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

NUREG-1437, Volume 3
Revision 2

Generic Environmental Impact Statement for License Renewal of Nuclear Plants

Appendices

Final Report

Office of Nuclear Material Safety and Safeguards

AVAILABILITY OF REFERENCE MATERIALS IN NRC PUBLICATIONS

NRC Reference Material

As of November 1999, you may electronically access NUREG-series publications and other NRC records at the NRC's Library at www.nrc.gov/reading-rm.html. Publicly released records include, to name a few, NUREG-series publications; *Federal Register* notices; applicant, licensee, and vendor documents and correspondence; NRC correspondence and internal memoranda; bulletins and information notices; inspection and investigative reports; licensee event reports; and Commission papers and their attachments.

NRC publications in the NUREG series, NRC regulations, and Title 10, "Energy," in the *Code of Federal Regulations* may also be purchased from one of these two sources:

1. **The Superintendent of Documents**
U.S. Government Publishing Office
Washington, DC 20402-0001
Internet: https://bookstore.gpo.gov/
Telephone: (202) 512-1800
Fax: (202) 512-2104

2. **The National Technical Information Service**
5301 Shawnee Road
Alexandria, VA 22312-0002
Internet: https://www.ntis.gov/
1-800-553-6847 or, locally, (703) 605-6000

A single copy of each NRC draft report for comment is available free, to the extent of supply, upon written request as follows:

Address: **U.S. Nuclear Regulatory Commission**
Office of Administration
Digital Communications and Administrative Services Branch
Washington, DC 20555-0001
E-mail: Reproduction.Resource@nrc.gov
Facsimile: (301) 415-2289

Some publications in the NUREG series that are posted at the NRC's Web site address www.nrc.gov/reading-rm/doc-collections/nuregs are updated periodically and may differ from the last printed version. Although references to material found on a Web site bear the date the material was accessed, the material available on the date cited may subsequently be removed from the site.

Non-NRC Reference Material

Documents available from public and special technical libraries include all open literature items, such as books, journal articles, transactions, *Federal Register* notices, Federal and State legislation, and congressional reports. Such documents as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings may be purchased from their sponsoring organization.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at—

The NRC Technical Library
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852-2738

These standards are available in the library for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from—

American National Standards Institute
11 West 42nd Street
New York, NY 10036-8002
Internet: www.ansi.org
(212) 642-4900

Legally binding regulatory requirements are stated only in laws; NRC regulations; licensee, including technical specifications; or orders, not in NUREG-series publications. The views expressed in contractor prepared publications in this series are not necessarily those of the NRC.

The NUREG series comprises (1) technical and administrative reports and books prepared by the staff (NUREG–XXXX) or agency contractors (NUREG/CR–XXXX), (2) proceedings of conferences (NUREG/CP–XXXX), (3) reports resulting from international agreements (NUREG/IA–XXXX),(4) brochures (NUREG/BR–XXXX), and (5) compilations of legal decisions and orders of the Commission and the Atomic and Safety Licensing Boards and of Directors' decisions under Section 2.206 of the NRC's regulations (NUREG-0750), (6) Knowledge Management prepared by NRC staff or agency contractors (NUREG/KM-XXXX).

DISCLAIMER: This report was prepared as an account of work sponsored by an agency of the U.S. Government. Neither the U.S. Government nor any agency thereof, nor any employee, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use, or the results of such use, of any information, apparatus, product, or process disclosed in this publication, or represents that its use by such third party would not infringe privately owned rights.

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

NUREG-1437, Volume 3
Revision 2

Generic Environmental Impact Statement for License Renewal of Nuclear Plants

Appendices

Final Report

Manuscript Completed: August 2024
Date Published: August 2024

Office of Nuclear Material Safety and Safeguards

COVER SHEET

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

Title: Final *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (NUREG-1437) Volumes 1, 2, and 3, Revision 2

For additional information or copies of this Final *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, contact:

Jennifer A. Davis, Senior Environmental Project Manager
Kevin T. Folk, Senior Environmental Project Manager
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Mail Stop T-4B72
11545 Rockville Pike
Rockville, Maryland 20852
Phone: 1-800-368-5642, extension 3835 or 6944
Email: Jennifer.Davis@nrc.gov or Kevin.Folk@nrc.gov

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, 59 nuclear power plants (96 reactor units) have undergone license renewal environmental reviews and have received renewed licenses (either an initial license renewal [initial LR] or subsequent license renewal [SLR]), 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 LR and SLR environmental reviews provide an important source 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 initial LR and one term of SLR.

The purpose of the LR GEIS is to identify and evaluate environmental issues for license renewal and determine which could result in the same or similar impact at all nuclear power plants or a specific subset of plants (i.e., generic issues) and which issues could result in different levels of impact.

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.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid Office of Management and Budget control number.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS, ABBREVIATIONS, AND CHEMICAL NOMENCLATURE

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 effects
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
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
DSM	demand-side management
EFH	essential fish habitat
EI	exposure index
EIA	Energy Information Administration
EIS	environmental impact statement
EMF	electromagnetic field
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
EPU	extended power uprate
ESA	Endangered Species Act

FLEX	flexible coping strategies
FPRA	fire probabilistic risk assessment
FR	*Federal Register*
FWS	U.S. Fish and Wildlife Service
GEIS	generic environmental impact statement
GHG	greenhouse gas
gpm	gallon(s) per minute
GTCC	greater-than-Class C
GWd	gigawatt day(s)
GWd/MT	gigawatt-days (units of energy) per metric tonne
H_2O	water; water vapor
HAPCs	habitat areas of particular concern
HLW	high-level waste
hr	hour(s)
Hz	hertz
ICRP	International Commission on Radiological Protection
IM&E	impingement mortality and entrainment
initial LR	initial license renewal
IPE	Individual Plant Examination
IPEEE	Individual Plant Examination of External Events
ISFSI	independent spent fuel storage installation
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
LOOP	loss of offsite power
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	millirad(s)
mrem	millirem(s)
MSA	Magnuson-Stevens Fishery Conservation and Management Act
mSv	millisievert(s)
MT	metric ton/tonne(s)
MTHM	metric tonne(s) of heavy metal
MTU	metric tonne(s) of uranium
MW	megawatt(s)
MWe	megawatt(s) electric
MWt	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

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
PSHA	probabilistic seismic hazard assessment
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
RY	reactor year
s	second(s)
SAMA	severe accident mitigation alternative
SAMDA	severe accident mitigation design alternative
SAMG	severe accident management guideline
SBO	station blackout
SCDF	seismic core damage frequency
scf	standard cubic foot (feet)
SEIS	supplemental environmental impact statement
SFP	spent fuel pool
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
SST	siting source term
Sv	sievert(s)
T	ton(s)
TDS	total dissolved solids
TEDE	total effective dose equivalent

T/yr	ton(s) per year
UA	uncertainty analysis
UCB	upper confidence bound
UF_6	uranium hexafluoride
U.S.	United States
USACE	U.S. Army Corps of Engineers
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 Nuclear Power Plant
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 (ac)	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)	3.7×10^{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/tonnes (MT)
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)	2.7×10^{-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/tonnes (MT)	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 licenses to operate commercial nuclear power plants for up to 40 years and permits the renewal of these licenses. By regulation, the NRC is allowed to renew these licenses for up to an additional 20 years, depending on the outcome of 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 (impacts) 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 specific 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 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 plants or a specific 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.

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

[1] Final rules were also issued on 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.

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 approximately 7 years after the last revision cycle (see 85 FR 47252). For further information regarding the review and update of this LR GEIS see Section 1.6. As part of this review and update, the following activities occurred:

- NRC staff conducted a series of public scoping meetings in August 2020 (see 85 FR 47252 for more details). The scoping period concluded on November 2, 2020.
- NRC staff submitted a rulemaking plan in July 2021 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 directed the NRC staff to develop a new rulemaking plan that would update the LR GEIS to fully account for subsequent license renewal (SLR) in light of recent Commission adjudicatory decisions.
- NRC staff submitted a revised rulemaking plan in March 2022.
- In April 2022, the Commission approved the staff's recommendation to proceed with the rulemaking.
- NRC staff submitted the proposed rule package and draft revised LR GEIS to the Commission for its review on December 6, 2022.
- On January 23, 2023, the Commission approved publication of the proposed rule in the *Federal Register* for a 60-day comment period.
- NRC staff published the proposed rule, draft LR GEIS, and associated guidance for public comment in the *Federal Register* on March 3, 2023 (88 FR 13329).
- NRC staff conducted a series of public meetings in March and April 2023 to take comment on the proposed rule package.

The 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, (3) lessons learned and knowledge gained from previously completed and ongoing initial license renewal (initial LR) and SLR environmental reviews, (4) Commission direction, and (5) comments received from the public and other stakeholders on the draft LR GEIS and proposed rule. 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 initial LR term or SLR.

Changes made in response to comments in this final LR GEIS, as well as changes made to include updated information, corrections, and substantial editorial revisions, are marked with a change bar (vertical line) on the side margin of the page where the changes or additions were made. Minor editorial revisions and those limited to formatting are not marked. The NRC also made several targeted text changes that are not marked, which included the removal of duplicative text and organizational changes to this LR GEIS to address changes to NEPA from the Fiscal Responsibility Act of 2023.

The purpose of the review for this LR GEIS was 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 in its possession from scientific literature and nuclear power plant operations, collective experience, and lessons learned and knowledge gained from conducting initial LR and SLR environmental reviews since development of the 2013 LR GEIS. The NRC also considered comments received on the draft LR GEIS and proposed rule (see Section 1.10) in finalizing this LR GEIS. As a result of the NRC's review and update, the NRC identified 80 environmental issues for inclusion in revised Table B-1. They include 59 issues which were determined to be same or similar impact at all nuclear power plants or a specific subset of plants (i.e., generic issues, Category 1); 20 issues which require a plant-specific analysis (Category 2); and one issue that remains uncategorized.

ES.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 that allows for baseload power generation capability beyond the term of the current nuclear power plant operating license to meet future system generating needs, as such needs may be determined by State, utility, system, and, where authorized, Federal (other than NRC) decisionmakers. Except to the extent that findings in the safety review required by the Atomic Energy Act or in the environmental review could 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.

ES.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 effects (impacts) of renewing the operating licenses of commercial nuclear power plants. 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; (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.

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. The NRC held four public webinars in August 2020 to support public participation in the LR GEIS revision. 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 and public comment periods, new and updated technical and regulatory information, as well as Commission direction, 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 environmental issue, the revised LR GEIS (1) describes the nuclear power plant activity or operational aspect 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 effect (impact) from initial LR or SLR on the affected resource; (5) characterizes the significance of the effect; (6) determines whether the results of the analysis apply to all or a specific subset of nuclear power plants (i.e., whether the environmental issue is Category 1, Category 2, or uncategorized); and (7) considers additional mitigation measures for reducing 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, new 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.

Together with publication of the proposed rule, the NRC issued the draft LR GEIS for public comment. This LR GEIS provides the technical basis for the Commission's license renewal regulations in 10 CFR Part 51, including for the 80 identified environmental issues associated with continued operation and refurbishment of nuclear power plants during a license renewal term. In the proposed rule, the NRC sought comment on whether the scope of the rule, including the scope and applicability of Table B-1 of 10 CFR Part 51, should be expanded beyond two license renewal terms. The NRC also issued for public comment associated guidance documents, including draft Revision 2 (DG-4027) of Regulatory Guide 4.2, Supplement 1, and draft Revision 2 to NUREG-1555, Supplement 1.

The public comment period ran from March 3, 2023, to May 2, 2023. The NRC received 1,889 comment submissions (i.e., letters, emails, and other documents), which the NRC posted to the Regulations.gov website. During the public comment period, the NRC held six hybrid public meetings, which were transcribed. The NRC also conducted an informational meeting with Federally recognized Tribes on April 19, 2023, to afford Tribal representatives the opportunity to discuss the rule with the staff. All comment submissions, including those received in writing and those provided at the public meetings, were considered in preparing this LR GEIS. The NRC's responses to all comments are provided in Appendix A.2 of this LR GEIS.

ES.3 Impact Definitions and Categories

The NRC's environmental impact standard considers Council on Environmental Quality terminology, including Council on Environmental Quality revisions in Part 1501—NEPA and Agency Planning (40 CFR Part 1501) and Part 1508—Definitions (40 CFR 1508; 89 FR 35442).

In determining whether the incremental environmental effects (impacts) of the proposed action (license renewal—either initial LR or SLR) are significant, the NRC analyzes the context (i.e., geographic area and resources) and intensity of the effects. The geographic area consists of the characteristics of the area and its resources, such as proximity to unique or sensitive resources or communities with environmental justice concerns. For nuclear power plant-specific environmental issues, significance depends on the effects in the relevant geographic area, including but not limited to consideration of short- and long-term effects, as well as beneficial and adverse effects.

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 evaluating 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 (i.e., generic issues and applicable to all or a specific subset of nuclear plants) or Category 2 (i.e., requiring a plant-specific analysis), as further described in Section 1.5.2.3 of this LR GEIS.

ES.4 Affected Environment

For purposes of the evaluation in this LR GEIS revision, the "affected environment" is the environment currently existing at and around operating commercial nuclear power plants. Current conditions in the affected environment are the result of past construction and ongoing operations at the plants, as well as reasonably foreseeable environmental trends. 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 emissions and climate change. The affected environment of the operating plant sites represents diverse environmental conditions.

ES.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 specific subset of plants, and one issue remains uncategorized. The conclusions for each Category 1 or Category 2 environmental issue are presented by resource area or subject matter. The conclusions for each issue are summarized in Table 2.1-1. Chapter 4 provides the NRC's detailed analysis of and technical basis for each issue and supports the finding codified in Table B-1 of Appendix B to Subpart A of 10 CFR Part 51.

ES.6 Comparison of Alternatives

This LR GEIS 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, new 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.

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.

APPENDIX B

COMPARISON OF ENVIRONMENTAL ISSUES AND FINDINGS IN THIS LR GEIS REVISION TO THE ISSUES AND FINDINGS IN TABLE B-1 OF 10 CFR PART 51 (1996, 2013, AND 2024 REVISIONS)

APPENDIX B

COMPARISON OF ENVIRONMENTAL ISSUES AND FINDINGS IN THIS LR GEIS REVISION TO THE ISSUES AND FINDINGS IN TABLE B-1 OF 10 CFR PART 51 (1996, 2013, AND 2024 REVISIONS)

B.1 Comparison of Environmental Issues and Findings

The tables in this appendix provide a resource area comparison of the issues and findings presented in this revision of NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (LR GEIS) with the issues and findings presented in the 1996 and 2013, and this 2024 revision of Table B-1 of Title 10 of the *Code of Federal Regulations* Part 51 (10 CFR Part 51) (61 FR 28467; 61 FR 66537; 64 FR 48496; 66 FR 39278; 78 FR 37282; 79 FR 56262).

Table B.1-1 Comparison of Land Use-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Onsite land use	**SMALL (Category 1).** Projected onsite land use changes required during refurbishment and the renewal period would be a small fraction of any nuclear power plant site and would involve land that is controlled by the applicant.	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.	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 (refurbishment)	**SMALL or MODERATE (Category 2).** Impacts may be of moderate significance at plants in low population areas. See § 51.53(c)(3)(ii)(I).	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	**SMALL (Category 1).** Offsite land use would not be affected by continued operations and refurbishment associated with license renewal.
Offsite land use (license renewal term)	**SMALL, MODERATE, or LARGE (Category 2).** Significant changes in land use may be associated with population and tax revenue changes resulting from license renewal. See § 51.53(c)(3)(ii)(I).				

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Power line right of way	**SMALL (Category 1).** Ongoing use of power line right of ways would continue with no change in restrictions. The effects of these restrictions are of small significance.	Offsite land use in transmission line right-of-ways (ROWs)[(b)]	**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.	Offsite land use in transmission line right-of-ways (ROWs)[(b)]	**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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

(b) 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.

Table B.1-2 Comparison of Visual Resource-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Aesthetic impacts (refurbishment)	**SMALL (Category 1).** No significant impacts are expected during refurbishment.	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.	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.
Aesthetic impacts (license renewal term)	**SMALL (Category 1).** No significant impacts are expected during the license renewal term.				
Aesthetic impacts of transmission lines (license renewal term)	**SMALL (Category 1).** No significant impacts are expected during the license renewal term.				

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

Table B.1-3 Comparison of Air Quality-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Air quality during refurbishment (non-attainment and maintenance areas)	**SMALL, MODERATE, or LARGE (Category 2).** Air quality impacts from plant refurbishment associated with license renewal are expected to be small. However, vehicle exhaust emissions could be cause for concern at locations in or near nonattainment or maintenance areas. The significance of the potential impact cannot be determined without considering the compliance status of each site and the numbers of workers expected to be employed during the outage. See § 51.53(c)(3)(ii)(F).	Air quality impacts (all plants)	**SMALL (Category 1).** Air quality impacts from continued operations and refurbishment associated with license renewal are expected to be small at all plants. 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 refurbishment 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, the imposition of permit conditions in State and local air emissions permits would ensure conformance with applicable State or Tribal implementation plans. Emissions from emergency diesel generators and fire pumps and routine operations of boilers used	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. 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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
			for space heating would not be a concern, even for plants located in or adjacent to nonattainment areas. Impacts from cooling tower particulate emissions even under the worst-case situations have been small.		emissions permits, would ensure conformance with applicable State or Tribal implementation plans.
Air quality effects of transmission lines	**SMALL (Category 1).** Production of ozone and oxides of nitrogen is insignificant and does not contribute measurably to ambient levels of these gases.	Air quality effects of transmission lines[(b)]	**SMALL (Category 1).** Production of ozone and oxides of nitrogen is insignificant and does not contribute measurably to ambient levels of these gases.	Air quality effects of transmission lines[(b)]	**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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

(b) 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.

