for smaller (i.e., low-flow[1]) rivers.

As stated earlier, increased temperatures and/or decreased rainfall would result in lower river flows, increased cooling pond evaporation, and lowered water levels in lakes or reservoirs. Regardless of overall climate change, droughts could result in problems with water supplies and allocations. Conflicts might arise due to competing agricultural, municipal, and industrial user demands for surface water with power plants. Closed-cycle cooling systems are more susceptible to these issues than once-through cooling systems because they consume more water per unit volume of water withdrawn from the water source. For this reason, climate change is more of a potential concern for water use conflicts associated with nuclear power plants with closed-cycle cooling systems.

Population growth around nuclear power plants has caused increased demand on municipal water systems, including systems that rely on surface water. Municipal intakes located downstream from a nuclear power plant could experience water shortages, especially in times of drought. Similarly, water demands upstream from a nuclear power plant could affect the water availability at the plant's intake.

As discussed in the 2013 LR GEIS, potential water use conflicts have been documented for nuclear power plants with closed-cycle cooling systems. State regulatory agencies have imposed surface water withdrawal limits on a number of operating nuclear power plants with cooling towers and cooling ponds. The Limerick plant is equipped with natural draft cooling towers, on the Schuylkill River in Pennsylvania. It is cited as an example of a plant in the 1996 LR GEIS on which limits were imposed on the rate of withdrawal from a river for the purpose of avoiding water use conflicts, including downstream water availability and water quality. As further documented in the SEIS for initial LR of Limerick, plant operations are subject to low-flow augmentation requirements during low river flow (NRC 2014d). In another example, as documented in the SEIS for initial LR of the Braidwood plant, the plant's makeup water withdrawal from the Kankakee River to its cooling pond is subject to a maximum withdrawal rate imposed by the State of Illinois (NRC 2015d). Further, availability problems for downstream habitat and users may be anticipated at other plants.

Water use conflicts associated with plants with cooling ponds or cooling towers using makeup water from a river with low flow are considered to vary among sites because of differing site-specific factors, such as makeup water requirements, water availability (especially in terms of varying river flow rates), changing or anticipated changes in population distributions, or changes in agricultural or industrial demands. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term.

On the basis of these considerations, the impact of water use conflicts from the continued operation of nuclear power plants with cooling ponds or cooling towers using makeup water from a river could be SMALL or MODERATE during the initial LR and SLR terms, depending on

[1] A river with low flow was previously defined in 10 CFR 51.53(c)(3)(ii)(A) and in the 1996 LR GEIS as one with an annual flow rate that is less than $3.15 \times 10^{12}$ $ft^3/yr$ ($9 \times 10^{10}$ $m^3/yr$) (100,000 $ft^3/s$ (2,830 $m^3/s$)).

factors such as plant-specific design characteristics affecting consumptive water use, the characteristics of the water body serving as the source for makeup water, and the amount of competing use for that water. Because the impact could vary among nuclear plants, this is a Category 2 issue.

*4.5.1.1.10 Effects of Dredging on Surface Water Quality*

Dredging in the vicinity of surface water intakes, canals, and discharge structures is undertaken by nuclear power plant licensees to remove deposited sediment and maintain the function of plant cooling systems. Dredging may also be needed to maintain barge shipping lanes. Whether accomplished by mechanical, suction, or other methods, dredging disturbs sediments in the surface water body and affects surface water quality by temporarily increasing the turbidity of the water column. In areas affected by industries, dredging can also mobilize heavy metals, polychlorinated biphenyls (PCBs), or other contaminants in the sediments.

The frequency of dredging depends on the rate of sedimentation. At the Oyster Creek plant in New Jersey (which permanently shut down in September 2018), dredging took place during site construction to create canals for the once-through cooling system (NRC 2007b). Depth measurements were performed there every 2 years, and dredging took place on portions of the canal system during operations. At the Susquehanna Steam Electric Station (Susquehanna) in Pennsylvania, the plant’s river intake and diffuser pipe are dredged annually (NRC 2009c).

More recently, as documented by the NRC in the Surry SLR SEIS, the licensee conducts maintenance dredging of its cooling water intake channel in the James River every 3 to 4 years in accordance with a USACE permit. The licensee also performs debris removal on an as-needed basis from its low-level intake structure under a USACE Nationwide Permit (NRC 2020f).

In general, maintenance dredging affects localized areas for a brief period of time. Dredging operations are performed under permits issued by the USACE and possibly by State or local agencies. The physical alteration of water bodies is regulated by Federal and State statutes under Section 401 (Certification) and Section 404 (Permits) of the Clean Water Act (CWA; 33 U.S.C. § 1251 et seq.). The USACE regulates the discharge of dredged and/or fill material under Section 404, while Section 401 requires the applicant for a Section 404 permit to also obtain a Water Quality Certification from the State in order to confirm that the discharge of fill materials will be in compliance with applicable State water quality standards. If dredging could affect threatened or endangered species or critical habitat, as established under the Endangered Species Act (ESA; 16 U.S.C. § 1531 et seq.), the USACE must consult with the U.S. Fish and Wildlife Service (FWS) or the National Marine Fisheries Service (NMFS) before it makes a permit decision. When issuing a Section 404 permit, the USACE also considers other potential impacts on aquatic resources, archaeological resources, Tribal concerns, and the permitting requirements of State and local agencies. The permitting process may include planning for the sampling and disposal of the dredged sediments.

The impact of dredging has not been found to be a problem at operating nuclear power plants. Dredging has localized effects on water quality that tend to be short-lived. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The impact of dredging on water quality would be SMALL during the initial LR and SLR terms for all nuclear plants. This is a Category 1 issue.

*4.5.1.1.11 Temperature Effects on Sediment Transport Capacity*

Increased temperature and the resulting decreased viscosity have been hypothesized to change the sediment transport capacity of water, leading to potential sedimentation problems, altered turbidity of rivers, and changes in riverbed configuration. As referenced in the 2013 LR GEIS, there is no indication that this has been a significant problem at operating power plants. Examples of altered sediment characteristics are more likely the result of power plant structures (e.g., jetties or canals) or current patterns near intakes and discharges; such alterations are readily mitigated.

Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and public comments on previous license renewal reviews, there is no evidence that temperature effects on sediment transport capacity have caused adverse environmental effects at any existing nuclear power plant. Regulatory agencies have expressed no concerns regarding the impacts of temperature on sediment transport capacity. Furthermore, because of the small area near a nuclear power plant affected by increased water temperature, it is not expected that plant operations would have a significant impact. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Effects are considered to be of SMALL significance during the initial LR and SLR terms for all plants. No change in the operation of the cooling system is expected during the license renewal term so no change in effects on sediment transport capacity is anticipated. This is a Category 1 issue.

*4.5.1.2 Groundwater Resources*

Operational activities during the license renewal term would be similar to those occurring during the current license term. The impact issues of concern are availability of groundwater and the effect of nuclear plant operations on groundwater quality.

The following issues concern impacts on groundwater that may occur during the license renewal (initial LR or SLR) term:

- groundwater contamination and use (non-cooling system impacts);
- groundwater use conflicts (plants that withdraw less than 100 gallons per minute [gpm]);
- groundwater use conflicts (plants that withdraw more than 100 gallons per minute [gpm]);
- groundwater use conflicts (plants with closed-cycle cooling systems that withdraw makeup water from a river);
- groundwater quality degradation resulting from water withdrawals;
- groundwater quality degradation (plants with cooling ponds) (consolidation of two issues from the 2013 LR GEIS: (1) groundwater quality degradation (plants with cooling ponds in salt marshes) and (2) groundwater quality degradation (plants with cooling ponds at inland sites); and
- radionuclides released to groundwater.

*4.5.1.2.1 Groundwater Contamination and Use (Non-Cooling System Impacts)*

As indicated in Section 3.5.2, the original construction of some plants required dewatering of a shallow aquifer, and operational dewatering takes place at some plants, including for groundwater contaminant plume control. This is accomplished by systems of pumping wells or drain tiles. Continued operations and refurbishment activities during the initial LR or SLR term are not expected to require any significant dewatering that would have an incremental effect on groundwater availability over that which has already taken place. Such dewatering impacts are expected to remain SMALL and confined to the boundaries of operating plants.

The contamination of soil and underlying groundwater can result from general industrial practices at any site and is not limited to those occurring at nuclear power plants. Such industrial practices can be evaluated generically, because they are common to industrial facilities and nuclear power plants. Activities that result in contamination may include the use of solvents, hydrocarbon fuels (diesel and gasoline), heavy metals, or other chemicals. These materials all have the potential to affect soils, sediments, and groundwater if released. Furthermore, contaminants present in the soil can act as long-term sources of contamination to underlying groundwater depending on the severity of the spill.

Based on previous plant-specific reviews, these types of groundwater and soil contamination problems have occurred at some operating plants. Release of contaminants into groundwater and soil degrades the quality of these resources, even if applicable groundwater quality standards are not exceeded. This includes *de minimis* quantities of contaminants that do not typically require reporting to regulatory agencies because they are below applicable threshold quantities and/or have been promptly remediated and would not otherwise pose a long-term threat to human health and the environment.

Historical examples of the types of contamination that may be present at a nuclear power plant include hydrocarbon leaks or spills at a storage tank, leaked or spilled solvents from barrels, and a hydraulic oil-line break (NRC 2006d); thallium in soil at a seepage pit, heavy metals in soil at a sand blasting site, a diesel fuel line leak, methyl tertiary butyl ether from spills of a gasoline storage tank, and PCBs in soil as a result of former dielectric fluid use (NRC 2007b); hydrocarbon spills and sulfuric acid leaks (NRC 2009c); and sodium hypochlorite solution spilled to soil, diesel fuel spills to groundwater, sewage discharged to the ground from a sanitary sewer line break, and nonradioactive oily water spilled to the ground from an oil/water separator (NRC 2016c). Some of these situations have required regulatory involvement by State agencies during both monitoring and remediation phases. Remediation has taken place in the form of excavation and recovery wells. In these instances, all contamination was either remediated with no further action required by regulatory agencies or contamination was confined to the plant site with remediation continuing until completed. Nevertheless, the number of occurrences of such problems can be minimized by means of proper chemical storage, secondary containment, and leak-detection equipment. In addition, nuclear plants have their own programs for handling chemicals, waste, and other hazardous and toxic materials in accordance with Federal and State regulations. Environmental permits held by nuclear power plant licensees (e.g., NPDES permits) generally require the use of BMPs to prevent pollutant releases to the environment. Continued implementation of such programs and procedures such as pollution and spill prevention and control plans including BMPs (e.g., good housekeeping of the plant site, preventive maintenance, routine inspections, etc.) would reduce the likelihood of any inadvertent releases to soils and/or groundwater.

An additional source of groundwater contamination can be the use of wastewater disposal ponds or lagoons. At the Donald C. Cook Nuclear Plant (D.C. Cook) in Michigan, permitted wastewater ponds have been used for receiving treated sanitary wastewater and for process wastes from the turbine room sump. Groundwater monitoring showed that concentrations of water quality parameters had increased to levels above background but below drinking water standards (EPA maximum contaminant levels) (NRC 2005c). As a result, in an arrangement with the county, the use of groundwater by other users in a designated area was restricted and the affected groundwater was limited to the southwestern portion of the plant property.

In contrast, a number of licensees have continued to operate treatment ponds and lagoons without significant adverse impact. As described in the SEIS for initial LR of the Sequoyah plant, the licensee operated two former metal-cleaning waste ponds that discharged to an NPDES internal monitoring point to the plant's diffuser pond system. Ultimately, this system discharged collected wastewater through the plant's submerged diffuser structure into the Chickamauga Reservoir (NRC 2015f). In a more recent example, as described by the NRC in the SEIS for the initial LR of the River Bend plant, the licensee operated two sets of open aeration and sedimentation lagoons located at the sanitary wastewater treatment plant. The lagoons received sanitary waste from across the plant. As a safeguard, waste from sinks and drains within the plant containing waste that was known to be or was potentially contaminated with chemicals or radioactivity were physically separated from the sanitary drains. Effluent from the system was discharged to an NPDES-permitted outfall (NRC 2018c).

Contaminants in wastewater disposal ponds and lagoons, whether lined or unlined, at a plant have the potential to enter groundwater and soils. However, the use of wastewater disposal ponds and lagoons is subject to discharge authorizations under the NPDES and other applicable State wastewater discharge permit and monitoring programs.

Remediation of groundwater contamination can involve long-duration cleanup processes that depend on the types, properties, and concentrations of the contaminants; aquifer properties; groundwater flow field characteristics; and remedial objectives. Contaminants may be able to migrate to onsite potable wells or to the wells of offsite groundwater users. Groundwater monitoring programs, including monitoring of onsite drinking water quality in accordance with safe drinking water regulations, would be expected to identify problems before contaminated groundwater reached receptors; however, monitoring wells need to be present and in proper locations in order to detect contaminants.

In the 2013 LR GEIS, the NRC found that the impact of continued operations and refurbishment activities on groundwater use and quality unrelated to cooling system operations would be SMALL for all nuclear plants. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On the basis of these considerations, the impact of continued operations and refurbishment activities on groundwater use would be SMALL during the initial LR and SLR terms for all nuclear plants. Further, the impact of plant industrial practices and their impact on groundwater quality associated with continued operations and refurbishment activities would continue to be SMALL during the initial LR and SLR terms. This is a Category 1 issue.

*4.5.1.2.2 Groundwater Use Conflicts (Plants That Withdraw Less Than 100 Gallons per Minute [gpm])*

Water wells are commonly used at nuclear power plant sites to provide water for the potable water system, although municipal water is available at some nuclear plants. Groundwater may also be used for landscaping (see Section 3.5.2). At some sites, groundwater is the source for the makeup and service water systems. In this case, the water undergoes treatment to prepare it for its intended use.

The pumping of groundwater creates a cone of depression in the potentiometric surface around the pumping well. The amount the water table or potentiometric surface declines and the overall extent of the cone depend on the pumping rate, characteristics of the aquifer (e.g., its permeability), whether the aquifer is confined or unconfined, and certain boundary conditions (including the nearby presence of a hydrologically connected surface water body). Generally, plants with a peak withdrawal rate of less than 100 gpm (378 Lpm) do not have a significant cone of depression. Depending upon hydrogeologic conditions and siting factors, withdrawal rates in excess of 100 gpm (378 Lpm) may not create conflicts. The potential for nuclear plant production wells to cause conflicts with other groundwater users would depend largely on the proximity of other wells. As stated in the 2013 LR GEIS, cones of depression usually do not extend past the property boundary, thereby reducing the possibility of a groundwater use conflict.

For example, as documented in the Peach Bottom SLR SEIS, three active groundwater production wells supply water for miscellaneous, nonpotable uses across the plant site. In total, these wells withdraw a maximum of about 15 gpm (57 Lpm) of water from the crystalline rock aquifer. The NRC found that this groundwater withdrawal would be unlikely to affect offsite domestic water supplies (NRC 2020g).

In the 2013 LR GEIS, the groundwater impacts associated with continued operations during the license renewal term were considered to be SMALL for all nuclear plants and designated as Category 1. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue either during an initial LR or SLR term. On the basis of these considerations, the impact on groundwater use conflicts from continued operations for all nuclear plants that withdraw less than 100 gpm (378 Lpm) would be SMALL during the initial LR and SLR terms. This is a Category 1 issue.

*4.5.1.2.3 Groundwater Use Conflicts (Plants That Withdraw More Than 100 Gallons per Minute [gpm])*

Nuclear power plants withdraw groundwater for various purposes. Most plants use groundwater to supply their potable water and service water needs. In some cases, groundwater is pumped to intentionally lower high water tables. At the Grand Gulf plant in Mississippi, Ranney wells in the Mississippi River alluvium are used to provide cooling system makeup water (see Section 3.5.2).

As described in the section above, the pumping of groundwater is expected to create a cone of depression around the well, with the degree of aquifer dewatering dependent on various factors. A nuclear plant may have several wells, with combined pumping in excess of 100 gpm (378 Lpm). Overall site pumping rates of this magnitude have the potential to create conflicts with other local groundwater users if the cone of depression extends to the offsite well(s). Large offsite pumping rates for municipal, industrial, or agricultural purposes may, in turn, lower the water level at power plant wells. For any user, allocation is normally determined though a State-issued permit.

In the initial LR SEIS for the South Texas plant (NRC 2013b), the NRC evaluated the potential for groundwater use conflicts from operation of the plant's five onsite groundwater production wells completed in the confined Deep Chicot aquifer and located near the plant site boundary. Over a 10-year period, the site's actual groundwater withdrawals averaged 768 gpm (2,910 Lpm). The licensee maintained a permit from the Coastal Plains Groundwater Conservation District to withdraw groundwater at a rate of approximately 1,860 gpm (7,040 Lpm). The NRC performed a confirmatory analysis of the licensee's analysis of potential aquifer drawdown in the Deep Chicot aquifer after 40 and 60 years of pumping for an offsite production well and also performed drawdown analyses out to distances of 1 and 5 mi (1.6 and 8 km). The NRC found that while operation of the South Texas production wells and associated drawdown could impact the pumping lift of nearby offsite wells, the overall increase in drawdown in the aquifer over an additional 20 years beyond the current license period would be less than 1 ft (0.3 m). This would have a negligible impact on neighboring wells and the NRC concluded that groundwater use conflicts from groundwater withdrawals would be SMALL (NRC 2013b).

As described in the SEIS for initial LR of Callaway (NRC 2014f), the licensee maintained three deep groundwater wells to supply groundwater for plant uses. Potable groundwater was being supplied to the plant at a rate of 33 gpm (124 Lpm). Another well located near the Missouri River was used to lubricate intake structure pump bearings with a usage rate of 120 gpm (454 Lpm). Groundwater was also being withdrawn from the backfill surrounding the nuclear island by a sump pump at a rate of 65 gpm (246 Lpm). Total groundwater withdrawal was 218 gpm (825 Lpm). The NRC determined that groundwater withdrawals at Callaway would likely have little impact on groundwater use as a result of the relatively small amount of groundwater consumed and the good aquifer yields in the area. The NRC concluded that the impact of groundwater consumption at Callaway on groundwater availability was SMALL (NRC 2014f).

In the Turkey Point SLR SEIS, the NRC evaluated the potential groundwater use conflicts associated with the licensee's sitewide groundwater withdrawals from the Biscayne and Upper Floridan aquifers (NRC 2019c). In 2018, the licensee's groundwater withdrawals from the Biscayne aquifer averaged 12.7 million gallons per day (Mgd) (48 million liters per day [MLd]). These withdrawals were associated with operating a site recovery well system installed to extract hypersaline groundwater from near the base of the Biscayne aquifer and to limit the operational influence of the plant's cooling canal system (CCS) on the regional saltwater interface. Construction and operation of this recovery well system was instituted by the licensee in order to meet the requirements of a Consent Agreement with the Miami-Dade County Division of Environmental Resources Management and a Consent Order issued by the Florida Department of Environmental Protection. As also described in the SEIS, the licensee operates the recovery well system under a State-issued permit (NRC 2019c).

During 2018, the licensee's groundwater withdrawals from the Upper Floridan aquifer averaged 20.3 Mgd (76.8 MLD). This total included about 12.7 Mgd (48.1 MLd) associated with groundwater withdrawn and discharged into the Turkey Point CCS for salinity management (freshening) with the remainder (about 7.6 Mgd [28.8 MLd]) withdrawn for other site uses. The licensee's groundwater usage from the Upper Floridan aquifer is governed by a State power plant site certification issued for Turkey Point by the State of Florida Siting Board.

In consideration of groundwater modeling performed in support of the referenced withdrawals, projected drawdowns in affected aquifers, potential impacts on other groundwater users, and conditions imposed by State regulators, the NRC concluded that the potential for groundwater use conflicts from the licensee's groundwater withdrawals would be SMALL for the Biscayne aquifer and MODERATE for the Upper Floridan aquifer during the Turkey Point SLR term (NRC 2019c).

As described for the Turkey Point plant, this is the first time the NRC has identified groundwater use conflicts at an operating nuclear power plant. The NRC considers this to be a unique occurrence because the licensee has the need to withdraw large volumes of groundwater for salinity management and groundwater remediation at a site located within a complex hydrogeologic setting. For most operating nuclear power plants, no significant change in water well systems would be expected over the license renewal term. If a conflict did occur, it might be possible to resolve it if the power plant relocated its well or wellfield to a different part of the property. The siting of new wells would be determined through a hydrogeologic assessment and governed by applicable production well siting, construction, groundwater allocation permitting processes.

In the 2013 LR GEIS, groundwater use conflicts were considered for plants that withdraw more than 100 gpm (378 Lpm) or plants that use Ranney wells. The NRC concluded that the impacts of continued operations and refurbishment would not necessarily be the same at all nuclear plant sites (i.e., a Category 2 issue) because of site-specific factors (e.g., well pump rates, well locations, and hydrogeologic factors) and that the impacts could be SMALL, MODERATE, or LARGE. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On the basis of these considerations, groundwater use conflicts for plants that withdraw more than 100 gpm (378 Lpm) could be SMALL, MODERATE, or potentially LARGE during the initial LR and SLR terms, depending on the plant-specific characteristics described above. This is a Category 2 issue.

*4.5.1.2.4 Groundwater Use Conflicts (Plants with Closed-Cycle Cooling Systems That Withdraw Makeup Water from a River)*

In the case of nuclear power plants with cooling towers or cooling ponds that rely on a river for makeup of consumed (evaporated) cooling water, it is possible that water withdrawals from the river could lead to groundwater use conflicts with other groundwater users. This situation could occur because of the interaction between groundwater and surface water, especially in the setting of an alluvial aquifer in a river valley. Consumptive use of the river water, if significant enough to lower the river's water level, would also influence water levels in the alluvial aquifer. Shallow wells of nearby groundwater users could therefore have reduced water availability or go dry. During times of drought, the effect would occur naturally, although withdrawals for makeup water would increase the effect. In the 1996 LR GEIS, a situation at the Duane Arnold Energy Center (Duane Arnold) in Iowa (which permanently shut down on August 10, 2020) was described in which a reservoir on a small tributary is used as a secondary supply of makeup water for the plant's cooling towers. During low-flow conditions in the plant's usual source of water, the Cedar River, the plant was not allowed to withdraw river water. Instead, it used the reservoir temporarily. In such a situation, because the high rate of water usage can lower the water level in the reservoir significantly, local users of shallow groundwater may be affected, particularly during times of drought affecting a small river. Similar to other water resources-related issues described in this section, such conflicts are highly dependent on the area's hydrogeologic framework and the locations, depths, and pump rates of wells, in addition to the amount that the surface water level declines. The NRC's license renewal environmental reviews performed since 2013 have revealed no tangible instances where this issue is of concern.

As described in the SEIS for initial LR of the South Texas plant (NRC 2013b), the NRC assessed the impact of the licensee's withdrawal of water from the lower Colorado River as makeup for the plant's main cooling reservoir. The NRC considered potential impacts on the Shallow Chicot aquifer discharges and the alluvial aquifer that separates the Shallow Chicot aquifer from the Colorado River. The Shallow Chicot aquifer is used primarily for low-yield livestock watering near the plant site and this shallow aquifer is hydraulically separated from the regional Deep Chicot aquifer. Separately, withdrawals from the lower Colorado River during lower river flow are regulated by a Certificate of Adjudication for water use. The NRC found, in part, that the Shallow Chicot aquifer would not be substantially influenced by the bank storage effects of alluvial aquifer recharge and discharge to the lower Colorado River. Therefore, the NRC concluded that continued withdrawals of surface water from the river for operation of South Texas during low-flow periods would have a SMALL impact on recharge to the alluvial aquifer during the license renewal term (NRC 2013b).

In the 2013 LR GEIS, groundwater use conflicts were evaluated for plants that use cooling towers withdrawing makeup water from a river during continued operations and refurbishment. The NRC found that that conflicts would not necessarily be the same at all nuclear power plant sites because of site-specific factors (e.g., the amount of surface water decline, well pump rates, well locations, and hydrogeologic conditions). The resulting impact could be SMALL, MODERATE, or LARGE. Therefore, this was considered a Category 2 issue. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. On the basis of these considerations, groundwater use conflicts for nuclear plants that use closed-cycle cooling systems that withdraw makeup water from a river could have SMALL, MODERATE, or LARGE impacts during the initial LR and SLR terms, depending on the plant-specific characteristics of surrounding areas described above. This is a Category 2 issue.

*4.5.1.2.5 Groundwater Quality Degradation Resulting from Water Withdrawals*

This issue considers the possibility of groundwater quality becoming degraded as a result of drawing water of potentially lower quality into an aquifer.

A well near a river may draw lower quality river water into the aquifer as a function of the interaction between groundwater and surface water. An example of this type of hydrologic interaction is the use of Ranney wells (see Section 3.5.2) at the Grand Gulf plant in Mississippi. The resulting induced infiltration of Mississippi River water into the alluvial aquifer was discussed in the 1996 LR GEIS. This aspect of Ranney well operation was reexamined by the NRC in the SEIS for the initial LR of the Grand Gulf plant (NRC 2014e). At Grand Gulf, the sandstone layers comprising the Catahoula aquifer underlie the Mississippi River Alluvial aquifer. The analysis in the SEIS confirms that the water quality from the plant's Ranney wells that pump water from the Mississippi River Alluvial aquifer is nearly identical to the water quality of the Mississippi River. As also stated in the SEIS, the transmissivity (ability of an aquifer to transmit water) of the Catahoula aquifer is so substantially less than that of the Mississippi River Alluvial aquifer that wells pumping water from the Mississippi River Alluvial aquifer would obtain their water as induced infiltration from the Mississippi River rather than from upward discharge of groundwater from the Catahoula aquifer. As a result, any groundwater contamination entering the Mississippi River Alluvial aquifer would likely remain in the Mississippi River Alluvial aquifer or discharge into the Mississippi River, rather that migrating to deeper aquifers (NRC 2014e).

While site-specific hydrogeologic factors and well design may provide some control of the flow of surface water to the well, the bulk of the groundwater pumped by a well in an alluvial aquifer near a river is expected to be induced surface water, with a smaller component of groundwater from the direction opposite the river. If well pumping is continuous, the only portion of the shallow aquifer significantly affected by induced infiltration remains in the capture zone of the well(s). Therefore, the portion of the aquifer with water quality parameters approaching those of the river water would usually be located on the power plant's property.

Wells in a coastal setting (e.g., ocean shore or estuary) have the potential to cause saltwater intrusion into the aquifer. This water quality problem is a common concern for large pumping centers associated with municipal or industrial users. The degree of saltwater intrusion depends on the cumulative pumping rates of wells, their screen depths, and hydrogeologic conditions. Deep, confined aquifers, for example, may be separated from saline aquifers closer to the surface. However, as evaluated in the 2013 LR GEIS, the potential for inducing saltwater intrusion was considered to be of SMALL significance at all sites because groundwater consumption from confined aquifers for potable and service water uses by nuclear power plants is a small fraction of groundwater use in all cases. Where saltwater intrusion has historically been a problem, the large users have been those related to agricultural (irrigation) and municipal water supply uses.

In the Turkey Point SLR SEIS (NRC 2019c), the aspect of induced saltwater intrusion and groundwater quality degradation in general was previously considered and discussed, albeit indirectly (see issue discussion in Section 4.5.1.2.3).

As previously described, at the Turkey Point plant, large volumes of groundwater are pumped from both the upper Biscayne and Upper Floridan aquifers for a variety of applications in support of Turkey Point operations, as well as for other activities conducted on the Turkey Point site unrelated to Units 3 and 4. These principal uses include withdrawals of brackish water from the Upper Floridan aquifer for freshening of the CCS, operation of a recovery well system and associated underground injection well to extract and dispose of hypersaline groundwater from the Biscayne aquifer, operation of Biscayne aquifer marine wells that withdraw saltwater to supplement CCS freshening, and operation of Upper Floridan aquifer site production wells for various onsite uses (e.g., Unit 5 gas-fired power plant usage) and including CCS freshening, as previously described (NRC 2019c).

The NRC staff's analysis of potential groundwater use conflicts for SLR of Turkey Point first considered the potential effects of site recovery well system and marine well operation on existing groundwater quality. As described in the SEIS, the recovery well system is designed to extract hypersaline groundwater radiating from the CCS. The permit for operation of the system issued by the South Florida Water Management District requires the licensee to (1) mitigate interference with existing legal uses of groundwater and (2) mitigate harm to natural resources. The permit requires mitigation for harm including effects on surface water or groundwater that result in lateral movement of the saltwater interface, reductions in the hydroperiod of wetlands or natural water bodies, causes the movement of contaminants contrary to water quality standards, or causes harm to the natural system including habitats for rare or endangered species. In such cases, the licensee would be required to take corrective action. Based on the NRC staff's review of groundwater modeling performed by the licensee and State regulators, it is likely that operation of the recovery well system will have beneficial water quality impacts by retracting the CCS hypersaline plume and the westward expansion of the regional saltwater interface, while providing reasonable assurance that any impacts on groundwater resources and users would be mitigated.

The Turkey Point marine wells, completed in the Biscayne aquifer, had been used intermittently since they were installed in 2015 to lower salinity in the CCS under abnormal conditions. As detailed in the Turkey Point SLR SEIS, the NRC staff determined that periodic use of the marine wells during the period of continued operations extending through the SLR term would not have any substantial impact on groundwater quality or quantity. This is because the permeable Biscayne aquifer in the affected area is recharged from Biscayne Bay, and any future marine well operation on a temporary basis would be unlikely to substantially alter groundwater flow beyond the affected area or result in any substantial drawdown in the Biscayne aquifer (NRC 2019c).

Regarding continued operation of the Upper Floridan aquifer site production wells, the NRC staff reviewed groundwater modeling commissioned by the licensee to support the 2014 site certification modification approval process with the State of Florida. The licensee’s modified site certification and conditions (issued in 2016) authorize a total average daily withdrawal of 28.06 Mgd (106,200 $m^3$/day) from the Upper Floridan aquifer. As of 2018, groundwater withdrawals from the Upper Floridan aquifer have been less than the authorized amounts. As documented in the SEIS, groundwater modeling indicated that operation of the freshening well system would be unlikely to result in any changes in regional water quality because the Upper Floridan aquifer is already brackish, no saltwater interface exists in the confined system, and water quality changes experienced by other aquifer users have been minor. However, the SEIS noted that there is the potential for degradation of water quality in wells producing from the Upper Floridan aquifer over time due to vertical seepage or lateral movement of more saline water. Nevertheless, the licensee’s modified site certification and associated conditions of certification for Turkey Point require the licensee to mitigate harm to offsite groundwater users (either related to water quantity or quality) as well as to offsite water bodies, land uses, and other beneficial uses. In conclusion, the staff found that while continued operation of the Upper Floridan aquifer production wells at the Turkey Point site, including the freshening well system, would increase regional drawdown in the aquifer, the effects would not be expected to affect water availability or impair the Upper Floridan aquifer as a resource during the SLR term.

The issue of groundwater quality degradation from groundwater withdrawals for nuclear plants, including induced saltwater intrusion, was designated as a Category 1 issue in the 2013 LR GEIS. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. For this issue, groundwater quality degradation resulting from water withdrawals, the impacts would be SMALL for all nuclear plants during the initial LR and SLR terms. This is a Category 1 issue.

*4.5.1.2.6 Groundwater Quality Degradation (Plants with Cooling Ponds)*

This issue is a consolidation of two related issues in the 2013 LR GEIS: (1) groundwater quality degradation (plants with cooling ponds in salt marshes) and (2) groundwater quality degradation (plants with cooling ponds at inland sites). These two issues both consider the possibility of groundwater quality and beneficial use becoming degraded as a result of the migration of contaminants discharged to cooling ponds. For this reason, they are discussed here as a single issue. This new combined issue is a Category 2 issue.

Nuclear plants that use cooling ponds, impoundments, or similar structures as part of their recirculating cooling water system discharge heated cooling water effluent back to the pond. The effluent's concentration of contaminants and other solids increases relative to that of the makeup water as it passes through the cooling system. These changes include increased total dissolved solids (TDS) because they concentrate as a result of evaporation, increased heavy metals (because cooling water contacts the cooling system components), and increased chemical additives to prevent biofouling.

Other relatively small volumes of wastewater are released from other plant systems depending on the design of each plant. They are discharged from such sources as the service water and auxiliary cooling systems, water treatment plant, laboratory and sampling wastes, boiler blowdown, floor drains, stormwater runoff, and metal-treatment wastes. These waste streams are discharged as separate point sources or are combined with the cooling water discharges. While these discharges at operating nuclear power plants are normally addressed in NPDES permits, upsets and bypasses of treatment systems along with spills and leaks of wastewater and chemical substances can and do occur.

Because the ponds are generally unlined, the water discharged to them can interact with the shallow groundwater system and may create a groundwater mound. In this case, groundwater below the pond can flow radially outward, and this groundwater would have some of the characteristics of the cooling system effluent.

In many coastal locations, including salt marshes, the groundwater is naturally brackish (i.e., with a TDS concentration of about 1,000 to more than 10,000 milligrams per liter [mg/L]) and, thus, is already limited in its uses. As such, this issue primarily concerns the potential for changing the groundwater use category of the underlying shallow and brackish groundwater due to the introduction of cooling water contaminants. Two nuclear plants, the South Texas plant in Texas and Turkey Point plant in Florida, have cooling systems (a human-made cooling pond and CCS, respectively) located relatively near or constructed in salt marshes.

Plants relying on brackish water cooling systems would generally not be expected to further degrade the quality of the shallow aquifer relative to its use classification. This is because groundwater quality beneath salt marshes is already too poor for human use (i.e., it is nonpotable water) and is only suitable for industrial use. Plants relying on cooling ponds in salt marsh settings were expected to have a SMALL impact on groundwater quality.

The NRC staff evaluated new information related to the impact of the continued operation of the Turkey Point CCS on surface water and groundwater quality in the Turkey Point SLR SEIS in the context of new, plant-specific analyses (NRC 2019c). As described in the SEIS, no surface water is withdrawn to provide makeup water for the plant's CCS. The plant's intake and discharge structures are located within the enclosed CCS, which does not directly discharge to the surface waters of Biscayne Bay. Instead, water in the CCS is sustained by groundwater inflow from the underlying surficial aquifer (Biscayne aquifer) into which the CCS was excavated. The Biscayne aquifer, in turn, is hydrologically connected to the surrounding marsh land, mangrove areas, adjacent drainage canals, Biscayne Bay, and Card Sound. The surficial groundwater underlying Turkey Point and CCS was classified by the State of Florida in 1983 as Class G-III (nonpotable use) with TDS levels of 10,000 mg/L or greater, while the Biscayne aquifer to the west side of the CCS was classified as Class G-II (potable use). Information presented in the SEIS shows that the inland movement of seawater through the Biscayne aquifer (marked by the saltwater interface) had already progressed inland and to the west of the location of the Turkey Point site prior to construction of the CCS in the 1970s. As of 2017, the saltwater interface was located about 4.7 mi (7.6 km) west of the CCS at its closest point, and moving west at a projected rate of 460 ft (140 m) per year. Nevertheless, through wells located inland of the saltwater interface, the Biscayne aquifer is the major public water supply source across Miami-Dade County as well as for the Florida Keys.

Due to a variety of environmental and other factors, the average salinity in the CCS increased over time from that in nearby Biscayne Bay (approximately 34 practical salinity unit (PSU)) to approximately 90 PSU in 2014 and 2015, and becoming hypersaline (i.e., saltier than seawater). When the NRC staff prepared the Turkey Point initial LR SEIS in 2002 (NRC 2002a), the staff acknowledged the existence of a hypersaline plume in the Biscayne aquifer directly beneath the CCS. What was not fully understood at the time was the potential for the hypersaline plume to migrate vertically downward through the Biscayne aquifer and then to move laterally within the Biscayne aquifer beyond the CCS boundaries. Over the operational life of the CCS, the size of the hypersaline plume grew larger. By 2018, the maximum extent of the hypersaline plume was approximately 3 mi (4.8 km) west of the CCS in the intermediate zone of the Biscayne aquifer and also to the east beneath Biscayne Bay and Card Sound. At the direction of the Florida Department of Environmental Protection, groundwater modeling performed by the licensee indicated that operating the CCS with salinity in excess of 35 PSU was the single largest contributor to changes (movement) in the location of the saltwater interface (NRC 2019c).

In general, the results of extensive groundwater monitoring conducted by the licensee under the direction of State of Florida and Miami-Dade County have shown that the extent of “potential CCS influence” is 4.5 mi (7.2 km) west of the CCS as measured at the base (deep interval) of the Biscayne aquifer. At this distance, and as detailed in the SEIS, the composition of the groundwater includes ambient saline water mixed with small quantities of CCS water (including soluble salts, nutrients, and tritium), whereas the degree of CCS influence (marked by higher chloride and tritium concentrations) increases closer to the CCS. Further, elevated tritium levels in the intermediate and deep monitored portions of the aquifer also indicate the potential influence of CCS water in groundwater to the east of the CCS beneath Biscayne Bay. At no location outside the boundary of the Turkey Point site did tritium levels in groundwater approach the EPA and State primary drinking water standard for tritium (20,000 picocuries per liter [pCi/L]) (40 CFR Part 141), while the highest tritium levels observed in offsite monitoring wells near the site during the 2018 reporting period were approximately 15 percent of the standard. Further, the monitoring showed that no CCS-sourced constituents had affected the overlying surface water quality (NRC 2019c).

In accordance with the regulatory agreements reached with and requirements imposed by the Florida Department of Environmental Protection and Miami-Dade County, the licensee implemented a salinity management plan and has undertaken other measures to abate hypersaline water discharges and to actively remediate the hypersaline groundwater west and north of the CCS. In 2016, the licensee also instituted pumping of brackish groundwater into the CCS for salinity management purposes and specifically to maintain the average annual salinity of the CCS at or below 34 PSU (see issue discussion Section 4.5.1.2.3). In 2017, the licensee commenced operation of a recovery well system to extract hypersaline groundwater from near the base of the Biscayne aquifer, and to limit the operational influence of the plant’s CCS. As described in the SEIS, it is projected that operation of the recovery well system will achieve retraction of the hypersaline plume back to within the Turkey Point site boundaries within 10 years (i.e., by about 2028) (NRC 2019c).

Regarding surface water quality impacts, the NRC staff concluded that the impacts on adjacent surface water bodies via the groundwater pathway from continued CCS operations were SMALL and projected to remain SMALL during the SLR term. With respect to groundwater, the staff found that hypersaline groundwater containing tritium had migrated beyond the boundaries of the CCS and Turkey Point property at the base of the Biscayne aquifer from Class G-III groundwater (i.e., nonpotable groundwater) to the west and to the east beneath Biscayne Bay. The hypersaline groundwater plume was also a significant contributor to the westward migration of the saltwater interface and would remain so without mitigation. The staff further determined that based on the data evaluated in the SEIS, CCS-influenced water had migrated into portions of the Biscayne aquifer that are a potential source of potable water. These aspects of cooling pond operations and their effects on groundwater quality were not considered in the 1996 or 2013 LR GEIS, and thus represented new and significant information compared to the 2013 LR GEIS. As a result, the NRC staff concluded that the plant-specific impacts for this issue at Turkey Point were MODERATE for operations during the initial LR term but were projected to be SMALL during the SLR term as a result of ongoing remediation measures and State and county regulatory oversight (NRC 2019c).

For the South Texas plant initial LR, the NRC staff considered potential groundwater quality impacts from operation of the plant's main cooling reservoir (MCR), a 7,000 ac (2,833 ha) engineered impoundment enclosed by a 12.4 mi (20 km) embankment. It is unlined and is the source of the plant's condenser cooling water and receives various wastewater effluents, regulated under a Texas Pollutant Discharge Elimination System permit. As described in the SEIS, the MCR is a local source of recharge for the Upper Shallow Chicot aquifer (NRC 2013b).

The unlined MCR acts as a local recharge source for the Upper Shallow Chicot aquifer. Further, a substantial portion of the seepage through the MCR is collected by the 770 relief wells that surround the MCR, which discharge the seepage water to a perimeter drainage system and then to local drainages (NRC 2013b). Therefore, locally relative to the South Texas site, the MCR influences the groundwater quality of the Upper Shallow Chicot aquifer and potentially local surface water quality.

The NRC staff's analysis found that seepage from the MCR to the Upper Shallow aquifer would initially have the same TDS concentration as the MCR (i.e., median concentration of about 2,000 mg/L). The staff also noted that for radionuclides the impact on water quality would be bounded by the maximum observed ambient concentration of tritium in the MCR (i.e., 17,410 in 1996 and levels less than 14,000 pCi/L thereafter). Groundwater monitoring showed that tritium levels in the Shallow Chicot aquifer around the MCR remained below the EPA drinking water standard of 20,000 pCi/L (40 CFR Part 141), with a maximum concentration of 8,600 pCi/L in 2012. As also discussed in the SEIS, relief wells had measured tritium concentrations of less than 7,000 pCi/L at the time of the staff's review (NRC 2013b).

The Shallow Chicot aquifer exhibits poor water quality and low productivity, with TDS concentrations in the local groundwater exceeding the EPA secondary drinking water standard of 500 mg/L (40 CFR Part 143) and averaging 1,200 mg/L. The shallow aquifer has been used in the vicinity of the South Texas plant for livestock watering. In contrast, water drawn from the Deep Chicot aquifer is of higher quality. The licensee's five onsite supply wells draw from the deep aquifer, as do public supply wells for the nearby communities to the east of the plant site (NRC 2013b).

In summary, for the South Texas plant initial LR, the NRC staff found that seepage from the MCR and other onsite contaminant releases had not substantially affected the groundwater quality within the plant site and impacts on groundwater quality offsite would be less. TDS levels were consistent with the existing groundwater quality and its past and potential future use as a source of water for livestock. Any impacts from this change in groundwater quality would be localized because the groundwater plumes originating from the MCR are local to the plant site and the region immediately downgradient of the site to the lower Colorado River. Thus, the staff concluded that groundwater quality impacts from MCR seepage and other contaminant releases to groundwater from South Texas operations would remain SMALL during the license renewal term (NRC 2013b).

Some nuclear power plants that rely on unlined cooling ponds are located at inland sites surrounded by farmland or forest or undeveloped open land. Degraded groundwater has the potential to flow radially from the ponds and reach offsite groundwater wells. The degree to which this occurs depends on the water quality of the cooling pond; site hydrogeologic conditions (including the interaction of surface water and groundwater); and the location, depth, and pump rate of water wells. Mitigation of significant problems stemming from this issue could include lining existing ponds, constructing new lined ponds, or installing subsurface flow barrier walls. At either coastal (salt marsh) sites as discussed above or inland sites, groundwater monitoring networks would be necessary to detect and evaluate groundwater quality degradation.

The degradation of groundwater quality associated with cooling ponds had not been reported for any inland nuclear plant sites at the time the 2013 LR GEIS was prepared.

In addition to the Turkey Point and South Texas plants, as evaluated above, the other operating plants with cooling ponds as identified in Section 3.1.3 are Dresden Nuclear Power Station (Dresden), Robinson, Virgil C. Summer Nuclear Station (Summer), and Wolf Creek Generating Station (Wolf Creek) plants. Since publication of the 2013 LR GEIS, the NRC has performed license renewal environmental reviews for two nuclear power plants with cooling ponds at inland sites (Braidwood and LaSalle).

As contained in the SEIS for the Braidwood plant initial LR review, the NRC notes that the plant’s cooling pond (constructed from a former strip mine) was built with a slurry wall to isolate the pond from the Upper aquifer. As a result, no movement of water between the aquifer and cooling pond would be expected, and the bottom of the cooling pond is filled with low-permeability shale, clay, and siltstone mine spoils. Much of the cooling pond is accessible to the public for fishing and other recreational activities. Wastewater discharges from the pond (i.e., blowdown) to the Kankakee River are regulated under an Illinois-issued NPDES permit. The NRC staff concluded that the impact of the cooling pond on groundwater quality would be SMALL during the license renewal term (NRC 2015d).

In the LaSalle plant initial LR SEIS (NRC 2016d), the staff described the plant’s cooling pond as being formed from the construction of earthen dikes to enclose the north, east, and south sides of the pond; a natural levee created by existing topography forms the fourth side. Engineered fill consisting of silty-clay, taken from borrow areas within the pond basin, was used in the construction of the dikes. A perimeter drainage ditch designed to intercept runoff and to capture and direct seepage toward surface drainages and away from the dikes flanks the pond’s dikes. The staff found that seepage from the cooling pond is negligible because the pond was built on the Glacial Drift Aquitard (Wedron Silty-Clay Till), a geologic unit with very low permeability. The pond’s ambient water quality has also supported a recreational fishery. Between 2009 and 2014, with the exception of a few tritium samples that were near background values, no radionuclides have been detected in the pond above background values. Cooling pond blowdown is discharged to the Illinois River in accordance with an Illinois-issued NPDES permit. For these reasons, the NRC staff concluded that that the impact of operation of LaSalle’s cooling pond on groundwater quality would be SMALL during the license renewal term (NRC 2016d).

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. On the basis of the information reviewed and the preceding discussion, the impacts of groundwater quality degradation for plants using cooling ponds in either coastal (salt marsh) settings or at inland sites could be greater than SMALL (i.e., SMALL or MODERATE) depending on site-specific differences in the cooling pond's construction and operation; water quality; site hydrogeologic conditions (including the interaction of surface water and groundwater); and the location, depth, and pump rate of any water supply wells contributing to or impacted by outflow or seepage from a cooling pond. Therefore, this revised, consolidated issue is a Category 2 issue.

*4.5.1.2.7 Radionuclides Released to Groundwater*

As described in the 2013 LR GEIS, this Category 2 issue was added to evaluate the potential contamination of groundwater from the inadvertent (abnormal) release of liquids containing radioactive material from nuclear power plant systems into the environment.

The issue remains relevant to license renewal because all commercial nuclear power plants routinely release radioactive gaseous and liquid materials into the environment. These radioactive releases are designed to be planned, monitored, documented, and released into the environment at designated discharge points. However, numerous events at power reactor sites have involved unknown, uncontrolled, and unmonitored releases of liquids containing radioactive material into the environment and affecting groundwater. NRC regulations in 10 CFR Part 20 and in 10 CFR Part 50 limit the amount of radioactive material, from all sources at a nuclear power plant, released into the environment to levels that are as low as is reasonably achievable (ALARA) along with associated radiation dose limits. The regulations are designed to protect the public and the environment.

The majority of the inadvertent liquid release events have involved tritium, which is a radioactive isotope of hydrogen. However, other radioactive isotopes, such as cesium and strontium, have also been inadvertently released into the groundwater. The types of events have included, but have not been limited to, leakage from spent fuel pools (SFPs), storage tanks, buried piping, failed pressure relief valves on an effluent discharge line, and other nuclear power plant equipment.

As summarized in Section 3.5.2 of this LR GEIS, in 2006, the NRC's Executive Director for Operations chartered a task force to conduct a lessons learned review of these incidents. On September 1, 2006, the task force issued its report: *Liquid Radioactive Release Lessons Learned Task Force Report* (NRC 2006e).

The most significant conclusion dealt with the potential health impacts on the public from the inadvertent releases. Although there were numerous events where radioactive liquid was released to the groundwater in an unplanned, uncontrolled, and unmonitored fashion, based on the data available, the task force did not identify any instances where public health and safety was adversely affected.

Specific examples from NRC (2006e), as discussed in the 2013 LR GEIS, focused on tritium releases at 15 operating plants. Concentrations of tritium in sampled onsite groundwater at many of these plants ranged well above the EPA drinking water standard of 20,000 pCi/L.

Examples include onsite monitoring well samples of up to 250,000 pCi/L at the Braidwood plant in Illinois, up to 211,000 pCi/L at the Indian Point plant in New York, up to 486,000 pCi/L at the Dresden plant in Illinois, more than 30,000 pCi/L at the Watts Bar Nuclear Plant (Watts Bar) in Tennessee, and 71,400 pCi/L at the Palo Verde Nuclear Generating Station (Palo Verde) in Arizona. Examples of samples taken either directly from the source of the leak or from nearby onsite monitoring wells included samples with up to 200,000 pCi/L of tritium at the Callaway Plant in Missouri, up to 15,000,000 pCi/L at the Salem Nuclear Generating Station (Salem) in New Jersey, and up to 750,000 pCi/L at the Seabrook Station (Seabrook) in New Hampshire. At the Byron plant in Illinois, tritium in monitoring wells was above the background level but below drinking water standards (up to 3,800 pCi/L). The location and construction of the monitoring wells relative to potential leak locations have not been evaluated. For each example, it is possible that a different well placement could detect higher or lower activity concentrations.

Other reported instances (NRC 2006e) of tritium above background levels have been a result of operator error, licensed discharge, or leaks or discharges to drain systems. At the Oyster Creek plant in New Jersey (which permanently shut down in September 2018), a mistake involving a valve allowed tritium-contaminated water to flow into the discharge canal. Sampling of this water showed levels of 16,000 pCi/L. At the Wolf Creek plant in Kansas, an onsite lake receiving liquid effluent was found to have a tritium activity concentration of 13,000 pCi/L. The Perry Nuclear Power Plant (Perry) in Ohio had water samples in its drainage system with an activity concentration of 60,000 pCi/L. In each of these cases, the tritium present at the surface could infiltrate or seep into the groundwater system.

The NRC task force did not find the referenced tritium releases to be a health risk to the public or onsite workers (NRC 2006e) because the tritiated groundwater is expected to remain onsite. However, one identified exception was an event at the Braidwood plant, which resulted in detectable concentrations of tritium at an offsite location. Sampling of an offsite residential well at Braidwood showed 1,600 pCi/L of tritium, a level that was above the background level but well below the EPA drinking water standard. There would be no potential for risk to workers unless onsite wells were used for the potable water system and if the leak was in the capture zone of the well. However, the NRC requires that the onsite potable well water be monitored for radioactivity to protect plant workers.

The task force identified that under current NRC regulations the potential exists for unplanned, uncontrolled, and unmonitored releases of radioactive liquids to migrate offsite into the public domain. The following elements collectively contribute to this conclusion:

- Some of the power plant components that contain radioactive fluids that have leaked were constructed to commercial standards, in contrast to plant safety systems that are typically fabricated to more stringent requirements. The result is a lower level of assurance that these types of components will be leak-proof over the life of the plant.
- Some of the components that have leaked were not required by NRC regulations to be subject to surveillance, maintenance, or inspection activities by the licensee. This increases the likelihood that leakage in such components can go undetected. Additionally, relatively low leakage rates may not be detected by plant operators, even over an extended period of time.
- Portions of some components or structures are physically not visible to operators, thereby reducing the likelihood that leakage will be identified. Examples of such components include buried pipes and SFPs.

- Leakage that enters the ground below the plant may be undetected because there are generally no NRC requirements to monitor the groundwater onsite for radioactive contamination unless an onsite well is used for drinking water or irrigation.
- Contamination in groundwater onsite may migrate offsite undetected. Although the power plant operator is required by NRC regulations to perform offsite environmental monitoring, the sampling locations are typically in the vicinity of the routine effluent discharge point into the environment, not around plant systems, piping, and tanks containing radioactive liquids.

Another aspect encountered by the NRC due to the inadvertent releases was the high level of concern from the public, even at the very low radiation levels caused by the events. There has also been significant media coverage and demands by State and local government officials and members of Congress for the NRC to take action to stop these events.

The NRC has continued its oversight and evaluation of inadvertent releases of liquids containing radioactive material from nuclear power plants, particularly those that result in groundwater contamination. A discussion of NRC staff and Commission engagement and actions on this issue since 2006 is presented in Section 3.5.2.

The NRC has also considered the impact of the inadvertent release of radioactive liquids during its environmental reviews performed for initial LR and SLR applications since 2013. The following narrative discusses noteworthy findings from these reviews.

As described in the SEIS for initial LR of the Seabrook plant, the NRC evaluated the impact of historical inadvertent releases of radionuclides on groundwater resources. The releases originated from the cask loading area and transfer canal, which is connected to the plant's SFP. Before repairs were completed in 2004, tritium concentrations in the primary auxiliary building were reported at up to 84,000 pCi/L in 2000 and, in the Unit 1 containment enclosure ventilation area (CEVA), concentrations were reported up to 3,560,000 pCi/L in 2003. As part of the licensee's corrective actions, a groundwater dewatering and pumping system was installed to provide hydraulic containment of contaminated groundwater, and an extensive groundwater monitoring network was also installed. By 2011, tritium concentrations in the CEVA had dropped substantially, and ranged from 2,150 to 50,000 pCi/L. By the end of 2011, the highest detection of tritium in the shallow aquifer at the site was 2,850 pCi/L in a well located near the Unit 1 containment structure. The NRC determined that inadvertent releases of tritium had not substantially impaired site groundwater quality or affected groundwater use downgradient of the Seabrook plant. The NRC further concluded that groundwater quality impacts would remain SMALL during the license renewal term (NRC 2015b).

There is a long history of documented spills and leaks of liquids containing radioactive material at the Indian Point site in New York (Units 2 and 3 permanently shut down on April 30, 2020 and April 30, 2021, respectively). The NRC in the second supplement to the SEIS for the initial LR of the Indian Point plant (NRC 2018e) evaluated the environmental impact of inadvertent releases to site groundwater, along with actions taken by the licensee, the NRC, and State regulators to assess contamination and to take corrective action. As detailed in the SEIS, groundwater contamination across the site has primarily been traced to the Unit 1 and Unit 2 SFPs. Historically, leaks from the Unit 1 SFP created contaminant plumes consisting of strontium-90 and tritium, and leaks from various sources associated with Unit 2 created another plume of tritium. These plumes comingle with each other and extend to the Hudson River. Over much of the site, the plumes occur under buildings and other plant structures. Before they reach the Hudson River, all three plumes are confined to the site and both vertically and laterally to the Inwood Marble. Other radionuclides have been sporadically identified in the groundwater at discrete locations onsite. Since 2005, the licensee has maintained an extensive long-term groundwater monitoring program designed in part to characterize the current and potential future offsite groundwater contaminant migration to the Hudson River. Based on the data presented in the SEIS, concentrations of several radionuclides (e.g., tritium, strontium-90, cesium-137) in groundwater exceeded the EPA drinking water standard (i.e., yielding an equivalent annual dose of 4 mrem). In February 2016, the licensee notified the NRC of a significant increase in groundwater tritium levels in monitoring wells located near the Unit 2 fuel storage building. Tritium concentrations in one well increased from 18,900 pCi/L to 8.97 million pCi/L. Investigations and inspection by the licensee, the NRC, and State followed. The sources of the spills were identified. As a followup action, the NRC on January 17, 2017, issued a notice of violation with a finding of very low safety significance under 10 CFR 20.1406(c) for failure by the licensee to conduct operations to minimize the introduction of residual radioactivity into the site, including the subsurface. The NRC's environmental review determined that site groundwater contamination will either remain onsite or be discharged into the Hudson River. Offsite groundwater supplies should continue to be unaffected by ongoing operations. However, the NRC concluded that the impact on onsite groundwater quality was MODERATE and likely to remain MODERATE through the end of scheduled plant operations (i.e., by no later than April 30, 2025, for Unit 3). However, with the elimination of radionuclide leaks to the groundwater and with the use of monitored natural attenuation, the impact on onsite groundwater quality could move to SMALL. The NRC also concluded that the impact of site groundwater contamination on surface water quality was SMALL, because the concentrations of radionuclides in groundwater discharging to the Hudson River should be rapidly diluted to low levels (NRC 2018e).

A number of inadvertent releases of radionuclides to groundwater have been documented at the River Bend plant over the period 2008–2015, as described in the initial LR SEIS (NRC 2018c). These releases resulted in the NRC issuing the licensee a non-cited violation of 10 CFR 20.1406(c) in 2016 for failure to conduct operations to minimize the introduction of residual radioactivity into the site. The licensee took corrective actions to remedy and prevent future leaks from the turbine building in the power block, including pumping groundwater from areas near the power block. However, as documented in the SEIS, tritium exists in site groundwater in a small area within the power block area, including groundwater within the structural fill and in the underlying Upland Terrace aquifer. Monitoring wells are installed at various depths within the structural fill and the Upland Terrace aquifer. The direction of groundwater flow in the structural fill and the Upland Terrace aquifer is southwestward toward the Mississippi River aquifer and from there into the Mississippi River. In 2017, tritium concentrations in the structural fill of the power block and in the underlying Upland Terrace aquifer were 740,000 pCi/L and 223,000 pCi/L, respectively. Meanwhile, a short distance away from the power block, tritium concentrations were much lower, with a maximum value of 54,900 pCi/L. The NRC staff concluded that the impact of radionuclides released to groundwater at River Bend during the license renewal term could range from SMALL to MODERATE (i.e., if the licensee has not identified and stopped all leak sources, and if tritium continued to leak into site groundwater) (NRC 2018c).

In the SLR SEIS for the Peach Bottom plant, the NRC evaluated the history of inadvertent releases of radionuclides at the site and corrective actions taken by the licensee since 2006. While the licensee had recorded no inadvertent releases between 2011 and 2014, a release in April 2015 was traced to floor drains in the Unit 3 turbine building moisture separator area. The highest tritium level observed in a nearby overburden well was 38,100 pCi/L. As described in the SEIS, a plume of tritium-contaminated groundwater remains in the overburden material beneath the plant site. The plume is the result of previous inadvertent spills and leaks of radionuclide-containing liquids from the plant. The plume extends northeast of the Unit 3 turbine building toward the Peach Bottom intake basins. The NRC found that inadvertent releases of radionuclides (primarily tritium) had not substantially impaired or noticeably altered groundwater quality with respect to drinking water standards within the overburden and bedrock groundwater beneath the plant site. Onsite inadvertent releases had no measurable effect on surface waters adjoining the site, and did not threaten offsite groundwater. The NRC concluded that impacts on groundwater resources from inadvertent releases of radionuclides were SMALL and projected to remain SMALL during the SLR term (NRC 2020g).

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. On the basis of the information reviewed and cited about inadvertent releases at operating nuclear power plants, the NRC concludes that the impact on groundwater quality from the release of radionuclides could be SMALL or MODERATE during the initial LR and SLR terms, depending on the magnitude of the leak, radionuclides involved, hydrogeologic factors, the distance to receptors, and the response time of plant personnel to identify and stop the leak in a timely fashion. Therefore, this is a Category 2 issue.

### 4.5.2 Environmental Consequences of Alternatives to the Proposed Action

*Construction* – For all alternatives discussed in this section, the impacts of construction on water resources would be similar but could vary considerably in magnitude. For land-based facilities, construction-related impacts on hydrology (land clearing, excavation work, and installation of impervious surfaces) could alter surface drainage patterns and groundwater recharge zones, as applicable. Potential hydrologic impacts would vary depending on the nature and acreage of the land area disturbed and the intensity of the excavation work. Surface water runoff over disturbed ground, construction laydown areas, and material stockpiles could increase the levels of dissolved and suspended solids and other contaminants. Water quality could also be affected by spills and leaks of petroleum, oil, and lubricant products from construction equipment and conveyed in stormwater runoff or otherwise discharge into water bodies and potentially affecting underlying groundwater. Groundwater withdrawn from onsite wells and dewatering systems could depress the water table and possibly change the direction of groundwater flow near the affected sites. Concrete production and wetting of ground surfaces and unpaved roadways for fugitive dust control could require substantial amounts of water. Appropriate permits, including a CWA Section 404 permit for dredge and fill activities, Section 401 certification, and Section 402(p) NPDES general stormwater permit, would be required prior to construction. These impacts would apply generally to the construction phase of each of the alternatives discussed below. Differences among alternatives would depend not only on the selected technology but on site-specific factors, which cannot be evaluated here. For example, locating new alternative facilities, particularly thermoelectric power-generating plants, at existing or former power plant sites to maximize the use of existing infrastructure would reduce environmental impacts. However, the discussion of such differences and considerations is outside the scope of this LR GEIS but is considered in plant-specific SEISs.

*Operation* – Most large electrical power plants require water for cooling. As a result, fossil-fueled and nuclear power plants are generally located near large surface water bodies, including lakes, rivers, or oceans. Table 4.5-1 compares water demands and consumptive use for various technologies. Water cooling systems at existing thermoelectric power plants use either once-through or closed-cycle systems (i.e., cooling towers). New thermoelectric power plants are generally constructed with a closed-cycle cooling system to meet CWA Section 316(b) requirements. Surface water and any groundwater withdrawals for cooling or other uses would be subject to applicable State water appropriation and registration requirements. Potable water could be purchased from municipalities or commercial water providers or obtained from onsite wells or a combination of the above.

Potential operational water quality impacts could occur from blowdown (from cooling towers, ponds, or other plant systems) and evaporative losses in the steam cycle and cooling system and from drift of chemically treated cooling water from the cooling tower. Releases of industrial wastewaters, stormwater, and other effluents would be controlled by an NPDES permit, issued by the EPA or State permitting authority. The operational aspects and impacts of alternative energy technologies on water resources are presented in the following sections.

**Table 4.5-1 Water Withdrawal and Consumptive Use Factors for Select Electric Power Technologies**

| Electric Power Technologies | Water Withdrawal (gal/MWh)[(a)] | Consumptive Use (gal/MWh)[(a)] |
|---|---|---|
| IGCC (coal) with cooling towers | 358 to 605 | 318 to 439 |
| IGCC (coal) with cooling towers and carbon capture and sequestration (storage) | 479 to 678 | 522 to 558 |
| Supercritical (coal) with once-through cooling | 22,5551 to 22,611 | 64 to 124 |
| Supercritical (coal) with cooling towers | 582 to 669 | 458 to 594 |
| Supercritical (coal) with cooling towers and carbon capture and sequestration (storage) | 1,098 to 1,148 | 846[(c)] |
| NGCC with once-through cooling | 7,500 to 20,000 | 20 to 100 |
| NGCC with cooling towers | 150 to 283 | 130 to 300 |
| NGCC with cooling towers and carbon capture and sequestration (storage) | 487 to 506 | 378[(c)] |
| Nuclear (conventional LWR) with once-through cooling | 25,000 to 60,000 | 100 to 400 |
| Nuclear (conventional LWR) with cooling towers | 800 to 2,600 | 581 to 845 |
| Nuclear (conventional LWR) with cooling pond | 500 to 13,000 | 560 to 720 |
| Biopower (steam) with cooling towers | 500 to 1,460 | 480 to 965 |
| Geothermal (EGS) with cooling towers | 2,885 to 5,147[(b)] | 2,885 to 5,147[(b)] |
| Concentrated solar power (power tower) with cooling towers | 740 to 860[(b)] | 740 to 860[(b)] |
| Solar photovoltaic | 0 to 33[(b)] | 0 to 33[(b)] |
| Wind turbine | 0 to 1[(b)] | 0 to 1[(b)] |
| Hydropower (instream and reservoir losses due to power production) | Not applicable | 1,425 to 18,000 |

EGS = enhanced geothermal system; gal/MWh = gallons per megawatt-hour; IGCC = integrated gasification combined cycle; LWR = light water reactor; NGCC = natural gas combined cycle.

(a) Water withdrawal and consumptive use are expressed in units of volume per unit of electrical output (gallons per megawatt-hour) to provide a direct comparison among technologies based on NREL 2011.

(b) Water withdrawal factors and consumptive use for geothermal, concentrated solar, solar photovoltaic, and wind technologies are assumed to be equal (i.e., all water is assumed to be lost through evaporation or consumed in process, etc.).

(c) Only a single value is included in the source data.

Note: To convert gallons (gal) to liters, multiply by 3.7854.

Source: NREL 2011.

#### *4.5.2.1 Fossil Energy Alternatives*

*Operation* – All thermoelectric energy facilities, including fossil fuel power plants, require a continuous supply of water to operate. Water demands vary greatly among energy technologies and cooling system designs. In general, facilities using once-through cooling systems withdraw 10 to 100 times more water per unit of electric generation than those using cooling towers, but cooling tower consumptive use is twice as much or more water per unit of electricity production (NREL 2011). As indicated in Table 4.5-1, coal-fired facilities generally have higher consumptive water use than natural gas combined-cycle plants. The use of carbon capture and sequestration (storage) increases both water withdrawal (demand) requirements and consumptive use. In total, water usage is a function of the fossil fuel combustion technology, heating value of the fuel being consumed, the design of the primary cooling systems, and the operation of various other devices, many of which require water.

Water resources would be affected not only by water withdrawals but by reintroduction of water from steam cycle, cooling tower, gasifier blowdown water, and other wastewaters, as applicable to the technology. Water quality would also be affected by wastewater generated by exhaust-gas cleaning devices that may be operating and by other ancillary industrial activities, such as runoff and the leachate from onsite coal storage and ash piles.

#### *4.5.2.2 New Nuclear Alternatives*

Water resources would be affected by operation of the cooling system and by discharges of blowdown water from the cooling system and steam cycle, both of which can introduce chemical contaminants and heat to the receiving surface water body. Operation of these systems could also affect hydrology by reducing available surface water volume, altering current patterns at intake and discharge structures, altering salinity gradients where applicable, scouring and increases in sediment caused by discharges of treated cooling water, and increasing water temperature. Hydrologic impacts would vary, depending on the surface water source or groundwater used for cooling as well as the cooling water system employed (see Table 4.5-1). Hydrology can also be affected by a nuclear power plant's service water system, which provides water for turbine and reactor auxiliary equipment cooling, reactor shutdown cooling, and other services. Surface water and groundwater can also be affected by discharges authorized under NPDES and other permits and by accidental spills and leaks of radionuclides, chemicals, and fuels to the ground surface. Overall, impacts on water resources at a greenfield site could be substantial and would depend highly on local circumstances and factors such as other dependencies on the hydrologic resources. Hydrologic impacts at a brownfield site or an existing nuclear facility could also be substantial, depending in part on whether or not the new nuclear plant could use the existing cooling water system.

#### *4.5.2.3 Renewable Alternatives*

The operational impacts of renewable energy technologies on water resources would vary greatly based on the technology (see Table 4.5-1).

For biomass-fired plants, water demands for cooling and steam would be similar to those of some fossil fuel-fired power plants. Water demand could equal evaporative water loss from cooling tower and flue gas scrubbers. Water quality could be affected by blowdown and contaminants released in runoff from piles of feedstock materials, fly and bottom ash, and scrubber sludge.

Geothermal plants have water demands and consumptive water use rates equal to or greater than those of many conventional thermoelectric (nonrenewable) technologies (Table 4.5-1) during operation. Potential operational impacts on surface water or groundwater from geothermal plants include releases of contaminants from faulty geothermal wells or release of geothermal fluids (brines) to the surface and being conveyed by stormwater runoff or otherwise affecting surface water bodies. These potential impacts can be mitigated with proper safeguards (DOE 1997b).

As shown in Table 4.5-1, solar PV facilities and wind farms (either onshore or offshore) have minimal water demands during normal operation. Similarly, solar PV and wind farm installations have little or no wastewater discharge during normal operation. In contrast, concentrated thermal power facilities can have water demands similar to those of many other thermoelectric (nonrenewable) technologies. For some facilities, cooling tower blowdown must be managed (typically in an arid environment), and there is the potential for water quality impacts from accidental release of heat transfer fluids or thermal storage media (molten salts) used in concentrated solar plants (DOE 1997b).

Reservoirs used by hydroelectric dams could be affected by changes in water temperature and amounts of dissolved oxygen. Surface water temperatures in the reservoir could be affected when water flow is reduced. Warm water released from the top of a hydroelectric dam and cooler water released from the lower portions of the dam could affect river water temperatures downstream. Additionally, both low- and high-flow conditions would alter sediment transport and deposition patterns.

## 4.6 Ecological Resources

### 4.6.1 Environmental Consequences of the Proposed Action – Continued Operations and Refurbishment Activities

Environmental conditions at operating nuclear power plants have been well established during the current licensing term. Continued operations are not expected to change substantially during the license renewal term, and therefore, existing conditions are expected to persist during initial LR and SLR terms. Initial LR or SLR generally represent a continuation of current environmental stressors that have existed during many years of operation. License renewal is unlikely to introduce wholly new stressors on the ecological environment. However, due to the ever-changing nature of ecological communities, the magnitude of impact that these stressors exhibit on ecological resources may change. Sections 3.6.1, 3.6.2, and 3.6.2.3 discuss terrestrial resources, aquatic resources, and federally protected ecological resources, respectively, and existing environmental stressors. The following sections present the potential effects on these resources associated with continued operations of a nuclear power plant during a license renewal term.

#### 4.6.1.1 Terrestrial Resources

Continued operations of nuclear power plants during an initial LR or SLR term are expected to include continued operation of the cooling water intake system (e.g., once-through system, cooling pond, or cooling tower[s]), continued management of in-scope transmission lines and associated ROWs, maintenance of site facilities, releases of gaseous and liquid effluents, and ground disturbances and other effects associated with refurbishment, if applicable.

Terrestrial plants and animals would continue to be exposed to chemical and radionuclide releases and cooling tower drift (at sites with cooling towers). Continued site and transmission line maintenance could affect vegetation and disturb wildlife. Nuclear power plant structures and transmission lines would continue to pose collision hazards for birds. Wildlife near the site would experience elevated noise, vibration, and general human disturbance. Habitat loss, degradation, disturbance, or fragmentation could result from construction, refurbishment, or other site activities, including site maintenance and infrastructure repairs. Plants and animals would also be exposed to electromagnetic fields (EMFs). Section 3.6.1 discusses the basis for these factors; this section evaluates how these factors would affect terrestrial resources during the course of a license renewal term.

This section considers the effects that terrestrial resources may experience as a result of initial LR or SLR as eight issues. These issues are:

- non-cooling system impacts on terrestrial resources;[1]
- exposure of terrestrial organisms to radionuclides;
- cooling system impacts on terrestrial resources (plants with once-through cooling systems or cooling ponds);
- cooling tower impacts on terrestrial plants;[1]
- bird collisions with plant structures and transmission lines;
- water use conflicts with terrestrial resources (plants with cooling ponds or cooling towers using makeup water from a river);
- transmission line right-of-way (ROW) management impacts on terrestrial resources; and
- electromagnetic field effects on terrestrial plants and animals.[1]

##### 4.6.1.1.1 Non-Cooling System Impacts on Terrestrial Resources

This issue concerns the effects of nuclear power plant operations on terrestrial resources during an initial LR or SLR term that are unrelated to operation of the cooling system. Such activities include landscape and grounds maintenance, stormwater management, elevated noise levels and vibration, and ground-disturbing activities. These impacts are expected to be like past and ongoing impacts that terrestrial resources are already experiencing at the nuclear power plant site.