Table B.1-4 Comparison of Noise-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Noise	**SMALL (Category 1).** Noise has not been found to be a problem at operating plants and is not expected to be a problem at any plant during the license renewal term.	Noise impacts	**SMALL (Category 1).** Noise levels would remain below regulatory guidelines for offsite receptors during continued operations and refurbishment associated with license renewal.	Noise impacts	**SMALL (Category 1).** Noise levels would remain below regulatory guidelines for offsite receptors during continued operations and refurbishment associated with license renewal.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

Table B.1-5 Comparison of Geologic Environment-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Not addressed	Not applicable	Geology and soils	**SMALL (Category 1).** The effect of geologic and soil conditions on plant operations and 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.	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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

Table B.1-6 Comparison of Surface Water Resources-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Impacts of refurbishment on surface water quality	**SMALL (Category 1).** Impacts are expected to be negligible during refurbishment because best management practices are expected to be employed to control soil erosion and spills.	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.	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.
Impacts of refurbishment on surface water use	**SMALL (Category 1).** Water use during refurbishment will not increase appreciably or will be reduced during plant outage.				
Altered current patterns at intake and discharge structures	**SMALL (Category 1).** Altered current patterns 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.	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 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).** Salinity gradients have not been found to be a problem at operating	Altered salinity gradients	**SMALL (Category 1).** Effects on salinity gradients would be limited to the area in the vicinity of the	Altered salinity gradients	**SMALL (Category 1).** Effects on salinity gradients would be limited to the area in the vicinity of

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	nuclear power plants and are not expected to be a problem during the license renewal term.		intake and discharge structures. These impacts have been small at operating nuclear power plants.		the intake and discharge structures. These impacts have been small at operating nuclear power plants.
Altered thermal stratification of lakes	**SMALL (Category 1).** Generally, lake stratification has not been found to be a problem at operating nuclear power plants and is not expected to be a problem during the license renewal term.	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.	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 has not been found to be a problem at most operating nuclear power plants and has caused only localized effects at a few plants. It is not expected to be a problem during the license renewal term.	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.	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.
Discharge of other metals in waste water	**SMALL (Category 1).** These discharges 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. They are not expected to be a problem during the license renewal term.	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	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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
			System (NPDES) permit process.		System (NPDES) permit process.
Discharge of chlorine or other biocides	**SMALL (Category 1).** Effects are not a concern among regulatory and resource agencies, and are not expected to be a problem during the license renewal term.	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.	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.
Discharge of sanitary wastes and minor chemical spills	**SMALL (Category 1).** Effects are readily controlled through NPDES permit and periodic modifications, if needed, and are not expected to be a problem during the license renewal term.				
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 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 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.
Water use conflicts (plants with cooling ponds or cooling towers using make-up water from a small river with low flow)	**SMALL or MODERATE (Category 2).** The issue has been a concern at nuclear power plants with cooling ponds and at plants with cooling towers. Impacts on instream and riparian communities near	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.	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.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	these plants could be of moderate significance in some situations. See § 51.53(c)(3)(ii)(A).				
Not addressed	Not applicable	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.	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.	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.	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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

Table B.1-7 Comparison of Groundwater Resources-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Impacts of refurbishment on ground-water use and quality	**SMALL (Category 1).** Extensive dewatering during the original construction on some sites will not be repeated during refurbishment on any sites. Any plant wastes produced during refurbishment will be handled in the same manner as in current operating practices and are not expected to be a problem during the license renewal term.	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 Environmental Protection Agency 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 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.
Ground-water use conflicts (potable and service water; plants that use <100 gpm)	**SMALL (Category 1).** Plants using less than 100 gpm are not expected to cause any ground-water use conflicts.	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 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.
Ground-water use conflicts (potable and service water,	**SMALL, MODERATE, or LARGE (Category 2).** Plants that use more than	Groundwater use conflicts (plants that withdraw	**SMALL, MODERATE, or LARGE (Category 2).** Plants that withdraw more	Groundwater use conflicts (plants that withdraw	**SMALL, MODERATE, or LARGE (Category 2).** Plants that withdraw more

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
and dewatering; plants that use >100 gpm)	100 gpm may cause ground-water use conflicts with nearby ground-water users. See § 51.53(c)(3)(ii)(C).	more than 100 gallons per minute [gpm])	than 100 gpm could cause groundwater use conflicts with nearby groundwater users.	more than 100 gallons per minute [gpm])	than 100 gpm could cause groundwater use conflicts with nearby groundwater users.
Ground-water use conflicts (Ranney wells)	**SMALL, MODERATE, or LARGE (Category 2).** Ranney wells can result in potential ground-water depression beyond the site boundary. Impacts of large ground-water withdrawal for cooling tower makeup at nuclear power plants using Ranney wells must be evaluated at the time of application for license renewal. See § 51.53(c)(3)(ii)(C).				
Ground-water use conflicts (plants using cooling towers withdrawing make-up water from a small river)	**SMALL, MODERATE, or LARGE (Category 2).** Water use conflicts may result from surface water withdrawals from small water bodies during low-flow conditions which may affect aquifer recharge, especially if other ground-water or upstream surface water users come on line before the time of license renewal. See § 51.53(c)(3)(ii)(A).	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 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.
Ground-water quality	**SMALL (Category 1).** Ground-water quality at river sites may be	Groundwater quality degradation	**SMALL (Category 1).** Groundwater withdrawals at operating nuclear power	Groundwater quality degradation	**SMALL (Category 1).** Groundwater withdrawals at operating nuclear power

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
degradation (Ranney wells)	degraded by induced infiltration of poor-quality river water into an aquifer that supplies large quantities of reactor cooling water. However, the lower quality infiltrating water would not preclude the current uses of ground water and is not expected to be a problem during the license renewal term.	resulting from water withdrawals	plants would not contribute significantly to groundwater quality degradation.	resulting from water withdrawals	plants would not contribute significantly to groundwater quality degradation.
Ground-water quality degradation (saltwater intrusion)	**SMALL (Category 1).** Nuclear power plants do not contribute significantly to saltwater intrusion.				
Ground-water quality degradation (cooling ponds in salt marshes)	**SMALL (Category 1).** Sites with closed-cycle cooling ponds may degrade ground-water quality. Because water in salt marshes is brackish, this is not a concern for plants located in salt marshes.	Groundwater quality degradation (plants with cooling ponds in salt marshes)	**SMALL (Category 1).** Sites with closed-cycle cooling ponds could degrade groundwater quality. However, groundwater in salt marshes is naturally brackish and thus, not potable. Consequently, the human use of such groundwater is limited to industrial purposes.	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.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Ground-water quality degradation (cooling ponds at inland sites)	**SMALL, MODERATE, or LARGE (Category 2).** Sites with closed-cycle cooling ponds may degrade ground-water quality. For plants located inland, the quality of the ground water in the vicinity of the ponds must be shown to be adequate to allow continuation of current uses. See § 51.53(c)(3)(ii)(D).	Groundwater quality degradation (plants with cooling ponds at inland sites)	**SMALL, MODERATE, or LARGE (Category 2).** Inland sites with closed-cycle cooling ponds could degrade groundwater quality. The significance of the impact would depend on 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.		
Not addressed	Not applicable	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.	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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

Table B.1-8 Comparison of Terrestrial Resources-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Refurbishment impacts	**SMALL, MODERATE, or LARGE (Category 2).** Refurbishment impacts are insignificant if no loss of important plant and animal habitat occurs. However, it cannot be known whether important plant and animal communities may be affected until the specific proposal is presented with the license renewal application. See § 51.53(c)(3)(ii)(E).	Effects on terrestrial resources (non-cooling system impacts)	**SMALL, MODERATE, or LARGE (Category 2).** Impacts resulting from continued operations and refurbishment associated with license renewal may affect terrestrial communities. Application of best management practices would reduce the potential for impacts. The magnitude of impacts would depend on the nature of the activity, the status of the resources that could be affected, and the effectiveness of mitigation.	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.
Not addressed	Not applicable	Exposure of terrestrial organisms to radionuclides	**SMALL (Category 1).** Doses to terrestrial organisms from continued operations and refurbishment associated with license renewal are expected to be well below exposure guidelines developed to protect these organisms.	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.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Cooling pond impacts on terrestrial resources	**SMALL (Category 1).** Impacts of cooling ponds on terrestrial ecological resources are considered to be of small significance at all sites.	Cooling system impacts on terrestrial resources (plants with once-through cooling systems or cooling ponds)	**SMALL (Category 1).** No adverse effects to terrestrial plants or animals have been reported as a result of increased water temperatures, fogging, humidity, or reduced habitat quality. Due to the low concentrations of contaminants in cooling system effluents, uptake and accumulation of contaminants in the tissues of wildlife exposed to the contaminated water or aquatic food sources are not expected to be significant issues.	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 waterbodies, 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 crops and ornamental vegetation	**SMALL (Category 1).** Impacts from salt drift, icing, fogging, or increased humidity associated with cooling tower operation 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.	Cooling tower impacts on vegetation (plants with cooling towers)	**SMALL (Category 1).** Impacts from salt drift, icing, fogging, or increased humidity associated with cooling tower operation have the potential to affect adjacent vegetation, but these impacts have been small at operating nuclear power plants and are not	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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
			expected to change over the license renewal term.		occurred have successfully mitigated the impact. These impacts are not expected to be significant issues during the license renewal term.
Cooling tower impacts on native plants	**SMALL (Category 1).** Impacts from salt drift, icing, fogging, or increased humidity associated with cooling tower operation 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.				
Bird collisions with cooling towers	**SMALL (Category 1).** These collisions 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.	Bird collisions with plant structures and transmission lines[(b)]	**SMALL (Category 1).** Bird collisions with cooling towers and other plant structures and transmission lines occur at rates that are unlikely to affect local or migratory populations and the rates are not expected to change.	Bird collisions with plant structures and transmission lines[(b)]	**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.
Bird collisions with power lines	**SMALL (Category 1).** Impacts are expected to be of small significance at all sites.				
Not addressed	Not applicable	Water use conflicts with	**SMALL or MODERATE (Category 2).** Impacts on	Water use conflicts with terrestrial	**SMALL or MODERATE (Category 2).** Nuclear

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
		terrestrial resources (plants with cooling ponds or cooling towers using makeup water from a river)	terrestrial resources in riparian communities affected by water use conflicts could be of moderate significance.	resources (plants with cooling ponds or cooling towers using makeup water from a river)	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.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Power line right-of-way management (cutting and herbicide application)	**SMALL (Category 1).** The impacts of right-of-way maintenance on wildlife are expected to be of small significance at all sites.	Transmission line right-of-way (ROW) management impacts on terrestrial resources[(b)]	**SMALL (Category 1).** Continued ROW management during the license renewal term is expected to keep terrestrial communities in their current condition. Application of best management practices would reduce the potential for impacts.	Transmission line right-of-way (ROW) management impacts on terrestrial resources[(b)]	**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.
Floodplains and wetland on power line right of way	**SMALL (Category 1).** Periodic vegetation control is necessary in forested wetlands underneath power lines and can be achieved with minimal damage to the wetland. No significant impact is expected at any nuclear power plant during the license renewal term.				

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Impacts of electromagnetic fields on flora and fauna (plants, agricultural crops, honeybees, wildlife, livestock)	**SMALL (Category 1).** No significant impacts of electromagnetic fields on terrestrial flora and fauna have been identified. Such effects are not expected to be a problem during the license renewal term.	Electromagnetic fields on flora and fauna (plants, agricultural crops, honeybees, wildlife, livestock)[(b)]	**SMALL (Category 1).** No significant impacts of electromagnetic fields on terrestrial flora and fauna have been identified. Such effects are not expected to be a problem during the license renewal term.	Electromagnetic field effects on terrestrial plants and animals[(b)]	**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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

(b) 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.

Table B.1-9 Comparison of Aquatic Resources-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Impingement of fish and shellfish [for plants with once-through and cooling-pond heat dissipation systems]	**SMALL, MODERATE, or LARGE (Category 2).** The impacts of impingement are small at many plants but may be moderate or even large at a few plants with once-through and cooling-pond cooling systems. See § 51.53(c)(3)(ii)(B).	Impingement and entrainment of aquatic organisms (plants with once-through cooling systems or cooling ponds)	**SMALL, MODERATE, or LARGE (Category 2).** The impacts of impingement and entrainment are small at many plants but may be moderate or even large at a few plants with once-through and cooling-pond cooling systems, depending on cooling system withdrawal rates and volumes and the aquatic resources at the site.	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.
Entrainment of fish and shellfish in early life stages [for plants with once-through and cooling-pond heat dissipation systems]	**SMALL, MODERATE, or LARGE (Category 2).** The impacts of entrainment are small at many plants but may be moderate or even large at a few plants with once-through and cooling-pond				

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	cooling systems. Further, ongoing efforts in the vicinity of these plants to restore fish populations may increase the numbers of fish susceptible to intake effects during the license renewal period, such that entrainment studies conducted in support of the original license may no longer be valid. See § 51.53(c)(3)(ii)(B).				
Impingement of fish and shellfish [for plants with cooling-tower-based heat dissipation systems]	**SMALL (Category 1).** The impingement has not been found to be a problem at operating nuclear power plants with this type of cooling system and is not expected to be a problem during the license renewal term.	Impingement and entrainment of aquatic organisms (plants with cooling towers)	**SMALL (Category 1).** Impingement and entrainment rates are lower at plants that use closed-cycle cooling with cooling towers because the rates and volumes of water withdrawal needed for makeup are minimized.	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, effects of these cooling water intake systems would be mitigated through adherence to NPDES permit conditions established pursuant to CWA Section 316(b).

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Entrainment of fish and shellfish in early life stages [for plants with cooling-tower based heat dissipation systems]	**SMALL (Category 1).** Entrainment of fish has not been found to be a problem at operating nuclear power plants with this type of cooling system and is not expected to be a problem during the license renewal term.				
Entrainment of phytoplankton and zooplankton	**SMALL (Category 1).** Entrainment of phytoplankton and zooplankton has not been found to be a problem at operating nuclear power plants and is not expected to be a problem during the license renewal term.	Entrainment of phytoplankton and zooplankton (all plants)	**SMALL (Category 1).** Entrainment of phytoplankton and zooplankton has not been found to be a problem at operating nuclear power plants and is not expected to be a problem during the license renewal term.	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).
Heat shock [for plants with once-through and cooling-pond heat dissipation systems]	**SMALL, MODERATE, or LARGE (Category 2).** Because of continuing concerns about heat shock and the possible need to modify thermal discharges in response to changing environmental conditions, the impacts may be of moderate or large significance at some plants. See § 51.53(c)(3)(ii)(B).	Thermal impacts on aquatic organisms (plants with once-through cooling systems or cooling ponds)	**SMALL, MODERATE, or LARGE (Category 2).** Most of the effects associated with thermal discharges are localized and are not expected to affect overall stability of populations or resources. The magnitude of impacts, however, would depend on site-specific thermal plume characteristics and the nature of aquatic resources in the area.	Effects of thermal effluents on aquatic organisms (plants with once-through cooling systems or cooling ponds)	**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 have and maintain a valid CWA Section 316(a) variance. For all other

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
					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.
Heat shock [for plants with cooling-tower-based heat dissipation systems]	**SMALL (Category 1).** Heat shock has not been found to be a problem at operating nuclear power plants with this type of cooling system and is not expected to be a problem during the license renewal term.	Thermal impacts on aquatic organisms (plants with cooling towers)	**SMALL (Category 1).** Thermal effects associated with plants that use cooling towers are expected to be small because of the reduced amount of heated discharge.	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.
Cold shock	**SMALL (Category 1).** Cold shock has been satisfactorily mitigated at operating nuclear plants with once-through cooling systems, has not endangered fish populations or been found to be a problem at	Infrequently reported thermal impacts (all plants)	**SMALL (Category 1).** Continued operations during the license renewal term are expected to have small thermal impacts with respect to the following: Cold shock has been satisfactorily mitigated at	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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	operating nuclear power plants with cooling towers or cooling ponds, and is not expected to be a problem during the license renewal term.		operating nuclear plants with once-through cooling systems, has not endangered fish populations or been found to be a problem at operating nuclear power plants with cooling towers or cooling ponds, and is not expected to be a problem.		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.
Thermal plume barrier to migrating fish	**SMALL (Category 1).** Thermal plumes 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.		Thermal plumes have not been found to be a problem at operating nuclear power plants and are not expected to be a problem.		
Distribution of aquatic organisms	**SMALL (Category 1).** Thermal discharge may have localized effects but is not expected to effect		Thermal discharge may have localized effects but is not expected to affect the larger geographical		

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	[sic] the larger geographical distribution of aquatic organisms.		distribution of aquatic organisms.		
Premature emergence of aquatic insects	**SMALL (Category 1).** Premature emergence has been found to be a localized effect at some operating nuclear power plants but has not been a problem and is not expected to be a problem during the license renewal term.		Premature emergence has been found to be a localized effect at some operating nuclear power plants but has not been a problem and is not expected to be a problem.		
Stimulation of nuisance organisms (e.g., shipworms)	**SMALL (Category 1).** Stimulation of nuisance organisms has been satisfactorily mitigated at the single nuclear power plant with a once-through cooling system where previously it was a problem. It has not been found to be a problem at operating nuclear power plants with cooling towers or cooling ponds and is not expected to be a problem during the license renewal term.		Stimulation of nuisance organisms has been satisfactorily mitigated at the single nuclear power plant with a once-through cooling system where previously it was a problem. It has not been found to be a problem at operating nuclear power plants with cooling towers or cooling ponds and is not expected to be a problem.		
Gas supersaturation (gas bubble disease)	**SMALL (Category 1).** Gas supersaturation was a concern at a small number of operating nuclear power plants with once-through cooling	Effects of cooling water discharge on dissolved oxygen, gas supersaturation,	**SMALL (Category 1).** Gas supersaturation was a concern at a small number of operating nuclear power plants with once-through cooling		

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	systems but has been satisfactorily mitigated. It has not been found to be a problem at operating nuclear power plants with cooling towers or cooling ponds and is not expected to be a problem during the license renewal term.	and eutrophication	systems but has been mitigated. Low dissolved oxygen was a concern at one nuclear power plant with a once-through cooling system but has been mitigated. Eutrophication (nutrient loading) and resulting effects on chemical and biological oxygen demands have not been found to be a problem at operating nuclear power plants.		
Low dissolved oxygen in the discharge	**SMALL (Category 1).** Low dissolved oxygen has been a concern at one nuclear power plant with a once-through cooling system but has been effectively mitigated. It has not been found to be a problem at operating nuclear power plants with cooling towers or cooling ponds and is not expected to be a problem during the license renewal term.				
Eutrophication	**SMALL (Category 1).** Eutrophication has not been found to be a problem at operating nuclear power plants and				

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	is not expected to be a problem during the license renewal term.				
Losses from predation, parasitism, and disease among organisms exposed to sublethal stresses	**SMALL (Category 1).** These types of losses 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.	Losses from predation, parasitism, and disease among organisms exposed to sublethal stresses	**SMALL (Category 1).** These types of losses 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.		
Accumulation of contaminants in sediments or biota	**SMALL (Category 1).** Accumulation of contaminants has been a concern at a few nuclear power plants but has been satisfactorily mitigated by replacing copper alloy condenser tubes with those of another metal. It is not expected to be a problem during the license renewal term.	Effects of nonradiological contaminants on aquatic organisms	**SMALL (Category 1).** Best management practices and discharge limitations of NPDES permits are expected to minimize the potential for impacts to aquatic resources during continued operations and refurbishment associated with license renewal. Accumulation of metal contaminants has been a concern at a few nuclear power plants but has been satisfactorily mitigated by replacing copper alloy condenser tubes with those of another metal.	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.
Not addressed	Not applicable	Exposure of aquatic organisms to radionuclides	**SMALL (Category 1).** Doses to aquatic organisms are expected to be well below exposure guidelines developed to	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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
			protect these aquatic organisms.		be expected to remain well below U.S. Department of Energy exposure guidelines developed to protect these organisms.
Not addressed	Not applicable	Effects of dredging on aquatic organisms	**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. Dredging is performed under permit from the U.S. Army Corps of Engineers, and possibly from other State or local agencies.	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 (plants with cooling ponds or cooling towers using make-up water from a small river with low flow)	**SMALL or MODERATE (Category 2).** The issue has been a concern at nuclear power plants with cooling ponds and at plants with cooling towers. Impacts on instream and riparian communities near these plants could be of moderate significance in some situations. See § 51.53(c)(3)(ii)(A).	Water use conflicts with aquatic resources (plants with cooling ponds or cooling towers using makeup water from a river)	**SMALL or MODERATE (Category 2).** Impacts on aquatic resources in stream communities affected by water use conflicts could be of moderate significance in some situations.	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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[a]	2024 LR GEIS Finding[a]
					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.
Refurbishment	**SMALL (Category 1).** During plant shutdown and refurbishment there will be negligible effects on aquatic biota because of a reduction of entrainment and impingement of organisms or a reduced release of chemicals.	Effects on aquatic resources (non-cooling system impacts)	**SMALL (Category 1).** Licensee application of appropriate mitigation measures is expected to result in no more than small changes to aquatic communities from their current condition.	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.
Not addressed	Not applicable	Impacts of transmission line right-of-way (ROW) management on aquatic resources[b]	**SMALL (Category 1).** Licensee application of best management practices to ROW maintenance is expected to result in no more than small impacts on aquatic resources.	Impacts of transmission line right-of-way (ROW) management on aquatic resources[b]	**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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
					term would be negligible. Application of best management practices would reduce the potential for impacts.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

(b) 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.

Table B.1-10 Comparison of Federally Protected Ecological Resources-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Threatened or endangered species	**SMALL, MODERATE, or LARGE (Category 2).** Generally, plant refurbishment and continued operation are not expected to adversely affect threatened or endangered species. However, consultation with appropriate agencies would be needed at the time of license renewal to determine whether threatened or endangered species are present and whether they would be adversely affected. See § 51.53(c)(3)(ii)(E).	Threatened, endangered, and protected species and essential fish habitat	**(Category 2).** The magnitude of impacts on threatened, endangered, and protected species, critical habitat, and essential fish habitat would depend on the occurrence of listed species and habitats and the effects of power plant systems on them. Consultation with appropriate agencies would be needed to determine whether special status species or habitats are present and whether they would be adversely affected by continued operations and refurbishment associated with license renewal.	Endangered Species Act: federally listed species and critical habitats under U.S. Fish and Wildlife 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 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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
					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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
					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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

Table B.1-11 Comparison of Historic and Cultural Resources-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Historic and archaeological resources	**SMALL, MODERATE, or LARGE (Category 2).** Generally, plant refurbishment and continued operation are expected to have no more than small adverse impacts on historic and archaeological resources. However, the National Historic Preservation Act requires the Federal agency to consult with the State Historic Preservation Officer to determine whether there are properties present that require protection. See § 51.53(c)(3)(ii)(K).	Historic and cultural resources[(b)]	**(Category 2).** Continued operations and refurbishment associated with license renewal are expected to have no more than small impacts on historic and cultural resources located onsite and in the transmission line ROW because most impacts could be mitigated by avoiding those resources. The National Historic Preservation Act (NHPA) requires the Federal agency to consult with the State Historic Preservation Officer (SHPO) and appropriate Native American Tribes to determine the potential effects on historic properties and mitigation, if necessary.	Historic and cultural resources[(b)]	**(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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

(b) 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.