In the 1996 LR GEIS, the NRC evaluated the impacts of refurbishment on terrestrial resources. In the 2013 LR GEIS, the NRC expanded this issue to include impacts of other site activities, unrelated to cooling system operation, that may affect terrestrial resources. In both the 1996

[1] Issue retitled from the 2013 LR GEIS for clarity and consistency with other ecological resource issues. No substantive changes to this issue have been made.

and 2013 LR GEISs, the NRC concluded that effects could be SMALL, MODERATE, or LARGE. Therefore, these were considered Category 2 issues for all nuclear power plants. This LR GEIS refines the title of this issue from “effects on terrestrial resources (non-cooling system impacts)” to “non-cooling system impacts on terrestrial resources” for clarity and consistency with other ecological resource LR GEIS issue titles.

Industrial-use portions of nuclear power plant sites are typically maintained as modified habitats with lawns and other landscaped areas; however, these areas may also include disturbed early successional habitats or small areas of relatively undisturbed habitat. Developed areas are generally maintained through physical (e.g., mowing and cutting) and chemical (e.g., herbicides or pesticides) means. Plant diversity in these areas is generally low and often consists of cultivated varieties or weedy species tolerant of disturbance. Nonindustrial-use portions of nuclear power plant sites may include natural areas, such as forests, shrublands, prairies, riparian areas, or wetlands. These habitats may be undisturbed or in various degrees of disturbance.

Certain areas may also be managed to preserve natural resources, either privately by the nuclear power plant operator or in conjunction with local, State, or Federal agencies. For instance, approximately 13,000 ac (5.300 ha) of land to the south and west of the Turkey Point site in Florida is part of the Everglades Mitigation Bank (NRC 2019c). Under the guidance of Federal and State agencies, Florida Power and Light Company creates, restores, and enhances this habitat to provide compensatory mitigation of wetland losses elsewhere. At Shearon Harris Nuclear Power Plant (Harris) in North Carolina, Duke Energy leases land, including part of Harris Lake, to Wake County which co-manages the area with the North Carolina Wildlife Resources Commission for natural resource preservation and recreational opportunities (Duke Energy 2017). Continued conservation efforts during the license renewal term would have beneficial effects on the local ecology.

The characteristics of terrestrial vegetation and wildlife communities on nuclear power plant sites have generally developed in response to many years of plant operations and maintenance. While some communities may have reached a relatively stable condition, some may have continued to change gradually over time. Operations and maintenance activities as well as any refurbishment during the license renewal term are expected to be like current activities (see Section 2.1). Because the plants and animals present on nuclear power plant sites are generally tolerant of disturbance and acclimated to human activity, continued operations during the license renewal term would not affect the composition of terrestrial communities or any current trends of change.

Continued site landscape maintenance would maintain vegetation on developed portions of nuclear power plant sites as low-diversity habitat. Wildlife diversity immediately surrounding industrial-use portions of sites and within other landscaped areas is typically limited by low-quality habitat and generally includes species adapted to developed land uses. Animals in these areas may be exposed to elevated noise levels and vibration associated with transformers, cooling towers, and other site activities that could cause animals to avoid suitable habitat or otherwise disrupt behavioral patterns.

Stormwater management may affect onsite and adjacent wetlands. Effects may include changes in plant community characteristics, altered hydrology, decreased water quality, and sedimentation (EPA 1993, EPA 1996; Wright et al. 2006). Impervious surfaces within the watershed generally result in increased runoff and reduced infiltration, which can cause changes in the frequency or duration of inundation or soil saturation and greater fluctuations in wetland water levels. Runoff may contain sediments, contaminants from road and parking surfaces, or herbicides. Erosion of wetland substrates and plants can result from increased flow from impervious surfaces.

If activities associated with continued nuclear power plant operations disturb nonindustrial-use portions of sites, some wildlife could be displaced to nearby available habitats, and competition could increase among species. Terrestrial plants and animals could experience adverse effects from fugitive dust, altered surface water flow patterns, water quality degradation, introduction or proliferation of non-native and invasive species, and general disturbance from human activity. Species that are more sensitive to disturbance may be displaced by more tolerant species. Impervious surfaces within watersheds generally result in more runoff and less infiltration to shallow groundwater, which alters the hydrologic input to nearby wetlands (EPA 1993, EPA 1996; Wright et al. 2006). This can change the frequency or duration of inundation or soil saturation, cause greater fluctuations in wetland water levels, and degrade or erode wetland substrates. Site runoff often contains sediments, contaminants from road and parking surfaces, or herbicides (EPA 1993, EPA 1996; Wright et al. 2006). In rare or unique plant communities, sensitive habitats such as wetlands or bird rookeries, or high-quality undisturbed habitats occur in or near affected areas, impacts on such resources could be considered MODERATE or LARGE if they would noticeably alter or destabilize important attributes of those resources. Impacts would be considered SMALL if only previously disturbed or other lower-quality habitats would be affected and no noticeable or detectable impacts on the ecological environment would result.

The 2013 LR GEIS indicates that elevated noise levels and vibration from transformers and cooling towers could disrupt wildlife behavioral patterns or cause animals to avoid such areas. However, limited wildlife inhabit most areas of nuclear power plant sites that experience elevated noise levels due to the developed, industrial nature of the site, regular presence of human activity, and associated lack of high-quality habitat. Wildlife that does occur in developed areas has already adapted to the conditions of the plant site and is tolerant of disturbance. The NRC staff have not identified noise or vibration associated with normal nuclear power plant operations to be of concern in any SEISs (initial LR or SLR) completed since development of the 2013 LR GEIS. Therefore, continued noise associated with the operation of transformers and cooling towers during the license renewal term is unlikely to create noticeable impacts on terrestrial resources.

In the 1996 and 2013 LR GEISs, the NRC staff anticipated that nuclear power plants may require refurbishment to support continued operations during a license renewal term (see Section 2.1.2). However, refurbishment has not typically been necessary for license renewal. Only two nuclear power plants have undertaken refurbishment as part of license renewal (Beaver Valley Power Station [Beaver Valley] and Three Mile Island, Unit 1 [Three Mile Island; no longer operating], both of which are located in Pennsylvania) (NRC 2009a; NRC 2009b). In addition to refurbishment, license renewal could also require construction of additional onsite spent fuel storage. Refurbishment or spent fuel storage construction could require new parking areas for workers as well as new access roads, buildings, and facilities. Temporary project support areas for equipment storage, overflow parking, and material laydown areas could also be required.

Any activities that require construction or involve ground disturbance could affect terrestrial habitats. Ground-disturbing activities may be related to refurbishment or other planned activities during the license renewal term that involve demolition or construction. Natural habitats could be destroyed or altered and wildlife could be displaced or killed. Indirect effects include erosion and sedimentation, both of which are typically proportional to the amount of surface disturbance, slope of the disturbed land, and condition of the area at the time of disturbance. Chemical contamination could also occur from fuel or lubricant spills. Temporarily disturbed habitats would likely recover over time, while permanently disturbed habitats would be permanently lost. Associated noise, vibration, and human activity could cause wildlife to temporarily avoid the affected area or otherwise alter behaviors.

Some activities during a license renewal period could require Federal permits or review, which would mitigate potential effects. For instance, site activities involving the discharge of dredge or fill material into wetlands would likely require the nuclear power plant operator to obtain a CWA Section 404 (33 U.S.C. § 1251 et seq.) permit from the USACE. Actions that may affect federally endangered or threatened species or other federally protected resources would require interagency consultation with the FWS or the National Oceanic and Atmospheric Administration (NOAA). Some states and local jurisdictions also require permits for actions that may affect State-listed species and rare habitats. Such permits would ensure that effects on sensitive habitats and species are minimized during the license renewal term.

Many nuclear power plant operators have developed site or fleet-wide environmental review procedures that help workers identify and avoid impacts on the ecological environment when performing site activities. These procedures generally include checklists to help identify potential effects and required permits and BMPs to minimize the affected area. BMPs relevant to terrestrial resources may include measures to control fugitive dust, runoff, and erosion from project sites; minimize the spread of nuisance and invasive species; and reduce wildlife disturbance. Proper implementation of environmental procedures and BMPs would minimize or mitigate potential effects on terrestrial resources during the license renewal term.

Some utilities are members of the Wildlife Habitat Council, which helps corporations manage their land for broad-based biodiversity enhancement and conservation. As part of membership, sites develop wildlife management plans that include a comprehensive strategy for enhancing and conserving site ecological resources. For instance, at the Limerick plant in Pennsylvania, Exelon places and monitors artificial avian nesting structures and bat roost boxes (NRC 2014d). At the Peach Bottom plant in Pennsylvania, Exelon has established a butterfly garden to support and promote native pollinator diversity (Exelon 2011). To maintain membership, sites must undertake projects that promote native biodiversity, gather data on conservation efforts, and report on their progress. Other nuclear power plant sites that maintain Wildlife Habitat Council membership include Braidwood, Byron Station (Byron), Calvert Cliffs, Clinton Power Station (Clinton), Dresden, James A. FitzPatrick Nuclear Power Plant (Fitzpatrick), R.E. Ginna Nuclear Power Plant (Ginna), LaSalle, Nine Mile Point Nuclear Station (Nine Mile Point), and Quad Cities Nuclear Power Station (Quad Cities). Continued participation in this or similar environmental conservation organizations would minimize or mitigate potential effects on terrestrial resources during the license renewal term.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. In summary, the potential non-cooling system effects during an initial LR or SLR term depend on numerous site-specific factors, including the ecological setting of the plant; the planned activities during the license renewal period; the characteristics of the plants and animals present in the area (e.g., life history, distribution, population trends, management objectives, etc.); and the implementation of BMPs or other conservation initiatives. Non-cooling system impacts would be SMALL at most nuclear power plants but may be MODERATE or LARGE at some plants. Therefore, a generic determination of potential impacts on terrestrial resources from continued operations during a license renewal term is not possible.

The NRC concludes that non-cooling system effects on terrestrial resources during the license renewal term (initial LR or SLR) could be SMALL, MODERATE, or LARGE. This is a Category 2 issue.

#### *4.6.1.1.2 Exposure of Terrestrial Organisms to Radionuclides*

This issue concerns the potential impacts on terrestrial organisms from exposure to radionuclides from routine radiological effluent releases during an initial LR or SLR term.

The 1996 LR GEIS did not address this issue. In 2007, the International Commission on Radiation Protection (ICRP) issued revised recommendations for a system of protection to control exposure from radiation sources (ICRP 2007). The recommendations included a section about the protection of the environment in which the ICRP found that a clearer framework for assessing nonhuman organisms was warranted. The ICRP indicated that it would develop a set of reference animals and plants as the basis for relating exposure to dose, and dose to radiation effects, for different types of organisms. This information would then provide a basis from which agencies and responsible organizations could make policy and management decisions. Subsequently, the ICRP developed and published a set of 12 reference animals and plants (ICRP 2008a, ICRP 2009). They include a large and small terrestrial mammal, an aquatic bird, and a large and small terrestrial plant, among others. The ICRP also issues publications and information related to radiological effects and radiosensitivity in non-human biota (Adam-Guillermin et al. 2018).

In 2009, following the NRC staff's review of the ICRP's 2007 recommendations, the Commission found that there is no evidence that the NRC's current set of radiation protection controls is not protective of the environment (NRC 2009e). For this reason, the Commission determined that the NRC staff should not develop separate radiation protection regulations for plant and animal species (NRC 2009e).[1] The Commission directed the NRC staff to continue monitoring international developments on this issue and to keep the Commission informed. Nonetheless, the NRC addressed radiological exposure of nonhuman organisms in the 2013 LR GEIS due to public concern about these impacts at some nuclear power plants.

In the 2013 LR GEIS, the NRC determined that the impacts of exposure of terrestrial organisms to radionuclides would be SMALL at all nuclear power plants. Therefore, this was considered a Category 1 issue for all nuclear power plants.

Radionuclides may be released from nuclear power plants into the environment through several pathways. During normal operations and potentially during refurbishment, nuclear power plants can release gaseous emissions that deposit small amounts of radioactive particulates in the surrounding environment. Gaseous emissions typically include krypton, xenon, and argon (which may or may not be radioactive), tritium, isotopes of iodine, and cesium. Emissions may also include strontium, cobalt, and chromium. Radionuclides may also be released into water as liquid effluent. Terrestrial plants can absorb radionuclides that enter shallow groundwater or surface waters through their roots. Animals may experience exposure to ionizing radiation through direct contact with air, water, or other media; inhalation; or ingestion of contaminated food, water, or soil.

[1] See also SECY-04-0223 (NRC 2004f), SECY-06-0168 (NRC 2006g), SECY-08-0197 (NRC 2008c), SECY-04-0055 (NRC 2004e), and related Staff Requirements Memorandums SRM-SECY-04-0223 (NRC 2005e), SRM-SECY-06-0168 (NRC 2005f), SRM-SECY-08-0197 (NRC 2009e), and SRM-SECY-04-0055 (NRC 2004d).

The DOE has produced a standard on a graded approach for evaluating radiation doses to terrestrial and aquatic biota (DOE 2019). The DOE standard provides methods, models, and guidance that can be used to characterize radiation doses to terrestrial and aquatic biota exposed to radioactive material (DOE 2019). The following DOE guidance dose rates are the levels below which no adverse effects to resident populations are expected:

- riparian animal (0.1 radiation-absorbed dose per day [rad/d]; 0.001 gray per day [Gy/d])
- terrestrial animal (0.1 rad/d) (0.001 Gy/d)
- terrestrial plant (1 rad/d) (0.01 Gy/d)
- aquatic animal (1 rad/d) (0.01 Gy/d)

Previously, in 1992, the International Atomic Energy Agency (IAEA) (IAEA 1992) had also concluded that chronic dose rates of 0.1 rad/d (0.001 Gy/d) or less do not appear to cause observable changes in terrestrial animal populations. The United Nations Scientific Committee on the Effects of Atomic Radiation concluded in 1996 and re-affirmed in 2008 that chronic dose rates of less than 0.1 mGy/hr (0.24 rad/d or 0.0024 Gy/d) to the most highly exposed individuals would be unlikely to have significant effects on most terrestrial communities (UNSCEAR 2010).

In the 2013 LR GEIS, the NRC estimated the total radiological dose that the four non-human receptors listed above (i.e., riparian animal, terrestrial animal, terrestrial plant, and aquatic animal) would be expected to receive during normal nuclear power plant operations based on plant-specific radionuclide concentrations in water, sediment, and soils at 15 operating nuclear power plants using Argonne National Laboratory's RESRAD-BIOTA dose evaluation model. The NRC found that total calculated dose rates for all terrestrial receptors at all 15 plants were significantly less than the DOE guideline values. As a result, the NRC anticipated in the 2013 LR GEIS that normal operations of these facilities would not result in negative effects on terrestrial biota. The 2013 LR GEIS concluded that the impact of radionuclides on terrestrial biota from past operations would be SMALL for all nuclear plants and would not be expected to change appreciably during the license renewal period.

In this revision, the NRC staff conducted an updated and expanded analysis for this issue to assess whether the 2013 LR GEIS conclusions are valid for initial LR and apply to the SLR term. As part of this expanded analysis, the staff reviewed effluent release reports, performed additional RESRAD-BIOTA dose calculations, and analyzed dose to biota using the ICRP biota dose calculator. The staff reviewed a subset of operating PWR and BWR plants[1] to evaluate the potential impacts of radionuclides on terrestrial biota from continued operations. The staff reviewed effluent releases for this subset of plants between 2013 and 2020 to evaluate releases since the 2013 LR GEIS was published. The staff found that all data for this time period were below reportable thresholds.

The NRC staff evaluated Radiological Environmental Monitoring Program (REMP) reports for the year 2020 for the subset of operating PWR and BWR plants. This review yielded expected radionuclide concentrations in the environment that may be sourced from nuclear power plants. In addition to regulated Lower Limits of Detection (LLD) stated in NUREG-1301 and NUREG-1302 (NRC 1991b, NRC 1991a), the NRC staff obtained site-specific radionuclide concentrations and LLDs in water, sediment, and soils when available from the REMP reports.

[1] The subset of plants included the following PWR plants: Comanche Peak, D.C. Cook, Palo Verde 1-3, Robinson, Salem 1-2, Seabrook, and Surry; and the following BWR plants: Fermi 2, Hatch 1-2, Hope Creek, Limerick, and Columbia.

To estimate radioactive impacts to environmental receptors, the staff used the RESRAD-BIOTA dose evaluation model (DOE 2004c) to calculate estimated dose rates for terrestrial biota (see Section D.5 in Appendix D for further details on this approach). The values reported in the reviewed REMP reports were frequently listed as being below the LLD. Measurements below the LLD are too low to statistically confirm the presence of the radionuclide in the sample. Accordingly, the staff conducted a RESRAD-BIOTA analysis using either the maximum values from a measured media concentration or an LLD, when all measurements for that radionuclide were below detection limits. The staff then aggregated these values to form a single RESRAD-BIOTA analysis. This method is considered a bounding analysis because it assumes that all radionuclides included in the RESRAD-BIOTA analysis are present in the environment, even though some radionuclides are not confirmed to actually be present (i.e., those radionuclides that are below the LLD). Table 4.6-1 presents the results of the NRC staff's RESRAD-BIOTA analysis. This table shows the total dose estimates to the four ecological receptors: riparian animal,[1] terrestrial animal, terrestrial plant, and aquatic animal.

**Table 4.6-1 Estimated Radiation Dose Rates to Terrestrial Ecological Receptors from Radionuclides in Water, Sediment, and Soils at U.S. Nuclear Power Plants**

| Receptor | Riparian Animal | Terrestrial Animal | Terrestrial Plant | Aquatic Animal |
|---|---|---|---|---|
| Sum of Total Dose (rad/d)[(a)(b)] | 4.86 E-2 | 1.25 E-2 | 9.18 E-3 | 7.48 E-2 |

(a) Dose rates were estimated with RESRAD-BIOTA (DOE 2004c) by using site-specific radionuclide concentrations and lower limits of detection in water, sediment, and soils obtained from the REMP reports.
(b) These values exclude potassium-40 because it is a naturally occurring radionuclide.

All dose estimates found using RESRAD-BIOTA and shown in Table 4.6-1 were below the DOE guideline dose levels. Based on the staff's analysis, it is unlikely that radionuclide releases during normal operations of these nuclear power plants would have adverse effects on resident populations of these biota because calculated doses are below protective guidelines.

In addition to the RESRAD-BIOTA analysis discussed above, the NRC staff estimated dose rates to a riparian organism using the ICRP biota dose calculator (ICRP 2022) (see Section D.5 in Appendix D for full description of ICRP BiotaDC methodology). A small subset of nuclear power plant REMP reports[2] were evaluated to determine available non-human biota tissue concentrations for the ICRP biota dose calculator analysis. These tissue concentrations, as well as site-specific LLDs and media measurements for surface water and soil when available, were used to estimate a dose to a riparian organism. The staff used the ICRP BiotaDC tool to develop dose coefficients (DCs, expressed in $\mu Gy\ h^{-1}$ per $Bq\ kg^{-1}$) for water and soil/sediment exposure of a generic organism. A hypothetical small burrowing mammal with mass of 0.016 kg was chosen as a representative "riparian" organism. The mass and dimensions of the animal are similar to that of the meadow jumping mouse (*Zapus hudsonius*), a common North American rodent (Smith 1999). The staff developed DCs using the ICRP's BiotaDC v.1.5.2, which incorporates the radionuclide decay data of ICRP 107 (ICRP 2008b). The staff established this methodology to obtain conservative dose estimates (see Section D.5 in Appendix D for a further discussion of methodology). None of the radionuclides evaluated singly, or in common, produced dose rates that approached the DOE's guidance dose rate of 0.1 rad/d for riparian animals using the ICRP BiotaDC tool (DOE 2019). The dose rates

[1] Defined in RESRAD-BIOTA as an animal that was assumed to spend approximately 50 percent of its time in aquatic environments and 50 percent of its time in terrestrial environments.
[2] The subset of plants included Comanche Peak, Columbia, and Callaway.

calculated for the riparian organism ranged between 2E-4 and 2E-5 rad per day, which is orders of magnitude lower than the DOE guideline dose rate. Additionally, the calculated dose rates did not approach the level advocated by the National Council on Radiation Protection and Measurements to initiate additional evaluation (Cool et al. 2019). In fact, the dose rates for the riparian organism calculated using the ICRP's calculator were lower than the RESRAD conservative analysis, and both were well below the DOE guideline values.

Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and initial LR or SLR on terrestrial organisms would be similar. For these reasons, the effects of exposure of terrestrial organisms to radionuclides would be minor and would neither destabilize nor noticeably alter any important attribute of populations of exposed organisms during the initial LR or SLR terms of any nuclear power plants. Continued adherence of nuclear power plants to regulatory limits on radioactive effluent releases would minimize the potential impacts on the terrestrial environment. Doses to terrestrial organisms would be expected to remain within the DOE's guidance dose levels and, therefore, impacts to terrestrial communities are not expected. The staff reviewed information in scientific literature and from SEISs (for initial LRs or SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term.

The NRC concludes that the impacts of exposure of terrestrial organisms to radionuclides during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants. This is a Category 1 issue.

*4.6.1.1.3 Cooling System Impacts on Terrestrial Resources (Plants with Once-Through Cooling Systems or Cooling Ponds)*

This issue concerns the potential impacts of once-through cooling systems and cooling ponds at nuclear power plants on terrestrial resources during an initial LR or SLR term. The impacts of plants with cooling towers on terrestrial resources are addressed in Sections 4.6.1.1.4 and 4.6.1.1.5.

In the 1996 and 2013 LR GEISs, the NRC determined that cooling system impacts on terrestrial resources would be SMALL. Therefore, this was considered a Category 1 issue. The 1996 LR GEIS considered this issue for nuclear power plants with cooling ponds; the 2013 LR GEIS expanded this issue to include plants with once-through cooling systems.

Cooling system operation can alter the ecological environment in a manner that affects terrestrial resources. Such alterations may include thermal effluent additions to receiving water bodies; chemical effluent additions to surface water or groundwater; impingement of waterfowl; disturbance of terrestrial plants and wetlands associated with maintenance dredging; disposal of dredged material; and erosion of shoreline habitat.

Thermal effluents discharged from once-through cooling systems and cooling ponds can contribute to localized elevated water temperatures in receiving water bodies that may affect the distributions of some terrestrial plants and animals in adjacent riparian or wetland habitats. For example, at the Robinson plant in South Carolina, the growth of plants along the cooling pond shoreline is restricted by the thermal effluent (NRC 2003a). In general, however, thermal impacts on the terrestrial environment have not been identified at nuclear power plants. Thermal effluents to waters of the United States are regulated through NPDES permits to limit the effects of such discharges on the ecological environment. In addition, because wetland and riparian plant communities present near nuclear power plants have been influenced by many years of facility operation, elevated temperatures are unlikely to result in the mortality of any plants that may be exposed to effluent discharges because vegetation present in these areas has likely acclimated to local conditions. The available information indicates that the effects of thermal effluents on the terrestrial environment is not of concern for license renewal.

Along with thermal effluents, nonradiological chemical contaminants may be present in cooling system discharges. Terrestrial plants and animals may be exposed to these contaminants by direct contact with effluent discharges or through uptake from contaminated food or water. Plants and animals associated with wetland or riparian communities along the receiving water body, along with waterfowl and other wildlife that forage in these waters, are the most likely to be exposed to such chemicals, and exposure may have adverse impacts on these organisms. Contaminants of potential concern include chlorine and other biocides, heavy metals, VOCs, and oil products. NPDES permits typically limit the allowable concentrations of these contaminants in liquid effluent to minimize impacts on the ecological environment. Because of the low concentrations of nonradiological chemical contaminants within liquid effluents, the uptake and accumulation of contaminants in the cells of exposed plants or animals are not expected to be a significant issue for license renewal. Radionuclide contaminants, such as tritium and strontium, are discussed in Section 4.6.1.1.2 as a separate license renewal issue.

In the past, heavy metals used in condenser tubing was found to be an issue at two plants. Elevated concentrations of these contaminants are toxic to terrestrial organisms. Copper alloy condenser tubes in the cooling systems at the Robinson plant and the Diablo Canyon plant in California resulted in the discharge of copper in these plants' liquid effluent. At Robinson, these metals resulted in adverse effects on the morphology and reproduction of resident bluegill (*Lepomis macrochirus*) populations (Harrison 1985). At Diablo Canyon, abalone (*Haliotis* species) deaths were attributed to exposure to copper in plant effluents (NRC 1996). Terrestrial wildlife that feed on these aquatic organisms could have also been exposed to elevated copper levels and could have experienced adverse effects. However, these nuclear power plants subsequently replaced the copper alloy condenser tubes with tubes made of different materials (e.g., titanium), which has eliminated these impacts. This issue has not been reported at any other nuclear power plants. The available information indicates that the effects of heavy metals on the terrestrial environment is not of concern for license renewal.

Groundwater quality can be degraded by nonradiological contaminants present in cooling ponds and cooling canals. Deep-rooted terrestrial plants could be exposed to these contaminants. However, as noted above, nonradiological contaminant concentrations are typically very low, and any effects on terrestrial plants would be expected to be SMALL. Mitigation may also be implemented where sensitive resources could be affected. At the Turkey Point plant in Florida, for example, the flow of hypersaline groundwater from the cooling canals toward the Everglades to the west is prevented by an interceptor ditch, located along the west side of the canal system, from which groundwater inflow is extracted (NRC 2002a). However, since the publication of the 2013 LR GEIS, new information indicates that the interceptor ditch has not prevented movement of hypersaline groundwater in the deeper Biscayne aquifer. Based on ecological monitoring data, the NRC concluded that movement of the hypersaline water did not have discernable ecological impacts. Data also suggest that the interceptor ditch did prevent westward movement of near surface groundwater (NRC 2019c). This issue has not been identified at any other operating nuclear power plant.

The impingement of waterfowl at cooling water intakes has been observed at some nuclear power plants, such as the D.C. Cook plant in Michigan, Nine Mile Point plant in New York, and

Point Beach plant in Wisconsin. About 400 ducks, primarily lesser scaup (*Aythya affinis*), were impinged at D.C. Cook in December 1991 (Mitchell and Carlson 1993); about 100 ducks, both greater scaup (*Aythya marila*) and lesser scaup, were impinged in January 2000 at Nine Mile Point (NRC 2006b). At the Point Beach plant, several double-crested cormorants (*Phalacrocorax auritus*) were impinged in September 1990, and 33 birds (mostly gulls) were impinged from June 2001 through December 2003 (NRC 2005a). These nuclear power plants have changed operational procedures, such as periodically cleaning zebra mussels (*Dreissena polymorpha)* off intake structures or have changed intake structure designs to minimize impacts on waterfowl. This issue has not been found to be a problem at any other nuclear power plants or in any of the initial LR or SLR reviews conducted since publication of the 2013 LR GEIS. The available information indicates that bird impingement is not of concern for license renewal.

Maintenance dredging near cooling system intakes or outfalls may physically disturb or alter wetland or riparian habitats. Dredging may alter current patterns or increase local water velocities and cause erosion of shoreline wetlands or riparian habitats. Dredging and disposal of dredged material would likely require the nuclear power plant operator to obtain a CWA Section 404 permit from the USACE. BMPs and conditions associated with these permits would minimize impacts on the ecological environment. Granting of such permits would also require the USACE to conduct its own environmental reviews prior to the undertaking of dredging.

License renewal would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of once-through cooling systems and cooling ponds on terrestrial resources would be similar. For these reasons, the effects of these systems on terrestrial resources would be minor and would neither destabilize nor noticeably alter any important attribute of populations of plants or animals during the initial LR or SLR terms of any nuclear power plants. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term, as described above.

The NRC concludes that cooling system impacts on terrestrial resources during the license renewal term (initial LR or SLR) would be SMALL for nuclear power plants with once-through cooling systems or cooling ponds. This is a Category 1 issue.

##### *4.6.1.1.4 Cooling Tower Impacts on Terrestrial Plants*

This issue concerns the potential impacts of cooling tower operation on terrestrial plant communities during an initial LR or SLR term. This issue applies only to nuclear power plants with cooling towers. Terrestrial habitats near cooling towers can be exposed to particulates, such as salt, and can experience increased humidity, which can deposit water droplets or ice on vegetation. These effects can lead to structural damage and changes in plant communities.

In the 1996 and 2013 LR GEISs, the NRC determined that cooling tower impacts on terrestrial plants would be SMALL. Therefore, this was considered a Category 1 issue for all nuclear power plants with cooling towers. The 1996 LR GEIS evaluated this issue as two separate issues; the 2013 LR GEIS consolidated the two issues into one issue. This GEIS refines the title of this issue from “cooling tower impacts on vegetation (plants with cooling towers)” to “cooling tower impacts on terrestrial plants” for clarity and consistency with other ecological resource GEIS issue titles.

Cooling tower drift contains small amounts of particulates that are dispersed over a wide area. Most deposition from cooling towers, regardless of cooling tower type, occurs in close proximity to the towers. Particulates from natural draft towers generally disperse over a larger area, while particulates from mechanical draft towers tend to concentrate closer to the towers (Roffman and Van Vleck 1974). Generally, particulate deposition from cooling towers has not resulted in measurable adverse impacts on vegetation. At most nuclear power plants with cooling towers, no effects on agricultural crops or natural plant communities have been observed (NRC 1996). Where impacts have been observed, vegetation has typically adapted to cooling tower operation following the period of initial operation. For instance, at Palisades Nuclear Plant (Palisades) (no longer operating) on Lake Michigan, condensate plumes and drift associated with the site's two mechanical draft cooling towers caused the loss of about 5 ac (2 ha) of vegetation on dune ridges adjacent to the cooling towers within the first several years of operation (NRC 1996). Within 4 months of plant startup, white pines (*Pinus strobus*) near the cooling towers began to show signs of chemically induced injury. During the second summer of operation, deciduous trees began exhibiting observable effects. Researchers determined that sulfate deposition from the cooling towers was responsible for the damage. Severe icing associated with the cooling towers during the following winter further damaged these trees, and within the first several years of operation, early successional scrub-shrub vegetation had replaced the mature forest stand. Subsequently, Palisades stopped adding sulfuric acid to the cooling water, which eliminated observable effects on vegetation. The NRC (NRC 2006d) anticipated no additional impacts associated with cooling tower drift during the license renewal period.

Icing of vegetation and roads can occur near mechanical draft towers when fog is present and temperatures are below freezing. Associated impacts have been rare, minor, and localized. The 1996 LR GEIS reports the results of vegetation monitoring at 10 plants with mechanical draft cooling towers and 8 nuclear power plants with natural draft cooling towers. Vegetation at only three sites exhibited ice-related damage: the Palisades plant (discussed above), Prairie Island Nuclear Generating Plant (Prairie Island) in Minnesota, and Catawba Nuclear Station (Catawba) in North Carolina. At Prairie Island, researchers observed frequent ice damage to red oaks (*Quercus rubra*) adjacent to the site's mechanical draft cooling towers and a subsequent change in canopy structure (NRC 1996). Acorn viability was also found to be low, although acorn production appeared normal. In 1984, Prairie Island stopped operating the cooling towers during the winter, which eliminated these impacts. At Catawba, researchers observed the browning of the needles on several loblolly pines (*Pinus taeda*) within 200 ft (61 m) of the mechanical draft cooling towers that was attributed to possible icing effects (NRC 1996). During license renewal, the NRC anticipated no additional impacts associated with cooling tower drift at either of these nuclear power plants (NRC 2011a, NRC 2002b).

The 1996 LR GEIS contemplated that salt deposition could be a concern at coastal nuclear power plants that use estuarine or marine water for cooling. The only such plant is Hope Creek in New Jersey, whose natural draft cooling towers withdraw cooling water from the Delaware River estuary (see Section 3.3.2 for a discussion of Hope Creek cooling tower drift emissions). However, no measurable effects on plant communities near Hope Creek's cooling towers have been observed (NRC 1996), and the NRC anticipated none during the license renewal period (NRC 2011b). Soil salinization associated with cooling tower drift is also not expected to be an issue because rainfall is sufficient to leach salts from the soil profile.

In summary, vegetation near nuclear power plant cooling towers has been exposed to many years of cooling tower operation and have acclimated to any minor effects associated with cooling tower drift. Icing effects would continue to be rare, minor, and localized. All nuclear power plants at which effects of cooling tower drift were observed during the initial period of operation have modified operations to mitigate these effects.

Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and license renewal on vegetation would be similar. For these reasons, the effects of cooling towers on plants would be minor and would neither destabilize nor noticeably alter any important attribute of plant populations during initial LR or SLR terms at nuclear power plants with cooling towers. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term.

The NRC concludes that cooling tower impacts on terrestrial plants during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants with cooling towers. This is a Category 1 issue.

*4.6.1.1.5 Bird Collisions with Plant Structures and Transmission Lines*

This issue concerns the risk of birds colliding with plant structures and transmission lines during an initial LR or SLR term. Tall structures on nuclear power plant sites, such as cooling towers, meteorological towers, and transmission lines, create collision hazards for birds that can result in injury or death.

In the 1996 and 2013 LR GEISs, the NRC determined that the impacts of bird collisions with plant structures and transmission lines would be SMALL. Therefore, this was considered a Category 1 issue for all nuclear power plants. The 1996 LR GEIS evaluated this issue as two separate issues; the 2013 LR GEIS consolidated them into one issue.

Throughout the United States, millions of birds are killed each year when they collide with human-made objects, including buildings, windows, vehicles, transmission lines, communication towers, wind turbines, cooling towers, and numerous other objects (Erickson et al. 2001). Associated bird mortality is of concern if the stability of the population of a species is threatened or if the reduction in numbers within any bird population significantly impairs its function within the ecosystem. Table 4.6-2 shows estimated annual bird collision mortality in the United States from several categories of human-made objects. Collisions with buildings and windows account for the greatest number of collision mortalities annually (365 to 988 million). Transmission lines account for 12 to 64 million mortalities per year (Table 4.6-2).

As of April 2022, more than 133,000 standing communication towers (32 to 3,280 ft (10 to 1,000 m) in height) are registered with the Federal Communications Commission Antenna Structure Registration database (FCC Undated), some of which have caused large numbers of avian collision mortalities (Able 1973; Kemper 1996; Crawford and Engstrom 2001). Most large mortality events occur at night during spring and fall migration periods and involve songbirds that appear to become confused by tower lights (Taylor and Kershner 1986; Larkin and Frase 1988; Manville 2005). For example, at a single television tower in northern Florida, Crawford and Engstrom (2001) reported more than 44,000 bird collision mortalities over a 29-year period. Communication towers involved with the most bird collisions are tall (exceeding 1,000 ft [305 m]), illuminated at night with incandescent lights, guyed, and located near wetlands and migration pathways (Manville 2005). During nights of heavy cloud cover or fog, the incandescent lights illuminating the communication towers may attract migrating songbirds to the towers, increasing the likelihood of collisions.

**Table 4.6-2 Estimated Annual Bird Collision Mortality in the United States**

| Objects | Estimated Annual Mortality (in millions)[(a)] |
|---|---|
| Buildings and windows[(b)] | 365 to 988 |
| Vehicles[(c)] | 89 to 340 |
| Transmission lines[(d)] | 12 to 64 |
| Communication towers[(e)] | 6.8 |
| Wind generation facilities[(f)] | 0.415 to 1.4[(g)] |

(a) Estimated annual mortality was extrapolated from literature reviews.
(b) Includes residences, low-rises, and high-rises. Source: Loss et al. 2014.
(c) Includes automobiles on U.S. roadways. Source: Loss et al. 2014.
(d) Includes all electric communication lines and transmission lines. Source: Loss et al. 2014.
(e) Includes mortality estimates from communication towers in Canada. Source: Longcore et al. 2012.
(f) Includes wind turbines and supporting structures.
(g) Based on projections from two studies (Smallwood et al. 2020 and Erickson et al. 2014).

Compared to communication towers, cooling towers at nuclear power plants are shorter (generally less than 500 ft [152 m]), which may reduce the likelihood that migrating birds would encounter cooling towers while in flight. Mechanical draft cooling towers, which are smaller (usually shorter than 100 ft [30 m]), are thought to cause negligible mortality (NRC 1996). Cooling towers are usually illuminated with low-intensity light sources (1.0 ft-candle or less) at night, although it is unknown whether this attracts or detracts birds. Several nuclear power plants with natural draft cooling towers have studied bird mortality, including plants within three of the four major United States flyways. These include plants in the Atlantic Flyway (Susquehanna, Beaver Valley, and Three Mile Island [no longer operating] in Pennsylvania), Mississippi Flyway (Davis-Besse in Ohio and Arkansas Nuclear One [Arkansas] in Arkansas), and Pacific Flyway (Trojan [no longer operating] in Oregon).

At the Susquehanna plant, researchers conducted bird mortality surveys during spring and fall migration from 1978 through 1986. The plant's natural draft towers are 165 m (540 ft) tall and illuminated with 480V aircraft warning strobe lights. Researchers collected about 1,500 dead birds representing 63 species during monitoring whose deaths were likely attributable to collisions with the cooling towers. Most were songbirds. Fewer collisions occurred after Susquehanna began commercial operations; researchers considered that cooling tower vapor plumes and noise may have discouraged birds from entering the area (NRC 1996).

At the Davis-Besse plant, researchers conducted bird mortality surveys during spring and fall migration from 1972 to 1979. During this period, early morning surveys were conducted almost daily at the 152 m tall (499 ft tall) cooling tower. Researchers collected 1,561 dead birds, including 1,229 at the cooling tower, 224 around Unit 1 structures, and 108 at the meteorological tower. Notably, after the cooling tower began operating in the fall of 1976, some dead birds were discovered in the water outlets of the tower basin. Most mortalities were of night-migrating songbirds, particularly wood-warblers (family Parulidae), vireos (*Vireo* species), and kinglets (*Regulus* species). Waterfowl, which were abundant in nearby marshes and ponds, suffered little collision mortality. Most collision mortalities at the cooling tower occurred during years when the tower was not well illuminated. After the completion of Unit 1 structures and installation of many safety lights around the buildings in the fall of 1978, collision mortality significantly decreased. Observed mortalities averaged 236 per year from 1974 through 1977, 135 in 1978, and 51 in 1979. This reduction was attributed to low-intensity light sources (1.0 ft-candle or less) that illuminated the cooling tower at night. Researchers concluded that lights at nuclear power plants more successfully detract birds than do lights on communication towers (NRC 2015e).

At the Fermi plant, researchers studied bird strikes from 2005 to 2014. The highest number of bird strikes occurred in October 2007 when researchers found a total of 45 dead birds near the south cooling tower (approximately 400 ft (122 m) tall) in a 1-week period. The licensee conducted 2 years of followup monitoring in 2008 and 2009 to further investigate the numbers and species of birds colliding with nuclear power plant structures. During this period, researchers collected 31 dead birds and no more than 4 in any given week (NRC 2016c).

At the Beaver Valley plant, researchers conducted surveys at the cooling tower during spring and fall migration from 1974 to 1978. Researchers collected 27 dead birds over the five-year period. At the Trojan plant (no longer operating) researchers conducted weekly surveys in 1984 and 1988 at the cooling tower, meteorological tower, switchyard, and generation building. No dead birds were found. At the Three Mile Island plant, researchers collected 66 dead birds near the cooling towers from 1973 to 1975. No dead birds were found at the Arkansas plant, where cooling tower monitoring was conducted twice weekly from October through April from 1978 to 1980 (NRC 2013a).

The available data on bird collision mortality associated with nuclear power plant cooling towers and other structures suggest that nuclear power plants cause a small number of bird mortalities annually. A large percentage of these mortalities occur during the spring and fall migratory periods and primarily involve songbirds migrating at night. Natural draft cooling towers appear to be the structures that pose the largest collision risk at nuclear power plant sites. Operating cooling towers appear to detract birds; the vapor plume, noise, or lighting may mitigate the risk of bird collision. Data are not available on bird injuries, but the NRC staff assumes that some birds that collide with nuclear power plant structures are injured and either die later or suffer reduced fitness until they recover. The relatively few nuclear power plants in the United States that have natural draft towers, combined with the relatively low bird mortality at studied sites, indicate that bird populations are unlikely to be measurably affected by collisions with nuclear power plant structures and that the contribution of nuclear power plant sites to the cumulative effects of bird collision mortalities in the United States is very small.

The risk of bird collisions with site structures would remain the same for a given nuclear power plant during an initial LR or SLR period. Because the number of associated bird mortalities is small for any species, it is unlikely that losses would threaten the stability of local or migratory bird populations or result in a noticeable impairment of the function of a species within the ecosystem. Mitigation measures to reduce bird collisions may include illuminating natural draft cooling towers and other tall structures at night with low-intensity lights so that birds can see the structures and avoid colliding with them.

The potential for birds to collide with transmission lines depends on a number of factors, such as species, migration behavior, and the location and physical characteristics of the transmission line (Bevanger 1988; Janss 2000; Manville 2005). Larger-bodied bird species such as raptors are more likely to collide with transmission lines (Harness and Wilson 2001; Manville 2005), whereas smaller-bodied birds such as migrating songbirds are more likely to collide with towers (Temme and Jackson 1979). This difference is most likely the result of differences in the behaviors of raptors and songbirds. Raptors are known to use utility structures as perch locations and nest sites more often than do songbirds (Blue 1996; Manville 2005), whereas nocturnal migrating songbirds may become confused by the lights on communication towers

(Crawford and Engstrom 2001). Lights are not a contributing factor in bird collisions at transmission lines because lights are not generally used to mark transmission lines.

Transmission lines cause 12 million to 64 million bird mortalities per year (see Table 4.6-2). However, no nuclear power plants have reported high bird collision mortality associated with in-scope transmission lines. In a 1974 through 1978 study conducted at the Prairie Island plant, a total of 453 bird deaths were attributed to collisions with transmission lines; most collisions occurred during inclement weather (NRC 1996). Researchers collected dead mourning doves (*Zenaida macroura*), starlings (family Sturnidae), red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscula*), brown-headed cowbirds (*Molothrus ater*), ring-necked pheasants (*Phasianus colchicus*), American coots (*Fulica americana*), and sora rails (*Porzana carolina*) (NSP 1978). This study was conducted along large tracts of transmission lines constructed to connect the Davis-Besse plant to the regional electric grid upon initial operation. As described in Section 3.1.6.5 and further in Section 3.1.1, transmission lines relevant to initial LR or SLR include only those lines that connect the nuclear power plant to the first substation that feeds into the regional power distribution system. This substation is frequently, but not always, located on the plant property. Many of the transmission lines that were constructed with nuclear power plants are now interconnected with the regional electric grid and would remain energized regardless of license renewal. Thus, the length of transmission lines directly associated with nuclear power plants is a small fraction of the total length of transmission lines in the United States (Manville 2005). Therefore, transmission lines associated with nuclear power plants are likely responsible for a negligible number of bird collision mortalities per year.

The risk of bird collisions with transmission lines associated with nuclear power plants would remain the same for a given nuclear power plant during an initial LR or SLR period. Because the number of associated bird mortalities is negligible for any species, it is unlikely that losses would threaten the stability of resident or migratory bird populations or result in a noticeable impairment of the function of a species within the ecosystem.

Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and license renewal on birds would be similar. For these reasons, the effects of bird collisions with plant structures and transmission lines would be minor and would neither destabilize nor noticeably alter any important attribute of bird populations during initial LR or SLR terms at nuclear power plants. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The NRC concludes that the impacts of bird collisions with plant structures or transmission lines during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants. This is a Category 1 issue.

##### *4.6.1.1.6 Water Use Conflicts with Terrestrial Resources (Plants with Cooling Ponds or Cooling Towers Using Makeup Water from a River)*

This issue concerns water use conflicts that may arise at nuclear power plants with cooling ponds or cooling towers that use makeup water from a river and how those conflicts could affect terrestrial resources during an initial LR or SLR term.

In the 1996 and 2013 LR GEISs, the NRC determined that the impacts of water use conflicts on terrestrial resources would be SMALL at many nuclear power plants but that these impacts could be MODERATE at some plants. Therefore, this was considered a Category 2 issue for nuclear power plants with cooling ponds or cooling towers using makeup water from a river. The 1996 LR GEIS addressed cooling towers that withdraw water from small rivers with low flow; the 2013 LR GEIS expanded this issue to include all cooling towers that withdraw water from rivers. Notably, this issue also applies to nuclear power plants with hybrid cooling systems that withdraw makeup water from a river (i.e., once-through cooling systems with helper cooling towers) (e.g., NRC 2020g).

Nuclear power plant cooling systems may compete with other users relying on surface water resources, including downstream municipal, agricultural, or industrial users. Closed-cycle cooling is not completely closed because the system discharges blowdown water to a surface water body and withdraws water for makeup of both the consumptive water loss due to evaporation and drift (for cooling towers) and blowdown discharge. For plants using cooling towers, while the volume of surface water withdrawn is substantially less than once-through systems for a similarly sized nuclear power plant, the makeup water needed to replenish the consumptive loss of water to evaporation can be significant. Cooling ponds also require makeup water. Section 4.5.1 addresses factors relevant to water use conflicts at nuclear power plants in detail. Water use conflicts with terrestrial resources, especially riparian communities, could occur when water that supports these resources is diminished by a combination of anthropogenic uses.

Consumptive use by nuclear power plants with cooling ponds or cooling towers using makeup water from a river during the license renewal term is not expected to change unless power uprates, with associated increases in water use, occur. Such uprates would require separate NRC review and approval. Any river, regardless of size, can experience low-flow conditions of varying severity during periods of drought and changing conditions in the affected watershed, such as upstream diversions and use of river water. However, the direct impacts on instream flow and potential water availability for other users from nuclear power plant surface water withdrawals are greater for small (i.e., low-flow) rivers.

To date, the NRC has identified water use conflicts with terrestrial resources at only one nuclear power plant: Wolf Creek plant in Kansas. This plant uses Coffee County Lake for cooling, and makeup water for the lake is drawn from the Neosho River downstream of John Redmond Reservoir (NRC 2008a). The Neosho River is a small river with especially low water flow during drought conditions. Riparian communities downstream of this reservoir may be affected by Wolf Creek makeup water withdrawals from the Neosho River during periods when the lake level is low. During the license renewal review, the NRC found that water use conflicts would be SMALL to MODERATE for this nuclear power plant. As part of the NRC's ESA consultation with the FWS, Wolf Creek developed and implemented a water level management plan for Coffey County Lake, which includes withdrawing makeup water proactively during high river flows to support downstream populations of the federally endangered Neosho madtom (*Noturus placidus*), a small species of catfish (FWS 2012). This plan effectively mitigated not only water use conflicts that the Neosho madtom might experience, but also the effects that downstream riparian communities might experience from the plant's cooling water withdrawals. The NRC has identified no concerns about water use conflicts with terrestrial resources at any other nuclear power plant with cooling ponds or cooling towers.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. In summary, water use conflicts during an initial LR or SLR term depend on numerous site-specific factors, including the ecological setting of the nuclear power plant; the consumptive use of other municipal, agricultural, or industrial water users; and the plants and animals present in the area. Water use conflicts with terrestrial resources would be SMALL at most nuclear power plants with cooling ponds or cooling towers that withdraw makeup from a river, but may be MODERATE at some plants. Therefore, a generic determination of potential impacts on terrestrial resources from continued operations during a license renewal term is not possible.

The NRC concludes that water use conflicts on terrestrial resources during the license renewal term (initial LR or SLR) could be SMALL or MODERATE at nuclear power plants with cooling ponds or cooling towers using makeup water from a river. This is a Category 2 issue.

*4.6.1.1.7 Transmission Line Right-of-Way (ROW) Management Impacts on Terrestrial Resources*

This issue concerns the effects of transmission line ROW management on terrestrial plants and animals during an initial LR or SLR term.

In the 1996 and 2013 LR GEISs, the NRC determined that transmission line ROW maintenance impacts would be SMALL at all nuclear power plants. Therefore, this was considered a Category 1 issue for all nuclear power plants. The 1996 LR GEIS evaluated this issue as two separate issues; the 2013 LR GEIS consolidated them into one issue.

When this issue was originally contemplated in the 1996 LR GEIS, the NRC considered as part of its plant-specific license renewal reviews all transmission lines that were constructed to connect a nuclear power plant to the regional electric grid. However, in the 2013 GEIS, the NRC clarified that the transmission lines relevant to license renewal include only the lines that connect the nuclear power plant to the first substation that feeds into the regional power distribution system (see Section 3.1.6.5 and 3.1.1). Typically, the first substation is located on the nuclear power plant property within the primary industrial-use area. This decision was informed by the fact that many of the transmission lines that were constructed with nuclear power plants are now interconnected with the regional electric grid and would remain energized regardless of initial LR or SLR. Accordingly, the discussion of this issue in this LR GEIS is brief because in-scope transmission lines for license renewal tend to occupy only industrial-use or other developed portions of nuclear power plant sites. Therefore, effects on terrestrial plants and animals are generally negligible. The 1996 and 2013 LR GEISs provide further background about this issue and discuss it in more detail.

Utilities maintain transmission line ROWs so that the ground cover is composed of low-growing herbaceous or shrubby vegetation and grasses. Generally, ROWs are initially established by clear-cutting during transmission line construction and are subsequently maintained by physical (e.g., mowing and cutting) and chemical (e.g., herbicides or pesticides) means. These activities alter the composition and diversity of plant communities and generally result in lower-quality habitat for wildlife. Heavy equipment used for ROW maintenance can crush vegetation and compact soils, which can affect soil quality and reduce infiltration to shallow groundwater. This is especially of concern in sensitive habitats, such as wetlands. Chemical herbicides can be transported to neighboring undisturbed habitats through precipitation and runoff. Disturbed habitats often favor non-native or nuisance species and can lead to their proliferation.

Noise and general human disturbance during ROW management can temporarily disturb wildlife and affect their behaviors. The presence of ROWs can favor wildlife species that prefer edge or early successional habitats. Some species, such as neotropical migrating songbirds that prefer interior forest habitat may be adversely affected by the increase in edge habitat. These species require large blocks of forest for successful reproduction and survival (Wilcove 1988). Studies have found that nests of these bird species placed near edges are more likely to fail as a result of predation or nest parasitism than nests located near the forest interior (Paton 1994; Robinson et al. 1995). Transmission line ROWs may represent a barrier for species, such as large mammalian carnivores, that require large tracts of contiguous forested habitat (Crooks 2002). Maintenance of ROWs may also have negative effects on smaller, less mobile wildlife species. For example, studies have shown that some amphibian species have difficulty crossing disturbed habitat and may experience increased rates of mortality as a result of physiological stress (Gibbs 1998; Rothermel 2004). Other wildlife may benefit from ROW habitat. For instance, in a study of rodent populations in Oregon, Wolff et al. (1997) found higher densities of gray-tailed voles (*Microtus canicaudus*) in disturbed open habitats than in other habitats.

Most nuclear power plants maintain procedures to minimize or mitigate the potential impacts of ROW management. For instance, heavy machinery and herbicide use is often prohibited in or near wetlands or surface waters. Procedures often include checklists to ensure that workers obtain the necessary local, State, or Federal permits if work could affect protected resources. At the Millstone Power Station (Millstone) in Connecticut, mowing is conducted only from November through April to protect saturated soils and minimize loss of fruit and seeds (NRC 2005d). At the Seabrook plant in New Hampshire, workers are trained to recognize Federally or State-protected species to avoid impacts on them (NRC 2015b). At Browns Ferry Nuclear Plant (Browns Ferry) in Alabama, all vegetation clearing in sensitive habitats is done by hand, and vehicle and machinery use is prohibited (NRC 2005b).

Terrestrial communities in transmission line ROWs have been exposed to many years of transmission line operation and have acclimated to regular ROW maintenance. License renewal would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and license renewal on terrestrial resources would be similar. Further, and as stated above, in-scope transmission lines for license renewal tend to occupy only industrial-use or other developed portions of nuclear power plant sites and, therefore, the effects of ROW maintenance on terrestrial plants and animals during an initial LR or SLR term would be negligible. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term.

The NRC concludes that the transmission line ROW maintenance impacts on terrestrial resources during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants. This is a Category 1 issue.

##### *4.6.1.1.8 Electromagnetic Field Effects on Terrestrial Plants and Animals*

This issue concerns the effects of EMFs on terrestrial plants and animals, including agricultural crops, honeybees, wildlife, and livestock, during an initial LR or SLR term.

In the 1996 and 2013 LR GEISs, the NRC determined that the impacts of EMFs on terrestrial plants and animals would be SMALL at all nuclear power plants. Therefore, this was considered a Category 1 issue for all nuclear power plants. This LR GEIS refines the title of this issue from “electromagnetic fields on flora and fauna (plants, agricultural crops, honeybees, wildlife, livestock)” to “electromagnetic fields on terrestrial plants and animals” for clarity and consistency with other ecological resource LR GEIS issue titles.

When this issue was originally contemplated in the 1996 LR GEIS, the NRC considered as part of its plant-specific license renewal reviews all transmission lines that were constructed to connect a nuclear power plant to the regional electric grid. However, in the 2013 LR GEIS, the NRC clarified that the transmission lines relevant to license renewal include only the lines that connect the nuclear power plant to the first substation that feeds into the regional power distribution system (see Section 3.1.6.5 and 3.1.1). Typically, the first substation is located on the nuclear power plant property within the primary industrial-use area. This decision was informed by the fact that many of the transmission lines that were constructed with nuclear power plants are now interconnected with the regional electric grid and would remain energized regardless of initial LR or SLR. Accordingly, the discussion of this issue in this LR GEIS is brief because in-scope transmission lines for license renewal tend to occupy only industrial-use or other developed portions of nuclear power plant sites. Therefore, the effects of EMFs on terrestrial plants and animals are generally negligible. The 1996 and 2013 LR GEISs provide further background about this issue and discuss it in more detail.

Operating transmission lines produce electric and magnetic fields, collectively referred to as EMFs. EMF strength at the ground level varies greatly but is generally stronger for higher-voltage lines. Corona is the electrical discharge occurring in air from EMFs; it can be detected adjacent to phase conductors. Corona is generally not an issue for transmission lines of 345 kV or less. Corona results in audible noise, radio and television interference, energy losses, and ozone and nitrogen oxide production. Studies investigating the effects of EMFs produced by operating transmission lines up to 1,100 kV have generally not detected any ecologically significant impact on terrestrial plants and animals.

Miller (1983) determined that minor damage to plant foliage and buds can occur from corona-related heat. Exhibited damage is like what plants might exhibit in response to drought. In one experiment under an 1,100 kV prototype line, alder (*Alnus* species) and Douglas fir (*Pseudotsuga menziesii*) trees exhibited reduced upward growth (Rogers et al. 1984). The crowns of the trees became somewhat flattened on top and the overall crown developed a broader appearance than usual. Growth of the lower parts of the trees and of lower-growing plants, such as pasture grass, barley, and peas, were unaffected (Rogers and Hinds 1983). Studies of agricultural crops, including corn, bluegrass, alfalfa, and sunflower, have detected no effects or minor effects that did not ultimately affect germination or crop yield (Bankoske et al. 1976; Lee et al. 1989; Poznaniak and Reed 1978).

The literature on the effect of EMF on wildlife is somewhat mixed, although most studies have detected virtually no concern about the impacts of EMFs on animals. For instance, Kroodsma (1984, 1987) found that the density of breeding birds under 500 kV lines in eastern Tennessee is greater than that in adjacent forests and in most grassland habitats or agricultural fields. A Minnesota study of a 500 kV line found little evidence of either a positive or negative effect of the power line on bird populations (Niemi and Hanowski 1984). Schreiber et al. (1976) as cited in the 2013 LR GEIS found that the density of small mammal populations near transmission lines appears to depend on habitat type rather than on the presence of the lines. Bird and small mammal populations under an 1,100 kV line in Oregon were also apparently unaffected by line operation (Rogers and Hinds 1983). In a review of numerous studies on livestock, Lee et al. (1989) found no evidence that the growth, production, or behavior of beef and dairy cattle, sheep, hogs, or horses are affected by EMFs.

Other studies have observed the impacts of EMFs on animals. They showed that EMFs influence the development, reproduction, and physiology of insects (Greenberg et al. 1981) and mammals (Burchard et al. 1996). Fernie and Reynolds (2005) determined that EMF exposure can alter the behavior, physiology, endocrine system, and the immune function of birds, including passerines, birds of prey, and chickens studied in laboratory and field situations. Nonetheless, birds often nest on transmission line structures. However, on high-voltage lines supported by metal lattice towers, birds usually nest on the top bridge of the tower where EMF strength is minimal (e.g., 5 kV/m or less) (Lee, Jr. 1980). The success of nests on transmission line structures appears to be no different from nests in areas not exposed to EMFs (e.g., Gilmer and Stewart 1983; Lee, Jr. 1980; Steenhof et al. 1993).

Honeybees in hives under transmission lines can suffer increased propolis (a resin-like material produced to build hives) production, reduced growth, greater irritability, and increased mortality (Greenberg and Bindokas 1985; Rogers and Hinds 1983). Bindokas et al. (1988) determined that these impacts were the result of voltage buildup and electric currents within the hives. Bees kept in moisture-free nonconductive conditions were not adversely affected, even in electric fields as strong as 100 kV/m. These effects can also be mitigated by shielding hives with a grounded metal screen or by moving them away from transmission lines (Rogers and Hinds 1983; Lee, Jr. 1980).

Plants and animals near transmission lines have been exposed to many years of transmission line operation and associated EMFs and have acclimated to regular ROW maintenance. Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and initial LR or SLR on terrestrial resources would be similar. Further, and as stated above, in-scope transmission lines for license renewal tend to occupy only industrial-use or other developed portions of nuclear power plant sites and, therefore, the effects of EMF plants and animals during an initial LR or SLR term would be negligible. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The NRC concludes that the effects of EMFs on plants and animals during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants. This is a Category 1 issue.

##### *4.6.1.2 Aquatic Resources*

Continued operation of a nuclear power plant during a license renewal term involves continued cooling water intake system operation, including source water withdrawals and effluent discharges; gaseous and liquid effluent releases; facility upkeep, including transmission line maintenance; and construction or ground-disturbing activities, in cases where license renewal necessitates refurbishment. Aquatic organisms would continue to be subject to the effects of impingement, entrainment, thermal discharges, chemical and radiological contaminants, and erosion and sedimentation.

This section considers the effects that aquatic resources may experience as a result of initial LR or SLR. These issues are as follows:

- impingement mortality and entrainment of aquatic organisms (plants with once-through cooling systems or cooling ponds);[1,2]
- impingement mortality and entrainment of aquatic organisms (plants with cooling towers); [1,2]
- entrainment of phytoplankton and zooplankton; [3]
- effects of thermal effluents on aquatic organisms (plants with once-through cooling systems or cooling ponds);[3]
- effects of thermal effluents on aquatic organisms (plants with cooling towers);[3]
- infrequently reported effects of thermal effluents;[4]
- effects of nonradiological contaminants on aquatic organisms;
- exposure of aquatic organisms to radionuclides;
- effects of dredging on aquatic resources;[3]
- water use conflicts with aquatic resources (plants with cooling ponds or cooling towers using makeup water from a river);
- non-cooling system impacts on aquatic resources; and[3]
- impacts of transmission line right-of-way (ROW) management on aquatic resources.

**Impingement and Entrainment**

Impingement occurs when organisms are trapped against the outer part of an intake structure's screening device (79 FR 48300). The force of the intake water traps the organisms against the screen, and individuals are unable to escape. Impingement can kill organisms immediately or cause exhaustion, suffocation, injury, and other physical stresses that contribute to later mortality. The potential for injury or death is generally related to the amount of time an organism is impinged, its fragility (susceptibility to injury), and the physical characteristics of the screen wash and fish return systems of the intake structure. Because some individuals may survive impingement, this effect is often assessed in terms of impingement mortality. The EPA has found that impingement mortality is typically less than 100 percent if the cooling water intake system includes fish return or backwash systems. Because impingeable organisms are typically fish with fully formed scales and skeletal structures and well-developed survival traits, such as behavioral responses to avoid danger, many impinged organisms can survive under proper conditions.

[1] This issue was modified from the 2013 LR GEIS to address updated regulatory criteria under CWA Section 316(b).
[2] This issue was consolidated to include the impingement component of the 2013 LR GEIS issue, "losses from predation, parasitism, and disease among organisms exposed to sublethal stresses."
[3] Issue retitled from the 2013 LR GEIS for clarity and consistency with other ecological resource issues. No substantive changes to this issue have been made.
[4] Issue consolidated to include the 2013 LR GEIS issue, "effects of cooling water discharge on dissolved oxygen, gas supersaturation, and eutrophication," and the thermal effluent component of the 2013 LR GEIS issue, "losses from predation, parasitism, and disease among organisms exposed to sublethal stresses."

Depending on the configuration of the cooling water intake system, impinged organisms may also become entrapped. Entrapment occurs when impingeable fish and shellfish lack the means to escape the cooling water intake. Entrapment includes but is not limited to organisms caught in the bucket of a traveling screen and unable to reach a fish return; organisms caught in the forebay of a cooling water intake system without any means of being returned to the source water body without experiencing mortality; or cooling water intake systems where the velocities in the intake pipes or in any channels leading to the forebay prevent organisms from being able to return to the source water body through the intake pipe or channel (40 CFR 125.92(j)).

Entrainment occurs when organisms pass through the screening device and travel through the entire cooling system, including the pumps, condenser or heat exchanger tubes, and discharge pipes (79 FR 48300). Organisms susceptible to entrainment are of smaller size, such as ichthyoplankton, meriplankton, zooplankton, and phytoplankton. During travel through the cooling system, entrained organisms experience physical trauma and stress, pressure changes, excess heat, and exposure to chemicals (Mayhew et al. 2000). Because entrainable organisms generally consist of fragile life stages (e.g., eggs, which exhibit poor survival after interacting with a cooling water intake structure, and early larvae, which lack a skeletal structure and swimming ability), the EPA has concluded that, for purposes of assessing the impacts of a cooling water intake system on the aquatic environment, all entrained organisms die (79 FR 48300).

Entrainment susceptibility is highly dependent upon life history characteristics. For example, broadcast spawners with nonadhesive, free-floating eggs that drift with water current may become entrained in a cooling water intake system. Nest-building species or species with adhesive, demersal eggs are less likely to become entrained during their early life stages. The susceptibility of larval life stages to entrainment depends on body morphometrics and swimming ability.

If several life stages of a species occupy the source water, that species can be susceptible to both impingement and entrainment. For instance, adults and juveniles of a given species of fish may be impinged against the intake screens, while larvae and eggs may pass through the screening device and be entrained through the cooling system. The susceptibility to either impingement or entrainment is related to the size of the individual relative to the size of the mesh on the screening device. By definition, the EPA considers aquatic organisms that can be collected or retained on a sieve that has 0.56 in. (1.4 centimeters [cm]) diagonal openings to be susceptible to impingement (79 FR 48300). This equates to screen device mesh openings of 1/2 in. by 1/4 in. (1.3 cm by 0.635 cm), which is slightly larger than the openings on the typical 3/8-in. (0.95-cm) square mesh found at many nuclear power plants. Organisms smaller than the 0.56 in. (1.4 cm) mesh are considered susceptible to entrainment.

The magnitude of impact that impingement mortality and entrainment (IM&E) creates on the aquatic environment depends on the nuclear power plant-specific characteristics of the cooling system as well as characteristics of the local aquatic community. Relevant nuclear power plant characteristics include the location of the cooling water intake structure, intake velocities, withdrawal volumes, screening device technologies, and the presence or absence of a fish return system. Impingement and impingement mortality reduction technologies can greatly reduce the likelihood of impingement mortality of susceptible organisms. Relevant characteristics of the aquatic community include species present in the environment, life history characteristics, population abundances and distributions, special species statuses and designations, and regional management objectives.

The most visible direct impacts of IM&E are the losses of large numbers of aquatic organisms, distributed nonuniformly among fish, benthic invertebrates, phytoplankton, zooplankton, and other susceptible aquatic taxa (e.g., sea turtles). These losses have immediate and direct effects on the population size and age distribution of affected species and may cascade through food webs (79 FR 48300).

**Ichthyoplankton** are early life stages of finfish, including eggs, yolk-sac larvae, and post yolk-sac larvae.

**Meriplankton** are larval stages of shellfish and other macroinvertebrates.

**Zooplankton** are animals that either spend their entire lives as plankton (holoplankton) or exist as plankton for a short time during development (meroplankton).

**Phytoplankton** are single-celled plant plankton and include diatoms (single-celled yellow algae) and dinoflagellates (a single-celled organism with two flagella).

In some cases, IM&E have been shown to be a significant source of anthropogenic mortality of depleted stocks of commercially targeted species. For example, approximately 5.4 percent of the estimated A1E population of the Southern New England/Massachusetts stock of winter flounder (*Pseudopleuronectes americanus*) is lost to IM&E (NEFSC 2011). IM&E also increase the pressure on native freshwater species, such as lake whitefish (*Coregonus clupeaformi*) and yellow perch (*Perca flavescens*), whose populations have seen dramatic declines in recent years (79 FR 48300).

IM&E are also likely to contribute to reduced population sizes of species targeted by commercial and recreational fishers, particularly for stocks that are being harvested at unsustainable levels or that are undergoing rebuilding. Thus, reducing IM&E may lead to more rapid stock recovery, a long-term increase in commercial fish catches, increased population stability following periods of poor recruitment and, as a consequence of increased resource utilization, an increased ability to minimize the invasion of exotic species (Stachowicz and Byrnes 2006).

Table 4.6-3 lists taxa commonly impinged or entrained at nuclear power plants by ecosystem type. Specific species vary by region. For instance, in northeastern estuaries, common herrings (family Clupidae) include alewife (*Alosa pseudoharengus*), blueback herring (*A. aestivalis*), and American shad (*A. sapidissima*). In southeastern estuaries, skipjack herring (*A. chrysochloris*) and threadfin shad (*D. petenense*) are prevalent. Gizzard shad (*D. cepedianum*) are found in estuarine waters all along the eastern coast and the Gulf of Mexico.

**Table 4.6-3 Commonly Impinged and Entrained Taxa at Nuclear Power Plants by Ecosystem Type**

| Family | Common Name | Ocean | Estuaries | Rivers | Great Lakes |
|---|---|---|---|---|---|
| Carangidae | jacks and pompanos | x | - | - | - |
| Centrarchidae | sunfishes and crappies | - | - | x | - |
| Clupeidae | herrings | - | x | x | x |
| Cottoidei | sculpins | - | - | - | x |
| Cyprinidae | carps and minnows | - | - | x | - |

| Family | Common Name | Ocean | Estuaries | Rivers | Great Lakes |
|---|---|---|---|---|---|
| Engraulidae | anchovies | x | x | - | - |
| Ephippidae | spadefishes, batfishes, and scats | x | - | - | - |
| Gobiidae | gobies | x | - | - | - |
| Ictaluridae | catfish | - | x | x | - |
| Lutjanidae | snappers | - | - | - | - |
| Moronidae | temperate basses | - | - | x | - |
| Osmeridae | smelts | - | - | - | x |
| Percidae | perch | - | - | x | x |
| Pleuronectidae | flounders | - | x | - | - |
| Pleuronectiformes | flatfishes | x | - | - | - |
| Sciaenidae | drums and croakers | x | x | x | - |
| Penaeidae | penaeid shrimp | x | - | - | - |
| Portunidae | swimming crabs | x | - | - | - |

No entry has been denoted by “-”.

IM&E are more of a concern at nuclear power plants that withdraw large volumes of water at higher velocities. In general, this means that plants with once-through cooling water intake systems impinge and entrain more organisms than plants with closed-cycle cooling systems, such as cooling towers because the former require more water to operate. The Palisades plant (no longer operating), which lies on Lake Michigan on the Michigan coast, demonstrates this difference. In 1972, the plant began operating with a once-through cooling system. In 1976, the plant transitioned to a closed-cycle system after cooling towers were constructed. An impingement study found that with the once-through cooling system, Palisade withdrew 400,000 gpm and impinged 654,000 fish annually (Consumers Energy Company and Nuclear Management Company 2001 as cited in the 2013 LR GEIS). Once cooling towers were installed, the plant withdrew only 78,000 gpm annually, and impingement dropped to 7,200 fish per year.

Impingement risk is also related to a fish’s ability to avoid the flow of water into the cooling water intake system. Fish swimming speeds are typically characterized as burst, prolonged, or sustained. Burst speeds are the highest speeds a fish can attain over very short periods of time (typically less than 20 seconds). Burst speeds are exhibited when an individual is capturing prey, avoiding a predator, or negotiating high water velocities, such as those associated with riffles and eddies in a fast-flowing river or the draw of a power plant’s intake. Sustained speeds are low speeds fish can maintain indefinitely without fatigue. These speeds are observed during routine activities, including foraging, holding, and schooling. Prolonged (or critical) speeds are those of intermediate endurance that a fish could endure for approximately 20 to 30 minutes before ending in fatigue. If a species’ reported swimming ability indicates that individuals can typically swim faster than a nuclear power plant’s intake velocity, the species would exhibit a low likelihood of being impinged. Certain species may not be capable of maintaining a sustained speed that would allow escape from an intake velocity, but an individual could swim in a burst to avoid impingement. Many fish can avoid becoming impinged when intake velocities are less than 0.5 feet per second (fps) (0.15 meters per second [m/s]). As discussed below, the EPA has established this rate as one of the impingement mortality CWA Section 316(b) compliance options for existing facilities.

At the Turkey Point plant in Florida, the NRC found that all fish in the CCS would be susceptible to impingement due to the 4.5 fps (1.4 m/s) intake velocity (NRC 2019c). Documented burst speeds of the three known species in the canal system—sheepshead minnow (*Cyprinodon variegatus*), sailfin molly (*Poecilia latipinna*), and eastern mosquitofish (*Gambusia holbrooki*)—were all significantly less than this value. Depending on the ecosystem of the source water, however, fish may be capable of navigating much higher flows than 0.5 fps (0.1-5 m/s) because the environment they live in requires this capacity. For instance, unimpounded rivers can flow at several feet per second during high seasonal flows. Fish and other aquatic organisms in these rivers are likely already navigating waters of higher velocities than the draw of a cooling water intake system, and this physiological capability of local populations reduces the risk of impingement.

Intake velocities and swimming ability is not relevant to entrainment because early life stages of fish and other organisms susceptible to entrainment are either not motile or are semi-motile. Therefore, all organisms in the water column from which a cooling water intake structure draws water are susceptible to entrainment. However, some nuclear power plants seasonally reduce water consumption during periods of high entrainment. Several nuclear power plants operate a once-through cooling system but have helper cooling towers that are seasonally operated to reduce thermal load to the receiving water body, reduce entrainment during peak spawning periods, or reduce consumptive water use during periods of low river flow. These seasonal reductions are often conditions of NPDES permits or agreements made with regional water quality control boards. Plants with helper cooling towers include the Dresden plant on the Kankakee River in Illinois, Browns Ferry plant on the Tennessee River in Alabama, Monticello Nuclear Generating Plant (Monticello) and Prairie Island plant on the Mississippi River in Minnesota, Peach Bottom plant on Conowingo Pond in Pennsylvania, and Sequoyah plant on the Chickamauga Reservoir in Tennessee.