Table B.1-12 Comparison of Socioeconomics-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Public services: public safety, social services, and tourism and recreation	**SMALL (Category 1).** Impacts to public safety, social services, and tourism and recreation are expected to be of small significance at all sites.	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.	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.
Considered in the 1996 LR GEIS, but not listed as a separate issue	Not applicable	Tax revenues	**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.	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.
Public services: public safety, social services, and tourism and recreation	**SMALL (Category 1).** Impacts to public safety, social services, and tourism and recreation are expected to be of small significance at all sites.	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	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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
			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.		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.
Public services: public utilities	**SMALL or MODERATE (Category 2).** An increased problem with water shortages at some sites may lead to impacts of moderate significance on public water supply availability. See § 51.53(c)(3)(ii)(I).				
Public services, education (license renewal term)	**SMALL (Category 1).** Only impacts of small significance are expected.				
Public services, education (refurbishment)	**SMALL, MODERATE, or LARGE (Category 2).** Most sites would experience impacts of small significance but larger impacts are possible depending on site- and				

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	project-specific factors. See § 51.53(c)(3)(ii)(I).				
Housing impacts	**SMALL, MODERATE, or LARGE (Category 2).** Housing impacts are expected to be of small significance at plants located in a medium or high population area and not in an area where growth control measures that limit housing development are in effect. Moderate or large housing impacts of the workforce associated with refurbishment may be associated with plants located in sparsely populated areas or in areas with growth control measures that limit housing development. See § 51.53(c)(3)(ii)(I).	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.	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.
Public services, Transportation	**SMALL, MODERATE, or LARGE (Category 2).** Transportation impacts (level of service) of highway traffic generated during plant refurbishment and during the term of the renewed license are generally expected to be of small significance. However, the increase in traffic associated with additional workers and the	Transportation	**SMALL (Category 1).** Changes resulting from continued operations and refurbishment associated with license renewal to traffic volumes would be small.	Transportation	**SMALL (Category 1).** Changes resulting from continued operations and refurbishment associated with license renewal to traffic volumes would be small.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	local road and traffic control conditions may lead to impacts of moderate or large significance at some sites. See § 51.53(c)(3)(ii)(J).				

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

Table B.1-13 Comparison of Human Health-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Occupational radiation exposures during refurbishment	**SMALL (Category 1).** Occupational doses from refurbishment are expected to be within the range of annual average collective doses experienced for pressurized-water reactors and boiling-water reactors. Occupational mortality risk from all causes including radiation is in the mid-range for industrial settings.	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 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.
Occupational radiation exposures (license renewal term)	**SMALL (Category 1).** Projected maximum occupational doses during the license renewal term are within the range of doses experienced during normal operations and normal maintenance outages, and would be well below regulatory limits.				
Radiation exposures to the public during refurbishment	**SMALL (Category 1).** During refurbishment, the gaseous effluents would result in doses that are similar to those from current operation. Applicable regulatory dose limits to the public are not expected to be exceeded.	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	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.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
			be well below regulatory limits.		
Radiation exposures to public (license renewal term)	**SMALL (Category 1).** Radiation doses to the public will continue at current levels associated with normal operations.				
Not addressed	Not applicable	Human health impact from chemicals	**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 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.	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 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.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Microbiological organisms (occupational health)	**SMALL (Category 1).** Occupational health impacts are expected to be controlled by continued application of accepted industrial hygiene practices to minimize worker exposures.	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 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 organisms (public health) (plants using lakes or canals, or cooling towers or cooling ponds that discharge to a small river)	**SMALL, MODERATE, or LARGE (Category 2).** These organisms are not expected to be a problem at most operating plants except possibly at plants using cooling ponds, lakes, or canals that discharge to small rivers. Without site-specific data, it is not possible to predict the effects generically. See § 51.53(c)(3)(ii)(G).	Microbiological hazards to the public (plants with cooling ponds or canals or cooling towers that discharge to a river)	**SMALL, MODERATE, or LARGE (Category 2).** These organisms are not expected to be a problem at most operating plants except possibly at plants using cooling ponds, lakes, or canals, or that discharge into rivers. Impacts would depend on site-specific characteristics.	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 publicly accessible surface waters. Impacts would depend on site-specific characteristics.
Electromagnetic fields, chronic effects[(b)]	**UNCERTAIN (NA).** Biological and physical studies of 60-Hz electromagnetic fields have not found consistent evidence linking harmful effects with field exposures. However, research is continuing in this area and a consensus scientific view has not been reached.	Chronic effects of electromagnetic fields (EMFs)[(b,c)]	**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,	Electromagnetic fields (EMFs)[(b,c)]	**Uncertain impact.** Studies of 60Hz 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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
			are subtle. Because the state of the science is currently inadequate, no generic conclusion on human health impacts is possible.		the science is currently inadequate, no generic conclusion on human health impacts is possible.
Not addressed	Not applicable	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.	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.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Electromagnetic fields, acute effects (electric shock)	**SMALL, MODERATE, or LARGE (Category 2).** Electrical shock resulting from direct access to energized conductors or from induced charges in metallic structures have not been found to be a problem at most operating plants and generally are not expected to be a problem during the license renewal term. However, site-specific review is required to determine the significance of the electric shock potential at the site. See § 51.53(c)(3)(ii)(H).	Electric shock hazards[(b)]	**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 plant's in-scope transmission lines, it is not possible to determine the significance of the electrical shock potential.	Electric shock hazards[(b)]	**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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

(b) 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.

(c) If, in the future, the Commission finds that, contrary to current indications, a consensus has been reached by appropriate Federal health agencies that there are adverse health effects from electromagnetic fields, the Commission will require applicants to submit plant-specific reviews of these health effects as part of their license renewal applications. Until such time, applicants for license renewal are not required to submit information on this issue.

Table B.1-14 Comparison of Postulated Accidents-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
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.	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.	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	**SMALL (Category 2).** The probability weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to ground water, and societal and economic impacts from severe accidents are small for all plants. However, alternatives to mitigate severe accidents must be considered for all plants that have not considered such alternatives. See § 51.53(c)(3)(ii)(L).	Severe accidents	**SMALL (Category 2).** 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. However, alternatives to mitigate severe accidents must be considered for all plants that have not considered such alternatives.	Severe accidents[(b)]	**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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

(b) 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 and would be the functional equivalent of a Category 2 issue requiring plant-specific analysis.

Table B.1-15 Comparison of Environmental Justice-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Environmental justice	**None (NA).** The need for and the content of an analysis of environmental justice will be addressed in plant-specific reviews.[(b)]	Minority and low-income populations	**(Category 2).** Impacts on minority and low-income populations and subsistence consumption resulting from continued operations and refurbishment associated with license renewal will be addressed in plant-specific reviews. See NRC Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions (69 FR 52040; August 24, 2004).	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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

(b) Environmental Justice was not addressed in NUREG-1437, ‘‘Generic Environmental Impact Statement for License Renewal of Nuclear Plants,’’ because guidance for implementing Executive Order 12898 [59 FR 7629] issued on February 11, 1994, was not available prior to completion of NUREG-1437. This issue will be addressed in individual license renewal reviews.

Table B.1-16 Comparison of Waste Management-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
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 to the environment will remain small during the term of a renewed license. The maximum additional on-site land that may be required for low-level waste storage during the term of a renewed license and associated impacts will be small. Nonradiological impacts on air and water will be negligible. The radiological and nonradiological environmental impacts of long-term disposal of low-level waste from any individual plant at licensed sites are small. In addition, the Commission concludes that there is reasonable assurance that sufficient low-level waste disposal capacity will be made available	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.	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 to the environment would remain small during the license renewal term.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	when needed for facilities to be decommissioned consistent with NRC decommissioning requirements.				
On-site spent fuel	**SMALL (Category 1).** The expected increase in the volume of spent fuel from an additional 20 years of operation can be safely accommodated on site with small environmental effects through dry or pool storage at all plants if a permanent repository or monitored retrievable storage is not available.	Onsite storage of spent nuclear fuel	**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 effects through dry or pool storage at all plants.	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. 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 (spent fuel and high level waste disposal)	**(Category 1).** The NRC did not assign a single level of significance for the impacts of spent fuel and high-level waste disposal, but considered the issue Category 1.[(b)]	Offsite radiological impacts of spent nuclear fuel and high-level waste disposal	**Uncertain impact.** The generic conclusion on offsite radiological impacts of spent nuclear fuel and high-level waste is not being finalized pending the completion of	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)

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
			a generic environmental impact statement on waste confidence.[(c)]		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. 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	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	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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	materials for the public and the environment at all plants. License renewal will 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. In addition, the Commission concludes that there is reasonable assurance that sufficient mixed waste disposal capacity will be made available when needed for facilities to be decommissioned consistent with NRC decommissioning requirements.		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.		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.
Nonradiological waste	**SMALL (Category 1).** No changes to generating systems are anticipated for license renewal. Facilities and procedures are in place to ensure continued proper handling and disposal at all plants.	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	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

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
			toxic materials for the public and the environment at all plants.		toxic materials for the public and the environment at all plants.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

(b) For the high level waste and spent fuel disposal component of the fuel cycle, there are no current regulatory limits for offsite releases of radionuclides for the current candidate repository site. However, if we assume that limits are developed along the lines of the 1995 National Academy of Sciences (NAS) report, “Technical Bases for Yucca Mountain Standards,” and that in accordance with the Commission's Waste Confidence Decision, 10 CFR 51.23, a repository can and likely will be developed at some site which will comply with such limits, peak doses to virtually all individuals will be 100 millirem per year or less. However, while the Commission has reasonable confidence that these assumptions will prove correct, there is considerable uncertainty since the limits are yet to be developed, no repository application has been completed or reviewed, and uncertainty is inherent in the models used to evaluate possible pathways to the human environment. The NAS report indicated that 100 millirem per year should be considered as a starting point for limits for individual doses, but notes that some measure of consensus exists among national and international bodies that the limits should be a fraction of the 100 millirem per year. The lifetime individual risk from 100 millirem annual dose limit is about 3×10^{-3}.

Estimating cumulative doses to populations over thousands of years is more problematic. The likelihood and consequences of events that could seriously compromise the integrity of a deep geologic repository were evaluated by the Department of Energy in the “Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste,” October 1980. The evaluation estimated the 70-year whole-body dose commitment to the maximally exposed individual and to the regional population resulting from several modes of breaching a reference repository in the year of closure, after 1,000 years, after 100,000 years, and after 100,000,000 years. Subsequently, the NRC and other Federal agencies have expended considerable effort to develop models for the design and for the licensing of a high level waste repository, especially for the candidate repository at Yucca Mountain. More meaningful estimates of doses to the population may be possible in the future as more is understood about the performance of the proposed Yucca Mountain repository. Such estimates would involve very great uncertainty, especially with respect to cumulative population doses over thousands of years. The standard proposed by the NAS is a limit on maximum individual dose. The relationship of potential new regulatory requirements, based on the NAS report, and cumulative population impacts has not been determined, although the report articulates the view that protection of individuals will adequately protect the population for a repository at Yucca Mountain. However, the EPA's generic repository standards in 40 CFR part 191 generally provide an indication of the order of magnitude of cumulative risk to population that could result from the licensing of a Yucca Mountain repository, assuming the ultimate standards will be within the range of standards now under consideration. The standards in 40 CFR part 191 protect the population by imposing “containment requirements” that limit the cumulative amount of radioactive material released over 10,000 years. Reporting performance standards that will be required by EPA are expected to result in releases and associated health consequences in the range between 10 and 100 premature cancer deaths with an upper limit of 1,000 premature cancer deaths world-wide for a 100,000 metric tonne (MTHM) repository.

Nevertheless, despite all the uncertainty, 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. Even taking the uncertainties into account, 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 impacts of spent fuel and high level waste disposal, this issue is considered Category 1.

(c) As a result of the decision of *United States Court of Appeals in New York v. NRC*, 681 F.3d 471 (D.C. Cir. 2012), the NRC cannot rely upon its waste confidence decision and rule until it has taken those actions that will address the deficiencies identified by the D.C. Circuit. Although the waste confidence decision and rule did not assess the impacts associated with disposal of spent nuclear fuel and high-level waste in a repository, it did reflect the Commission’s confidence, at the time, in the technical feasibility of a repository and when that repository could have been expected to become available. Without the analysis in the waste confidence decision and rule regarding the technical feasibility and availability of a repository, the NRC cannot assess how long the spent fuel will need to be stored onsite. Note: In 2014, the NRC issued the Continued Storage Final Rule (79 FR 56238) that addressed the generic determination of the environmental impacts of continued storage of spent nuclear fuel beyond a reactor’s licensed life for operation. This 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.”

Table B.1-17 Comparison of Greenhouse Gas Emissions and Climate Change-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Not addressed	Not applicable	Not addressed	Not applicable	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. Greenhouse gas emissions from construction vehicles and other motorized equipment for refurbishment activities would be intermittent and temporary, 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.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Not addressed	Not applicable	Not addressed	Not applicable	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 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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

Table B.1-18 Comparison of Cumulative Effects-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Not addressed	Not applicable	Cumulative impacts	**(Category 2).** Cumulative impacts of continued operations and refurbishment associated with license renewal must be considered on a plant-specific basis. Impacts would depend on regional resource characteristics, the resource-specific impacts of license renewal, and the cumulative significance of other factors affecting the resource.	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.

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

Table B.1-19 Comparison of Uranium Fuel Cycle-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Offsite radiological impacts (individual effects from other than the disposal of spent fuel and high level waste)	**SMALL (Category 1).** Off-site impacts of the uranium fuel cycle have been considered by the Commission in Table S-3 of this part. Based on information in the GEIS, impacts on individuals from radioactive gaseous and liquid releases including radon-222 and technetium-99 are small.	Offsite radiological impacts—individual impacts from other than the disposal of spent fuel and high-level waste	**SMALL (Category 1).** The impacts on 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 on 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—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 effects)	**(Category 1).** The NRC did not assign a single level of significance for the collective effects of the fuel cycle, but considered the issue Category 1.[(b)]	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. The Commission concludes that the	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.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
			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.		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 are found to be small.	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.	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 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	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.	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.

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	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 § 51.52.				

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

(b) The 100 year environmental dose commitment to the U.S. population from the fuel cycle, high level waste and spent fuel disposal excepted, is calculated to be about 14,800 person rem, or 12 cancer fatalities, for each additional 20-year power reactor operating term. Much of this, especially the contribution of radon releases from mines and tailing piles, consists of tiny doses summed over large populations. This same dose calculation can theoretically be extended to include many tiny doses over additional thousands of years as well as doses outside the U.S. The result of such a calculation would be thousands of cancer fatalities from the fuel cycle, but this result assumes that even tiny doses have some statistical adverse health effect which will not ever be mitigated (for example no cancer cure in the next thousand years), and that these doses projected over thousands of years are meaningful. However, these assumptions are questionable. In particular, science cannot rule out the possibility that there will be no cancer fatalities from these tiny doses. For perspective, the doses are very small fractions of regulatory limits, and even smaller fractions of natural background exposure to the same populations.

Nevertheless, despite all the uncertainty, 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. Even taking the uncertainties into account, 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 is considered Category 1.

Table B.1-20 Comparison of Termination of Nuclear Power Plant Operations and Decommissioning-Related Environmental Issues and Findings in This LR GEIS Revision to Prior Versions of Table B-1 of 10 CFR Part 51

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
Air quality	**SMALL (Category 1).** Air quality impacts of decommissioning are expected to be negligible either at the end of the current operating term or at the end of the license renewal term.	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.	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.
Water quality	**SMALL (Category 1).** The potential for significant water quality impacts from erosion or spills is no greater whether decommissioning occurs after a 20-year license renewal period or after the original 40-year operation period, and measures are readily available to avoid such impacts.				
Ecological resources	**SMALL (Category 1).** Decommissioning after either the initial operating period or after a 20-year license renewal period is not expected to have any direct ecological impacts.				
Socioeconomic impacts	**SMALL (Category 1).** Decommissioning would have some short-term				

1996 LR GEIS Issue	1996 LR GEIS Finding	2013 LR GEIS Issue	2013 LR GEIS Finding	2024 LR GEIS Issue[(a)]	2024 LR GEIS Finding[(a)]
	socioeconomic impacts. The impacts would not be increased by delaying decommissioning until the end of a 20-year relicense period, but they might be decreased by population and economic growth.				
Radiation doses	**SMALL (Category 1).** Doses to the public will be well below applicable regulatory standards regardless of which decommissioning method is used. Occupational doses would increase no more than 1 man-rem caused by buildup of long-lived radionuclides during the license renewal term.				
Waste management	**SMALL (Category 1).** Decommissioning at the end of a 20-year license renewal period would generate no more solid wastes than at the end of the current license term. No increase in the quantities of Class C or greater than Class C wastes would be expected.				

(a) The technical bases for these issues and findings in the LR GEIS have been revised to fully account for the impacts of initial and one term of subsequent license renewal.

B.2 References

10 CFR Part 51. *Code of Federal Regulations*, Title 10, *Energy*, Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions."

59 FR 7629. February 16, 1994. "Executive Order 12898 of February 11, 1994: Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations." *Federal Register*, Office of the President.

61 FR 28467. June 5, 1996. "Environmental Review for Renewal of Nuclear Power Plant Operating Licenses." Final Rule, *Federal Register*, Nuclear Regulatory Commission.

61 FR 66537. December 18, 1996. "Environmental Review for Renewal of Nuclear Power Plant Operating Licenses." Final Rule, *Federal Register*, Nuclear Regulatory Commission.

62 FR 59276. November 3, 1997. "10 CFR Parts 13, 32, 50, 51, 55, 60, 72, and 110, Minor Correcting Amendments." Final Rule; Technical amendment, *Federal Register*, Nuclear Regulatory Commission.

64 FR 48496. September 3, 1999. "Changes to Requirements for Environmental Review for Renewal of Nuclear Power Plant Operating Licenses." Final Rule, *Federal Register*, Nuclear Regulatory Commission.

66 FR 39278. July 30, 2001. "Environmental Review for Renewal of Nuclear Power Plant Operating Licenses; Correction." Final Rule: Correcting amendment, *Federal Register*, Nuclear Regulatory Commission.

78 FR 37282. June 20, 2013. "Revisions to Environmental Review for Renewal of Nuclear Power Plant Operating Licenses." Final Rule, *Federal Register*, Nuclear Regulatory Commission.

79 FR 56262. September 19, 2014. "Continued Storage of Spent Nuclear Fuel." Final Rule, *Federal Register,* Nuclear Regulatory Commission.

NRC (U.S. Nuclear Regulatory Commission). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*. Volumes 1 and 2, NUREG-1437, Washington, D.C. ADAMS Accession Nos. ML040690705, ML040690738.

NRC (U.S. Nuclear Regulatory Commission). 2013. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* [GEIS]. NUREG-1437, Revision 1, Washington, D.C. ADAMS Package Accession No. ML13107A023.

APPENDIX C

GENERAL CHARACTERISTICS AND ENVIRONMENTAL SETTINGS OF OPERATING DOMESTIC NUCLEAR POWER PLANTS

APPENDIX C

GENERAL CHARACTERISTICS AND ENVIRONMENTAL SETTINGS OF OPERATING DOMESTIC NUCLEAR POWER PLANTS

This appendix contains brief descriptions of each operating commercial nuclear power plant site in the United States.[1] The material is intended to serve as an overview of the important characteristics of each plant and its environmental setting. The information was taken from the 1996 and 2013 *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (LR GEIS, NUREG-1437, Revisions 0 and 1; NRC 1996, NRC 2013) and updated with the best available information from recently published supplemental environmental impacts statements, U.S. Census Bureau population estimates (USCB 2021), U.S. Environmental Protection Agency Level III ecoregion data (EPA 2013), National Wetlands Inventory data (FWS 2022), National Land Cover Database data (USGS 2019), the 2022–2023 U.S. Nuclear Regulatory Commission Information Digest (NRC 2023a), and license renewal applications, including associated environmental reports, as docketed by the U.S. Nuclear Regulatory Commission.

[1] The scope of this revised LR GEIS is limited to nuclear power plants for which an operating license, construction permit, or combined license was issued as of June 30, 1995. Nuclear power plants not meeting these conditions (such as Vogtle Units 3 and 4 in Waynesboro, Georgia, which commenced commercial operations in July 2023 and April 2024, respectively), are not included in this appendix.

ARKANSAS NUCLEAR ONE (Arkansas)

Location: Pope County, Arkansas
6 mi (10 km) WNW of Russellville
Latitude 35.3100°N; longitude 93.2308°W
Licensee: Entergy Operations, Inc.