IM&E often varies by season. Impingement can occur year-round, but it is often correlated with seasonal movements and migrations of species, especially for plants located on estuaries and bays. Entrainment is primarily of concern in the spring and summer when many species spawn and early life stages of fish are present in the water column. For instance, Surry withdraws cooling water from the James River in Virginia at the transitional zone between the tidally influenced freshwater river upstream and the saline estuary downstream. Because of its location, freshwater, estuarine, and marine fishes may all be found in the river near the plant depending on season and salinity conditions. The local finfish community includes permanent residents that occur year-round and diadromous species that pass through the region seasonally during migrations to and from spawning grounds. Therefore, impingement frequency for many migrating species is expected to be highly seasonal. Impingement studies confirm this assumption. During impingement studies conducted at the plant, spot (*Leiostomus xanthurus*) and Atlantic menhaden (*Brevvortia tyrannus*) impingement was highest in summer and early fall, which correlates with the seasonal movements of juveniles between oceanic spawning grounds, inshore nurseries, and overwintering areas (NRC 2020f). In contrast, white perch (*Morone americana*), blueback herring, and threadfin shad were primarily impinged in late fall and winter. Bay anchovy (*Anchoa mitchilli*) and Atlantic croaker (*Micropogonias undulatus*) impingement was prominent only in the spring. The catfishes (*Ictalurus* and *Pylodictis* species), which are resident species, were impinged at relatively constant levels throughout the year. At Point Beach plant on Lake Michigan in Wisconsin, approximately 96 percent of estimated impingement occurs from late April through early August, which mirrors the annual die-offs of alewife in the lake as well as the species' offshore/onshore movement patterns (NextEra Energy 2021; NRC 2021f). Alewife accounts for more than 99 percent of impingement at this plant annually. Entrainment is also highly seasonal at Point Beach. Several studies have observed that fish eggs and larvae are entrained in highest densities from early June to early August. Rainbow smelt (*Osmerus mordax*) dominate the early sample period, while burbot (*Lota lota*) become more abundant in the mid-season, correlating with these species' spawning habits (NextEra Energy 2021; NRC 2021f). The 2013 LR GEIS discusses several additional examples of seasonal impingement at the Quad Cities plant in Illinois, McGuire plant in North Carolina, and Summer plant in South Carolina.

If a facility withdraws cooling water farther from shore, at greater depths, or otherwise in a less biologically productive area of the source water, IM&E may be less than if the facility were to withdraw water from elsewhere in the water body. In many water bodies, cooling water withdrawal from shoreline locations can result in greater environmental impacts because shoreline areas are typically the most biologically productive waters and contain a high density of early life stage organisms. The lowest potential for impingement and entrainment is often at far offshore locations at distances of several hundred feet (79 FR 48300). Although offshore areas may exhibit a lower density of organisms, the species found will also change as a function of the distance of the intake from the shoreline and the depth of the intake within the water column. Thus, the assemblage of impingeable and entrainable organisms, in addition to the sheer number of organisms, changes with distance from the shoreline. At the Point Beach plant, fish and other aquatic organisms in the source water first interact with the cooling water intake system at an intake crib that lies 1,750 ft (533 m) offshore at an approximate depth of 22 ft (7 m) below the lake's surface (NRC 2021f). A study conducted in 2007 determined that the offshore location of Point Beach's intake reduces impingement by 79 percent and entrainment by 89 percent relative to if the intake were to be located in the shallow nearshore waters of Lake Michigan (NextEra Energy 2021). At the LaSalle plant on the Illinois River in Illinois, estimated annual entrainment is 38 million organisms (EA Engineering 2015). However, researchers estimated that this rate is 28 to 38 percent of annual entrainment at the Dresden plant, which is located downstream at the confluence of the Kankakee and Illinois Rivers in a more biologically rich region.

Some nuclear power plants have exclusion technologies that divert organisms that would have otherwise been subject to impingement and entrainment away from the intake. Collection and return technologies allow organisms to be impinged, but these technologies collect and return the organisms to the source water, thereby reducing or preventing impingement mortality. Collection and return technologies do not affect entrainment. The Surry plant's cooling water intake system includes a fish return system that returns impinged fish to the James River. The system includes continuously rotating Ristroph traveling screens, low-pressure spray washes, steel fish buckets, and a return trough. Researchers determined that 56 of the 70 taxa impinged at Surry during a 2015–2016 study exhibited an impingement survival rate of 70 percent or greater (HDR 2017). This included many species that the EPA defines as fragile, such as Atlantic menhaden and gizzard shad. The NRC staff calculated impingement mortality for all taxa (fragile and nonfragile) at Surry to be between 2.03 percent (using 2015–2016 data) and 5.60 percent (1974–1978 data), which demonstrates the effectiveness of the fish return system (NRC 2020f). The Columbia plant, which lies on the Columbia River in Washington, is equipped with cylindrical intake screens, which could hydraulically deflect fish and stimulate the fish's behavior to avoid the intake screens. Thus, there is low likelihood of impingement and entrainment in nearly all river flow and direction cases due to the generally high ratio of tangential (sweeping) flow to normal (approach) flow toward the screens (Anchor QEA, LLC 2020).

Impinged organisms that are returned to the source water body may experience stunning, disorientation, or injury. These sublethal effects can subsequently affect an organism's susceptibility to predation, parasitism, or disease. The 1996 and 2013 LR GEISs reported that neither scientific literature reviews nor consultations with agencies or utilities yielded clear evidence of sublethal effects on fish or finfish resulting in noticeable increases in impinged organisms' susceptibility to predation, parasitism, or disease. Since the publication of the 2013 LR GEIS, the NRC has determined that the impacts of impingement and entrainment at four nuclear power plants with once-through cooling systems or cooling ponds could be SMALL to MODERATE (2 plants), MODERATE (1 plant), or SMALL to LARGE (1 plant) during the license renewal term (see Table 4.6-4). However, increased susceptibility to predation, parasitism, or disease or predation resulting from impingement was not found to be an issue in any of these reviews. The available information indicates that these secondary impacts of impingement are not expected to be of concern during initial LR or SLR terms at any nuclear power plants. As stated earlier in this section, because entrainable organisms generally consist of fragile life stages, all entrained organisms are assumed to die (79 FR 48300). Therefore, sublethal effects of entrainment do not apply.

At some nuclear power plants, marine reptiles and marine mammals can be impinged or entrained by the cooling water intake system in addition to finfish and shellfish. For instance, at the Salem plant in New Jersey, sea turtles from the Delaware Estuary can become impinged in the trash bars. When discovered, plant personnel remove the sea turtles and assess their condition. Live, healthy turtles are returned to the estuary. At St. Lucie Nuclear Plant (St. Lucie) in Florida, sea turtles and other marine organisms can enter one of three intake pipes located in the Atlantic Ocean and be drawn into the intake canal where they become entrapped. Because marine organisms that enter the intake canal cannot return to the ocean on their own, divers capture sea turtles, transport them over the beach dunes, and release them back to the ocean. Injured or sick sea turtles are sent to a rehabilitation facility. Sea turtle impingement or entrainment has also occurred at the Diablo Canyon plant and San Onofre plant (no longer operating) on the Pacific Ocean in California; Oyster Creek plant (no longer operating) on Barnegat Bay in New Jersey; Brunswick Steam Electric Plant (Brunswick) on the Cape Fear River estuary in Virginia, and Crystal River Nuclear Power Plant (Crystal River) (no longer operating) on the Gulf Coast in Florida. Sea turtles are federally protected under the ESA. Sections 3.6.3 and 4.6.1.3 address these species.

At Seabrook on the Gulf of Main in New Hampshire, harbor (*Phoca vitulina*), gray (*Halichoerus grypus*), harp (*Pagophilus groenlandicus*), and hooded (*Cystophora cristata*) seals have been entrained into the intake tunnels. From 1993 through 1998, approximately 55 seals drowned from entrainment into the intake tunnels. In 1999, following coordination with NMFS, the plant installed seal deterrents that included vertical barriers on each of the three intake structures that reduced the vertical spacing of the bars to less than 5 in. (13 cm) (NRC 2015b). Since installment of these barriers, no seals have been entrained at Seabrook (NRC 2015b). At Diablo Canyon, several California sea lions (*Zalophus californianus*) and harbor seals and one elephant seal (*Mirounga angustirostris*) have become entrapped in the cooling water intake system. All of the California sea lions and harbor seals were discovered dead against the intake trash bars or in one of the traveling screen forebays, and plant personnel removed the carcasses from the intake structure in accordance with Diablo Canyon's Marine Mammal Protection Act letter of authorization (PG&E 2007, PG&E 2008a, PG&E 2008c, PG&E 2008d, PG&E 2009a, PG&E 2009b, PG&E 2014a, PG&E 2014b, PG&E 2015a, PG&E 2015b, PG&E 2015c). Most of these animals were in some state of decomposition, and their deaths were not attributed to plant operation. The elephant seal, a juvenile, was discovered in a recess between concrete tri-bars on the intake cover breakwater; plant personnel successfully returned it to the intake cove (PG&E 2008b). The Diablo Canyon plant has not reported any marine mammal impingements or strandings since 2015.

Table 4.6-4 summarizes the results of the NRC's impingement and entrainment analyses for initial LR and SLR environmental reviews conducted since the 2013 LR GEIS was published. The 2013 LR GEIS discusses impingement and entrainment findings from reviews prior to 2013 and includes many additional examples relevant to this issue.

**Table 4.6-4 Results of NRC Impingement and Entrainment Analyses at Nuclear Power Plants, 2013–Present**

| Nuclear Power Plant | Cooling System Type | Cooling Water Source | Impingement and Entrainment Conclusion |
|---|---|---|---|
| Braidwood | Cooling pond | Constructed cooling pond with makeup water from the Kankakee River | SMALL to MODERATE(a) |
| Byron | Cooling towers (ND) | Rock River | SMALL |
| Callaway | Cooling towers (ND) | Missouri River | SMALL |
| Davis-Besse | Cooling towers (ND) | Lake Erie | SMALL |
| Fermi | Cooling towers (ND) | Lake Erie | SMALL |
| Grand Gulf | Cooling towers (ND) | Mississippi River | SMALL |
| Indian Point(b) | Once-through | Hudson River | MODERATE(c) |
| LaSalle | Cooling pond | Constructed cooling pond with makeup from the Illinois River | SMALL |
| Limerick | Cooling towers (ND) | Schuylkill River | SMALL |
| North Anna(d) | Cooling pond | Lake Anna | SMALL |
| Peach Bottom(d) | Hybrid: once-through (Unit 2); once-through and cooling towers (MD) (Unit 3) | Conowingo Pond | SMALL |
| Point Beach(d) | Once-through | Lake Michigan | SMALL |
| River Bend | Cooling towers (MD) | Mississippi River | SMALL |
| Seabrook | Once-through | Gulf of Maine | SMALL to LARGE(e) |
| Sequoyah | Hybrid: once-through and cooling towers (ND) | Chickamauga Reservoir | SMALL |
| South Texas | Cooling pond | Constructed cooling reservoir with makeup water from the Colorado River | SMALL |
| Surry(b) | Once-through | James River | SMALL |
| Turkey Point(b) | Cooling pond | Constructed CCS with makeup from the Upper Floridan aquifer | SMALL to MODERATE(f) |
| Waterford | Once-through | Mississippi River | SMALL |

MD = mechanical draft; ND = natural draft; CCS = cooling canal system.

(a) Impingement and entrainment effects would be SMALL for aquatic resources in the Kankakee River as a whole. Impacts on cyprinids, especially uncommon cyprinids (pallid shiner [*Notropis amnis*], mimic shiner [*N. volucellus*], and ghost shiner [*N. buchanani*]); darters; and *Percina* species would be MODERATE. The NRC cannot make a

determination on the impact of impingement and entrainment on the aquatic resources in the cooling pond because no studies exist on impingement and entrainment at the lake screen house.
(b) This evaluation was a part of a review that supplemented the NRC's final SEIS.
(c) While most aquatic organisms would experience SMALL effects, some would experience noticeable effects as a result of impingement and entrainment. These organisms include blueback herring, rainbow smelt, and hogchoker (*Trinectes maculatus*).
(d) This review evaluated a subsequent license renewal term.
(e) Impingement and entrainment would be SMALL for most aquatic resources in the Gulf of Maine. Impacts on winter flounder would be LARGE because monitoring data indicate that the abundance of winter flounder has decreased to a greater and observable extent near the Seabrook plant compared to reference sites. The local decrease suggests that local subpopulations of this species have been destabilized through operation of Seabrook's cooling water system.
(f) Impingement and entrainment effects would be SMALL to MODERATE for aquatic organisms of the CCS. Impingement and entrainment do not apply to aquatic organisms in Biscayne Bay and connected water bodies (e.g., Card Sound, the Atlantic Ocean) because these organisms never interact with the Turkey Point intake structure.
Sources: NRC 2013b, NRC 2014d, NRC 2014e, NRC 2014f, NRC 2015b, NRC 2015c, NRC 2015d, NRC 2015e, NRC 2015f, NRC 2016c, NRC 2016d, NRC 2018c, NRC 2018e, NRC 2020f, NRC 2020g, NRC 2021f, NRC 2021g.

IM&E of aquatic organisms would continue throughout the license renewal term for any operating nuclear power plant. The effects of IM&E are discussed below as three issues:

- impingement mortality and entrainment of aquatic organisms (plants with once-through cooling systems or cooling ponds);
- impingement mortality and entrainment of aquatic organisms (plants with cooling towers); and
- entrainment of phytoplankton and zooplankton.

A number of mitigative measures can reduce the effects of IM&E. These include withdrawal of water at rates of 0.5 fps (0.15 m/s) or less, seasonal reductions in intake volume during peak periods of entrainment; locating the cooling water intake system in a less biological productive area of the source water, and use of exclusion technologies or fish return systems. Additionally, Section 316(b) of the CWA addresses these effects and requires that cooling water intake structures of regulated facilities must reflect the best technology available (BTA) for minimizing IM&E, as discussed below.

**Clean Water Act Section 316(b) Requirements for Minimizing IM&E at Existing Facilities**

Section 316(b) of the CWA addresses the adverse environmental impacts caused by the intake of cooling water from waters of the United States. This section of the CWA grants the EPA the authority to regulate cooling water intake structures to minimize adverse impacts on the aquatic environment. In 2014, pursuant to CWA Section 316(b), the EPA issued regulations for existing facilities at 40 CFR 122 and 40 CFR 125, Subpart J (79 FR 48300). Existing facilities include power generation and manufacturing facilities that are not new facilities as defined at 40 CFR 125.83 and that withdraw more than 2 Mgd of water from waters of the United States and use at least 25 percent of the water they withdraw exclusively for cooling purposes.

Under the CWA Section 316(b) regulations, the location, design, construction, and capacity of cooling water intake structures of regulated facilities must reflect the BTA for minimizing IM&E. The EPA, or authorized States and Tribes, impose BTA requirements through NPDES permitting programs.

With respect to impingement mortality, the BTA standard requires that existing facilities comply with one of the following seven alternatives (40 CFR 125.94(c)):

- operate a closed-cycle recirculating system as defined at 40 CFR 125.92(c)
- operate a cooling water intake structure that has a maximum through-screen design intake velocity of 0.5 fps (0.15 m/s)
- operate a cooling water intake structure that has a maximum through-screen intake velocity of 0.5 fps (0.15 m/s)
- operate an offshore velocity cap as defined at 40 CFR 125.92 that is installed before October 14, 2014
- operate a modified traveling screen that the NPDES Permit Director determines meets the definition at 40 CFR 125.92(s) and that the NPDES Permit Director determines is the BTA for impingement reduction at the site
- operate any other combination of technologies, management practices, and operational measures that the NPDES Permit Director determines is the BTA for impingement reduction
- achieve the specified impingement mortality performance standard.

Options 1, 2, and 4 above are essentially preapproved technologies requiring no demonstration or only a minimal demonstration that the flow reduction and control measures are functioning as EPA envisioned. Options 3, 5, and 6 require that more detailed information be submitted to the permitting authority before the permitting authority may specify it as BTA for a given facility. Under Option 7, the permitting authority may also review plant-specific data and conclude that a *de minimis* rate of impingement exists and, therefore, no additional controls are warranted to meet the BTA impingement mortality standard.

With respect to entrainment, the CWA Section 316(b) regulations do not prescribe a single nationally applicable entrainment performance standard because the EPA did not identify a technology for reducing entrainment that is effective, widely available, feasible, and does not lead to unacceptable non-water quality impacts. Instead, the permitting authority must establish the BTA entrainment requirement for each facility on a plant-specific basis. In establishing plant-specific requirements, the regulations direct the permitting authority to consider the following factors (40 CFR 125.98(f)(2)):

- the numbers and types of organisms entrained, including, specifically, the numbers and species (or lowest taxonomic classification possible) of federally listed, threatened and endangered species, and designated critical habitat (e.g., prey base);
- the impact of changes in particulate emissions or other pollutants associated with entrainment technologies;
- the land availability inasmuch as it relates to the feasibility of entrainment technology;
- the remaining useful plant life; and
- the quantified and qualitative social benefits and costs of available entrainment technologies when such information about both benefits and costs is of sufficient rigor to make a decision.

In support of entrainment BTA determinations, facilities must conduct plant-specific studies and provide data to the permitting authority to aid in its determination of whether plant-specific controls would be required to reduce entrainment and which controls, if any, would be necessary.

The NRC considers whether nuclear power plants have implemented BTA when assessing the impacts of IM&E, as discussed below.

**Thermal Impacts**

Thermal impacts associated with thermal effluent discharges from cooling water systems include acute effects, sublethal effects, and community-level effects. Acute effects cause immediate or latent death of aquatic organisms. Sublethal effects include stunning, disorientation, or injury that affect an organism's fitness, behavior, or susceptibility to predation, parasitism, or disease. Community-level effects can include reduced habitat availability or quality and reduced species diversity.

The primary thermal impact of concern at operating nuclear power plants is the acute effect of heat shock. Heat shock occurs when water temperatures meet or exceed the thermal tolerance of a species for some duration of exposure. In most situations, fish can move out of an area that exceeds their thermal tolerance limits, although some aquatic species lack such mobility. Heat shock is typically observable only for finfish, particularly those that float when dead. In addition to heat shock, thermal plumes resulting from thermal effluents can create barriers to fish passage, which is of particular concern for migratory species. Thermal effluents are not as likely to affect shellfish because plumes tend to rise to the surface of the water and shellfish typically inhabit the benthic zone. In addition to having direct effects on aquatic organisms, thermal plumes can also reduce the available aquatic habitat or alter habitat characteristics in a manner that results in cascading effects on the local aquatic community.

The magnitude of thermal impacts on the aquatic environment depends on the plant-specific characteristics of the cooling system as well as the characteristics of the local aquatic community. Relevant plant characteristics include discharge location, temperature of the effluent when it enters the receiving water body, thermal plume characteristics, and any technologies that assist in mixing or otherwise reducing thermal impacts. Relevant characteristics of the aquatic community include the species present in the environment, life history characteristics, population abundances and distributions, special species statuses and designations, and regional management objectives, as well as the characteristics of the receiving water, such as ambient temperatures and typical flow of water near the discharge point.

Thermal effects are more of a concern at nuclear power plants that discharge large volumes of heated effluents. In general, this means that plants with once-through cooling water intake systems or cooling ponds have a larger thermal impact than plants with closed-cycle cooling systems, such as cooling towers, because the former require more water to operate.

Fish kills are an acute thermal effect that is typically observed only at plants with cooling ponds. This may be because heat dissipation of the thermal effluent is limited by the size of the receiving water body and because aquatic organisms in cooling ponds are unable to escape thermal plumes. Many freshwater fish, such as those species that inhabiting cooling ponds, experience thermal stress and can die when they encounter water temperatures at or above 95 °F (35 °C). Fish kills tend to occur when water temperatures rise above this level for some prolonged period of time and fish are unable to tolerate the higher temperatures or cannot retreat into cooler waters. Fish that experience thermal effects within the region of a receiving water body that is thermally affected by a nuclear power plant's effluent discharge are experiencing effects that are, at least in part, attributable to plant operation.

Fish kills have been observed in the summer months at several midwestern plants with cooling ponds, including the Braidwood and LaSalle plants in Illinois. Such events tend to be correlated with periods of high ambient air temperatures, low winds, and high humidity. For instance, six reportable fish kill events occurred in the Braidwood cooling pond from 2001 through 2015. The fish kill events, which occurred in July 2001, August 2001, June 2005, August 2007, June 2009, and July 2012, primarily affected threadfin shad and gizzard shad, although bass, catfish, carp, and other game fish were also affected (NRC 2015d). Reported peak temperatures in the cooling pond during these events ranged from 98.4 °F (36.9 °C) to over 100 °F (37.8 °C), and each event resulted in the death of between 700 to as many as 10,000 fish. During the July 2012 event, cooling pond temperatures exceeded 100 °F (37.8 °C), which resulted in the death of approximately 3,000 gizzard shad and 100 bass, catfish, and carp. This event coincided with the NRC's granting of Enforcement Discretion to allow the Braidwood plant to continue to operate above the technical specification limit of less than or equal to 100 °F (37.8 °C) (NRC 2021b). At the LaSalle plant, Exelon has reported four fish kill events since 2001. The events occurred in July 2001, June 2005, June 2009, and August 2010, and primarily affected gizzard shad. The Illinois Department of Natural Resources identified other dead fish to include carp (*Cyprinus carpio*), smallmouth buffalo (*Ictiobus bubalus*), freshwater drum (*Aplodinotus grunniens*), channel catfish (*Ictalurus punctatus*), striped bass hybrid (*Morone chrysops x M. saxatilis*), smallmouth bass (*Micropterus dolomieu*), walleye *(Sander vitreus*), bluegill (*Lepomis macrochirus*), white bass (Morone chrysops), yellow bullhead catfish (*Ameiurus natalis*), and yellow bass (*M. mississippiensis*) (NRC 2016d). The temperature in the cooling pond during these events ranged from 93 °F (33.9 °C) to 101 °F (38.3 °C), and each event resulted in the death of approximately 1,500 to 94,500 fish (NRC 2021a).

Fish kill events have rarely been reported at nuclear power plants without cooling ponds. Two fish kills occurred at Pilgrim Nuclear Power Station (Pilgrim) on Cape Cod in Massachusetts in the 1970s, but no such events have been reported since then. In 1975, about 3,000 Atlantic menhaden (*Brevoortia tyrannus*) were killed, and in 1978, about 2,300 Clupeidae (herrings, shads, sardines, and menhadens) were killed (NRC 2007c). After several fish kills at the Summer plant on the Monticello Reservoir in South Carolina in the 1980s, the licensee modified the discharge to reduce the likelihood of future fish kills by removing a hump in the discharge canal, dredging the canal, and limiting reservoir drawdowns (NRC 2004b).

Thermal effluents of nuclear power plants can also contribute to sublethal effects, such as the stunning or disorientation of fish and other aquatic organisms exposed to elevated water temperatures. Such effects can increase the susceptibility of affected individuals to predation. Schubel et al. (1977) concluded that the exposure of blueback herring, American shad, and striped bass (*Morone saxatilis*) larvae to an excess of 59 °F (15 °C) would significantly increase their vulnerability to predation. However, such effects are difficult to prove from field studies. The 1996 and 2013 LR GEISs did not report such effects, and no license renewal environmental reviews since the publication of the 2013 LR GEIS have identified this issue to be of concern.

Aquatic organisms overwintering within thermal plumes can also experience chronic malnutrition (Hall et al. 1978). Thermal discharges can also increase the susceptibility of fish to disease and parasites because of a combination of increased density of fish within the thermal plume (potentially leading to an increased risk of exposure to infectious diseases or other stresses) and the proliferation of many diseases and parasites in warmer water. Examples of other temperature-related impacts on aquatic resources could include the loss of smolt characteristics in salmon (McCormick et al. 1999) and premature spawning (Hall et al. 1978). However, none of these effects have been specifically linked to operation of any nuclear power plants.

Community-level effects of thermal effluent discharges can include reduced habitat availability or quality and reduced species diversity. These effects are typically localized and often only affect certain microhabitats, species, or taxa groups. For instance, at the Peach Bottom plant, which discharges to Conowingo Pond in Pennsylvania, the NRC found that thermal effluents would result in no noticeable effect on the aquatic community during most of the year and in most areas of the cooling pond (NRC 2020g). However, during summer months, thermal studies indicated that a narrow 12 ac (4.9 ha) band of shallow water habitat downstream of the discharge canal exhibited short-term, observable changes, including reduced macroinvertebrate community health and lower fish diversity. The NRC determined that these impacts would likely continue during the license renewal term because the characteristics of thermal discharges would remain the same as those during the initial period of operation. As a result, aquatic organisms in this shallow water habitat would seasonally experience thermal stress and might exhibit avoidance behaviors.

Table 4.6-5 summarizes the results of the NRC's thermal analyses for initial LR and SLR environmental reviews conducted since the publication of the 2013 LR GEIS. The 2013 LR GEIS discusses thermal findings from reviews prior to 2013 and includes many additional examples relevant to this issue.

**Table 4.6-5 Results of NRC Thermal Analyses at Nuclear Power Plants, 2013–Present**

| Nuclear Power Plant | Cooling System Type | Cooling Water Source | Thermal Impact Conclusion |
|---|---|---|---|
| Braidwood | Cooling pond | Constructed cooling pond with makeup water from the Kankakee River | SMALL to MODERATE[(a)] |
| Byron | Cooling towers (ND) | Rock River | SMALL |
| Callaway | Cooling towers (ND) | Missouri River | SMALL |
| Davis-Besse | Cooling towers (ND) | Lake Erie | SMALL |
| Fermi | Cooling towers (ND) | Lake Erie | SMALL |
| Grand Gulf | Cooling towers (ND) | Mississippi River | SMALL |
| Indian Point[(b)] | Once-through | Hudson River | SMALL |
| LaSalle | Cooling pond | Constructed cooling pond with makeup from the Illinois River | SMALL to MODERATE[(c)] |
| Limerick | Cooling towers (ND) | Schuylkill River | SMALL |
| North Anna[(d)] | Cooling pond | Lake Anna | SMALL |
| Peach Bottom[(d)] | Hybrid: once-through (Unit 2); once-through and cooling towers (MD) (Unit 3) | Conowingo Pond | SMALL to MODERATE[(e)] |
| Point Beach[(d)] | Once-through | Lake Michigan | SMALL |

| Nuclear Power Plant | Cooling System Type | Cooling Water Source | Thermal Impact Conclusion |
|---|---|---|---|
| River Bend | Cooling towers (MD) | Mississippi River | SMALL |
| Seabrook | Once-through | Gulf of Maine | SMALL |
| Sequoyah | Hybrid: once-through and cooling towers (ND) | Chickamauga Reservoir | SMALL |
| South Texas | Cooling pond | Constructed cooling reservoir with makeup water from the Colorado River | SMALL |
| Surry[(b)] | Once-through | James River | SMALL |
| Turkey Point[(b)] | Cooling pond | Constructed CCS with makeup from the Upper Floridan aquifer | SMALL to MODERATE[(f)] |
| Waterford | Once-through | Mississippi River | SMALL |

MD = mechanical draft; ND = natural draft; cooling canal system = CCS.
(a) Thermal impacts associated with license renewal would result in SMALL impacts on aquatic resources in the Kankakee River and SMALL to MODERATE impacts on aquatic resources in the cooling pond. MODERATE impacts would primarily be experienced by gizzard shad and other non-stocked and low-heat tolerant species.
(b) This evaluation was a part of a review that supplemented the NRC's final SEIS.
(c) Thermal impacts would be SMALL for all aquatic resources in the Illinois River and SMALL for aquatic resources in the cooling pond, except for gizzard shad and threadfin shad. Gizzard shad and threadfin shad would experience MODERATE thermal impacts in the cooling pond.
(d) This review evaluated a subsequent license renewal term.
(e) During most of the year and in most areas of Conowingo Pond, the thermal effluent would not noticeably affect the aquatic community and its impact would be SMALL. However, during summer months, a narrow 12 ac (4.9 ha) band of shallow water habitat downstream of the discharge canal would exhibit short-term, observable changes, including reduced macroinvertebrate community health and lower fish diversity. Seasonal impacts in this region would be MODERATE because water temperatures would result in thermal stress and avoidance behaviors.
(f) Thermal impacts would be SMALL to MODERATE for aquatic organisms because the thermal effluent may result in some degree of physiological stress on cooling canal system aquatic organisms. However, thermal impacts are unlikely to create effects great enough to destabilize important attributes of the aquatic environment over the course of the subsequent license renewal term because the cooling canal system aquatic community is composed of species that exhibit no unique ecological value or niche and have no commercial or recreational value. Aquatic organisms inhabiting Biscayne Bay are not subject to thermal impacts associated with Turkey Point because there are no surface water connections that allow flow between these waters and the cooling canal system.
Sources: NRC 2013b, NRC 2014d, NRC 2014e, NRC 2014f, NRC 2015b, NRC 2015c, NRC 2015d, NRC 2015e, NRC 2015f, NRC 2016c, NRC 2016d, NRC 2018c, NRC 2018e, NRC 2020f, NRC 2020g, NRC 2021f, NRC 2021g.

Thermal effluent discharges would continue throughout the license renewal term for any operating nuclear power plant. The effects of thermal effluent discharges are discussed below as three issues:

- effects of thermal effluents on aquatic organisms (plants with once-through cooling systems or cooling ponds);
- effects of thermal effluents on aquatic organisms (plants with cooling towers); and
- infrequently reported effects of thermal effluents.

Several mitigative measures can reduce thermal effects. These include routing effluent through discharge canals or settling ponds that dissipate heat before the effluent enters the receiving water body and using high-velocity discharge jets that disperse thermal effluents and promote rapid mixing. Additionally, Section 316(a) of the CWA addresses thermal effects and requires that facilities operate under effluents limitations that assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the receiving body of water, as discussed below.

**Clean Water Act Section 316(a) Requirements for Point Source Discharges**

CWA Section 316(a) (79 FR 48300) addresses the adverse environmental impacts associated with thermal discharges into waters of the United States. Under this section of the Act, the EPA, or authorized States and Tribes, establish thermal surface water quality criteria for waters of the United States within their jurisdiction. States have established standards that incorporate several different types of temperature criteria. These criteria include the following:

- Maximum temperature limit: a limit on the maximum temperature in a water body. This is the core of temperature standards in nearly every state.
- Temperature rise above ambient: a limit on the temperature rise above ambient or natural conditions. This criterion is common among states and is usually specific to habitat type, seasons, designated uses, or specific water body.
- Abrupt temperature change: a restriction in the rate of temperature change over a brief period of time to protect aquatic life from heat shock that can result in lethal or sub-lethal effects.
- Diel and seasonal variability: an allowance for varied temperature depending on the time of day or season. This type of standard is usually narrative rather than quantitative.
- Species diversity: a standard that ensures that the aquatic ecosystem continues to provide an array of microhabitats with a range of temperatures to promote species and spatial diversity. This type of standard is usually narrative.
- Other criteria: other types of temperature criteria have been established in certain states. For instance, California has established a limit on the difference between the discharge temperature and the receiving water body temperature. Florida maintains a maximum temperature of the discharge itself.

Additionally, water quality criteria typically address thermal mixing zones, which the EPA (2017) defines as “a limited area or volume of water where initial dilution of a discharge takes place and where numeric water quality criteria can be exceeded but acutely toxic conditions are prevented.” Mixing zones should provide a continuous zone of passage that meets water quality criteria for free-swimming and drifting organisms and that prevents impairment of critical resource areas. An example of State standards where the mixing zone is specified is in Illinois, where the specified temperature criteria must be met outside the mixing zone, defined as no greater than a circle with a radius of 1,000 ft (305 m) or equivalent simple shape.

Under CWA Section 316(a), the EPA, or authorized States and Tribes, also have the authority to impose alternative, less-stringent, facility-specific effluent limits (called “variances”) on the thermal component of individual point source discharges. To be eligible, regulated facilities must demonstrate, to the satisfaction of the NPDES permitting authority, that facility-specific effluent limitations will assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the receiving body of water. CWA

Section 316(a) variances are valid for the term of the NPDES permit (i.e., 5 years). Facilities must reapply for variances with each NPDES permit renewal application. The EPA has issued regulations under CWA Section 316(a) at 40 CFR 125, Subpart H.

The NRC considers whether nuclear power plants have valid CWA 316(a) variances when assessing the impacts of thermal discharges on aquatic organisms, as discussed later in this section (see Section 4.6.1.2.4).

*4.6.1.2.1 Impingement Mortality and Entrainment of Aquatic Organisms (Plants with Once-Through Cooling Systems or Cooling Ponds)*

This issue pertains to IM&E of finfish and shellfish at nuclear power plants with once-through cooling systems and cooling ponds during an initial LR or SLR term. This includes plants with helper cooling towers that are seasonally operated to reduce thermal load to the receiving water body, reduce entrainment during peak spawning periods, or reduce consumptive water use during periods of low river flow. IM&E of finfish and shellfish at nuclear power plants with cooling towers operated in a fully closed-cycle mode is addressed in Section 4.6.1.2.2. Entrainment of phytoplankton and zooplankton is addressed in Section 4.6.1.2.3. Impingement and entrainment of federally protected species subject to interagency consultation, such as sea turtles and sturgeon, is addressed in Section 4.6.1.3.2.

In the 1996 and 2013 LR GEISs, the NRC determined that the impacts of impingement and entrainment of aquatic organisms would be SMALL at many nuclear power plants with once-through cooling systems or cooling ponds, as well as plants that operate in a hybrid mode (i.e., once-through cooling with cooling towers that operate intermittently), but that these impacts could be MODERATE or LARGE at some plants. Therefore, impingement and entrainment were considered Category 2 issues for these plants. The 1996 LR GEIS addressed impingement and entrainment as two distinct issues. The 2013 LR GEIS combined the two issues into one issue titled, “impingement and entrainment of aquatic organisms (plants with once-through cooling systems or cooling ponds).”

In this LR GEIS, the NRC refines the title of this issue to include impingement mortality, rather than simply impingement. This change is consistent with the EPA’s 2014 CWA Section 316(b) regulations and the EPA’s assessment that impingement reduction technology is available, feasible, and has been demonstrated to be effective. For example, and as described above, impingement mortality at the Surry plant is estimated at between 2.03 and 5.60 percent (NRC 2020f). Therefore, although the plant’s once-through cooling system impinges a large number of organisms, the highly effective fish return system ensures that the majority of organisms are returned back to the river unharmed. Additionally, the EPA’s 2014 CWA Section 316(b) regulations establish BTA standards for impingement mortality based on the fact that survival is a more appropriate metric for determining environmental impact than simply looking at total impingement. Survival studies typically take into account latent mortality associated with stunning, disorientation, or injury. Such effects can result from the injury itself or from increased susceptibility to predation, parasitism, or disease that results from the sublethal effects of impingement. Therefore, this LR GEIS also consolidates the impingement component of the issue of “losses from predation, parasitism, and disease among organisms exposed to sublethal stresses,”[1] for plants with once-through cooling systems or cooling ponds into this issue.

As a result of the 2014 CWA Section 316(b) regulations, nuclear power plants must submit detailed information about their cooling water intake systems as part of NPDES permit renewal applications to support the permitting authority in making BTA determinations. Of note, for existing facilities that withdraw greater than 125 Mgd of water for cooling purposes, 40 CFR 122.21(r)(9) requires these facilities to submit an entrainment characterization study, and 40 CFR 122.21(r)(6) requires these facilities to submit their chosen method(s) of compliance with the impingement mortality standard, including supporting studies and data for Options (3), (5), and (6) listed above. In NPDES permits issued since 2014, permitting authorities have typically included a timeline for submittal of this information as special conditions of the permit, and the permitting authority has used this information to make final BTA determinations during the subsequent five-year NPDES permitting cycle. Thus, some nuclear power plants have received final BTA determinations under the 2014 CWA Section 316(b) regulations. Many others have submitted the required information and are awaiting final determinations. The NRC staff expects that most operating nuclear power plants will have final BTA determinations within the next several years.

When available, the NRC staff relies on the expertise and authority of the NPDES permitting authority with respect to the impacts of IM&E. Therefore, if the NPDES permitting authority has made BTA determinations for a nuclear power plant pursuant to CWA Section 316(b) in accordance with the current regulations at 40 CFR Part 122 and 40 CFR Part 125, which were promulgated in 2014, and that plant has implemented any associated requirements or those requirements would be implemented before the license renewal period, then the NRC staff assumes that adverse impacts on the aquatic environment would be minimized (see 10 CFR 51.10(c); 10 CFR 51.53(c)(3)(ii)(B); 10 CFR 51.71(d)). In such cases, the NRC staff concludes that the impacts of either impingement mortality, entrainment, or both would be SMALL over the course of the initial LR or SLR renewal term for these nuclear power plants.

In cases where the NPDES permitting authority has not made BTA determinations, the NRC staff analyzes the potential impacts of impingement mortality, entrainment, or both using a weight-of-evidence approach. In this approach, the staff considers multiple lines of evidence to assess the presence or absence of ecological impairment (i.e., noticeable or detectable impact) on the aquatic environment. For instance, as its lines of evidence, the staff might consider characteristics of the cooling water intake system design, the results of impingement and entrainment studies performed at the facility, and trends in fish and shellfish population abundance indices. The staff then considers these lines of evidence together to predict the level of impact (SMALL, MODERATE, or LARGE) that the aquatic environment is likely to experience over the course of the initial LR or SLR term.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. In summary, the potential effects of IM&E during an initial LR or SLR term depend on numerous site-specific factors, including the ecological setting of the plant; the characteristics of the cooling system; and the characteristics of the fish, shellfish, and

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[1] The potential for thermal effluents to cause sublethal stresses that increase the susceptibility of aquatic organisms to predation, parasitism, or disease is evaluated in Section 4.6.1.2.6. The potential for impingement to cause sublethal stresses at plants with cooling towers is addressed in Section 4.6.1.2.2. Entrainment would not result in sublethal stresses because entrainable organisms generally consist of fragile life stages, and all entrained organisms are assumed to die (79 FR 48300).

other aquatic organisms present in the area (e.g., life history, distribution, population trends, management objectives, etc.). Additionally, whether the NPDES permitting authority has made BTA determinations pursuant to CWA Section 316(b) and whether the nuclear power plant has implemented any associated requirements is also a relevant factor. In general, if the NPDES permitting authority has made such determinations and the nuclear power plant has implemented any associated requirements, then the NRC staff assumes that adverse impacts on the aquatic environment will be minimized and that the impacts of IM&E will be SMALL; if this is not the case, impacts could be SMALL, MODERATE, or LARGE.

The NRC concludes that the impacts of IM&E of aquatic organisms during the license renewal term (initial LR or SLR) at nuclear power plants with once-through cooling systems or cooling ponds could be SMALL, MODERATE, or LARGE. This is a Category 2 issue.

*4.6.1.2.2 Impingement Mortality and Entrainment of Aquatic Organisms (Plants with Cooling Towers)*

This issue pertains to IM&E of finfish and shellfish at nuclear power plants with cooling towers that operate in a fully closed-cycle mode during an initial LR or SLR term. IM&E of finfish and shellfish at nuclear power plants with once-through cooling systems or cooling ponds is addressed in Section 4.6.1.2.1. Entrainment of phytoplankton and zooplankton is addressed in Section 4.6.1.2.3. Impingement and entrainment of federally protected species subject to interagency consultation, such as sea turtles and sturgeon, are addressed in Section 4.6.1.3.2.

In the 1996 and 2013 LR GEISs, the NRC determined that the impacts of impingement and entrainment of aquatic organisms would be SMALL at all nuclear power plants with cooling towers operated in a fully closed-cycle mode. Therefore, impingement and entrainment were considered Category 1 issues for these plants. The 1996 LR GEIS addressed impingement and entrainment as two distinct issues. The 2013 LR GEIS combined the two issues into one issue titled, “impingement and entrainment of aquatic organisms (plants with cooling towers).” In this LR GEIS, the NRC refines the title of this issue to include impingement mortality, rather than simply impingement. This change is consistent with the EPA’s 2014 CWA Section 316(b) regulations and because assessing survival of impinged organisms is a more appropriate metric for determining environmental impact than simply looking at total impingement. Survival studies typically take into account latent mortality associated with stunning, disorientation, or injury. Such effects can result from the injury itself or from increased susceptibility to predation, parasitism, or disease that results from the sublethal effects of impingement. Therefore, this LR GEIS also consolidates the impingement component of the issue of “losses from predation, parasitism, and disease among organisms exposed to sublethal stresses,”[1] for plants with cooling towers into this issue.

In the 1996 and 2013 LR GEISs, the NRC found that impingement and entrainment of finfish and shellfish at plants with cooling towers operated in a fully closed-cycle mode did not result in noticeable effects on finfish or shellfish populations within source water bodies, and this impact was not expected to be an issue during the license renewal term. This finding was based, in

[1] The potential for thermal effluents to cause sublethal stresses that increase the susceptibility of aquatic organisms to predation, parasitism, or disease is evaluated in Section 4.6.1.2.6. The potential for impingement to cause sublethal stresses at plants with once-through cooling systems or cooling ponds is addressed in Section 4.6.1.2.1. Entrainment would not result in sublethal stresses because entrainable organisms generally consist of fragile life stages, and all entrained organisms are assumed to die (79 FR 48300).

part, on the lower rates of water withdrawal at plants with cooling towers that operate in a fully closed-cycle mode. Of the various factors that can influence IM&E, the volume of water withdrawn by a cooling water intake system relative to the size of the source water body appears to be the best predictor of the quantity of organisms that would be impinged or entrained within a given aquatic system (Henderson and Seaby 2000). Because cooling towers minimize the volume of water withdrawn by a nuclear power plant, the impacts of IM&E from a plant with cooling towers that operates in a fully closed-cycle mode would generally be smaller than the impacts from a plant with a once-through cooling system or a cooling pond. This finding is further supported by the EPA's 2014 CWA Section 316(b) regulations for existing facilities at 40 CFR 122 and 40 CFR 125, Subpart J (79 FR 48300). As described in Section 4.6.1.2 under "Clean Water Act Section 316(b) Requirements for Minimizing IM&E at Existing Facilities," operation of a closed-cycle recirculating system is an essentially preapproved technology for achieving impingement mortality BTA. This finding does not apply to nuclear power plants that seasonally or intermittently use cooling towers in a helper mode to mitigate thermal effects, entrainment, or consumptive water use, but that otherwise operate as once-through system. These hybrid systems are included under the evaluation of once-through cooling water intake systems above.

The 1996 and 2013 LR GEISs considered that impingement may result in sublethal effects that could increase the susceptibility of fish or shellfish to predation, disease, or parasitism. However, only once-through cooling systems were anticipated to be of concern for this issue. The lower volume of water required by nuclear power plants with cooling towers that operate in a fully closed-cycle mode would also minimize this potential effect. The 1996 and 2013 LR GEISs reported that neither scientific literature reviews nor consultations with agencies or utilities yielded clear evidence of sublethal effects on fish or finfish resulting in noticeable increases in impinged organisms' susceptibility to predation, parasitism, or disease, regardless of cooling system type. Since the publication of the 2013 LR GEIS, the NRC has identified no information about this issue for plants with cooling towers. The available information indicates that these secondary impacts of impingement are not expected to be of concern during initial LR or SLR terms at nuclear power plants with cooling towers. As stated earlier in this section, because entrainable organisms generally consist of fragile life stages, all entrained organisms are assumed to die (79 FR 48300). Therefore, sublethal effects of entrainment do not apply.

In considering the effects of IM&E of closed-cycle cooling systems on aquatic ecology, the NRC evaluated the same issues that were evaluated for nuclear power plants with once-through cooling systems or cooling ponds in Section 4.6.1.2.1. No significant impacts on aquatic populations have been reported at any existing nuclear power plants with cooling towers operating in a closed-cycle mode in scientific literature or in license renewal SEISs published to date. Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and license renewal on aquatic resources would be similar. For these reasons, the effects of IM&E on aquatic organisms at plants with cooling towers would be minor and would neither destabilize nor noticeably alter any important attribute of finfish or shellfish populations in source water bodies during initial LR or SLR terms. As part of obtaining BTA determinations under CWA 316(b), permitting authorities may require some nuclear power plants to implement additional plant-specific controls to reduce IM&E. Implementation of such controls would further reduce or mitigate IM&E during the license renewal term. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The NRC concludes that the impacts of IM&E on aquatic organisms during the license renewal term (initial LR or SLR) would be SMALL for nuclear power plants with cooling towers operated in a fully closed-cycle mode. This is a Category 1 issue.

*4.6.1.2.3 Entrainment of Phytoplankton and Zooplankton*

This issue pertains to the entrainment of phytoplankton and zooplankton during an initial LR or SLR term. The IM&E of fish and shellfish, including ichthyoplankton and larval stages of shellfish, are addressed above in two issues based on cooling water intake system type in Sections 4.6.1.2.1 and 4.6.1.2.2.

In the 1996 and 2013 LR GEISs, the NRC determined that entrainment of phytoplankton and zooplankton would be SMALL at all nuclear power plants. Therefore, this was considered a Category 1 issue for all plants regardless of cooling water intake system type. Impingement does not apply to phytoplankton or zooplankton because these organisms are too small to be trapped against intake structure screening devices.

Most nuclear power plants were required to monitor for entrainment effects during the initial years of operation. The effects of entrainment on phytoplankton and zooplankton are considered to be of SMALL significance if monitoring indicates no evidence that nuclear power plant operation has reduced or otherwise affected populations of these organisms in the source water body. For example, about 70 percent of the copepods (a group of planktonic crustaceans) entrained at the Millstone plant in Connecticut suffered mortality, but this loss only represented 0.1 to 0.3 percent of the copepod production of eastern Long Island Sound (Carpenter et al. 1974). At the Calvert Cliffs plant, which withdraws cooling water from the Chesapeake Bay in Maryland, entrainment survival for the five most abundant zooplankton species was 65 to 100 percent (NRC 1999c). At the D.C. Cook plant on Lake Michigan, researchers determined that zooplankton losses associated with entrainment were too small to be detected in the lake. Researchers concluded that fish predation, rather than entrainment, was the major source of zooplankton mortality in inshore waters during most of the year (Evans et al. 1986). At the Seabrook plant on the Gulf of Maine in New Hampshire, researchers compared the densities of holoplankton, meroplankton, and hyperbenthos taxa prior to and during operation at nearfield and farfield sites and found no significant differences in densities prior to and during operations or between the sampling sites (NAI 1998). Researchers also found no significant differences in phytoplankton abundance or chlorophyll concentrations between the nearfield and farfield sites, nor was there any significant difference prior to and during operations (NAI 1998). Based on these results, the NRC (NRC 2015b) found that Seabrook operation had not noticeably altered zooplankton or phytoplankton abundance near the Seabrook site.

Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and license renewal on aquatic resources would be similar. For these reasons, the effects of entrainment of phytoplankton and zooplankton would be minor and would neither destabilize nor noticeably alter any important attribute of populations of these organisms in source water bodies during the initial LR or SLR terms of any nuclear power plants. As part of obtaining BTA entrainment determinations under CWA 316(b), permitting authorities may require some nuclear power plants to implement additional plant-specific controls to reduce entrainment. Implementation of such controls would further reduce or mitigate entrainment of phytoplankton and zooplankton. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The NRC concludes that the impacts of entrainment of phytoplankton and zooplankton during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants. This is a Category 1 issue.

*4.6.1.2.4 Effects of Thermal Effluents on Aquatic Organisms (Plants with Once-Through Cooling Systems or Cooling Ponds)*

This issue pertains to acute, sublethal, and community-level effects of thermal effluents on finfish and shellfish from operation of nuclear power plants with once-through cooling systems and cooling ponds during an initial LR or SLR term. This includes plants with helper cooling towers that are seasonally operated to reduce thermal load to the receiving water body, reduce entrainment in the during peak spawning periods, or reduce consumptive water use during periods of low river flow. The effects of thermal effluents on aquatic organisms at nuclear power plants with cooling towers operated in a fully closed-cycle mode are addressed in Section 4.6.1.2.5. Infrequently reported effects of thermal effluents are addressed in Section 4.6.1.2.6.

In the 1996 and 2013 LR GEISs, the NRC determined that the effects of thermal effluents on aquatic organisms would be SMALL at many nuclear power plants with once-through cooling systems or cooling ponds, as well as plants that operate in a hybrid mode (i.e., once-through cooling with cooling towers that operate intermittently), but that these impacts could be MODERATE or LARGE at some plants. Therefore, this was considered a Category 2 issue for these plants. In the 1996 LR GEIS, this issue was evaluated as "heat shock." The 2013 LR GEIS retitled this issue to "thermal impacts on aquatic organisms (plants with once-through cooling systems or cooling ponds)" to acknowledge that, in addition to acute effects, aquatic organisms could suffer sublethal effects from exposure to thermal effluents. For instance, during some license renewal environmental reviews, thermal effluents have been found to seasonally affect the geographic distribution or diversity of aquatic organisms (see Table 4.6-5 and the discussion concerning Peach Bottom plant's thermal effluent in Section 4.6.1.2 under, "Thermal Impacts"). This LR GEIS refines the title of this issue from "thermal impacts on aquatic organisms (plants with once-through cooling systems or cooling ponds)" to "effects of thermal effluents on aquatic organisms (plants with once-through cooling systems or cooling ponds)" for clarity and consistency with other ecological resource LR GEIS issue titles.

When available, the NRC staff relies on the expertise and authority of the NPDES permitting authority with respect to thermal impacts on aquatic organisms. Therefore, if the NPDES permitting authority has made a determination under CWA Section 316(a) that thermal effluent limits are sufficiently stringent to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the receiving body of water, and the nuclear power plant has implemented any associated requirements, then the NRC staff assumes that adverse impacts on the aquatic environment will be minimized (see 10 CFR 51.10(c); 10 CFR 51.53(c)(3)(ii)(B); and 10 CFR 51.71(d) [10 CFR Part 51]). In such cases, the NRC staff concludes that thermal impacts on aquatic organisms would be SMALL over the course of the initial LR or SLR term for these nuclear power plants.

In cases where the NPDES permitting authority has not granted a CWA Section 316(a) variance, the NRC staff analyzes the potential impacts of thermal discharges using a weight-of-evidence approach. In this approach, the staff considers multiple lines of evidence to assess the presence or absence of ecological impairment (i.e., noticeable or detectable impact) on the aquatic environment. For instance, as its lines of evidence, the staff might consider the characteristics of the cooling water discharge system design, the results of thermal studies performed at the facility, and the trends in fish and shellfish population abundance indices. The staff then considers these lines of evidence together to predict the level of impact (SMALL, MODERATE, or LARGE) that the aquatic environment is likely to experience over the course of the initial LR or SLR term.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. In summary, the potential effects of thermal effluent discharges during an initial LR or SLR term depends on numerous site-specific factors, including the ecological setting of the nuclear power plant; the characteristics of the cooling system and effluent discharges; and the characteristics of the fish, shellfish, and other aquatic organisms present in the area (e.g., life history, distribution, population trends, management objectives, etc.). Additionally, whether the NPDES permitting authority has granted a 316(a) variance is also a relevant factor. In general, if the NPDES permitting authority has granted such a variance and the nuclear power plant has implemented any associated requirements, then the NRC staff assumes that adverse impacts on the aquatic environment will be minimized and that thermal impacts will be SMALL; if this is not the case, impacts could be SMALL, MODERATE, or LARGE.

The NRC concludes that the effects of thermal effluents on aquatic organisms during the license renewal term (initial LR or SLR) at nuclear power plants with once-through cooling or cooling ponds could be SMALL, MODERATE, or LARGE. This is a Category 2 issue.

*4.6.1.2.5 Effects of Thermal Effluents on Aquatic Organisms (Plants with Cooling Towers)*

This issue pertains to acute, sublethal, and community-level effects of thermal effluents on finfish and shellfish from operation of nuclear power plants with cooling towers operated in a fully closed-cycle mode during an initial LR or SLR term. The effects of thermal effluents on aquatic organisms at nuclear power plants with once-through cooling systems or cooling ponds are addressed in Section 4.6.1.2.4. Infrequently reported effects of thermal effluents are addressed in Section 4.6.1.2.6.

In the 1996 and 2013 LR GEISs, the NRC determined that the effect of thermal effluents on aquatic organisms would be SMALL at all nuclear power plants with cooling towers operated in a fully closed-cycle mode. Therefore, this was considered a Category 1 issue for these plants. In the 1996 LR GEIS, this issue was evaluated as “heat shock.” The 2013 LR GEIS retitled this issue to “thermal impacts on aquatic organisms (plants with cooling towers)” to acknowledge that, in addition to acute effects, aquatic organisms could suffer sublethal effects from exposure to thermal effluents. This LR GEIS refines the title of this issue from “thermal impacts on aquatic organisms (plants with cooling towers)” to “effects of thermal effluents on aquatic organisms (plants with cooling towers)” for clarity and consistency with other ecological resource LR GEIS issue titles.

In the 1996 and 2013 LR GEISs, the NRC found that the effects of thermal effluents on aquatic organisms at plants with cooling towers operated in a fully closed-cycle mode did not result in noticeable effects on aquatic populations within receiving water bodies, and this impact was not expected to be an issue during the license renewal term. This finding was based, in part, on the presence of smaller thermal plumes at plants with closed-cycle cooling systems.

When considering the effects of thermal effluents of closed-cycle cooling systems on aquatic organisms, the NRC evaluated the same issues that were evaluated for plants with once-through cooling systems or cooling ponds in Section 4.6.1.2.4. No significant impacts on aquatic populations have been reported at any existing nuclear power plants with cooling towers operating in a closed-cycle mode in scientific literature or in license renewal SEISs published to date. Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and initial LR or SLR on aquatic resources would be similar. For these reasons, the effects of thermal effluents on aquatic organisms at plants with cooling towers would be minor and would neither destabilize nor noticeably alter any important attribute of aquatic populations in receiving water bodies during initial LR or SLR terms. As part of obtaining a variance under CWA Section 316(a), permitting authorities may impose conditions concerning thermal effluent discharges at some nuclear power plants. Implementation of such conditions would further reduce or mitigate thermal impacts during the license renewal term. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term.

The NRC concludes that the effects of thermal effluents on aquatic organisms during the license renewal term (initial LR or SLR) would be SMALL for nuclear power plants with cooling towers operated in a fully closed-cycle mode. This is a Category 1 issue.

*4.6.1.2.6 Infrequently Reported Effects of Thermal Effluents*

This issue concerns the infrequently reported effects of thermal effluents during an initial LR or SLR term. These effects include cold shock, thermal migration barriers, accelerated maturation of aquatic insects, and proliferated growth of aquatic nuisance species, as well as the effects of thermal effluents on dissolved oxygen, gas supersaturation, and eutrophication. This issue also considers sublethal stresses associated with thermal effluents that can increase the susceptibility of exposed organisms to predation, parasitism, or disease.

In the 1996 and 2013 LR GEISs, the NRC determined that the infrequently reported effects of thermal effluents would be SMALL at all nuclear power plants. Therefore, this was considered a Category 1 issue. The 1996 LR GEIS evaluated this issue as eight separate issues; the 2013 LR GEIS consolidated these issues into two issues titled “infrequently reported thermal impacts (all plants)” and “effects of cooling water discharge on dissolved oxygen, gas supersaturation, and eutrophication.” This LR GEIS further consolidates these two issues, as well as the thermal effluent component of the issue of “losses from predation, parasitism, and disease among organisms exposed to sublethal stresses,”[1] (a Category 1 issue in both the 1996 and 2013 LR GEISs) into one issue. This LR GEIS refines the title of this issue to “infrequently reported effects of thermal effluents” for clarity and consistency with other ecological resource LR GEIS issue titles.

**Cold Shock**

Cold shock occurs when an organism has been acclimated to a specific water temperature or range of temperatures and is subsequently exposed to a rapid decrease in temperature. This can result in a cascade of physiological and behavioral responses and, in some cases, death

[1] The potential for impingement to cause sublethal stresses that increase the susceptibility of aquatic organisms to predation, parasitism, or disease is evaluated in Section 4.6.1.2.1 (plants with once-through cooling systems or cooling ponds) and Section 4.6.1.2.2 (plants with cooling towers). Entrainment would not result in sublethal stresses because entrainable organisms generally consist of fragile life stages, and all entrained organisms are assumed to die (79 FR 48300).

(Donaldson et al. 2008). Rapid temperature decreases may occur from either natural sources (e.g., thermocline temperature variation and storm events) or anthropogenic sources (e.g., thermal effluent discharges). The magnitude, duration, and frequency of the temperature change, as well as the initial acclimation temperatures of individuals, can influence the extent of the consequences of cold shock on fish and other aquatic organisms (Donaldson et al. 2008). At nuclear power plants, cold shock could occur during refueling outages, reductions in power generation level, or other situations that would quickly reduce the amount of cooling capacity required at the plant. Cold shock is most likely to be observable in the winter. The 1996 LR GEIS reports that cold shock events have only rarely occurred at nuclear power plants (e.g., Haddam Neck [no longer operating] in Connecticut, Prairie Island and Monticello in Minnesota, and Oyster Creek [no longer operating] in New Jersey). Fish mortalities usually involved only a few fish and did not result in population-level effects. Gradual depowering or shutdown of plant operations, especially in winter months, can mitigate the effects of cold shock. No cold shock events have been reported since the events described in the 1996 LR GEIS occurred, and no noticeable or detectable impacts on aquatic populations have been reported at any existing nuclear power plants related to this issue in scientific literature or in license renewal SEISs published to date. The available information indicates that cold shock resulting from thermal effluents of nuclear power plants is not of concern for initial LR or SLR.

**Thermal Migration Barriers**

Thermal effluents have the potential to create migration barriers if the thermal plume covers an extensive cross-sectional area of a river and temperatures within the plume exceed a species' physiological tolerance limit. This impact has been examined at several nuclear power plants, but it has not been determined to result in observable effects. For example, at Vermont Yankee Nuclear Power Station (Vermont Yankee) (no longer operating) on the Connecticut River in Vermont, the NRC examined the potential for the plant's thermal plume to affect the outmigration of American shad and Atlantic salmon (*Salmo salar*). This potential effect was of particular concern because the fish passage facility was located on the same side of the river as the plant's discharge, and a hydroelectric facility was located immediately downstream (NRC 2007d). However, the licensee's CWA Section 316(b) demonstration found that smolt migration of these species would not be affected because the thermal plume covered only a small cross-sectional area of the river. The NRC staff also examined this potential effect related to migration of federally endangered sturgeon (*Acipenser brevirostrum* and *A. oxyrinchus oxyrinchus*) past the Surry plant on the James River in Virginia (NRC 2019d) and past the Indian Point plant (no longer operating) on the Hudson River in New York (NRC 2018e). To date, thermal effluents of nuclear power plants have resulted in no noticeable or detectable impacts on the migrations of fish. The available information indicates that migration barriers resulting from thermal effluents of nuclear power plants are not of concern for initial LR or SLR.

**Accelerated Maturation of Aquatic Insects**

The 1996 and 2013 LR GEISs considered that the heated effluents of nuclear power plants could accelerate the maturation of aquatic insects in freshwater systems and cause premature emergence. The maturation and emergence of aquatic insects are often closely associated with water temperature regimes. If insects develop or emerge early in the season, they may be unable to feed or reproduce or they may die because the local climate is not warm enough to support them. Premature emergence has been observed in laboratory investigations (e.g., Nebeker 1971) but not in field investigations (e.g., Langford 1975). To date, thermal effluents of nuclear power plants have resulted in no noticeable or detectable impacts on the life cycles of aquatic insects. The available information indicates that accelerated maturation of aquatic insects resulting from thermal effluents of nuclear power plants is not of concern for initial LR or SLR.

**Proliferation of Aquatic Nuisance Organisms**

The 1996 and 2013 LR GEISs also considered that heated effluents could proliferate the growth of aquatic nuisance organisms. Aquatic nuisance species are organisms that disrupt the ecological stability of infested inland (e.g., rivers and lakes), estuarine, or marine waters (EPA 2022b). The previous LR GEISs discuss zebra mussels (*Dreissena polymorpha*) and Asiatic clam (*Corbicula fluminea*), two bivalves that are of particular concern in many freshwater systems because they can cause significant biofouling of industrial intake pipes at power and water facilities. These species are also of ecological concern because they outcompete and lead to the decline of native freshwater mussels. Nuclear power plants that withdraw water from water bodies in which these species are known to occur often periodically chlorinate intake pipes or have other procedures in place to mitigate the spread of these bivalves. There is no evidence, however, that thermal effluent leads to these species' proliferation. No noticeable or detectable impacts on aquatic populations have been reported at any existing nuclear power plants related to this issue in scientific literature or in license renewal SEISs published to date.

Langford (1983) reports several instances in which wood-boring crustaceans and mollusks, notably "shipworms," have caused concern in British waters. Although increased abundance of shipworms in the area influenced by heated power plant effluents caused substantial damage to wooden structures, replacement of old wood with concrete or metal structures eliminated the problem. Langford concluded that increased temperatures could enhance the activity and reproduction of wood-boring organisms in enclosed or limited areas but that elevated temperature patterns were not sufficiently stable to cause widespread effects. The influence of the operation of the Oyster Creek plant (no longer operating) on Barnegat Bay on the abundance and distribution of the shipworm *Teredo bartschi* has been extensively studied (see summary by Kennish and Lutz 1984). Although studies have varied somewhat in their conclusions, researchers have agreed that heated effluents from the Oyster Creek plant increased the distribution and abundance of these organisms (Kennish and Lutz 1984). This species has not been found in Barnegat Bay since 1982, perhaps because of reduced water temperatures during a station outage in the winter of 1981-82 and the pathological effects of a parasite, as well as the removal of substantial amounts of driftwood and the replacement of untreated structural wood in the area of concern (NRC 1996). The NRC has identified no other concerns about nuisance aquatic organisms associated with nuclear power plant thermal effluents in scientific literature or in license renewal SEISs published to date. The available information indicates that proliferation of nuisance organisms resulting from thermal effluents of nuclear power plants is not of concern for initial LR or SLR.

**Dissolved Oxygen**

Aerobic organisms, such as fish, require oxygen, and the concentration of dissolved oxygen in a water body is one of the most important ecological water quality parameters. Dissolved oxygen also influences several inorganic chemical reactions. In general, dissolved oxygen concentrations of less than 3 ppm in warmwater habitats or less than 5 ppm in cold-water habitats can adversely affect fish (Morrow and Fischenich 2000). Oxygen dissolves into water via diffusion, aeration, and as a product of photosynthesis. The amount of oxygen water can absorb depends on temperature; the amount of oxygen that can dissolve in a volume of water (i.e., the saturation point) is inversely proportional to the temperature of the water. Thus, when other chemical and physical conditions are equal, the warmer the water is, the less dissolved oxygen it can hold. Increased water temperatures also affect the amount of oxygen that aquatic organisms need by increasing metabolic rates and chemical reaction rates. The rates of many chemical reactions in water approximately doubles for every 18 °F (10 °C) increase in temperature.

The thermal effluent discharges of nuclear power plants have the potential to stress aquatic organisms by simultaneously increasing these organisms' need for oxygen and decreasing oxygen availability. Aquatic organisms are more likely to experience adverse effects from thermal effluents in ecosystems where dissolved oxygen levels are already approaching suboptimal levels as a result of other factors in the environment. This is most likely to occur in ecosystems where increased levels of detritus and nutrients (e.g., eutrophication), low flow, and high ambient temperatures already exist. These conditions can occur as a result of drought conditions or in hot weather, especially in lakes, reservoirs, or other dammed freshwaters.

Although the thermal effluents of nuclear power plants may contribute to reduced dissolved oxygen in the immediate vicinity of the discharge point, as the effluent disperses, diffusion and aeration from turbulent movement introduces additional oxygen into the water. As the water cools, the saturation point increases, and the water can absorb additional oxygen as it is released by aquatic plants and algae through photosynthesis, which is a continuously ongoing process during daylight hours. Therefore, lower dissolved oxygen is generally only a concern within the thermal mixing zone, which is typically a small area of the receiving water body. As described earlier in Section 4.6.1.2 under "Clean Water Act Section 316(a) Requirements for Point Source Discharges," many states address thermal mixing zones in State water quality criteria to ensure that mixing zones provide a continuous zone of passage for aquatic organisms. Additionally, the EPA, or authorized States and Tribes, often impose conditions specifically addressing dissolved oxygen through NPDES permits to ensure that receiving water bodies maintain adequate levels of oxygen to support aquatic life. These conditions are established pursuant to CWA Section 316(a), which requires that regulated facilities operate under effluents limitations that assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the receiving water body. No noticeable or detectable impacts on aquatic populations have been reported at any existing nuclear power plants related to oxygen availability in scientific literature or in license renewal SEISs published to date. The available information indicates that reduced dissolved oxygen resulting from thermal effluents of nuclear power plants is not of concern for initial LR or SLR.

**Gas Supersaturation**

Rapid heating of cooling water can also affect the solubility and saturation point of other dissolved gases, including nitrogen. As water passes through the condenser cooling system, it can become supersaturated with gases. Once the supersaturated water is discharged in the receiving water body, dissolved gas levels equilibrate as the effluent cools and mixes with ambient water. This process is of concern if aquatic organisms remain in the supersaturated effluent for a long enough period to become equilibrated to the increased pressure associated with the effluent. If these organisms then move into water of lower pressure too quickly when, for example, swimming out of the thermal effluent or diving to depths, the dissolved gases within the affected tissues may come out of solution and form embolisms (bubbles). The resulting condition is known as gas bubble disease. In fish, it is most noticeable in the eyes and fins. Affected tissues can swell or hemorrhage and result in behavioral abnormalities, increased susceptibility to predation, or death (Noga 2000). Mortality in fish generally occurs at gas supersaturation levels above 110 or 115 percent (EPA 1986). Aquatic insects and crustaceans appear to be more tolerant of supersaturated water (Nebeker et al. 1981).

The ability to detect and avoid supersaturated waters varies among species. A fish can avoid supersaturated waters by either not entering the affected area or by diving to avoid the onset of supersaturated conditions near the surface. Some species, however, may not avoid supersaturated waters until symptoms of gas bubble disease occur; at that point, some fish may already be lethally exposed. Other species may be attracted to supersaturated waters because it is often warmer (Gray et al. 1983).

As reported in the 1996 and 2013 LR GEISs, fish mortality from gas bubble disease has been reported at hydroelectric dams and coal-fired power plants. Typically, gas bubble disease is of concern at facilities where the configuration of the discharge allows organisms to reside in the supersaturated effluent for extended periods of time (e.g., discharge canals that fish can freely enter). Fish mortality from gas bubble disease has been observed at one nuclear power plant: the Pilgrim plant (no longer operating) on Cape Cod in Massachusetts. In 1973 and 1976, 43,000 and 5,000 Atlantic menhaden deaths, respectively, were attributed to gas bubble disease because of individuals entering and residing in the discharge canal for a prolonged period (McInerny 1990). Some sources reported that other species of fish may also have been affected (Fairbanks and Lawton 1977). After these events, the Pilgrim plant installed a barrier net to prevent fish from entering the discharge canal, and no such events occurred again following implementation of this mitigation. Discharges that promote the rapid mixing of effluent into receiving waters, such as those equipped with multiport or jet diffusers, can also be effective in preventing gas bubble disease mortalities because they limit the extent of the thermal plume and promote rapid mixing (Lee and Martin 1975).

No noticeable or detectable impacts on aquatic populations have been reported at any other nuclear power plants related to gas supersaturation in scientific literature or in license renewal SEISs published to date. The one plant for which this was of concern (Pilgrim) successfully mitigated the issue in the 1970s and did not report any other such events for the remainder of its operating period (i.e., through 2019, when the plant permanently shut down). Additionally, NPDES permit conditions established pursuant to CWA Section 316(a) may also address thermal effluent factors that would reduce the potential for aquatic organisms to experience gas bubble disease as a result of nuclear power plant thermal effluents. The available information indicates that gas supersaturation resulting from thermal effluents of nuclear power plants is not of concern for initial LR or SLR.

**Eutrophication**

An early concern about nuclear power plant discharges was that thermal effluents would cause or speed eutrophication by stimulating biological productivity in receiving water bodies (NRC 1996). Eutrophication is the gradual increase in the concentration of phosphorus, nitrogen, and other nutrients in a slow-flowing or stagnant aquatic ecosystem, such as a lake. These nutrients enter the ecosystem primarily through runoff from agricultural land and impervious surfaces. The increase in nutrient content allows alga to proliferate on the water's surface, which reduces light penetration and oxygen absorption necessary for underwater life. The 1996 LR GEIS reports that several nuclear power plants conducted long-term monitoring to investigate this potential effect, including the McGuire plant on Lake Norman in North Carolina and Oconee plant on Lake Keowee in South Carolina. No evidence of eutrophication was detected. No such effects have been reported in scientific literature or in license renewal SEISs to date. Therefore, eutrophication is not expected to be of concern during initial LR or SLR terms at any nuclear power plants.

**Susceptibility to Predation, Parasitism, and Disease**

Fish and shellfish that are exposed to the thermal effluent of a nuclear power plant may experience stunning, disorientation, or injury. These sublethal effects can subsequently affect an organism's susceptibility to predation, parasitism, or disease.

With respect to susceptibility to predation, laboratory studies of the secondary mortality of fish following exposure to heat or cold shock demonstrate increased susceptibility of these fish to predation; however, field evidence of such effects is often limited to anecdotal information, such as observations of increased feeding activity of seagulls and predatory fish near effluent outfalls (e.g., Cada et al. 1981). For example, Barkley and Perrin (1971) and Romberg et al. (1974) reported increased concentrations of predators feeding on forage fish attracted to thermal plumes. However, these studies did not quantify whether the observed behaviors resulted in population-level effects on prey species.

With respect to susceptibility to parasitism and disease, Langford (1983) found that the tendency for fish to congregate in heated effluent plumes, the increased physiological stress that higher water temperatures exert on fish, and the ability of some diseases and parasites to proliferate at higher temperatures were all factors that could contribute to increased rates of disease or parasitism in exposed fish. Some studies have suggested that crowding of fish within the thermal plume, rather than the thermal plume itself, may lead to an increased risk of exposure to infectious diseases (Coutant 1987).