Unit Information	Unit 1	Unit 2
Docket Number:	50-313	50-368
Construction Permit:	1968	1972
Operating License:	1974	1978
Commercial Operation:	1974	1980
License Expiration:	2034	2038
Licensed Thermal Power (MWt):	2,568	3,026
Net Capacity (MWe):	833	985
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	B&W	CE

Cooling Water System

Type: Unit 1: Once-through; Unit 2: Natural draft cooling tower
Source: Dardanelle Reservoir
Source Temperature Range: 40–83°F (4–28°C)
Condenser Flow Rate: 762,400 gpm (48.1 m^3/s) for Unit 1
422,000 gpm (26.6 m^3/s) for Unit 2
Design Condenser Temperature Rise: 5°F (8.3°C) for Unit 1
30.7°F (17.1°C) for Unit 2
Intake Structure: 4,400 ft (1,340 m) canal
Discharge Structure: 520 ft (158 m) canal

Site Information

Total Area: 1,164 ac (471 ha)
Exclusion Area Distance: 0.7 mi (1 km) radius
Low Population Zone: 4 mi (6.44 km) radius
Nearest City: Little Rock: 2020 population: 202,591
Site Topography: Flat
Surrounding Area Topography: Hilly to mountainous
Dominant Land Cover within 5 mi (8 km): Forest, agriculture, open water
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Arkansas Valley
Percent Wetland within 5 mi (8 km): 0.9
Nearby Features: The nearest town is London 2 mi (3 km) NW. The size of Lake Dardanelle is 37,000 ac (15,000 ha). The reservoir is part of the Arkansas River. Interstate Highway I-40 is directly north of the site.
Population within a 50 mi (80 km) Radius: 312,591.

BEAVER VALLEY POWER STATION (Beaver Valley)

Location: Beaver County, Pennsylvania
25 mi (40 km) NW of Pittsburgh
Latitude 40.6219°N; longitude 80.4339°W
Licensee: Energy Harbor Nuclear Corporation

Unit Information	Unit 1	Unit 2
Docket Number:	50-334	50-412
Construction Permit:	1970	1974
Operating License:	1976	1987
Commercial Operation:	1976	1987
License Expiration:	2036	2047
Licensed Thermal Power (MWt):	2,900	2,900
Net Capacity (MWe):	892	901
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Natural draft cooling towers
Source: Ohio River
Source Temperature Range: 36.5–79.5°F (2.5–26.4°C)
Condenser Flow Rate: 480,400 gpm (30.31 m^3/s) each unit
Design Condenser Temperature Rise: 26°F (14°C)
Intake Structure: Concrete structure at river edge
Discharge Structure: At river edge

Site Information

Total Area: 453 ac (183 ha)
Exclusion Area Distance: 0.38 mi (0.61 km)
Low Population Zone: 3.60 mi (5.79 km)
Nearest City: Pittsburgh; 2020 population: 302,971
Site Topography: Flat
Surrounding Area Topography: Hilly
Dominant Land Cover within 5 mi (8 km): Forest, agriculture, developed: open space
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Western Allegheny Plateau
Percent Wetland within 5 mi (8 km): 0.5
Nearby Features: The nearest town is Midland 1 mi (1.6 km) NW. A large industrial area is about 1 mi (1.6 km) WNW. Beaver Creek and Raccoon Creek State Parks are within 10 mi (16 km).
Population within a 50 mi (80 km) Radius: 3,146,489.

BRAIDWOOD STATION (Braidwood)

Location: Will County, Illinois
39 km (24 mi) SSW of Joliet
Latitude 41.2436°N; longitude 88.2297°W
Licensee: Constellation Energy Generation, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-456	50-457
Construction Permit:	1975	1975
Operating License:	1987	1988
Commercial Operation:	1988	1988
License Expiration:	2046	2047
Licensed Thermal Power (MWt):	3,645	3,645
Net Capacity (MWe):	1,183	1,154
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Cooling pond
Source: Kankakee River
Source Temperature Range: 32–87°F (0–31°C)
Condenser Flow Rate: 729,800 gpm (46.05 m^3/s)
Design Condenser Temperature Rise: 21°F (12°C)
Intake Structure: Concrete structure at lake shore (Braidwood Lake cooling pond)
Discharge Structure: Surface discharge flume to lake

Site Information

Total Area: 4,457 ac (1,804 ha)
Exclusion Area Distance: 0.3 mi (0.48 km) minimum
Low Population Zone: 1.125 mi (1.810 km) radius
Nearest City: Joliet; 2020 population: 150,362
Site Topography: Flat to rolling
Surrounding Area Topography: Flat to rolling
Dominant Land Cover within 5 mi (8 km): Agriculture, forest, developed: high, medium, low density
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Central Corn Belt Plains
Percent Wetland within 5 mi (8 km): 3.9
Nearby Features: The nearest town is Godley 0.5 mi (0.8 km) SW. There are 4 State parks within 10 mi (16 km). Midewin National Tallgrass Prairie and Abraham Lincoln National Cemetery are about 8 mi (13 km) NE. Dresden Nuclear Power Station is about 10 mi (16 km) N, and LaSalle County Station (nuclear) is about 20 mi (32 km) WSW. Interstate Highway I-55 is about 2 mi (3 km) NW.
Population within a 50 mi (80 km) Radius: 5,033,013.

BROWNS FERRY NUCLEAR PLANT (Browns Ferry)

Location: Limestone County, Alabama
16 km (10 mi) NW of Decatur
Latitude 34.7042°N; longitude 87.1186°W
Licensee: Tennessee Valley Authority

Unit Information	Unit 1	Unit 2	Unit 3
Docket Number:	50-259	50-260	50-296
Construction Permit:	1967	1967	1968
Operating License:	1973	1974	1976
Commercial Operation:	1974	1975	1977
License Expiration:	2033	2034	2036
Licensed Thermal Power (MWt):	3,952	3,952	3,952
Net Capacity (MWe):	1,256	1,259	1,260
Type of Reactor:	BWR	BWR	BWR
Nuclear Steam Supply System Vendor:	GE	GE	GE

Cooling Water System

Type: Once-through with helper towers
Source: Tennessee River
Source Temperature Range: 40–90°F (4–32°C)
Condenser Flow Rate: 734,000 gpm (139 m^3/s); for all three units
Design Condenser Temperature Rise: 28.7°F (15.9°C)
Intake Structure: Concrete structure in small inlet
Discharge Structure: Diffuser pipes

Site Information

Total Area: 840 ac (340 ha)
Exclusion Area Distance: 0.76 mi (1.22 km) radius
Low Population Zone: 7 mi (11.3 km)
Nearest City: Huntsville; 2020 population: 215,006
Site Topography: Flat
Surrounding Area Topography: Flat to rolling
Dominant Land Cover within 5 mi (8 km): Agriculture, open water, forest
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Interior Plateau
Percent Wetland within 5 mi (8 km): 11.9, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Lawngate 1 mi (1.6 km) NE. The Redstone Arsenal is 25 mi (40 km) E. Two wildlife management areas are located within 3 mi (5 km) of the plant.
Population within a 50 mi (80 km) Radius: 1,081,319.

BRUNSWICK STEAM ELECTRIC PLANT (Brunswick)

Location: Brunswick County, North Carolina
16 mi (26 km) S of Wilmington
Latitude 33.9583°N; longitude 78.0106°W
Licensee: Duke Energy Progress, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-325	50-324
Construction Permit:	1967	1968
Operating License:	1976	1974
Commercial Operation:	1977	1975
License Expiration:	2036	2034
Licensed Thermal Power (MWt):	2,923	2,923
Net Capacity (MWe):	938	932
Type of Reactor:	BWR	BWR
Nuclear Steam Supply System Vendor:	GE	GE

Cooling Water System

Type: Once-through
Source: Cape Fear River
Source Temperature Range: 40–86°F (4–30°C)
Condenser Flow Rate: 675,000 gpm (42.6 m^3/s)
Design Condenser Temperature Rise: 17°F (9°C)
Intake Structure: 3 mi (5 km) canal from Cape Fear River
Discharge Structure: 6 mi (10 km) canal to Atlantic Ocean

Site Information

Total Area: 1,200 ac (490 ha)
Exclusion Area Distance: 0.57 mi (0.92 km)
Low Population Zone: 2 mi (3.22 km)
Nearest City: Wilmington; 2020 population: 115,451
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Wetland, open water, forest
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Middle Atlantic Coastal Plain
Percent Wetland within 5 mi (8 km): 32.3, mostly freshwater forested/shrub wetland and estuarine and marine wetland
Nearby Features: The nearest town is Southport 3 mi (5 km) S. Sunny Point Military Ocean Terminal is about 5 mi (8 km) N.
Population within a 50 mi (80 km) Radius: 548,758.

BYRON STATION (Byron)

Location: Ogle County, Illinois
17 mi (27 km) SW of Rockford
Latitude 42.0750°N; longitude 89.2811°W
Licensee: Constellation Energy Generation, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-454	50-455
Construction Permit:	1975	1975
Operating License:	1985	1987
Commercial Operation:	1985	1987
License Expiration:	2044	2046
Licensed Thermal Power (MWt):	3,645	3,645
Net Capacity (MWe):	1,182	1,154
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Natural draft towers
Source: Rock River
Source Temperature Range: Not available
Condenser Flow Rate: 632,000 gpm (39.9 m^3/s)
Design Condenser Temperature Rise: 24°F (13°C)
Intake Structure: Concrete structure on river bank
Discharge Structure: Discharged to river

Site Information

Total Area: 1,398 ac (565.8 ha)
Exclusion Area Distance: 0.26 mi (0.42 km)
Low Population Zone: 3 mi (4.83 km)
Nearest City: Rockford; 2020 population: 148,655
Site Topography: Rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Agriculture, forest, developed: open space
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Central Corn Belt Plains
Percent Wetland within 5 mi (8 km): 1.8, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Byron about 3 mi (5 km) NNE. White Pines State Park is about 11 mi (18 km) WSW.
Population within a 50 mi (80 km) Radius: 1,284,960.

CALLAWAY PLANT (Callaway)

Location: Callaway County, Missouri
10 mi (16 km) SE of Fulton
Latitude 38.7622°N; longitude 91.7817°W
Licensee: Ameren Missouri

Unit Information	Unit 1
Docket Number:	50-483
Construction Permit:	1976
Operating License:	1984
Commercial Operation:	1984
License Expiration:	2044
Licensed Thermal Power (MWt):	3,565
Net Capacity (MWe):	1,190
Type of Reactor:	PWR
Nuclear Steam Supply System Vendor:	WEST

Cooling Water System

Type: Natural draft cooling tower
Source: Missouri River
Source Temperature Range: Not available
Condenser Flow Rate: 530,000 gpm (33 m^3/s)
Design Condenser Temperature Rise: 30°F (17°C)
Intake Structure: Intake from river
Discharge Structure: Discharged to river

Site Information

Total Area: 5,228 ac (2,115.8 ha)
Exclusion Area Distance: 0.75 mi (1.21 km) radius
Low Population Zone: 2.50 mi (4.02 ha)
Nearest City: Columbia; 2020 population: 126,254
Site Topography: Flat, on a small plateau
Surrounding Area Topography: Rolling to hilly
Dominant Land Cover within 5 mi (8 km): Forest, agriculture, developed: open space
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Interior River Valley and Hills
Percent Wetland within 5 mi (8 km): 3.3, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Portland 5 mi (8 km) SE. Interstate Highway I-70 is about 10 mi (16 km) N.
Population within a 50 mi (80 km) Radius: 585,372.

CALVERT CLIFFS NUCLEAR POWER PLANT (Calvert Cliffs)

Location: Calvert County, Maryland
35 mi (56 km) S of Annapolis
Latitude 38.4347°N; longitude 76.4419°W
Licensee: Constellation Energy Generation, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-317	50-318
Construction Permit:	1969	1969
Operating License:	1974	1976
Commercial Operation:	1975	1977
License Expiration:	2034	2036
Licensed Thermal Power (MWt):	2,737	2,737
Net Capacity (MWe):	866	842
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	CE	CE

Cooling Water System

Type: Once-through
Source: Chesapeake Bay
Source Temperature Range: 34–87°F (1–31°C)
Condenser Flow Rate: 1,200,000 gpm (76 m^3/s) each unit
Design Condenser Temperature Rise: 12°F (6.7°C).
Intake Structure: 4,500 ft (1,372 m) from shore
Discharge Structure: 850 ft (260 m) from shore

Site Information

Total Area: 2,108 ac (853 ha)
Exclusion Area Distance: 0.67 mi (1.08 km) radius
Low Population Zone: 2 mi (3.2 km)
Nearest City: Washington, D.C.; 2020 population: 689,545
Site Topography: Rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Open water, forest, agriculture
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Southeastern Plains; Middle Atlantic Coastal Plain
Percent Wetland within 5 mi (8 km): 2.1, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Long Beach 1 mi (1.6 km) NNW. Calvert Cliffs State Park is about 4 mi (6 km) SSE. A naval ordinance facility is 7 mi (11 km) SSW.
Population within a 50 mi (80 km) Radius: 3,962,475.

CATAWBA NUCLEAR STATION (Catawba)

Location: York County, South Carolina
6 mi (10 km) NNW of Rock Hill
Latitude 35.0514°N; longitude 81.0708°W
Licensee: Duke Energy Carolinas, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-413	50-414
Construction Permit:	1975	1975
Operating License:	1985	1986
Commercial Operation:	1985	1986
License Expiration:	2043	2043
Licensed Thermal Power (MWt):	3,469	3,411
Net Capacity (MWe):	1,160	1,150
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Mechanical draft towers
Source: Lake Wylie
Source Temperature Range: 43–83°F (6–28°C)
Condenser Flow Rate: 660,000 gpm (42 m^3/s) each unit
Design Condenser Temperature Rise: 24°F (13°C)
Intake Structure: Skimmer wall on cove of the lake
Discharge Structure: On another cove of the lake

Site Information

Total Area: 391 ac (158 ha)
Exclusion Area Distance: 2,500 ft (0.76 km; 0.47 mi) radius
Low Population Zone: 3.8 mi (6.12 km) radius
Nearest City: Charlotte, North Carolina; 2020 population: 874,579
Site Topography: Rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Forest, agriculture, developed: open space
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Piedmont
Percent Wetland within 5 mi (8 km): 0.7, mostly freshwater forested/shrub wetland and freshwater pond
Nearby Features: The nearest town is Rock Hill 6 mi (10 km) SSE. Interstate Highway I-77 is about 6 mi (10 km) E and I-85 is about 17 mi (27 km) N.
Population within a 50 mi (80 km) Radius: 3,034,933.

CLINTON POWER STATION (Clinton)

Location: DeWitt County, Illinois
6 mi (10 km) E of Clinton
Latitude 40.1731°N; longitude 88.8342°W
Licensee: Constellation Energy Generation, LLC

Unit Information	Unit 1
Docket Number:	50-461
Construction Permit:	1976
Operating License:	1987
Commercial Operation:	1987
License Expiration:	2027
Licensed Thermal Power (MWt):	3,473
Net Capacity (MWe):	1,065
Type of Reactor:	BWR
Nuclear Steam Supply System Vendor:	GE

Cooling Water System

Type: Once-through (cooling pond)
Source: Salt Creek
Source Temperature Range: 32–83°F (0–28°C)
Condenser Flow Rate: 568,701 gpm (35.89 m^3/s)
Design Condenser Temperature Rise: 23°F (13°C)
Intake Structure: Concrete structure at shoreline of North Fork Salt Creek
Discharge Structure: 3 mi (5 km) flume discharging to Salt Creek

Site Information

Total Area: 14,090 ac (5,702 ha)
Exclusion Area Distance: 0.60 mi (0.97 km) radius
Low Population Zone: 2.5 mi (4.02 km) radius
Nearest City: Decatur; 2020 population: 70,522
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Agriculture, forest, open water
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Central Corn Belt Plains
Percent Wetland within 5 mi (8 km): 0.7, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is DeWitt 2 mi (3 km) ENE. Weldon Springs State Park is 6 mi (10 km) SW. Interstate Highway I-74 is 11 mi (18 km) NE. A dam on Salt Creek near the site creates the reservoir Lake Clinton for the cooling water system.
Population within a 50 mi (80 km) Radius: 815,617.

COLUMBIA GENERATING STATION (Columbia)

Location: Benton County, Washington
10 mi (17 km) NW of Richland
Latitude 46.4714°N; longitude 119.3331°W
Licensee: Energy Northwest

Unit Information	Unit 1
Docket Number:	50-397
Construction Permit:	1973
Operating License:	1984
Commercial Operation:	1984
License Expiration:	2043
Licensed Thermal Power (MWt):	3,544
Net Capacity (MWe):	1,163
Type of Reactor:	BWR
Nuclear Steam Supply System Vendor:	GE

Cooling Water System

Type: Mechanical draft cooling towers
Source: Columbia River
Source Temperature Range: 38–64°F (3–18°C)
Condenser Flow Rate: 550,000 gpm (35 m^3/s)
Design Condenser Temperature Rise: 28.7°F (15.9°C)
Intake Structure: 2 perforated pipe inlets supported offshore above the river bed 900 ft (270 m) from pump structure on river bank
Discharge Structure: Buried 3 mi (5 km) pipeline, terminating at the river bed 175 ft (53 m) from the shoreline

Site Information

Total Area: 1,089 ac (441 ha)
Exclusion Area Distance: 1.21 mi (1.95 km) radius
Low Population Zone: 3 mi (4.83 km)
Nearest City: Spokane; 2020 population: 228,989
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Shrub/scrub, open water, agriculture
Level 1 Ecoregion within 5 mi (8 km): North American Desert
Level 3 Ecoregion within 5 mi (8 km): Columbia Plateau
Percent Wetland within 5 mi (8 km): 0.3
Nearby Features: The nearest town is Richland 10 mi (17 km) S. The site is in the SE part of the Hanford Reservation.
Population within a 50 mi (80 km) Radius: 517,245.

COMANCHE PEAK NUCLEAR POWER PLANT (Comanche Peak)

Location: Somervell County, Texas
40 mi (64 km) SW of Fort Worth
Latitude 32.2983°N; longitude 97.7856°W
Licensee: Vistra Operations Company, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-445	50-446
Construction Permit:	1974	1974
Operating License:	1990	1993
Commercial Operation:	1990	1993
License Expiration:	2030	2033
Licensed Thermal Power (MWt):	3,612	3,612
Net Capacity (MWe):	1,205	1,195
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Once-through
Source: Comanche Peak Reservoir
Source Temperature Range: Not available
Condenser Flow Rate: 1,030,000 gpm (65 m^3/s)
Design Condenser Temperature Rise: 15°F (8°C)
Intake Structure: On shore of reservoir
Discharge Structure: Canal to reservoir

Site Information

Total Area: 7,669 ac (3,104 ha)
Exclusion Area Distance: 0.96 mi (1.54 km) minimum
Low Population Zone: 4 mi (6.44 km) radius
Nearest City: Fort Worth; 2020 population: 918,915
Site Topography: Flat, with hills rising from the reservoir
Surrounding Area Topography: Rolling to hilly
Dominant Land Cover within 5 mi (8 km): Herbaceous, forest, open water
Level 1 Ecoregion within 5 mi (8 km): Great Plains
Level 3 Ecoregion within 5 mi (8 km): Cross Timbers
Percent Wetland within 5 mi (8 km): 1.1, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Glen Rose 5 mi (8 km) SSE. Dinosaur Valley State Park is 5 mi (8 km) SW. A 26 in. (66 cm) oil pipeline traverses the site, and a 36 in. (91 cm) natural gas line is about 2 mi (3 km) from the site.
Population within a 50 mi (80 km) Radius: 2,077,599.

COOPER NUCLEAR STATION (Cooper)

Location: Nemaha County, Nebraska
23 mi (37 km) S of Nebraska City
Latitude 40.3619°N; longitude 95.6411°W
Licensee: Nebraska Public Power District

Unit Information	Unit 1
Docket Number:	50-298
Construction Permit:	1968
Operating License:	1974
Commercial Operation:	1974
License Expiration:	2034
Licensed Thermal Power (MWt):	2,419
Net Capacity (MWe):	770
Type of Reactor:	BWR
Nuclear Steam Supply System Vendor:	GE

Cooling Water System

Type: Once-through
Source: Missouri River
Source Temperature Range: 34–73°F (1–23°C)
Condenser Flow Rate: 631,000 gpm (39.8 m^3/s)
Design Condenser Temperature Rise: 18°F (10°C)
Intake Structure: At shoreline
Discharge Structure: At shoreline

Site Information

Total Area: 1,090 ac (441 ha)
Exclusion Area Distance: 0.68 mi (1.09 km)
Low Population Zone: 1 mi (1.61 km) radius
Nearest City: Lincoln; 2020 population: 291,082
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Agriculture, wetland, forest
Level 1 Ecoregion within 5 mi (8 km): Great Plains
Level 3 Ecoregion within 5 mi (8 km): Western Corn Belt Plains
Percent Wetland within 5 mi (8 km): 4.4, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Nemaha about 1 mi (1.6 km) S. Indian Cave State Park is about 8 mi (13 km) SSE.
Population within a 50 mi (80 km) Radius: 153,581.

DAVIS-BESSE NUCLEAR POWER STATION (Davis-Besse)

Location: Ottawa County, Ohio
21 mi (34 km) E of Toledo
Latitude 41.5972°N; longitude 83.0864°W
Licensee: Energy Harbor Nuclear Corp.

Unit Information	Unit 1
Docket Number:	50-346
Construction Permit:	1971
Operating License:	1977
Commercial Operation:	1978
License Expiration:	2037
Licensed Thermal Power (MWt):	2,817
Net Capacity (MWe):	894
Type of Reactor:	PWR
Nuclear Steam Supply System Vendor:	B&W

Cooling Water System

Type: Natural draft cooling tower
Source: Lake Erie
Source Temperature Range: 34–73°F (1–23°C)
Condenser Flow Rate: 480,000 gpm (30 m^3/s)
Design Condenser Temperature Rise: 26°F (14°C)
Intake Structure: Submerged intake about 3,000 ft (900 m) offshore
Discharge Structure: Submerged discharge about 930 ft (280 m) offshore

Site Information

Total Area: 954 ac (386 ha)
Exclusion Area Distance: 0.45 mi (0.72 km) radius
Low Population Zone: 2 mi (3.22 km)
Nearest City: Toledo; 2020 population: 270,871
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Open water, agriculture, wetland
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Huron/Erie Lake Plains
Percent Wetland within 5 mi (8 km): 11.6, mostly freshwater emergent wetland
Nearby Features: The nearest town is Oak Harbor about 6 mi (10 km) SW. Several wildlife refuge areas are within 5 mi (8 km) of the site.
Population within a 50 mi (80 km) Radius: 1,812,385.

DIABLO CANYON POWER PLANT (Diablo Canyon)

Location: San Luis Obispo County, California
12 mi (19 km) W of San Luis Obispo
Latitude 35.2117°N; longitude 120.8544°W
Licensee: Pacific Gas and Electric Co.

Unit Information	Unit 1	Unit 2
Docket Number:	50-275	50-323
Construction Permit:	1968	1970
Operating License:	1984	1985
Commercial Operation:	1985	1986
License Expiration:[2]	2024	2025
Licensed Thermal Power (MWt):	3,411	3,411
Net Capacity (MWe):	1,122	1,118
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Once-through
Source: Pacific Ocean
Source Temperature Range: 50–63°F (10–17°C)
Condenser Flow Rate: 863,000 gpm (54.5 m^3/s)
Design Condenser Temperature Rise: 18°F (10°C)
Intake Structure: Reinforced-concrete structure in shoreline cove with artificial breakwater wall
Discharge Structure: Reinforced-concrete structure drops water in stair-step type weir overflow from elevation 70 ft (21 m) and discharges to the ocean surface

Site Information

Total Area: 750 ac (300 ha)
Exclusion Area Distance: 0.50 mi (0.80 km)
Low Population Zone: 6 mi (9.66 km)
Nearest City: Santa Barbara; 2020 population: 88,665
Site Topography: Hilly
Surrounding Area Topography: Hilly to mountainous
Dominant Land Cover within 5 mi (8 km): Open water, forest, shrub/scrub
Level 1 Ecoregion within 5 mi (8 km): Mediterranean California
Level 3 Ecoregion within 5 mi (8 km): Southern & Central California Chaparral/Oak Woodlands
Percent Wetland within 5 mi (8 km): 0.67
Nearby Features: The nearest town is San Luis Obispo 12 mi (19 km) E. Pismo Beach State Park and Morro Bay State Park are within 15 mi (24 km). Vandenberg Air Base is 35 mi (56 km) ESE.
Population within a 50 mi (80 km) Radius: 499,952.

---

[2] On March 2, 2023, the NRC granted Pacific Gas and Electric Company an exemption from 10 CFR 2.109(b), provided a sufficient license renewal application is submitted by December 31, 2023, and the NRC staff finds it acceptable for docketing, which would render the existing operating licenses effective until the NRC has made a final determination on the application (NRC 2023b). On November 7, 2023, the licensee submitted a license renewal application. On December 19, 2023, the NRC issued a *Federal Register* notice that the application was acceptable for docketing and announced a hearing opportunity.

DONALD C. COOK NUCLEAR PLANT (D.C. Cook)

Location: Berrien County, Michigan
10 mi (16 km) S of St. Joseph
Latitude 41.9761°N; longitude 86.5664°W
Licensee: Indiana Michigan Power Co.

Unit Information	Unit 1	Unit 2
Docket Number:	50-315	50-316
Construction Permit:	1969	1969
Operating License:	1974	1977
Commercial Operation:	1975	1978
License Expiration:	2034	2037
Licensed Thermal Power (MWt):	3,304	3,468
Net Capacity (MWe):	1,009	1,060
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Once-through
Source: Lake Michigan
Source Temperature Range: 34–73°F (1–23°C)
Condenser Flow Rate: 1.6 million gal/min both units
Design Condenser Temperature Rise: 20°F (11°C)
Intake Structure: Intake cribs 2,250 ft (686 m) from shore
Discharge Structure: 1,150 ft (351 m) from shore

Site Information

Total Area: 650 ac (260 ha)
Exclusion Area Distance: 0.38 mi (0.61 km)
Low Population Zone: 2 mi (3.22 km)
Nearest City: South Bend, Indiana; 2020 population: 103,453
Site Topography: Rolling
Surrounding Area Topography: Flat to rolling
Dominant Land Cover within 5 mi (8 km): Open water, agriculture, forest
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): S. Michigan/N. Indiana Drift Plains
Percent Wetland within 5 mi (8 km): 3.1, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Livingston 1 mi (1.6 km) SW. Interstate Highway I-94 is directly E of the site. Warren Dunes State Park is about 5 mi (8 km) SSW.
Population within a 50 mi (80 km) Radius: 1,265,894.

DRESDEN NUCLEAR POWER STATION (Dresden)

Location: Grundy County, Illinois
9 mi (14 km) E of Morris
Latitude 41.3897°N; longitude 88.2711°W
Licensee: Constellation Energy Generation, LLC

Unit Information	Unit 2	Unit 3
Docket Number:	50-237	50-249
Construction Permit:	1966	1966
Operating License:	1969	1971
Commercial Operation:	1970	1971
License Expiration:	2029	2031
Licensed Thermal Power (MWt):	2,957	2,957
Net Capacity (MWe):	902	895
Type of Reactor:	BWR	BWR
Nuclear Steam Supply System Vendor:	GE	GE

Cooling Water System

Type: Cooling lake and spray canal; mechanical draft towers
Source: Kankakee River
Source Temperature Range: 40–85°F (4–29°C)
Condenser Flow Rate: 940,000 gpm both units
Design Condenser Temperature Rise: Not available
Intake Structure: Canal from Kankakee River to a crib house
Discharge Structure: A canal carries water to a cooling lake of about 1,275 ac (516 ha)

Site Information

Total Area: 2,500 ac (1,012 ha)
Exclusion Area Distance: 0.5 mi (0.8 km) radius
Low Population Zone: 5 mi (8 km)
Nearest City: Joliet; 2020 population: 150,362
Site Topography: Flat
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Agriculture, herbaceous, forest
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Central Corn Belt Plains
Percent Wetland within 5 mi (8 km): 10.7, mostly freshwater emergent wetland
Nearby Features: The nearest town is Channahon 3 mi (5 km) NNE. Braidwood Station (nuclear plant) is about 10 mi (16 km) S and LaSalle County Station (nuclear plant) is about 22 mi (35 km) SW.
Population within a 50 mi (80 km) Radius: 7,525,651.

EDWIN I. HATCH NUCLEAR PLANT (Hatch)

Location: Appling County, Georgia
11 mi (18 km) N of Baxley
Latitude 31.9342°N; longitude 82.3444°W
Licensee: Southern Nuclear Operating Company, Inc.

Unit Information	Unit 1	Unit 2
Docket Number:	50-321	50-366
Construction Permit:	1969	1972
Operating License:	1974	1978
Commercial Operation:	1975	1979
License Expiration:	2034	2038
Licensed Thermal Power (MWt):	2,804	2,804
Net Capacity (MWe):	876	883
Type of Reactor:	BWR	BWR
Nuclear Steam Supply System Vendor:	GE	GE

Cooling Water System

Type: Mechanical draft towers
Source: Altamaha River
Source Temperature Range: 43–90°F (6–32°C)
Condenser Flow Rate: 556,000 gpm (35.1 m^3/s) each unit
Design Condenser Temperature Rise: 20°F (11°C)
Intake Structure: At edge of river
Discharge Structure: 120 ft (37 m) from shore

Site Information

Total Area: 2,244 ac (908 ha)
Exclusion Area Distance: 0.78 mi (1.26 km)
Low Population Zone: 0.78 mi (1.26 km)
Nearest City: Savannah; 2020 population: 147,780
Site Topography: Flat to rolling
Surrounding Area Topography: Flat to rolling
Dominant Land Cover within 5 mi (8 km): Forest, wetland, agriculture
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Southeastern Plains; Southern Coastal Plain
Percent Wetland within 5 mi (8 km): 21.4, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Cedar Crossing about 7 mi (11 km) NNW.
U.S. Highway 1 is directly W of the site.
Population within a 50 mi (80 km) Radius: 464,024.

ENRICO FERMI ATOMIC POWER PLANT (Fermi)

Location: Monroe County, Michigan
30 mi (48 km) SW of Detroit
Latitude 41.9631°N; longitude 83.2578°W
Licensee: DTE Electric Company

Unit Information	Unit 2
Docket Number:	50-341
Construction Permit:	1972
Operating License:	1985
Commercial Operation:	1988
License Expiration:	2045
Licensed Thermal Power (MWt):	3,486
Net Capacity (MWe):	1,141
Type of Reactor:	BWR
Nuclear Steam Supply System Vendor:	GE

Cooling Water System

Type: Natural draft cooling towers
Source: Lake Erie
Source Temperature Range: 34–76°F (1–24°C)
Condenser Flow Rate: 836,000 gpm (52.80 m^3/s)
Design Condenser Temperature Rise: 18°F (10°C)
Intake Structure: At edge of lake
Discharge Structure: To the lake via a 50 ac (20 ha) pond

Site Information

Total Area: 1,120 ac (453 ha)
Exclusion Area Distance: 0.57 mi (0.92 km)
Low Population Zone: 3 mi (4.83 km)
Nearest City: Detroit; 2020 population: 639,111
Site Topography: Flat
Surrounding Area Topography: Flat to rolling
Dominant Land Cover within 5 mi (8 km): Open water, agriculture, developed: high, medium, low density
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Huron/Erie Lake Plains
Percent Wetland within 5 mi (8 km): 6.0, mostly freshwater emergent wetland
Nearby Features: The town of Stony Point is adjacent to the site to the S. Sterling State Park and General Custer Historical Site are about 5 mi (8 km) SW.
Population within a 50 mi (80 km) Radius: 4,908,826.

JAMES A. FITZPATRICK NUCLEAR POWER PLANT (FitzPatrick)

Location: Oswego County, New York
6 mi (10 km) NE of Oswego
Latitude 43.5239°N; longitude 76.3983°W
Licensee: Constellation Energy Generation, LLC

Unit Information	Unit 1
Docket Number:	50-333
Construction Permit:	1970
Operating License:	1974
Commercial Operation:	1975
License Expiration:	2034
Licensed Thermal Power (MWt):	2,536
Net Capacity (MWe):	848
Type of Reactor:	BWR
Nuclear Steam Supply System Vendor:	GE

Cooling Water System

Type: Once-through
Source: Lake Ontario
Source Temperature Range: 32–68°F (0–20°C)
Condenser Flow Rate: 352,600 gpm (22.25 m^3/s)
Design Condenser Temperature Rise: 32°F (18°C)
Intake Structure: 900 ft (274 m) from shore
Discharge Structure: 1,400 ft (427 m) from shore

Site Information

Total Area: 702 ac (284 ha)
Exclusion Area Distance: 3,000 ft (914 m) to the east, over 1 mi (1.6 km) to the west, and about 1.5 mi (2.4 km) to the southern site boundary
Low Population Zone: 3.4 mi (5.47 km)
Nearest City: Syracuse; 2020 population: 148,620
Site Topography: Flat to rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Open water, forest, agriculture
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Eastern Great Lakes and Hudson Lowlands
Percent Wetland within 5 mi (8 km): 3.4, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Lakeview about 1 mi (1.6 km) WSW. Fort Ontario is about 5 mi (8 km) SW. Nine Mile Point Nuclear Station is about 0.5 mi (0.8 km) W.
Population within a 50 mi (80 km) Radius: 932,913.

JOSEPH M. FARLEY NUCLEAR PLANT (Farley)

Location: Houston County, Alabama
16 mi (26 km) E of Dothan
Latitude 31.2228°N; longitude 85.1125°W
Licensee: Southern Nuclear Operating Company, Inc.

Unit Information	Unit 1	Unit 2
Docket Number:	50-348	50-364
Construction Permit:	1972	1972
Operating License:	1977	1981
Commercial Operation:	1977	1981
License Expiration:	2037	2041
Licensed Thermal Power (MWt):	2,775	2,775
Net Capacity (MWe):	874	877
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Mechanical draft cooling towers
Source: Chattahoochee River
Source Temperature Range: 86°F (130°C) maximum
Condenser Flow Rate: 635,000 gpm (40.1 m^3/s) each unit
Design Condenser Temperature Rise: 20°F (11°C)
Intake Structure: Intake from river bank via storage pond
Discharge Structure: At river bank

Site Information

Total Area: 1,850 ac (749 ha)
Exclusion Area Distance: 0.78 mi (1.26 km)
Low Population Zone: 2 mi (3.22 km)
Nearest City: Columbus, Georgia; 2020 population: 206,922
Site Topography: Flat to rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Forest, agriculture, wetland
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Southeastern Plains
Percent Wetland within 5 mi (8 km): 11.8, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Columbia about 4 mi (6 km) N. Chattahoochee State Park is about 12 mi (19 km) S.
Population within a 50 mi (80 km) Radius: 425,394.

GRAND GULF NUCLEAR STATION (Grand Gulf)

Location: Clairborne County, Mississippi
25 mi (40 km) S of Vicksburg
Latitude 32.0075°N; longitude 91.0475°W
Licensee: Entergy Operations, Inc.

Unit Information	Unit 1
Docket Number:	50-416
Construction Permit:	1974
Operating License:	1984
Commercial Operation:	1985
License Expiration:	2044
Licensed Thermal Power (MWt):	4,408
Net Capacity (MWe):	1,401
Type of Reactor:	BWR
Nuclear Steam Supply System Vendor:	GE

Cooling Water System

Type: Natural draft cooling towers
Source: Mississippi River
Source Temperature Range: 34–82°F (1–28°C)
Condenser Flow Rate: 572,000 gpm (36.1 m^3/s)
Design Condenser Temperature Rise: 30°F (17°C)
Intake Structure: A series of radial-collector wells along the shoreline
Discharge Structure: Discharge to river via a barge slip

Site Information

Total Area: 2,100 ac (850 ha)
Exclusion Area Distance: 0.43 mi (0.69 km) radius
Low Population Zone: 2 mi (3.22 km)
Nearest City: Jackson; 2020 population: 153,701
Site Topography: Flat to rolling
Surrounding Area Topography: Flat to rolling
Dominant Land Cover within 5 mi (8 km): Forest, wetland, open water
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Mississippi Valley Loess Plains; Mississippi Alluvial Plain
Percent Wetland within 5 mi (8 km): 25.3, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Grand Gulf 2 mi (3 km) N. The Natchez Trace Parkway is about 6 mi (10 km) SE. The Grand Gulf Military Park is directly N of the site.
Population within a 50 mi (80 km) Radius: 323,744.

H.B. ROBINSON STEAM ELECTRIC STATION (Robinson)

Location: Darlington County, South Carolina
26 mi (42 km) NE of Florence
Latitude 34.4025°N; longitude 80.1586°W
Licensee: Duke Energy Progress, LLC

Unit Information	Unit 2
Docket Number:	50-261
Construction Permit:	1967
Operating License:	1970
Commercial Operation:	1971
License Expiration:	2030
Licensed Thermal Power (MWt):	2,339
Net Capacity (MWe):	759
Type of Reactor:	PWR
Nuclear Steam Supply System Vendor:	WEST

Cooling Water System

Type: Once-through (cooling pond)
Source: Lake Robinson
Source Temperature Range: 46–85°F (8–29°C)
Condenser Flow Rate: 454,167 gpm (28.7 m^3/s)
Design Condenser Temperature Rise: 18°F (10°C)
Intake Structure: Concrete structure on edge of lake
Discharge Structure: 4.2 mi (6.8 km) canal discharging about 4 mi (6 km) upstream from intake

Site Information

Total Area: 6,020 ac (2,435 ha)
Exclusion Area Distance: 0.27 mi (0.43 km) radius
Low Population Zone: 4.5 mi (7.24 km)
Nearest City: Columbia; 2020 population: 136,632
Site Topography: Rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Forest, agriculture, herbaceous
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Southeastern Plains
Percent Wetland within 5 mi (8 km): 9.6, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Hartsville 5 mi (8 km) SE. Sand Hills State Forest is about 4 mi (6 km) N. The Carolina Sandhills National Wildlife Refuge is about 5 mi (8 km) NNW.
Population within a 50 mi (80 km) Radius: 922,132.

HOPE CREEK GENERATING STATION (Hope Creek)

Location: Salem County, New Jersey
8 mi (13 km) SW of Salem
Latitude 39.4678°N; longitude 75.5381°W
Licensee: PSEG Nuclear, LLC

Unit Information	Unit 1
Docket Number:	50-354
Construction Permit:	1974
Operating License:	1986
Commercial Operation:	1986
License Expiration:	2046
Licensed Thermal Power (MWt):	3,902
Net Capacity (MWe):	1,172
Type of Reactor:	BWR
Nuclear Steam Supply System Vendor:	GE

Cooling Water System

Type: Natural draft cooling tower
Source: Delaware River
Source Temperature Range: 34–81°F (1–27°C)
Condenser Flow Rate: 552,000 gpm (34.8 m^3/s)
Design Condenser Temperature Rise: 28°F (16°C)
Intake Structure: At edge of river
Discharge Structure: Pipe 10 ft (3 m) offshore

Site Information

Total Area: 740 ac (300 ha)
Exclusion Area Distance: 0.56 mi (0.90 km) radius
Low Population Zone: 5 mi (8.05 km) radius
Nearest City: Wilmington, Delaware; 2020 population: 70,898
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Open water, wetland, agriculture
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Middle Atlantic Coastal Plain
Percent Wetland within 5 mi (8 km): 37.4, mostly estuarine and marine wetland
Nearby Features: The nearest town is Port Penn about 4 mi (6 km) NW in Delaware. The plant is on the same site as the Salem Nuclear Generating Station.
Population within a 50 mi (80 km) Radius: 5,946,917.

LASALLE COUNTY STATION (LaSalle)

Location: LaSalle County, Illinois
11 mi (18 km) SE of Ottawa
Latitude 41.2439°N; longitude 88.6708°W
Licensee: Constellation Energy Generation, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-373	50-374
Construction Permit:	1973	1973
Operating License:	1982	1984
Commercial Operation:	1984	1984
License Expiration:	2042	2043
Licensed Thermal Power (MWt):	3,546	3,546
Net Capacity (MWe):	1,131	1,134
Type of Reactor:	BWR	BWR
Nuclear Steam Supply System Vendor:	GE	GE

Cooling Water System

Type: Cooling pond
Source: Illinois River
Source Temperature Range: 47–85°F (8–29°C)
Condenser Flow Rate: 645,000 gpm (40.7 m^3/s) each unit
Design Condenser Temperature Rise: 24°F (13°C)
Intake Structure: Intake from 2,058 ac (832.8 ha) cooling pond, makeup from river
Discharge Structure: Discharge to cooling pond

Site Information

Total Area: 3,060 ac (1,240 ha)
Exclusion Area Distance: 0.32 mi (0.51 km)
Low Population Zone: 3.98 mi (6.41 km)
Nearest City: Joliet; 2020 population: 150,362
Site Topography: Flat
Surrounding Area Topography: Flat with hills along river
Dominant Land Cover within 5 mi (8 km): Agriculture, forest, open water
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Central Corn Belt Plains
Percent Wetland within 5 mi (8 km): 0.6
Nearby Features: The nearest town is Seneca about 5 mi (8 km) NNE. Braidwood Station (nuclear plant) is about 20 mi (32 km) ENE, and Dresden Nuclear Power Station is about 22 mi (35 km) NE.
Population within a 50 mi (80 km) Radius: 1,948,438.