The 1996 and 2013 LR GEISs reported that neither scientific literature reviews nor consultations with agencies or utilities yielded clear evidence of sublethal effects on fish or finfish resulting in noticeable increases in exposed organisms' susceptibility to predation, parasitism, or disease. Since the publication of the 2013 LR GEIS, the NRC has determined that thermal effects on aquatic organisms at four nuclear power plants could be SMALL to MODERATE during the license renewal term (see Table 4.6-5). At three of the four plants (i.e., Braidwood, LaSalle, and Turkey Point), these impacts were limited to species confined to cooling pond environments. In the fourth example (Peach Bottom), the adverse effects were found to be confined to a narrow band of shallow water habitat downstream of the discharge canal during the summer months. However, increased susceptibility to predation, parasitism, or disease or predation resulting from exposure to thermal effluent was not found to be responsible for these small to moderate findings. Rather, these effects were attributed to other acute (i.e., heat shock) or community-level effects (i.e., reduced habitat availability or quality and reduced species diversity over time) of thermal effluents evaluated as part of the former Category 2 issue, "Thermal impacts on aquatic organisms (plants with once-through cooling systems or cooling ponds)." This Category 2 issue has been renamed in this LR GEIS (see Section 4.6.1.2.4). The available information indicates that this issue is not expected to be of concern during initial LR or SLR terms at any nuclear power plants.

**Conclusion**

Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and license renewal on aquatic resources would be similar. For these reasons, the infrequently reported effects of thermal effluents discussed in this section would be minor and would neither destabilize nor noticeably alter any important attribute of aquatic populations in receiving water bodies during initial LR or SLR terms of any nuclear power plants. As part of obtaining a variance under CWA Section 316(a), permitting authorities may impose conditions concerning thermal effluent discharges at some nuclear power plants. Implementation of such conditions would further reduce or mitigate thermal impacts during the license renewal term. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The NRC concludes that infrequently reported effects of thermal effluents during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants. This is a Category 1 issue.

*4.6.1.2.7 Effects of Nonradiological Contaminants on Aquatic Organisms*

This issue concerns the potential effects of nonradiological contaminants on aquatic organisms that could occur as a result of nuclear power plant operations during an initial LR or SLR term.

In the 1996 and 2013 LR GEISs, the NRC determined that the effects of nonradiological contaminants on aquatic resources would be SMALL. Therefore, this was considered a Category 1 issue.

This issue was originally of concern because some nuclear power plants used heavy metals in condenser tubing that could leach from the tubing and expose aquatic organisms to these contaminants. Because aquatic organisms can bioaccumulate heavy metals, even when exposed at low levels, this can cause toxicity in fish and other animals that consume contaminated organisms. Section 4.6.1.1.3 describes instances in which copper contamination was an issue at operating nuclear power plants. Heavy metals have not been found to be of concern other than these few instances, and in all cases, the nuclear power plants eliminated leaching by replacing the affected piping.

In addition to heavy metals, nuclear power plants often add biocides to cooling water to kill algae, bacteria, macroinvertebrates, and other organisms that could cause buildup in plant systems and structures. For example, zebra mussels and Asiatic clams within the intake pipes or cooling systems can cause partial to full blockage of grates and pipes or otherwise damage the integrity of pipes and other cooling system components. Nuclear power plants in areas where these mollusks are an operating concern typically treat cooling water with nonoxidizing molluscicides that may include chlorine, chlorine dioxide, chloramines, ozone, bromine, hydrogen peroxide and potassium permanganate. Most molluscicides have very restricted uses due to their toxic effects on non-target organisms and are primarily used in closed systems. Nuclear power plants typically maintain site procedures that specify when and how to treat the cooling water system with such chemicals and BMPs to minimize impacts on the ecological environment. For instance, plants use only EPA-approved biocides according to label instructions. Some plants with cooling towers discharge blowdown to settling ponds to allow heat and chemicals to dissipate before discharging the effluent to surface waters. NPDES permits mitigate potential effects of chemical effluents by limiting the allowable concentrations in effluent discharges to ensure the protection of the aquatic community within the receiving water body. Some nuclear power plants also use physical deterrents to reduce the need for chemical treatment. For instance, the Browns Ferry plant in Alabama recirculates small sponge balls through the condenser tubes to keep them clear of Asiatic clams (NRC 2005b).

Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and license renewal on aquatic resources would be similar. For these reasons, the effects of nonradiological contaminants on aquatic organisms would be minor and would neither destabilize nor noticeably alter any important attribute of populations of these organisms in source water bodies during initial LR or SLR terms of any nuclear power plants. Continued adherence of nuclear power plants to chemical effluent limitations established in NPDES permits would minimize the potential impacts of nonradiological contaminants on the aquatic environment. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The NRC concludes that the effects of nonradiological contaminants on aquatic organisms during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants. This is a Category 1 issue.

*4.6.1.2.8 Exposure of Aquatic Organisms to Radionuclides*

This issue concerns the potential impacts on aquatic organisms from exposure to radionuclides from routine radiological effluent releases during an initial LR or SLR term.

As explained in Section 4.6.1.1.2, radionuclides may be released from nuclear power plants into the environment through several pathways, including via gaseous and liquid emissions. Aquatic plants can absorb radionuclides that enter shallow groundwater or surface waters through their roots. Aquatic animals can be exposed externally to ionizing radiation from radionuclides in water, sediment, and other biota and can be exposed internally through ingested food, water, and sediment and absorption through the integument and respiratory organs.

As discussed in Section 4.6.1.1.2, the DOE has produced a standard on a graded approach for evaluating radiation doses to aquatic and terrestrial biota (DOE 2019). The DOE standard provides methods, models, and guidance that can be used to characterize radiation doses to terrestrial and aquatic biota exposed to radioactive material (DOE 2019). For aquatic animals, the DOE guidance dose rate is 1 rad/d (0.1 Gy/d), which represents the level below which no adverse affects to resident populations are expected. The DOE also recommends that the screening-level concentrations of most radionuclides in aquatic environments should be based on internal exposure as well as external exposure to contaminated sediments, rather than external exposure to contaminated water (DOE 2019).

Previously, in the early 1990s, the IAEA (1992) and the National Council on Radiation Protection and Measurements (NCRP) (1991) also concluded that a chronic dose rate of no greater than 1 rad/d (0.01 Gy/d) to the maximally exposed individual in a population of aquatic organisms would ensure protection of the population. The United Nations Scientific Committee on the Effects of Atomic Radiation concluded in 1996 and re-affirmed in 2008 that chronic dose rates less than 0.4 mGy/hr (1.0 rad/day or 0.01 Gy/day) to the most highly exposed individuals would be unlikely to have significant effects on most aquatic communities (UNSCEAR 2010).

In the 2013 LR GEIS, the NRC estimated the total radiological dose that aquatic biota would be expected to receive during normal nuclear power plant operations using plant-specific radionuclide concentrations in water and sediments at 15 nuclear power plants using Argonne National Laboratory's RESRAD-BIOTA dose evaluation model. The NRC found that total calculated dose rates for aquatic animals at all 15 plants were all less than 0.2 rad/d (0.002 Gy/d), which is less than the guideline value of 1 rad/d (0.01 Gy/d). As a result, the NRC anticipated in the 2013 LR GEIS that normal operations of these facilities would not result in negative effects on aquatic biota. The 2013 LR GEIS concluded that the impact of radionuclides on aquatic biota from past operations would be SMALL for all nuclear power plants and would not be expected to change appreciably during the license renewal period.

In this revision, the NRC staff conducted an updated and expanded analysis of this issue relative to the 2013 LR GEIS. As part of this expanded analysis, the staff reviewed a subset of operating nuclear power plants[1] to evaluate the potential impacts of radionuclides on biota from continued operations. Section 4.6.1.1.2 describes the NRC staff's methods, which included reviewing effluent release reports, a RESRAD-BIOTA analysis, and an ICRP biota dose calculator analysis (see Section D.5 in Appendix D for full description of methodology). Results can be found in Section 4.6.1.1.2 and are summarized in this section.

Table 4.6-1 in Section 4.6.1.1.2 shows the estimated radiation dose rates to four ecological receptors (i.e., riparian animal, terrestrial animal, terrestrial plant, and aquatic animal) resulting from the staff's RESRAD-BIOTA dose modeling. Based on the staff's RESRAD-BIOTA analysis, it is unlikely that radionuclide releases during normal operations of these nuclear power plants would have adverse effects on resident populations of aquatic animals because the calculated doses are well below DOE protective guidelines.

In addition to the RESRAD-BIOTA analysis discussed above, the NRC staff estimated dose rates to a riparian organism using the ICRP biota dose calculator (ICRP 2022) (see Section 4.6.1.1.2 and Section D.5 in Appendix D for full description of ICRP BiotaDC methodology). The dose rates calculated for a riparian organism ranged between 2E-4 and 2E-5 rad per day which is orders of magnitude lower than the DOE guideline dose rate. None of the radionuclides evaluated singly, or in common, produced dose rates that approached the DOE's guidance dose rate of 0.1 rad/d for riparian animals using the ICRP BiotaDC tool (DOE 2019). Additionally, the calculated dose rates did not approach the level advocated by the National Council on Radiation Protection and Measurements to initiate additional evaluation (Cool et al. 2019). In fact, the dose rates for the riparian organism calculated using the ICRP's calculator were lower than the RESRAD conservative analysis, and both were well below the DOE guideline values.

Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and initial LR or SLR on aquatic organisms would be similar. For these reasons, the effects of exposure of aquatic organisms to radionuclides would be minor and would neither destabilize nor noticeably alter any important attribute of populations of exposed organisms during initial LR or SLR terms of any nuclear power plant. Continued adherence of nuclear power plants to regulatory limits on radioactive effluent releases would minimize the potential impacts on the aquatic environment. Doses to aquatic organisms would be expected to remain below the DOE's dose limits and, therefore, impacts to aquatic communities are not expected. The staff reviewed information in scientific literature and from SEISs (for initial LRs or SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term.

The NRC concludes that the impacts of exposure of aquatic organisms to radionuclides during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants. This is a Category 1 issue.

[1] The subset of plants included the following PWR plants: Comanche Peak, D.C. Cook, Palo Verde 1-3, Robinson, Salem 1-2, Seabrook, and Surry; and the following BWR plants: Fermi 2, Hatch 1-2, Hope Creek, Limerick, and Columbia.

*4.6.1.2.9 Effects of Dredging on Aquatic Resources*

This issue concerns the effects of dredging at nuclear power plants on aquatic resources during an initial LR or SLR term.

In the 2013 LR GEIS, the NRC determined that the effects of dredging on aquatic resources would be SMALL at all nuclear power plants. Therefore, this was considered a Category 1 issue for all nuclear power plants. The 1996 LR GEIS did not address this issue.

Small-particle sediment, such as sand and silt, that enters water bodies through erosion can subsequently deposit and accumulate along shorelines and in shallow water areas. If sediment deposition affects cooling system function or reliability, a nuclear power plant may need to periodically dredge to improve intake flow and keep the area clear of sediment. Nuclear power plants where dredging may be necessary are typically located along fast-flowing waters with sandy or silty bottoms, such as large rivers or the ocean. In some instances, dredging may be performed to maintain barge slips for transport of materials and waste to and from the site. Dredging entails excavating a layer of sediment from the affected areas and transporting that sediment to onshore or offshore areas for disposal. The three main types of dredges are mechanical dredges, hydraulic dredges, and airlift dredges. The selection of dredge type generally is related to the sediment type, the size of the area to be dredged, and the aquatic resources present.

At operating nuclear power plants, dredging is performed infrequently, if at all. For example, dredging at the Peach Bottom plant is performed approximately once every 20 years over a total area of approximately 6 ac (2.4 ha) (NRC 2003b). When it was operating, the Oyster Creek plant dredged portions of either the intake or the discharge canals approximately every 10 years (NRC 2007b). The Monticello plant requires dredging every 6 to 8 years (NRC 2006c). The Surry plant is one exception; because of the tidal influence of the James River near the plant and the site's location on a peninsula within the river, Surry dredges every 3 to 4 years (NRC 2020f).

Dredging results in the direct removal of soft bottom substrates along with infaunal and epifaunal organisms of limited mobility inhabiting those substrates. Small organisms living within and on the affected sediments are likely to be killed in the process. Smaller benthic invertebrates, such as mollusks and crustaceans, may also be susceptible to entrainment into the dredge head. Larger benthic individuals or those that are farther from the dredge head could move away from the suction flow field to avoid being entrained. Thus, dredging can be expected to cause short-term reductions in the biomass of benthic organisms. Dredging also creates sediment plumes that increase water turbidity, which can adversely affect aquatic biota and create short-term decreases in habitat quality during and after dredging. Turbidity primarily affects liquid-breathing organisms, such as fish and shellfish, as well as aquatic plants, because turbid conditions typically decrease photosynthetic capabilities. Turbidity levels associated with the sediment plumes of cutterhead dredges typically range from 11.5 to 282.0 milligrams per liter (mg/L) with decreasing concentrations at greater distances from the dredge head (Nightingale and Simenstad 2001). Studies of benthic community recovery following dredging indicate that species abundance and diversity can recover within several years of dredging (Michel et al. 2013). Specifically, within temperate, shallow water regions containing a combination of sand, silt, or clay substrate, benthic communities can recover in 1 to 11 months, according to studies reviewed by Wilber et al. (2006). Recovery of benthic communities following dredging also tends to be faster in areas exposed to periodic disturbances, such as tidally influenced habitats (Diaz 1994).

With respect to turbidity and sedimentation caused by dredging, studies of the effects of turbid waters on fish suggest that concentrations of suspended solids can reach thousands of milligrams per liter before an acute toxic reaction occurs (Burton 1993 as cited in NMFS 2014a). In a literature review, Burton (1993 as cited in NMFS 2014a) demonstrated that lethal effects on fish due to turbid waters can occur at levels between 580 mg/L and 700,000 mg/L, depending on the species. Studies of striped bass, an anadromous species, showed that pre-spawners did not avoid concentrations of 954 to 1,920 mg/L to reach spawning sites (Summerfelt and Mosier 1976; Combs 1979). Sedimentation could also affect benthic macroinvertebrates. However, these individuals could avoid the plume or uncover themselves from any sedimentation experienced during dredging such that these impacts would be negligible and short term in nature.

Sediments may be contaminated with a variety of pollutants from agricultural runoff and stormwater runoff from impervious surfaces. These pollutants can also be introduced to waterways from point sources, such as combined sewer overflows, municipal and industrial discharges, and spills. Contaminants that have accumulated in buried layers of sediment are often less readily bioavailable or less chemically active (EPA 2004). Depending on the concentrations of specific contaminants in accumulated sediments, dredging could increase the bioavailability of those contaminants if they are resuspended in the water column (Petersen et al. 1997; Su et al. 2002; EPA 2004).

Dredging would require nuclear power plant licensees to obtain permits from the USACE under CWA Section 404. BMPs and conditions associated with these permits would minimize impacts on the ecological environment. The granting of such permits would also require the USACE to conduct its own environmental reviews prior to undertaking dredging.

Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and license renewal on aquatic resources would be similar. For these reasons, the effects of dredging on aquatic resources would be minor and would neither destabilize nor noticeably alter any important attribute of the aquatic environment during initial LR or SLR terms of any nuclear power plants. The NRC assumes that nuclear power plants would continue to implement site environmental procedures and would obtain any necessary permits for dredging activities. Implementation of such controls would further reduce or mitigate potential effects. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term.

The NRC concludes that effects of dredging on aquatic resources during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants. This is a Category 1 issue.

*4.6.1.2.10 Water Use Conflicts with Aquatic Resources (Plants with Cooling Ponds or Cooling Towers Using Makeup Water from a River)*

The issue concerns water use conflicts that may arise at nuclear power plants with cooling ponds or cooling towers that use makeup water from a river and how those conflicts could affect aquatic resources during an initial LR or SLR term.

In the 1996 and 2013 LR GEISs, the NRC determined that the impacts of water use conflicts on aquatic resources would be SMALL at many nuclear power plants but that these impacts could be MODERATE at some plants. Therefore, this was considered a Category 2 issue for nuclear power plants with cooling ponds or cooling towers using makeup water from a river. The 1996 LR GEIS addressed cooling towers that withdraw from small rivers with low flow; the 2013 LR GEIS expanded this issue to include all cooling towers that withdraw from rivers. Notably, this issue also applies to nuclear power plants with hybrid cooling systems that withdraw makeup water from a river (i.e., once-through cooling systems with helper cooling towers) (e.g., NRC 2020g).

Nuclear power plant cooling systems may compete with other users relying on surface water resources, including downstream municipal, agricultural, or industrial users. Closed-cycle cooling is not completely closed because the system discharges blowdown water to a surface water body and withdraws water for makeup of both the consumptive water loss due to evaporation and drift (for cooling towers) and blowdown discharge. For plants using cooling towers, while the volume of surface water withdrawn is substantially less than once-through systems for a similarly sized nuclear power plant, the makeup water needed to replenish the consumptive loss of water to evaporation can be significant. Cooling ponds also require makeup water. Section 4.5.1.1.9 addresses factors relevant to water use conflicts at nuclear power plants in detail. Water use conflicts with aquatic resources could occur when water that supports these resources is diminished by a combination of anthropogenic uses.

Consumptive use by nuclear power plants with cooling ponds or cooling towers using makeup water from a river during the license renewal term is not expected to change unless power uprates, with associated increases in water use, occur. Such uprates would require separate NRC review and approval. Any river, regardless of size, can experience low-flow conditions of varying severity during periods of drought and changing conditions in the affected watershed, such as upstream diversions and use of river water. However, the direct impacts on instream flow and potential water availability for other users from nuclear power plant surface water withdrawals are greater for small (i.e., low-flow) rivers.

To date, the NRC has identified water use conflicts with aquatic resources at only one nuclear power plant: the Wolf Creek plant in Kansas. This plant uses Coffee County Lake for cooling, and makeup water for the lake is drawn from the Neosho River downstream of John Redmond Reservoir (NRC 2008a). The Neosho River is a small river with especially low water flow during drought conditions. During the license renewal review, the NRC found that the aquatic communities in the Neosho River downstream included the federally endangered Neosho madtom, a small species of catfish, and that this species could be adversely affected by the nuclear power plant's water use during periods when the lake level is low and makeup water is obtained from the Neosho River. The NRC concluded that water use conflicts would be SMALL to MODERATE for this nuclear power plant. As part of the NRC's ESA consultation with the FWS, the Wolf Creek plant developed and implemented a water level management plan for Coffey County Lake, which includes withdrawing makeup water proactively during high river flows in order to support downstream populations of the Neosho madtom (FWS 2012). This plan effectively mitigated not only water use conflicts that the Neosho madtom might experience, but also the effects that the entire downstream aquatic community might experience from the plant's cooling water withdrawals. The NRC has identified no concerns about water use conflicts with aquatic resources at any other nuclear power plant with cooling ponds or cooling towers.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. In summary, water use conflicts during an initial LR or SLR term depend on numerous site-specific factors, including the ecological setting of the plant; the consumptive use of other municipal, agricultural, or industrial water users; and the aquatic resources present in the area. Water use conflicts with aquatic resources would be SMALL at most nuclear power plants with cooling ponds or cooling towers that withdraw makeup from a river but may be MODERATE at some plants. Therefore, a generic determination of potential impacts on terrestrial resources from continued operations during a license renewal term is not possible.

The NRC concludes that water use conflicts on aquatic resources during the license renewal term (initial LR or SLR) could be SMALL or MODERATE at nuclear power plants with cooling ponds or cooling towers using makeup water from a river. This is a Category 2 issue.

*4.6.1.2.11 Non-Cooling System Impacts on Aquatic Resources*

This issue concerns the effects of nuclear power plant operations on aquatic resources during an initial LR or SLR term that are unrelated to operation of the cooling system. Such activities include landscape and grounds maintenance, stormwater management, and ground-disturbing activities that could directly disturb aquatic habitat or cause runoff or sedimentation. These impacts are expected to be like past and ongoing impacts that aquatic resources are already experiencing at the nuclear power plant site.

In the 1996 LR GEIS, the NRC evaluated the impacts of refurbishment on aquatic resources. In the 2013 LR GEIS, the NRC expanded this issue to include impacts of other site activities, unrelated to cooling system operation, that may affect aquatic resources. In both the 1996 and 2013 LR GEISs, the NRC concluded that effects would be SMALL at all nuclear power plants. Therefore, these were considered Category 1 issues for all nuclear power plants. This LR GEIS refines the title of this issue from “effects on aquatic resources (non-cooling system impacts)” to “non-cooling system impacts on aquatic resources” for clarity and consistency with other ecological resource LR GEIS issue titles.

Industrial-use portions of nuclear power plant sites are typically maintained as modified habitats with lawns and other landscaped areas; these areas typically do not include natural aquatic features. Nonindustrial-use portions of nuclear power plant sites may include natural aquatic habitats, such as streams, ponds, lakes, and usually interface with larger water bodies, such as rivers, reservoirs, estuaries, bays, or the ocean. These habitats may be undisturbed or in various degrees of disturbance (e.g., dammed reservoirs, human-made cooling lakes, and channelized rivers).

Certain areas may also be managed to preserve natural resources, either privately by the nuclear power plant operator or in conjunction with local, State, or Federal agencies. For instance, approximately 13,000 ac (5,300 ha) of land to the south and west of the Turkey Point site in Florida is part of the Everglades Mitigation Bank (NRC 2019c). Under the guidance of Federal and State agencies, Florida Power and Light Company creates, restores, and enhances this habitat to provide compensatory mitigation of wetland losses elsewhere. At the Harris plant in North Carolina, Duke Energy leases land, including part of Harris Lake, to Wake County who co-manages the area with the North Carolina Wildlife Resources Commission for natural resource preservation and recreational opportunities (Duke Energy 2017). Continued conservation efforts would have beneficial effects on the local aquatic ecology.

The characteristics of aquatic habitats and communities on nuclear power plant sites have generally developed in response to many years of plant operations and maintenance. While some communities may have reached a relatively stable condition, some may have continued to change gradually over time. Operations and maintenance activities during the license renewal term are expected to be like current activities (see Section 2.1).

In the 1996 and 2013 LR GEISs, the NRC staff anticipated that nuclear power plants may require refurbishment to support continued operations during a license renewal term (see Section 2.1.2). However, refurbishment has not typically been necessary for license renewal. Only two nuclear power plants have undertaken refurbishment as part of license renewal (Beaver Valley and Three Mile Island [no longer operating], both of which are located in Pennsylvania) (NRC 2009a, NRC 2009b). In addition to refurbishment, license renewal could require construction of additional onsite spent fuel storage. Refurbishment or spent fuel storage construction could require new parking areas for workers as well as new access roads, buildings, and facilities. Temporary project support areas for equipment storage, overflow parking, and material laydown areas could also be required.

Any activities that require construction or involve ground disturbance could affect nearby aquatic features and habitats. Surface water habitats could be directly affected if activities cause ponds to be drained or blocked or streams to be redirected. Depending on the size and nature of the water body affected, aquatic plants and animals could be displaced or killed, or the community structure within the water body could be altered. Indirect effects include erosion and sedimentation, both of which are typically proportional to the amount of surface disturbance, slope of the disturbed land, condition of the area at the time of disturbance, and proximity to aquatic habitats. Chemical contamination could also occur from fuel or lubricant spills. If impacts to aquatic habitats are anticipated, these activities would require nuclear power plant licensees to obtain applicable permits under the CWA, to develop stormwater management plans and spill prevention plans, and to implement BMPs to minimize soil erosion and deposition. Standard BMPs often include buffer zones surrounding waterways, aquatic features, and wetlands. BMPs and conditions associated with necessary permits would minimize impacts on the ecological environment. To date, the NRC staff has not identified noticeable or detectable impacts on aquatic features or habitats in connection with construction or ground disturbance during the license renewal period at any nuclear power plant.

Many nuclear power plant operators have developed site or fleet-wide environmental review procedures that help workers identify and avoid impacts on the ecological environment when performing site activities. These procedures generally include checklists to help identify potential effects and required permits and BMPs to minimize the affected area. BMPs relevant to aquatic resources may include measures to control runoff, erosion, and sedimentation from project sites; revegetate disturbed areas to control future erosion; and avoid the use of chemicals or machinery near waterways and aquatic features. Proper implementation of environmental procedures and BMPs would minimize or mitigate potential effects on aquatic resources during the license renewal term. Many activities that could affect aquatic habitats would also require nuclear power plant licensees to obtain Federal permits under CWA Section 404, which would include conditions to minimize or mitigate impacts on affected waterways.

Some utilities are members of the Wildlife Habitat Council, which helps corporations manage their land for broad-based biodiversity enhancement and conservation. As part of membership, sites develop wildlife management plans that include a comprehensive strategy for enhancing and conserving site ecological resources. For instance, at the Braidwood plant in Illinois, Exelon places artificial habitats in Braidwood Lake to create microhabitats and support fish populations, especially largemouth bass (*Micropterus salmoides*) (Exelon 2012). At the LaSalle plant in Illinois, Exelon participates in supplemental stocking of a variety of warm and cool water fish that are raised in an onsite hatchery (Exelon 2012). To maintain membership, sites must undertake projects that promote native biodiversity, gather data on conservation efforts, and report on their progress. Other nuclear power plant sites that maintain Wildlife Habitat Council membership include the Byron, Calvert Cliffs, Clinton, Dresden, Fitzpatrick, Ginna, Limerick, Nine Mile Point, Peach Bottom, and Quad Cities plants. Continued participation in this or similar environmental conservation organizations would minimize or mitigate potential effects on aquatic resources during the license renewal term.

Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and license renewal on aquatic resources would be similar. For these reasons, the effects of site activities, unrelated to cooling system operation, would be minor and would neither destabilize nor noticeably alter any important attribute of the aquatic environment during initial LR or SLR terms of any nuclear power plants. The NRC assumes that nuclear power plants would continue to implement site environmental procedures and would obtain any necessary permits for activities that could affect waterways or aquatic features. Implementation of such controls would further reduce or mitigate potential effects. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The NRC concludes that non-cooling system effects on aquatic resources during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants. This is a Category 1 issue.

*4.6.1.2.12 Impacts of Transmission Line Right-of-Way (ROW) Management on Aquatic Resources*

This issue concerns the effects of transmission line ROW management on aquatic plants and animals during an initial LR or SLR term.

In the 1996 and 2013 LR GEISs, the NRC determined that transmission line ROW maintenance impacts would be SMALL at all nuclear power plants. Therefore, this was considered a Category 1 issue for all nuclear power plants.

When this issue was originally contemplated in the 1996 LR GEIS, the NRC considered as part of its plant-specific license renewal reviews all transmission lines that were constructed to connect a nuclear power plant to the regional electric grid. However, in the 2013 LR GEIS, the NRC clarified that the transmission lines relevant to license renewal include only the lines that connect the nuclear power plant to the first substation that feeds into the regional power distribution system (see Section 3.1.6.5 and 3.1.1). Typically, the first substation is located on the nuclear power plant property within the primary industrial-use area. This decision was informed by the fact that many of the transmission lines that were constructed with nuclear power plants are now interconnected with the regional electric grid and would remain energized regardless of initial LR or SLR. Accordingly, the discussion of this issue in this LR GEIS is brief because in-scope transmission lines for license renewal tend to occupy only industrial-use or other developed portions of nuclear power plant sites. Therefore, effects on aquatic plants and animals are generally negligible. The 2013 LR GEIS provides further background about this issue and discusses it in more detail.

Transmission line management can directly disturb aquatic habitats if ROWs traverse aquatic features and heavy machinery is used in these areas. Heavy equipment can also compact soils, which can affect soil quality and reduce infiltration to shallow groundwater, resulting in runoff and erosion in nearby aquatic habitats. Chemical herbicides applied in ROWs can be transported to nearby aquatic habitats through precipitation and runoff. For small streams, trees may grow sufficiently between cutting cycles to provide shading and support microhabitats. Tree removal to maintain appropriate transmission line clearance could alter the suitability of habitats for fish and other aquatic organisms and locally increase water temperatures.

Most nuclear power plants maintain procedures to minimize or mitigate the potential impacts of ROW management. For instance, heavy machinery and herbicide use is often prohibited in or near wetlands or surface waters. Vegetated buffers are often maintained near surface waters. Procedures also often include checklists to ensure that workers obtain necessary local, State, or Federal permits if work could affect protected resources.

Aquatic communities in transmission line ROWs have been exposed to many years of transmission line operation and have acclimated to regular ROW maintenance. Initial LR or SLR would continue current operating conditions and environmental stressors rather than introduce wholly new impacts. Therefore, the impacts of current operations and license renewal on aquatic resources would be similar. Further, and as stated above, in-scope transmission lines for license renewal tend to occupy only industrial-use or other developed portions of nuclear power plant sites and, therefore, the effects of ROW maintenance on aquatic plants and animals during an initial LR or SLR term would be negligible. The staff reviewed information in scientific literature and from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. The NRC concludes that the transmission line ROW maintenance impacts on aquatic resources during the license renewal term (initial LR or SLR) would be SMALL for all nuclear power plants. This is a Category 1 issue.

#### *4.6.1.3 Federally Protected Ecological Resources*

The NRC must consider the effects of its actions on ecological resources protected under several Federal statutes and must consult with the FWS or the NOAA prior to taking action in cases where an agency action may affect those resources. These statutes include the following:

- the Endangered Species Act of 1973 (16 U.S.C. § 1531 et seq.),
- the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. § 1801 et seq.), as amended by the Sustainable Fisheries Act of 1996, and
- the National Marine Sanctuaries Act (NMSA) (16 U.S.C. § 1431 et seq.).

Section 3.6.3 describes each of these statutes and the ecological resources protected under them. During initial LR and SLR reviews, the NRC may be required to consult under one or more of these statutes depending on the ecological setting of the nuclear power plant and the federally protected species and habitats that may be affected by continued operation of the plant. Under the ESA, the NRC may be required to consult with FWS, NMFS, or both. Individually, these agencies are also referred to as the Service or jointly as the Services. The NRC addresses the ecological resources that each type of interagency consultation addresses as four separate issues in the subsections below. These issues are:

- Endangered Species Act: federally listed species and critical habitats under U.S. Fish and Wildlife Service jurisdiction;[1]
- Endangered Species Act: federally listed species and critical habitats under National Marine Fisheries Service jurisdiction;[1]
- Magnuson-Stevens Fishery Conservation and Management Act: essential fish habitat;[1] and
- National Marine Sanctuaries Act: sanctuary resources.[1]

*4.6.1.3.1 Endangered Species Act: Federally Listed Species and Critical Habitats Under U.S. Fish and Wildlife Jurisdiction*

This issue concerns the potential effects of continued nuclear power plant operation and any refurbishment during an initial LR or SLR term on federally listed species and critical habitats protected under the ESA and under the jurisdiction of the FWS.

Under the ESA, the FWS is responsible for listing and managing terrestrial and freshwater species and designating critical habitat of these species. Continued operation of a nuclear power plant during an initial LR or SLR term could affect these species and their habitat. Listed species are likely to occur near all operating nuclear power plants. However, the potential for a given species to occur in the action area of a specific nuclear power plant depends on the life history, habitat requirements, and distribution of the species and the ecological environment present on or near the plant site. Section 3.6.3.1 describes some of the listed species and critical habitats under FWS jurisdiction that the NRC has analyzed during past license renewal reviews and the relevant environmental stressors related to license renewal.

Potential effects of particular concern for listed terrestrial species, including bats, birds, mammals, reptiles, amphibians, and invertebrates, include the following:

- habitat loss, degradation, disturbance, or fragmentation resulting from construction, refurbishment, or other site activities, including site maintenance and infrastructure repairs
- noise and vibration and general human disturbance
- mortality or injury from collisions with plant structures and vehicles.

Additionally, terrestrial listed species and their habitats can be adversely affected by any of the factors described in Section 4.6.1.1 relevant to terrestrial resources. However, the magnitude and significance of such impacts can be greater for listed species because—by virtue of being eligible for Federal listing—these species are significantly more sensitive to environmental stressors because their populations are already in decline. Similarly, critical habitats are afforded special protections because they are critical to the preservation of the listed species.

Potential effects of particular concern for listed aquatic species, including fish, shellfish and other aquatic invertebrates, and sea turtles, include the following:

- impingement (including entrapment) and entrainment
- thermal effects

[1] These issues have been separated from one 2013 LR GEIS issue into distinct issues that individually address specific categories of federally protected ecological resources that may require separate interagency consultation.

- exposure to radionuclides and other contaminants
- reduction in available food resources due to IM&E or thermal effects on prey species
- effects associated with maintenance dredging.

Additionally, aquatic listed species and their habitats can be adversely affected by any of the factors described in Section 4.6.1.1.2 relevant to aquatic resources. As noted above, the magnitude and significance of such effects can be greater for listed species and critical habitats than for other aquatic resources.

As established in the 2013 LR GEIS, the NRC reports findings under the ESA in accordance with terminology used in the ESA and its implementing regulations (see Table 4.6-6). Individual effect determinations are made for each listed species and critical habitat, so the number of ESA findings for a given license renewal will depend on the number of listed species and critical habitats present in the action area. Table 3.6-2 and Table 3.6-4 identify the NRC's findings for listed species and critical habitats evaluated during initial LR and SLR environmental reviews conducted since the 2013 LR GEIS.

**Table 4.6-6 Possible ESA Effect Determinations**

| Listed Species | Proposed Species | Designated or Proposed Critical Habitat |
|---|---|---|
| "may affect and is likely to adversely affect" | "may affect and is likely to adversely affect" | "is likely to destroy or adversely modify" |
| "may affect but is not likely to adversely affect" | "may affect but is not likely to adversely affect" | "is not likely to destroy or adversely modify" |
| "no effect" | "no effect" | "no effect" |

Depending on the NRC's ESA effect determinations, the NRC may be required to consult with the Services under ESA Section 7(a)(2). The Services maintain joint regulations that implement ESA Section 7 at 50 CFR Part 402, "Interagency Cooperation – Endangered Species Act of 1973, as Amended." Subpart B prescribes the Section 7 interagency consultation requirements. The NRC also relies upon the Services' detailed procedural guidance for conducting Section 7 consultation in *Endangered Species Consultation Handbook: Procedures for Conducting Consultation and Conference Activities Under Section 7 of the Endangered Species Act* (FWS and NMFS 1998).

Under ESA Section 7, Federal agencies must consult with the Services for actions that "may affect" federally listed species and critical habitats and to ensure that their actions do not jeopardize the continued existence of those species or destroy or adversely modify those habitats. Section 7 consultation may be informal or formal. Generally, the appropriate type of consultation is related to the effect determinations made by the Federal agency. For proposed species and proposed critical habitats (the species or habitats for which the Services have issued proposed listing or designation rules, but for which final rules have yet to be issued or adopted), the regulations prescribe a process called a conference. NUREG-1555, Supplement 1, Revision 2, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants for Operating License Renewal* (NRC 2023), describes informal consultation, formal consultation, and conference in detail. The Services' regulations also allow for early, special, and emergency consultations. However, instances that would necessitate these types of consultation are unlikely to arise for license renewal. Table 4.6-7 summarizes the appropriate type of consultation or conference for each possible effect determination.

**Table 4.6-7 Appropriate Type of Consultation by ESA Effect Determination**

| Type of Consultation | Listed Species | Proposed Species | Designated Critical Habitats | Proposed Critical Habitats |
|---|---|---|---|---|
| Formal Consultation | "may affect and is likely to adversely affect" | N/A | "is likely to destroy or adversely modify" | N/A |
| Informal Consultation | "may affect but is not likely to adversely affect" | N/A | "is not likely to destroy or adversely modify" | N/A |
| Conference | N/A | "may affect and is likely to adversely affect" | N/A | "is likely to destroy or adversely modify" |
| No Consultation or Conference | "no effect" | "may affect but is not likely to adversely affect"(a) or "no effect" | "no effect" | "is not likely to destroy or adversely modify" or "no effect" |

N/A = not applicable
(a) Although not required, it is a best practice to confer with the Services when a proposed action may affect but is not likely to adversely affect proposed species.

In cases where adverse effects on listed species or critical habitats are possible, the NRC staff has engaged the Services in formal ESA Section 7 consultation as part of the license renewal review and obtained a biological opinion. The FWS has issued one biological opinion in connection with initial LR and SLR environmental reviews conducted since the publication of the 2013 LR GEIS. This biological opinion is for continued operation of the Turkey Point plant during an SLR term, and it addresses the American crocodile (*Crocodylus acutus*), its critical habitat, and the eastern indigo snake (*Drymarchon corais couperi*) (FWS 2019a, FWS 2022a). The incidental take statement of the opinion allows for a specified amount of take of these species that is incidental to, and not the purpose of, carrying out the Federal action of license renewal, as well as reasonable and prudent measures and terms and conditions to minimize such take. In accordance with these requirements, the Turkey Point plant monitors and reports the effects of continued operation under the license renewal term to the FWS and the NRC. Section 3.6.3 discusses biological opinions in more detail.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. In summary, the potential effects of continued nuclear power plant operation during an initial LR or SLR term depends upon numerous site-specific factors, including the ecological setting of the plant; the listed species and critical habitats present in the action area; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and refurbishment and other ground-disturbing activities. Section 7 of the ESA requires that Federal agencies consult with the Services for actions that "may affect" federally listed species and critical habitats. Additionally, listing status is not static, and the Services frequently issue new rules to list or delist species and designate or remove critical habitats. Therefore, a generic determination of potential impacts on listed species and critical habitats under FWS jurisdiction during a nuclear power plant's license renewal term is not possible. The NRC would need to perform a plant-specific impact assessment as part of each initial LR or SLR environmental review to determine the potential effects on these resources and consult with the FWS, as appropriate. Consequently, this is a Category 2 issue.

*4.6.1.3.2 Endangered Species Act: Federally Listed Species and Critical Habitats Under National Marine Fisheries Service Jurisdiction*

This issue concerns the potential effects of continued nuclear power plant operation and any refurbishment during an initial LR or SLR term on federally listed species and critical habitats protected under the ESA and under the jurisdiction of NMFS.

Under the ESA, NMFS is responsible for listing and managing marine and anadromous species and designating critical habitat of these species. Continued operation of a nuclear power plant during an initial LR or SLR term could affect these species and their habitat. The potential for a given species to occur in the action area of a specific nuclear power plant depends on the life history, habitat requirements, and distribution of that species and the ecological environment present on or near the power plant site. In general, listed species and critical habitats under NMFS jurisdiction are only of concern at nuclear power plants that withdraw or discharge from estuarine or marine waters. However, anadromous listed species under NMFS jurisdiction may be seasonally present in the action area of plants located within freshwater reaches of rivers well upstream of the saltwater interface. For instance, the Columbia plant in Washington withdraws from and discharges to the Columbia River at approximately river mile 352 (river kilometer 566). During the NRC's license renewal review, the NRC consulted with NMFS concerning Upper Columbia River spring run chinook salmon (*Oncorhynchus tshawytscha*) and Upper Columbia River steelhead (*O. mykiss*) due to these species' susceptibility to impingement on the intake screens or entrainment into the intake system. These species migrate past the plant seasonally as fry, which are only a few centimeters in length at this life stage (NRC 2012a, NRC 2012b).

The discussion of potential effects on listed species and critical habitats under FWS jurisdiction provided above in Section 4.6.1.3.1 also applies to this issue. As established in the 2013 LR GEIS, the NRC reports findings under the ESA in accordance with terminology used in the ESA and its implementing regulations (see Table 4.6-6). Depending on the NRC's ESA effect determinations, the NRC may be required to consult with NMFS under ESA Section 7 (see Table 4.6-7).

Since the publication of the 2013 LR GEIS, NMFS has issued several biological opinions in connection with nuclear power plant operation during a license renewal term. These include the following:

- Indian Point plant (no longer operating) biological opinion addressing the effects of continued operation and decommissioning on shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*A. oxyrinchus oxyrinchus*), and critical habitat of the New York Bight distinct population segment of Atlantic sturgeon (NMFS 2013, NMFS 2018a, NMFS 2018b, NMFS 2020a)
- Salem plant and Hope Creek plant biological opinion addressing the effects of continued operation on Atlantic sturgeon; shortnose sturgeon; and green (*Chelonia mydas*), Kemp's (*Lepidochelys kempii*), and loggerhead (*Caretta caretta*) sea turtles (NMFS 2014c, NMFS 2018c)
- St. Lucie plant biological opinion addressing the effects of continued operation on green, hawksbill (*Eretmochelys imbricata*), Kemp's, leatherback (*Dermochelys coriacea*), and loggerhead sea turtles and smalltooth sawfish (*Pristis pectinata*) (NMFS 2016)

- Columbia plant biological opinion addressing the effects of continued operation on Upper Columbia River spring run chinook salmon and Upper Columbia River steelhead (NMFS 2017)
- Oyster Creek plant (no longer operating) biological opinion addressing the effects of continued operation and decommissioning on green, Kemp's, and loggerhead sea turtles (NRC 2020b).

The incidental take statements of these opinions allow for a specified amount of take of listed species that is incidental to, and not the purpose of, carrying out the Federal action of license renewal, as well as reasonable and prudent measures and terms and conditions to minimize such take. In accordance with these requirements, these plants monitor and report the effects of continued operation under the license renewal term to the NMFS and the NRC. Notably, two of these opinions (for the Indian Point and Oyster Creek plants) also address the effects of shutdown and decommissioning. Section 3.6.3 discusses these and other biological opinions in more detail.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. In summary, the potential effects of continued nuclear power plant operation during an initial LR or SLR term depend on numerous site-specific factors, including the ecological setting of the plant; the listed species and critical habitats present in the action area; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and refurbishment and other ground-disturbing activities. Section 7 of the ESA requires that Federal agencies consult with the Services for actions that "may affect" federally listed species and critical habitats. Additionally, listing status is not static, and the Services frequently issue new rules to list or delist species and designate or remove critical habitats. Therefore, a generic determination of potential impacts on listed species and critical habitats under NMFS jurisdiction during a nuclear power plant's license renewal term is not possible. The NRC would need to perform a plant-specific impact assessment as part of each initial LR or SLR environmental review to determine the potential effects on these resources and consult with NMFS, as appropriate. Consequently, this is a Category 2 issue.

##### *4.6.1.3.3 Magnuson-Stevens Act: Essential Fish Habitat*

This issue concerns the potential effects of continued nuclear power plant operation and any refurbishment during an initial LR or SLR term on essential fish habitat (EFH) protected under the MSA.

Under the MSA, the Fishery Management Councils, in conjunction with NMFS, designate areas of EFH and manage marine resources within those areas. Within EFH, habitat areas of particular concern (HAPCs) may be designated if the area meets certain additional criteria. Continued operation of a nuclear power plant during an initial LR or SLR term could affect EFH, including HAPCs. EFH may occur at nuclear power plants located on or near estuaries, coastal inlets and bays, and the ocean. EFH is generally not relevant for license renewal reviews of plants located on rivers well above the saltwater interface or confluence with marine waters; plants located on freshwater lakes, including the Great Lakes; or at plants that draw cooling water from human-made cooling ponds or canals that do not hydrologically connect to natural surface waters. One exception is in cases where a plant draws cooling water from the freshwater portion of a river that is inhabited by diadromous prey of federally managed species (herein referred to as "EFH species") with designated EFH downstream of the plant. Section 3.6.3.2 discusses this in more detail and provides examples of license renewal reviews where this caveat has applied; it also describes EFH that the NRC has analyzed during other past license renewal reviews and the relevant environmental stressors related to license renewal.

EFH is assessed in terms of impacts on the habitat of each EFH species, life stage, and their prey and each HAPC. Importantly, EFH effect determinations characterize the effects on the habitat of the EFH species and their life stages. They do not characterize the effects on the species or the life stages themselves. Similarly, effect determinations for EFH prey characterize the effects on the prey as a food resource rather than the effects on the prey species themselves. For instance, a proposed action that involves water withdrawal from a river for cooling purposes could cause habitat loss (i.e., temporary or permanent physical loss of a portion of the water column). Associated effluent discharge could cause chemical or biological (i.e., temperature and dissolved oxygen content) alterations to the habitat. With respect to prey species, water withdrawals could impinge or entrain prey organisms, which would represent a reduction in available food resources for EFH species within that habitat. Potential effects of particular concern for EFH include the following:

- physical removal of habitat through cooling water withdrawals
- physical alteration of habitat through heated effluent discharges
- chemical alteration of habitat through radionuclides and other contaminants in heated effluent discharges
- physical removal of habitat through maintenance dredging
- reduction in the prey base of the habitat.

Additionally, EFH can be adversely affected by any of the factors described in Section 4.6.1.2 relevant to aquatic resources. However, the magnitude and significance of such impacts can be greater for EFH because—by virtue of being designated as EFH—these habitats are significantly more sensitive to environmental stressors because the EFH species they support are already experiencing many pressures that affect their spawning, breeding, feeding, or growth.

As established in the 2013 LR GEIS, the NRC reports findings under the MSA in accordance with terminology used in the MSA and its implementing regulations (see Table 4.6-8). Individual effect determinations are made for the EFH of each life stage of each EFH species, so the number of MSA findings for a given license renewal will depend on the number of EFH species and life stages with EFH present in the area. For instance, a license renewal could result in no adverse effects to EFH of eggs of Atlantic butterfish (*Peprilus triacanthus*) but could result in minimal adverse effects to EFH of juveniles and adults of the same species. Table 3.6-5 identifies the NRC's findings for EFH evaluated during initial LR and SLR environmental reviews conducted since the publication of the 2013 LR GEIS.

**Table 4.6-8 Possible EFH Effect Determinations**

| EFH Effect Determinations | Spatial Extent | Duration |
|---|---|---|
| "substantial adverse effects" | surface area, depth, and seasonality described in writing with explicit measurements, to the extent possible, or pictorially on a map | temporary versus permanent<br>short-term versus long-term |
| "more than minimal, but less than substantial adverse effects" | | |
| "minimal adverse effects" | | |
| "no adverse effects" | | |

Depending on the NRC's EFH effect determinations, the NRC may be required to consult with NMFS under MSA Section 305(b). The NMFS maintains regulations that implement MSA Section 305 at 50 CFR Part 600, "Magnuson-Stevens Act Provisions." Subpart K of these regulations prescribes the EFH interagency consultation requirements. Subpart J includes definitions and other information relevant to EFH. The NRC also relies upon the NMFS's detailed procedural guidance for conducting EFH consultation in *Essential Fish Habitat Consultation Guidance* (NMFS 2004a) and *Preparing Essential Fish Habitat Assessments: A Guide for Federal Action Agencies* (NMFS 2004b).

EFH consultation may be abbreviated, expanded, or programmatic. Generally, the appropriate type of consultation is related to effect determinations made by the Federal agency. NUREG-1555, Supplement 1, Revision 2, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants for Operating License Renewal* (NRC 2023), describes informal consultation, formal consultation, and conference in detail. The NMFS regulations also allow for general concurrences concerning EFH. However, situations are rare in which a general concurrence would apply to an NRC action. Table 4.6-9 summarizes the appropriate type of consultation for each possible effect determination.

**Table 4.6-9 Appropriate Type of Consultation by Type of Proposed Action and EFH Effect Determination**

| Types of Consultation | Type of Proposed Action | EFH Effect Determination |
|---|---|---|
| Abbreviated Consultation | individual proposed action | "minimal adverse effects"<br>or<br>"more than minimal, but less than adverse effects"[(a)] |
| Expanded Consultation | individual proposed action | "substantial adverse effects"<br>or<br>"more than minimal, but less than adverse effects"[(a)] |
| Programmatic Consultation | proposed actions with a large number of individual actions, such as rulemakings or those involving development of a GEIS | no more than "minimal adverse effects" either individually or cumulatively |
| No Consultation | any | "no adverse effects" |

EFH = essential fish habitat; GEIS = generic environmental impact statement.
(a) For this finding, the NRC should work with NMFS to determine whether abbreviated or expanded consultation is most appropriate.

In cases where adverse effects on EFH are possible, the NRC staff has engaged NMFS in EFH consultation as part of the license renewal review and obtained EFH conservation recommendations. The NMFS has developed EFH conservation recommendations in connection with four initial LR and SLR environmental reviews conducted since the publication of the 2013 LR GEIS: the Columbia (NMFS 2017), Seabrook (NMFS 2011), Limerick (NMFS 2014b), and Surry (NMFS 2019) plant reviews. These recommendations are intended to help an action agency avoid and minimize impacts on EFH, and when there is unavoidable impact, offset this impact (NOAA 2021). For instance, NMFS (2014b) recommended restricting in-water maintenance work during certain parts of the year during the Limerick license renewal term:

- “Avoid in-water maintenance work from March 1 to June 30 of each year to minimize adverse effects on migrating and spawning activities of anadromous fish.”

If EFH consultation is conducted concurrently with ESA consultation, NMFS may make recommendations based on requirements of the biological opinion. For instance, NMFS (2017) made the following recommendations with respect to the Columbia plant license renewal:

(a) “Minimize adverse effects on water quality by monitoring and reporting as stated in term and condition #1 in the accompanying [biological] opinion.”

(b) “Minimize the risk of artificial obstruction by conducting the entrainment and impingement studies as stated in term and condition #2 in the accompanying [biological] opinion.”

The NRC has a statutory obligation to reply to EFH conservation recommendations within 30 days of receiving the recommendations (50 CFR 600.920(k)(1)). A response must be provided at least 10 days prior to the NRC’s issuance of a renewed license renewal if the response is inconsistent with any of NMFS's recommendations, unless NMFS and NRC agree to an alternative timeline (50 CFR 600.920(k)(1)).

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. In summary, the potential effects of continued nuclear power plant operation during an initial LR or SLR term depends upon numerous site-specific factors, including the ecological setting of the plant; the EFH present in the action area, including HAPCs; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and any other activities that may affect aquatic habitats during the license renewal term, such as refurbishment or any in-water activities. Section 305(b) of the MSA requires that Federal agencies consult with NMFS for actions that may adversely affect EFH. Additionally, EFH status is not static. NMFS and the Fishery Management Councils frequently update management plans for EFH species and issue new rules to designate or modify EFH and HAPCs. Therefore, a generic determination of potential impacts on EFH during a nuclear power plant’s license renewal term is not possible. The NRC would need to perform a plant-specific impact assessment as part of each initial LR or SLR environmental review to determine the potential effects on these resources and consult with NMFS, as appropriate. Consequently, this is a Category 2 issue.

*4.6.1.3.4 National Marine Sanctuaries Act: Sanctuary Resources*

This issue concerns the potential effects of continued nuclear power plant operation and any refurbishment during an initial LR or SLR term on sanctuary resources protected under the NMSA.

Under the NMSA, NOAA's Office of National Marine Sanctuaries (ONMS) designates and manages the National Marine Sanctuary System. Marine sanctuaries may occur near nuclear power plants located on or near marine waters as well as the Great Lakes. Currently, five operating nuclear power plants—Ginna, Nine Mile Point, and FitzPatrick on Lake Ontario; Point Beach on Lake Michigan; and Turkey Point near Biscayne Bay—are located near designated or proposed national marine sanctuaries (see Table 3.6-6).

Impacts on marine sanctuaries are broad-ranging because such resources include any living or nonliving resource of a national marine sanctuary. With respect to ecological sanctuary resources, potential effects of particular concern include the following:

- impingement (including entrapment) and entrainment
- thermal effects
- exposure to radionuclides and other contaminants
- reduction in available food resources due to IM&E or thermal effects on prey species
- effects associated with maintenance dredging.

Additionally, sanctuary resources can be adversely affected by any of the factors described in Section 4.6.1.2 relevant to aquatic resources or, in the case of certain sanctuary resources, such as seabirds, the factors described in Section 4.6.1.1 relevant to terrestrial resources. However, the magnitude and significance of such impacts can be greater for sanctuary resources because—by virtue of being part of a national marine sanctuary—these resources are more sensitive to environmental stressors. Notably, because sanctuary resources can include those that contribute to the recreational, ecological, historical, educational, cultural, archaeological, scientific, or aesthetic value of the sanctuary, proper assessment of potential impacts may require coordination with other environmental resource areas, such as visual resources, socioeconomics, and historical and cultural resources. Table 4.6-10 provides examples of types of sanctuary resources included in the regulatory definition at 15 CFR 922.3.

**Table 4.6-10 Types of Sanctuary Resources**

| | |
|---|---|
| substratum of the area of the Sanctuary | phytoplankton and zooplankton |
| submerged features[(a)] and the surrounding seabed | Fish |
| carbonate rock, corals, and other bottom formations | Seabirds |
| coralline algae and other marine plants and algae | sea turtles and other marine reptiles |
| marine invertebrates | marine mammals |
| brine seep biota | historic resources[(b)] |

(a) Submerged features may include human-made features, such as artificial coral reef structures and shipwrecks.
(b) Because sanctuary resources include historic resources, this review necessitates coordination with the historic and cultural resource review to determine whether any historic resources are present that would be relevant to the NMSA consultation. In such cases, multiple NRC staff may be involved in discussions with the ONMS.

The NRC reports findings under the NMSA in accordance with terminology used in the NMSA (see Table 4.6-11). Depending on the NRC's effect determinations, the NRC may be required to consult with ONMS under NMSA Section 304(d). Unlike ESA Section 7 or EFH consultation, for which there are each several possible types of consultation depending on the specific circumstances, the ONMS's guidance prescribes only a single process for consultation. NMSA consultation is required when a Federal agency determines that an action "is likely to destroy, cause the loss of, or injure" a sanctuary resource. Federal actions subject to consultation may be inside or outside the boundary of a national marine sanctuary.

**Table 4.6-11 Possible NMSA Effect Determinations**

| |
|---|
| "may affect and is likely to destroy, cause the loss of, or injure" |
| "may affect but is not likely to destroy, cause the loss of, or injure" |
| "no effect" |

The NOAA has not promulgated regulations concerning NMSA Section 304(d). In 2008, NOAA issued an advance notice of proposed rulemaking in the *Federal Register* soliciting comments about whether development of regulations implementing certain aspects of the NMSA Section 304(d) consultation provisions is appropriate (73 FR 50259). The NOAA later withdrew its proposal in 2011. However, the ONMS has issued guidance for conducting NMSA consultation, which the NRC relies upon, in *Overview of Conducting Consultation Pursuant to Section 304(d) of the National Marine Sanctuaries Act* (NOAA 2009). NUREG-1555, Supplement 1, Revision 2, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants for Operating License Renewal* (NRC 2023), describes NMSA consultation in detail.

The NRC staff has evaluated the potential impacts of license renewal on national marine sanctuaries in two environmental reviews conducted since the publication of the 2013 LR GEIS: Turkey Point and Point Beach plants, both of which were subsequent license renewals. Section 3.6.3.3 summarizes these reviews. Neither license renewal ultimately required NMSA consultation with ONMS. However, these reviews highlighted the need for the NRC to consider potential impacts on sanctuary resources within national marine sanctuaries in its license renewal reviews and to consult with ONMS, as appropriate.

If the initial LR or SLR would injure sanctuary resources, the NRC would consult with ONMS, and ONMS would formulate recommended reasonable and prudent alternatives. In the context of NMSA Section 304(d), these alternatives can best be understood as the actions necessary to protect sanctuary resources. Alternatives generally focus on the location, timing, and methods of the proposed action. For example, the ONMS may recommend that the proposed action be conducted:

- at an alternate location, including a location outside the sanctuary(ies),
- during a different season or that it be delayed for a specified period of time,
- with alternative equipment or procedures, or
- in some combination of these recommendations.

If the ONMS provides the NRC with recommended alternatives, the NRC must discuss the recommendations with the ONMS. If the NRC (or applicant) plans to fully implement the recommended alternatives and fully incorporate them into the proposed action, the NRC need not take any further action beyond this discussion to conclude the consultation. If the NRC (or applicant) does not follow the recommended alternatives, the NRC must prepare a written response that describes the reasons for not implementing the alternatives.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. In summary, the potential effects of continued nuclear power plant operation during an initial LR or SLR term depends upon numerous site-specific factors, including the ecological setting of the plant; the sanctuary resources present in the action area; and plant-specific factors related to operations, including water withdrawal, effluent discharges, and any other activities that may affect sanctuary resources during the license renewal term, such as refurbishment or any in-water activities. Section 304(d) of the NMSA requires that Federal agencies consult with the ONMS for actions that may injure sanctuary resources. Additionally, national marine sanctuary status is not static. The geographic extent of existing sanctuaries may change or expand in the future, and NOAA is likely to designate new sanctuaries as additional areas of conservation need are identified and assessed. Therefore, a generic determination of potential impacts on sanctuary resources during a nuclear power plant's license renewal term is not possible. The NRC would need to perform a plant-specific impact assessment as part of each initial LR or SLR environmental review to determine the potential effects on these resources and consult with NMFS, as appropriate. Consequently, this new issue is being established as a plant-specific, or Category 2 issue.

### 4.6.2 Environmental Consequences of Alternatives to the Proposed Action

*Construction* – For all alternative energy technologies discussed in this section, the impacts of construction on ecological resources would be similar but could vary considerably in magnitude. For land-based facilities, land clearing, excavation work, and installation of impervious surfaces could result in habitat loss, alteration, or fragmentation as well as disturbance, displacement, or mortality of animals. Potential ecological impacts would vary depending on the nature and acreage of the land area disturbed and the intensity of the excavation work. At greenfield sites, impacts would likely be greater than at brownfield and other developed sites because habitat could be permanently lost. Surface water runoff over disturbed ground, construction laydown areas, and material stockpiles could increase levels of dissolved and suspended solids and other contaminants in nearby waterways and aquatic features. Terrestrial and aquatic habitats could also be affected by spills and leaks of petroleum, oil, and lubricant products from construction equipment that is conveyed in stormwater runoff or that otherwise enters nearby water bodies. Noise, vibration, and human activity could alter wildlife behaviors and result in avoidance of neighboring areas of otherwise suitable habitat. Dredging and other in-water work could directly remove or alter the aquatic environment and disturb or kill aquatic organisms. Because construction effects would be short term, some of these effects would be relatively localized and temporary. Effects could be minimized by using existing infrastructure at an existing site, such as retired intake and discharge systems, as well as by using existing transmission lines, roads, parking areas, and certain existing buildings and structures on the site. Co-location of utility and transmission line ROWs with other existing ROWs would minimize the amount of habitat disturbance. Aquatic habitat alteration and loss could be minimized by siting components of the alternatives farther from water bodies and away from drainages and other aquatic features.

Water quality permits required through Federal and State regulations would control, reduce, or mitigate potential effects on the aquatic environment. Through such permits, the permitting agencies could include conditions requiring BMPs or mitigation measures to avoid adverse impacts. For instance, the USACE oversees Section 404 permitting for dredge and fill activities, and EPA, or authorized States and Tribes, oversee NPDES permitting and general stormwater permitting. Companies would likely be required to obtain each of these permits to construct a new replacement power alternative. Notably, the EPA final rule under Phase I of the CWA Section 316(b) regulations applies to new facilities and sets standards to limit intake capacity and velocity to minimize impacts on fish and other aquatic organisms in the source water (40 CFR 125.84). Any new replacement power alternative subject to this rule would be required to comply with the associated technology standards, so construction of once-through cooling systems for alternatives that require cooling water is unlikely.

*Operation* – Many of the operational impacts of a fossil fuel-fired or nuclear power plant alternative would be like those resulting from continued operation of a nuclear power plant during an initial LR or SLR term. Impacts on the ecological environment would include cooling tower deposition of salt and moisture on plants; bird collisions with plant structures and transmission lines; impingement and entrainment of aquatic organisms; thermal and chemical effects related to cooling water effluent discharges; effects of periodic dredging; and potential water use conflicts. Water quality permits required through Federal and State regulations would control, reduce, or mitigate potential effects on the aquatic environment. The operational impacts of other alternative energy technologies would differ and are presented in the following sections.

The above-described impacts would apply generally to construction and operation of each of the alternatives discussed below. Differences among alternatives would depend not only on the selected technology but also on site-specific factors, which cannot be evaluated here. Discussion of such differences is outside the scope of this LR GEIS but is considered in plant-specific SEISs.

#### *4.6.2.1 Fossil Energy Alternatives*

The general impacts of the construction and operation of new fossil fuel energy technologies are described above in Section 4.6.2. The magnitude of impacts on ecological resources would be site-dependent. Impacts would depend on the type and location of a proposed facility, the size of the area affected by construction, the type of cooling system, and the characteristics of the ecological resources present on the site. The magnitude of potential impacts from a proposed facility could be greater than or less than renewing the license for an existing nuclear power plant depending upon site-specific and project-specific factors. Many of the potential ecological impacts from operations of a new fossil fuel energy technologies (coal- or gas-fired) would essentially be like those for a nuclear power plant.

Unique features of a coal-fired power plant that could affect ecological resources include coal delivery, cleaning, and storage, which would involve periodic maintenance dredging (if coal is delivered by barge); noise; dust; loss of habitat; sedimentation and turbidity; and introduction of minerals and terrace elements (including contaminants that can cause impacts like acid mine drainage). Limestone preparation and storage could result in fugitive dust and runoff. Air emissions, most notably acid rain, can cause direct and indirect effects, including foliage injury, nutrient leaching, and decreased biodiversity. Disposal of combustion waste can result in habitat loss and potential seepage of trace and other elements into groundwater, soils, and surface waters.

The unique features of a gas-fired power plant that could affect ecological resources would be those associated with gas pipelines. Pipeline construction could result in the loss, modification, and fragmentation of natural habitats. Co-location of these lines within existing utility ROWs could minimize these impacts. Gas leaks and spills could also adversely affect terrestrial and aquatic ecosystems.

*4.6.2.2 New Nuclear Alternatives*

Many of the impacts of construction and operation of new nuclear technologies are described above in Section 4.6.2. The magnitude of these impacts on ecological resources would be site-dependent and would depend on the type and location of a proposed facility, the size of the area affected by construction, the type of cooling system, and the characteristics of the ecological resources present on the site. For instance, small modular reactors can be more easily sited on existing industrial-use sites, which would minimize disturbance of natural habitats and maximize the use of existing infrastructure. The impacts of operation of a new nuclear power plant and operation of an existing nuclear power plant during an initial LR or SLR term would be similar. However, impacts could be greater than or less than renewing the license for an existing nuclear power plant depending upon site-specific and project-specific factors.

*4.6.2.3 Renewable Alternatives*

The impacts of renewal energy technologies on the ecological environment would vary based on the technology.

Biomass-fired plants would require large amounts of land for cultivation of energy crops, which would result in habitat alteration and loss. Over time, cultivation could deplete the quality of soils. For biomass plants that use agricultural residues (e.g., corncobs, rice husk, jute sticks, cotton stock, coffee prunings, and coconut shells that do not decompose easily and have potential as energy sources), the impacts would potentially be smaller because the affected land would already be in use for cultivation. For biomass plants that use municipal solid waste feedstock, deposition of toxic constituents could adversely affect nearby ecosystems. Water demands for cooling would be like those of fossil fuel-fired plants and, therefore, similar impacts on the ecological environment would be expected (e.g., cooling tower deposition of salt and moisture on plants; impingement and entrainment of aquatic organisms; thermal and chemical effects related to cooling water effluent discharges; effects of periodic dredging; and potential water use conflicts).

The effects of geothermal energy alternatives depend on how the geothermal energy is converted to useful energy. Direct use applications and geothermal heat pumps have almost no negative effects on the environment. Geothermal plants may release chemicals in liquid fractions that could include various heavy metals, which could leach into nearby terrestrial and aquatic habitats and bioaccumulate in plants and animals (Kristmannsdottir and Armannsson 2003). If makeup water is derived from natural water bodies, impacts would be like those of fossil fuel-fired plants.

Onshore wind projects could affect terrestrial species through mechanical noise, collision with turbines and meteorological towers, and interference with migratory behavior. Bird and bat collision mortality is an ongoing concern at operating wind projects, but recent developments in turbine design have reduced strike risk. At 43 wind facilities in Canada, researchers estimated bird fatality at 8.2 birds (plus or minus 1.4 birds) per turbine per year (Zimmerling et al. 2013). Publications examining 2012 data from U.S. wind energy facilities estimated that in total, about a quarter to a half-million birds are killed per year at U.S. wind turbines (Johnson et al. 2016). Another estimate using data through 2014 estimated that U.S. wind turbines account for the death of over a half-million birds per year (Loss et al. 2015). Numbers are likely higher now because many new wind projects have been developed in the past 10 years. At a wind facility in southern Texas, researchers estimated bat fatalities at 16 bats per megawatt per year across all species (Weaver et al. 2020). Onshore wind projects are generally sited away from waterways. Therefore, construction would be unlikely to disturb or otherwise affect aquatic habitats or features. Operation would not require cooling or consumptive water use and, thus, would not affect aquatic resources.

Offshore wind projects could cause increased turbidity, noise, vibration, and other physical disturbances to the aquatic environment from pile-driving, turbine construction, and submarine power cable installation associated with construction. Cable installation could disturb large spans of aquatic habitat and would be especially detrimental to nearshore and estuarine habitats used by early life stages of finfish and shellfish. Dredging would likely be necessary in some areas to prepare for cable installation and would result in destruction of the existing benthic habitat and temporary habitat loss until the benthic community could repopulate the area. Increased vessel anchoring during survey activities, construction, installation, and maintenance would increase turbidity and disturb the benthic environment. Accidental releases of contaminants from fuel and chemical spills would also pose a hazard to the aquatic environment and would be especially detrimental to nearshore, estuarine, and unique or sensitive habitats (BOEM 2020b). During operation, fuel and chemical spills would remain a potential hazard. The presence of permanent structures could lead to impacts on finfish and aquatic invertebrates through entanglement from gear loss, hydrodynamic disturbance, fish aggregation, habitat conversion, and migration disturbances. These impacts may arise from buoys, meteorological towers, foundations, scour/cable protection, and transmission cable infrastructure. However, structure-oriented or hard-bottom species could benefit from the new structures because they would have new material upon which to anchor themselves and build colonies. Bird and bat collisions would remain a concern for offshore wind projects, although such effects are not well studied. Offshore wind projects are more likely to affect birds that conduct transoceanic migrations.

Solar PV facilities occupy large areas of land that could reduce or preclude natural vegetation communities and wildlife use. Misalignment of mirrors could also increase fire risk. Impacts on terrestrial habitats could be largely avoided if solar installations were installed on the roofs of existing residential, commercial, or industrial buildings or at existing standalone solar facilities. Synthetic organic heat transfer fluids could affect surrounding vegetation. Utility-scale solar facilities may also pose hazards to birds and their insect prey if individual birds or insects mistake a facilities’ reflective panel arrays for water. Birds and insects may be injured or killed by colliding with solar panels if they try to land on or enter what they interpret to be water, in what has been termed by researchers as the “lake effect hypothesis” (Kosciuch et al. 2020). The FWS is currently developing mitigation strategies and BMPs related to birds and solar facilities (MASCWG 2016). Discussions with the FWS and other relevant agencies during the planning phases of a new solar project could minimize impacts on birds and other wildlife by incorporating mitigation and BMPs into the design of the facility and construction plans. Solar projects are generally sited away from waterways. Therefore, construction would be unlikely to disturb or otherwise affect aquatic habitats or features. Operation would not require cooling or consumptive water use and, thus, would not affect aquatic resources.

For hydroelectric power alternatives, construction of dams could fragment river and stream habitat and convert these free-flowing ecosystems into lake-like ecosystems. As a result, native riverine species could suffer because many typically cannot thrive in the altered environment. Fish species that migrate through the area to feed and spawn would be prohibited from migrating if fish passages are not installed. Temperature and nutrient stratification in the reservoir and reduced levels of dissolved oxygen could result in hypotoxic or anoxic conditions for aquatic organisms. Aquatic biodiversity would likely decline before reaching some new, less diverse equilibrium within the newly created reservoir. Terrestrial animals that feed on fish and shellfish could experience reduced prey availability. Water use conflicts could affect downstream conditions. Aquatic and riparian habitats and wetlands could experience fluctuating water levels downstream of the dam. When river levels are low, aquatic organisms would temporarily lose habitat or could become stranded. Downstream habitats would be affected by a variety of other dam-induced conditions, such as changes in sediment transport and deposition patterns and channel erosion or scouring.

## 4.7 Historic and Cultural Resources

### 4.7.1 Environmental Consequences of the Proposed Action – Continued Operations and Refurbishment Activities

For the issue of historic and cultural resources, the NRC evaluated the impact of continued operations and refurbishment activities during the license renewal term on historic and cultural resources located onsite and in transmission line ROWs. This issue was addressed in the 2013 LR GEIS (NRC 2013a), and it is a Category 2 issue. The issue has been updated to include discussion of impacts on cultural resources that are not eligible for or listed in the National Register of Historic Places that would also need to be considered during license renewal reviews.

Section 106 of the National Historic Preservation Act (NHPA; 54 U.S.C. § 300101 et seq.) requires Federal agencies to take into account the effects of their undertakings (e.g., initial LR and SLR) on historic properties and consult with the appropriate parties as defined in 36 CFR 800.2. The NEPA requires Federal agencies to consider the potential effects of their actions on the “affected human environment,” which includes “aesthetic, historic, and cultural resources.” As discussed in Section 3.7.2, the NRC fulfills its Section 106 requirements through the NEPA process in accordance with 36 CFR 800.8(c).

Historic and cultural resources, especially archaeological sites, are sensitive to ground disturbance and are nonrenewable. Even a small amount of ground disturbance (e.g., ground clearing and grading) could affect a significant resource. Much of the information contained in an archaeological site is derived from the spatial relationships between soil layers and associated artifacts. Once these spatial relationships are altered, they can never be reclaimed. Aboveground resources and traditional cultural properties (TCPs) are sensitive to impacts from alterations in the viewshed.

Continued operations and refurbishment activities during the renewal term (i.e., initial LR and SLR) can affect historic and cultural resources through (1) ground-disturbing activities associated with plant operations and ongoing maintenance (e.g., construction of new parking lots or buildings), landscaping, agricultural or other use of plant property; (2) activities associated with transmission line maintenance (e.g., maintenance of access roads or removal of danger trees); and (3) changes in the appearance of nuclear power plants and transmission lines. License renewal environmental reviews have shown that the appearance of nuclear power plants and transmission lines has not changed significantly over time; therefore, additional viewshed impacts on historic and cultural resources are not anticipated.

The NHPA requires the NRC to conduct a plant-specific assessment to determine whether historic properties are present in the area of potential effect (APE), and if so, whether the license renewal (initial LR or SLR) would result in any adverse effect upon such properties. There are three potential determinations (see 36 CFR 800.4) for plant-specific license renewal reviews:

- no historic properties present, the undertaking will have no effect to historic properties
- historic properties present, the undertaking will have no adverse effect upon them
- historic properties present, the undertaking will have an adverse effect upon one or more historic properties (see 36 CFR 800.5).

For historic or cultural resources that do not meet the criteria to be considered a historic property under the NHPA, the NRC will assess whether there would or would not be any potential significant impacts on these resource through the NEPA process.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. As discussed in Section 3.7, historic and cultural resources vary widely from site to site; there is no generic way of determining their existence or significance. Based on the information reviewed and the preceding discussion, the NRC concludes that potential impacts from continued operations and refurbishment activities on historic and cultural resources during the initial LR and SLR terms are unique to each nuclear power plant site. Therefore, the impacts on historic and cultural resources cannot be determined generically, and it is a Category 2 issue.

### 4.7.2 Environmental Consequences of Alternatives to the Proposed Action

If construction and operation of replacement energy alternatives require a Federal undertaking (e.g., license, permit), the Federal agency would need to make a reasonable effort to identify historic properties within the direct and indirect effects APE and consider the effects of the undertaking on historic properties, in accordance with Section 106 of the NHPA. If historic properties are present and are affected by the undertaking, adverse effects would be assessed, and resolved in consultation with the State Historic Preservation Officer/Tribal Historic Preservation Officer and any Indian Tribe that attaches religious and cultural significance to identified historic properties through the NHPA Section 106 process. Additionally, NEPA requires Federal agencies to consider the potential effects of their actions on the “affected human environment,” which includes “aesthetic, historic, and cultural resources.”

*Construction* – Construction impacts would be similar regardless of the energy alternative considered. Most impacts on historic and cultural resources would occur primarily from both onsite and offsite preparation-related ground-disturbing activities (e.g., land clearing, grading and excavation, and road work) and the construction of power-generating facilities and non-safety-related facilities such as administration buildings, parking lots, switchyards, pipelines, access roads, and transmission lines. Any land needed to support an alternative energy facility including roads, transmission corridors, rail lines, or other ROWs would also need to be assessed. Before constructing a new replacement power plant at a greenfield, brownfield, or existing nuclear power plant site, cultural resource surveys would need to be performed by a qualified cultural resource professional.

*Operations* – Operation of a replacement energy alternative can affect historic and cultural resources through (1) ground-disturbing activities associated with plant operations and ongoing maintenance (e.g., construction of new parking lots or buildings), landscaping, agricultural or other use of plant property; (2) activities associated with transmission line maintenance (e.g., maintenance of access roads or removal of danger trees); and (3) changes in the appearance of nuclear power plants and transmission lines. The appearance of the power-generating facility and transmission lines could result in alterations to the visual setting, which, whether temporary or permanent, could affect other types of historic and cultural resources such as cultural landscapes, architectural resources, or TCPs. Impacts would vary with plant heights and associated exhaust stacks or cooling towers.

#### *4.7.2.1 Fossil Energy Alternatives*

Impacts from operations of a fossil fuel power plant would be the same as those described in Section 4.7.2.

#### *4.7.2.2 New Nuclear Alternatives*

Impacts from operations of a new nuclear power plant would be the same as those described in Section 4.7.2.

#### *4.7.2.3 Renewable Alternatives*

Impacts from operations of a new renewable energy facility would be the same as those described in Section 4.7.2.

## 4.8 Socioeconomics

### 4.8.1 Environmental Consequences of the Proposed Action – Continued Operations and Refurbishment Activities

Environmental reviews have shown that continued operations and refurbishment activities in support of license renewal have had little to no socioeconomic effect on communities near nuclear plants. Socioeconomic effects of power plant operations have become well established and normal fluctuations in employment, income, and tax revenue have not altered the quality and availability of community services and housing or increased traffic volumes.

License renewal applicants consistently indicate they have no plans to add operations workers, and increased maintenance and safety inspection activities during the renewal term can be managed using the current workforce. Consequently, people living near nuclear power plants have not experienced any significant socioeconomic impact since construction and the onset of reactor operations. In addition, refurbishment activities, including steam generator and vessel head replacement, have been conducted during regularly scheduled power plant refueling and maintenance outages.

The environmental review of socioeconomic impacts conducted for this LR GEIS revision consists of five issues.

- employment and income, recreation, and tourism
- tax revenue
- community services and education
- population and housing
- transportation

#### *4.8.1.1 Employment and Income, Recreation, and Tourism*

As explained in Section 3.8, the nuclear power plant and the communities that support it can be described as a dynamic socioeconomic system. The communities provide the people, goods, and services required to operate the nuclear power plant. Power plant operation, in turn, provides employment and income and pays for goods and services from the communities.

Employees receive income from the nuclear power plant in the form of wages, salaries, and benefits. Employees and their families, in turn, spend this income on goods and services within the community, thereby creating additional employment opportunities and income. In addition, people and businesses in the community receive income for the goods and services sold to the nuclear power plant. Payments for these goods and services create additional employment and income opportunities within the community.

As previously discussed, the number of nuclear plant operations workers is not expected to change, and license renewal environmental reviews have shown no need for additional workers. In addition, refurbishment activities, including steam generator and vessel head replacement, are conducted during regularly scheduled refueling and maintenance outages. Consequently, employment levels at a nuclear power plant are not expected to change as a result of license renewal.

Some communities experience seasonal transient population growth due to local tourism and recreational activities. Income from tourism and recreational activities creates employment and income opportunities in the communities around nuclear power plants. Communities located near nuclear power plants in coastal regions, notably the D.C. Cook and Palisades plants (Palisades was shut down in May of 2022) on the eastern shore of Lake Michigan, experience summer and weekend population increases due to the recreational and tourism activities that attract visitors. Some communities attract visitors interested in outdoor recreational activities, such as camping, hiking, and skiing.

As discussed in Section 4.2.1.2, the NRC considered the aesthetic impacts of nuclear plant operations and refurbishment activities potentially affecting tourism and recreational business interests. The NRC concluded in the 1996 and 2013 LR GEISs that aesthetic impacts would be SMALL for all nuclear plants and a Category 1 issue. This is primarily because the visual impact occurred during and after construction, and the appearance of nuclear power plants is not expected to change as a result of license renewal.

However, a case study performed for the 1996 LR GEIS found situations where nuclear power plants have had a negative effect on the public. Negative perceptions were based on aesthetic considerations (for instance, the nuclear plant is out of character or scale with the community or the viewshed), physical environmental concerns, safety and perceived risk issues, an anti-nuclear plant attitude, or an anti-nuclear outlook. It is believed that these negative perceptions would persist regardless of any mitigation. Subsequently, license renewal environmental reviews have not revealed any new information that would change this perception.

Nevertheless, the effects of power plant operations on employment, income, recreation, and tourism are ongoing and have become well-established for all nuclear power plants. The impacts from power plant operations during the license renewal term on employment and income in communities near nuclear power plants are not expected to change from those currently being experienced. In addition, tourism and recreational activities in the vicinity of nuclear plants are not expected to change as a result of license renewal. Based on these considerations, the NRC concludes impacts from continued nuclear plant operations during initial LR and SLR terms and refurbishment on employment, income, recreation, and tourism would be the same—SMALL for all nuclear plants. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, employment, income, recreation, and tourism impacts would be SMALL for all nuclear plants and a Category 1 issue for both initial LRs and SLRs.

#### *4.8.1.2 Tax Revenue*

Nuclear power plants are an important source of tax revenue for many local governments and public school districts. Property taxes or payments in lieu of (property) taxes (PILOTs) are the principal source of tax revenue in many tax jurisdictions with nuclear power plants, although in some jurisdictions energy production is also taxed. County and municipal governments and public school districts receive tax revenue either directly from the licensee, owner of the nuclear plant, or indirectly through State tax and revenue-sharing programs.

Counties and municipal governments also receive revenue from sales taxes and fees paid by the nuclear plant and its employees. Changes in the workforce and property taxes or PILOTs paid to local governments and public schools can directly affect socioeconomic conditions in the counties and communities near the nuclear power plant.

Environmental reviews have shown that refurbishment activities, such as steam generator and vessel head replacement, have not had a noticeable effect on the assessed value of nuclear plants, thus changes in tax revenues are not anticipated from these activities. Refurbishment involving the one-for-one replacement of existing nuclear plant components and equipment are generally not considered a taxable improvement. Also, property tax assessments; proprietary PILOT stipulations, settlements, and agreements; and State tax laws are continually changing the amount of taxes paid to tax jurisdictions by nuclear plant owners. These tax revenue changes are independent of license renewal and refurbishment activities.

The primary impact of initial LR or SLR would be the continuation of the receipt of tax revenue from nuclear plants to local governments and public school districts. The environmental impact of continued power plant operations on tax revenue in local communities and the expenditure of tax revenue are not expected to change appreciably. Tax payments during the license renewal term would be similar to those already being paid. Based on these considerations, the NRC concludes impacts from continued nuclear plant operations during initial LR and SLR terms and refurbishment on tax revenue would be the same—SMALL for all nuclear plants. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, tax revenue impacts would be SMALL for all nuclear plants and a Category 1 issue for both initial LRs and SLRs.

#### *4.8.1.3 Community Services and Education*

Impacts from continued power plant operations and refurbishment activities on public (community) services and education were evaluated based on the projected number of “in-migrating” workers with families during the renewal term. Public safety, social services, and public utility impacts were also considered.

Workforce changes at a nuclear plant can affect the demand for public services in local communities. Environmental reviews have shown, however, that the number of operations workers at nuclear plants has not changed significantly because of license renewal, so demand-related impacts on community services and public utilities are not anticipated. In addition, refurbishment activities, including steam generator and vessel head replacement, are being conducted during regularly scheduled refueling and maintenance outages.

Tax payments support a range of community services, including public water, safety, fire protection, health, social, and educational services. In some communities, tax revenue from nuclear plants have had a noticeable beneficial impact on the quality and availability of public services to local residents. Nevertheless, the impact of continued operations and refurbishment activities on community services and education is SMALL and is not expected to change as a result of license renewal.

Based on these considerations, the NRC concludes that impacts from continued nuclear plant operations during initial LR and SLR terms and refurbishment on community services and education would be the same—SMALL for all nuclear plants. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, community services and education impacts would be SMALL for all nuclear plants and a Category 1 issue for both initial LRs and SLRs.

#### *4.8.1.4 Population and Housing*

Nuclear power plant-induced population changes, while not an impact in themselves, were studied as a potential influence on a number of socioeconomic impact issues analyzed in the LR GEIS. As previously discussed, however, employment levels at nuclear plants are not expected to change. Therefore, the operational effects of continued operations and refurbishment activities on population and housing values and availability are not expected to change from what is already being experienced near nuclear power plants, and no changes in housing demand is expected during the license renewal term.

The increased number of workers at nuclear power plants during regularly scheduled refueling and maintenance outages increases the short-term demand for temporary (rental) housing units near each nuclear plant. However, because of its short duration and repeated nature, employment-related housing impacts have little or no long-term effect on the price and availability of rental housing. In addition, refurbishment activities, including steam generator and vessel head replacement, are being conducted during these refueling and maintenance outages. Therefore, refurbishment-related housing demand impacts would be similar to what is already being experienced during regularly scheduled refueling and maintenance outages.

Environmental reviews performed since development of the 2013 LR GEIS have shown that the number of workers at nuclear plants are not expected to change because of license renewal, so changes in population and housing availability and value are not anticipated. Based on these considerations, the NRC concludes impacts from continued nuclear plant operations during initial LR and SLR terms and refurbishment on population and housing would be the same—SMALL for all nuclear plants. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, population and housing impacts would be SMALL for all nuclear plants and a Category 1 issue for both initial LRs and SLRs.

#### *4.8.1.5 Transportation*

Transportation impacts depend on the size of the workforce, the capacity of the local road network, traffic patterns, and the availability of alternate commuting routes to and from the nuclear plant. Because most nuclear power plants have a single access road, there is often congestion during shift changes.

Transportation impacts are ongoing and have become well-established at all nuclear power plants. As previously discussed, the number of workers is unlikely to change during the license renewal term, and environmental reviews have shown little or no need for additional operations workers. In addition, refurbishment activities, including steam generator and vessel head replacement, are being conducted during regularly scheduled refueling and maintenance outages.

The increased number of workers at nuclear power plants during refueling and maintenance outages have caused short-term increases in traffic volumes on roads in the vicinity of each plant. However, because of the relative short duration of these outages, increased traffic volumes have had little or no lasting impact. Therefore, there would be no transportation impacts during the license renewal term beyond those already being experienced. Based on these considerations, the NRC concludes transportation impacts from continued nuclear plant operations during initial LR and SLR terms and refurbishment would be the same—SMALL for all nuclear plants. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, transportation impacts would be SMALL for all nuclear plants and a Category 1 issue for both initial LRs and SLRs.

### 4.8.2 Environmental Consequences of Alternatives to the Proposed Action

Communities have the potential to be both directly and indirectly affected by the construction and operation of a new power plant. The power plant and the communities that support it can be described as a dynamic socioeconomic system. Communities provide the people, goods, and services needed to construct and operate the new power plant. The power plant, in turn, provides employment and income (wages, salaries, and benefits) and pays for goods and services. The measure of a communities' ability to support the new power plant depends on its ability to respond to changing environmental, social, economic, and demographic conditions.

*Construction* – The scale and duration of the socioeconomic impact is determined by the cost, complexity, and size of the replacement energy-generating facility and the workforce needed to construct the new power plant. Socioeconomic impacts may be greater at greenfield sites in rural areas than at brownfield sites in urban areas. Overall, construction would have a temporary effect on the local economy.

Some construction workers may temporarily relocate from outside the region depending on the need for and the availability of skilled crafts and trades workers. Larger numbers of workers would likely relocate to rural construction sites, while urban construction sites would likely see workers commuting daily to the job site. Some construction material (e.g., sand, gravel, fill, etc.) and equipment may be available locally. Other construction materials, equipment, and components may need to be shipped in from outside the region. Transportation during construction would include commuter vehicles and truck, barge, or rail material and equipment delivery to and from the construction site.

*Operations* – Operating a new power plant would have a greater permanent effect on the local economy than during construction. Socioeconomic impacts would be greater in rural areas and may be less noticeable in urban areas. Local property values could be affected by the need for permanent housing by power plant operations workers. Conversely, the visual industrial impact of the power plant during operations, traffic, and noise, could negatively affect property values.

Depending on location, an operating power plant could also negatively affect recreation and tourism interests, resulting in reduced employment and income opportunities in these sectors of the economy. Transportation during power plant operations includes commuter vehicle and material and equipment truck deliveries and removal of waste.

The following sections briefly highlight the socioeconomic impacts of replacement energy alternatives.

#### *4.8.2.1 Fossil Energy Alternatives*

Construction and operation of fossil fuel-fired power plants requires a very large workforce compared to other types of power plants and renewable technologies. Differences between natural gas- and coal-fired power plants include the transportation impacts associated with coal deliveries (rail or barge) and the removal of coal ash, waste, and other byproducts that may affect property values and, depending on location, recreation and tourism interests in the vicinity of the power plant.

#### *4.8.2.2 New Nuclear Alternatives*

Similar to a fossil-fueled power plant, a large workforce would be required to construct and operate a new nuclear power plant. The presence of a nuclear power plant could affect property values and, depending on location, recreation and tourism interests in the vicinity of the power plant.

#### *4.8.2.3 Renewable Alternatives*

*Construction and Operation* – Compared to fossil fuel and new nuclear energy, renewable energy production would require a very small construction and operation workforce. In addition, the construction of a new reservoir and dam for hydroelectric power generation would create new recreational employment and income opportunities based on park, campground, and boat ramp visitors. Traffic would increase on roads in the vicinity of the reservoir. Wind, solar, and geothermal power generation could adversely affect recreation interests and property values in rural communities. Transportation impacts would be limited due to the small size of the workforce.

Conversely, local transportation networks could be affected by truck and rail traffic delivering biomass fuel and removing waste to offsite disposal facilities. Property values, recreation, and tourism interests could be adversely affected near the biomass and municipal solid waste, refuse-derived and landfill gas-fired power plants.

Tourist and recreational interests and commerce on coastal beaches could be affected by the visual impact of offshore wind turbines and ocean wave and current power-generating facilities. Wave energy devices on the ocean surface could affect navigation and waterborne recreational and commerce activities.

## 4.9 Human Health

### 4.9.1 Environmental Consequences of the Proposed Action – Continued Operations and Refurbishment Activities

Human health conditions at all nuclear power plants and associated transmission lines have been well established during the current licensing term. Based on past environmental monitoring data and trends, no significant human health impacts are anticipated during the license renewal (initial LR or SLR) term that would be different from those occurring during the current license term. Certain operational changes (such as extended power uprates) that could potentially affect human health would be evaluated by the NRC in a separate safety and environmental review.

#### *4.9.1.1 Environmental Consequences of Normal Operating Conditions*

This section provides an evaluation of the impacts of radiological, chemical, microbiological, EMFs, and physical hazards on occupational personnel and members of the public from continued operation and any refurbishment activities during the initial LR and SLR terms. This evaluation extends to all U.S. commercial nuclear power reactors. For safe and reliable operation of a nuclear power plant, it is necessary to perform routine maintenance on plant systems and components. Maintenance activities conducted at nuclear power plants include inspection, surveillance, and repair and/or replacement of material and equipment to maintain the current licensing basis of the plant and maintain compliance with environmental and public safety requirements. Certain activities can be performed while the reactor is operating, and others require that the reactor be shut down. Long-term outages are scheduled for refueling and for certain types of repairs or maintenance activities, such as the replacement of steam generators for pressurized water reactors (PWRs).

##### *4.9.1.1.1 Radiological Exposure and Risk*

Two environmental issues related to radiological exposure and risk are reviewed here: (1) radiation exposures to plant workers and (2) radiation exposures to the public, both of which would result from continued operation and refurbishment activities during the initial LR or SLR terms.

For the purposes of assessing radiological impacts, impacts are considered to be SMALL if releases and doses do not exceed the permissible levels in the NRC's regulations. This definition of SMALL applies to occupational doses as well as to doses to individual members of the public. Accidental releases or noncompliance with the standards could conceivably result in releases that would cause MODERATE or LARGE radiological impacts. Such conditions are beyond the scope of regulations for controlling normal operations and providing an adequate level of protection. Environmental consequences and the human health effects of potential accidents are addressed in Section 4.9.1.2.

**Radiation Exposures to Plant Workers**

The occupational radiological exposures from current operations at nuclear power plants and the risk estimates from this radiation exposure are discussed in Section 3.9.

In the 1996 LR GEIS, the impacts from occupational radiological exposure from refurbishment and continued operations were evaluated separately. To estimate radiation-related impacts on workers over the license renewal term, occupational radiation exposure was used as the environmental impact initiator that was quantified. It was assumed that occupational radiation exposure would change relative to current nuclear plant operations as a result of actions taken to support license renewal. To evaluate the impacts, two types of license renewal programs were considered: a "typical" or "mid-stream" license renewal program, and a "conservative" or "bounding" program (NRC 1996). Each program applied to both PWRs and boiling water reactors (BWRs). Thus, in all, four scenarios were considered. It was assumed that activities carried out in support of license renewal would be performed primarily during selected outages.

Five types of outages were considered: normal refuelings, 5-year in-service inspection (ISI) outages, 10-year ISI outages, current-term refurbishment outages, and major refurbishment outages. The potential actions and activities that would be undertaken during these outages were identified. All of the rules and regulations, in particular the Maintenance Rule (10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants"), were taken into account in developing typical license renewals or plant-life extensions (NRC 1996). The occupational exposure for each of the five types of outages was estimated for all four scenarios (see Table 4.9-1). This analysis is bounding for both the initial LR and SLR terms as discussed below.

For refurbishment efforts, collective occupational dose estimates for activities during each of the four current-term refurbishment outages were 11 and 10 person-rem for PWRs and BWRs, respectively, for the typical case; and 200 and 191 person-rem, respectively, for the conservative case. Collective occupational dose estimates for the assumed single period of major refurbishment were 79 and 153 person-rem for PWRs and BWRs, respectively, for the typical case; and 1,380 and 1,561 person-rem, respectively, for the conservative case. The individual occupational doses would be well below regulatory limits specified in Table 3.9-1 (i.e., the impact would be SMALL), and the issue was designated as a Category 1 issue.

**Table 4.9-1 Additional Collective Occupational Dose (person-rem) for Different Actions under Typical and Conservative Scenarios during the License Renewal Term**

| Outage Type | Typical BWR | Conservative BWR | Typical PWR | Conservative PWR |
|---|---|---|---|---|
| Normal refueling[(a)] | 4 | 10 | 3 | 7 |
| 5-yr ISI refueling[(b)] | 71 | 27 | 30 | 35 |
| 10-yr ISI refueling[(c)] | 91 | 108 | 51 | 66 |
| Current-term refurbishment[(d)] | 10 | 191 | 11 | 200 |
| Major refurbishment outage[(e)] | 153 | 1,561 | 79 | 1,380 |
| Total all occurrences | 457 | 2,666 | 261 | 2,374 |

BWR = boiling water reactor; ISI = in-service inspection; PWR = pressurized water reactor.
(a) 8 occurrences, 2-month duration each.
(b) 2 occurrences, 3-month duration each.
(c) 1 occurrence, 4-month duration for conservative and 3-month duration for typical scenario.
(d) 4 occurrences, 4-month duration for conservative and 3-month duration for typical scenario.
(e) 1 occurrence, 9-month for conservative and 4-month duration for typical scenario.
Sources: Tables 2.8 and 2.11 in the 1996 LR GEIS.

For continued operations during the license renewal term, the NRC observed in the 1996 LR GEIS that the greatest increment to occupational dose over the present dose would occur during a 10-year ISI refueling. In a typical case, the collective occupational dose would increase over the present dose by 91 person-rem for a BWR and by 51 person-rem for a PWR. In a conservative case, the collective occupational dose would increase over the present dose by 108 person-rem and 66 person-rem, respectively, for BWRs and PWRs. The individual occupational doses would be well below regulatory limits (i.e., the impact would be SMALL), and the issue was designated as a Category 1 issue.

For estimating the impacts from continued operation and any refurbishment activities during the initial LR or SLR term in this LR GEIS revision, the occupational exposure histories for all commercial nuclear power plants were evaluated for trends.

Throughout the nuclear power industry, modification and upgrade activities have continued at each operating plant. They have included a broad range of activities in response to NRC requirements and industry initiatives, including post-Three Mile Island upgrades, radioactive waste system modifications, and spent fuel storage upgrades. In addition, several nuclear power plants have undergone major refurbishment efforts, such as PWR steam generator replacement and the replacement of coolant recirculation piping in BWRs. These activities offered a significant potential for occupational exposure. Thus, occupational exposure histories accumulated to date reflect normal operation plus modifications and additions to existing systems. This information forms the basis for evaluating the occupational doses that result from refurbishment and continued operations during initial LR or SLR terms. The data in Table 3.9-11, Table 3.9-12, Table 3.9-13, and Table 3.9-14 show that there are variations in occupational dose from year to year, but there is no consistent trend that shows that occupational doses are increasing over time.

Since 1996, 96 operating reactors at approximately 58 nuclear power plant sites have undergone an environmental review for license renewal. Many nuclear power plants have already replaced major components like steam generators during their current license term. Moreover, as part of the license renewal application, the plant licensees have conducted an aging management review. All of the plant licensees expect to conduct the activities related to managing impacts from aging during plant operation or normal refueling and other outages, but they do not plan any outage specifically for the purpose of refurbishment. License renewal applicants have indicated that the activities conducted during the initial LR or SLR terms are expected to be within the bounds of normal operations; thus, even the typical scenario in the 1996 LR GEIS can be considered conservative.

Overall, data presented in tables in Section 3.9 provide ample evidence that occupational doses at all commercial power plants are far below the occupational dose limit of 5 rem/yr established by 10 CFR Part 20 and that the continuing efforts to maintain doses at ALARA levels have been successful.

The wide range of annual collective doses experienced at PWRs and BWRs in the United States results from a number of factors, such as the reactor design, amount of required maintenance, and amount of reactor operations and in-plant surveillance. Because these factors can vary widely and unpredictably, it is difficult to determine in advance specific year-to-year occupational radiation doses for a particular plant over its operating lifetime. On occasion, relatively high collective occupational doses (compared to the average annual collective dose) may be unavoidable, even at plants with radiation protection programs designed to make sure that occupational doses will be kept to ALARA levels.

Occupational doses have shown a declining trend over the past 10 years and have recently leveled off. As plants age, there may be slight increases in radioactive inventories, which would result in slight increases in occupational radiation doses, but no such trend has been observed in the monitoring data.

Overall, data presented in the tables in Section 3.9 provide evidence that doses to nearly all radiation workers are far below the worker dose limit established by 10 CFR Part 20 and that the continuing efforts to maintain doses at ALARA levels have been successful.

Occupational doses from refurbishment activities associated with license renewal and occupational doses for continued operations during the initial LR or SLR terms are expected to be similar to the doses during the current operations and bounded by the analysis conducted in the 1996 LR GEIS. It is estimated that the occupational doses would be much less than the regulatory dose limits, as described above. Expected occupational radiation exposures meet the standard for being of SMALL significance. No mitigation measures beyond those implemented during the current license term would be warranted, because the ALARA process continues to be effective in reducing radiation doses.

In the 1996 and 2013 LR GEISs, the NRC concluded that the occupational radiological exposure impact during license renewal and refurbishment would be SMALL for all plants; it was therefore designated as a Category 1 issue. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On this basis, the NRC concludes that the impact of continued operations during initial LR or SLR terms and any refurbishment activities on occupational radiological exposure during the initial LR or SLR terms would be SMALL for all nuclear plants. This is a Category 1 issue.

**Radiation Exposures to the Public**

Radiological exposures to the public from current operations at nuclear power plants are discussed in Section 3.9.1.3. That section includes a discussion of the effluent pathways used in calculating dose and the radiological monitoring performed at each nuclear plant site to make sure that unanticipated buildup of radioactivity has not occurred in the environment. The risk estimates for the public from radiation exposure are discussed in Section 3.9.1.4.

During continued operations following initial LRs or SLRs, small quantities of radioactivity (fission, corrosion, and activation products) will continue to be released to the environment in a manner similar to that occurring during present operations (see Section 3.9).

In both the 1996 and 2013 LR GEIS, the NRC evaluated the significance of the estimated public dose from refurbishment activities such as steam generator replacement in PWRs and replacement of recirculation piping in BWRs. Public radiation exposures from gaseous and liquid effluents produced during refurbishment activities can be evaluated on the basis of effluent data from the replacement of steam generators and recirculation piping as discussed in the 2013 LR GEIS. During the replacement of steam generators and recirculation piping, releases of effluents have occurred under controlled conditions and in accordance with ALARA principles. Similar refurbishment efforts that may occur as part of continued operations following initial LR or SLR would also take place under controlled conditions and in accordance with ALARA principles.

The concentration of radioactive materials in soils and sediments increases in the environment at a rate that depends on the rate of release and the rate of removal. Removal can take place through radioactive decay or through chemical, biological, or physical processes. For a given rate of release, the concentrations of longer-lived radionuclides and, consequently, the dose rates attributable to them would continue to increase if license renewal was granted.

Regulatory Guide 1.109 (NRC 1977) provides guidance for calculating the dose for significant release pathways. To account for the buildup of radioactive materials, buildup factors are included in the calculations. The accumulation of radioactive materials in the environment is of concern not only with regard to license renewal but also with regard to operation under current licenses. NRC reporting rules require that pathways that may arise as a result of unique conditions at a specific nuclear power plant site be considered in licensees' evaluations of radiation exposures. If an exposure pathway is likely to contribute significantly to total dose (10 percent or more to the total dose from all pathways), it must be routinely monitored and evaluated. Environmental monitoring programs are in place at all plant sites to provide a backup to the calculated doses based on effluent release measurements. Because these programs are ongoing for the duration of the plant's license, locations where unique situations give rise to significant pathways that are not detailed in NRC Regulatory Guide 1.109 are to be identified if and when they become significant. If such pathways result in doses at a plant exceeding the design objectives of Appendix I to 10 CFR Part 50, action is required.

The radiation dose to the public from current operations results from gaseous effluent releases and from liquid effluent releases, as presented in Section 3.9.1.3. At present, for all operating nuclear plants, doses to the maximally exposed individual (MEI) are much less than the design objectives of Appendix I to 10 CFR Part 50 (Table 3.9-2). No aspect of future operation has been identified that would substantially alter this situation.

Maximum individual doses are reported in annual effluent release reports, and if these doses exceed Appendix I to 10 CFR Part 50 design objectives, the NRC would pursue remedial action. Thus, these issues are handled on a case-by-case basis. Almost all nuclear power plants have gone through initial LR, and no aging phenomenon that would increase public radiation doses has been identified. The operating reactors are not expected to reach regulatory dose limits more often in the period after initial LR or SLR than they do at present. For these reasons, dose impacts on MEIs in the public during future operation are judged to be unchanged from those during present operations. Although dose rates (mrem/yr) are not expected to change during initial LRs or SLRs, the cumulative dose (total mrem) would increase as a result of 20 to 40 more years of operations. However, it is unlikely that the same person would be exposed to these doses during the initial LR or SLR term.

One of the pathways considered when calculating the MEI doses is direct radiation from operating plants. Radiation fields are produced around nuclear plants as a result of radioactivity within the reactor and its associated components, low-level storage containers, and components such as steam generators that have been removed from the reactor. Direct radiation from sources within a light water reactor (LWR) plant is due primarily to nitrogen-16, a radionuclide produced in the reactor core by neutron activation of oxygen-16 in the water. Because the primary coolant of an LWR is contained in a heavily shielded area, dose rates in the vicinity of LWRs are generally undetectable and less than 1 mrem/yr at the site boundary. Some plants (mostly BWRs) do not have completely shielded secondary systems and may contribute some measurable offsite dose. However, these sources of direct radiation will be unaffected by license renewal.

In addition to the regulations within 10 CFR 20.1101 that speak directly to required operation under ALARA principles, 10 CFR 50.36a imposes conditions on nuclear plant licensees in the form of technical specifications on effluents from nuclear power reactors. These specifications are intended to keep releases of radioactive materials to unrestricted areas during operations to ALARA levels. Appendix I to 10 CFR Part 50 provides numerical guidance on dose-design objectives and limiting conditions for the operation of LWRs to meet the ALARA requirements. These regulations will remain in effect during the period of license renewal.

To date, 96 operating reactors at 58 nuclear power plant sites have gone through license renewal. In all cases, the radiation dose to members of the public from routine operations was within NRC regulations as presented in Section 3.9.1.3. This information was used to support the conclusion that the radiation dose to the public will continue at current levels associated with normal operations and is expected to remain much lower than the applicable standards.

Offsite doses to the public attributable to refurbishment activities were examined for the MEI. Because the focus of the analysis is on annual dose, only the results based on the most likely major refurbishment action were examined (i.e., replacing steam generators in PWRs and primary recirculation piping in BWRs). For this action, doses to the public were found to be SMALL. To date, effluents and doses during periods of major refurbishments have not been observed to differ significantly from those during normal operations. Consequently, gaseous effluents and liquid discharges occurring during major refurbishment actions are not expected to result in maximum individual doses exceeding the design objectives of Appendix I to 10 CFR Part 50 (Table 3.9-2) or the allowable EPA standards of 40 CFR Part 190, Subpart B (Table 3.9-3).

Radiation doses to members of the public from current operations of nuclear power plants have been examined from a variety of perspectives, and the impacts were found to be well within design objectives and regulations in each instance. No effect of aging that would significantly affect the radioactive effluents has been identified. Public doses are expected to remain well within design objectives and regulations.

Because there is no reason to expect effluents to increase in the period during the initial LR or SLR term, doses from continued operation are expected to be well within regulatory limits. No mitigation measures beyond those implemented during the current-term license would be warranted because current mitigation practices have kept public radiation doses well below regulatory standards and are expected to continue to do so.

Public radiological exposure impacts during license renewal and refurbishment activities were considered to be SMALL for all plants and were designated as Category 1 issues in the 1996 and 2013 LR GEISs. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On the basis of these considerations, the NRC concludes that the impact of continued operations and refurbishment activities on public radiological exposure during the initial LR and SLR terms would be SMALL for all nuclear plants. This is a Category 1 issue.

##### *4.9.1.1.2 Nonradiological Hazards*

Nonradiological hazards, such as chemical, biological, EMFs, and physical hazards are not unique to nuclear power plants and occur in many types of industrial facilities. However, certain nonradiological hazards can be enhanced by physical plant elements or characteristics of nuclear power plants, as discussed in detail in Section 3.9.2.

**Chemical Hazards**

This renamed issue has been revised from the issue "Human health impact from chemicals" in the 2013 LR GEIS for the purposes of clarity and to reflect the fact that chemicals can have environmental effects beyond human health.

A chemical hazard occurs when workers or members of the public are exposed to a nonradiological hazardous substance by inhalation, skin absorption, or ingestion. Chemical hazards can have immediate effects (nausea, vomiting, acid burns, asphyxiation—also known as acute hazards) or the effects might take time to develop (dermatitis, asthma, liver damage, cancer—also known as chronic hazards). In nuclear power plants, chemical effects could result from discharges of chlorine or other biocides, small-volume discharges of sanitary and other liquid wastes, chemical spills, or heavy metals leached from cooling system piping and condenser tubing. Impacts of chemical discharges on human health are considered to be SMALL if the discharges of chemicals to water bodies are within effluent limitations designed to protect water quality and if ongoing discharges have not resulted in adverse effects on aquatic biota. During the initial LR or SLR term, human health impacts from chemicals are expected to be the same as those experienced during operations under the original license term (see Section 3.9.2 for more details).

The types of chemical hazards that exist at a nuclear power plant are discussed in Section 3.9.2.1. Plant workers may encounter hazardous chemicals when the chemistries of the primary and secondary coolant systems are being adjusted, biocides are being applied to address the fouling of cooling system components, equipment containing hazardous oils or other chemicals is being repaired or replaced, solvents are being used for cleaning, or other equipment is being repaired. Exposures to hazardous chemicals are minimized when plant workers follow good industrial hygiene practices.

Reviews of the literature and operational monitoring reports and consultations with utilities and regulatory agencies that were conducted for the 1996 LR GEIS indicated that the effects of the discharge of chlorine and other biocides on water quality would be of SMALL significance for all nuclear power plants. Small quantities of biocides are readily dissipated and/or chemically altered in the water body receiving them, so significant cumulative impacts on water quality would not be expected. Major changes in the operation of the cooling system are not expected during the license renewal terms, so no change in the effects of biocide discharges on the quality of the receiving water is anticipated. Major proposed changes in cooling system operations (e.g., those affecting the plant's licensing basis and possibly triggering a license amendment) would require a separate NEPA review, including an examination of human health effects. In addition, proposed changes in the use of cooling water treatment chemicals would require review by the plant's NPDES permit-issuing authority and possible modification of the existing NPDES permit, including examination of the human health effects of the change. The effects of biocide discharges could be reduced by increasing the degree to which discharge water is treated, reducing the concentration of biocides, or treating only a portion of the plant cooling and service water systems at one time. Discharges of sanitary wastes are regulated by the plant's NPDES permit or other regulatory approval, and discharges that do not violate the permit limits are considered to be of SMALL significance.

The effects of minor chemical discharges and spills at nuclear plants on water quality have been of SMALL significance and mitigated as needed. Significant cumulative impacts on water quality would not be expected because the small amounts of chemicals released by these minor discharges or spills are readily dissipated in the receiving water body. While there may be additional management practices or discharge-control devices that could further reduce the frequency of accidental spills and off-specification discharges, they are not warranted because impacts are already SMALL and occur at a low frequency.

Heavy metals (e.g., copper, zinc, and chromium) may be leached from condenser tubing and other heat exchangers and discharged by power plants as small-volume waste streams or corrosion products. Although all are found in small quantities in natural waters (and many are essential micronutrients), concentrations in the power plant discharge are controlled in the NPDES permit because excessive concentrations of heavy metals can be toxic to aquatic organisms.

Nuclear power plants may be required in some instances to submit annual reports on the environmental releases of listed toxic chemicals manufactured, processed, or otherwise used that are above identified threshold quantities depending on State regulations or other specific circumstances. The disposal of essentially all of the hazardous chemicals used at nuclear power plants is regulated by Resource Conservation and Recovery Act (RCRA; 42 U.S.C. § 6901 et seq.) or NPDES permits. The NRC requires nuclear power plants to operate in compliance with all of its environmental permits, thereby minimizing adverse impacts on the environment and on workers and the public. It is anticipated that all plants will continue to operate in compliance with all applicable permits, and no mitigation measures beyond those implemented during the current-term license would be warranted as a result of initial LR or SLR.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On the basis of these considerations, the health impact from chemicals on workers and the public, as well as on the environment, during the initial LR and SLR terms is considered SMALL for all nuclear plants. This renamed issue is a Category 1 issue.

##### *4.9.1.1.3 Microbiological Hazards*

Microbiological hazards occur when workers or members of the public come into contact with disease-causing microorganisms, also known as etiological agents. Microbiological organisms of concern for public and occupational health, include enteric pathogens (bacteria that typically exist in the intestines of animals and humans [e.g., *Pseudomonas aeruginosa*]), thermophilic fungi, bacteria (e.g., *Legionella spp*. and *Vibrio spp*.), free-living amoebae (e.g., *Naegleria fowleri* and *Acanthamoeba spp*.), as well as organisms that produce toxins that affect human health (e.g., dinoflagellates [*Karenia brevis*] and blue-green algae). During initial LR and SLR terms, plant workers and members of the public would be exposed to microbiological hazards in the same way that they are exposed during operations under the original license term (see Section 3.9.2.2 for details).

Two environmental issues related to microbiological hazards are reviewed here: (1) microbiological hazards to plant workers and (2) microbiological hazards to the public (this issue was modified and renamed from the 2013 LR GEIS to include waters of the United States accessible to the public).

**Microbiological Hazards to Plant Workers**

No change in existing microbiological hazards is expected due to license renewal, for the reasons discussed in detail in the 2013 LR GEIS. It is considered unlikely that any plants that have not already experienced occupational microbiological hazards would do so during the license renewal term or that hazards would increase during that period. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. It is anticipated that all plants will continue to employ proven industrial hygiene principles so that adverse occupational health effects associated with microorganisms during the initial LR and SLR terms will be of SMALL significance at all sites, and no mitigation measures beyond those implemented during the current-term license would be warranted. Aside from continued application of accepted industrial hygiene procedures, no additional mitigation measures are expected to be warranted as a result of license renewal. This is a Category 1 issue.

**Microbiological Hazards to the Public**

This renamed issue is an expansion of the issue “Microbiological hazards to the public (plants with cooling ponds or canals or cooling towers that discharge to a river)” in the 2013 LR GEIS because this issue is a concern wherever receiving waters are accessible to the public. Specifically, members of the public could be exposed to microorganisms in thermal effluents at nuclear power plants that use cooling ponds, lakes, canals, or that discharge to any waters of the United States accessible to the public. As discussed in Section 3.9.2.2, the SEISs published since 2013 were reviewed to determine the level of thermophilic microbiological organism enhancement in waters accessible to the public. Although reviews to date note that health departments did not have concerns related to microbiological hazards, changes in microbial populations and in the public use of water bodies might occur after the operating license is issued and the application for initial LR or SLR is filed. Other factors could also change, including the average temperature of the water, which could result from climate change affecting water levels and air temperature. Finally, the long-term presence of a power plant might change the natural dynamics of harmful microorganisms within a body of water. Therefore, the magnitude of the potential public health impacts associated with thermal enhancement of thermophilic organisms during the initial LR and SLR terms could be SMALL, MODERATE, or LARGE, depending on plant-specific conditions. This renamed issue is a Category 2 issue.

*4.9.1.1.4 Electromagnetic Fields (EMFs)*

This renamed issue is a clarification of the issue “Chronic effects of electromagnetic fields” in the 2013 LR GEIS because this issue concerns effects beyond just those that might be chronic in nature. Nuclear power plants use power transmission systems that consist of switching stations (or substations) located on the plant site and transmission lines located primarily offsite that connect the power plant to the regional electric grid. Electric fields and magnetic fields, collectively referred to as EMFs, are produced by any electrical equipment, including operating transmission lines. During the initial LR or SLR, plant workers and members of the public who live, work, or pass near an associated operating transmission line may be exposed to EMFs in the same way that they are exposed during the current license term (see Section 3.9.2.3 for more detail). One environmental issue related to EMFs is reviewed in this section: chronic effects of EMFs. The issue was further evaluated in the 2013 LR GEIS by reviewing the relevant literature.

As in the 2013 LR GEIS, it should be noted that the scope of the evaluation of transmission lines includes only those transmission lines that connect the plant to the switchyard where electricity is fed into the regional power distribution system (encompassing those lines that connect the plant to the first substation of the regional electric power grid) and power lines that feed the plant from the grid are considered within the regulatory scope of license renewal environmental review (see Sections 3.1.1 and 3.1.6.5 in this GEIS).

EMF health studies have been the subject of published studies, and a discussion of some of these studies was presented in the 2013 LR GEIS in Section 4.9.1.1.4 and is incorporated here by reference. A review of the biological and physical studies of 60 hertz (Hz) EMFs completed during preparation of the 2013 LR GEIS did not find any consistent evidence that would link harmful effects with field exposures. EMFs are unlike other agents that have a toxic effect (e.g., toxic chemicals and ionizing radiation) in that dramatic acute effects cannot be forced, and longer-term effects, if real, are subtle. Nonetheless, a wide range of biological responses have been reported to be affected by EMFs.

Even if clear adverse effects were apparent in the epidemiology literature or with some biological assay, considerable additional work would be required to determine how and what to mitigate because evidence suggests that the severity of some EMF biological effects may not correlate directly with exposure. Furthermore, there may be a subtle relationship between the intensity of the local geomagnetic field and the appearance of effects for some intensities of 60 Hz fields. This complicating evidence points to the fact that, while much experimental and epidemiological evidence has been accrued, understanding of this issue continues to evolve.

For this renamed issue, because of inconclusive scientific evidence, the health effects of EMFs during the initial LR and SLR terms are considered UNCERTAIN, and currently, no generic impact level can be assigned. The NRC will continue to monitor the research initiatives—both those within the national EMF program and others internationally—to evaluate the potential carcinogenicity of EMFs as well as other progress in the EMF study disciplines. If the NRC finds that the appropriate Federal health agencies have reached a consensus on the potential human health effects of exposure to EMF, the NRC will revise the LR GEIS to include the new information and describe effective mitigating measures.

*4.9.1.1.5 Physical Hazards*

Two additional human health issues are addressed in this section: (1) physical occupational hazards and (2) electric shock hazards, both previously considered in the LR GEIS. Nuclear power plants are industrial facilities that have many of the typical occupational hazards found at any other electric power generation facility. Power plant and maintenance workers could be working under potentially hazardous physical conditions (e.g., excessive heat, cold, and hazardous locations), including those experienced when conducting electrical work, power line maintenance, and repair work. The issue of physical occupational hazards is generic to all nuclear power plants.

Transmission lines are needed to transfer energy from the nuclear power plant to consumers. The workers and general public at or around the nuclear power plants and along the transmission lines are potentially exposed to acute electrical shock from these lines. The issue of electrical shock is generic to all nuclear power plants. As described in Sections 3.1.1 and 3.1.6.5, in-scope transmission lines include only those lines that would not continue to operate if a plant's license was not renewed. Using this criterion, in-scope transmission lines are those lines that connect the plant to the first substation of the regional electric grid. This substation is frequently, but not always, located on the nuclear plant property.

During the initial LR or SLR terms, human health impacts from physical occupational hazards and acute shock hazards would be the same as those from operations during the original license term (see Section 3.9.2.4 for more detail).

**Physical Occupational Hazards**

The types of physical hazards that exist at a nuclear power plant are discussed in Section 3.9.2.4. The issue of occupational hazards is evaluated by comparing the rate of fatal injuries and nonfatal occupational injuries and illnesses in the utility sector with the rate in all industries combined. Occupational hazards can be minimized when workers adhere to safety standards and use appropriate personal protective equipment; however, fatalities and injuries from accidents can still occur. Data for occupational injuries from the U.S. Bureau of Labor Statistics are discussed in detail in Section 3.9.2.4. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. It is expected that during the initial LR or SLR term, workers would continue to adhere to safety standards and use protective equipment, so adverse occupational impacts during the initial LR and SLR terms would be of SMALL significance at all sites, and no mitigation measures beyond those implemented during the current license term would be warranted. This is a Category 1 issue.

**Electric Shock Hazards**

In-scope transmission lines are those lines that connect the plant to the first substation of the regional electric grid. This substation is frequently, but not always, located on the plant property. The greatest hazard from a transmission line is direct contact with the conductors. Tower designs preclude direct access to the conductors. However, electrical contact can be made without physical contact between a grounded object and the conductor, as discussed in Section 3.9.2.4.1. A person who contacts such an object could receive a shock and experience a painful sensation at the point of contact. The intensity of the shock would depend on the EMF strength, size of the object, and how well the object and person were insulated from ground.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. Design criteria for nuclear power plants that limit hazards from steady-state currents are based on the National Electrical Safety Code (NESC), adherence to which requires that power companies design transmission lines so that the short-circuit current to ground produced from the largest anticipated vehicle or object is limited to less than 5 mA (IEEE SA 2017). The electrical shock issue, which is generic to all types of electrical generating stations, including nuclear plants, is of SMALL significance for transmission lines that are operated in adherence with the NESC. Without a review of the conformance of each nuclear plant's transmission lines, within this scope of review, with NESC criteria, it is not possible to determine the significance of the electrical shock potential generically during the initial LR or SLR term; it could be SMALL, MODERATE, or LARGE. The hazard of electric shock is a Category 2 issue.

*4.9.1.2 Environmental Consequences of Postulated Accidents*

*4.9.1.2.1 Design-Basis Accidents and Severe Accidents*

Chapter 5 of the 1996 LR GEIS assessed the impacts of postulated accidents at nuclear power plants on the environment. The postulated accidents included design-basis accidents and severe accidents (e.g., those with reactor core damage). The impacts considered included:

- dose and health effects of accidents (5.3.3.2 through 5.3.3.4 of the 1996 LR GEIS);
- economic impacts of accidents (5.3.3.5 of the 1996 LR GEIS); and
- impact of uncertainties on results (5.3.4 of the 1996 LR GEIS).

The estimated impacts were based upon the analysis of severe accidents at 28 nuclear power plants,[1] as reported in the environmental impact statements (EISs) and/or final environmental statements prepared for each of the 28 plants in support of their operating licenses. With few exceptions, the severe accident analyses were limited to consideration of reactor accidents caused by internal events. The 1996 LR GEIS addressed the impacts from external events qualitatively. The severe accident analysis for the 28 plants was extended to the remainder of plants whose EISs did not consider severe accidents (because such analysis was not required at the time the other plants' EISs were prepared). The estimates of environmental impact contained in the 1996 LR GEIS used 95th percentile upper confidence bound estimates whenever available. This provides conservatism to cover uncertainties, as described in Section 5.3.3.2.2 of the 1996 LR GEIS. The 1996 LR GEIS concluded that the probability-weighted consequences and impacts were SMALL compared to other risks to which the populations surrounding NPPs are routinely exposed.

Appendix E of this document provides an update on postulated accident risk. Because the NRC's understanding of accident risk has evolved since the issuance of the 1996 LR GEIS and extends beyond issuance of the 2013 LR GEIS, Appendix E assesses more recent information about postulated accidents that might have had the potential to alter the conclusions in Chapter 5 of the 1996 LR GEIS. This update considers how these developments would affect the conclusions in the original LR GEIS and provides comparative data where appropriate.

The different sources of new information can be generally categorized by their effect of either decreasing, not affecting, or increasing the best-estimate environmental impacts associated with postulated severe accidents. The areas where a decrease in best-estimate impacts would be expected are:

- new internal events information (decreases in impacts by over an order of magnitude), and
- new source term information (significant decreases).

[1] The 28 sites are listed in Table 5.1 of the 1996 LR GEIS. There are a total of 44 units included in this list, but 4 of the units never operated (Grand Gulf 2, Harris 2, Perry 2, and Seabrook 2). For the purpose of this document, this list will be referred to as containing 28 NPPs, but when mean values are calculated for this subset of NPPs, the 40 units that operated are considered.

Areas likely leading to either a small change or no change include:

- use of Biological Effects of Ionizing Radiation VII (BEIR-VII) risk coefficients.

Lastly, the areas leading to an increase in best-estimate impacts would consist of:

- consideration of external events (comparable to internal event impacts),
- power uprates (small increase),
- higher fuel burnup (small increases),
- low power and reactor shutdown events (could be comparable to at-power event impacts), and
- new SFP accidents (newer studies demonstrate less risk, much less than full power event impacts).

Given the difficulty in conducting a rigorous aggregation of these results (due to the differences in the information sources used and in the impact metrics evaluated), a fairly simple approach is taken. The latter group contains two areas (power uprates and higher fuel burnup) where the increase in environmental impact (probability-weighted consequences) would cumulatively be less than 50 percent. For one area (SFP accidents) the increase in environmental impact would be less than that from power reactor operations, but is conservatively considered to be comparable to that from full power reactor operations. The increase in environmental impact from consideration of low power and shutdown events is comparable to that from at-power operations, but is conservatively assumed to be up to a factor of 2 to 3 higher. The final factor, external events, wasn't assessed separately but as an integrated assessment considering all hazards. The net increase from the four factors is conservatively an increase of up to a factor of 4 to 5, or 400 to 500 percent.

The reduction in environmental impact associated with the new source term information is dramatic. The early fatality risk is orders-of-magnitude less than the NRC safety goal, and the latent cancer fatality risk is well below the NRC safety goal. However, because the state-of-the-art reactor consequence analysis (SOARCA) (NUREG-1935; NRC 2012i) did not evaluate the risk of all accident scenarios, this reduction in environmental impact is not credited in this assessment. The other factor that has resulted in a decrease in environmental impact is the risk of at-power severe reactor accidents due to internal events. The internal events core damage frequency (CDF) has decreased, on average, by a factor of 4 to 6. However, the reduction in environmental impact is substantial, ranging from a factor of 2 to 600 and, on average is about a factor of 30 lower when compared to the expected value of the population dose risk reported in the 1996 LR GEIS. Because the 1996 LR GEIS did not consider the environmental impact contribution from external events, consideration of these events results in an increase in the environmental impact. The net result when all hazards are considered is that the All Hazards CDF, on average, is comparable to that assumed for just internal events in the 1996 LR GEIS. However, the reduction in All Hazards population dose risk, or probability-weighted dose consequence, ranges from a factor of 3 to over 1000 and is, on average, about a factor of 120 (or 12,000%) less than the corresponding predicted 95 percent upper confidence bound values.

The net effect of a maximum increase of accident risk on the order of 400 to 500 percent and an average decrease in accident risk of 12,000 percent would be a substantial reduction in estimated impacts (compared to the 1996 LR GEIS assessment). This result demonstrates the substantial level of conservatism incorporated in the upper bound estimates used in the 1996 LR GEIS, which supported the conclusion that the probability-weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to ground water, and societal and economic impacts of severe accidents are of small significance for all plants.

With respect to uncertainties, the 1996 LR GEIS contained an assessment of uncertainties in the information used to estimate the environmental impacts. Section 5.3.5 of the 1996 LR GEIS discusses the uncertainties and concludes that they could cause the impacts to vary anywhere from a factor of 10 to a factor of 1,000. This range of uncertainties bounds the uncertainties discussed in Section E.3.9 of Appendix E of this revised LR GEIS, as well as the uncertainties brought in by the other sources of new information, by one or more orders of magnitude. Section E.3.9 of this LR GEIS notes that more recent detailed quantitative analyses indicate that the 95th percentile bounds of consequence uncertainty are likely to be about a factor of 10 or less compared to point-estimates or compared to other central-tendency estimates.

Based on the analysis presented in Appendix E, the staff concludes that the reduction in environmental impacts from the use of new information (since the 1996 and 2013 LR GEIS analyses) outweighs any increases resulting from this same information for initial LR or SLR. In part, the staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. As a result, the findings in the 1996 LR GEIS and 2013 LR GEIS remain valid. Therefore, the environmental impacts of design-basis accidents are SMALL for all plants during the initial LR and SLR terms and the issue is Category 1.

In the 2013 LR GEIS, the issue of severe accidents remained a Category 2 issue to the extent that only the alternatives to mitigate severe accidents must be considered for all nuclear power plants where the licensee had not previously performed a severe accident mitigation alternatives analysis for the plant. This LR GEIS update provides a technical basis for reclassifying this issue as Category 1.

Consistent with the NRC’s approach to severe accident mitigation in the 1996 LR GEIS and the 2013 LR GEIS, alternatives to mitigate severe accidents still must be considered for all plants that have not considered such alternatives; however, as discussed further in Appendix E, the plants that have already had a severe accident mitigation alternatives analysis considered by the NRC as part of an EIS, supplement to an EIS, or environmental assessment, need not perform an additional severe accident mitigation alternatives analysis for license renewal. Table E-19 provides a summary of the NRC staff’s findings with respect to these issues. Based on current industry plans, the NRC expects very few, if any, license renewal applications for a plant that has not previously considered severe accidents under NEPA. Consequently, severe accidents are most accurately categorized as a Category 1 issue because it will be resolved generically for the vast majority of, if not all, applicants. The impacts of all new information in this update confirms the basis for the NRC’s previous requirement that license renewal applicants need not consider severe accident mitigation for plants that have already done so. This new information demonstrates that further mitigation analysis would not contribute sufficiently to reducing the environmental impacts of severe accident risk to warrant further severe accident mitigation alternatives analysis because the likelihood of finding cost-effective significant plant improvements is small.

In part, the staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. On the basis of these considerations, the NRC staff concludes that the probability-weighted consequences of severe accidents during the initial LR and SLR terms is SMALL for all operating nuclear power plants. As a result, the issue of severe accidents is revised from Category 2, as evaluated in the 2013 LR GEIS, to Category 1.

### 4.9.2 Environmental Consequences of Alternatives to the Proposed Action

Impacts on human health from construction of a replacement power station (including fossil energy, new nuclear, and renewable or other energy replacement alternatives) discussed in this section, would be similar to those experienced during construction of any major industrial facility. Compliance with worker protection rules, the use of personal protective equipment, training, and placement of engineered barriers would limit those impacts on workers to acceptable levels. Because the NRC staff expects that access to active construction areas would be limited to only authorized individuals, the impacts on human health from construction are minimal.

#### *4.9.2.1 Fossil Energy Alternatives*

Operational human health impacts for fossil energy alternatives (i.e., natural gas, coal, and oil) include significant impacts on air quality, as discussed in Section 4.3.2.1. The operation of fossil energy alternatives has a range of potential human health impacts such as risks from coal and limestone mining; worker and public risk from coal, lime, and limestone transportation; worker and public risk from disposal of coal-combustion waste; public risk from inhalation of stack emissions; and noise both onsite and offsite (i.e., natural gas). There are also potential impacts from nonradiological hazards, including exposure to microbiological organisms, occupational safety risks, impacts from EMFs, and exposure to chemicals used onsite by the workforce. In addition, human health risks may extend beyond the facility workforce to the public depending on their proximity to the facility or associated waste disposal site. The character and the constituents of the waste depend on both the chemical composition and the technology used to combust it. The human health impacts from the operation of a fossil energy power station include public risk from inhalation of gaseous emissions. Regulatory agencies, including both Federal and State agencies, base air emission standards and requirements on human health impacts. These agencies also impose facility-specific emission limits to protect human health (e.g., coal-combustion residuals) (40 CFR Part 257).

#### *4.9.2.2 New Nuclear Alternatives*

Operational human health impacts for a new nuclear plant (i.e., advanced light water reactors and small modular reactors) would include radiation exposure to the public and to the operational workforce at levels below regulatory limits, as discussed for current operating reactors in Section 3.9. In addition to radiological impacts, there are also potential impacts from the same nonradiological hazards as discussed in Section 3.9.1.1 for current reactors and described in Section 4.9.2.1 above for fossil energy alternatives. Impacts on human health for initial LR and SLR for operating nuclear plants, in most cases, were determined to be SMALL. Similar human health impacts would be expected from the operation of a new nuclear facility.

A detailed analysis of postulated accidents in currently operating reactors (affected by initial LR or SLR) is provided in Section 4.9.1.2 and Appendix E. Although the analysis is specific to initial LR and SLR, the impacts are representative of the impacts expected for new reactors. New reactor designs incorporate additional safety features not found in currently operating reactors. As a result, the risks associated with the new reactors are expected to be comparable to or less than the risks associated with current operating reactors. Before a license is granted, the application for a new reactor would undergo a detailed safety and environmental review to make sure that the plant, if constructed, would operate in accordance with all applicable NRC rules and regulations.

#### *4.9.2.3 Renewable Alternatives*

The operational impacts of renewable and other energy replacement alternative technologies on human health are similar to the impacts related to construction and current operations of industrial facilities. Operational hazards for the workforce include potential exposure to toxic gas or chemicals (i.e., geothermal, biomass, municipal solid waste, refuse-derived fuel, and landfill gas), working in extreme weather (i.e., wind and ocean wave and ocean currents for offshore wind turbines), and physical hazards that include working at heights, near energized or rotating systems, high pressure water (i.e., hydroelectric), exposure to low-frequency sound, EMF exposure (i.e., wind and solar), and potential for electric shock. These operational impacts are reduced by compliance with worker protection rules, the use of personal protective equipment, and training, which would limit those impacts on workers to acceptable levels.

## 4.10 Environmental Justice

### 4.10.1 Environmental Consequences of the Proposed Action – Continued Operations and Refurbishment Activities

As explained in Chapter 3, Executive Order 12898, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations” (1994) (59 FR 7629), directs each Federal agency to identify and address, as appropriate, “disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations.” Although independent agencies, like the NRC, were only requested, rather than directed, to comply with Executive Order 12898, the NRC Chairman, in a March 1994 letter to the President, committed the NRC to endeavoring to carry out its measures “ … as part of NRC’s efforts to comply with the requirements of NEPA” (NRC 1994).

#### *4.10.1.1 Impacts on Minority Populations, Low-Income Populations, and Indian Tribes*

The environmental justice impact analysis determines whether human health or environmental effects from continued reactor operations and refurbishment activities at a nuclear power plant would disproportionately affect a minority population, low-income population, or Indian Tribe and whether these effects may be high and adverse. Adverse health effects are measured in terms of the risk and rate of fatal or nonfatal exposure to an environmental hazard. Disproportionately high and adverse human health effects occur when the risk or rate of exposure for a minority population, low-income population, or Indian Tribe to an environmental hazard is significant and exceeds the risk or rate to the general population or other comparison group.

Disproportionately high and adverse environmental effects occur when an impact on the natural or physical environment significantly and adversely affects a minority population, low-income population, or Indian Tribe and exceeds those on the general population or other comparison group. Such effects may include ecological, cultural, socioeconomic, or social impacts. These environmental effects are discussed in this chapter for each of these and other resource areas. For example, increased demand for rental housing during the construction of a new power plant for one of the energy replacement alternatives could disproportionately affect low-income populations.

The NRC's environmental justice impact analysis (1) identifies minority populations, low-income populations, and Indian Tribes that could be affected by continued reactor operations during the license renewal term and refurbishment activities at a nuclear power plant, (2) determines whether there would be any human health or environmental effects on these populations, and (3) determines whether these effects may be disproportionately high and adverse. The NRC strives to engage with representatives of affected environmental justice communities and Tribal Nations to establish long-term relationships and identify license renewal-related concerns and issues to be addressed in the NEPA review. Minority and low-income populations, Indian Tribes, and environmental justice issues are different at each nuclear power plant site.

Continued reactor operations during the license renewal term and refurbishment activities at a nuclear power plant could affect land, air, water, and ecological resources, which could result in human health or environmental effects. Consequently, minority and low-income populations and Indian Tribes could be disproportionately affected. The NRC's environmental justice impact analysis must therefore determine whether continued reactor operations during the license renewal term and refurbishment activities at a nuclear power plant would result in disproportionately high and adverse human health or environmental effects on a minority population, low-income population, or Indian Tribe.

Section 4–4 of Executive Order 12898 also directs Federal agencies, whenever practical and appropriate, to collect and analyze information about the consumption patterns of populations that rely principally on fish and wildlife for subsistence and to communicate the risks of these consumption patterns to the public. Consumption patterns (e.g., subsistence agriculture, hunting, and fishing) and certain resource dependencies often reflect the traditional or cultural practices of minority populations, low-income populations, and Indian Tribes. Consequently, the NRC considers the means by which these populations could be disproportionately affected by examining potential human health and environmental effects from continued reactor operations and refurbishment activities at nuclear power plants. In assessing the human health effects of license renewal, the NRC examines radiological risk from consumption of fish, wildlife, and local produce; exposure to radioactive material in water, soils, and vegetation; and the inhalation of airborne radioactive material during nuclear power plant operation. To assess the effect of nuclear reactor operations, licensees are required to collect samples from the environment, as part of their REMP. These samples are then analyzed for radioactivity to assess the impact from nuclear power plant operations.

A nuclear plant effect may be indicated if the radiation level detected in a sample is higher than the background level. Two types of samples are collected. The first type—control samples—are collected from areas of the environment beyond or outside the influence of the nuclear power plant. Control samples are used to determine normal background radiation levels. The second type—indicator samples—are collected from the environment near the nuclear power plant where any radioactivity would be at its highest concentration. Indicator samples are then compared to control samples to determine the contribution of nuclear power plant operation to radiation or radioactivity levels in the environment. A nuclear plant effect is indicated if radioactivity levels in an indicator sample exceeds the background radiation levels in the control sample.

Moreover, as noted in the Commission's "Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions" (69 FR 52040), the NRC recognizes that environmental justice issues "differ from site to site and, thus, do not lend themselves to generic resolutions. Consequently, [environmental justice], as well as other … issues, are considered in site-specific EISs." For this reason, environmental justice is a Category 2 issue, and the NRC makes its license renewal impact determination in nuclear plant-specific SEISs.

Based on these considerations, the NRC concludes environmental justice impacts during initial LR and SLR terms and refurbishment are unique to each nuclear power plant. In addition, the NRC identified no new information or situations regarding initial LR or SLR that would result in different conclusions from the 2013 LR GEIS. Therefore, the environmental justice impacts of license renewal cannot be determined generically and is a Category 2 issue for both initial LRs and SLRs.

### 4.10.2 Environmental Consequences of Alternatives to the Proposed Action

*Construction and Operation* – Minority populations, low-income populations, and Indian Tribes could be directly or indirectly affected by the construction and operation of a new power plant. However, the extent of human health or environmental effects is difficult to determine because it depends on the location and type of power plant. For example, emissions from fossil fuel-fired power plants may disproportionately affect human health conditions in minority populations, low-income populations, and Indian Tribes. Power plant operations may also affect populations that subsist on the consumption of fish, wildlife, and local produce.

New replacement power-generating facilities are often located at an existing power plant or industrial brownfield site to make use of the existing infrastructure. Unfortunately, these sites are also frequently located in or near low-income and minority communities who may be disproportionately affected by construction dust, noise, truck, and commuter traffic. In addition, during construction, increased demand for temporary rental housing could disproportionately affect low-income populations who rely on low-cost rental housing. Conversely, the construction and operation of new power-generating facilities can create new employment and income opportunities in these communities. Also, rental housing demand could be mitigated if the new replacement power plant is located near a metropolitan area where construction workers could commute to the job site.

Low-income populations can also benefit from demand-side management energy conservation and efficiency weatherization and insulation programs. This would have a beneficial economic effect because low-income households generally experience greater home energy cost burdens than the average household. Conversely, higher utility bills due to increasing power-generating costs could disproportionately affect low-income families. However, the Federal Low Income Home Energy Assistance Program and State energy assistance programs (if available) can help low-income families pay for electricity.

## 4.11 Waste Management and Pollution Prevention

### 4.11.1 Environmental Consequences of the Proposed Action – Continued Operations and Refurbishment Activities

The effects of license renewal including operations and refurbishment on waste management are presented in this section. Baseline conditions at operating reactors are discussed in Section 3.11. License renewal is expected to result in a continuation of these conditions for an extended period commensurate with the license renewal term (initial LR or SLR). Accumulated quantities of waste material needing long-term storage or disposal are expected to increase at a rate proportional to the length of operation.

The impacts associated with onsite waste management activities during a license renewal term (initial LR and SLR) at nuclear power plants are addressed in other sections of Chapter 4 under various resource discussions. These activities include waste collection, treatment, packaging, and loading onto conveyance vehicles for shipment offsite. These activities are considered to be part of the normal operations at a plant site. For example, the annual radioactive effluent release reports issued by plant licensees include a summary of radioactive effluent releases from all the facilities on the plant site, including the waste management and storage facilities. The same reports also provide data on the volume and radioactivity content of solid radioactive waste shipped offsite for processing and disposal. Similarly, the REMP conducted by nuclear power plant licensees measures the direct radiation as well as environmental concentrations of all radionuclides originating at the site as well as background radiation. The impact from the transportation of wastes from the reactor to a third-party waste treatment center or directly to a disposal site is addressed generically in Table S-4 in 10 CFR 51.52 (see Section 4.14.1.1).

The issues addressed in this section regarding waste management during the license renewal term (as evaluated in the 2013 LR GEIS) include:

- low-level radioactive waste (LLW) storage and disposal,
- onsite storage of spent nuclear fuel,
- offsite radiological impacts of spent nuclear fuel and high-level waste disposal,
- mixed waste storage and disposal, and
- nonradiological waste storage and disposal.

These five issues relate to waste management at all nuclear fuel cycle facilities, including nuclear power plants. Four other issues, which pertain specifically to aspects of the uranium fuel cycle other than the nuclear power plants themselves, are addressed in Section 4.14.1.1. These fuel cycle facilities include uranium mining and milling, uranium hexafluoride ($UF_6$) production, isotopic enrichment, fuel fabrication, fuel reprocessing, and disposal facilities.

#### *4.11.1.1 Low-Level Waste Storage and Disposal*

Section 3.11.1.1 provides a detailed discussion of the quantities and characteristics of LLW that are normally generated at nuclear plants under routine operating conditions. As stated in the introduction to Section 4.11.1, these baseline conditions are expected to continue during the license renewal (initial LR and SLR) terms.

The NRC requires that all licensees implement measures to minimize, to the extent practicable, the generation of radioactive waste (10 CFR 20.1406). Licensees may consider construction of additional radiological storage facilities on their plant sites and/or enter into an agreement with a third-party contractor to process, store, own, and ultimately dispose of LLW from the reactor sites. The environmental impacts, if these options are chosen, would be assessed at that time.

Most of the LLW generated at reactor sites continues to be shipped offsite for disposal either immediately after generation or after a brief storage period onsite. This trend is expected to continue during the license renewal (initial LR and SLR) term. Operating disposal facilities for radioactive waste are discussed in Section 3.11.1.1. In addition, the reactor sites have the option to store their Class B and C (and Class A as appropriate) wastes onsite. Such activities are conducted in accordance with NRC regulations and any applicable State or local requirements.

The NRC believes that the comprehensive regulatory controls that are in place and the low public doses being achieved at reactors ensure that the radiological impacts on the environment from low-level waste (LLW) storage and disposal will remain SMALL during the term of a renewed license (initial LR and SLR). The maximum additional onsite land that may be required for LLW storage during the term of a renewed license and associated impacts would be SMALL. The radiological and nonradiological environmental impacts of long-term disposal of LLW from any individual plant at licensed sites are SMALL. In addition, the NRC concludes that the available information supports a conclusion that sufficient LLW disposal capacity will be made available when needed for facilities to be decommissioned consistent with NRC decommissioning requirements.

Based on the above considerations and the information presented in Section 3.11.1.1, the existing radiological waste infrastructure and management program could support the additional radiological wastes generated by the operation of the nuclear power plant through the renewal licensing term. The impact of LLW storage and disposal during the renewal term (initial LR and SLR) is considered SMALL for all sites and is designated as a Category 1 issue. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, the environmental impacts associated with LLW storage and disposal during the initial LR and SLR terms would be SMALL for all nuclear plants. This issue is Category 1.

In addition to being generated at the reactor sites, LLW is also generated from the rest of the uranium fuel cycle as part of the front-end operations during the mining and milling of uranium ores and during the steps leading up to the manufacture of new fuel. If the recycling option is made available and the decision is made to reprocess the spent nuclear fuel in the United States, the reprocessing operations would also generate LLW. The impacts associated with management of LLW from these other fuel cycle operations are addressed in Table S-3 in 10 CFR 51.51 (see Section 4.14.1.1).

##### *4.11.1.2 Onsite Storage of Spent Nuclear Fuel*

A history of the NRC's Waste Confidence activities related to this issue is provided in Section 1.1, History of Waste Confidence, of NUREG-2157, *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel* (Continued Storage GEIS; NRC 2014c). The scope of this LR GEIS with regard to the management and ultimate disposition of spent nuclear fuel is limited to the findings codified in the September 19, 2014 Continued Storage of Spent Nuclear Fuel, Final Rule (79 FR 56238) and associated NUREG-2157 (79 FR 56263), Continued Storage GEIS (NRC 2014c). (See Section 1.7.2 of this LR GEIS for the history of this document and associated rulemaking.) During the license renewal term, which corresponds to part of the licensed life for operation of a reactor described in NUREG-2157, the expected increase in the volume of spent fuel from an additional 20 years of operation (either during initial LR or SLR) can be safely accommodated onsite during the license renewal term with small environmental impacts through dry or pool storage at all plants. For the period after the licensed life for reactor operations, the impacts of onsite storage of spent nuclear fuel during the continued storage period are discussed in NUREG–2157 and are as stated in § 51.23(b). As defined in NUREG-2157 and clarified in the Continued Storage Final Rule (79 FR 56263), the licensed life for operation of a reactor assumes an original licensed life of 40 years and up to two 20-year license extensions for each reactor, for a total of up to 80 years of operation.

As discussed in Section 3.11.1.2, spent fuel is currently stored at reactor sites either in SFPs or in ISFSIs. This onsite storage of spent fuel and HLW is expected to continue into the foreseeable future.

As previously considered in the 2013 LR GEIS, and further supported by analyses presented in the 2014 Continued Storage GEIS (NRC 2014c) for the short-term storage timeframe for spent nuclear fuel, current and potential environmental impacts from spent fuel storage at the current reactor sites have been studied extensively, are well understood, and the environmental impacts were found to be SMALL. The issue of onsite storage during the license renewal term was designated a Category 1 issue in the 2013 LR GEIS with an impact of SMALL. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, the environmental impacts associated with the storage of spent nuclear fuel during the initial LR and SLR terms would be SMALL for all nuclear plants. For the period after the licensed life for reactor operations, the impacts of onsite storage of spent nuclear fuel during the continued storage period are discussed in NUREG–2157 and are stated in § 51.23(b) (NRC 2014c). This issue is Category 1.

#### *4.11.1.3 Offsite Radiological Impacts of Spent Nuclear Fuel and High-Level Waste Disposal*

A history of the NRC's Waste Confidence activities (related to this issue) is provided in Section 1.1, History of Waste Confidence, of NUREG-2157, Continued Storage GEIS (NRC 2014c). The scope of this LR GEIS with regard to the management and ultimate disposition of spent nuclear fuel is limited to the findings codified in the September 19, 2014 Continued Storage of Spent Nuclear Fuel, Final Rule (79 FR 56238) and associated NUREG-2157 (79 FR 56263), the Continued Storage GEIS (NRC 2014c). (See Section 1.7.2 of this LR GEIS for the history of this document and associated rulemaking.)