LIMERICK GENERATING STATION (Limerick)

Location: Montgomery County, Pennsylvania
21 mi (34 km) NW of Philadelphia
Latitude 40.2200°N; longitude 75.5900°W
Licensee: Constellation Energy Generation, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-352	50-353
Construction Permit:	1974	1974
Operating License:	1985	1989
Commercial Operation:	1986	1989
License Expiration:	2049	2049
Licensed Thermal Power (MWt):	3,515	3,515
Net Capacity (MWe):	1,120	1,122
Type of Reactor:	BWR	BWR
Nuclear Steam Supply System Vendor:	GE	GE

Cooling Water System

Type: Natural draft cooling towers
Source: Schuylkill River
Source Temperature Range: 42–82°F (6–28°C)
Condenser Flow Rate: 450,000 gpm (28 m^3/s) each unit
Design Condenser Temperature Rise: 30°F (17°C)
Intake Structure: Intake from river
Discharge Structure: Discharge to river

Site Information

Total Area: 595 ac (241 ha)
Exclusion Area Distance: 0.47 mi (0.76 km)
Low Population Zone: 1.30 mi (2.09 km)
Nearest City: Reading; 2020 population: 95,112
Site Topography: Rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Agriculture, forest, developed: high, medium, low density
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Northern Piedmont
Percent Wetland within 5 mi (8 km): 1.0, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Linfield about 1 mi (1.6 km) SE. Valley Forge State Park is 10 mi (16 km) SSE. Interstate Highway I-76 is about 10 mi (16 km) S.
Population within a 50 mi (80 km) Radius: 8,594,665.

MCGUIRE NUCLEAR STATION (McGuire)

Location: Mecklenburg County, North Carolina
17 mi (27 km) NNW of Charlotte
Latitude 35.4322°N; longitude 80.9483°W
Licensee: Duke Energy Carolinas, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-369	50-370
Construction Permit:	1973	1973
Operating License:	1981	1983
Commercial Operation:	1981	1984
License Expiration:	2041	2043
Licensed Thermal Power (MWt):	3,469	3,469
Net Capacity (MWe):	1,159	1,158
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Once-through
Source: Lake Norman
Source Temperature Range: 38–89°F (3–32°C)
Condenser Flow Rate: 1,756,944 gpm (111 m^3/s) both units
Design Condenser Temperature Rise: 22.1°F (12.3°C)
Intake Structure: Submerged and surface intakes at shoreline
Discharge Structure: 2,000 ft (610 m) discharge canal

Site Information

Total Area: 577 ac (234 ha)
Exclusion Area Distance: 0.47 mi (0.76 km) radius
Low Population Zone: 5.50 mi (8.85 km)
Nearest City: Charlotte; 2020 population: 874,579
Site Topography: Rolling
Surrounding Area Topography: Hilly
Dominant Land Cover within 5 mi (8 km): Forest, open water, agriculture
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Piedmont
Percent Wetland within 5 mi (8 km): 2.1, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Lowesville about 3 mi (5 km) W. The dam forming Lake Norman and a hydroelectric power plant are adjacent to the site.
Population within a 50 mi (80 km) Radius: 3,351,808.

MILLSTONE POWER STATION (Millstone)

Location: New London County, Connecticut
3 mi (5 km) WSW of New London
Latitude 41.3086°N; longitude 72.1681°W
Licensee: Dominion Energy Nuclear Connecticut, Inc.

Unit Information	Unit 2	Unit 3
Docket Number:	50-336	50-423
Construction Permit:	1970	1974
Operating License:	1975	1986
Commercial Operation:	1975	1986
License Expiration:	2035	2045
Licensed Thermal Power (MWt):	2,700	3,709
Net Capacity (MWe):	853	1,220
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	CE	WEST

Cooling Water System

Type: Once-through
Source: Long Island Sound
Source Temperature Range: 36–72°F (2–22°C)
Condenser Flow Rate: 1.46 million gpm (92 m^3/s) both units
Design Condenser Temperature Rise: 21°F (13°C) for Unit 2; 17.5°F (9.7°C) for Unit 3
Intake Structure: On shore of Niantic Bay off Long Island Sound
Discharge Structure: Discharge to Niantic Bay via holding pond

Site Information

Total Area: 500 ac (200 ha)
Exclusion Area Distance: 0.34 mi (0.55 km) minimum
Low Population Zone: (2.40 mi 3.86 km) radius
Nearest City: New Haven; 2020 population: 134,023
Site Topography: Flat
Surrounding Area Topography: Flat to rolling
Dominant Land Cover within 5 mi (8 km): Open water, forest, developed: high to low density
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Northeastern Coastal Zone
Percent Wetland within 5 mi (8 km): 4.5, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Niantic 2 mi (3 km) NW. Interstate Highway I-95 is about 4 mi (6 km) NNE. Stone Ranch Military Reservation is about 6 mi (10 km) NW. Harkness Memorial, Bluff Point, and Rocky Neck State Parks are within 5 mi (8 km) of the site. The U.S. Department of Agriculture Plum Island facility is 10 mi (16 km) S in Long Island Sound.
Population within a 50 mi (80 km) Radius: 3,071,351.

MONTICELLO NUCLEAR GENERATING PLANT (Monticello)

Location: Wright County, Minnesota
35 mi (56 km) NW of Minneapolis
Latitude 45.3333°N; longitude 93.8483°W
Licensee: Northern States Power Company-Minnesota

Unit Information	Unit 1
Docket Number:	50-263
Construction Permit:	1967
Operating License:	1970
Commercial Operation:	1971
License Expiration:	2030
Licensed Thermal Power (MWt):	2,004
Net Capacity (MWe):	617
Type of Reactor:	BWR
Nuclear Steam Supply System Vendor:	GE

Cooling Water System

Type: Once-through and mechanical draft towers
Source: Mississippi River
Source Temperature Range: 32–85°F (0–29°C)
Condenser Flow Rate: 292,000 gpm (18 m^3/s)
Design Condenser Temperature Rise: 26.8°F (14.9°C)
Intake Structure: Canal
Discharge Structure: Canal

Site Information

Total Area: 2,150 ac (860 ha)
Exclusion Area Distance: 0.30 mi (0.48 km)
Low Population Zone: 1 mi (1.61 km)
Nearest City: Minneapolis; 2020 population: 429,954
Site Topography: Flat terraces
Surrounding Area Topography: Flat to gently sloping
Dominant Land Cover 5 mi within (8 km): Agriculture, forest, developed: open space
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): North Central Hardwood Forests
Percent Wetland within 5 mi (8 km): 1.6, mostly freshwater forested/shrub wetland
Nearby Features: The business district of Monticello is about 2 mi (3.2 km) SE. Sherburne National Wildlife Refuge is about 9 mi (14 km) N. Lake Maria State Park is about 6 mi (10 km) WSW, and Sand Dunes State Forest and campground are 9 mi (14 km) NE.
Population within a 50 mi (80 km) Radius: 3,347,158.

NINE MILE POINT NUCLEAR STATION (Nine Mile Point)

Location: Oswego County, New York
6 mi (10 km) NE of Oswego
Latitude 43.5222°N; longitude 76.4100°W
Licensees: Constellation Energy Generation, LLC and Nine Mile Point Nuclear Station, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-220	50-410
Construction Permit:	1965	1974
Operating License:	1968	1987
Commercial Operation:	1969	1988
License Expiration:	2029	2046
Licensed Thermal Power (MWt):	1,850	3,988
Net Capacity (MWe):	621	1,292
Type of Reactor:	BWR	BWR
Nuclear Steam Supply System Vendor:	GE	GE

Cooling Water System

Type: Unit 1: Once-through
Unit 2: Natural draft tower
Source: Lake Ontario
Source Temperature Range: 33–77°F (1–25°C)
Condenser Flow Rate: Unit 1: 290,278 gpm (18 m^3/s);
Unit 2: 580,000 gpm (36.6 m^3/s)
Design Condenser Temperature Rise: Unit 1: 35°F (19.4°C);
Unit 2: 30°F (16.7°C)
Intake Structure: Unit 1: submerged pipeline about 850 ft (260 m) from shore;
Unit 2: submerged pipelines about 950 ft (300 m) and 1,050 ft (320 m) from shore
Discharge Structure: Diffuser pipe 555 ft (169 m) long serving both sides

Site Information

Total Area: 900 ac (360 ha)
Exclusion Area Distance: 1 mi (1.6 km) to the east, 0.87 mi (1.4 km) to the southwest, and 1.3 mi (2 km) to the southern site boundary
Low Population Zone: 4 mi (6.44 km) radius
Nearest City: Syracuse; 2020 population: 148,620
Site Topography: Flat to rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Open water, forest, agriculture
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Eastern Great Lakes and Hudson Lowlands
Percent Wetland within 5 mi (8 km): 3.4, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Lakeview about 1 mi (1.6 km) WSW. Fort Ontario is about 6 mi (10 km) SW. James A. Fitzpatrick Nuclear Power Plant is 0.5 mi (0.8 km) E.
Population within a 50 mi (80 km) Radius: 927,862.

NORTH ANNA POWER STATION (North Anna)

Location: Louisa County, Virginia
40 mi (64 km) NW of Richmond
Latitude 38.0608°N; longitude 77.7906°W
Licensee: Virginia Electric and Power Company

Unit Information	Unit 1	Unit 2
Docket Number:	50-338	50-339
Construction Permit:	1971	1971
Operating License:	1978	1980
Commercial Operation:	1978	1980
License Expiration:	2038	2040
Licensed Thermal Power (MWt):	2,940	2,940
Net Capacity (MWe):	948	944
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Once-through
Source: Lake Anna
Source Temperature Range: 48–83°F (9–28°C)
Condenser Flow Rate: 1,900,000 gpm (120 m^3/s) both units
Design Condenser Temperature Rise: 14.5°F (8.1°C)
Intake Structure: Intake at lake shore
Discharge Structure: Discharged through lake via a 3,400 ac (1,400 ha) cooling pond

Site Information

Total Area: 18,643 ac (7,550 ha)
Exclusion Area Distance: 0.84 mi (1.35 km)
Low Population Zone: 9.66 km (6 mi)
Nearest City: Richmond; 2020 population: 226,610
Site Topography: Rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Agriculture, forest, agriculture, open water
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Piedmont
Percent Wetland within 5 mi (8 km): 3.6, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Centreville 1 mi (1.6 km) SW. Fredericksburg and Spotsylvania National Military Park is about 15 mi (24 km) NE.
Population within a 50 mi (80 km) Radius: 2,237,934.

OCONEE NUCLEAR STATION (Oconee)

Location: Oconee County, South Carolina
26 mi (42 km) W of Greenville
Latitude 34.7917°N; longitude 82.8986°W
Licensee: Duke Energy Carolinas, LLC

Unit Information	Unit 1	Unit 2	Unit 3
Docket Number:	50-269	50-270	50-287
Construction Permit:	1967	1967	1967
Operating License:	1973	1973	1974
Commercial Operation:	1973	1974	1974
License Expiration:	2033	2033	2034
Licensed Thermal Power (MWt):	2,610	2,610	2,610
Net Capacity (MWe):	847	848	859
Type of Reactor:	PWR	PWR	PWR
Nuclear Steam Supply System Vendor:	B&W	B&W	B&W

Cooling Water System

Type: Once-through
Source: Lake Keowee
Source Temperature Range: 44–77°F (7–25°C)
Condenser Flow Rate: 1,527,778 gpm (96 m^3/s) all units
Design Condenser Temperature Rise: 17.2°F (9.6°C)
Intake Structure: A skimmer wall draws water from the depths of 735 ft (223 m)
Discharge Structure: All three units discharge through one structure near the Keowee Dam

Site Information

Total Area: 510 ac (210 ha)
Exclusion Area Distance: 1 mi (1.6 km) radius
Low Population Zone: 6 mi (9.66 km)
Nearest City: Greenville; 2020 population: 70,720
Site Topography: Flat to rolling
Surrounding Area Topography: Hilly
Dominant Land Cover within 5 mi (8 km): Forest, open water, agriculture
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Piedmont
Percent Wetland within 5 mi (8 km): 0.8
Nearby Features: The nearest town is Six Mile (6 4 mi km) ENE. Keowee Dam is close to the plant. Chattahoochee National Forest is about 15 mi (24 km) W.
Population within a 50 mi (80 km) Radius: 1,577,801.

PALISADES NUCLEAR PLANT (Palisades)

Location: Van Buren County, Michigan
35 mi (56 km) W of Kalamazoo
Latitude 42.3222°N; longitude 86.3153°W
Licensee: Holtec Decommissioning International, LLC

Unit Information	Unit 1
Docket Number:	50-255
Construction Permit:	1967
Operating License:	1972
Commercial Operation:	1973
License Expiration:[3]	2031
Licensed Thermal Power (MWt):	2,565.4
Net Capacity (MWe):	769
Type of Reactor:	PWR
Nuclear Steam Supply System Vendor:	CE

Cooling Water System

Type: Mechanical draft cooling towers
Source: Lake Michigan
Source Temperature Range: 35–75°F (2–24°C)
Condenser Flow Rate: 98,000 gpm (6.2 m^3/s)
Design Condenser Temperature Rise: 25°F (14°C)
Intake Structure: Intake crib 3,300 ft (1,000 m) from shore
Discharge Structure: 108 ft (33 m) long canal

Site Information

Total Area: 432 ac (174.8 ha)
Exclusion Area Distance: 0.44 mi (0.71 km) radius
Low Population Zone: Not available
Nearest City: Kalamazoo; 2020 population: 73,598
Site Topography: Flat to rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Open water, forest, agriculture
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): S. Michigan/N. Indiana Drift Plains
Percent Wetland within 5 mi (8 km): 10.0, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is South Haven about 4 mi (6 km) N. Van Buren State Park adjoins the plant on the north. Interstate Highway I-196 is about 1 mi (1.6 km) E.
Population within a 50 mi (80 km) Radius: 1,441,106.

[3] On June 28, 2022, the license for Palisades was transferred from Entergy Nuclear Operations, Inc. to Holtec Decommissioning International, LLC (NRC 2022a). Palisades shutdown in May 2022; however, shortly thereafter the plant operator began exploring options to resume operations. As of the time of this update, the status for the plant has yet to be determined. As a result, the plant has been retained in this appendix for the purposes of this LR GEIS update.

PALO VERDE NUCLEAR GENERATING STATION (Palo Verde)

Location: Maricopa County, Arizona
34 mi (55 km) W of Phoenix
Latitude 33.3881°N; longitude 112.8644°W
Licensee: Arizona Public Service Co.

Unit Information	Unit 1	Unit 2	Unit 3
Docket Number:	50-528	50-529	50-530
Construction Permit:	1976	1976	1976
Operating License:	1985	1986	1987
Commercial Operation:	1986	1986	1988
License Expiration:	2045	2046	2047
Licensed Thermal Power (MWt):	3,990	3,990	3,990
Net Capacity (MWe):	1,311	1,314	1,312
Type of Reactor:	PWR	PWR	PWR
Nuclear Steam Supply System Vendor:	CE	CE	CE

Cooling Water System

Type: Mechanical draft cooling towers treatment plant
Source: Phoenix City Sewage
Source Temperature Range: Not available
Condenser Flow Rate: 560,000 gpm (35 m^3/s) each unit
Design Condenser Temperature Rise: 32.1°F (17.8°C)
Intake Structure: 35 mi (56 km) underground pipeline from Phoenix 91st Avenue Sewage Treatment Plant
Discharge Structure: Blowdown from the circulating water system is directed to onsite evaporation ponds without requiring any offsite discharge

Site Information

Total Area: 4,050 ac (1,640 ha)
Exclusion Area Distance: 0.54 mi (0.87 km) minimum
Low Population Zone: 4 mi (6.44 km) radius
Nearest City: Phoenix; 2020 population: 1,608,139
Site Topography: Flat with hills
Surrounding Area Topography: Flat with hills
Dominant Land Cover within 5 mi (8 km): Shrub/scrub, agriculture, developed: open space
Level 1 Ecoregion within 5 mi (8 km): North American Desert
Level 3 Ecoregion within 5 mi (8 km): Sonoran Basin and Range
Percent Wetland within 5 mi (8 km): 0.1
Nearby Features: The nearest town is Wintersburg about 3 mi (5 km) N. Interstate Highway I-10 is about 7 mi (11 km) N.
Population within a 50 mi (80 km) Radius: 2,350,442.

PEACH BOTTOM ATOMIC POWER STATION (Peach Bottom)

Location: York County, Pennsylvania
18 mi (29 km) S of Lancaster
Latitude 39.7589°N; longitude 76.2692°W
Licensee: Constellation Energy Generation, LLC

Unit Information	Unit 2	Unit 3
Docket Number:	50-277	50-278
Construction Permit:	1968	1968
Operating License:	1973	1974
Commercial Operation:	1974	1974
License Expiration:[4]	2033	2034
Licensed Thermal Power (MWt):	4,016	4,016
Net Capacity (MWe):	1,265	1,285
Type of Reactor:	BWR	BWR
Nuclear Steam Supply System Vendor:	GE	GE

Cooling Water System

Type: Once-through, with helper mechanical draft towers
Source: Conowingo Pond, an impoundment on the Susquehanna River
Source Temperature Range: 34–80°F (1–27°C)
Condenser Flow Rate: 1.5 million gpm (95 m^3/s) both units
Design Condenser Temperature Rise: 20.8°F (11.5°C)
Intake Structure: Intake from Conowingo Pond through a small intake pond
Discharge Structure: 5,000 ft (1,520 m) canal to Conowingo Pond

Site Information

Total Area: 620 ac (248 ha)
Exclusion Area Distance: 0.51 mi (0.82 km)
Low Population Zone: 1.38 mi (2.22 km)
Nearest City: Lancaster; 2020 population: 58,039
Site Topography: Rolling to hilly
Surrounding Area Topography: Rolling to hilly
Dominant Land Cover within 5 mi (8 km): Agriculture, forest, open water
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Northern Piedmont
Percent Wetland within 5 mi (8 km): 0.6
Nearby Features: The nearest town is Slate Hill 2 mi (3 km) SW. Susquehanna State Park is about 3 mi (5 km) N. Interstate Highway I-95 is 15 mi (24 km) SE. Conowingo Dam, 8 mi (13 km) SE, forms Conowingo Pond. Unit 1 is a 40 MWe nuclear plant on the same site (maintained in safe storage). Three Mile Island Nuclear Station (no longer operating) is 35 mi (56 km) upstream.
Population within a 50 mi (80 km) Radius: 6,005,101.

[4] The subsequent renewed licenses for Peach Bottom are still in place. In CLI-22-04 (NRC 2022b), the Commission ordered that the expiration date of the subsequently renewed licensees be reset to the end of the initial period of extended operation (as affirmed in Order CLI-22-07 [NRC 2022c]). The Commission's direction will hold until the staff completes its re-evaluation of generic environmental issues for subsequent license renewal.

PERRY NUCLEAR POWER PLANT (Perry)

Location: Lake County, Ohio
7 mi (11 km) NE of Painesville
Latitude 41.8008°N; longitude 81.1442°W
Licensee: Energy Harbor Nuclear Corp.

Unit Information	Unit 1
Docket Number:	50-440
Construction Permit:	1977
Operating License:	1986
Commercial Operation:	1987
License Expiration:	2026
Licensed Thermal Power (MWt):	3,758
Net Capacity (MWe):	1,261
Type of Reactor:	BWR
Nuclear Steam Supply System Vendor:	GE

<u>Cooling Water System</u>

Type: Natural draft cooling tower
Source: Lake Erie
Source Temperature Range: 32–79°F (0–26°C)
Condenser Flow Rate: 545,400 gpm (34.41 m^3/s)
Design Condenser Temperature Rise: 32°F (18°C)
Intake Structure: Submerged multiport structure 2,550 ft (777 m) offshore
Discharge Structure: Submerged diffuser 1,650 ft (503 m) offshore

<u>Site Information</u>

Total Area: 1,100 ac (450 ha)
Exclusion Area Distance: 0.55 mi (0.89 km) radius
Low Population Zone: 2.50 mi (4.02 km)
Nearest City: Euclid; 2020 population: 49,692
Site Topography: Flat
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Open water, forest, developed: high, medium, low density
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Eastern Great Lakes and Hudson Lowlands; Erie Drift Plain
Percent Wetland within 5 mi (8 km): 2.1, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is North Perry 1 mi (1.6 km) SW. Interstate Highway I-90 is about 5 mi (8 km) S.
Population within a 50 mi (80 km) Radius: 2,299,476.