The ultimate disposal of spent fuel in a potential future geologic repository is a separate and independent licensing action that is outside the regulatory scope of license renewal. The following discussion provides relevant information with respect to developments pertaining to the consideration of an ultimate repository site for the disposal of spent fuel.

At the time the 1996 LR GEIS was issued, there were no established regulatory limits for offsite releases of radionuclides from the ultimate disposal of spent fuel and HLW, because a candidate repository site had not been established. It was assumed that for such a site, limits would eventually be developed along the lines of those given in the 1995 National Academy of Sciences report, *Technical Bases for Yucca Mountain Standards* (National Research Council 1995).

On February 15, 2002, on the basis of a recommendation by the Secretary of Energy, the President recommended the Yucca Mountain site for the development of a repository for the geologic disposal of spent fuel and HLW. Congress approved this recommendation on July 9, 2002, in Joint Resolution 87, which designated Yucca Mountain as the repository for spent fuel. On July 23, 2002, the President signed Joint Resolution 87 into law. Public Law 107-200, 116 *Statutes at Large* 735, 42 U.S.C. 10135 (note) (H.J. Res. 87), designates Yucca Mountain as the site for the development of the repository for spent fuel.

Subsequently, the EPA developed Yucca-Mountain-specific repository release standards, which were also adopted by the NRC in 10 CFR Part 63. These standards:

- Establish a dose limit of 15 millirem (0.15 mSv) per year for the first 10,000 years after disposal.
- Establish a dose limit of 100 millirem (1.0 mSv) exposure per year between 10,000 years and 1 million years.
- Require the DOE to consider the effects of climate change, earthquakes, volcanoes, and corrosion of the waste packages to safely contain the waste during the 1 million-year period.
- Establish a radiological protection standard consistent with the recommendations of the National Academy of Sciences for this facility at the time of peak dose up to 1 million years after disposal.

On June 3, 2008, the DOE submitted a license application to the NRC, seeking authorization to construct a geologic repository for the disposal of spent fuel and HLW at Yucca Mountain, Nevada. As part of the site characterization and recommendation process for the proposed geologic repository at Yucca Mountain the DOE was required by the Nuclear Waste Policy Act of 1982, 42 U.S.C. 10101 et seq., to prepare an EIS. In accordance with the Nuclear Waste Policy Act (42 U.S.C. 10134(f)(4)), the NRC was required to adopt DOE's EIS, to "the extent practicable," as part of any possible NRC construction authorization decision. DOE submitted the following NEPA documents along with its application, which include analyses that address radiological impacts to workers and the public:

- *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (FEIS) (DOE 2002).
- *Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (Repository SEIS) (DOE 2008).

The NRC formally accepted for docketing DOE's license application for Yucca Mountain, Nevada, on September 8, 2008. In its acceptance, the NRC staff also recommended that the Commission adopt, with further supplementation, the EIS and supplements prepared by DOE (73 FR 53284). With respect to radiological impacts, DOE's FEIS and Repository SEIS indicate that the disposal of spent fuel and HLW would be SMALL with exposures well below regulatory limits. However, on March 3, 2010, the DOE filed a motion with the Atomic Safety and Licensing Board (Board) seeking permission to withdraw its application for authorization to construct a HLW geological repository at Yucca Mountain, Nevada. The Board denied that request on June 29, 2010, in LBP-10-11 (NRC 2010d), whereupon the parties involved in the preceding filed petitions asking the Commission to uphold or reverse this decision.

On September 9, 2011, the Commission issued a Memorandum and Order, CLI-11-07, stating that it found itself evenly divided on whether to take the affirmative action of overturning or upholding the Board's June 29, 2010, decision (NRC 2011c). Exercising its inherent supervisory authority, the Commission directed the Board to complete all necessary and appropriate case management activities by September 30, 2011. On September 30, 2011, the Board issued a Memorandum and Order suspending the proceeding.

The NRC staff initiated an orderly closure of its Yucca Mountain activities. As part of the orderly closure, the NRC staff prepared three technical evaluation reports documenting its work. Subsequently, the NRC resumed work on its technical and environmental reviews of the Yucca Mountain application using available funds in response to an August 2013 ruling by the U.S.

Court of Appeals for the District of Columbia Circuit (see Section 1.7.2). The staff completed and published the final volumes of the safety evaluation report in January 2015. In 2016, the NRC completed and issued a supplement (NUREG-2184; NRC 2016a) to the DOE's 2002 Yucca Mountain FEIS (DOE 2002) and the DOE's 2008 Repository Supplemental EIS (DOE 2008). The NRC's supplement evaluated the potential environmental impacts on groundwater and impacts associated with the discharge of any contaminated groundwater to the ground surface due to potential releases from the proposed Yucca Mountain geologic repository. The NRC staff evaluated the potential impacts on the aquifer environment, soils, ecology, and public health, as well as the potential for disproportionate impacts on minority or low-income populations. The impacts on all of the resources evaluated in the supplement were found to be SMALL.

The adjudicatory hearing for the licensing of the repository, which must be completed before a licensing decision can be made, remains suspended.

The NRC's nonsensitive Yucca Mountain-related documents have been preserved and made available to the public as part of the NRC staff's activities to retain the accumulated knowledge and experience gained as a result of its Yucca Mountain-related activities. These documents can be viewed on the NRC's public website, http://www.NRC.gov/waste/hlw-disposal.html.

NRC decisions and recommendations concerning the ultimate disposition of spent nuclear fuel are ongoing and outside the scope of license renewal, and as such, are beyond the scope of this LR GEIS.

Separate from the regulatory actions taken by the NRC, in 2009 and early 2010 the President and his administration decided not to proceed with the Yucca Mountain nuclear waste repository. Instead, on January 29, 2010, the Secretary of Energy announced the formation of a Blue Ribbon Commission to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle (The White House 2010). The Blue Ribbon Commission would provide advice and make recommendations on issues including alternatives for the storage, processing, and disposal of civilian and defense spent fuel and HLW. The Blue Ribbon Commission issued its recommendations to the Secretary of Energy on January 26, 2012 (BRC 2012). The report contained eight key elements:

- A new, consent-based approach to siting future nuclear waste management facilities.
- A new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed.
- Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management.
- Prompt efforts to develop one or more geologic disposal facilities.
- Prompt efforts to develop one or more consolidated storage facilities.
- Prompt efforts to prepare for the eventual large-scale transport of spent nuclear fuel and HLW to consolidated storage and disposal facilities when such facilities become available.
- Support for continued U.S. innovation in nuclear energy technology and for workforce development.
- Active U.S. leadership in international efforts to address safety, waste management, nonproliferation, and security concerns.

DOE will be the lead Federal agency responsible for developing a new national strategy for nuclear waste management; the NRC will play a supporting role in the areas associated with its regulatory review.

If a repository is not available and away-from-reactor ISFSIs are developed, the operations and maintenance activities that would be conducted at an away-from-reactor ISFSI would be the same as those described in NUREG-2157 (NRC 2014c). NUREG-2157 also describes offsite radiological impacts from the continued storage of spent fuel at an away-from-reactor ISFSI.

In NUREG-2157, the NRC concluded that a range of potential impacts could occur for some resource areas if the spent nuclear fuel from multiple reactors is shipped to a large (roughly 40,000 metric tonnes of uranium) away-from-reactor ISFSI (see Section 5.20 of NRC 2014c). The ranges for some resources are driven by the uncertainty regarding the location of such a facility and the local resources that would be affected.

For away-from-reactor storage, the unavoidable adverse environmental impacts for most resource areas is SMALL across all timeframes, except for air quality, terrestrial resources, aesthetics, waste management, and transportation where the impacts are SMALL to MODERATE. Socioeconomic impacts range from SMALL (adverse) to LARGE (beneficial) and historic and cultural resource impacts could be SMALL to LARGE across all timeframes. The potential MODERATE impacts on air quality, terrestrial wildlife, and transportation are based on potential construction-related fugitive dust emissions, terrestrial wildlife direct and indirect mortalities, terrestrial habitat loss, and temporary construction traffic impacts. The potential impacts on aesthetics and waste management are based on noticeable changes to the viewshed from constructing a new away-from-reactor ISFSI, and the volume of nonhazardous solid waste generated by assumed facility ISFSI and Dry Transfer System replacement activities for the indefinite timeframe, respectively. The potential LARGE beneficial impacts on socioeconomics are due to local economic tax revenue increases from an away-from-reactor ISFSI.

The potential impacts on historic and cultural resources during the short-term storage timeframe would range from SMALL to LARGE. The magnitude of adverse effects on historic properties and impacts on historic and cultural resources largely depends on where facilities are sited, what resources are present, the extent of proposed land disturbance, whether the area has been previously surveyed to identify historic and cultural resources, and if the licensee has management plans and procedures that are protective of historic and cultural resources. Even a small amount of ground disturbance (e.g., clearing and grading) could affect a small but significant resource. In most instances, placement of storage facilities on the site can be adjusted to minimize or avoid impacts on any historic and cultural resources in the area. However, the NRC recognizes that this may not always be possible. The NRC’s plant-specific environmental review and compliance with the NHPA process could identify historic properties, identify adverse effects, and potentially resolve adverse effects on historic properties and impacts on other historic and cultural resources. Under the NHPA, mitigation does not eliminate a finding of adverse effect on historic properties. The potential impacts on historic and cultural resources during the long-term and indefinite storage timeframes would also range from SMALL to LARGE. This range takes into consideration routine maintenance and monitoring (i.e., no ground-disturbing activities), the absence or avoidance of historic and cultural resources, and potential ground-disturbing activities that could affect historic and cultural resources. The analysis also considers uncertainties inherent in analyzing this resource area over long timeframes. These uncertainties include any future discovery of previously unknown historic and cultural resources and resources that gain significance within the vicinity and the viewshed (e.g., nomination of a historic district) due to improvements in knowledge, technology, and excavation techniques and changes associated with predicting resources that future generations will consider significant. If construction of a Dry Transfer System and replacement of the ISFSI and Dry Transfer System occurs in an area with no historic or cultural resource present or construction occurs in a previously disturbed area that allows avoidance of historic and cultural resources, then impacts would be SMALL. By contrast, a MODERATE or LARGE impact could result if historic and cultural resources are present at a site and, because they cannot be avoided, they are affected by ground-disturbing activities during the long-term and indefinite timeframes.

Impacts on Federally listed species, designated critical habitat, and EFH would be based on site-specific conditions and determined as part of consultations required by the ESA and the Magnuson-Stevens Fishery Conservation and Management Act.

Continued storage of spent nuclear fuel at an away-from-reactor ISFSI is not expected to cause disproportionately high and adverse human health and environmental effects on minority and low-income populations. As indicated in the Commission's policy statement on environmental justice, if the NRC receives an application for a proposed away-from-reactor ISFSI, a site-specific NEPA analysis would be conducted, and this analysis would include consideration of environmental justice impacts. Pursuant to 10 CFR 51.23, the impact determinations for away-from-reactor storage are presented in NUREG-2157 (NRC 2014c).

The impact levels determined in NUREG-2157 of at-reactor storage, away-from-reactor storage, and cumulative impacts of continued storage when added to other past, present, and reasonably foreseeable activities are summarized in Table 6-4 of NUREG-2157 (NRC 2014c). The impact levels are denoted as SMALL, MODERATE, and LARGE as a measure of their expected adverse environmental impacts. Most impacts were found to be SMALL and SMALL to MODERATE. For some resource areas, the impact determination language is specific to the authorizing regulation, executive order, or guidance. Impact determinations that include a range of impacts reflect uncertainty related to both geographic variability and the temporal scale of the analysis. As a result, based on analyses performed in NUREG-2157, the NRC assumes that further project-specific analysis would be unlikely to result in impact conclusions with different ranges. The analyses of NUREG-2157 were codified in 10 CFR 51.23 (79 FR 56238).

Per 10 CFR Part 51 Subpart A the Commission concludes that the impacts presented in NUREG-2157 would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR Part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the impacts of spent nuclear fuel and HLW disposal, this issue is considered a Category 1 issue. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term.

#### *4.11.1.4 Mixed Waste Storage and Disposal*

This issue addresses the storage and disposal of mixed waste generated at nuclear power plants and other uranium fuel cycle facilities during the license renewal term. As discussed in Section 3.11.3, nuclear power plants generate small quantities of mixed waste. Other uranium fuel cycle facilities are also expected to generate small quantities of mixed waste. Mixed waste is regulated both by the EPA or the authorized State agency under RCRA and by the NRC or the Agreement State agency under the Atomic Energy Act of 1954, as amended (Public

Law 83-703). The waste is either treated onsite or sent offsite for treatment followed by disposal at a permitted site. The comprehensive regulatory controls and the facilities and procedures that are in place at nuclear power plants ensure that the mixed waste is properly handled and stored and that doses to and exposure to toxic materials by the public and the environment are negligible at all plants. The accumulated quantities of mixed waste generated onsite needing long-term storage or disposal are expected to increase at a rate proportional to the length of operation. License renewal (initial LR and SLR) will not increase the small but continuing risk to human health and the environment posed by mixed waste at all plants. The radiological and nonradiological environmental impacts from the long-term disposal of mixed waste at any individual plant at licensed sites are considered SMALL for all sites. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, the environmental impacts associated with mixed waste storage and disposal during the initial LR and SLR terms would be SMALL for all nuclear plants. This is a Category 1 issue.

#### *4.11.1.5 Nonradioactive Waste Storage and Disposal*

This issue addresses the storage and disposal of nonradioactive waste generated at commercial nuclear power plants and during the rest of the uranium fuel cycle during the license renewal term. Nonradioactive waste consists of hazardous and nonhazardous waste. Storage and disposal of hazardous waste generated at nuclear plants are discussed in Section 3.11.2. As indicated in that section, nuclear plants generate small quantities of hazardous waste during operation and maintenance. A special class of hazardous waste, known as universal waste, consisting of commonly used yet hazardous materials (batteries, pesticides, mercury-containing equipment, and lamps), is also generated. Similar types of hazardous wastes are also generated at other uranium fuel cycle facilities. The management of hazardous wastes generated at all of these facilities, both onsite and offsite, is strictly regulated by the EPA or the responsible State agencies per the requirements of RCRA.

As does any industrial facility, nuclear power plants and the rest of the uranium fuel cycle facilities also generate nonradioactive, nonhazardous waste (see Section 3.11.4). These wastes are managed by following good housekeeping practices and are generally disposed of in local landfills permitted under RCRA Subtitle D regulations.

In the 2013 LR GEIS, the impacts associated with managing nonradioactive wastes at uranium fuel cycle facilities, including nuclear power plants, were found to be SMALL and designated as a Category 1 issue. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, the environmental impacts associated with nonradioactive waste storage and disposal during the initial LR and SLR terms would be SMALL for all nuclear plants. The accumulated quantities of nonradioactive waste generated onsite needing long-term storage or disposal is expected to increase at a rate proportional to the length of operation. It was indicated that no changes in nonradioactive waste generation would be anticipated for license renewal (initial LR or SLR), and that systems and procedures are in place to ensure continued proper handling and disposal of the wastes at all plants. This is a Category 1 issue.

### 4.11.2 Environmental Consequences of Alternatives to the Proposed Action

*Construction* – Construction-related wastes include various fluids from the onsite maintenance of construction vehicles and equipment (e.g., used lubricating oils, hydraulic fluids, glycol-based coolants, spent lead-acid storage batteries) and incidental chemical wastes from the maintenance of equipment and the application of corrosion control protective coatings (e.g., solvents, paints, coatings), construction-related debris (e.g., lumber, stone, and brick), and packaging materials (primarily wood and paper). All materials and wastes would be accumulated onsite and disposed of or recycled through licensed offsite disposal and treatment facilities. Life-cycle management of chemicals and wastes generated during construction and pollution prevention initiatives (such as spill prevention plans) will serve to mitigate the impact of wastes. The impacts of waste management are expected to be the same for greenfield, brownfield, and existing nuclear power plant sites.

*Operations* – Solid wastes would be generated throughout the period of plant operations. The character of wastes would depend on chemical constituents of the fuel, efficiency of combustion, and operational efficiencies of the various air pollution control devices. Wastes routinely associated with the maintenance of mechanical and electrical equipment include used lubricating oils and hydraulic fluids, cleaning solvents, corrosion control paints and coatings, and dielectric fluids.

#### *4.11.2.1 Fossil Fuel Alternatives*

*Operations* – Solid wastes in the form of coal-combustion waste (and, in some instances, flue gas desulfurization sludge and spent catalysts) would be generated during plant operations. The exact character of the coal-combustion waste would depend on the chemical constituents of the coal, efficiency of the combustion device, and operational efficiencies of the various air pollution control devices.

#### *4.11.2.2 New Nuclear Alternatives*

*Operations* – Liquid, gaseous, and solid radioactive waste management systems would be used to collect and treat radioactive materials during operations. Waste processing systems would be designed so that radioactive effluents released to the environment would meet the objectives of Appendix I to 10 CFR Part 50. LLW disposal is assumed to occur at an offsite location, while spent nuclear fuel would be stored onsite either in SFP storage or dry cask storage.

Nonradioactive effluent and wastes include cooling water and steam condensate blowdowns that contain various water treatment chemicals or biocides, wastes from the onsite treatment of cooling water and steam cycle water, floor and equipment drain effluent, stormwater runoff, laboratory waste, trash, hazardous waste, effluent from the sanitary sewer system, miscellaneous gaseous emissions, and liquid and solid effluent. Wastes discharged to waters of the United States would be regulated by NPDES permits. All other wastes would be properly disposed of in accordance with Federal, State, and local regulations. Waste management impacts for a nuclear plant are described in Section 4.11.1. Impacts are expected to be SMALL for all facilities, whether located on greenfield sites, brownfield sites, or at existing nuclear plant sites.

#### *4.11.2.3 Renewable Alternatives*

Most renewable energy technologies would produce various wastes during operations. Biomass-fired and waste-derived fuel-fired facilities would produce combustion wastes such as fly ash and bottom ash. Toxic constituents in municipal solid waste or refuse-derived fuel could cause solid wastes from air pollution devices to become hazardous due to leachability of toxic constituents. Operational solid wastes from geothermal plants could include precipitates (scale) resulting from cooling and depressurized hydrothermal fluids that must be periodically removed from equipment; some precipitates may include naturally occurring radioactive material. Concentrated solar thermal plants have the potential to release heat transfer fluids, requiring the removal and disposal of affected soil. Sanitary and other wastewaters such as cooling water blowdown and steam cycle blowdown may be discharged to the land surface, surface water, or to surface impoundments in accordance with applicable regulatory requirements.

For all power-generating facilities, especially those with power substations, spills or leaks from electrical components could create waste dielectric fluids (all assumed to be free of PCBs).

Most facilities would also produce small amounts of industrial solid wastes associated with onsite maintenance of equipment and infrastructure. Such wastes could include used oils, used glycol-based antifreeze, waste lead-acid storage batteries, spent cleaning solvents, and excess corrosion control coatings, requiring proper characterization and disposal. However, normal operational maintenance activities associated with solar PV facilities and wind farms (either onshore or offshore) would generate minimal amounts of waste. For solar PV facilities, proper precautions would have to be taken for the disposal of solar cells, although recycling of materials would reduce impacts.

## 4.12 <u>Greenhouse Gas Emissions and Climate Change</u>

Research indicates that the cause of the Earth’s changing climate and warming over the last 50 to 100 years is the buildup of GHGs in the atmosphere resulting from human activities (USGCRP 2014; IPCC 2021). The GHGs are well-mixed throughout the Earth’s atmosphere, and their impact on climate is long-lasting and cumulative in nature as a result of their long atmospheric lifetime (EPA 2016). The extent and nature of climate change is not specific to where GHGs are emitted. Climate models indicate that over the next few decades, temperature increases will continue due to current GHG emission concentrations in the atmosphere (USGCRP 2014). This is because it takes time for Earth’s climate system to respond to changes in GHG levels.

The CEQ has recognized that climate change is a fundamental environmental issue within NEPA’s purview (CEQ 2016). In accordance with Executive Order 13990, CEQ rescinded draft guidance entitled, “Draft National Environmental Policy Act Guidance on Consideration of Greenhouse Gas Emissions,” and is reviewing, revising, and updating its 2016 final guidance entitled, “Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews,” (86 FR 7037). At the time of publication of this LR GEIS, CEQ had not published updated guidance on the consideration of the effects of GHG emissions and climate change when evaluating proposed Federal Actions.

The effects of a proposed action on climate change can be evaluated by quantifying the proposed action’s GHG emissions. Therefore, the contribution to GHG emissions over the license renewal term serves as proxy in assessing the impact from continued power plant operation on climate change. Changes in climate have broader implications for environmental resources (e.g., water resources, air quality, and ecosystems). For instance, changes in precipitation patterns and increase in air temperature can affect water availability and quality. As a consequence, climate change can have overlapping impacts on environmental resources by inducing changes in resource conditions that can also be affected by the proposed action.

On the basis of these considerations, the following two issues are considered in this section:

- Greenhouse gas impacts on climate change (new issue not considered in the 2013 LR GEIS).
- Climate change impacts on environmental resources (new issue not considered in the 2013 LR GEIS).

### 4.12.1 Greenhouse Gas Impacts on Climate Change

The issue of GHG impacts on climate change associated with nuclear power plant operations was not identified as either a generic or plant-specific issue in the 2013 LR GEIS. In the 2013 LR GEIS, the NRC staff presented GHG emission factors associated with the nuclear power life cycle.

At the time of publication of the 2013 LR GEIS, insufficient data existed to support a classification of GHG emission impacts and climate change as a generic or plant-specific issue. The 2013 LR GEIS, however, included a discussion summarizing nuclear power plant-based GHG emissions and climate change. Furthermore, following the issuance of Commission order CLI-09-21 (NRC 2009d), the NRC began to evaluate the effects of GHG emissions in environmental reviews for license renewal applications.

Impacts on climate change during normal operations at nuclear power plants can result from the release of GHGs from stationary combustion sources (e.g., diesel generators, pumps, diesel engines, boilers), refrigeration systems, electrical transmission and distribution systems, and mobile sources (worker vehicles and delivery vehicles) (see Section 3.12). The GHG emissions from nuclear power plants are typically very minor, because such plants do not normally combust fossil fuels to generate electricity. As can be observed from Table 3.12-2, direct and indirect GHG emissions from operations at nuclear power plants rarely exceed the 25,000 MT (27,557 T) of carbon dioxide equivalents ($CO_2$eq) reporting threshold established by EPA. Furthermore, when compared to State GHG emissions (see Table 3.12-1), GHG emissions from operating nuclear power plants are orders of magnitude lower. When compared to different GHG emission inventories for other facilities, GHG emissions from nuclear power plant operations are minor. For example, in the initial LR SEISs for Byron, Fermi, LaSalle, River Bend, and Waterford, the NRC compared the nuclear plant's GHG emissions to total annual county-level GHG emissions (NRC 2015c, NRC 2016c, NRC 2016d, NRC 2018c, NRC 2018d). The GHG emissions from these nuclear power plants ranged from less than 0.03 to about 3.9 percent of their respective county's total GHG emissions. In the Peach Bottom SLR SEIS, the NRC concluded that continued operation would result in at least 4.4 million tons/year (3.9 MMT/yr) of $CO_2$eq emissions avoidance compared to other replacement energy (power) alternatives (e.g., supercritical pulverized coal, natural gas-combined cycle, and combination alternatives) (NRC 2020g). Similarly, in the Surry SLR SEIS, the NRC concluded that continued operation would result in at least 4.8 MMT/yr (4.3 MMT/yr) of $CO_2$eq emission avoidance when compared to replacement energy alternatives considered (natural gas-combined cycle and combination alternative) (NRC 2020f).

Potential sources of GHG emissions during any license renewal refurbishment activities include motorized equipment, construction vehicles, and worker vehicles. Construction vehicles and other motorized equipment would generate exhaust emissions that include GHG emissions (primarily $CO_2$). These emissions, however, would be intermittent, temporary, and restricted to the refurbishment period. The GHG emissions would result primarily from the additional workforce. Findings from SEISs completed since development of the 2013 LR GEIS have shown that the duration of refurbishment activities would occur over a 2 to 3 month period and would require an additional 500-1,400 workers. The NRC estimates that this can result in up to an additional 5,800[1] tons (5,260 MT) of $CO_2$eq (NRC 2015d, NRC 2015e, NRC 2018e,). Emissions of GHGs from worker vehicles during refurbishment would be similar to those during normal nuclear power plant operations (see indirect emissions presented in Table 3.12-2). Therefore, GHG emissions from refurbishment activities would be minor.

On the basis of these considerations, the NRC concludes that the impacts of GHG emissions on climate change from continued operations and refurbishment during the initial LR and SLR terms and any refurbishment activities would be SMALL for all plants. This is a new Category 1 issue.

### 4.12.2 Environmental Consequence of Alternatives of the Proposed Action

*Construction* – Sources of GHG emissions would include earthmoving equipment, non-road vehicles, and worker and delivery vehicles. Operation of construction equipment (e.g., excavator, concrete batch plant, bulldozer, backhoe loader) release GHG emissions during fuel consumption (e.g., diesel). Similarly, employee and delivery vehicular exhaust will emit GHG emissions. The GHG emissions from construction equipment can be minimized by reducing the idling time of equipment and regularly maintaining diesel engines.

*Operations* – The impact from climate change as a result of GHG emissions from facility operations for a replacement power alternative would depend on the energy technology (e.g., nuclear, renewable, etc.). In general, fossil fuel power alternatives will emit more GHG emissions than nuclear or renewable replacement power alternatives.

#### *4.12.2.1 Fossil Energy Alternatives*

*Construction* – The GHG impacts would be the same as those described in Section 4.12.2 above.

*Operations* – The GHG emissions associated with operation of fossil fuel power plants can be significant. Fossil fuel power plants can emit large amounts of carbon dioxide, particularly if they are not equipped with carbon capture and storage devices. Table 4.12-1 presents representative carbon dioxide emission factors for various fossil fuel power plants with and without carbon capture technology. In comparing these emission factors, it is apparent that NGCC power plants would have lower carbon dioxide emissions than operation of an IGCC or SCPC plant, and that installation of carbon capture technology reduces emissions significantly.

[1] Calculated by conservatively assuming a 90 day refurbishment duration, 1,400 workers-vehicles, 100-mile roundtrip travel per vehicle, and 420 grams of $CO_2$eq/mi (DOE 2021a).

**Table 4.12-1 Carbon Dioxide Emission Factors[a] ($CO_2$ kg/MWh [lb/MWh]) for Representative Fossil Fuel Plants**

| NGCC | | SCPC | | IGCC | |
|---|---|---|---|---|---|
| without carbon capture and storage[b] | with carbon capture and storage[c] | without carbon capture and storage[d] | with carbon capture and storage[e] | without carbon capture and storage[f] | with carbon capture and storage[g] |
| 336 (741) | 36 (80) | 738 (1,627) | 84 (185) | 602 (1,328) | 73 (161) |

$CO_2$ = carbon dioxide; IGCC = integrated gasification combined cycle; kg/MWh = kilograms per megawatt-hr; lb/MWh = pounds per megawatt-hr; NGCC = natural gas combined cycle; SCPC = supercritical pulverized coal.
(a) Values based on gross output.
(b) Emission factors based on two combustion turbine-generators, and gross output of 740 MW.
(c) Emission factors based on two combustion turbine-generators, and gross output of 690 MW.
(d) Emission factors based on gross output of 685 MW and bituminous coal.
(e) Emission factors based on gross output of 770 MW and bituminous coal.
(f) Emission factors based on two Shell gasifiers, total gross output of 765 MW, and bituminous coal.
(g) Emission factors based on two Shell gasifiers, total gross output of 696 MW, and bituminous coal.
Source: NETL 2019.

#### *4.12.2.2 New Nuclear Alternatives*

*Construction* – The GHG impacts would be the same as those described in Section 4.12.2 above.

*Operations* – The GHG emissions from operation of a new nuclear alternative would be emitted from onsite combustion sources (diesel generators, boilers, pumps) and worker vehicles. GHG emissions would be intermittent and minor.

#### *4.12.2.3 Renewable Alternatives*

*Construction* – The GHG impacts would be the same as those described in Section 4.12.2 above. For facilities without a power block (solar PV, onshore, and offshore wind) the number of heavy equipment and workforce, level of activities, and construction duration would be lower and therefore GHG emissions would be less.

*Operations* – The GHG emissions associated with operation of renewable energy alternatives are generally negligible because no direct fossil fuels are burned to generate electricity. Sources of GHG emissions include engine exhaust from worker vehicles and equipment associated with site inspections or maintenance activities. Biomass facilities, however, can emit significant GHG emissions. For example, a biomass-fueled power plant can emit 2,650–3,852 lb of $CO_2$eq/MWh (NREL 1997, NREL 2004).

### 4.12.3 Climate Change Impacts on Environmental Resources

The issue of climate change impacts was not identified as either a generic or plant-specific issue in the 2013 LR GEIS. However, the 2013 LR GEIS described the environmental impacts that could occur on resource areas (land use, air quality, water resources, etc.) that are affected by the proposed action (license renewal). Climate change is an environmental trend (i.e., change in climate indicators such as precipitation over time) that could result in changes to the affected environment irrespective of license renewal. In plant-specific initial LR and SLR SEISs prepared since development of the 2013 LR GEIS, the NRC has considered climate change impacts for those resources that could be incrementally affected by the proposed action as part of the cumulative impacts analysis. As discussed in Section 3.12 of this LR GEIS, climate change and its impacts on resources can vary regionally. Observed climate change has not been uniform across the United States. For instance, annual precipitation has increased across most of the northern and eastern States and decreased across the southern and western States; along the Atlantic coast in the Northeast region, sea surface temperatures and sea level rise have increased at rates that exceed global averages; the Southeast region has not experienced an overall long-term increase in surface temperatures; the Northwest experienced the smallest increase in heavy precipitation events of any region in the United States.

Climate change may impact the affected environment in a way that alters the environmental resources that are impacted by the proposed action (license renewal). Similar to cumulative impacts, climate change impacts can occur across all resource areas that could be affected by the proposed action, including the effects of continued reactor operations during the license renewal term and any refurbishment activities at a nuclear power plant. In order for there to be a climate change impact on an environmental resource, the proposed action (license renewal) must have an incremental new, additive, or increased physical effect or impact on the resource or environmental condition beyond what is already occurring. The goal of the impacts of climate change on environmental resources analysis is to identify potentially significant impacts.

Future global GHG emission concentrations (emission scenarios) and climate models are commonly used to project possible climate change. Climate models indicate that over the next few decades, temperature increases will continue due to current GHG emission concentrations in the atmosphere (USGCRP 2014). If GHG concentrations were to stabilize at current levels, this would still result in at least an additional 1.1 °F (0.6 °C) of warming over this century (USGCRP 2018). Over the longer term, the magnitude of temperature increases and climate change related effects will depend on future global GHG emissions (IPCC 2021; USGCRP 2009, USGCRP 2014, USGCRP 2018). Climate model simulations often use GHG emission scenarios to represent possible future social, economic, technological, and demographic development that, in turn, drive future emissions. Consequently, the GHG emission scenarios, their supporting assumptions, and the projections of possible climate change effects entail substantial uncertainty.

The Intergovernmental Panel on Climate Change (IPCC) has generated various representative concentration pathway (RCP) scenarios commonly used by climate modeling groups to project future climate conditions (IPCC 2000, IPCC 2013, USGCRP 2017, USGCRP 2018). In the IPCC Fifth Assessment Report, four RCPs were developed and are based on the predicted changes in radiative forcing (a measure of the influence that a factor, such as GHG emissions, has in changing the global balance of incoming and outgoing energy) in the year 2100, relative to preindustrial conditions. The four RCP scenarios are numbered in accordance with the change in radiative forcing measured in watts per square meter (i.e., +2.6 [very low], +4.5 [lower], +6.0 [mid-high], and +8.5 [higher]) (USGCRP 2018). For example, RCP2.6 is representative of a mitigation scenario aimed at limiting the increase of global mean temperature to 1.1 °F (2 °C) (IPCC 2014). The RCP8.5 reflects a continued increase in global emissions resulting in increased warming by 2100. In the IPCC Sixth Assessment Report, five shared socioeconomic pathways were used along with associated modeling results as the basis for their climate change assessments (IPCC 2021). These five socioeconomic pathway scenarios cover a range of greenhouse pathways and climate change mitigation.

The Fourth National Climate Assessment relies on the four RCPs in the IPCC Fifth Assessment Report and presents projected climate change categorized by U.S. geographic region (see Figure 3-12; USGCRP 2018). Similar to the observed climate changes categorized by U.S. geographic region, as discussed in Section 3.12 of this LR GEIS, climate model projections indicate that changes in climate will not be uniform across the United States. Observed and projected differences in climate changes in the United States are further presented in initial LR and SLR SEISs prepared since 2013. For instance, the Point Beach plant SLR SEIS states that climate models predict an increase of 4–6 °F (2.2–3.3 °C) in annual mean temperature for Wisconsin under the RCP4.5 and RCP8.5 scenarios for the midcentury (NRC 2021f). The Turkey Point plant SLR SEIS indicates that for the same scenarios and timeframe models predict an increase in the annual mean temperature of 2–4 °F (1.1–2.2 °C) for Florida (NRC 2019c).

The North Anna and the Surry SLR SEISs discuss climate change projections in the Northeast region and the Commonwealth of Virginia along with associated impacts on the environment. In the Surry plant SLR SEIS, the NRC considered the salinity effects of sea level rise projections on the James River and deterioration of surface water quality due to saltwater intrusion (NRC 2021g). Unlike Surry, North Anna is not located on a tidal river, but on the Lake Anna Reservoir which is not directly affected by sea level changes along the Atlantic coast. Consequently, sea level rise projections were not pertinent in the consideration of climate change impacts to surface water quality in the North Anna SEIS. The Turkey Point plant SLR SEIS and the Waterford plant initial LR SEIS considered the impacts of projected sea level rise. However, these SEISs illustrate how sea levels can affect water resources differently. As noted in the Waterford plant initial LR SEIS, projected sea level rise could increase the upstream migration of the saltwater wedge, which could cause a general deterioration in surface water quality in the Lower Mississippi River (NRC 2018d). However, as noted in the Turkey Point SLR SEIS, for South Florida, higher sea levels will increase the rate of saltwater intrusion leading to the degradation of groundwater quality of aquifers designated as sources of drinking water (NRC 2019c).

While sea level rise impacts may occur in certain areas, decreases in water levels for the Great Lakes are projected for the future. For instance, the Fermi plant initial LR SEIS and the Point Beach SLR SEIS both discuss that while long-term water level projections are uncertain, model simulations indicate a future decline in lake levels for Lake Erie and Lake Michigan, due to increases in evaporative losses and warmer water temperatures (NRC 2016c; NRC 2021f). Higher surface water temperatures can result in a decrease in cooling efficiency and therefore have the potential to increase the use of cooling water and result in a slightly larger volume of heated water discharged back to the lake (NRC 2016c; NRC 2021f).

On the basis of these considerations, the NRC concludes that the impacts of climate change on environmental resources that are affected by continued nuclear power plant operations and any refurbishment during the initial LR and SLR terms are location-specific and cannot be evaluated generically. Changes in climate parameters and trends (e.g., temperature, precipitation, floods, storm frequency, sea level rise) affect environmental resource baseline conditions (i.e., the affected environment) that are incrementally affected by license renewal, thereby changing the future state of the environment. The effects of climate change can vary regionally and climate change information at the regional and local scale is necessary to assess the trends and impacts on the human environment for a specific location. Therefore, this is a new Category 2 issue because it requires a plant-specific evaluation.

## 4.13 Cumulative Effects of the Proposed Action

Actions considered in the cumulative effects (impacts) analysis include the proposed license renewal action (initial LR or SLR) when added to past, present, and reasonably foreseeable actions, including projects and programs that are conducted, regulated, or approved by a

Federal agency. The analysis takes into account all actions, however minor, because the effects of individually minor actions may be significant when considered collectively over time. The goal of the cumulative effects analysis is to identify potentially significant impacts.

**Definition of Cumulative Effects**

Effects on the environment that result from the incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions (40 CFR 1508.1(g)(3)).

The cumulative effects or impacts analysis only considers resources and environmental conditions that could be affected by the proposed license renewal action, including the effects of continued reactor operations during the license renewal term and any refurbishment activities at a nuclear power plant. In order for there to be a cumulative effect, the proposed action (license renewal) must have an incremental new, additive, or increased physical effect or impact on the resource or environmental condition beyond what is already occurring.

The CEQ's report, *Considering Cumulative Effects Under the National Environmental Policy Act,* provides a framework for addressing the cumulative effects of the proposed action in an EIS (CEQ 1997a). Using guidance from the CEQ report, the cumulative effects analysis considers the following:

- The geographic region of influence that encompasses the areas of potential effect and the distance at which the environmental effects of the proposed action and past, present, and reasonably foreseeable actions may be experienced. Geographic regions of influence vary by affected resource.
- The timeframe for the cumulative effects analysis incorporates the incremental effects of the proposed action (license renewal) with past, present, and reasonably foreseeable actions because these combined effects may accumulate or develop over time. Past and present actions include all actions up to and including the date of the license renewal request. The timeframe for the consideration of reasonably foreseeable future actions is the 20-year license renewal (initial LR or SLR) term. Reasonably foreseeable future actions include current and ongoing planned activities, approved and funded for implementation.
- The environmental effects from past and present actions are accounted for in baseline assessments presented in affected environment discussions in Chapter 3.0 of this LR GEIS. Chapter 4.0 accounts for the incremental effects or impacts of the proposed action (license renewal).
- The incremental effects of the proposed action (license renewal) when added to the effects from past, present, and reasonably foreseeable future actions and other actions (including trends such as global climate change) result in the overall cumulative effect. A qualitative cumulative effects analysis is conducted in instances where the incremental effects of the proposed action (license renewal) and past, present, and reasonably foreseeable future actions are uncertain or not well known.
- For some resource areas (e.g., water and aquatic resources), the incremental contributions of ongoing actions within a region are regulated and monitored through a permitting process (e.g., NPDES) under State or Federal authority. In these cases, it may be assumed that

cumulative effects are managed as long as these actions (facilities) are in compliance with their respective permits.

The following sections discuss the potential for cumulative effects to occur in environmental resources near a nuclear power plant—when the incremental environmental effects of the proposed license renewal action are compounded by the effects from past, present, and reasonably foreseeable future actions. For the most part, environmental conditions near the nuclear power plant are not expected to change appreciably during the license renewal term beyond what is already being experienced. Because environmental conditions are different at every nuclear power plant, cumulative effects is a Category 2 issue requiring a plant-specific analysis during the license renewal environmental review.

The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS. Based on the information reviewed and the preceding discussion, the NRC concludes that cumulative effects during the initial LR and SLR terms and refurbishment are unique to each nuclear power plant. Therefore, the cumulative effects of license renewal (initial LR or SLR) cannot be determined generically and it is a Category 2 issue.

### 4.13.1 Air Quality

Regional air quality conditions, due to past and present activities, could be affected by the emissions from continued reactor operations and refurbishment at a nuclear power plant when combined with the emissions from planned industrial, commercial, agricultural, and transportation development. These activities generate dust and emissions—affecting regional air quality. The magnitude of the cumulative effect depends on the location of the nuclear power plant, intensity of planned development, and the presence of air quality nonattainment areas.

### 4.13.2 Surface Water Resources

Surface water withdrawals, effluent discharges, stormwater runoff, and accidental spills and releases and their impacts on water quality and availability could increase due to the combined effects of continued reactor operations and refurbishment and existing and planned industrial, commercial, and agricultural development activities. The incremental effect of the proposed action, continued surface water withdrawal for nuclear power plant cooling systems (both once-through and closed-cycle), generally has had the greatest contributory effect. Water withdrawal for nuclear plant cooling often conflicts with the water needs of other surface water users. The magnitude of the cumulative effect depends on the location of the nuclear power plant, intensity of existing and planned development activities, and affected surface water resources.

### 4.13.3 Groundwater Resources

Groundwater demands and groundwater quality impacts could increase because of the combined effects of continued reactor operations and refurbishment, and existing and planned industrial, commercial, and agriculture development activities. The magnitude of the cumulative effect depends on the location of the nuclear power plant, intensity of existing and planned development activities that withdraw water, water demand, and the hydrogeologic characteristics of the affected aquifers.

### 4.13.4 Ecological Resources

Terrestrial wildlife impacts include habitat loss and degradation, disturbance and displacement, injury and mortality, and obstruction of movement due to the combined effects of continued reactor operations and refurbishment and existing and planned industrial, commercial, and agriculture development activities. Other impacts include exposure to noise and contaminants, altered surface water and groundwater quality and flow patterns, and collisions with buildings and other structures. Adverse effects typically result from construction activities associated with planned industrial and commercial development, agriculture, transportation, water projects, and tourism and recreation. Migratory bird species may be affected by activities occurring away from the nuclear power plant. Ecological communities (including floodplain and wetland) may also be affected by development activities (e.g., land clearing and grading) that create conditions that favor invasive species. The magnitude of the cumulative effect depends on the location of the nuclear power plant relative to important wildlife habitats and ecological communities and the intensity of existing and planned development activities.

There are three scales of aquatic resource effects: (1) cumulative effects from the nuclear power plant (e.g., entrainment, impingement, thermal discharges, and chemical discharges), (2) cumulative effects from other power plants, and (3) cumulative effects from activities affecting water bodies (e.g., dams, agriculture, urban, and industrial development). Aquatic impacts include the (1) loss and degradation of habitat; (2) species disturbance, displacement, injury, and mortality; (3) obstruction of movement; and (4) the introduction and spread of invasive species due to the combined effects of continued reactor operations and refurbishment and existing and planned industrial, commercial, and agriculture development activities. These effects result in increased water use and discharges to natural water bodies, increased and contaminated runoff from planned industrial, commercial, agriculture, and transportation development; water projects; and tourism and recreation. Similarly, the magnitude of the cumulative effect depends on the location of the nuclear power plant relative to important water bodies and the intensity of existing and planned development activities.

### 4.13.5 Historic and Cultural Resources

Historic and cultural resources (e.g., archaeological sites, historic structures, and TCPs) could be adversely affected by ground-disturbing maintenance and refurbishment activities at a nuclear power plant and by planned industrial and commercial development. Historic and cultural resource impacts from ground-disturbing activities (e.g., land clearance, grading, and excavation) could occur during the construction of planned industrial, commercial, and transportation infrastructure and maintenance activities—damaging or destroying cultural material. The magnitude of the cumulative effect depends on the location of the nuclear power plant, intensity of planned development, and mitigation.

### 4.13.6 Socioeconomics

Employment and income generated by the combined effects of continued reactor operations and refurbishment and industrial, commercial, and housing development can have a significant cumulative socioeconomic effect. Income generated from goods and services creates additional employment and income opportunities. New employment could increase the population and demand for public services, housing, and transportation. The magnitude of the cumulative socioeconomic effect depends on the location of the nuclear power plant and the intensity of development.

### 4.13.7 Human Health

Exposure to radiological, chemical, and microbiological hazards and the potentially chronic effects of EMFs could result in a cumulative health effect. Exposure may occur as a result of the accumulation of harmful constituents released from existing facilities and planned industrial and commercial development. The magnitude of the cumulative human health effect depends on the location of past, present, and reasonably foreseeable future actions, the number of facilities and activities involving radiological and hazardous material, and the amount of exposure.

### 4.13.8 Environmental Justice

The cumulative effects of license renewal (proposed action) at a nuclear power plant combined with the environmental effects of past, present, and reasonably foreseeable future actions could exacerbate any human health or environmental effects in a minority population, low-income population, or Indian Tribe. In addition, the combined effects of license renewal and industrial, commercial, and housing development near the nuclear plant could disproportionately affect consumption patterns (e.g., subsistence agriculture, hunting, and fishing) and the environmental resources on which these populations may depend (e.g., fish, wildlife, and local produce). Whether these effects are disproportionately high and adverse depends on the unique characteristics of these populations and their proximity to the nuclear power plant and planned development.

### 4.13.9 Waste Management and Pollution Prevention

Nuclear power plants, uranium fuel cycle facilities, and other commercial industrial facilities generate radioactive and nonradioactive waste material. Depending on the location of waste treatment and disposal facilities, nearby communities and people could experience the cumulative effects of transportation, treatment, and disposal activities. However, some nuclear power plants may be the only radioactive waste generator in a region. All commercial industrial waste-generating facilities must comply with Federal and State waste storage, treatment, and disposal regulations. These facilities must also ensure waste is properly handled and stored, and its release is closely monitored. The magnitude of the cumulative effect depends on the location of past, present, and reasonably foreseeable future actions involving facilities and activities that generate, treat, and store radiological and hazardous waste material.

### 4.13.10 Climate Change

Changes in climate during the license renewal term have the potential to significantly affect environmental resources and human health conditions near a nuclear power plant due to changes in precipitation, temperature, storm frequency and severity, sea level rise, floods, and droughts. Climate change caused by GHG emissions is a global concern; observations and future climate scenarios are being documented in reports developed by the NOAA and the IPCC. The direction and nature of these changes are expected to vary widely across the country. These effects are being documented in the U.S. Global Change Research Program state of knowledge reports.

# 4.14 Impacts Common to All Alternatives

This section describes impacts that are considered common to all alternatives discussed in this LR GEIS, including the proposed action (initial LR or SLR) and replacement power alternatives. The continued operation of a nuclear power plant and replacement fossil-fueled power plants both involve the mining, processing, and consumption of fuel, which results in comparative environmental impacts. Environmental impacts associated with the uranium fuel cycle are presented in Section 4.14.1.1, and impacts for other power plant fuel cycles are presented in Section 4.14.2. The impacts of license renewal on termination of operations and the decommissioning of a nuclear power plant and replacement energy facilities are presented in Section 4.14.3.1. In addition, GHG emissions from the nuclear life cycle and replacement fossil fuel power plants and climate change impacts are presented in Section 4.12.

## 4.14.1 Environmental Consequences of Fuel Cycles

Most replacement power alternatives use a process to obtain their fuels. Nuclear power plants use a process to obtain the uranium from the Earth and refine it for its use within the reactors. The continued operation of the nuclear power plants during the license renewal term (initial LR or SLR) requires uranium processing. Getting fuel may include extracting, transforming, transporting, and combusting, among other activities. Emissions may result at each step within the processing. Also, some aspects of any fuel cycle (for example, storage and disposal) described here are common to each alternative.

### *4.14.1.1 Uranium Fuel Cycle*

In the United States, all currently operating commercial plants are LWRs and use uranium for fuel. Therefore, in this section and in the rest of this LR GEIS, the term “uranium fuel cycle” is used interchangeably with “nuclear fuel cycle.”

#### *4.14.1.1.1 Background on Uranium Fuel Cycle Facilities*

The NRC evaluated the environmental impacts that would be associated with operating uranium fuel cycle facilities other than the reactors themselves in two NRC publications: WASH-1248 (AEC 1974a) and NUREG-0116 (NRC 1976). More recently, facilities for managing the back end of the nuclear fuel cycle were considered in NUREG-2157 (NRC 2014c). The types of facilities considered in these documents include the following:

- uranium mining – facilities where the uranium ore is mined.
- uranium milling – facilities where the uranium ore is refined to produce uranium concentrates in the form of triuranium octaoxide ($U_3O_8$).
- $UF_6$ production – facilities where the uranium concentrates are converted to $UF_6$.
- isotopic enrichment – facilities where the isotopic ratio of the uranium-235 isotope in natural uranium is increased to meet the requirements of LWRs.
- fuel fabrication – facilities where the enriched $UF_6$ is converted to uranium dioxide ($UO_2$) and made into sintered $UO_2$ pellets. The pellets are subsequently encapsulated in fuel rods, and the rods are assembled into fuel assemblies ready to be inserted into the reactors. Two options were considered: (1) carrying out all steps involved in manufacturing the fuel assemblies at the same location, and (2) carrying the steps out at two separate facilities (at

one facility, uranium dioxide is produced in powder form from the enriched $UF_6$; and at the other facility, the fuel assemblies are manufactured).

- reprocessing – facilities that disassemble the spent fuel assemblies, chop up the fuel rods into small sections, chemically dissolve the spent fuel out of sectioned fuel rod pieces, and chemically separate the spent fuel into reusable uranium, plutonium, and other radionuclides (primarily fission products and actinides).
- independent spent fuel storage installations (ISFSIs) – Two options are considered:
  - At-Reactor Continued Storage ISFSIs – facilities designed and constructed at a nuclear power plant for the interim storage of spent nuclear fuel pending permanent disposal, used by operating plants to add spent nuclear fuel storage capacity beyond that available in the nuclear power plant's SFP.
  - Away-from-Reactor ISFSIs – facilities designed and constructed away from a nuclear power plant for the short-term, long-term, and indefinite storage of spent nuclear fuel pending permanent disposal, used by operating and formerly operating nuclear plants to add spent nuclear fuel storage capacity beyond that available in the nuclear power plant's SFP and at-reactor ISFSIs.
- disposal – facilities where the radioactive wastes generated at all fuel cycle facilities, including the reactors, are buried. Spent nuclear fuel that is removed from the reactors and not reprocessed was also assumed to be disposed of at a geologic repository.

As evaluated in NUREG-2157 (NRC 2014c), the NRC reaffirmed in 2014 that geological disposal remains technically feasible and that acceptable sites can be identified.

*4.14.1.1.2 Environmental Impacts*

In addition to impacts occurring at the above facilities, the impacts associated with the transportation of radioactive materials among these facilities, including the transportation of wastes to disposal facilities, were evaluated. The results were summarized in a table and promulgated as Table S-3 in 10 CFR 51.51(b). Table S-3 is provided at the end of this section as Table 4.14-1 for ease of reference. 10 CFR 51.51(a) states:

> Every environmental report prepared for the construction permit stage of a light-water-cooled nuclear power reactor, and submitted on or after September 4, 1979, shall take Table S-3, Table of Uranium Fuel Cycle Environmental Data, as the basis for evaluating the contribution of the environmental effects of uranium mining and milling, the production of uranium hexafluoride, isotopic enrichment, fuel fabrication, reprocessing of irradiated fuel, transportation of radioactive materials and management of low level wastes and high level wastes related to uranium fuel cycle activities to the environmental costs of licensing the nuclear power reactor. Table S-3 shall be included in the environmental report and may be supplemented by a discussion of the environmental significance of the data set forth in the table as weighed in the analysis for the proposed facility.

Specific categories of natural resource use included in Table 4.14-1 relate to land use; water consumption and thermal effluents; radioactive releases; burial of transuranic waste, HLW, and LLW; and radiation doses from transportation and occupational exposures. The contributions in the table for reprocessing, waste management, and transportation of wastes are maximized for either of the two fuel cycles (uranium only and no recycle); that is, the cycle that results in the greater impact is used. For each resource area, Table 4.14-1 presents a result that has been integrated over the entire fuel cycle except the reactors. The only exception to this is that the waste quantities provided under the entry called “solids (buried onsite)” also includes wastes generated at the reactor.

The environmental impact values are expressed in terms normalized to show the potential impacts attributable to processing the fuel required for the operation of a 1,000 MWe nuclear power plant for 1 year at an 80 percent availability factor to produce about 800 MW-yr (0.8 GW-yr) of electricity. This is referred to as 1 reference reactor year.

Many of the nuclear fuel cycle facilities and processes assessed for Table 4.14-1 still exist today. However, some have undergone several industrial developments and technological advances that have significantly reduced their environmental effects. As discussed in NUREG-2226, the Clinch River ESP FEIS (NRC 2019b), recent changes in the uranium fuel cycle may have some bearing on environmental impacts. As discussed below, the NRC is confident that the contemporary normalized uranium fuel cycle impacts for LWRs are less than those identified in Table 4.14-1. This assertion is true in light of the following recent uranium fuel cycle trends in the United States:

- Increasing use of in situ leach uranium mining, which does not produce mine tailings and would lower the release of radon gas (NRC 2020e).
- Transitioning of U.S. uranium enrichment technology from gaseous diffusion to gas centrifugation. The latter process uses only a fraction of the electrical energy per separation unit compared to gaseous diffusion and U.S. gaseous-diffusion plants that relied on electricity derived mainly from the burning of coal.
- Current LWRs are using nuclear fuel more efficiently because of higher levels of fuel burnup. Thus, less uranium fuel per year of reactor operation is required than in the past to generate the same amount of electricity (an increase in the time for refueling [from 12 months to 18 months or more] as applied for Table S–3).

The values in Table 4.14-1 were calculated from industry averages for the performance of each type of facility or operation within the fuel cycle. Recognizing that this approach meant that there would be a range of reasonable values for each estimate, the staff chose the assumptions or factors to be applied so that the calculated values would not be underestimated. This approach was intended to make sure that the actual environmental impacts would be less than the quantities shown in Table 4.14-1 for all LWR nuclear power plants within the widest range of operating conditions. The staff recognizes that many of the fuel cycle parameters and interactions vary in small ways from the estimates in Table 4.14-1 and concludes that these variations would have no impacts on the Table 4.14-1 calculations. For example, to determine the quantity of fuel required for a year’s operation of a nuclear power plant in Table 4.14-1, the staff defined the reference reactor as a 1,000 MW LWR operating at 80 percent capacity with a 12-month fuel-reloading cycle and an average fuel burnup of 33,000 MWd/MTU. These values are not challenged by the current LWR fleet, which is operating with an average factor of approximately 95 percent capacity for peak fuel rod burnup of up to 62,000 MWd/MTU with refueling occurring at approximately 18-months to 2-year intervals (NRC 2019b). This means fuel can be used more efficiently, requiring less total fuel, resulting in less environmental effects than those presented in Table 4.14-1 (Table S–3).

The analysis presented in Table 4.14-1 (circa 1970s) was also based on most of the electricity generated in the United States being produced in plants that burn fossil fuels, and coal composing the bulk of fossil fuel utilization (AEC 1974a). However, today the energy sources for utility-scale electrical generation are more diverse (DOE/EIA 2020b):

- 23 percent from coal;
- 38 percent from natural gas, for which air emissions are much less than those from coal;
- 20 percent from nuclear power plants;
- 17 percent from renewables (10 percent from non-hydroelectric renewables and 7 percent from hydroelectric); and
- 1 percent from petroleum and other sources.

Therefore, environmental impacts related to air emissions, associated pollutants, and water/thermal impacts from today's electrical generation contribution to the nuclear fuel cycle are clearly less than and are bounded by the coal-electrical generation data assessed by WASH-1248 (AEC 1974a) and found in Table 4.14-1. This trend of decreasing reliance on fossil fuels for electrical generation will continue, spurred by actions to combat climate change (DOE/EIA 2020c).

Based on several of the items discussed above, the 2013 LR GEIS states:

> It was concluded that even though certain fuel cycle operations and fuel management practices have changed over the years, the assumptions and methodology used in preparing Table S–3 were conservative enough that the impacts described by the use of Table S–3 would still be bounding. The NRC believes that this conclusion still holds.

A detailed discussion of impacts associated with the production and processing of fuel needed for 1 reference reactor year operation of the model LWR was provided in the 1996 LR GEIS. Included in the discussion were the collective offsite radiological impacts that would be associated with radon-222 and technetium-99 releases to the environment during the fuel cycle operations, which Table 4.14-1 does not address.

One part of the fuel cycle that was not discussed either in the technical support documents for the original Table 4.14-1 or in the 1996 LR GEIS was the disposition of the depleted $UF_6$ tails generated during the enrichment process. Originally, these tails were intended to be used as a feedstock to make fuel for proposed fast breeder reactors. However, the United States abandoned the fast breeder reactor program in 1983 (Breeder Reactor Corporation 1985). Before the creation of the United States Enrichment Corporation in 1993, DOE was the custodian of all the depleted $UF_6$ generated in the United States at the three gaseous-diffusion plants (in Oak Ridge, Tennessee; Portsmouth, Ohio; and Paducah, Kentucky). DOE prepared several NEPA documents evaluating the impacts associated with the disposition of approximately 700,000 MT (1.54 billion lb) of depleted $UF_6$ (DOE 1999, DOE 2004a, DOE 2004b, DOE 2007). DOE decided to convert the depleted $UF_6$ back to $U_3O_8$ and dispose of it as LLW (69 FR 44654, 69 FR 44649). The results of these analyses indicate that the operational impacts of the depleted $UF_6$ management facilities would not be very different from the impacts estimated for other parts of the fuel cycle in Table 4.14-1. In particular, the impacts of the depleted $UF_6$ conversion facilities, where the depleted $UF_6$ is converted to triuranium octaoxide, would be similar to the impacts of the $UF_6$ production facilities, where $U_3O_8$ is converted to $UF_6$. If the depleted uranium oxide is disposed of as LLW, the conversion product corresponding to 1 reference reactor year would be in addition to the LLW quantities already listed in Table 4.14-1.

This value is estimated to be approximately 12 Ci ($4.4 \times 10^{11}$ Bq) (35 MT of uranium per reference reactor year multiplied by 0.34 Ci/MT of depleted uranium).

As discussed above and in the following sections, the NRC staff reviewed information from technical literature as well as from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for either an initial LR or SLR term with respect to the uranium fuel cycle.

**Table 4.14-1 Table S-3 Taken from 10 CFR 51.51 on Uranium Fuel Cycle Environmental Data (Normalized to model light water reactor annual fuel requirement [WASH-1248; AEC 1974a] or reference reactor year [NUREG-0116; NRC 1976])[(a)]**

| Environmental Considerations | Total | Maximum Effect per Annual Fuel Requirement or Reference Reactor Year of Model 1,000 MWe Light Water Reactor |
|---|---|---|
| **Natural Resource Use** | | |
| ***Land (acres)*** | | |
| Temporarily committed[(b)] | 100 | |
| Undisturbed area | 79 | |
| Disturbed area | 22 | Equivalent to a 110 MWe coal-fired power plant. |
| Permanently committed | 13 | |
| Overburden moved (millions of MT) | 2.8 | Equivalent to 95 MWe coal-fired power plant. |
| ***Water (millions of gallons)*** | | |
| Discharged to air | 160 | Equal to 2 percent of model 1,000 MWe light water reactor with cooling tower. |
| Discharged to water bodies | 11,090 | |
| Discharged to ground | 127 | |
| Total | 11,377 | Less than 4 percent of model 1,000 MWe light water reactor with once-through cooling. |
| ***Fossil Fuel*** | | |
| Electrical energy (thousands of MW-hour) | 323 | Less than 5 percent of model 1,000 MWe output. |
| Equivalent coal (thousands of MT) | 118 | Equivalent to the consumption of a 45 MWe coal-fired power plant. |
| Natural gas (millions of scf) | 135 | Less than 0.4 percent of model 1,000 MWe energy output. |
| **Effluents – Chemical (MT)** | | |
| ***Gases (including entrainment)[(c)]*** | | |
| $SO_x$ | 4,400 | |
| $NO_x$[(d)] | 1,190 | Equivalent to emissions from 45 MWe coal-fired plant for a year. |

| Environmental Considerations | Total | Maximum Effect per Annual Fuel Requirement or Reference Reactor Year of Model 1,000 MWe Light Water Reactor |
|---|---|---|
| Hydrocarbons | 14 | |
| CO | 29.6 | |
| Particulates | 1,154 | |
| Other gases | | |
| F | 0.67 | Principally from $UF_6$ production, enrichment, and reprocessing. Concentration within range of State standards and below level that has effects on human health. |
| HCl | 0.014 | |
| ***Liquids*** | | |
| $SO^{-}_{4}$ | 9.9 | From enrichment, fuel fabrication, and reprocessing steps. Components that constitute a potential for adverse environmental effects are present in dilute concentrations and receive additional dilution by receiving bodies of water to levels below permissible standards. The constituents that require dilution and the flow of dilution water are $NH_3$: 600 cfs, $NO_3$: 20 cfs, fluoride: 70 cfs. |
| $NO^{-}_{3}$ | 25.8 | |
| Fluoride | 12.9 | |
| $Ca^+$ | 5.4 | |
| $C1^-$ | 8.5 | |
| $Na^+$ | 12.1 | |
| $NH_3$ | 10.0 | |
| Fe | 0.4 | |
| Tailings solutions (thousands of MT) | 240 | From mills only – no significant effluents to environment. |
| ***Solids*** | 91,000 | Principally from mills – no significant effluents to environment. |
| **Effluents – Radiological (curies)** | | |
| ***Gases (including entrainment)*** | | |
| Rn-222 | – | Presently under reconsideration by the Commission. |
| Ra-226 | 0.02 | |
| Th-230 | 0.02 | |
| Uranium | 0.034 | |
| Tritium (thousands) | 18.1 | |
| C-14 | 24 | |
| Kr-85 (thousands) | 400 | |
| Ru-106 | 0.14 | Principally from fuel reprocessing plants. |
| I-129 | 1.3 | |
| I-131 | 0.83 | |

| Environmental Considerations | Total | Maximum Effect per Annual Fuel Requirement or Reference Reactor Year of Model 1,000 MWe Light Water Reactor |
|---|---|---|
| Tc-99 | – | Presently under consideration by the Commission. |
| Fission products and transuranics | 0.203 | |
| ***Liquids*** | | |
| Uranium and daughters | 2.1 | Principally from milling –included tailings liquor and returned to ground, no effluents; therefore, no effect on the environment. |
| Ra-226 | 0.0034 | From $UF_6$ production. |
| Th-230 | 0.0015 | |
| Th-234 | 0.01 | From fuel fabrication plants – concentration 10 percent of 10 CFR Part 20 for total processing 26 annual fuel requirements for model light water reactor. |
| Fission and activation products | $5.9 \times 10^{-6}$ | |
| ***Solids (buried onsite)*** | | |
| Other than high level (shallow) | 11,300 | 9,100 Ci comes from low-level reactor wastes and 1,500 Ci comes from reactor decontamination and decommissioning – buried at land burial facilities. 600 Ci comes from mills – included in tailing returned to ground. Approximately 60 Ci comes from conversion and spent fuel storage. No significant effluent to the environment. |
| Transuranic and high-level waste (deep) | $1.1 \times 10^{7}$ | Buried at Federal Repository. |
| **Effluents – Thermal (billions of Btu)** | 4,063 | Less than 5 percent of model 1,000 MWe light water reactor. |
| **Transportation (person-rem)** | | |
| Exposure of workers and general public | 2.5 | |
| Occupational exposure | 22.6 | From reprocessing and waste management. |

(a) In some cases where no entry appears, it is clear from the background documents that the matter was addressed and that, in effect, the table should be read as if a specific zero entry had been made. However, there are other areas that are not addressed in the table. Table S-3 does not include health effects from the effluents described in the table, estimates of releases of radon-222 from the uranium fuel cycle, or estimates of technetium-99 released from waste management or reprocessing activities. These issues may be the subject of litigation in the individual licensing proceedings.

Data supporting this table are given in the *Environmental Survey of the Uranium Fuel Cycle*, WASH-1248, April 1974; the *Environmental Survey of the Reprocessing and Waste Management Portion of the LWR Fuel Cycle*,' NUREG-0116 (Supp. 1 to WASH–1248); the *Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle*, NUREG-0216 (Supp. 2 to WASH-1248); and in the record of the final rulemaking pertaining to *Uranium Fuel Cycle Impacts from Spent Fuel Reprocessing and Radioactive Waste Management*, Docket RM-50-3. The contributions from reprocessing, waste management, and transportation of wastes are maximized for either of the two fuel cycles (uranium only and no recycle). The contribution from transportation excludes transportation

of cold fuel to a reactor and transportation of irradiated fuel and radioactive wastes from a reactor, which are considered in Table S-4 of Section 51.20(g) [sic, Table S-4 now appears in Section 51.52(c)]. The contributions from the other steps of the fuel cycle are given in columns A–E of Table S-3A of WASH-1248.
(b) The contributions to temporarily committed land from reprocessing are not prorated over 30 years, because the complete temporary impact accrues regardless of whether the plant services 1 reactor for 1 year or 57 reactors for 30 years.
(c) Estimated effluents based upon combustion of equivalent coal for power generation.
(d) 1.2 percent from natural gas use and process.
Source: 10 CFR 51.51.

*4.14.1.1.3 Consideration of Environmental Justice*

As stated in the NRC's *Policy* Statement *on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions* (69 FR 52040),

> An NRC EJ [environmental justice] analysis should be limited to the impacts associated with the proposed action (i.e., the communities in the vicinity of the proposed action). EJ-related issues differ from site to site and normally cannot be resolved generically. Consequently, EJ, as well as other socioeconomic issues, are normally considered in site-specific EISs. Thus, due to the site-specific nature of an EJ analysis, EJ-related issues are usually not considered during the preparation of a generic or programmatic EIS. EJ assessments would be performed as necessary in the underlying licensing action for each particular facility.

The environmental impacts of various individual operating uranium fuel cycle facilities are addressed in separate site-specific environmental reviews and NEPA documents prepared by the NRC. These documents include analyses that address human health and environmental impacts on minority populations, low-income populations, and Indian Tribes. Electronic copies of these NEPA documents are available through the NRC's public Web site under Publications Prepared by NRC Staff document collection of the NRC's Electronic Reading Room at http://www.nrc.gov/reading-rm/doc-collections/; and the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html.

*4.14.1.1.4 Transportation Impacts*

The impacts associated with transporting fresh fuel to one 1,000 MWe model LWR and with transporting spent fuel and radioactive waste (LLW and mixed waste) from that LWR are provided in Table S-4 in 10 CFR 51.52. Similar to Table S-3 (Table 4.14-1), and as indicated in 10 CFR 51.52, every environmental report prepared for the construction permit stage of a commercial nuclear power plant must contain a statement concerning the transportation of fuel and radioactive waste to and from the reactor. A similar statement is also required in license renewal (initial LR and SLR) applications. Table S-4 forms the basis of such a statement and is presented here as Table 4.14-2.

A discussion of the values included in Table S-4 of 10 CFR 51.52 (see Table 4.14-2) and how they may change during the license renewal term was included in Section 6.3 of the 1996 LR GEIS. However, after the 1996 LR GEIS was issued and during the rulemaking process for codifying Table B-1 in 10 CFR Part 51, a number of comments were received from the public that raised some questions about the adequacy of Table 4.14-2 values for license renewal application reviews. As a result, the NRC reevaluated the transportation issues and the adequacy of Table 4.14-2 values for license renewal (initial LR or SLR) application reviews. In 1999, the NRC issued an addendum to the 1996 LR GEIS in which the agency evaluated the applicability of Table S-4 (Table 4.14-2) to future license renewal proceedings, given that the spent fuel is likely to be shipped to a single repository (as opposed to several destinations, as originally assumed in the preparation of Table S-4) and given that shipments of spent fuel are likely to involve more highly enriched fresh fuel (more than 4 percent as assumed in Table S-4) and higher-burnup spent fuel (higher than 33,000 MWd/MTU as assumed in Table 4.14-2). In the addendum, the NRC evaluated the impacts of transporting the spent fuel from reactor sites to the proposed geologic repository at Yucca Mountain in Nevada and the impacts of shipping more highly enriched fresh fuel and higher-burnup spent fuel. On the basis of the evaluations, the NRC concluded that the values given in Table 4.14-2 (Table S-4 in 10 CFR 51.52) would still be bounding, as long as the (1) enrichment of the fresh fuel was 5 percent or less, (2) burnup of the spent fuel was 62,000 MWd/MTU or less, and (3) higher-burnup spent fuel (higher than 33,000 MWd/MTU) was cooled for at least 5 years before being shipped offsite. The conditions evaluated in Addendum 1 have not changed, and no new conditions have been introduced that would alter the conclusions in Addendum 1 (NRC 1999a). A later study found that the impacts from the transportation of spent nuclear fuel with up to 75,000 MWd/MTU burnup would not have significant adverse environmental impacts, provided that the impacts are not significantly affected by fission gas releases and the fuel is cooled for at least 5 years before shipment (Ramsdell et al. 2001). Table 4.14-2 as currently encoded in 10 CFR 51.52 is provided below.

**Table 4.14-2 Table S-4 Taken from 10 CFR 51.52 on the Environmental Impact of Transporting Fuel and Waste to and from One Light-Water-Cooled Nuclear Power Reactor[(a)]**

| Normal Conditions of Transport | | Environmental Impact | |
|---|---|---|---|
| Heat (per irradiated fuel cask in transit) | | 250,000 Btu/hr | |
| Weight (governed by Federal or State restrictions) | | 73,000 lb per truck; 100 tons per cask per rail car | |
| Traffic density: | | | |
| Truck | | Less than 1 per day | |
| Rail | | Less than 3 per month | |
| **Exposed Population** | **Estimated No. of Persons Exposed** | **Range of Doses to Exposed Individuals[(b)] (per reactor year)** | **Cumulative Dose to Exposed Population (per reactor year)[(c)]** |
| Transportation workers | 200 | 0.01 to 300 millirem | 4 person-rem |
| General public: | | | |
| Onlookers | 1,100 | 0.003 to 1.3 millirem | 3 person-rem |
| Along route | 600,000 | 0.0001 to 0.06 millirem | |

| Accidents in Transport | |
|---|---|
| **Types of Effects** | **Environmental Risk** |
| Radiological effects | Small[(d)] |
| Common (nonradiological) causes | 1 fatal injury in 100 reactor years; 1 nonfatal injury in 10 reactor years; $475 property damage per reactor year |

(a) Data supporting this table are given in the Commission's *Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants*, WASH-1238, December 1972, and Supp. 1, NUREG-75/038, April 1975. Both documents are available for inspection and copying at the Commission's Public Document Room, One White Flint North, 11555 Rockville Pike (first floor), Rockville, Maryland 20852 and may be obtained from National Technical Information Service, Springfield, VA 22161.
(b) The Federal Radiation Council has recommended that the radiation doses from all sources of radiation other than natural background and medical exposures should be limited to 5,000 millirem per year for individuals as a result of occupational exposure and should be limited to 500 millirem per year for individuals in the general population. The dose to individuals due to average natural background radiation is about 130 millirem per year.
(c) Man-rem is an expression for the summation of whole body doses to individuals in a group. Thus, if each member of a population group of 1,000 people received a dose of 0.001 rem (1 millirem), or if 2 people received a dose of 0.5 rem (500 millirem) each, the total man-rem dose in each case would be 1 man-rem.
(d) Although the environmental risk of radiological effects stemming from transportation accidents is currently incapable of being numerically quantified, the risk remains small, regardless of whether it is being applied to a single reactor or a multireactor site.
Source: 10 CFR 51.52.