POINT BEACH NUCLEAR PLANT (Point Beach)

Location: Manitowoc County, Wisconsin
13 mi (21 km) NNW of Manitowoc
Latitude 44.2808°N; longitude 87.5361°W
Licensee: NextEra Energy Point Beach, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-266	50-301
Construction Permit:	1967	1968
Operating License:	1970	1972
Commercial Operation:	1970	1972
License Expiration:	2030	2033
Licensed Thermal Power (MWt):	1,800	1,800
Net Capacity (MWe):	598	603
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Once-through
Source: Lake Michigan
Source Temperature Range: Not available
Condenser Flow Rate: 350,000 gpm (22 m^3/s) each unit
Design Condenser Temperature Rise: 19.3°F (10.7°C)
Intake Structure: Submerged structure 1,750 ft (533 m) from shore
Discharge Structure: 2 steel piling troughs, extending 200 ft (61 m) into Lake Michigan

Site Information

Total Area: 1,260 ac (510 ha)
Exclusion Area Distance: 0.74 mi (1.19 km) radius
Low Population Zone: 5.60 mi (9.01 km)
Nearest City: Green Bay; 2020 population: 107,395
Site Topography: Flat to rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Open water, agriculture, wetland
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Southeastern Wisconsin Till Plains
Percent Wetland within 5 mi (8 km): 4.6, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Two Creeks 1 mi (1.6 km) NNW. Point Beach State Forest is directly S of the site. The Kewaunee Nuclear Power Plant, which is no longer operating, is about 5 mi (8 km) N.
Population within a 50 mi (80 km) Radius: 826,680.

PRAIRIE ISLAND NUCLEAR GENERATING PLANT (Prairie Island)

Location: Goodhue County, Minnesota
28 mi (45 km) SE of Minneapolis
Latitude 44.6219°N; longitude 92.6331°W
Licensee: Northern States Power Company-Minnesota

Unit Information	Unit 1	Unit 2
Docket Number:	50-282	50-306
Construction Permit:	1968	1968
Operating License:	1973	1974
Commercial Operation:	1973	1974
License Expiration:	2033	2034
Licensed Thermal Power (MWt):	1,677	1,677
Net Capacity (MWe):	521	519
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Once-through and/or mechanical draft cooling towers
Source: Mississippi River
Source Temperature Range: 32–82°F (0–28°C)
Condenser Flow Rate: 294,000 gpm (18.6 m^3/s) each unit
Design Condenser Temperature Rise: 27°F (15°C)
Intake Structure: Short canal
Discharge Structure: Discharges to a basin then to towers and/or river

Site Information

Total Area: 560 ac (230 ha)
Exclusion Area Distance: 0.43 mi (0.69 km) radius
Low Population Zone: 1.50 mi (2.41 km)
Nearest City: Minneapolis; 2020 population: 429,954
Site Topography: Flat to rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Agriculture, forest, wetland
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Driftless Area
Percent Wetland within 5 mi (8 km): 18.5, mostly freshwater forested/shrub wetland
Nearby Features: The business district of the town of Red Wing is 6 mi (9.6 km) SE. The Prairie Island Indian Community is located immediately NW of the site.
Population within a 50 mi (80 km) Radius: 3,309,059.

QUAD CITIES NUCLEAR POWER STATION (Quad Cities)

Location: Rock Island County, Illinois
20 mi (32 km) NE of Moline
Latitude 41.7261°N; longitude 90.3100°W
Licensee: Constellation Energy Generation, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-254	50-265
Construction Permit:	1967	1967
Operating License:	1972	1972
Commercial Operation:	1973	1973
License Expiration:	2032	2032
Licensed Thermal Power (MWt):	2,957	2,957
Net Capacity (MWe):	908	911
Type of Reactor:	BWR	BWR
Nuclear Steam Supply System Vendor:	GE	GE

Cooling Water System

Type: Once-through
Source: Mississippi River
Source Temperature Range: 32–85°F (0–29°C)
Condenser Flow Rate: 970,000 gpm (61 m^3/s) both units
Design Condenser Temperature Rise: 28°F (15.6°C)
Intake Structure: Canal at edge of river
Discharge Structure: Two-pipe diffuser system on bottom of river

Site Information

Total Area: 817 ac (331 ha)
Exclusion Area Distance: 0.50 mi (0.80 km)
Low Population Zone: 3 mi (4.83 km)
Nearest City: Davenport, Iowa; 2020 population: 101,724
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Agriculture, wetland, forest
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Interior River Valley and Hills; Western Corn Belt Plains
Percent Wetland within 5 mi (8 km): 12.1, mostly freshwater forested/shrub wetland
Nearby Features: The village of Cordova is 4 mi (6 km) S. The Rock Island Arsenal is about 15 mi (24 km) SW.
Population within a 50 mi (80 km) Radius: 655,699.

R.E. GINNA NUCLEAR POWER PLANT (Ginna)

Location: Wayne County, New York
20 mi (32 km) NE of Rochester
Latitude 43.2778°N; longitude 77.3089°W
Licensee: Constellation Energy Generation, LLC

Unit Information	Unit 1
Docket Number:	50-244
Construction Permit:	1966
Operating License:	1969
Commercial Operation:	1970
License Expiration:	2029
Licensed Thermal Power (MWt):	1,775
Net Capacity (MWe):	581
Type of Reactor:	PWR
Nuclear Steam Supply System Vendor:	WEST

<u>Cooling Water System</u>

Type: Once-through
Source: Lake Ontario
Source Temperature Range: 32–80°F (0–27°C)
Condenser Flow Rate: 340,000 gpm (21.4 m^3/s)
Design Condenser Temperature Rise: 20°F (11°C)
Intake Structure: 3,100 ft (945 m) from shore, at a depth of 33 ft (10 m)
Discharge Structure: Canal discharges to Lake Ontario at shoreline

<u>Site Information</u>

Total Area: 488 ac (197 ha)
Exclusion Area Distance: 0.29–0.85 mi (0.47–1.38 km)
Low Population Zone: 3 mi (4.83 km)
Nearest City: Rochester; 2020 population: 211,328
Site Topography: Gently rolling to flat
Surrounding Area Topography: Sloping
Dominant Land Cover within 5 mi (8 km): Open water, agriculture, forest
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Eastern Great Lakes and Hudson Lowlands
Percent Wetland within 5 mi (8 km): 4.3, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Lakeside 2 mi (3 km) SW.
Population within a 50 mi (80 km) Radius: 1,299,149.

RIVER BEND STATION (River Bend)

Location:	West Feliciana County, Louisiana 24 mi (39 km) NNW of Baton Rouge Latitude 30.7569°N; longitude 91.3314°W
Licensee:	Entergy Operations, Inc.

Unit Information	Unit 1
Docket Number:	50-458
Construction Permit:	1977
Operating License:	1985
Commercial Operation:	1986
License Expiration:	2045
Licensed Thermal Power (MWt):	3,091
Net Capacity (MWe):	968
Type of Reactor:	BWR
Nuclear Steam Supply System Vendor:	GE

Cooling Water System

Type: Mechanical draft cooling towers
Source: Mississippi River
Source Temperature Range: Not available
Condenser Flow Rate: 508,470 gpm (32.08 m^3/s)
Design Condenser Temperature Rise: 27°F (15°C)
Intake Structure: At river bank
Discharge Structure: Pipe extending into the river

Site Information

Total Area: 3,342 ac (1,352 ha)
Exclusion Area Distance: 0.57 mi (0.92 km) radius
Low Population Zone: 2.50 mi (4.02 km) radius
Nearest City: Baton Rouge; 2020 population: 227,470
Site Topography: Flat
Surrounding Area Topography: Flat to rolling
Dominant Land Cover within 5 mi (8 km): Wetland, forest, agriculture
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Mississippi Valley Loess Plains; Mississippi Alluvial Plain
Percent Wetland within 5 mi (8 km): 17.7, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is St. Francisville 3 mi (5 km) NW. Audubon Memorial State Park is about 3 mi (5 km) NNE.
Population within a 50 mi (80 km) Radius: 1,037,151.

ST. LUCIE NUCLEAR PLANT (St. Lucie)

Location: St. Lucie County, Florida
7 mi (11 km) SE of Fort Pierce
Latitude 27.3486°N; longitude 80.2464°W
Licensee: Florida Power & Light Co.

Unit Information	Unit 1	Unit 2
Docket Number:	50-335	50-389
Construction Permit:	1970	1977
Operating License:	1976	1983
Commercial Operation:	1976	1983
License Expiration:	2036	2043
Licensed Thermal Power (MWt):	3,020	3,020
Net Capacity (MWe):	981	987
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	CE	CE

Cooling Water System

Type: Once-through
Source: Atlantic Ocean
Source Temperature Range: 87°F (31°C)
Condenser Flow Rate: 968,000 gpm (61 m^3/s) both units
Design Condenser Temperature Rise: 24°F (13°C).
Intake Structure: 1,200 ft (370 m) offshore
Discharge Structure: Unit 1 is 1,500 ft (460 m) offshore; Unit 2 is a multiport discharge 3,400 ft (1,040 m) offshore

Site Information

Total Area: 1,130 ac (457 ha)
Exclusion Area Distance: 0.97 mi (1.56 km) radius
Low Population Zone: 1 mi (1.61 km)
Nearest City: West Palm Beach; 2020 population: 117,415
Site Topography: Flat land and water
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Open water, wetland, developed: high, medium, low density
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Southern Coastal Plain
Percent Wetland within 5 mi (8 km): 9.5, mostly freshwater emergent wetland and estuarine and marine wetland
Nearby Features: The nearest town is Ankona 2 mi (3 km) W. The plant is on Hutchinson Island, which is separated from the mainland by the Indian River, which is part of the Intracoastal Waterway. A causeway to the mainland is about 6 mi (10 km) SSE.
Population within a 50 mi (80 km) Radius: 1,456,749.

SALEM NUCLEAR GENERATING STATION (Salem)

Location: Salem County, New Jersey
8 mi (13 km) SW of Salem
Latitude 39.4628°N; longitude 75.5358°W
Licensee: PSEG Nuclear, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-272	50-311
Construction Permit:	1968	1968
Operating License:	1976	1981
Commercial Operation:	1977	1981
License Expiration:	2036	2040
Licensed Thermal Power (MWt):	3,459	3,459
Net Capacity (MWe):	1,174	1,130
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Once-through
Source: Delaware River
Source Temperature Range: 33–79°F (1–26°C)
Condenser Flow Rate: 1,100,000 gpm (69 m^3/s) each unit
Design Condenser Temperature Rise: 13.6°F (7.6°C)
Intake Structure: 12-bay structure on edge of river
Discharge Structure: Submerged pipes extending 500 ft (150 m) into the river

Site Information

Total Area: 700 ac (280 ha)
Exclusion Area Distance: 0.80 mi (1.29 km)
Low Population Zone: 5 mi (8.05 km)
Nearest City: Wilmington, Delaware; 2020 population: 70,898
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Open water, wetland, agriculture
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Middle Atlantic Coastal Plain
Percent Wetland within 5 mi (8 km): 37.9, mostly estuarine and marine wetland
Nearby Features: The nearest town is Port Penn about 4 mi (6 km) NW in Delaware. The plant is on the same site as the Hope Creek Generating Station (nuclear).
Population within a 50 mi (80 km) Radius: 5,873,042.

SEABROOK STATION (Seabrook)

Location: Rockingham County, New Hampshire
13 mi (21 km) SSW of Portsmouth
Latitude 42.8983°N; longitude 70.8497°W
Licensee: NextEra Energy Seabrook, LLC

Unit Information	Unit 1
Docket Number:	50-443
Construction Permit:	1976
Operating License:	1990
Commercial Operation:	1990
License Expiration:	2050
Licensed Thermal Power (MWt):	3,648
Net Capacity (MWe):	1,295
Type of Reactor:	PWR
Nuclear Steam Supply System Vendor:	WEST

Cooling Water System

Type: Once-through
Source: Gulf of Maine
Source Temperature Range: 37–55°F (3–13°C)
Condenser Flow Rate: 399,000 gpm (25.2 m^3/s)
Design Condenser Temperature Rise: 38°F (21°C)
Intake Structure: 3 structures 50 ft (15 m) below sea level with pipeline submerged about 175 ft (50 m) below mean sea level and extending about 7,000 ft (2,100 m) offshore
Discharge Structure: Submerged pipeline ending in a diffuser located about 5,500 ft (1,675 m) offshore and about 5,000 ft (1,525 m) S of intake

Site Information

Total Area: 896 ac (363 ha)
Exclusion Area Distance: 0.57 mi (0.92 km) minimum
Low Population Zone: 1.25 mi (2.01 km)
Nearest City: Lawrence, Massachusetts; 2020 population: 89,143
Site Topography: Flat
Surrounding Area Topography: Flat to rolling
Dominant Land Cover within 5 mi (8 km): Open water, forest, developed: high, medium, low density
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Northeastern Coastal Zone
Percent Wetland within 5 mi (8 km): 21.2, mostly estuarine and marine wetland
Nearby Features: The nearest town is Seabrook 1 mi (1.6 km) W. Interstate Highway I-95 is about 1 mi (1.6 km) W. Hampton Beach State Park is 2 mi (3 km) E.
Population within a 50 mi (80 km) Radius: 4,693,723.

SEQUOYAH NUCLEAR PLANT (Sequoyah)

Location: Hamilton County, Tennessee
10 mi (16 km) NE of Chattanooga
Latitude 35.2233°N; longitude 85.0878°W
Licensee: Tennessee Valley Authority

Unit Information	Unit 1	Unit 2
Docket Number:	50-327	50-328
Construction Permit:	1970	1970
Operating License:	1980	1981
Commercial Operation:	1981	1982
License Expiration:	2040	2041
Licensed Thermal Power (MWt):	3,455	3,455
Net Capacity (MWe):	1,152	1,126
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Once-through and/or natural draft cooling towers
Source: Chickamauga Lake
Source Temperature Range: 42–83°F (6–28°C)
Condenser Flow Rate: 522,000 gpm (32.9 m^3/s) each unit
Design Condenser Temperature Rise: 30°F (17°C)
Intake Structure: Intake from lake
Discharge Structure: Discharge to lake

Site Information

Total Area: 525 ac (212 ha)
Exclusion Area Distance: 0.35 mi (0.56 km)
Low Population Zone: 3 mi (4.83 km)
Nearest City: Chattanooga; 2020 population: 181,099
Site Topography: Rolling
Surrounding Area Topography: Hilly
Dominant Land Cover within 5 mi (8 km): Forest, agriculture, open water
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Ridge and Valley
Percent Wetland within 5 mi (8 km): 0.5
Nearby Features: The nearest town is Shady Grove about 2 mi (3 km) NW. Harrison Bay State Park is 3 mi (5 km) S. Chickamauga Lake is part of the Tennessee River.
Population within a 50 mi (80 km) Radius: 1,172,704.

SHEARON HARRIS NUCLEAR POWER PLANT (Harris)

Location: Wake County, North Carolina
20 mi (32 km) SW of Raleigh
Latitude 35.6336°N; longitude 78.9564°W
Licensee: Duke Energy Progress, LLC

<u>Unit Information</u>	<u>Unit 1</u>
Docket Number:	50-400
Construction Permit:	1978
Operating License:	1987
Commercial Operation:	1987
License Expiration:	2046
Licensed Thermal Power (MWt):	2,948
Net Capacity (MWe):	964
Type of Reactor:	PWR
Nuclear Steam Supply System Vendor:	WEST

<u>Cooling Water System</u>

Type: Natural draft cooling tower
Source: Buckhorn Creek
Source Temperature Range: 41–81°F (5–27°C)
Condenser Flow Rate: 483,000 gpm (30.5 m^3/s)
Design Condenser Temperature Rise: 25.7°F (14.3°C)
Intake Structure: At shoreline of reservoir on Buckhorn Creek
Discharge Structure: Discharged to reservoir

<u>Site Information</u>

Total Area: 10,744 ac (4,348 ha)
Exclusion Area Distance: 6,640 ft (2 km) (northwest) to 7,000 ft (2.1 km) (east) to 7,200 ft (2.2 km) (south)
Low Population Zone: 3 mi (4.83 km)
Nearest City: Raleigh; 2020 population: 467,665
Site Topography: Rolling
Surrounding Area Topography: Rolling
Dominant Land Cover within 5 mi (8 km): Forest, herbaceous, open water
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Piedmont; Southeastern Plains
Percent Wetland within 5 mi (8 km): 3.9, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Bonsal 2 mi (3 km) NW. Buckhorn Creek feeds into the Cape Fear River.
Population within a 50 mi (80 km) Radius: 3,041,733.

SOUTH TEXAS PROJECT NUCLEAR GENERATING STATION (South Texas)

Location: Matagorda County, Texas
12 mi (19 km) SSW of Bay City
Latitude 28.7950°N; longitude 96.0481°W
Licensee: STP Nuclear Operating Co.

Unit Information	Unit 1	Unit 2
Docket Number:	50-498	50-499
Construction Permit:	1975	1975
Operating License:	1988	1989
Commercial Operation:	1988	1989
License Expiration:	2047	2048
Licensed Thermal Power (MWt):	3,853	3,853
Net Capacity (MWe):	1,280	1,280
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Cooling reservoir
Source: Colorado River
Source Temperature Range: 58–84°F (14–29°C)
Condenser Flow Rate: 907,400 gpm (57.26 m^3/s) each unit
Design Condenser Temperature Rise: 19°F (11°C)
Intake Structure: On bank of Colorado River
Discharge Structure: On bank of Colorado River

Site Information

Total Area: 12,350 ac (4,998 ha)
Exclusion Area Distance: 0.89 mi (1.43 km) minimum
Low Population Zone: 3 mi (4.83 km)
Nearest City: Galveston; 2020 population: 53,695
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Agriculture, open water, wetland
Level 1 Ecoregion within 5 mi (8 km): Great Plains
Level 3 Ecoregion within 5 mi (8 km): Western Gulf Coastal Plain
Percent Wetland within 5 mi (8 km): 6.2, mostly freshwater forested/shrub wetland and freshwater emergent wetland
Nearby Features: The nearest town is Matagorda 8 mi (13 km) SE. The Port of Bay City terminal is located 5 mi (8 km) NNE.
Population within a 50 mi (80 km) Radius: 268,364.

SURRY POWER STATION (Surry)

Location: Surry County, Virginia
17 mi (27 km) NW of Newport News
Latitude 37.1656°N; longitude 76.6983°W
Licensee: Virginia Electric and Power Company

Unit Information	Unit 1	Unit 2
Docket Number:	50-280	20-281
Construction Permit:	1968	1968
Operating License:	1972	1973
Commercial Operation:	1972	1973
License Expiration:	2052	2053
Licensed Thermal Power (MWt):	2,587	2,587
Net Capacity (MWe):	838	838
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Once-through
Source: James River
Source Temperature Range: 35–84°F (2–29°C)
Condenser Flow Rate: 1.68 million gpm (106 m^3/s) both units
Design Condenser Temperature Rise: 14°F (7.8°C)
Intake Structure: 1.7 mi (2.7 km) concrete canal
Discharge Structure: 2,900 ft (880 m) canal

Site Information

Total Area: 840 ac (340 ha)
Exclusion Area Distance: 1,650 ft (500 m) radius or 0.31 mi (0.5 km)
Low Population Zone: 3 mi (4.83 km)
Nearest City: Newport News; 2020 population: 186,247
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Open water, forest, agriculture
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Middle Atlantic Coastal Plain; Southeastern Plains
Percent Wetland within 5 mi (8 km): 9.6, mostly freshwater emergent wetland, estuarine and marine wetland, and freshwater forested/shrub wetland
Nearby Features: The nearest town is Scotland 5 mi (8 km) W. Jamestown Island, a Federal park, is 4 mi (6 km) NW. Chippokes Plantation, a State park, is 3 mi (5 km) WSW. Jamestown National Historical Park is 5 mi (8 km) WNW. Colonial Williamsburg is 7 mi (11 km) NNW. Adjacent to the site on the north is Hog Island, a waterfowl refuge. Interstate Highway I-64 is 12 mi (19 km) NW.
Population within a 50 mi (80 km) Radius: 2,462,820.