*4.14.1.1.5 Consideration of Environmental Justice*

The human health effects of transporting spent nuclear fuel were originally addressed in an addendum to the 1996 GEIS (NRC 1999b) in which the agency evaluated the applicability of Table S-4 to future license renewal proceedings given that spent fuel is likely to be shipped to a single geologic repository. As part of the site characterization and recommendation process for the proposed geologic repository at Yucca Mountain, Nevada, the DOE is required by the Nuclear Waste Policy Act of 1982 to prepare an EIS. By law, the NRC is required to adopt DOE's EIS, to "the extent practicable," as part of any possible NRC construction authorization decision. As a result, DOE prepared and submitted to NRC the *Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (Repository Supplemental EIS) (DOE/EIS-0250F-S1; DOE 2008). This document includes analyses that address the human health and environmental impacts on minority populations, low-income populations, and Indian Tribes.

As noted in DOE's Repository Supplemental EIS, shipments of spent nuclear fuel (as well as fresh fuel) would use the nation's existing railroads and highways. Consequently, DOE estimates that transportation-related environmental impacts affecting land use; air quality; hydrology; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetic resources; utilities, energy, and materials; and waste management would be SMALL. Nonetheless, segments of the population, including minority populations, low-income populations, and Indian Tribes, would likely experience some transportation-related environmental effects.

The DOE did not identify any high and adverse human health or environmental impacts on members of the public from the transport of spent nuclear fuel, and determined that subsections of the population, including minority populations, low-income populations, and Indian Tribes, would not experience disproportionate effects. In addition, DOE did not identify any unique patterns of subsistence consumption, exposure pathways, sensitivities, or cultural practices that would expose these populations to disproportionately high and adverse effects. Consequently, DOE concluded that minority populations, low-income populations, and Indian Tribes would not experience any disproportionately high and adverse human health or environmental effects from the transportation of spent nuclear fuel to Yucca Mountain (DOE 2008). On September 8, 2008, the NRC staff recommended the Commission adopt DOE's Repository Supplemental EIS with supplements (73 FR 53284).

As discussed in Section 4.11.1.3, the NRC prepared and issued an EIS supplement in 2016 (NUREG-2184; NRC 2016a) that evaluated environmental impacts due to potential radiological releases from the proposed Yucca Mountain geologic repository. The supplement did not evaluate transportation impacts. The NRC determined that there would be no disproportionately high and adverse human health or environmental effects from the use or discharge of groundwater flowing from the repository on minority or low-income populations.

In light of DOE's decision to not proceed with the Yucca Mountain nuclear waste geologic repository and comprehensive reevaluation of policies for managing spent nuclear fuel from nuclear power plants (see Section 4.11.1.3), some or all of the environmental impact analyses in DOE's Repository Supplemental EIS will have to be revisited. Nevertheless, as reaffirmed by the NRC in the 2014 Continued Storage Final Rule (79 FR 56238) and as supported by the analyses in NUREG-2157, disposal in a geologic repository continues to be technically feasible. International progress in the development of repositories provides confidence that it is likely that a repository can and will be developed in the United States, with 25 to 35 years being a reasonable period for repository development. The NRC expects that DOE's analysis for the Yucca Mountain geologic repository would be representative of any future repository.

#### *4.14.1.1.6 Environmental Impact Issues of the Uranium Fuel Cycle*

Nuclear fuel is needed for the operation of light water reactors during the license renewal term (initial LR or SLR) in the same way that it is needed during the current license period. Therefore, the factors that affect the data presented in Tables S-3 (Table 4.14-1) and S-4 (Table 4.14-2) of 10 CFR 51.51 and 51.52, respectively, do not change whether a light water reactor is operating under its original license or a renewed license. In the 1996 LR GEIS, there are nine issues that relate to uranium fuel cycle and waste management; five of them that relate to waste management are addressed in Section 4.11.1.

The remaining four impact issues include the following (as evaluated in the 2013 LR GEIS):

- offsite radiological impacts – individual impacts from other than the disposal of spent fuel and high-level waste;
- offsite radiological impacts – collective impacts from other than the disposal of spent fuel and high-level waste);
- nonradiological impacts of the uranium fuel cycle; and
- transportation.

**Offsite Radiological Impacts – Individual Impacts from Other than the Disposal of Spent Fuel and High-Level Waste**

This issue addresses the radiological impacts on individuals who live near uranium fuel cycle facilities. The primary indicators of impact are the concentrations of radionuclides in the effluents from the fuel cycle facilities and the radiological doses received by an MEI (a maximally exposed individual) on the site boundary or at some location away from the site boundary. As discussed in Section 3.9.1 of this LR GEIS, an MEI can be exposed to radiation from radionuclides found in the effluents of nuclear fuel cycle facilities and from radiation "shine" from buildings, storage facilities, and storage tanks containing radioactive material. The basis for establishing the significance of individual effects is the comparison of the releases in the effluents and the MEI doses with the permissible levels in applicable regulations. The analyses performed by the NRC in the preparation of Table 4.14-1 and found in the 1996 LR GEIS indicate that as long as the facilities operate under a valid license issued by either the NRC or an agreement State, the individual effects will meet the applicable regulations. On the basis of these considerations, the NRC has concluded that the impacts on individuals from radioactive gaseous and liquid releases during the initial LR or SLR term would remain at or below the NRC's regulatory limits. Accordingly, the NRC concludes that offsite radiological impacts of the uranium fuel cycle (individual effects from sources other than the disposal of spent fuel and high-level waste) are SMALL. The efforts to keep the releases and doses ALARA will continue to apply to fuel-cycle-related activities. This was considered a Category 1 issue in the 2013 LR GEIS. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Therefore, this is a Category 1 issue for both initial LR and SLR.

**Offsite Radiological Impacts – Collective Impacts from Other than the Disposal of Spent Fuel and High-Level Waste**

The focus of this issue is the collective radiological doses to and health impacts on the general public resulting from uranium fuel cycle facilities over the license renewal term. The radiological doses received by the general public are calculated on the basis of releases from the facilities to the environment, as provided in Table 4.14-1. These estimates were provided in the 1996 LR GEIS for the gaseous and liquid releases listed in Table S-3 as well as for radon-222 and technetium-99 releases (Rn-222 and Tc-99), which are not listed in Table 4.14-1. The population dose commitments were normalized for each year of operation of the model 1,000 MWe LWR (reference reactor year).

On the basis of the analyses provided in the 1996 LR GEIS and reexamined and discussed in the 2013 LR GEIS, the estimated involuntary 100-year dose commitment to the U.S. population resulting from the radioactive gaseous releases from uranium fuel cycle facilities (excluding the reactors and releases of Rn-222 and Tc-99) was estimated to be 400 person-rem (4 person-Sv) for 1 reference reactor year. Similarly, the environmental dose commitment to the U.S. population from the liquid releases was estimated to be 200 person-rem (3 person-Sv) per reference reactor year. As a result, the total estimated involuntary 100-year dose commitment to the U.S. population from radioactive gaseous and liquid releases listed in Table 4.14-1 was given as 600 person-rem (6 person-Sv) per reference reactor year (see Section 6.2.2 of the 1996 LR GEIS).

The 1996 and 2013 LR GEISs also provided a detailed analysis of potential doses to the U.S. population from Rn-222 releases, which primarily occur during mining and milling operations and as emissions from mill tailings, and Tc-99 releases, which primarily occur during the enrichment process (Section 6.2.2 of the 1996 LR GEIS). Tc-99 releases during enrichment occurred through a gaseous diffusions process that is no longer used within the United States. Tc-99 is not released through centrifuge enrichment processes and is not reconsidered in this analysis. The U.S. population doses resulting from the Rn-222 releases for 1 reference reactor year are summarized in Table 4.14-3 from the 2013 LR GEIS. The total population dose from all releases to the environment, including the Rn-222, is given as 838.6 person-rem (8.386 person-Sv) per reference reactor year.

**Table 4.14-3 Population Doses from Uranium Fuel Cycle Facilities Normalized to One Reference Reactor Year**

| Source | Collective Dose (person-rem)[(a)] |
|---|---|
| Gaseous releases | 400 |
| Liquid releases | 200 |
| Rn-222 releases from uranium mining and milling | 140 |
| Rn-222 releases from unreclaimed open-pit mines | 96 |
| Rn-222 releases from stabilized tailings piles | 2.6 |
| Total | 838.6 |

Rn-222 = Radon-222.
(a) To convert person-rem to person-Sv, multiply by 0.01.
Source: Modified from NRC 1996.

As discussed in the 1996 LR GEIS and as confirmed in the 2013 LR GEIS, the dose estimates given above were based on highly conservative assumptions. In actuality, the doses received by most members of the public would be so small that they would be indistinguishable from the variations in natural background radiation. There are no regulatory limits applicable to collective doses to the general public from fuel cycle facilities. All regulatory limits are based on individual doses. All fuel cycle facilities are designed and operated to meet the applicable regulatory limits.

As discussed in the 1996 LR GEIS and as confirmed in the 2013 LR GEIS, despite the lack of definitive data, some judgment as to the regulatory NEPA implications of these matters should be made and it makes no sense to repeat the same judgment in every case. The Commission concludes that these impacts are acceptable in that these impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR Part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the collective effects of the fuel cycle; this issue was considered Category 1. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. This is a Category 1 issue for both initial LR and SLR.

*4.14.1.1.7 Nonradiological Impacts of the Uranium Fuel Cycle*

This section addresses the nonradiological impacts associated with the uranium fuel cycle facilities as they relate to license renewal. Data on the nonradiological impacts of the fuel cycle are provided in Table 4.14-1. These data cover land use, water use, fossil fuel use, and chemical effluents. The significance of the environmental impacts associated with these data was evaluated in the 1996 LR GEIS on the basis of several relative comparisons. The land requirements were compared to those for a coal-fired power plant that could be built to replace the nuclear capacity if the operating license is not renewed. Water requirements for the uranium fuel cycle were compared to the annual requirements for a nuclear power plant. The amount of fossil fuel (coal and natural gas) consumed to produce electrical energy and process heat during the various phases of the uranium fuel cycle was compared to the amount of fossil fuel that would have been used if the electrical output from the nuclear plant were supplied by a coal-fired plant. Similarly, the gaseous effluents $SO_2$, nitric oxide (NO), hydrocarbons, carbon monoxide (CO), and other particulate matter (PM) released as a consequence of the coal-fired electrical energy used in the uranium fuel cycle were compared with equivalent quantities of the same effluents that would be released from a 45 MWe coal-fired plant. It was noted that the impacts associated with uses of all of the above resources would be SMALL. Any impacts associated with nonradiological liquid releases from the fuel cycle facilities would also be SMALL. As a result, the aggregate nonradiological impacts of the uranium fuel cycle resulting from the renewal (initial LR or SLR) of an operating license for a plant would be SMALL, and it was considered a Category 1 issue in the 2013 LR GEIS. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. Thus, this is a Category 1 issue for both initial LR and SLR.

##### *4.14.1.1.8 Transportation*

This section addresses the impacts associated with transportation of fuel and waste to and from one light water reactor during the license renewal term (initial LR and SLR). Table S-4 (Table 4.14-2) in 10 CFR 51.52 forms the basis for analysis of these impacts when evaluating the applications for license renewal (initial LR and SLR) from owners of light water reactors. As discussed previously in this section, the applicability of Table 4.14-2 for license renewal (initial LR and SLR) applications was extensively studied in the 1996 LR GEIS and its Addendum 1 (NRC 1999b) and confirmed in the 2013 LR GEIS. The impacts were found to be SMALL, and the findings were stated as follows:

> The impacts of transporting spent fuel enriched up to 5 percent uranium-235 with average burnup for the peak rod to current levels approved by NRC up to 62,000 MWd/MTU and the cumulative impacts of transporting high-level waste to a single repository, such as Yucca Mountain, Nevada are found to be consistent with the impact values contained in 10 CFR 51.52(c), Summary Table S-4, "Environmental Impact of Transportation of Fuel and Waste to and from One Light-Water-Cooled Nuclear Power Reactor." If fuel enrichment or burnup conditions are not met, the applicant must submit an assessment of the implications for the environmental impact values reported in 10 CFR 51.52.

The issue was designated as Category 1. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts from what was concluded in the 2013 LR GEIS for this issue for either an initial LR or SLR term. This is a Category 1 issue for both initial LR and SLR.

### 4.14.2 Replacement Energy Alternative Fuel Cycles

#### *4.14.2.1 Fossil Energy Alternatives*

The environmental consequences of the fuel cycle for a fossil fuel-fired plant result from the initial extraction of the fuel from its natural setting, fuel cleaning and processing, transport of the fuel to the facility, and management and ultimate disposal of solid wastes resulting from combustion of the fuel.

The environmental impacts of coal mining vary with the location and type of mining technology employed, but generally includes:

- Significant change in land uses, especially when surface mining is employed.
- Degradation of visual resource values.
- Air quality impacts, including release of criteria pollutants from vehicles and equipment, release of fugitive dust from ground disturbance and vehicle travel on unpaved surfaces, release of VOCs from the storage and dispensing of vehicle and equipment fuels and the use of solvents and coatings in maintenance activities, and release of coalbed methane into the atmosphere as coal seams are exposed and overburden is removed.
- Noise impacts from the operation of vehicles and equipment and the possible use of explosives.
- Impacts on geology and soils due to land clearing, excavations, soil and overburden stockpiling (for strip mining operations), and mining.
- Water resources impacts, including degradation of surface water quality due to increased sediment and runoff to surface water bodies, possible degradation of groundwater resources due to consumptive use and potential contamination (especially when shaft mining techniques are employed), as well as generation of wastewater from coal cleaning operations and other supporting industrial activities.
- Ecological impacts, including extensive loss of natural habitat, loss of native vegetative cover, disturbance of wildlife, possible introduction of invasive species, changes in surface water hydrology, and degradation of aquatic systems.
- Impacts on historic and cultural resources within the mine footprint, as well as additional potential impacts resulting from auxiliary facilities and appurtenances (e.g., access roads, rail spurs).
- Direct socioeconomic impacts from employment of the workforce and indirect impacts from increased employment in service and support industries.
- Potential environmental justice impacts as a result of the presence of minority or low-income populations in the surrounding communities and/or within the workforce.
- Potential health impacts on workers from exposure to airborne dust, gases such as methane, and exhaust from internal combustion engines on vehicles and mining machinery.
- Generation of coal wastes and industrial wastes associated with the maintenance of vehicles and equipment, increased potential for spills of fuels from onsite fuel storage and dispensing.

#### *4.14.2.2 New Nuclear Alternatives*

Environmental impacts of the fuel cycle result from the initial extraction of the fuel from its natural setting, transport of the fuel to the facility, and management and ultimate disposal of solid wastes resulting from combustion of the fuel. For the fuel cycle associated with a nuclear power plant, these activities include uranium mining and milling, the production of uranium hexafluoride, isotopic enrichment, fuel fabrication, reprocessing of irradiated fuel, transportation of radioactive materials, and management of LLW and HLW (10 CFR Part 51). The NRC has summarized environmental data associated with the uranium fuel cycle in Table S-3 of 10 CFR 51.51 (Table 4.14-1). The analysis provides a basis for evaluating the environmental effects of the fuel cycle for all nuclear power plants, regardless of site location. The information is based on a 1000 MW LWR with an 80 percent capacity factor. The impacts associated with the transportation of fuel and waste to and from a power reactor are summarized in Table S-4 of 10 CFR 51.52 (Table 4.14-2). Detailed analysis of the uranium fuel cycle is also considered in Section 4.14.1.1. Although the uranium fuel cycle analysis is specific to the impacts of license renewal, it is applicable to new nuclear energy alternatives because existing the advanced reactor designs use the same type of fuel as existing operational designs. One difference may be that the new reactor may have a power rating of greater than 1,000 MWe, which may exceed the power rating of the existing reactor. In those cases, the impacts would be proportionally higher. However, all impacts associated with the uranium fuel cycle, as discussed in Section 4.14.1.1.6, would still be SMALL.

#### *4.14.2.3 Renewable Alternatives*

The term “fuel cycle” has varying degrees of relevance for renewable energy facilities. Clearly, the term has meaning for renewable energy technologies that rely on combustion of fuels such as biomass grown or harvested for the express purpose of power production. The term is somewhat more difficult to define for renewable technologies such as wind, solar, geothermal, and ocean wave and current. This is because the associated natural resources continue to exist (i.e., the resources are not consumed or irreversibly committed) regardless of any effort to harvest them for electricity production. The common technological strategy for harvesting energy from such natural resources is to convert the kinetic or thermal energy inherent in that resource to mechanical energy or torque. The torque is then applied directly (e.g., as in the case of a wind turbine) or indirectly (e.g., for the facilities that use conventional steam cycles to drive turbines that drive generators) to produce electricity. However, because such renewable technologies capture very small fractions of the total kinetic or thermal energy contained in the resources, impacts from the presence or absence of the renewable energy technology are often indistinguishable.

Environmental consequences of fuel cycles for biomass (e.g., energy crops, wood wastes, municipal solid waste, refuse-derived fuel, landfill gas) include the following:

- Land use impacts from the growing and harvesting of the energy crops.
- Reduced impacts on land from the avoidance of land disposal of anthropogenic biomass feedstocks such as municipal solid waste and refuse-derived fuel.
- Visual impacts from the establishment of farm fields and forest areas and processing facilities for the growing, harvesting, and preparation of biomass feedstocks.
- Air impacts from operation of vehicles and equipment used in the planting, cultivating, and harvesting of energy crops.
- Reductions in GHG emissions from landfills as a result of the capture and destruction by combustion of landfill gas for energy production.
- Removal of GHGs from the air (e.g., $CO_2$) by growing crops.
- Noise impacts from the operation of agriculture and silviculture equipment and transport vehicles in otherwise rural settings with low ambient noise levels.
- Soil impacts from the cultivation of fields and the potential for increased sediment in precipitation runoff.

- Hydrologic impacts from irrigation of the energy crops; impacts on groundwater resources from water removal for agricultural or silvicultural purposes or industrial water uses associated with the preparation of biomass feedstocks.
- Ecological impacts from the loss of habitat resulting from crop production; loss of hydrologic resources due to diversion for irrigation purposes; potential intrusion of invasive species on disturbed land surfaces; and potential contamination of adjacent habitat by pesticide and fertilizer runoff.
- Ecological impacts from the alteration of habitat due to human presence and activities in agricultural and silvicultural areas.
- Historic and cultural resource impacts from inadvertent destruction of resources in virgin fields that have not undergone appropriate efforts to survey, identify, and relocate cultural resources that may be present.
- Human health impacts from the exposure of workers to pesticides and fertilizers used in growing biomass fuels; work around mechanical planting, cultivating, and harvesting equipment; work in weather extremes; and exposure to dangerous plants and wildlife.
- Waste impacts in the form of residual wastes from the application of pesticides and fertilizers and wastes associated with the routine maintenance of equipment and vehicles used in crop production and transport (used lubricating oils, hydraulic fluids, glycol-based coolants, and battery electrolytes from maintenance of equipment and vehicles with internal combustion engines).
- Positive economic impacts from the creation of jobs in the agriculture, silviculture, and transportation sectors.

### 4.14.3 Environmental Consequences of Terminating Operations and Decommissioning

The following sections briefly summarize the environmental impacts of license renewal on terminating reactor operations and the decommissioning of nuclear power plants and replacement energy facilities. All electrical power-generating facilities will be decommissioned after the end of their operating life or after a decision is made to terminate its operation. For the proposed action, license renewal would delay this eventuality for up to an additional 20 years.

#### *4.14.3.1 Termination of Nuclear Power Plant Operations and Decommissioning*

This section describes the environmental consequences of terminating reactor operations and decommissioning nuclear power plants. Impacts attributable to the proposed action (license renewal) would be the environmental effects from an additional 20 years of nuclear power plant operations and refurbishment. The impacts from decommissioning a nuclear power plant are evaluated in the *Generic Environmental Impact Statement for Decommissioning of Nuclear Facilities: Supplement 1, Regarding the Decommissioning of Nuclear Power Reactors*, NUREG-0586 (NRC 2002c).

Most nuclear plant activities and systems dedicated to reactor operations would cease after reactor shutdown. Some activities (e.g., security and spent nuclear fuel management) would continue, while other activities (administration, laboratory analysis, and reactor surveillance, monitoring, and maintenance) may be reduced or eliminated. Shared systems at a nuclear power plant with multiple units, would continue to operate but at reduced capacity until all units cease operation. The cessation of activities needed to maintain and operate the reactor would reduce the need for workers at the nuclear power plant, but would not lead to the immediate dismantlement of the reactor or its infrastructure.

The decommissioning process begins when the licensee informs the NRC that it has permanently ceased reactor operation, defueled, and intends to decommission the nuclear plant. The licensee may notify the NRC of the permanent cessation of reactor operations prior to the end of the license term while still operating. Regulations in 10 CFR 50.82(a)(4)(i) and 10 CFR 52.110(d)(1) require licensees to submit a post-shutdown decommissioning activity report (PSDAR) to the NRC, with a copy forwarded to the affected State(s), no later than 2 years after the cessation of reactor operations.

The licensee must describe all planned activities in the PSDAR, including the schedule and estimated costs for radiological decommissioning (excluding site restoration and spent fuel management costs). The licensee also documents the evaluation of the environmental impacts of planned decommissioning activities at the nuclear plant, providing a basis for why impacts are bounded by previously issued environmental review documents (e.g., Decommissioning GEIS; NRC 2002c). The licensee must also describe any decommissioning activities whose impacts are not bounded and how the impacts will be addressed prior to conducting these activities at the nuclear plant (e.g., through regulatory exemption or license amendment requests). The licensee is required to update the PSDAR if there are any significant changes in decommissioning activity, costs, schedule, or environmental impact.

Once the NRC receives the PSDAR, the report will be docketed, and a notice of receipt will be published in the *Federal Register* to solicit public comments. The NRC conducts a public meeting near the nuclear plant to discuss the licensee's decommissioning plans and schedule, answer questions, and solicit comments.

The licensee submits a License Termination Plan with final status survey strategy to the NRC near the end of decommissioning, at least 2 years before the operating license can be terminated. Prior to completing decommissioning, the licensee must conduct a survey demonstrating compliance with site release criteria established in the License Termination Plan. The NRC verifies the survey results by one or more of the following: a quality assurance/quality control review, side-by-side or split sampling of radiological surveys of selected areas, and independent confirmatory surveys. When the NRC confirms that the criteria in the License Termination Plan and all other NRC regulatory requirements have been met, the NRC either terminates or amends the operating license, depending on the licensee's decision to use the licensed area. The nuclear plant and any remaining structures on the site can then be released for restricted or unrestricted use. The criteria for restricted use conditions and alternate criteria that the NRC may approve under certain conditions are listed in 10 CFR 20.1403 and 10 CFR 20.1404, respectively. The radiological criteria for releasing sites for unrestricted use are given in 10 CFR 20.1402.

Three decommissioning options are evaluated in the Decommissioning GEIS (NRC 2002c): DECON, SAFSTOR, and ENTOMB. In the DECON option, equipment, structures, and portions of a nuclear plant containing radioactive contaminants are removed and safely buried in a LLW landfill or are decontaminated to a level that permits the property to be released for unrestricted use shortly after the cessation of reactor operations. In the SAFSTOR option, the facility is maintained in such condition that the nuclear plant can be safely stored and subsequently decontaminated later to levels that permit the property to be released for restricted or unrestricted use. In the ENTOMB option, radioactive contaminants are encased in a structurally long-lived material, such as concrete. The entombment structure is maintained and surveillance is carried out until the radioactivity decays to a level permitting unrestricted release of the property.

The following sections discuss the potential effects from terminating reactor operations and the decommissioning nuclear power plants on environmental resources near a nuclear power plant.

#### *4.14.3.2 Land Use*

Land use activities after terminating reactor operations and during decommissioning would be comparable to what was experienced during construction and would not require land outside the developed areas of the site. Activities requiring land include equipment and large component laydown areas. Temporary changes in onsite land use would not affect the industrial use of the site.

#### *4.14.3.3 Visual Resources*

The termination of reactor operations would not change the visual appearance of the nuclear plant. The most notable change, however, would be the elimination of condensate plumes from cooling towers. License renewal would only delay decommissioning, prolonging the visual impact. The delay would have no new or added visual impact.

#### *4.14.3.4 Air Quality*

After the termination of reactor operations, air emissions from the nuclear power plant would continue, but at reduced levels. Natural or mechanical draft cooling tower drift would also be greatly reduced or eliminated. Air emissions from boilers and emergency diesel generators would continue until the decommissioning of the nuclear plant has been completed.

#### *4.14.3.5 Noise*

During decommissioning, noise would generally be far enough away from sensitive receptors outside nuclear plant boundaries, attenuated to nearly ambient levels, and scarcely noticeable offsite. However, during the demolition, offsite noise levels could be loud enough that activities may need to be curtailed during early morning and evening hours. Noise abatement procedures could also be used during decommissioning to reduce noise.

#### *4.14.3.6 Geology and Soils*

Termination of reactor operations and decommissioning are not expected to affect geology and soils. The demolition and removal of buildings, foundation slabs, parking lots, and roads would expose soil to possible erosion. Geologic resources in the form of gravel or crushed stone may be needed to construct temporary roads for heavy equipment.

*4.14.3.7 Water Resources – Surface Water and Groundwater*

After the termination of reactor operations, water use would be dramatically reduced; however, water demands would continue for the service water system to support activities such as temperature control of the spent fuel pool and other miscellaneous industrial maintenance applications. Surface water or groundwater intake and consumptive use would be very low compared to use during the operational phase. Discharge of liquid wastes and biocides would also be proportionately reduced.

Because the site workforce would be reduced, the volume of sanitary sewage effluent would be less than that during reactor operations. Pumping rates for groundwater used for potable water systems would also decrease because of the reduced workforce.

Hydrology and water quality impacts from soil erosion and storm events are expected to be unchanged. Erosion would be mitigated as part of general site maintenance during decommissioning.

*4.14.3.8 Ecological Resources*

Termination of reactor operations would reduce some ecological resource impacts and eliminate others. Nuclear plant structures including cooling towers and transmission lines would continue to be collision hazards for birds. The impingement and entrainment of aquatic organisms would decrease after reactor operations cease, and the potential for impacts on aquatic communities would be reduced. In general, the termination of entrainment and impingement would have positive effects on affected organisms. Because significantly smaller volumes of heated water would be discharged after reactor operations cease, the nuclear plant’s influence on the thermal conditions in the receiving waters would be greatly reduced.

Aquatic communities and organisms acclimated to warmer temperatures and biocides may have developed within the nuclear plant discharge mixing zone during years of reactor operation because of the warmer environment. These organisms would be adversely affected as the water temperature cooled and the original environmental conditions were restored within the body of water. Organisms susceptible to cold shock would be affected. Such effects, which normally occur during winter months, would occur after the reactor ceases operations.

Cooling ponds maintained during reactor operations by pumping water from another water body would likely revert to a terrestrial system after the termination of reactor operations and pumping stops and thermal effects on them cease. Cessation of the heated effluent would change the composition and dynamics of the pond community until it resembled that of other ponds in the region not used for cooling.

Dredging would no longer be needed in the vicinity of cooling water structures, thereby eliminating the effect on aquatic biota. The potential for gas supersaturation and its effect on biota would also be eliminated or decreased.

There is the potential for some effects on aquatic resources to continue regardless of whether the reactor is operating. Dams and reservoirs constructed to supply water may continue to prevent migration of anadromous fish unless these structures are removed.

The termination of reactor operations could have a beneficial impact on the Federally listed loggerhead sea turtle (threatened), green sea turtle (*Chelonia mydas*, threatened), leatherback sea turtle (endangered), hawksbill sea turtle (endangered), and Kemp's ridley sea turtle (endangered), which have been impinged at several nuclear power plants (e.g., St. Lucie and Oyster Creek). Similarly, potential benefits to the Federally endangered West Indian manatee and pinnipeds, protected under the Marine Mammal Protection Act, could occur. For example, the West Indian manatee has been impinged at St. Lucie, and incidental takes of harbor seals, gray seals, harp seals, and hooded seals occur at the Seabrook plant. Elimination of high-temperature discharges at nuclear plants in Florida may reduce habitat suitability for the West Indian manatee, particularly during winter. However, the West Indian manatee occupies other habitats in Florida that do not have artificially elevated temperatures, and it uses a number of thermal discharges from fossil fuel plants along both coasts of Florida (Laist and Reynolds 2005). Potential impingement and entrainment losses of special status fish species could also decrease.

The overall impact on ecological resources depends on the decommissioning activity. The greatest potential decommissioning impact on protected species is associated with the dismantlement of the nuclear plant, including intake and discharge structures. Many activities that could affect ecological resources during decommissioning are the same activities that occur during reactor operation. Continued reactor operations during initial LR and SLR terms will not change the level of impact during decommissioning.

#### *4.14.3.9 Historic and Cultural Resources*

The termination of reactor operations would not affect historic or cultural resources at a nuclear power plant. The continued reactor operations at a nuclear plant under a renewed license (i.e., initial LR or SLR) would not alter this conclusion. Most historic and cultural resource impacts occurred during construction of the nuclear power plant. Continued operations and maintenance activities have the potential to affect these resources, as discussed in Section 4.7.1. There is nothing inherent in operating a nuclear plant for a longer time period that would increase or decrease the impact on these resources from decommissioning. Delaying decommissioning is not expected to have any effect on historic and cultural resources within a transmission line ROW.

#### *4.14.3.10 Socioeconomics*

Terminating reactor operations could have a noticeable impact on socioeconomic conditions in the region around the nuclear plant. There would be immediate socioeconomic impacts from the loss of jobs (some, though not all, employees would begin to leave after reactor shutdown); and tax revenues generated by plant operations would also be reduced. Depending on the tax formula used to determine property tax payments, the amount of money paid to local taxing jurisdictions may be reduced. However, property tax payments would continue. Demand for services and housing would likely decline. Indirect employment and income created as a result of nuclear power plant operations would also be reduced.

Loss of employment at nuclear plants in rural communities would likely mean workers and their families would leave in search of jobs elsewhere. The decrease in the demand for housing and the increase in available housing would depress rural housing market prices. Conversely, in urban areas, nuclear plant workers and their families may remain because there are greater opportunities for reemployment.

Traffic congestion caused by commuting workers and truck deliveries during plant operations would also be reduced.

*4.14.3.11 Human Health*

After the termination of reactor operations, there is a period of time before the decommissioning of the nuclear plant begins—ranging from months to years. During this time, the reactor would be placed in a cold shutdown condition and maintained. Workers would continue to be exposed to radiation. Radioactive gaseous and liquid effluent releases to the environment would continue, although at lower levels. The radiological impacts on workers and members of the public during decommissioning would be less than those during reactor operations.

*4.14.3.11.1 Radiological Exposure*

During decommissioning activities, workers and members of the public would be exposed to radioactive materials released to the environment. Regulatory requirements and dose limits during decommissioning are the same as when reactors are operating (see Section 3.9.1.1). Many decommissioning activities are similar to those that occur during reactor operations including maintenance outages (e.g., decontamination of piping and surfaces; removal of piping, pumps, and valves; and removal of heat exchangers). Some activities, such as removal of the reactor vessel or demolition of facilities, are unique to decommissioning. Doses to the public would be well below applicable regulatory standards, regardless of which decommissioning option is chosen.

*4.14.3.11.2 Chemical Hazards*

Decommissioning involves many activities that expose workers to chemical hazards, including paints, asbestos, lead, polychlorobiphenyls, mercury, quartz, and other hazardous materials in building materials. A delay in terminating reactor operations and decommissioning would not change the projected human health impact from chemical hazards because there would not be any more hazardous chemicals present.

*4.14.3.11.3 Microbiological Hazards*

During decommissioning, workers may be exposed to molds and other biological organisms. License renewal (initial LR and SLR) would not change the microbiological hazard during decommissioning because workers would be practicing good industrial hygiene and using personal protective equipment when biological hazards were identified.

*4.14.3.11.4 Electromagnetic Fields*

After the termination of reactor operations, electricity is no longer being generated. Power would still be provided to the nuclear plant, and workers might be exposed to EMFs during decommissioning. The EMF impact during decommissioning would be unaffected by license renewal.

*4.14.3.12 Accidents During Termination of Reactor Operations and Decommissioning*

The impacts of postulated accidents during the license renewal term are discussed in Section 4.9.1.2. General characteristics and consequences of postulated accidents, including source term, are expected to be similar after reactor shutdown. Because of aging management activities and the extended life of certain systems, structures, and components, there may be small differences in the probabilities of occurrence of these accidents after reactor shutdown. These differences, however, are not expected to be significant, and the risks of accidents after reactor shutdown would generally be less than the risks discussed in Section 4.9.1.2.

The impacts associated with accidents during the decontamination and decommissioning of nuclear power plants are analyzed in the Decommissioning GEIS (NRC 2002c). Radiological accidents considered in the analysis included onsite storage and handling of spent nuclear fuel and decontamination, dismantlement, and storage accidents. Accidents included fires, handling accidents, explosions (e.g., explosion of liquid propane gas tanks), and accidental releases of liquid radioactive wastes from storage tanks.

License renewal would merely delay when accidents associated with the termination of reactor operations and decommissioning could occur and would not significantly affect their probability or consequence.

*4.14.3.13 Environmental Justice*

Termination of reactor operations and the resulting loss of jobs, income, and tax revenue could disproportionately affect minority and low-income populations and Indian Tribes. The loss of tax revenue, for example, could reduce the availability or eliminate some of the community services that low-income and minority populations may depend on. This situation could be offset with the construction and operation of replacement power generating facilities and the creation of other employment opportunities at or near the nuclear plant site.

Decontamination and decommissioning activities could affect air and water quality in the area around each nuclear plant site. This could cause health and other environmental effects in minority populations, low-income populations, or Indian Tribes, if present. Populations with resource dependencies or practices (e.g., subsistence agriculture, hunting, fishing) could be disproportionately affected. License renewal would only delay, but not alter, the impact of decommissioning on minority and low-income populations around each nuclear plant.

*4.14.3.14 Waste Management and Pollution Prevention*

After terminating operations, the reactor is placed in a cold shutdown condition and maintained prior to active decommissioning. The types of waste generated after reactor shutdown would be the same as those generated during operations. However, the volume of waste generated each day may be less than that generated during reactor operations.

Pollution prevention and waste minimization measures would likely continue. As discussed in Section 4.11.1.2, spent nuclear fuel can be safely stored onsite with minimal environmental impact during the license renewal term. The NRC's *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel* (NUREG-2157; NRC 2014c) addresses the environmental impacts of spent nuclear fuel storage after the termination of reactor operations.

Wastes generated after the termination of reactor operations and during decommissioning would be shipped offsite for treatment and disposal. Of the three decommissioning options, DECON would generate the most waste. In SAFSTOR or ENTOMB, contaminated materials remain onsite temporarily or permanently, respectively.

The types of wastes generated during decommissioning include LLW, mixed waste, hazardous waste, and nonradioactive, nonhazardous waste (see Section 3.11 for waste type definitions). No spent nuclear fuel, HLW, or transuranic waste would be generated after the termination of reactor operations and during decommissioning because any remaining fuel in the reactor would have been moved to either the spent fuel pool or an ISFSI.

Most of the waste generated during decommissioning would be LLW and nonradioactive, nonhazardous waste. Small quantities of mixed waste would be managed per RCRA and the Atomic Energy Act. Hazardous waste would mainly consist of paints, solvents, and batteries. Materials used to decontaminate surfaces could be classified as mixed waste. Mixed and hazardous wastes could be treated prior to being sent to a disposal facility. Nonradioactive, nonhazardous waste, mostly concrete rubble and debris, would be sent to a local landfill.

The volume of waste generated during decommissioning may be greater because of license renewal. Waste accumulated at the nuclear plant, and the radioactivity of some components undergoing decommissioning might be slightly higher after the license renewal term. Material near the core of the reactor may have slightly higher radioactivity because of the additional years of reactor operation due to the buildup in long-lived radionuclides. This situation would mainly affect the amount of greater-than-Class C LLW at the site. There would also be more spent fuel generated because of license renewal.

For the most part, environmental conditions near the nuclear plant are not expected to change appreciably because of license renewal. The impacts of license renewal on terminating reactor operations and decommissioning is considered to be SMALL for all nuclear plants and are a Category 1 issue in the 2013 LR GEIS. As previously noted, the impacts of decommissioning nuclear power plants are evaluated in the Decommissioning GEIS (NUREG-0586; NRC 2002c).

Based on these considerations, the NRC concludes that impacts from continued nuclear plant operations during initial LR and SLR terms and refurbishment on terminating reactor operations and decommissioning would be the same—SMALL for all nuclear plants. The staff reviewed information from SEISs (for initial LRs and SLRs) completed since development of the 2013 LR GEIS and identified no new information or situations that would result in different impacts for this issue for either an initial LR or SLR term. License renewal reviews have revealed no difference in environmental impacts whether decommissioning occurs at the end of the current operating license or following a 20-year initial LR or SLR term. Therefore, terminating reactor operations and decommissioning impacts would be SMALL for all nuclear plants and it is a Category 1 issue for both initial LR and SLR.

*4.14.3.15 Termination of Operations and Decommissioning of Replacement Power Plants*

*4.14.3.15.1 Fossil Energy Alternatives*

The environmental consequences of terminating operations and decommissioning a fossil fuel energy facility depends on planned decommissioning activities and other requirements. Decommissioning plans may include the following elements and requirements, intended to ensure site restoration to a condition equivalent in character and value to the greenfield or brownfield site on which the power-generating facility was first constructed:

- Removal of all unneeded structures and facilities to at least 3 ft (1 m) below grade (in order to provide an adequate root zone for site revegetation).
- Removal of fuel, all fuel combustion waste, and all flue gas desulfurization sludge and/or byproducts.
- Removal of water intake and discharge structures.
- Dismantlement and removal of ancillary facilities, including rail spurs, fuel-handling and -preparation facilities, cooling towers, natural gas pipelines, onsite wastewater treatment facilities, and access roads.
- Removal of all surface water intake and discharge structures.
- Removal of all accumulated sludge, and closure and removal of all surface water impoundments.
- Closure of all onsite groundwater wells.
- Recycling of removed equipment and dismantled building components; materials awaiting recycling would be stored at an offsite facility.
- Disposal of solid and hazardous wastes at approved facilities; as necessary, remediation of waste handling and storage areas.
- Cleanup and remediation of all incidental spills and leaks.
- Execution of an approved revegetation plan for the site.
- Other actions as necessary to ensure restoration of the site.

Environmental impacts (greenfield or brownfield site) would include:

- Air quality and noise impacts from vehicles and equipment needed to deconstruct structures and facilities; release of criteria pollutants, fugitive dust, and noise (e.g., from explosives); impacts would be similar to those experienced during construction.
- Land use and visual impacts; temporary land use holding areas for dismantled components and deconstruction debris; restoration of land to its previous use and visual appearance by removing human-made structures.
- Reduction in water use and water quality impacts as water consumption decreases after termination of operations. Dewatering and water used for spent nuclear fuel cooling would continue. Surface water runoff would continue.
- Increased truck and rail traffic delivering equipment and transporting dismantled material and deconstruction debris.
- Ecological resource impacts and disturbance during active decommissioning.

- Increase in economic activity followed by economic downturn due to loss of jobs at the former power-generating facility.
- Health and safety risks during dismantlement and removal of facility and risk of transportation-related accidents delivering equipment and transporting dismantled material and deconstruction debris.

*4.14.3.16 New Nuclear Alternatives*

According to 10 CFR Part 52, decommissioning impacts for a nuclear power plant include all activities related to the safe removal of the facility or site from service and the reduction of residual radioactivity to a level that permits release of the property under restricted conditions or unrestricted use and termination of the license. The process and activities during decommissioning would be similar to those discussed in Section 4.14.2.1.

*4.14.3.17 Renewable Alternatives*

The termination of operations and decommissioning of renewable energy systems would follow a decommissioning plan and would involve removal of the power-generating facility, waste material, and restoration of the land to its original state. Decommissioning involves the following actions:

- Removal of unneeded power-generating facilities and support structures.
- Removal of unspent biomass fuel and wastes from combustion.
- Removal of water intake and discharge structures (if present).
- Dismantlement and removal of ancillary facilities, including rail spurs, fuel-handling facilities, cooling towers, onsite wastewater treatment facilities, and/or access roads.
- Removal of surface water intake and discharge structures.
- Removal of sludge and surface water impoundments.
- Closure of onsite groundwater wells.
- Recycling of equipment and dismantled components.
- Disposal of hazardous wastes; remediation of waste handling and storage areas, as necessary.
- Cleanup and remediation of incidental spills and leaks.
- Ancillary facilities (access roads, utilities, pipelines, electrical transmission towers) would be removed unless it is determined that they can serve other purposes; buried utilities and pipelines could be abandoned in place if their removal would result in significant disruption to ecosystems.
- Other site restoration actions, as necessary.

Termination of operations and decommissioning of offshore power-generating facilities involve the following actions:

- Wind turbine tower foundations and communication and power cables buried in the seafloor could remain to avoid ecological disruption that would result if removed.

- Underwater structures that served as electrical service platforms could remain in place to serve as artificial reefs and fish habitats.

The termination of operations and the decommissioning of hydroelectric facilities may result in various environmental impacts. For large store-and-release hydroelectric facilities, eliminating the dam and reservoir and restoring the river to its natural flow would have a dramatic effect on upstream and downstream ecosystems. Turbines, generators, and electric power-generating equipment would be removed. Devices that control the release of water from the reservoir could remain functional, requiring a reduced workforce.

Small-scale, low-impact, run-of-the-river hydro facilities, causing limited impact on upstream water levels and downstream water flow rates, would be dismantled and removed during decommissioning.

## 4.15 Resource Commitments Associated with the Proposed Action

This section addresses the resources that would be committed under the proposed action (license renewal). In particular, it describes unavoidable adverse environmental impacts (Section 4.15.1), the relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity (Section 4.15.2), and the irreversible and irretrievable commitment of resources (Section 4.15.3) that would be associated with the proposed action. Potential unavoidable adverse environmental impacts and irreversible and irretrievable resource commitments that would be associated with alternatives to the proposed action are also discussed.

### 4.15.1 Unavoidable Adverse Environmental Impacts

Unavoidable adverse environmental impacts are impacts that would occur after implementation of all feasible mitigation measures. Continued nuclear power plant operations and the implementation of any of the replacement energy alternatives considered in this LR GEIS would result in some unavoidable adverse environmental impacts.

The impacts of continued nuclear power plant operations that are anticipated to occur are discussed for each resource area in Sections 4.1 through 4.12. Some of these impacts cannot be avoided because they are inherently associated with nuclear power plant operations and cannot be fully mitigated. Minor unavoidable adverse impacts on air quality would occur due to emission and release of various chemical and radiological constituents into the environment from plant operations. Nonradiological emissions are expected to comply with EPA emissions standards, though the alternative of operating a fossil-fueled power plant in some areas may worsen existing air quality attainment issues. Routine chemical and radiological emissions would not exceed the National Emission Standards for Hazardous Air Pollutants. Other unavoidable adverse impacts (depending on the plant) include the impact on land use and visual resources, some minor noise effects, surface water and groundwater use, thermal effluents discharged to the environment from the power conversion equipment, and entrainment and impingement of aquatic organisms in the cooling water system. Industrial wastewater effluents and cooling water system operations would be subject to regulations promulgated pursuant to the CWA.

During nuclear power plant operations, workers and members of the public would face unavoidable exposure to radiation and hazardous and toxic chemicals, but releases would be controlled and the resulting exposures would not exceed any standards or regulatory limits.

Workers would be exposed to radiation and chemicals associated with routine plant operations and the handling of nuclear fuel and waste material. Workers would have a higher risk of exposure than members of the public, but doses would be administratively controlled and would not exceed any standards or administrative control limits. Construction and operation of alternative replacement energy-generating facilities would also result in unavoidable exposure of workers and the general public to hazardous and toxic chemicals.

Also unavoidable would be the generation of spent nuclear fuel and waste material, including LLW, hazardous waste, and nonhazardous waste. Hazardous and nonhazardous wastes would also be generated at non-nuclear power-generating facilities. Wastes generated during plant operations would be collected, stored, and shipped for suitable treatment, recycling, or disposal in accordance with applicable Federal and State regulations. Due to the costs of handling these materials, power plant operators would be expected to conduct all activities and optimize all operations in a way that minimizes waste generation. Although pollution prevention and waste minimization efforts are intended to prevent emissions to the environment and prevent and/or minimize the quantities of waste generated and disposed of, some wastes and emissions cannot be entirely eliminated due to current technology.

Many of these unavoidable impacts are being mitigated by incorporating safety features and/or applying operational procedures at the nuclear power plants and are monitored by plant personnel and regulatory agencies. Thermal, entrainment, and impingement impacts at plants with once-through cooling water systems are unavoidable. These impacts could be reduced by modifying the once-through cooling system or by converting to a closed-cycle cooling system. Although closed-cycle cooling water systems can reduce thermal, entrainment, and impingement impacts, they increase water consumption (through cooling tower evaporation), fogging, icing, and salt drift. However, the NRC has neither the statutory nor the regulatory authority to determine which cooling water system or technology should be used, or to decide other environmental permitting issues.

Nuclear power plants being considered for license renewal already exist and nearly all have been operating for several decades. The environmental impacts considered for license renewal are those associated with continued nuclear power plant operation and refurbishment. Replacement energy (power) and other alternatives to license renewal generally involve major construction impacts. Therefore, unavoidable adverse impacts of a replacement energy alternative could be greater than those associated with the continued operation of an existing nuclear power plant.

Unavoidable adverse impacts would vary among the nuclear power plants, and the scale of the impact would depend on the specific characteristics of each power plant and its interaction with the environment. These unavoidable adverse impacts are evaluated in plant-specific SEISs.

### 4.15.2 Relationship between Short-Term Use of the Environment and Long-Term Productivity

The operation of power-generating facilities would result in short-term uses of the environment as described earlier in this Chapter. “Short-term” is the period of time during which continued power-generating activities would take place.

Power plant operations would necessitate short-term use of the environment and commitments of resources and would also commit certain resources (e.g., land and energy) indefinitely or permanently. Certain short-term resource commitments would be substantially greater under most energy alternatives, including license renewal (initial LR or SLR), than under the no action alternative due to the continued generation of electrical power as well as continued use of generating sites and associated infrastructure. During operations, all energy alternatives would entail similar relationships between local short-term uses of the environment and the maintenance and enhancement of long-term productivity.

Short-term use of the environment can affect long-term productivity of the ecosystem if the use alters the ability of the ecosystem to reestablish an equilibrium that is comparable to that of its original (natural) condition. An initial commitment regarding the trade-off between short-term use and long-term productivity at a nuclear power plant was made when the nuclear plant was first constructed. Renewal of the operating license and the continued operation of the nuclear power plant would not alter any existing effects on long-term productivity, but they might postpone the availability of the power plant site for other uses. The no action alternative would lead to a cessation of operations and shutdown of the power plant (an eventuality regardless whether or not a license is renewed).

Air emissions from power plant operations would introduce small amounts of radiological and nonradiological constituents to the region around the plant site. Over time, these emissions could result in increased concentrations and exposure but are not expected to affect air quality or radiation exposure to the extent that public health and long-term productivity of the environment would be impaired.

Continued employment, expenditures, and tax revenues generated during power plant operations would directly benefit local, regional, and State economies over the short-term. Local governments investing project-generated tax revenues into infrastructure and other required services could enhance economic productivity over the long term.

The management and disposal of spent nuclear fuel, LLW, hazardous waste, and nonhazardous waste would require an increase in energy and would consume space at treatment, storage, or disposal facilities. Regardless of the location, the conversion of land to meet waste disposal needs would reduce the long-term productivity of the land.

Power plant facilities would be committed to electricity production over the short term. After decommissioning these facilities and restoring the power plant site, the land would become available for other productive uses.

The nature of the relationship between short-term use of the environment and long-term productivity would vary among nuclear power plants and would depend on the specific characteristics of each plant and its interaction with the environment. This relationship is evaluated in plant-specific SEISs.

### 4.15.3 Irreversible and Irretrievable Commitment of Resources

An irreversible or irretrievable commitment of resources refers to impacts on or losses of resources that cannot be recovered or reversed. Irreversible and irretrievable commitment of resources for electrical power generation are considered to include the commitment of land, water, energy, raw materials, and other natural and human-made resources required for power plant operations during the license renewal term and any refurbishment activities that might be carried out that would not otherwise have taken place if the operating licenses had not been renewed. This section describes the irreversible and irretrievable commitments of resources that have been identified in this LR GEIS. A commitment of resources is irreversible when primary or secondary impacts limit the future options for a resource. It primarily applies to the impacts of use of nonrenewable resources, such as minerals or cultural resources, or to factors, such as soil productivity, that are renewable only over long periods of time. An irretrievable commitment refers to the use or consumption of resources neither renewable nor recoverable for future use. Irretrievable commitment applies to the loss of production, harvest, or natural resources. For example, if farmland is used for a nonagricultural purpose such as energy generation, some or all of the agricultural production from the farmland is lost irretrievably while the area is temporarily used for another purpose. The production lost is irretrievable, but the action is not irreversible. In general, the commitment of capital, energy, labor, and material resources would also be irreversible.

Resources include materials and equipment required for nuclear power plant maintenance and operation, energy and water needed to run the plants, the nuclear fuel used by the reactors to generate electricity, and the land required to permanently dispose of the radioactive and nonradioactive wastes. Some of these resources could be retrieved and reused at the end of the license renewal (initial LR or SLR) term. For example, some reactor equipment can be used at other reactors or can be decontaminated and released for recycling or restricted or unrestricted use by others. However, some of the equipment and irradiated components that might be replaced during the license renewal term might not be reused or recycled and therefore would need to be permanently disposed of. In addition, the fossil fuels used by power plants would be permanently lost. Most of the water used by power plants relying on once-through cooling is returned to the surface water bodies that supply the cooling water. The relatively small portion of the water that evaporates to the air would be lost to the local water bodies and the region but would be returned to the environment as part of the hydrologic cycle, potentially within another watershed. For closed-cycle cooling systems, a much larger percentage of the water used for cooling would be lost to evaporation, but that, too, would be returned as part of the hydrologic cycle.

The most significant irreversible and irretrievable commitment of resources related to nuclear power plant operations during the license renewal term would be the nuclear fuel used to generate electricity and the land used to dispose of and store wastes, including spent nuclear fuel generated during the license renewal term. The treatment, storage, and disposal of LLW, hazardous waste, and nonhazardous waste would require the irretrievable commitment of energy and fuel and could result in the irreversible commitment of space in disposal facilities. Some of the land used for the disposal of LLW may be available for other uses in a few hundred years because of the nearly complete decay of short-lived radionuclides in LLW, but most of the land used for the disposal of some mixed or hazardous wastes could be permanently (irreversibly) lost.

The irreversible and irretrievable commitment of resources would not be the same for all nuclear power plants and would depend on the specific characteristics of the power plant and its resource needs. This commitment is evaluated in plant-specific SEISs.

The implementation of any of the replacement energy alternatives would entail the irreversible and irretrievable commitment of energy, water, chemicals, and, in some cases, fossil fuels. These resources would be committed over the entire life cycle of the power plant—construction, operation, and decommissioning—and would essentially be unrecoverable.

Energy expended would be in the form of fuel for equipment, vehicles, power plant operations, and electricity for power plant construction and facility operations. Electricity and fuels would be purchased from offsite commercial sources. Water would be obtained from existing water supply systems. These resources are generally available, and the amounts required would not be expected to deplete available supplies or exceed available system capacities.

The irreversible and irretrievable commitment of material resources are the materials that cannot be recovered or recycled, materials that are rendered radioactive and/or cannot be decontaminated, and materials consumed or reduced to unrecoverable forms of waste. However, none of the resources used by potential replacement energy-generating facilities is in short supply, and, for the most part, they are readily available.

Various materials and chemicals, including acids and caustics, would be required to support operations activities. These materials would be derived from commercial vendors, and their consumption would not be expected to affect local, regional, or national supplies.

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# 6.0 LIST OF PREPARERS

This revision of NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (LR GEIS) was prepared by U.S. Nuclear Regulatory Commission (NRC) staff in the Office of Nuclear Material Safety and Safeguards (see Table 6-1) with assistance from other NRC organizations, and Pacific Northwest National Laboratory (Table 6-2).

**Table 6-1 U.S. Nuclear Regulatory Commission Preparers**

| Name | Education/Expertise | Contribution |
|---|---|---|
| Beth Alferink | M.S., Environmental Engineering; M.S., Nuclear Engineering; B.S., Nuclear Engineering; 25 years of national laboratory, industry, and government experience including radiation detection and measurements, nuclear power plant emergency response, operations, health physics, decommissioning, shielding and criticality | Human Health; Waste Management; Decommissioning |
| Briana Arlene | Masters Certification, National Environmental Policy Act; B.S., Conservation Biology; 16 years of experience in ecological impact analysis, Endangered Species Act Section 7 consultations, and Essential Fish Habitat consultations | Aquatic Resources; Terrestrial Resources; Federally Protected Ecological Resources |
| Phyllis Clark | M.S., Nuclear Engineering; M.B.A., Business Administration; B.S., Physics; 39 years of industry and government experience including nuclear power plant and production reactor operations, systems engineering, reactor engineering, fuels engineering, criticality analysis, safety analysis, nuclear power plant emergency response, and project management | Waste Management; Uranium Fuel Cycle; Human Health |
| Jennifer Davis | B.A., Historic Preservation and Classical Civilization (Archaeology); 5 years of archaeological fieldwork; 20 years of experience in NEPA compliance, project management, cultural resources impact analysis, and National Historic Preservation Act Section 106 consultations | Project Manager; Historic and Cultural Resources |
| Jerry Dozier | M.S., Reliability Engineering; M.B.A., Business Administration; B.S., Mechanical Engineering; 30 years of experience including operations, reliability engineering, technical reviews, and NRC branch management | Postulated Accidents; Severe Accident Mitigation Alternatives |

| Name | Education/Expertise | Contribution |
|---|---|---|
| Kevin Folk | M.S., Environmental Biology; B.A., Geoenvironmental Studies; 33 years of experience in NEPA compliance; geologic, hydrologic, and water quality impacts analysis; utility infrastructure analysis, environmental regulatory compliance; and water supply and wastewater discharge permitting | Project Manager; Geologic Environment; Water Resources; Cumulative Effects; Greenhouse Gas Emissions |
| Lifeng Guo | Ph.D., M.S., Geology; B.S., Hydrogeology and Engineering Geology; Certified Professional Geologist; over 30 years of combined experience in hydrogeologic investigation, remediation, and research | Water Resources |
| Bob Hoffman | B.S., Environmental Resource Management; 35 years of experience in NEPA compliance, environmental impact assessment, alternatives identification and development, and energy facility siting | Alternatives; Meteorology, Air Quality, and Noise; Historic and Cultural Resources |
| Nancy Martinez | B.S., Earth and Environmental Science; A.M., Earth and Planetary Science; 9 years of experience in environmental impact analysis | Greenhouse Gas Emissions; Meteorology, Air Quality, and Noise; Socioeconomic Resources; Environmental Justice; Water Resources |
| Don Palmrose | B.S., Nuclear Engineering; M.S., Nuclear Engineering; Ph.D., Nuclear Engineering; 35 years of experience including operations on U.S. Navy nuclear powered surface ships, technical safety and NEPA analyses, nuclear authorization basis support for DOE, and NRC project management | Uranium Fuel Cycle; Postulated Accidents; Severe Accident Mitigation Alternatives; Human Health |
| Jeffrey Rikhoff | B.A., English; M.S., Development Economics; M.R.P., Regional Planning; 42 years of industry and government experience including 35 years in NEPA compliance, comprehensive land use and development planning, energy facility siting and permitting, socioeconomics, and environmental justice impact analysis, and historic and cultural resource impacts | Land Use; Socioeconomics; Environmental Justice; Alternatives; Cumulative Effects; Termination of Reactor Operations and Decommissioning |

DOE = U.S. Department of Energy; NEPA = National Environmental Policy Act of 1969; NRC = U.S. Nuclear Regulatory Commission.

**Table 6-2 Pacific Northwest National Laboratory[a] Preparers**

| Name | Education/Expertise | Contribution |
|---|---|---|
| Dave Anderson | B.S., Forest Resources;<br>M.S., Forest Economics; 25 years of experience in NEPA compliance, socioeconomics, and environmental justice impact analysis | Socioeconomic Resources; Environmental Justice |
| Teresa Carlon | B.S., Information Technology; 25 years SharePoint Administer and database experience | Reference Coordinator |
| Garill Coles | B.S., Mechanical Engineering, 30 years of nuclear safety analysis, Probabilistic Risk Assessment, risk research, and review of risk-informed applications for NRC | Postulated Accidents; Severe Accident Mitigation Alternatives |
| Caitlin Condon | B.S., Environmental Health and Industrial Hygiene;<br>Ph.D., Radiation Health Physics; 3 years of experience in NEPA compliance in human health, waste management/fuel cycle, and decommissioning | Human Health; Waste Management/Fuel Cycle; Decommissioning |
| Susan Ennor | B.J., Journalism; more than 40 years of experience in full-spectrum communications and document production services | Document production, technical editing/formatting |
| Julia Flaherty | B.S., Civil Engineering;<br>M.S., Environmental Engineering; 17 years of experience in boundary layer meteorology, emergency response, project management, and NEPA | Meteorology, Air Quality, and Noise |
| Harish Gadey | B.S., Mechanical Engineering;<br>M.S., Nuclear Engineering;<br>Ph.D., Nuclear Engineering (Health Physics Minor); 6 years of experience in radiation detection, simulations, and spent fuel analysis | Human Health; Waste Management/Fuel Cycle; Decommissioning |
| Dave Goodman | B.S., Economics;<br>J.D., Law; 12 years of experience in NEPA compliance, land use and visual resources, noise, and alternatives | Land Use and Visual Resources; Noise; Alternatives |
| Ellen Kennedy | B.A., Anthropology;<br>M.A., Anthropology; 25 years of experience in NEPA and NHPA Section 106 assessment and consultation, and Tribal Nation engagement | Historic and Cultural Resources |
| Kim Leigh | B.S., Environmental Science; 20 years of experience in NEPA compliance, project management, and human health | Deputy Team Lead; Human Health |

| Name | Education/Expertise | Contribution |
|---|---|---|
| Philip Meyer | B.A., Physics; M.S., Civil Engineering; Ph.D., Civil Engineering; 30 years of experience in the application of hydrologic principles to the solution of environmental and engineering problems, including 13 years of NEPA experience in water, soil, and geological resources impact evaluations | Groundwater Resources; Geological Environment; Cooling Water Systems |
| Ann Miracle | B.A., Biology; M.S., Population Genetics; Ph.D., Molecular Genetics; 12 years of experience in NEPA compliance and 25 years in ecological resources | Ecological Resources |
| Sadie Montgomery | B.S., Mathematics; 12 years of experience in GIS data processing, visualizations, and mapping | Geographic Information Systems |
| Jon Napier | B.S., Environmental Science; Ph.D. and M.S. in Radiation Health Physics; 3 years of experience in Radiological Air Monitoring Inspection and Licensing, 2 years of experience in Occupational Health Physics, 1 year experience in NEPA compliance, human health, waste management/fuel cycle, and decommissioning | Human Health; Waste Management/Fuel Cycle; Decommissioning |
| Tara O'Neil | B.A., Anthropology; MBA, Business Administration; 30 years of experience project management, NEPA compliance, environmental impact assessment, cultural resource compliance, NHPA Section 106 consultation, Tribal engagement | Historic and Cultural Resources; Program Management |
| Mike Parker | B.S., English Literature and Creative Writing; 25 years of experience copyediting, document design, and formatting and 20 years of experience in technical editing | Technical Editing |
| Rajiv Prasad | B.E., Civil Engineering; Master in Technology, Hydraulic and Water Resources Engineering; Ph.D., Civil and Environmental Engineering; 25 years of experience in applying hydrologic principles to water resources engineering, hydrologic design, flooding assessments, environmental engineering, and impacts assessment including 15 years of experience in NEPA environmental assessments of surface water resources | Water Resources |
| Bo Saulsbury | B.A., History; M.S., Planning; 35 years of experience in NEPA environmental assessment, land use, socioeconomics, and alternatives | Alternatives |

| Name | Education/Expertise | Contribution |
|---|---|---|
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DOE = U.S. Department of Energy; GIS = geographic information system; NEPA = National Environmental Policy Act of 1969; NHPA = National Historic Preservation Act; NNSA = National Nuclear Security Administration; NRC = U.S. Nuclear Regulatory Commission.

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# 8.0 GLOSSARY

**absorbed dose:** The energy imparted by ionizing radiation per unit mass of tissue. The units of absorbed dose are the rad and the gray (Gy).

**acid:** A solution with a potential of hydrogen (pH) measurement less than 7.

**acid rain:** Also called acid precipitation or acid deposition, acid rain is precipitation containing harmful amounts of nitric and sulfuric acids formed from the smokestacks of coal and oil burning power plants and from nitrogen oxides emitted by motor vehicles. It can be wet precipitation (rain, snow, or fog) or dry precipitation (absorbed gaseous and particulate matter, aerosol particles, or dust). The term pH is a measure of acidity or alkalinity and ranges from 0 to 14. A pH measurement of 7 is regarded as neutral. Normal rain has a pH of about 5.6, which is slightly acidic. Acid rain has a pH below 5.6.

**activation products:** Radionuclides produced from the interaction of radiation with matter. Generally it is the neutrons that interact with stable atoms and make them radioactive.

**activity:** The rate of disintegration (transformation) or decay of radioactive material. The units of radioactivity are the curie (Ci) and the Becquerel (Bq).

**acute effects:** Effects resulting from short-term exposure to relatively high levels of a stressing factor (e.g., contaminant, disease, electromagnetic field, noise, and radionuclides) over long periods.

**acute radiation exposure:** A single accidental exposure to high doses of radiation for a short period of time, which may produce biological effects within a short time after exposure.

**adverse environmental impacts:** Impacts that are determined to be harmful to the environment.

**Advisory Council on Historic Preservation (ACHP):** Established by the National Historic Preservation Act of 1966, the Advisory Council on Historic Preservation is an independent Federal agency that promotes the preservation, enhancement, and productive use of the nation's historic resources *and advises the President and the Congress on national historic preservation policy*. The agency provides guidance on the application of Federal law concerning cultural resources and serves as an arbiter when disputes arise.

**aerobic:** Requiring the presence of oxygen to support life.

**air quality:** Assessment of the health-related and visual characteristics of the air often derived from quantitative measurements of the concentrations of specific injurious or contaminating substances. Air quality standards are the prescribed levels of substances in the outside air that cannot be exceeded during a specific time in a specified area.

**ALARA:** Acronym for “as low as (is) reasonably achievable.” This means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest (see 10 CFR 20.1003).

**alkalinity:** The capacity of water to neutralize acids; a property imparted by the water's content of carbonate, bicarbonate, hydroxide, and on occasion borate, silicate, and phosphate.

**alluvial:** Refers to soil or unconsolidated sediment that has been deposited by running water, as in a riverbed, floodplain, or delta.

**alluvial aquifer:** An aquifer composed of alluvial sediments, generally located in a river valley.

**alternatives to the proposed action considered in the license renewal generic environmental impact statement (LR GEIS):** (1) Not renewing the operating licenses of commercial nuclear power plants (no action alternative). This is the only alternative to the proposed action that is within the NRC's decision-making authority; (2) replacing existing nuclear generating capacity with other energy sources (including fossil energy generation, new nuclear generation, and renewable energy); (3) compensating for lost nuclear generation capacity by using demand-side management (conservation) or purchasing power.

**ambient air:** The surrounding atmosphere as it exists around people, plants, and structures.

**ambient noise level:** The level of acoustic noise at a given location, such as in a room or outdoors, that is representative of typical conditions unaffected by human activities.

**ambient water temperature:** The water temperature in a water body that is representative of typical conditions unaffected by human activities (e.g., the temperature of the surface water body away from the thermal effluent).

**anadromous:** Pertaining to fish that spend a part of their life cycle in the sea and return to freshwater streams to spawn; for example, salmon, steelhead, and shad.

**annual dose:** Dose received in one year.

**anoxic:** Absence of oxygen. Usually used in reference to an aquatic habitat when the water becomes completely depleted of oxygen and results in the death of any organism that requires oxygen for survival.

**anthropogenic:** Made or generated by a human or caused by human activity.

**aquatic biota:** Consisting of, relating to, or being in water; living or growing in, or near the water. An organism that lives in, on, or near the water.

**aquifer:** An underground layer of permeable, unconsolidated sediments or porous or fractured bedrock that yields usable quantities of water to a well or spring.

**Archaeological Resources Protection Act of 1979:** Requires Federal permitting for excavation or removal of archaeological resources from public or Native American lands.

**area of potential effect (APE):** The geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist. The APE for a license renewal action is the area at the power plant site and its immediate environs and viewshed that may be impacted by post-license renewal land-disturbing operations or possible refurbishment activities associated with the proposed action. The APE may extend beyond the immediate environs in those instances where post-license renewal land-disturbing operations or projected refurbishment activities specifically related to license renewal may potentially have an effect on known or proposed historic sites. This determination is made irrespective of ownership or control of the lands of interest (see also 36 FR 800.16(d)).

**Atomic Energy Act (AEA):** The AEA of 1954 is a United States Federal law that is, according to the Nuclear Regulatory Commission, “the fundamental U.S. law on both the civilian and the military uses of nuclear materials.” It covers the laws for the “development and the regulation of the uses of nuclear materials and facilities in the United States.” It was an amendment to the AEA of 1946 and substantially refined certain aspects of the law, including increased support for the possibility of a civilian nuclear industry.

**attainment:** An area is deemed in attainment by the U.S. Environmental Protection Agency (EPA) when the air quality is monitored and the resultant concentrations are found to be consistently below the National Ambient Air Quality Standards (NAAQS). Areas can be in attainment for some pollutants, while designated as nonattainment for others. Some areas are designated as “maintenance” areas. These are regions that were initially designated as attainment or unclassifiable and have since attained compliance with the NAAQS.

**attenuation:** The reduction or lessening in amount, such as in the concentration or effects of a pollutant.

**auxiliary buildings:** Auxiliary buildings house support systems, such as the ventilation system, emergency core cooling system, laundry facilities, water treatment system, and waste treatment system. An auxiliary building may also contain the emergency diesel generators and, in some pressurized water reactors, the fuel storage facility. The facility’s control room is often located in the auxiliary building.

**avian:** Of, relating to, or characteristic of birds.

**background radiation:** Radiation from cosmic sources; naturally occurring radioactive material, including radon (except as a decay product of source or special nuclear material); and global fallout as it exists in the environment from the testing of nuclear explosive devices or from past nuclear accidents such as Chernobyl and are not under the control of the licensee. Background radiation does not include radiation from sources, by-products, or special nuclear materials regulated by the Commission.

**baseline:** A quantitative expression of conditions, costs, schedule, or technical progress that constitutes the standard against which to measure the performance of an effort. For National Environmental Policy Act evaluations, baseline is defined as the existing environmental conditions against which impacts of the proposed action and its alternatives can be compared. The environmental baseline is the site environmental conditions as they exist or are estimated to exist in the absence of the proposed action.

**becquerel:** The unit of radioactive decay equal to 1 disintegration per second. 37 billion ($3.7 \times 10^{10}$) becquerels = 1 curie.

**BEIR reports:** Series of reports issued by the National Research Council to advise the Federal government on the relationship between exposure to ionizing radiation and human health. BEIR stands for Biological Effects of Ionizing Radiation.

**benthic:** Of, relating to, or occurring at the bottom of a body of water.

**Best Available Control Technology (BACT):** A pollution control standard created by the EPA that is used to determine what air pollution control technology will be used to control a specific pollutant to a specified limit.

**best management practice (BMP):** A practice or combination of pollution control techniques that aim to reduce pollution.

**beta particle:** An electron that is ejected from the nucleus of a radioactive atom. It is much lighter than an alpha particle and can travel a longer distance in air compared to an alpha particle, but can still be stopped by a thin sheet of aluminum foil.

**bioamplification:** Also known as biological magnification and bioconcentration, is the progressive increase in the concentration of chemical contaminants (e.g., dichloro-diphenyl-trichloroethane, polychlorinated biphenyls, methyl mercury) from the bottom of the food chain (e.g., bacteria, phytoplankton, zooplankton) to the top of the food chain (e.g., fishing-eating birds such as a bald eagle).

**bioavailability:** The degree to which chemicals can be taken up by organisms.

**biocide:** A chemical agent, such as a pesticide, that is used to kill and control living organisms.

**biological assessment:** Information prepared by or under the direction of the Federal agency concerning listed and proposed species and designated and proposed critical habitat that may be present in the action area and the evaluation of potential effects of the action on such species and habitat.

**biomass:** Organic nonfossil material of biological origin constituting a renewable energy source.

**biota:** The combined flora and fauna of a region.

**bituminous coal:** A dense black or brown coal that has on average 45–86 percent carbon by weight and a heating value as much as five times greater than lignite coal. U.S. deposits are 100–300 million years old and are found primarily in the states of West Virginia, Kentucky, and Pennsylvania, with lesser amounts in the Midwest. Bituminous coal is the most abundant rank of coal in the United States. It is used primarily to produce electricity, and in the industrial sector, to produce heat and process steam and as a starting material for the production of coke, an intensely hot-burning derivative fuel used in the steel industry.

**blast furnace:** A furnace in which solid fuel (coke) is burned with an air blast to smelt ore.

**blowdown:** Continual or periodic purging of a circulating working fluid to prevent buildup of impurities in the fluid.

**boiler:** A device for generating steam for power, processing, or heating purposes; or hot water for heating purposes or hot water supply. Heat from an external combustion source is transmitted to a fluid contained within the tubes found in the boiler shell. This fluid is delivered to an end-use at a desired pressure, temperature, and quality.

**boiling water reactor (BWR):** A reactor in which water, used as both coolant and moderator, boils in the core to produce steam, which drives a turbine connected to an electrical generator, thereby producing electricity.

**brownfield site:** Abandoned, idled, or under-used industrial and commercial facilities in which expansion or redevelopment is sometimes complicated by real or perceived environmental contaminations. (See also greenfield site).

**Btu:** British thermal unit. A measure of the energy required to raise the temperature of one pound of water by one degree Fahrenheit.

**burnup spent fuel:** See spent-fuel burnup.

**cap and trade:** An environmental policy instrument used by governments to limit the amount of pollutants emitted to the environment. The total emissions are capped at a specified level but polluters can trade the emission allowances among themselves as long as the total amount is not exceeded.

**capacity:** See generator capacity.

**capacity factor:** The actual energy output of an electricity-generating device divided by the energy output that would be produced if it operated at its rated power output for the entire year. Generally expressed as percentage.

**capacity rating:** See rated power.

**carbon:** A naturally abundant nonmetallic element that occurs in many inorganic and in all organic compounds, which exists freely as graphite and diamond and as a constituent of coal, limestone, and petroleum. Carbon is capable of chemical self-bonding to form an enormous number of chemically, biologically, and commercially important molecules. Carbon's atomic number is 6.

**carbon capture and storage:** Refers to the capture of carbon dioxide generated at fossil-fueled power plants and the storing of carbon dioxide so it is not released into the air. Underground storage media are being investigated for this feasibility (e.g., abandoned mines, depleted oil or natural gas fields, and other types of geologic media).

**carbon monoxide (CO):** A colorless, odorless gas formed when carbon in fuel is not burned completely. Motor vehicle exhaust is a major contributor to nationwide CO emissions, followed by other engines and vehicles. CO interferes with the blood's ability to carry oxygen to the body's tissues and results in numerous adverse health effects. CO is listed as a criteria air pollutant under Title I of the Clean Air Act.

**carbonaceous:** Consisting of, containing, relating to, or yielding carbon.

**carbon sequestration:** See carbon capture and storage.

**carcinogenesis:** The process by which normal cells are transformed into cancer cells.

**cask:** A heavily shielded container used to store and/or ship radioactive materials. Lead and steel are common materials used in the manufacture of casks.

**Category 1 issue:** Environmental impact issues that meet all of the following criteria: (1) the environmental impacts associated with the issue have been determined to apply either to all nuclear plants or, for some issues, to nuclear plants that have a specific type of cooling system or other specified plant or site characteristics; (2) a single significance level (i.e., small, moderate, or large) has been assigned to the impacts (except for collective offsite radiological impacts from the fuel cycle and from high-level waste and spent fuel disposal); (3) mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are likely not to be sufficiently beneficial to warrant implementation. For issues that meet the three Category 1 criteria, no additional plant-specific analysis is required in future supplemental environmental impact statements unless new and significant information is identified.

**Category 2 issue:** Environmental impact issues that do not meet one or more of the criteria of Category 1, and, therefore, additional plant-specific review for these issues is required.

**cesium:** A metal that may be stable (nonradioactive) or unstable (radioactive). The most common radioactive form of cesium is cesium-137. Another fairly common radioisotope is cesium-134.

**chain reaction:** A reaction that initiates its own repetition. In a fission chain reaction, a fissionable nucleus absorbs a neutron and fissions spontaneously, releasing additional neutrons. These, in turn, can be absorbed by other fissionable nuclei, releasing more neutrons. A fission chain reaction is self-sustaining when the number of neutrons released in a given time equals or exceeds the number of neutrons lost by absorption in nonfissionable material or by escape from the system.

**chlorinated hydrocarbons:** Organic compounds made up of atoms of carbon, hydrogen, and chlorine. All chlorinated hydrocarbons have a carbon-chlorine bond. Sometimes hydrogen is not present at all, as in carbon tetrachloride. Examples of chlorinated hydrocarbons include dichloro-diphenyl-trichloroethane and polychlorinated biphenyls. Chlorinated hydrocarbons tend to be very long-lived and persistent in the environment; they tend to be toxic; and they tend to accumulate in the food web and undergo bioamplification.

**chronic effects:** Effects resulting from exposure to low levels of a stressing factor (e.g., contaminant, disease, electromagnetic field, noise, and radionuclides) over long periods.

**chronic radiation exposure:** Long-term, low-level overexposure to radiation or radioactive materials.

**cladding:** The thin-walled metal tube that forms the outer jacket of a nuclear fuel rod. It prevents corrosion of the fuel by the coolant and the release of fission products into the coolant. Aluminum, stainless steel, and zirconium alloys are common cladding materials.

**Class I areas (Clean Air Act):** Class I areas are Federally owned properties for which air quality-related values are highly prized and for which no diminution of air quality, including visibility, can be tolerated. Class I areas fall under the stewardship of four Federal agencies: the

U.S. Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and the U.S. Forest Service. Air quality impacts in Class I areas are strictly limited, while restrictions in Class II areas are less strict.

**Class II areas (Clean Air Act):** See Class I areas.

**Class 2B carcinogenic:** Agents (e.g., electromagnetic fields) or substances that are possibly carcinogenic to humans.

**Clean Air Act (CAA):** Establishes NAAQS and requires facilities to comply with emission limits or reduction limits stipulated in State Implementation Plans. Under this act, construction and operating permits, as well as reviews of new stationary sources and major modifications to existing sources, are required. The Act also prohibits the Federal government from approving actions that do not conform to State Implementation Plans.

**clean coal technologies:** Technologies that would allow the continued use of coal (or coal-derived synthetic fuels) for electricity production, while at the same time, mitigating the potential adverse impacts to air quality and guaranteeing compliance with regulatory requirements. Clean coal initiatives include coal-cleaning processes to remove constituents that would ultimately be converted to problematic pollutants during combustion, synthesis of clean derivative fuels through coal gasification technologies, improved combustion technologies, and improved devices, and ancillary support systems for capturing and sequestering pollutants.

**Clean Water Act (CWA):** An Act, which amended the Federal Water Pollution Control Act, requiring National Pollutant Discharge Elimination System (NPDES) permits for discharges of effluents to surface waters, permits for stormwater discharges related to industrial activity, permits for discharges to or dredging of wetlands, notification of oil discharges to navigable waters of the United States, and water quality certification from the State in which the discharge will occur.

**climatology:** The meteorological study of climates and their phenomena.

**closed-cycle cooling:** In this type of cooling water system, the cooling water is recirculated through the condenser after the waste heat is removed by dissipation to the atmosphere, usually by circulating the water through large cooling towers constructed for that purpose.

**coal:** A readily combustible black or brownish-black rock whose composition, including inherent moisture, consists of more than 50 percent by weight and more than 70 percent by volume of carbonaceous material. It is formed from plant remains that have been compacted, hardened, chemically altered, and metamorphosed by heat and pressure over geologic time.

**coal combustion wastes:** Wastes produced from the combustion of coal, which contains concentrated levels of numerous contaminants, particularly metals like arsenic, mercury, lead, chromium, cadmium, and radioactive elements found naturally in coal.

**coal gasification:** The process of converting coal into gas. The basic process involves crushing coal to a powder, which is then heated in the presence of steam and oxygen to produce a gas. The gas is then refined to reduce sulfur and other impurities. The gas can be used as a fuel or processed further and concentrated into chemical or liquid fuel.

***Code of Federal Regulations* (CFR):** The codification of the general and permanent rules published in the *Federal Register* by the executive departments and agencies of the Federal government. It is divided into 50 titles that represent broad areas subject to Federal regulation. Each volume of the CFR is updated once each calendar year and is issued on a quarterly basis.

**co-firing:** The process of burning natural gas in conjunction with another fuel to reduce air pollutants.

**cold shutdown:** The term used to define a reactor coolant system at atmospheric pressure and at a temperature below 200 degrees Fahrenheit following a reactor cooldown.

**collective dose:** The sum of the individual doses received in a given period by a specified population from exposure to a specified source of radiation.

**combined cycle:** A technology through which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. This process increases the efficiency of the electric generating unit.

**combustion:** Chemical oxidation accompanied by the generation of energy, typically in the form of light and heat.

**committed dose equivalent:** The dose equivalent to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

**compact:** A group of two or more States formed to dispose of low-level radioactive waste on a regional basis. The Low-Level Radioactive Waste Policy Act of 1980 encouraged States to form compacts to ensure continuing low-level waste disposal capacity. As of December 2000, 44 States have formed 10 compacts. No compact has successfully sited and constructed a disposal facility.

**condenser:** A large heat exchanger designed to cool exhaust steam from a turbine below the boiling point so that it can be returned to the heat source as water. In a pressurized water reactor, the water is returned to the steam generator. In a boiling water reactor, it returns to the reactor core. The heat removed from the steam by the condenser is transferred to a circulating water system and is exhausted to the environment, either through a cooling tower or directly into a body of water.

**coniferous:** Of or relating to or part of trees or shrubs bearing cones and evergreen leaves.

**containment or reactor building:** The containment or reactor building in a pressurized water reactor is a massive concrete or steel structure that houses the reactor vessel, reactor coolant piping and pumps, steam generators, pressurizer, pumps, and associated piping. The reactor building structure of a BWR generally includes a containment structure and a shield building. The BWR containment reactor building is a massive concrete or steel structure that houses the reactor vessel, the reactor coolant piping and pumps, and the suppression pool. It is located inside a somewhat less substantive structure called the shield building. The shield building for a BWR also generally contains the spent fuel pool and the new fuel pool. The reactor building for both pressurized water reactor s and BWRs is designed to withstand natural disasters, such as hurricanes and earthquakes. The containment's ability to withstand such events and to contain the effects of accidents initiated by system failures constitutes the principal protection against releasing radioactive material to the environment.

**cooling pond:** A natural or man-made body of water that is used for dissipating waste heat from power plants.

**cooling tower:** Structures designed to remove excess heat from the condenser without dumping the heated cooling water directly into water bodies, such as lakes or rivers. There are two principal types of cooling towers: mechanical draft towers and natural draft towers. Most nuclear plants that have once-through cooling do not rely on cooling towers. However, five facilities with once-through cooling also have cooling towers.

**cooling tower drift:** Water lost from a cooling tower in the form of liquid droplets entrained in the exhaust air. Drift is independent of water lost through evaporation. Units may be in lb/hr or a percentage of circulating water flow. Drift eliminators control this loss from the tower.

**cooling water intake structure:** The structure and any associated constructed waterways used to withdraw cooling water from water bodies. The cooling water intake structure extends from the point at which water is withdrawn from the surface water source to the first intake pump or series of pumps.

**corona discharge:** The electrical breakdown of air into charged particles that results in the creation of ions or charged particles in air due to electric field discharge near transmission lines, most noticeable during thunder or rainstorms. Corona is a phenomenon associated with all energized transmission lines. It is the electrical breakdown of air into charged particles. The phenomenon appears as a bluish-purple glow on the surface of and adjacent to a conductor when the voltage gradient exceeds a certain critical value, thereby producing light, audible noise (described as crackling or hissing), and ozone.

**Council on Environmental Quality (CEQ):** Established by the National Environmental Policy Act (NEPA). Council on Environmental Quality regulations (40 CFR Parts 1500–1508) describe the process for implementing NEPA, including preparation of environmental assessments and environmental impact statements, and the timing and extent of public participation.

**criteria pollutants:** A group of very common air pollutants whose presence in the environment is regulated by the EPA on the basis of certain criteria (information on health and/or environmental effects of pollution). Criteria air pollutants are widely distributed all over the United States. There are six common air pollutants for which National Ambient Air Quality Standards have been established by the EPA under Title I of the Clean Air Act: sulfur dioxide, nitrogen oxides, carbon monoxide, ozone, particulate matter ($PM_{2.5}$ and $PM_{10}$), and lead. Standards were developed for these pollutants on the basis of scientific knowledge about their health and environmental effects.

**critical habitat:** Specific geographic areas, whether occupied by a listed species or not, that are essential for its conservation and that have been formally designated by rules published in the *Federal Register*.

**criticality:** A term used in reactor physics to describe the state when the number of neutrons released by fission is exactly balanced by the neutrons being absorbed (by the fuel and poisons) and escaping the reactor core. A reactor is said to be “critical” when it achieves a self-sustaining nuclear chain reaction, as when the reactor is operating.

**crude oil:** A mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. Depending upon the characteristics of the crude stream, it may also include: (1) small amounts of hydrocarbons that exist in the gaseous phase in natural underground reservoirs but are liquid at atmospheric pressure; (2) small amounts of nonhydrocarbons produced with the oil, such as sulfur and various metals, and (3) drip gases and liquid hydrocarbons produced from tar sands, oil sands, gilsonite, and oil shale.

**cultural resources:** The remains of past human activities that have historic or cultural meaning. They include archaeological sites (e.g., precontact campsites and villages), historic-era resources (e.g., farmsteads, forts, and canals), and traditional cultural properties (e.g., resource collection areas and sacred areas). Culture is understood to mean the traditions, beliefs, practices, lifeways, arts, crafts, and social institutions of any community, be it an Indian Tribe, a local ethnic group, or the people of the nation as a whole (see also National Park Service Bulletin #38).

**cumulative dose:** The total dose resulting from repeated or prolonged exposures to ionizing radiation over time.

**cumulative impacts:** The impacts on the environment that result from the incremental impacts of an action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or nonfederal) or person undertakes such other actions.

**cumulative risk:** The risk of a common toxic effect associated with concurrent exposure by all relevant pathways and routes of exposure to a group of chemicals that share a common mechanism of toxicity.

**curie (Ci):** The basic unit used to describe the intensity of radioactivity in a sample of material. The curie is equal to 37 billion ($3.7 \times 10^{10}$) disintegrations per second, which is approximately the activity of 1 gram of radium. A curie is also a quantity of any radionuclide that decays at a rate of 37 billion disintegrations per second. It is named for Marie and Pierre Curie, who discovered radium in 1898.

**decibel, A-weighted (dBA):** A standard unit for the measure of the relative loudness or intensity of sound. The relative intensity is the ratio of the intensity of a sound wave to a reference intensity. In general, a sound doubles in loudness with every increase of 10 dB. By convention, the intensity level of sound at the threshold of hearing for a young healthy individual is 0 dB.

**deciduous:** Trees and shrubs that shed their leaves on an annual cycle.

**decommissioning:** The process of closing down a facility followed by reducing residual radioactivity to a level that permits the release of the property for unrestricted use or restricted use (see 10 CFR 20.1003).

**DECON:** A method of decommissioning in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed and safety buried in a low-level radioactive waste landfill or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations.

**decontamination:** Removal of unwanted radioactive or hazardous contamination by a chemical or mechanical process.

**deep-dose equivalent:** The dose equivalent at a tissue depth of 1 cm; applies to external whole-body exposure.

**demand-side management:** The planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand. It only refers to energy and load-shape modifying activities that are undertaken in response to utility-administered programs. It does not refer to energy and load-shaped changes arising from the normal operation of the marketplace or from government-mandated energy-efficiency standards. Demand-side management covers the complete range of load-shape objectives, including strategic conservation and load management, as well as strategic load growth.

**demographics:** A term used to describe specific population characteristics such as age, gender, education, and income level.

**densitometer:** An apparatus for measuring the optical density of a material, such as a photographic negative.

**depleted uranium:** Uranium having a percentage of uranium-235 smaller than the 0.7 percent found in natural uranium. It results from uranium isotope enrichment operations.

**deposition:** The laying down of matter by a natural process (e.g., the settling of particulate matter out of air or water onto soil or sediment surfaces).

**design-basis accident:** A postulated accident that a nuclear facility must be designed and built to withstand without loss to the systems, structures, and components necessary to ensure public health and safety.

**desquamation:** To shed, peel, or come off in scales.

**detritus:** Dead, decaying plant material.

**dewatering:** To remove or drain water from an area.

**dielectric:** A nonconductor of electricity.

**diesel generator:** An electric generator that runs on diesel fuel.

**diffusion:** A process in which substances are transported from one area to another due to differences in the concentration of that material or in temperature.

**disposal:** The act of placing unwanted materials in an area with the intent of not recovering in the future.

**dissolved gas:** Gas dissolved in water or in other liquid without change in its chemical structure.

**dissolved oxygen:** Oxygen dissolved in water. Dissolved oxygen is necessary for the life of fish and most other aquatic organisms, and is one of the most important indicators of the condition of a water body.

**dose:** The absorbed dose, given in rads (or in SI units, grays), that represents the energy absorbed from the radiation in a gram of any material. The biological dose or dose equivalent, given in rem or sieverts, is a measure of the biological damage to living tissue from radiation exposure.

**dose equivalent:** The product of the absorbed dose in tissue, quality factor, and all other modifying factors at the location of interest. The units of dose equivalent are the rem and sievert.

**dose rates:** The ionizing radiation dose delivered per unit of time (e.g., rem or sieverts per hour).

**dosimeter:** A small, portable instrument (such as a film badge or thermoluminescent or pocket dosimeter) for measuring and recording the total accumulated personal dose of ionizing radiation.

**dredging:** Removing accumulated sediments from a water body to increase depth or remove contaminants.

**dry cask:** Large, rugged container made of steel or steel-reinforced concrete, 18 or more inches thick. A cask uses materials like steel, concrete and lead—instead of water—as a radiation shield.

**dry cask storage:** A method for storing spent nuclear fuel (see dry cask).

**dry steam:** Geothermal plants that use the steam from the geothermal reservoir as it comes from wells, and route it directly through turbine/generator units to produce electricity.

**dual-fired unit:** A generating unit that can produce electricity using two or more input fuels. In some of these units, only the primary fuel can be used continuously; the alternate fuel(s) can be used only as a start-up fuel or in emergencies.

**earthquake:** A sudden ground motion or vibration of the earth. It can be produced by a rapid release of stored-up energy along an active fault in the earth's crust.

**ecoregion:** A geographically distinct area of land that is characterized by a distinctive climate, ecological features, and plant and animal communities.

**ecosystem:** A group of organisms and their physical environment interacting and functioning as a unit.

**effective dose equivalent:** The sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.

**effluent:** Wastewater (treated or untreated) that flows out of a treatment plant, sewer, or industrial outfall. This term generally refers to wastes discharged into surface waters.

**electric power:** The rate at which electric energy is transferred. Electric power is measured by capacity and is commonly expressed in megawatts (MW).

**electric power grid:** A system of synchronized power providers and consumers connected by transmission and distribution lines and operated by one or more control centers. In the continental United States, the electric power grid consists of three systems: the Eastern Interconnect, the Western Interconnect, and the Texas Interconnect. In Alaska and Hawaii, several systems encompass areas smaller than the State (e.g., the interconnect serving Anchorage, Fairbanks, and the Kenai Peninsula).

**electricity:** A form of energy characterized by the presence and motion of elementary charged particles generated by friction, induction, or chemical change.

**electricity generation:** The process of producing electric energy or the amount of electric energy produced by transforming other forms of energy, commonly expressed in kilowatt hours (kWh) or megawatt hours (MWh).

**electromagnetic field (EMF):** The field of energy resulting from the movement of alternating electric current along the path of a conductor, composed of both electrical and magnetic components and existing in the immediate vicinity of, and surrounding, the electric conductor. Electromagnetic fields exist in both high-voltage electric transmission power lines and in low-voltage electric conductors in homes and appliances.

**electromagnetic radiation:** A traveling wave motion resulting from changing electric or magnetic fields. Familiar electromagnetic radiation ranges from x-rays (and gamma rays) of short wavelength, through the ultraviolet, visible, and infrared regions, to radar and radio waves of relatively long wavelength.

**endangered species:** Any species, plant or animal, that is in danger of extinction throughout all or a significant part of its range. Requirements for declaring a species endangered are found in the Endangered Species Act.

**Endangered Species Act of 1973 (ESA):** Requires consultation with the U.S. Fish and Wildlife Service and/or the National Marine Fisheries Service to determine whether endangered or threatened species or their habitats will be affected by a proposed activity and what, if any, mitigation measures are needed to address the impacts.

**energy:** The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world’s convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatt hours, while heat energy is usually measured in British thermal units (Btu).

**energy demand:** The energy needed by consumers at any point in time for household, business, or industrial purposes.

**Energy Information Administration:** An independent agency within the U.S. Department of Energy (DOE) that develops surveys, collects energy data, and analyzes and models energy issues. The Energy Information Administration must meet (1) the requests of Congress, other elements within the DOE, Federal Energy Regulatory Commission, and Executive Branch; (2) its own independent needs; and (3) assist the general public or other interest groups, without taking a policy position.

**energy supply:** Energy made available for use. Supply can be considered and measured from the point of view of the energy provider or the receiver.

**ENTOMB:** A method of decommissioning nuclear facilities in which radioactive contaminants are encased in a structurally long-lived material, such as concrete. The entombment structure is appropriately maintained and continued surveillance is carried out until the radioactivity decays to a level permitting unrestricted release of the property.

**entrainment:** The incorporation of all life stages of fish and shellfish with intake water flow entering and passing through a cooling water intake structure and into a cooling water system.

**environmental assessment (EA):** A concise public document that a Federal agency prepares under the National Environmental Policy Act to provide sufficient evidence and analysis to determine whether a proposed action requires preparation of an environmental impact statement or whether a Finding of No Significant Impact can be issued. An EA must include brief discussions on the need for the proposed action and the environmental impacts of the proposed action and the no action alternative.

**environmental impact statement (EIS):** A document required of Federal agencies by the National Environmental Policy Act for major proposals or legislation that will or could significantly affect the environment.

**environmental justice:** The fair treatment of people of all races, cultures, incomes, and educational levels with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

**erosion:** The process where wind, water, ice, and other mechanical and chemical forces wear away materials such as rocks and soil, breaking up particles and moving them from one place to another.

**erythema:** Superficial reddening of the skin due to the dilatation of blood vessels. Erythema is often a sign of infection or inflammation.

**essential fish habitat (EFH):** Those waters and substrates necessary to fish for spawning, breeding, feeding or growth to maturity. EFH is protected under the Magnuson-Stevens Fishery Conservation and Management Act of 1976.

**estuary:** A transitional zone along the coastline where ocean saltwater mixes with freshwater from the land, subject to tidal influences. Estuaries are often semi-enclosed by land, but their currents always have access to the open ocean.

**eutrophication:** A condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae (e.g., phytoplankton). Algal decomposition may lower dissolved oxygen concentrations. Although eutrophication is a natural process in the aging of lakes and some estuaries, it can be accelerated by both point and nonpoint sources of nutrients.

**exceedance probability:** The average frequency with which an event (e.g., flood, earthquake) of a particular magnitude will be exceeded during a certain length of time. Expressed as the probability that a level will be exceeded in any year (the annual exceedance probability) or as the average recurrence interval (e.g., a 100-year flood).

**exposure:** Being exposed to ionizing radiation, radioactive material, or other contaminants.

**external dose:** That portion of the dose equivalent received from radiation sources outside the body.

**Farmland Protection Policy Act:** An Act whose purpose is to reduce the conversion of farmland to nonagricultural uses as a result of Federal projects and programs. The Act requires that Federal agencies comply to the fullest extent possible with state and local government policies to preserve farmland. It includes a recommendation that evaluations and analyses of prospective farmland conversion impacts be made early in the planning process—before a site or design is selected—and that, where possible, agencies make such evaluations and analyses part of the National Environmental Policy Act process.

**fault (geology):** A fracture or a zone of fractures within a rock formation along which vertical, horizontal, or transverse slippage has occurred. A normal fault occurs when the hanging wall has been depressed in relation to the footwall. A reverse fault occurs when the hanging wall has been raised in relation to the footwall. A strike-slip fault occurs where two geologic plates are sliding past each other and stress builds up between them.

**fecundity:** Number of eggs an animal produces during each reproductive cycle; the potential reproductive capacity of an organism or population.

**Federal Energy Regulatory Commission:** Independent Federal agency with jurisdiction over interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, and oil pipeline rates.

***Federal Register*****:** The official daily publication for rules, proposed rules, and notices of Federal agencies and organizations, as well as Executive Orders and other presidential documents.

**fission:** The splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation.

**fission products:** The radioactive isotopes formed by the fission of heavy elements.

**floodplain:** Lowlands and relatively flat areas adjoining the channel of a river, stream, or other watercourse; or ocean, lake, or other body of water, which have been or may be inundated by flood water, and those other areas subject to flooding. Floodplains include, at a minimum, that area with at least a 1.0 percent chance of being inundated by a flood in any given year.

**flue gas:** The air coming out of a chimney after combustion in the burner it is venting. It can include nitrogen oxides, carbon oxides, water vapor, sulfur oxides, particles, and many chemical pollutants.

**flue gas desulfurization:** Equipment (also referred to as scrubbers) used to remove sulfur oxides from the combustion gases of a boiler plant before discharge to the atmosphere. Chemicals such as lime are used as scrubbing media.

**fluidized bed combustion:** A method of burning particulate fuel, such as coal, in which the amount of air required for combustion far exceeds that found in conventional burners. The fuel particles are continually fed into a bed of mineral ash in the proportions of 1 part fuel to 200 parts ash, while a flow of air passes up through the bed, causing it to act like a turbulent fluid.

**fossil fuel:** Fuel derived from ancient organic remains such as peat, coal, crude oil, and natural gas.

**fossil fuel plant:** A plant using coal, petroleum, or gas as its source of energy.

**fossil fuel electric (power) generation:** Electric generation in which the prime mover is a turbine rotated by high-pressure steam produced in a boiler by heat from burning fossil fuels.

**fuel:** Any material substance that can be consumed to supply heat or power. Includes petroleum, coal, and natural gas (the fossil fuels), and other consumable materials, such as uranium, biomass, and hydrogen.

**fuel assembly:** A cluster of fuel rods (or plates) that are also called fuel pins or fuel elements. Many fuel assemblies make up a reactor core.

**fuel cladding:** See cladding.

**fuel cycle:** The entire set of sequential processes or stages involved in the utilization of fuel, including extraction, transformation, transportation, and combustion. Emissions generally occur at each stage of the fuel cycle.

**fuel oil:** A liquid petroleum product less volatile than gasoline, used as an energy source. Fuel oil includes distillate fuel oil (No. 1, No. 2, and No. 4), and residual fuel oil (No. 5 and No. 6).

**fuel pellets:** As used in pressurized water reactors and boiling water reactors, a pellet is a small cylinder approximately 3/8-in. in diameter and 5/8-in. in length, consisting of uranium fuel in a ceramic form—uranium dioxide ($UO_2$). Typical fuel pellet enrichments in nuclear power reactors range from 2.0 percent to 5 percent uranium-235.

**fuel rod:** A long, slender tube that holds fissionable material (fuel) for nuclear reactor use. Fuel rods are assembled into bundles called fuel elements or fuel assemblies, which are loaded individually into the reactor core.

**fugitive dust:** Particulate air pollution released to the ambient air from ground-disturbing activities related to construction, manufacturing, or transportation (i.e., the discharges are not released through a confined stream such as a stack, chimney, vent, or other functionally equivalent opening). Specific activities that generate fugitive dust include, but are not limited to, land-clearing operations, travel of vehicles on disturbed land or unpaved access roads, or onsite roads.

**fugitive emissions:** Unintended leaks of gas from vessels, pipes, valves, or fittings used in the processing, transmission, and/or transportation of liquids or gases. These emissions can include the release of volatile vapors from a diesel fuel, natural gas, or solvent leak.

**fujita scale:** Classifies tornadoes based on wind damage. The scale ranges from F0 for the weakest to F5 for the strongest tornadoes.

**gamma rays:** High-energy, short wavelength, electromagnetic radiation emitted from the nucleus of an atom. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded by dense materials, such as lead or depleted uranium. Gamma rays are similar to x-rays. See also x-rays and gamma rays.

**gas bubble disease:** A condition that occurs when aquatic organisms are exposed to water with high partial pressures of certain gases (usually nitrogen) and then subsequently are exposed to water with lower partial pressures of the same gases. Dissolved gas (especially nitrogen) within the tissues comes out of solution and forms embolisms (bubbles) within the affected tissues, most noticeably the eyes and fins.

**gas supersaturation:** Concentrations of dissolved gases in water that are above the normal saturation limit.

**gas turbine:** A gas turbine consists typically of an axial-flow air compressor and one or more combustion chambers where liquid or gaseous fuel is burned and the hot gases are passed to the turbine, and where the hot gases expand, drive the generator, and are then used to run the compressor.

**gasification:** A method for converting coal, petroleum, biomass, wastes, or other carbon-containing materials into a gas that can be (1) burned to generate power or (2) processed into chemicals and fuels.

**generator capacity:** The maximum output, commonly expressed in megawatts (MW), that generating equipment can supply to system load, adjusted for ambient conditions.

**generic environmental impact statement (GEIS):** A GEIS assesses the scope and impact of environmental effects that would be associated with an action at numerous sites.

**geologic repository:** A deep underground engineered facility used to permanently isolate used nuclear fuel or high-level nuclear waste while its radioactivity decays safely.

**geology:** The science that deals with the study of the earth: its materials, processes, environments, and its history, including rocks and their formations and structures.

**geothermal energy:** Hot water or steam extracted from geothermal reservoirs in the earth's crust. Water or steam extracted from geothermal reservoirs can be used for geothermal heat pumps, water heating, or electricity generation.

**geothermal plant:** A plant in which the prime mover is a steam turbine driven either by steam produced from hot water or by natural steam that derives its energy from heat found in rock.

**global climate change:** Changes in the earth's surface temperature thought to be caused by the greenhouse effect and responsible for changes in global climate patterns. The greenhouse effect is the trapping and buildup of heat in the atmosphere (troposphere) near the earth's surface. Some of the heat flowing back toward space from the earth's surface is absorbed by water vapor, carbon dioxide, ozone, and certain other gases in the atmosphere and then reradiated back toward the earth's surface.

**global warming:** An increase in the near-surface temperature of the earth. Global warming has occurred in the distant past as the result of natural influences, but the term is today most often used to refer to the warming many scientists predict will occur as a result of increased anthropogenic emissions of greenhouse gases.

**global warming potential:** An index used to compare the relative radiative forcing per unit molecule or unit mass change for varied greenhouse gases of different gases without directly calculating the changes in atmospheric concentrations. The global warming potential s of a particular greenhouse gas are calculated as a time-integrated ratio of the radiative or climate forcing that would result from the emission of one kilogram of that greenhouse gas to that resulting from the emission of one kilogram of carbon dioxide over a fixed period of time, such as 100 years.

**gonads:** Male and female sex organs (testes and ovaries).

**graphite:** Pure carbon in mineral form. Technically, graphite at 100 percent carbon is the highest rank of coal. However, its relatively limited availability and physical characteristics and chemical characteristics have limited its use as an energy source. Instead, it is used primarily in lubricants.

**gray:** The international system (SI) unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule/kilogram (one gray equals 100 rads) (see 10 CFR 20.1004).

**greater-than-Class C (GTCC) waste:** Greater-than-Class C waste means low-level radioactive waste that exceeds the concentration limits of radionuclides established for Class C waste in 10 CFR 61.55.

**greenfield site:** Vacant land that has never been developed or was formerly occupied by farms or low-density development that left the land free of environmental contamination. Greenfield sites are typically located in suburban or ex-urban areas and can be less costly to develop than the brownfield sites that are often located in urban areas.

**greenhouse gases:** Gases, such as carbon dioxide, nitrous oxide, methane, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride, that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving the earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface. While also a product of industrial activities, carbon dioxide, nitrous oxide, methane, ozone, and water vapor are naturally occurring greenhouse gases.

**grid:** See electric power grid.

**gross generation:** The total amount of electric energy produced by generating units and measured at the generating terminal in kilowatt hours (kWh) or megawatt hours (MWh).

**groundwater:** The water found beneath the earth's surface, usually in porous rock formations (aquifers) or in a zone of saturation, which may supply wells and springs, as well as base flow to major streams and rivers. Generally, it refers to all water contained in the ground.

**habitat:** The place, including physical and biotic conditions, where a population or community of organisms, both plants and animals, lives.

**half-life:** The time in which one-half of the atoms of a particular radioactive substance disintegrate into another nuclear form. Measured half-lives vary from millionths of a second to billions of years. Also called physical or radiological half-life.

**hazardous air pollutants:** Air pollutants that are not covered by ambient air quality standards but which, as defined in the Clean Air Act, may present a threat of adverse human health effects or adverse environmental effects. Such pollutants include asbestos, beryllium, mercury, benzene, coke oven emissions, radionuclides, and vinyl chloride.

**hazardous waste:** A solid waste or combination of solid wastes that, because of its quantity, concentration, or physical, chemical, or infectious characteristics, may (1) cause or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed (as defined in the Resource Conservation and Recovery Act, as amended, Public Law 94-580).

**heat sink:** Anything that absorbs heat. It is usually part of the environment, such as the air, a river, or a lake.

**heavy metals:** Metallic elements with higher atomic weights, many of which are toxic at higher concentrations. Examples are mercury, chromium, cadmium, and lead.

**high-level waste (HLW):** The highly radioactive materials produced as a by-product of the reactions that occur inside nuclear reactors. High-level wastes take one of two forms, (1) Spent (used) reactor fuel when it is accepted for disposal, or (2) Waste materials remaining after spent fuel is reprocessed.

**historic property:** Any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the *National Register of Historic Places* maintained by the Secretary of the Interior. This term includes artifacts, records, and remains that are related to and located within such properties. The term can also include properties of traditional religious and cultural importance that meet the *National Register* criteria (see also 36 CFR 800.16(l)(1)).

**horizontal axis wind turbine:** The most common type of wind turbine, in which the axis of rotation is oriented horizontally.

**hydrocarbons:** Any compound or mix of compounds, solids, liquids, or gases, composed of carbon and hydrogen (e.g., coal, crude oil, and natural gas).

**hydrochlorofluorocarbons:** Chemicals composed of one or more carbon atoms and varying numbers of hydrogen, chlorine, and fluorine atoms.

**hydroelectric power:** The use of flowing water to produce electrical energy.

**hydrofluorocarbons:** A group of man-made chemicals composed of one or two carbon atoms and varying numbers of hydrogen and fluorine atoms. Most hydrofluorocarbons have 100-year Global Warming Potentials in the thousands.

**hydrology:** The study of water that considers its occurrence, properties distribution, circulation, and transport and includes groundwater, surface water, and rainfall.

**integrated gasification combined cycle:** See integrated gasification combined cycle technology.

**impacting factors:** The mechanisms by which an action affects a given resource or receptor.

**impingement:** The entrapment of all life stages of fish and shellfish on the outer part of an intake structure or against a screening device during periods of intake water withdrawal.

**impulse turbine:** A turbine that is driven by high-velocity jets of water or steam from a nozzle directed onto vanes or buckets attached to a wheel.

**independent spent fuel storage installation (ISFSI):** An ISFSI is designed and constructed for the interim storage of spent nuclear fuel and other radioactive materials associated with spent fuel storage. ISFSIs may be located at the site of a nuclear power plant or at another location. The most common design for an ISFSI, at this time, is a concrete pad with dry casks containing spent fuel bundles. ISFSIs are used by operating plants that require increased spent fuel storage capability because their spent fuel pools have reached capacity.

**in situ:** In its original place.

**integrated gasification combined cycle technology:** An energy generation technology in which coal, water, and oxygen are fed to a gasifier, which produces syngas. This medium-Btu gas is cleaned (particulates and sulfur compounds removed) and fed to a gas turbine. The hot exhaust of the gas turbine and heat recovered from the gasification process is routed through a heat recovery generator to produce steam, which drives a steam turbine to produce electricity.

**internal dose:** That portion of the dose equivalent received from radioactive material taken into the body.

**ionizing radiation:** Any radiation capable of displacing electrons from atoms or molecules, thereby producing ions. Some examples are alpha, beta, gamma, x-rays, neutrons, and ultraviolet light. High doses of ionizing radiation may produce severe skin or tissue damage.

**isotopic enrichment:** A process by which the relative abundance of the isotopes of a given element is altered, thus producing a form of the element that has been enriched in one particular isotope and depleted in its other isotopic forms.

**landfill gas:** Gas that is generated by decomposition of organic material at landfill disposal sites. The average composition of landfill gas is approximately 50 percent methane and 50 percent carbon dioxide and water vapor by volume. The methane percentage, however, can vary from 40 to 60 percent, depending on several factors including waste composition (e.g., carbohydrate and cellulose content). The methane in landfill gas may be vented, flared, or combusted to generate electricity or heat, or injected into a pipeline for combustion elsewhere.

**leachate:** The liquid that has percolated through the soil or other medium.

**license renewal:** Renewal of the operating license of a nuclear power plant.

**license renewal term (initial or subsequent):** That period of time past the current license term for which the renewed license is in force. Although the length of license renewal terms can vary, they cannot exceed 20 years in addition to the balance on the current license up to a maximum of 40 years.

**licensee:** The entity (usually an energy company) that holds the license to operate a nuclear power plant.

**light water reactors (LWRs):** Reactors that use ordinary water as coolant, including boiling water reactors (BWRs) and pressurized water reactors (PWRs), the most common types used in the United States.

**lower limit of detection (LLD):** The lowest limit that a detector can measure.

**lowest observed effects level (LOEL):** The lowest exposure level at which there are statistically or biologically significant increases in frequency or severity of an effect between the exposed population and its appropriate control group.

**low-income populations:** Persons whose average family income is below the poverty line. The poverty line takes into account family size and age of individuals in the family. In 1999, the poverty line for a family of five with three children below the age of 18 was $19,882. For any family below the poverty line, all family members are considered to be below the poverty line.

**low-level radioactive waste (LLW):** A general term for a wide range of wastes having low levels of radioactivity. Nuclear fuel cycle facilities (e.g., nuclear power reactors and fuel fabrication plants) that use radioactive materials generate low-level wastes as part of their normal operations. These wastes are generated in many physical and chemical forms and levels of contamination (see 10 CFR 61.2). Low-level radioactive wastes containing source, special nuclear, or by-product material are acceptable for disposal in a land disposal facility. For the purposes of this definition, low-level waste has the same meaning as in the Low-Level Radioactive Waste Policy Act, that is, radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or by-product material as defined in Section 11e.(2) of the AEA (uranium or thorium tailings and waste).

**macroinvertebrates:** Nonplanktonic, aquatic invertebrates, including insects, crustaceans, mollusks, and worms, which typically inhabit the bottom sediments of rivers, ponds, lakes, wetlands, or oceans. Their abundance and diversity are often used as an indicator of ecosystem health.

**maintenance areas:** Regions that were initially designated as nonattainment or unclassifiable and have since attained compliance with the National Ambient Air Quality Standards. The Clean Air Act outlines several conditions that must be met before an area can be reclassified from nonattainment to an attainment maintenance area, one of which is the development and EPA approval of a maintenance plan.

**man-rem:** See person-rem.

**marine:** Of or pertaining to ocean environments.

**maximally exposed individual (MEI):** A hypothetical individual who, because of proximity, activities, or living habits, could potentially receive the maximum possible dose of radiation or of a hazardous chemical from a given event or process.

**maximum achievable control technology:** The emission standard for sources of air pollution requiring the maximum reduction of hazardous emissions, taking cost and feasibility into account. Under the Clean Air Act Amendments of 1990, the maximum achievable control technology must not be less than the average emission level achieved by controls on the best performing 12 percent of existing sources, by category of industrial and utility sources.

**mechanical draft tower:** Cooling tower system that sprays heated cooling water downward, while large fans pull air across the dropping water to remove the heat. As the water drops downward onto the slats in the cooling tower, the drops break up into a finer spray, and, thus, facilitate cooling.

**megawatt:** A unit of power equal to 1 million watts. Megawatt-thermal is commonly used to define heat produced, while megawatt-electric defines electricity produced.

**methane:** A colorless, flammable, odorless hydrocarbon gas, which is the major component of natural gas. Methane is an important source of hydrogen in various industrial processes. Methane is a greenhouse gas.

**methyl tertiary butyl ether:** A gasoline additive, an oxygenate produced by reacting methanol with isobutylene.

**microorganism:** An organism that can be seen only through a microscope. Microorganisms include bacteria, protozoa, algae, and fungi.

**minority populations:** Include American Indian or Alaskan Native; Asian; Native Hawaiian or other Pacific Islander; Black races; or people of Hispanic ethnicity. "Other" races and multiracial individuals may be considered as separate minorities.

**mitigation:** A method or process by which impacts from actions can be made less injurious to the environment through appropriate protective measures.

**mixed waste:** Waste that contains both radioactive and hazardous constituents.

**motile:** Moving or having the power to move.

**municipal solid waste:** Residential solid waste and some nonhazardous commercial, institutional, and industrial wastes.

**National Ambient Air Quality Standards (NAAQS):** Air quality standards established by the Clean Air Act, as amended. The primary NAAQS specify maximum outdoor air concentrations of criteria pollutants that would protect the public health within an adequate margin of safety. The secondary NAAQS specify maximum concentrations that would protect the public welfare from any known or anticipated adverse effects of a pollutant.

**National Environmental Policy Act of 1969 (NEPA):** Act requiring Federal agencies to prepare a detailed statement on the environmental impacts of their proposed major actions that may significantly affect the quality of the human environment.

**National Historic Preservation Act (NHPA) of 1966:** Section 106 of the NHPA addresses the impacts of Federal undertakings on historic properties. Undertakings are defined in the NHPA as any project or activity that is funded or under the direct jurisdiction of a Federal agency, or any project or activity that requires a Federal permit, license, or approval (see also 36 CFR 800.16(y)).

**National Pollutant Discharge Elimination System (NPDES):** A Federal or, where delegated, State or Tribal permitting system controlling the discharge of pollutants into waters of the United States and regulated through the Clean Water Act, as amended.

**Native American Graves Protection and Repatriation Act:** This Act provides a process for museums and Federal agencies to return certain Native American cultural items—human remains, funerary objects, sacred objects, or objects of cultural patrimony—to lineal descendants and culturally affiliated Indian Tribes and Native Hawaiian organizations. The Act includes provisions for unclaimed and culturally unidentifiable Native American cultural items, intentional and inadvertent discovery of Native American cultural items on Federal and Tribal lands, and penalties for noncompliance and illegal trafficking. The Act also allows the intentional removal from or excavation of Native American cultural items from Federal or Tribal lands only with a permit or upon consultation with the appropriate Tribe.

**natural draft cooling towers:** Natural draft cooling towers use the differential pressure between the relatively cold outside air and the hot humid air on the inside of the tower as the driving force to move and cool water without the use of fans.

**natural gas:** A gaseous mixture of hydrocarbon compounds, the primary one being methane.

**natural gas combined-cycle technology:** An advanced power generation technology that improves the fuel efficiency of natural gas. Most new gas power plants in North America and Europe use natural gas combined-cycle technology.

**natural gas liquids:** Those hydrocarbons in natural gas that are separated from the gas as liquids through the process of absorption, condensation, adsorption, or other methods in gas processing or cycling plants. Generally such liquids consist of propane and heavier hydrocarbons and are commonly referred to as lease condensate, natural gasoline, and liquefied petroleum gases. Natural gas liquids include natural gas plant liquids (primarily ethane, propane, butane, and isobutene).

**naturally occurring radioactive materials:** Radioactive materials that are found in nature.

**neutron:** An uncharged elementary particle, with a mass slightly greater than that of the proton, found in the nucleus of every atom heavier than hydrogen.

**natural gas combined-cycle:** See natural gas combined cycle technology.

**nitrogen oxides:** Nitrogen oxides include various nitrogen compounds, primarily nitrogen dioxide and nitric oxide. They form when fossil fuels are burned at high temperatures and react with volatile organic compounds to form ozone, the main component of urban smog. They are also a precursor pollutant that contributes to the formation of acid rain. Nitrogen oxides are among the six criteria air pollutants specified under Title I of the Clean Air Act.

**no action alternative:** For this LR GEIS, the no action alternative represents a decision by the Nuclear Regulatory Commission to not allow for continued operation of nuclear power plants beyond the current operating license terms. All plants eventually would be required to shut down and undergo decommissioning. Under the no action alternative, these eventualities would occur sooner rather than later.

**noble gases:** A gaseous chemical element that does not readily enter into chemical combination with other elements. Examples are helium, argon, krypton, xenon, and radon.

**noise:** Unwanted sound; a subjective term reflective of societal values regarding what constitutes unwanted or undesirable intrusions of sound.

**nonattainment:** Any area that does not meet the national primary or secondary ambient air quality standard established by the EPA for designated pollutants, such as carbon monoxide and ozone.

**nonradioactive nonhazardous waste:** Waste that is neither radioactive nor hazardous.

**nonrenewable fuels:** Fuels that cannot be easily made or “renewed,” such as oil, natural gas, and coal.

**nonrenewable waste fuels:** Municipal solid wastes from nonbiogenic sources and tire-derived fuels.

**nonstochastic effect:** Health effects, the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a nonstochastic effect (also called a deterministic effect).

**North American Electric Reliability Council:** A council formed in 1968 by the electric utility industry to promote the reliability and adequacy of bulk power supply in the electric utility systems of North America. North American Electric Reliability Council consists of regional reliability councils and encompasses essentially all the power regions of the contiguous United States, Canada, and Mexico.

**North American Industry Classification System (NAICS):** A coding system developed jointly by the United States, Canada, and Mexico to classify businesses and industries according to the type of economic activity in which they are engaged. NAICS replaces the Standard Industrial Classification codes.

**nuclear fuel:** Fuel that produces energy in a nuclear reactor through the process of nuclear fission.

**nuclear fuel cycle:** The series of steps involved in supplying fuel for nuclear power reactors, including mining, milling, isotopic enrichment, fabrication of fuel elements, use in reactors, chemical reprocessing to recover the fissionable material remaining in the spent fuel, re-enrichment of the fuel material refabrication into new fuel elements, and waste disposal.

**nuclear power (nuclear electric power):** Electricity generated by the use of the thermal energy released from the fission of nuclear fuel in a reactor.

**nuclear power plant:** A facility that uses a nuclear reactor to generate electricity.

**nuclear reactor:** A device in which nuclear fission may be sustained and controlled in a self-supporting nuclear reaction. There are many types of reactors, but all incorporate certain features, including fissionable material or fuel, a moderating material (unless the reactor is operated on fast neutrons), a reflector to conserve escaping neutrons, provisions of removal of heat, measuring and controlling instruments, and protective devices. The reactor is the heart of a nuclear power plant.

**occupational dose:** The dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation or to radioactive material. Occupational dose does not include dose received from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive materials and released in accordance with 10 CFR 35.75, from voluntary participation in medical research programs, or as a member of the general public.

**occupational exposure:** An exposure that occurs during work with sources of ionizing radiation. For example, exposures received from working on a nuclear reactor, in nuclear reprocessing, or by a dental nurse taking x-rays would be classed as occupational.

**Occupational Safety and Health Administration:** Independent Federal agency whose mission is to prevent work-related injuries, illnesses, and deaths. Congress created Occupational Safety and Health Administration under the Occupational Safety and Health Act on December 29, 1970.

**once-through cooling system:** In this cooling system, circulating water for condenser cooling is obtained from an adjacent body of water, such as a lake or river, passed through the condenser tubes, and returned directly at a higher temperature to the adjacent body of water.

**organ dose:** Dose received as a result of radiation energy absorbed in a specific organ.

**organism:** An individual of any form of animal or plant life.

**Outer Continental Shelf:** The Outer Continental Shelf consists of the submerged lands, subsoil, and seabed, lying between the seaward extent of the States' jurisdiction and the seaward extent of Federal jurisdiction.

**overburden:** Any material, consolidated or unconsolidated, that overlies a coal or other rock or mineral deposit.

**ozone:** A strong-smelling, reactive toxic chemical gas consisting of three oxygen atoms chemically attached to each other. It is formed in the atmosphere by chemical reactions involving nitrogen oxide and volatile organic compounds. The reactions are energized by sunlight. Ozone is a criteria air pollutant under the Clean Air Act and is a major constituent of smog.

**particulate matter:** Fine solid or liquid particles, such as dust, smoke, mist, fumes, or smog, found in air or emissions. The size of the particulates is measured in micrometers. One micrometer is 1 millionth of a meter or 0.000039 inch. The EPA has set standards for $PM_{2.5}$ and $PM_{10}$ particulates.

**pathway (exposure):** The way in which people are exposed to radiation or other contaminants. The three basic pathways are inhalation (contaminants are taken into the lungs), ingestion (contaminants are swallowed), and direct (external) exposure (contaminants cause damage from outside the body).

**peak load:** The maximum load during a specified period of time.

**perched aquifer/groundwater:** A body of groundwater of small lateral dimensions separated from an underlying body of groundwater by an unsaturated zone.

**perfluorocarbons (PFCs):** A group of man-made chemicals composed of one or two carbon atoms and four to six fluorine atoms, containing no chlorine. PFCs have no commercial uses and are emitted as a by-product of aluminum smelting and semiconductor manufacturing. PFCs have very high 100-year Global Warming Potentials and are very long-lived in the atmosphere.

**personal protective equipment:** Clothing and equipment that are worn to reduce exposure to potentially hazardous chemicals and other pollutants.

**person-rem:** The sum of the individual radiation dose equivalents received by members of a certain group or population. It may be calculated by multiplying the average dose per person by the number of persons exposed. For example, a thousand people, each exposed to one millirem, would have a collective dose of one person-rem.

**petroleum:** A broadly defined class of liquid hydrocarbon mixtures. Includes crude oil, lease condensate, unfinished oils, refined products obtained from the processing of crude oil, and natural gas plant liquids. Volumes of finished petroleum products include nonhydrocarbon compounds, such as additives and detergents, after they have been blended into products.

**photosynthesis:** The process in green plants and certain other organisms by which carbohydrates are synthesized from carbon dioxide and water using sunlight as an energy source. Most forms of photosynthesis release oxygen as a by-product. Chlorophyll typically acts as the catalyst in this process.

**photovoltaic and solar thermal energy:** Energy radiated by the sun as electromagnetic waves (electromagnetic radiation) that is converted at electric utilities into electricity by means of solar (photovoltaic) cells or concentrating (focusing) collectors.

**photovoltaic cell:** An electronic device consisting of layers of semiconductor materials fabricated to form a junction (adjacent layers of materials with different electronic characteristics) and electrical contacts and being capable of converting incident light directly into electricity (direct current).

**photovoltaic system:** A system that converts light into electric current.

**phytoplankton:** Small, often single-celled plants that live suspended in bodies of water.

**plutonium:** A heavy, man-made, radioactive metallic element. The most important isotope is Pu-239, which has a half-life of more than 20,000 years; it can be used in reactor fuel and is the primary isotope in weapons.

**plume:** A visible or measurable emission or discharge of a contaminant from a given point of origin into any medium, such as that formed from a cooling water outfall into a receiving water body or smokestack into the atmosphere.

**$PM_{10}$:** Particulate matter with a mean aerodynamic diameter of 10 micrometers (0.0004 in.) or less. Particles less than this diameter are small enough to be deposited in the lungs.

**$PM_{2.5}$:** Particulate matter with a mean aerodynamic diameter of 2.5 micrometers (0.0001 in.) or less.

**polycyclic aromatic hydrocarbons:** Aromatic hydrocarbons containing more than one fused benzene ring. Polycyclic aromatic hydrocarbons are commonly formed during the incomplete burning of coal, oil, and gas, garbage, or other organic substances.

**population dose:** Dose received collectively by a population.

**potable water:** Water that is fit for humans to drink.

**power:** The rate of producing, transferring, or using energy, most commonly associated with electricity. Power is measured in watts and often expressed in kilowatts (kW) or megawatts (MW).

**pressurized water reactor (PWR):** A power reactor in which thermal energy is transferred from the core to a heat exchanger by high-temperature water kept under high-pressure in the primary system. Steam is generated in the heat exchanger in a secondary circuit.

**prevention of significant deterioration (PSD):** A Federal permit program for facilities defined as major sources under the New Source Review program. The intent of the program is to prevent the air quality in an attainment area from deteriorating.

**primary system:** A term that refers to the circulating water system in a pressurized water reactor, which removes the energy from the reactor and delivers it to the heat exchanger.

**proposed action:** An action proposed by a Federal agency and evaluated in an environmental impact statement or environmental assessment. In this LR GEIS, the proposed action is to renew commercial nuclear power plant operating licenses.

**proton:** A small particle, typically found within an atom's nucleus, that possesses a positive electrical charge. The number of protons is unique for each chemical element.

**proximity:** Used sparingly to evaluate the remoteness of areas in which nuclear plants are located. A measure of the distance to larger cities.

**public dose:** The dose received by members of the public from exposure to radiation or to radioactive material released by a licensee, or to any other source of radiation under the control of a licensee. Public dose does not include occupational dose or doses received from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive materials and released in accordance with 10 CFR 35.75, or from voluntary participation in medical research programs.

**pulverized coal:** Coal that has been crushed to a fine dust in a grinding mill. It is blown into the combustion zone of a furnace and burns very rapidly and efficiently.

**pumped-storage hydroelectric plant:** A hydropower plant that usually generates electric energy during peak load periods by using water previously pumped into an elevated storage reservoir during off-peak periods when excess generating capacity is available to do so. When additional generating capacity is needed, the water can be released from the reservoir through a conduit to turbine generators located in a power plant at a lower level.

**quality factor:** The modifying factor that is used to derive dose equivalent from absorbed dose.

**rad:** The special unit for radiation absorbed dose, which is the amount of energy from any type of ionizing radiation (e.g., alpha, beta, gamma, neutrons) deposited in any medium (e.g., water, tissue, air). A dose of one rad means the absorption of 100 ergs (a small but measurable amount of energy) per gram of absorbing tissue (100 rad = 1 gray).

**radiation (ionizing radiation):** Alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation, as used in http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/,10 CFR Part 20, does not include nonionizing radiation, such as radiowaves or microwaves, or visible, infrared, or ultraviolet light (see also 10 CFR 20.1003).

**radioactive decay:** The decrease in the amount of any radioactive material with the passage of time due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, often accompanied by gamma radiation.

**radioactive waste:** Radioactive materials at the end of a useful life cycle or in a product that is no longer useful and should be properly disposed of.

**radioactivity:** The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nucleus of an unstable isotope. Also, the rate at which radioactive material emits radiation. Measured in units of becquerels or disintegrations per second.

**radioisotope:** An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation. Approximately 5,000 natural and artificial radioisotopes have been identified.

**radionuclide:** A radioisotope of an element.

**raptor:** A bird of prey such as a falcon, hawk, or eagle.

**rated power:** The design power level of an electrical generating device, which is the maximum power the device is allowed to generate.

**reactor vessel:** A device in which nuclear fission may be sustained and controlled in a self-supporting nuclear reaction. It houses the core (made up of fuel rods, control rods, and instruments contained within a reactor vessel) of most types of power reactors.

**receptor:** The individual or resource being affected by the impact.

**reference reactor year:** Refers to one year of operation of a 1,000-MW electric capacity nuclear power plant operating at an 80 percent availability factor to produce about 80 MW-yr (0.8 GW-yr) of electricity.

**refurbishment:** Repair or replacement of reactor systems, structures, and components, such as turbines, steam generators, pressurizers, and recirculation piping systems.

**region of Influence:** Area occupied by affected resources and the distances at which impacts associated with license renewal may occur.

**rem (roentgen equivalent man):** The acronym for roentgen equivalent man is a standard unit that measures the effects of ionizing radiation on humans. The dose equivalent in rem is equal to the absorbed dose in rads multiplied by the quality factor of the type of radiation (see 10 CFR 20.1004).

**renewable energy resources:** Energy resources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration, but limited in the amount of energy that is available per unit of time. Renewable energy resources include biomass, hydro, geothermal, solar, wind, ocean thermal, wave action, and tidal action.

**renewable portfolio standards:** State policies that require electricity providers to generate a certain percentage, or, in some cases a certain specified amount, of electrical power through the use of renewable energy sources by a certain date.

**residual fuel oil:** A general classification for the heavier oils, known as No. 5 and No. 6 fuel oils, that remain after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations.

**Resource Conservation and Recovery Act (RCRA):** Act that regulates the storage, treatment, and disposal of hazardous and nonhazardous wastes.

**right-of-way:** The land and legal right to use and service the land along which a transmission line is located. Transmission line right-of-ways are usually acquired in widths that vary with the kilovolt (kV) size of the line.

**riparian:** Relating to, living in, or located on the bank of a river, lake, or tidewater.

**risk:** The combined answers to the following questions: (1) What can go wrong? (2) How likely is it? (3) What are the consequences?

**risk coefficient:** A coefficient used to convert dose to risk.

**roentgen equivalent man (rem):** See rem.

**runoff:** The portion of rainfall, melted snow, or irrigation water that flows across the ground and that may eventually enter surface waters.

**run-of-river hydroelectric plant:** A hydropower plant that uses the flow of a stream as it occurs and has little or no reservoir capacity for storage.

**SAFSTOR:** A method of decommissioning in which the nuclear facility is placed and maintained in such condition that the nuclear facility can be safely stored and subsequently decontaminated to levels that permit release for restricted or unrestricted use.

**savanna:** Grassland with scattered individual trees.

**scouring:** The rapid erosion of sediment caused by the movement of water.

**scrubbers:** Air pollution control devices that are used to remove particulates and/or gases from industrial or power exhaust streams.

**sediment:** Particles of geologic origin that sink to the bottom of a body of water, or materials that are deposited by wind, water, or glaciers.

**seismic:** Of, subject to, or caused by an earthquake or earth vibration.

**seismicity:** The frequency and distribution of earthquakes.

**service water:** Water used to cool heat exchangers or coolers in the powerhouse other than the condenser. Service water may or may not be treated for use.

**sievert (Sv):** The international system (SI) unit for dose equivalent equal to 1 Joule/kilogram. 1 sievert = 100 rem. Named for physicist Rolf Sievert.

**sludge:** A dense, slushy, liquid-to-semifluid product that accumulates as an end result of an industrial or technological process. Industrial sludges are produced from the processing of energy-related raw materials, chemical products, water, mined ores, sewage, and other natural and man-made products.

**socioeconomics:** Social and economic characteristics of a human population. Includes both the social impacts of economic activity and the economic impacts of social activity.

**soils:** All unconsolidated materials above bedrock. Natural earthy materials on the earth’s surface, in places modified or even made by human activity, containing living matter, and supporting or capable of supporting plants.

**solar energy:** The radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity.

**solar power tower:** A solar energy conversion system that uses a large field of independently adjustable mirrors (heliostats) to focus solar rays on a near single point atop a fixed tower (receiver). The concentrated energy may be used to directly heat the working fluid of a Rankin cycle engine or to heat an intermediary thermal storage medium (such as a molten salt).

**solar radiation:** A general term for the visible and near-visible (ultraviolet and near-infrared) electromagnetic radiation that is emitted by the sun. It has a spectral, or wavelength, distribution that corresponds to different energy levels; short wavelength radiation has a higher energy than long wavelength radiation.

**solar thermal systems or concentrating solar power:** See solar power tower.

**sound intensity:** The measure of the amount of energy that is transported over a given area per unit of time. Sound intensity is expressed in units of $W/m^2$.

**sparseness:** Used (with proximity) to evaluate the remoteness of areas in which nuclear plants are located. A measure of population density.

**spawning:** Release or deposition of spermatozoa or ova, of which some will fertilize or be fertilized to produce offspring.

**spent fuel burnup:** A measure of how much energy is extracted from the nuclear fuel before it is removed from the core. Its units are MW-day per metric tonne of uranium in fresh fuel.

**spent nuclear fuel:** Nuclear reactor fuel that has been removed from a nuclear reactor because it can no longer sustain power production for economic or other reasons.

**spent fuel pool:** An underwater storage and cooling facility for spent fuel elements that have been removed from a reactor.

**State Historic Preservation Office(r) (SHPO):** The State agency (or officer) charged with the identification and protection of prehistoric and historic resources in accordance with the National Historic Preservation Act in the State (see also 36 CFR 800.2(c)(1)).

**state implementation plan:** State-specific air quality plan for controlling air pollution emissions at levels that would attain and maintain compliance with the National Ambient Air Quality Standards or State-specific air quality standards. Each State must develop its own regulations to monitor, permit, and control air emissions within its boundaries.

**steam turbine:** A device that converts high-pressure steam, produced in a boiler, into mechanical energy that can then be used to produce electricity by forcing blades in a cylinder to rotate and turn a generator shaft.

**stochastic effect:** Health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effect.

**store and release dam:** Hydropower facilities that store water in a reservoir behind a dam and release the water through turbines as needed to generate electricity.

**stormwater:** Stormwater runoff, snowmelt runoff, and surface runoff and drainage.

**stratification:** The formation, accumulation, or deposition of materials in layers, such as layers of freshwater overlying higher salinity water (saltwater) in estuaries.

**strip mine:** An open cut in which the overburden is removed from a coal bed or other mineral deposit prior to the removal of the desired underlying material.

**sulfur:** A yellowish nonmetallic element. It is present at various concentrations in many fossil fuels whose combustion releases sulfur compounds that are considered harmful to the environment. Some of the most commonly used fossil fuels are categorized according to their sulfur content, with lower sulfur fuels usually selling at a higher price.

**sulfur dioxide:** A gas formed from burning fossil fuels. Sulfur dioxide is one of the six criteria air pollutants specified under Title I of the Clean Air Act and contributes to the formation of acid rain.

**sulfur oxides:** Pungent, colorless gases that are formed primarily by fossil fuel combustion. Sulfur oxides may damage the respiratory tract, as well as plants and trees.

**supercritical and subcritical:** Supercritical and subcritical define the thermodynamic state of the water in the steam cycle. In supercritical steam generating units, the pressure at which the steam cycle is maintained is above water's critical point so there is no distinction between water's liquid and gaseous phases and the steam behaves as a homogenous supercritical fluid. The supercritical point for water is 22.1 MPa (approximately 3,207 pounds per square inch). Supercritical steam generators offer numerous advantages over their subcritical counterparts, including higher thermal efficiencies, greater flexibility in changing loads, and greater combustion efficiencies, resulting in lesser amounts of pollutants per units of power generated. No ultra-supercritical units are operating in the United States.

**supplemental environmental impact statement (SEIS):** A SEIS updates or supplements an existing environmental impact statement (such as the LR GEIS). The NRC directs the staff to issue site-specific supplements to the LR GEIS for each license renewal application.

**surface mine (surface mining):** A coal-producing mine that is usually within a few hundred feet of the surface. Earth above or around the coal (overburden) is removed to expose the coalbed, which is then mined with surface excavation equipment, such as draglines, power shovels, bulldozers, loaders, and augers. It may also be known as an area, contour, open-pit, strip, or auger mine.

**surface water:** Water on the earth's surface that is directly exposed to the atmosphere, as distinguished from water in the ground (groundwater).

**switchyard:** A facility used at power plants to increase the electric voltage and feed into the regional power distribution system. Electricity generated at the plant is carried off the site by transmission lines.

**tallgrass:** Any of various grasses that are tall and that flourish with abundant moisture, typically associated with the prairies of the Midwestern United States.

**terrestrial:** Belonging to or living on land.

**thermal:** Having to do with heat. Also, a term used to identify a type of electric generating station, capacity, capability, or output in which the source of energy for the prime mover is heat.

**thermal efficiency:** A measure of the efficiency of converting the thermal energy generated by the burning of the fossil fuels or the fission of nuclear fuel to electrical energy.

**thermal effluents:** Heated discharge from a cooling water system.

**thermal plume:** The hot water discharged from a power-generating facility or other industrial plant. When the water at elevated temperature enters a receiving stream or body of water, it is not immediately dispersed and mixed with the cooler waters. The warmer water moves as a single mass (plume) from the discharge point until it cools and gradually mixes with that of the receiving water.

**thermal stratification:** The formation of layers of different temperatures in a lake or reservoir.

**thermophilic:** Organisms such as bacteria that require a relatively high-temperature environment for normal development.

**threatened species:** Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. Requirements for declaring a species threatened are contained in the Endangered Species Act.

**total body dose/whole-body dose:** Sum of the dose received from external exposure to the total body, gonads, active blood-forming organs, head and trunk, or lens of the eye and the dose due to the intake of radionuclides by inhalation and ingestion where a radioisotope is uniformly distributed throughout the body tissues rather than being concentrated in certain parts.

**total effective dose equivalent:** The sum of the deep-dose equivalent (for external exposure) and the committed effective dose equivalent (for internal exposure).

**transformer:** An electrical device for changing the voltage of alternating current.

**transmission:** The movement or transfer of electric energy over an interconnected group of lines and associated equipment between points of supply and points at which it is transformed for delivery to consumers or is delivered to other electric systems. Transmission is considered to end when the energy is transformed for distribution to the consumer.

**transmission line:** A set of conductors, insulators, supporting structures, and associated equipment used to move large quantities of power at high-voltage, usually over long distances between a generating or receiving point and major substations or delivery points.

**transuranic elements:** The chemical elements with atomic numbers greater than 92, the atomic number of uranium.

**transuranic waste:** Material contaminated with transuranic elements that is produced primarily from reprocessing spent fuel and from use of plutonium in fabrication of nuclear weapons.

**tritium:** A radioactive isotope of hydrogen with one proton and two neutrons. It decays by beta emission. It has a radioactive half-life of about 12.5 years.

**turbine:** A device in which a stream of water or gas turns a bladed wheel, converting the kinetic energy of the flow into mechanical energy available from the turbine shaft. Turbines are considered the most economical means of turning large electrical generators. They are typically driven by steam, fuel vapor, water, or wind.

**U.S. Environmental Protection Agency (EPA):** A Federal agency, created for the purpose of promoting human health by protecting the nation’s air, water, and soil from harmful pollution by enforcing environmental regulations based on laws passed by Congress. The agency conducts environmental assessment, research, and education. It has the responsibility of maintaining and enforcing national standards under a variety of environmental laws (e.g., Clean Air Act), in consultation with State, Tribal, and local governments. It delegates some permitting, monitoring, and enforcement responsibility to States and Native American Tribes. EPA enforcement powers include fines, sanctions, and other measures. The agency also works with industries and all levels of government in a wide variety of voluntary pollution prevention programs and energy conservation efforts.

**U.S. Nuclear Regulatory Commission (NRC):** An independent regulatory agency that is responsible for overseeing the civilian use of nuclear materials in the United States. The NRC was established on October 11, 1974, by President Gerald Ford as one of two successor organizations to the Atomic Energy Commission, which became defunct on that same day. The NRC took over the Atomic Energy Commission's responsibility for seeing that civilian nuclear materials and facilities are used safely and affect neither the public health nor the quality of the environment. The Commission's activities focus on the nuclear reactors in the United States that are used to generate electricity on a commercial basis. It licenses the construction of new nuclear reactors and regulates their operation on a continuing basis. It oversees the use, processing, handling, and disposal of nuclear materials and wastes; inspects nuclear power plants and monitors both their safety procedures and their security measures; enforces compliance with established safety standards; and investigates nuclear accidents. The NRC's Commissioners are appointed by the President of the United States and confirmed by the Senate for five-year terms.

**uranium:** A radioactive element with the atomic number 92 and, as found in natural ores, an atomic weight of approximately 238. The two principal natural isotopes are uranium-235 (0.7 percent of natural uranium) and uranium-238 (99.3 percent of natural uranium). Natural uranium also includes a minute amount of uranium-234.

**universal waste:** A special class of hazardous waste consisting of commonly used and yet hazardous materials: batteries, pesticides, mercury-containing equipment, and lamps.

**vertebrate:** Any species having a backbone or spinal column including fish, amphibians, reptiles, birds, and mammals.

**visual impact:** The creation of an intrusion or perceptible contrast that affects the scenic quality of a landscape.

**visual resources:** Refers to all objects (man-made and natural, moving and stationary) and features such as landforms and water bodies that are visible on a landscape.

**volatile organic compounds (VOCs):** A broad range of organic compounds that readily evaporate at normal temperatures and pressures. Sources include certain solvents, degreasers (e.g., benzene), and fuels. Volatile organic compounds react with other substances (primarily nitrogen oxides) to form ozone. They contribute significantly to photochemical smog production and certain health problems.

**waste coal:** Usable material that is a by-product of previous coal processing operations. Waste coal may be relatively clean material composed primarily of coal fines, material in which extraneous noncombustible constituents have been partially removed, or mixed coal, soil, and rock (mine waste) burned as is in unconventional boilers, such as fluidized bed units. Examples include fine coal, coal obtained from a refuse bank or slurry dam, anthracite culm, bituminous gob, and lignite waste.

**wastewater:** The used water and solids that flow to a treatment plant and/or are discharged to a receiving water body. Stormwater, surface water, and groundwater infiltration also may be included in the wastewater that enters a wastewater treatment plant. Domestic or sanitary wastewater is water originating from human sanitary water use and industrial wastewater is that derived from a variety of industrial processes.

**water table:** The boundary between the unsaturated zone and the deeper, saturated zone. The upper surface of an unconfined aquifer.

**water quality:** The condition of water with respect to the amount of impurities in it.

**weir:** A structure in a waterway or stormwater control device, over which water flows that serves to raise the water level or to direct or regulate flow.

**wetlands:** Areas that are inundated or saturated by surface water or groundwater and that typically support vegetation adapted for life in saturated soils. Wetlands generally include swamps, marshes, bogs, and similar areas (e.g., sloughs, potholes, wet meadows, river overflow areas, mudflats, natural ponds).

**wind energy:** Kinetic energy present in wind motion that can be converted to mechanical energy for driving pumps, mills, and electric power generators.

**wind farm:** One or more wind turbines operating within a contiguous area for the purpose of generating electricity. See also wind power plant.

**wind power plant:** Wind turbines interconnected to a common utility system through a system of transformers, distribution lines, and (usually) one substation. Operation, control, and maintenance functions are often centralized through a network of computerized monitoring systems, supplemented by visual inspection.

**wind turbine:** Wind energy conversion device that produces electricity; typically three blades rotating about a horizontal axis and positioned upwind of the supporting tower.

**X-rays and gamma rays:** Waves of pure energy that travel with the speed of light that are very penetrating and require thick concrete or lead shielding to stop them.

**Yucca Mountain:** The Yucca Mountain, Nevada, site of the DOE's proposed location for a repository for spent nuclear fuel and high-level radioactive waste. The EPA established the public health and environmental radiation protection standards for the facility. However, in March 2010, DOE filed a request with the NRC's Atomic Safety and Licensing Board to withdraw its application for authorization to construct a high-level waste geological repository at Yucca Mountain. The decisions and recommendations concerning the ultimate disposition of spent nuclear fuel are ongoing.

**zooplankton:** Small animals that float passively in the water column. Includes eggs and larvae of many fish and invertebrate species.

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| **NRC FORM 335** (12-2010) NRCMD 3.7 **U.S. NUCLEAR REGULATORY COMMISSION** **BIBLIOGRAPHIC DATA SHEET** *(See instructions on the reverse)* 1 | | 1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.) NUREG-1437, Volume 1, Revision 2 Draft Report |
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11. ABSTRACT (200 words or less)


U.S. Nuclear Regulatory Commission (NRC) regulations allow for the renewal of commercial nuclear power plant operating licenses. There are no specific limitations in the Atomic Energy Act or the NRC's regulations restricting the number of times a license may be renewed. To support license renewal environmental reviews, the NRC published the first Generic Environmental Impact Statement for License Renewal of Nuclear Plants (LR GEIS) in 1996. Per NRC regulations, a review and update of the LR GEIS is conducted every 10-years, if necessary. The proposed action is the renewal of nuclear power plant operating licenses.

Since publication of the 1996 LR GEIS, approximately 59 nuclear power plants (96 reactor units) have undergone license renewal environmental reviews and have received initial and subsequently renewed licenses, the results of which were published as supplements to the LR GEIS. This revision reviews and reevaluates the issues and findings of the 2013 LR GEIS (Revision 1). Lessons learned and knowledge gained from completed initial and subsequent license renewal environmental reviews provide major sources of new information for this assessment. In addition, new research, findings, public comments, changes in applicable laws and regulations, and other information were considered in evaluating the environmental impacts associated with license renewal.


| 12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.) | |
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