SUSQUEHANNA STEAM ELECTRIC STATION (Susquehanna)

Location: Luzerne County, Pennsylvania
7 mi (11 km) NE of Berwick
Latitude 41.0922°N; longitude 76.1467°W
Licensee: Susquehanna Nuclear, LLC

Unit Information	Unit 1	Unit 2
Docket Number:	50-387	50-388
Construction Permit:	1973	1973
Operating License:	1982	1984
Commercial Operation:	1983	1985
License Expiration:	2042	2044
Licensed Thermal Power (MWt):	3,952	3,952
Net Capacity (MWe):	1,247	1,247
Type of Reactor:	BWR	BWR
Nuclear Steam Supply System Vendor:	GE	GE

Cooling Water System

Type: Natural draft cooling towers
Source: Susquehanna River
Source Temperature Range: Not available
Condenser Flow Rate: 968,000 gpm (61 m^3/s) both units
Design Condenser Temperature Rise: 14°F (8°C)
Intake Structure: Intake bays on river bank
Discharge Structure: Diffuser pipe 200 ft (61 m) from river bank

Site Information

Total Area: 1,173 ac (475 ha)
Exclusion Area Distance: 0.34 mi (0.55 km) radius
Low Population Zone: 3 mi (4.83 km)
Nearest City: Wilkes-Barre; 2020 population: 44,328
Site Topography: Rolling
Surrounding Area Topography: Hilly with flat river valley
Dominant Land Cover within 5 mi (8 km): Forest, agriculture, developed: open space
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Ridge and Valley
Percent Wetland within 5 mi (8 km): 1.4, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Beach Haven about 1 mi (1.6 km) SW. Interstate Highway I-80 is 5 mi (8 km) E.
Population within a 50 mi (80 km) Radius: 1,829,035.

TURKEY POINT NUCLEAR PLANT (Turkey Point)

Location: Dade County, Florida
25 mi (40 km) S of Miami
Latitude 25.4350°N; longitude 80.3314°W
Licensee: Florida Power and Light Co.

Unit Information	Unit 3	Unit 4
Docket Number:	50-250	50-251
Construction Permit:	1967	1967
Operating License:	1972	1973
Commercial Operation:	1972	1973
License Expiration:[5]	2032	2033
Licensed Thermal Power (MWt):	2,644	2,644
Net Capacity (MWe):	837	861
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Cooling canal system
Source: Biscayne Bay; Supplemental makeup from the Upper Floridan aquifer
Source Temperature Range: 54–90°F (12–32°C)
Condenser Flow Rate: 1.3 million gpm (82 m^3/s) both units
Design Condenser Temperature Rise: 18°F (10°C)
Intake Structure: Intake canal and barge canal
Discharge Structure: Canal system covering about 4,000 ac (1,600 ha)

Site Information

Total Area: 24,000 ac (9,700 ha)
Exclusion Area Distance: 0.79 mi (1.27 km)
Low Population Zone: 5 mi (8.05 km)
Nearest City: Miami; 2020 population: 442,241
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Wetland, open water, agriculture
Level 1 Ecoregion within 5 mi (8 km): Tropical Wet Forest
Level 3 Ecoregion within 5 mi (8 km): Southern Florida Coastal Plain
Percent Wetland within 5 mi (8 km): 39.7, mostly estuarine and marine wetland and freshwater emergent wetland
Nearby Features: The nearest town is Florida City about 9 mi (14 km) W. Homestead Air Reserve Base is 6 mi (9.7 km) NW. Homestead Recreation Park is about 2 mi (3 km) NNW. Unit 5 is gas-fired and co-located onsite.
Population within a 50 mi (80 km) Radius: 3,813,589.

[5] The subsequent renewed licenses for Turkey Point are still in place. In CLI-22-02 (NRC 2022d), the Commission ordered that the expiration date of the subsequently renewed licensees be reset to the end of the initial period of extended operation (as affirmed in Order CLI-22-06 [NRC 2022e]). The Commission's direction will hold until the staff completes its re-evaluation of generic environmental issues for subsequent license renewal.

VIRGIL C. SUMMER NUCLEAR STATION (Summer)

Location: Fairfield County, South Carolina
26 mi (42 km) NW of Columbia
Latitude 34.2958°N; longitude 81.3203°W
Licensee: Dominion Energy South Carolina

Unit Information	Unit 1
Docket Number:	50-395
Construction Permit:	1973
Operating License:	1982
Commercial Operation:	1984
License Expiration:	2042
Licensed Thermal Power (MWt):	2,900
Net Capacity (MWe):	971
Type of Reactor:	PWR
Nuclear Steam Supply System Vendor:	WEST

Cooling Water System

Type: Once-through
Source: Lake Monticello
Source Temperature Range: 52–91°F (11–33°C)
Condenser Flow Rate: 507,000 gpm (32 m^3/s)
Design Condenser Temperature Rise: 25°F (14°C)
Intake Structure: Intake at shoreline
Discharge Structure: Discharge to lake via a discharge basin and 1,000 ft (305 m) canal

Site Information

Total Area: 2,200 ac (890 ha)
Exclusion Area Distance: 1.01 mi (1.63 m) radius
Low Population Zone: 3 mi (4.83 km)
Nearest City: Columbia; 2020 population: 136,632
Site Topography: Rolling
Surrounding Area Topography: Rolling to hilly
Dominant Land Cover within 5 mi (8 km): Forest, open water, herbaceous
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Piedmont
Percent Wetland within 5 mi (8 km): 2.5, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Jenkinsville 3 mi (5 km) SE. Interstate Highway I-26 is 7 mi (11 km) SSW. The Fairfield pumped storage hydrostation is about 1 mi (1.6 km) NW and uses Lake Monticello as well as the Parr Reservoir.
Population within a 50 mi (80 km) Radius: 1,289,146.

VOGTLE ELECTRIC GENERATING PLANT (Vogtle)

Location: Burke County, Georgia
26 mi (42 km) SE of Augusta
Latitude 33.1414°N; longitude 81.7625°W
Licensee: Southern Nuclear Operating Co., Inc.

Unit Information	Unit 1	Unit 2
Docket Number:	50-424	50-425
Construction Permit:	1974	1974
Operating License:	1987	1989
Commercial Operation:	1987	1989
License Expiration:	2047	2049
Licensed Thermal Power (MWt):	3,625.6	3,625.6
Net Capacity (MWe):	1,150	1,152
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Natural draft cooling towers
Source: Savannah River
Source Temperature Range: 39–86°F (4–30°C)
Condenser Flow Rate: 509,600 gpm (32.16 m^3/s) each unit
Design Condenser Temperature Rise: 33°F (18°C)
Intake Structure: At river bank
Discharge Structure: Single-point discharge pipe near the shoreline

Site Information

Total Area: 3,169 ac (1,282 ha)
Exclusion Area Distance: 0.68 mi (1.09 km) minimum
Low Population Zone: 2 mi (3.22 km) radius
Nearest City: Augusta-Richmond County; 2020 population: 202,081
Site Topography: Rolling
Surrounding Area Topography: Rolling, river flood plain
Dominant Land Cover within 5 mi (8 km): Forest, wetland, herbaceous
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Southeastern Plains
Percent Wetland within 5 mi (8 km): 26.5, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Shell Bluff about 7 mi (11 km) W. Vogtle Units 3 and 4 (next generation large light water reactors) are co-located onsite. The U.S. Department of Energy Savannah River Site is about 10 mi (16 km) NNE.
Population within 50 mi (80 km) Radius: 789,654.

WATERFORD STEAM ELECTRIC STATION (Waterford)

Location: St. Charles County, Louisiana
20 mi (32 km) W of New Orleans
Latitude 29.9947°N; longitude 90.4711°W
Licensee: Entergy Operations, Inc.

Unit Information	Unit 3
Docket Number:	50-382
Construction Permit:	1974
Operating License:	1985
Commercial Operation:	1985
License Expiration:	2044
Licensed Thermal Power (MWt):	3,716
Net Capacity (MWe):	1,250
Type of Reactor:	PWR
Nuclear Steam Supply System Vendor:	CE

Cooling Water System

Type: Once-through
Source: Mississippi River
Source Temperature Range: 46–82°F (8–28°C)
Condenser Flow Rate: 975,000 gpm (61.53 m^3/s)
Design Condenser Temperature Rise: 16°F (9°C)
Intake Structure: At river bank
Discharge Structure: At river bank

Site Information

Total Area: 3,561 ac (1,441 ha)
Exclusion Area Distance: 90.57 mi (0.92 km) radius
Low Population Zone: 2 mi (3.22 km)
Nearest City: New Orleans; 2020 population: 383,997
Site Topography: Flat
Surrounding Area Topography: Flat
Dominant Land Cover within 5 mi (8 km): Wetland, agriculture, developed: high, medium, low density
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Mississippi Alluvial Plain
Percent Wetland within 5 mi (8 km): 58.3, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Killona 1 mi (1.6 km) WNW. Interstate Highway I-10 is about 7 mi (11 km) NE and I-90 about 7 mi (11 km) SE. Lake Pontchartrain is about 7 mi (11 km) NE.
Population within a 50 mi (80 km) Radius: 2,171,180.

WATTS BAR NUCLEAR PLANT (Watts Bar)

Location: Rhea County, Tennessee
7 mi (11 km) SSE of Spring City
Latitude 35.6022°N; longitude 84.7894°W
Licensee: Tennessee Valley Authority

Unit Information	Unit 1	Unit 2
Docket Number:	50-390	50-391
Construction Permit:	1973	1973
Operating License:	1996	2015
Commercial Operation:	1996	2016
License Expiration:	2035	2055
Licensed Thermal Power (MWt):	3,459	3,459
Net Capacity (MWe):	1,123	1,122
Type of Reactor:	PWR	PWR
Nuclear Steam Supply System Vendor:	WEST	WEST

Cooling Water System

Type: Natural draft cooling towers
Source: Chickamauga Lake on the Tennessee River.
Source Temperature Range: 43–82°F (6–28°C)
Condenser Flow Rate: 410,000 gpm (26 m^3/s) each unit
Design Condenser Temperature Rise: 38°F (21°C)
Intake Structure: At lake bank
Discharge Structure: To lake via a holding pond

Site Information

Total Area: 1,770 ac (716 ha)
Exclusion Area Distance: 0.75 mi (1.21 km) radius
Low Population Zone: 3 mi (4.83 km)
Nearest City: Chattanooga; 2020 population: 181,099
Site Topography: Flat to rolling
Surrounding Area Topography: Rolling to hilly
Dominant Land Cover within 5 mi (8 km): Forest, agriculture, open water
Level 1 Ecoregion within 5 mi (8 km): Eastern Temperate Forest
Level 3 Ecoregion within 5 mi (8 km): Ridge and Valley
Percent Wetland within 5 mi (8 km): 1.5, mostly freshwater forested/shrub wetland
Nearby Features: The nearest town is Peakland 2 mi (3 km) NE. Watts Bar Dam is 1 mi (1.6 km) N. Interstate Highway I-75 is about 11 mi (18 km) SE.
Population within a 50 mi (80 km) Radius: 1,312,700.

WOLF CREEK GENERATING STATION (Wolf Creek)

Location: Coffey County, Kansas
4 mi (6 km) NE of Burlington
Latitude 38.2386°N; longitude 95.6894°W
Licensee: Wolf Creek Nuclear Operating Corporation

Unit Information	Unit 1
Docket Number:	50-482
Construction Permit:	1977
Operating License:	1985
Commercial Operation:	1985
License Expiration:	2045
Licensed Thermal Power (MWt):	3,565
Net Capacity (MWe):	1,166
Type of Reactor:	PWR
Nuclear Steam Supply System Vendor:	WEST

Cooling Water System

Type: Cooling pond
Source: Coffey County Lake
Source Temperature Range: 32–87°F (0–31°C)
Condenser Flow Rate: 500,000 gpm (30 m^3/s)
Design Condenser Temperature Rise: 30°F (1.1°C)
Intake Structure: On the shore of cooling lake
Discharge Structure: Discharged to 5,090 ac (2,060 ha) cooling lake, into an embayment separated from the intake

Site Information

Total Area: 9,818 ac (3,973 ha)
Exclusion Area Distance: 0.75 mi (1.21 km) radius
Low Population Zone: 2.5 mi (4.02 km) radius
Nearest City: Topeka; 2020 population: 126,587
Site Topography: Flat to rolling
Surrounding Area Topography: Flat to rolling
Dominant Land Cover within 5 mi (8 km): Herbaceous, agriculture, open water
Level 1 Ecoregion within 5 mi (8 km): Great Plains
Level 3 Ecoregion within 5 mi (8 km): Central Irregular Plains
Percent Wetland within 5 mi (8 km): 2.1, mostly freshwater pond and freshwater emergent wetland
Nearby Features: The nearest town is Sharpe about 2 mi (3 km) N. The Flint Hills National Wildlife Refuge is about 7 mi (11 km) W. The John Redmond Reservoir is about 4 mi (6 km) W. Interstate Highway I-35 is 14 mi (23 km) N. The cooling lake is formed by a dam on Wolf Creek.
Population within a 50 mi (80 km) Radius: 173,018.

°C = degree(s) Celsius; °F = degree(s) Fahrenheit; ac = acre(s); B&W = Babcock & Wilcox Nuclear Power Company; BWR = boiling water reactor; CE = Combustion Engineering; cm = centimeter(s); CONUS = continental United States; E = east; ENE = east-northeast; ESE = east-southeast; ft = feet/foot; GE = General Electric (Company); GEIS = generic environmental impact statement; gpm = gallon(s) per minute; ha = hectare(s); in. = inch(es); km = kilometer(s); LR GEIS = *Generic Environmental Impact*

Statement for License Renewal of Nuclear Plants; m = meter(s); m^3/s = cubic meter(s) per second; mi = mile(s); MWe = megawatt(s) electric; MWt = megawatt(s) thermal; N = north; NE = northeast; NNE = north-northeast; NNW = north-northwest; NRC = U.S. Nuclear Regulatory Commission; NW = northwest; PSEG = Public Service Enterprise Group Nuclear, LLC; PWR = pressurized water reactor; s = second(s); S = south; SE = southeast; SSE = south-southeast; SSW = south-southwest; SW = southwest; STP = South Texas Project; W = west; WEST = Westinghouse; WNW = west-northwest; WSW = west-southwest.

C.1 References

EPA (U.S. Environmental Protection Agency). 2013. "Level III and IV Ecoregions of the Continental United States." Washington, D.C. ADAMS Accession No. ML18023A341.

FWS (U.S. Fish and Wildlife Service). 2022. "National Wetlands Inventory, Wetlands Data Layer." Washington, D.C. Accessed May 5, 2022, at https://www.fws.gov/program/national-wetlands-inventory/wetlands-data.

NRC (U.S. Nuclear Regulatory Commission). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*. Volumes 1 and 2, NUREG-1437, Washington, D.C. ADAMS Accession Nos. ML040690705, ML040690738.

NRC (U.S. Nuclear Regulatory Commission). 2013. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* [GEIS]. NUREG-1437, Revision 1, Washington, D.C. ADAMS Package Accession No. ML13107A023.

NRC (U.S. Nuclear Regulatory Commission). 2022a. Letter from S.P. Wall to P. Oneid and K. Trice, dated June 28, 2022, regarding "Palisades Nuclear Plant and Big Rock Point Plant – Issuance of Amendment Nos. 129 and 273 Re: Order Approving Transfer of Licenses and Conforming Administrative License Amendments (EPIDS L-2022-LLM-0002 AND L-2020-LLM-0003)." Rockville, MD. ADAMS Accession No. ML22173A179.

NRC (U.S. Nuclear Regulatory Commission). 2022b. *Memorandum and Order in the Matter of Exelon Generation Company, LLC (Peach Bottom Atomic Power Station, Units 2 and 3)*. CLI-22-04, Rockville, MD. ADAMS Accession No. ML22055A557.

NRC (U.S. Nuclear Regulatory Commission). 2022c. *Memorandum and Order in the Matter of Constellation Energy Generation, LLC (F/K/A Exelon Generation Company, LLC) (Peach Bottom Atomic Power Station, Units 2 and 3)*. CLI-22-07, Rockville, MD. ADAMS Accession No. ML22154A217.

NRC (U.S. Nuclear Regulatory Commission). 2022d. *Memorandum and Order in the Matter of Florida Power & Light Co. (Turkey Point Nuclear Generating Units 3 and 4)*. CLI-22-02, Rockville, MD. ADAMS Accession No. ML22055A496.

NRC (U.S. Nuclear Regulatory Commission). 2022e. *Memorandum and Order in the Matter of Florida Power & Light Co. (Turkey Point Nuclear Generating Units 3 and 4)*. CLI-22-06, Rockville, MD. ADAMS Accession No. ML22154A215.

NRC (U.S. Nuclear Regulatory Commission). 2023a. *2022-2023 Information Digest*. NUREG-1350, Volume 34. Washington, D.C. ADAMS Accession No. ML23047A371.

NRC (U.S. Nuclear Regulatory Commission). 2023b. Letter from B.K. Harris to P. Gerfen, dated March 2, 2023, regarding “Diablo Canyon Power Plant, Units 1 and 2 – Exemption from Requirements Related to Submission of a License Renewal Application.” Washington, D.C. ADAMS Accession No. ML23026A102.

USCB (U.S. Census Bureau). 2021. “Quick Facts: United States, Population Estimates.” Washington, D.C. Accessed May 4, 2022, at https://www.census.gov/quickfacts/fact/table/US/PST045221.

USGS (U.S. Geological Survey). 2019. “NLCD 2019 Land Cover (CONUS).” Multi-Resolution Land Characteristics Consortium Project. Sioux Falls, SD. Accessed May 11, 2023, at https://www.mrlc.gov/data/nlcd-2019-land-cover-conus.

APPENDIX D

ALTERNATIVES TO THE PROPOSED ACTION CONSIDERED IN THE LR GEIS

APPENDIX D

ALTERNATIVES TO THE PROPOSED ACTION CONSIDERED IN THE LR GEIS

D.1 Introduction

This appendix provides additional descriptions of (1) the alternatives to the proposed action that are described in Chapter 2 of this revision of NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (LR GEIS), and (2) the environmental impacts to each resource area that would be associated with construction and operation of these alternatives to the proposed action.[1]

D.2 No Action Alternative

The no action alternative represents a decision by the U.S. Nuclear Regulatory Commission (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. As described in Chapter 4, Section 4.14.2.1 of this LR GEIS, expiration of a license will require the reactor to ultimately undergo decommissioning, whether it be more immediate or deferred. 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. The no action alternative 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 [DSM]), delayed retirements, purchased power, or some combination of these options.

[1] The information and analyses included here consist of certain relocated text from Chapters 2 and 4 of the draft LR GEIS to address changes to the National Environmental Policy Act (NEPA) (42 U.S.C. § 4321 et seq.) from the Fiscal Responsibility Act of 2023 (Public Law No. 118-5, 137 Stat. 10). The text was relocated to revise the document to be less than the 300-page limit (not including appendices, citations, figures, tables, and other graphics) for environmental impact statements analyzing proposed agency actions of "extraordinary complexity" specified in the revised NEPA statute. Changes made in response to comments in this final LR GEIS, additions of new text, as well as corrective and substantial editorial revisions are marked with a change bar (vertical line) on the side margin of the page where the changes or additions were made. Minor editorial revisions and those limited to formatting are not marked. Text that was simply relocated from Chapters 2 and 4, along with associated references, and not otherwise changed is not marked with a change bar.

D.3 Alternative Energy Sources

The following sections describe alternative energy sources identified by the NRC that may be 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 supplemental environmental impact statements (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.[2]

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 DSM 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, 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 license renewal [LR] or subsequent license renewal [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

[2] 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.

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 increased from 4,125 million megawatt-hours (MMWh) in 2010 to 4,243 MMWh in 2022. Coal and petroleum (oil) generation decreased substantially between 2010 and 2022, while natural gas, wind, and solar increased. Table D.3-1 includes the changes in values of net generation at utility-scale facilities between 2010 and 2022 (DOE/EIA 2022a, DOE/EIA 2023a).

Table D.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 2022
Nuclear	807	772
Coal	1,847	828
Natural Gas	988	1,689
Oil	37	23
Hydroelectric	260	262
Geothermal	15	17
Wind	95	435
Biomass	56	53
Solar	1	146
Other[(a)]	19	17
Total[(b)]	4,125	4,243

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.
(b) May not sum to the total due to rounding.

In the EIA's *Annual Energy Outlook 2023*, 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. Declining capital costs for solar panels, wind turbines, and battery storage, as well as government subsidies, are expected to result in renewables becoming increasingly cost-effective, with nuclear, coal, and natural gas expected to decline as a share of total energy generation (DOE/EIA 2023b).

In Sections D.3.1 through D.3.3 of this appendix, the NRC presents a variety of energy sources (including fossil fuel, new 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 Section D.4, the NRC compares the environmental impacts of these alternatives to the environmental impacts of license renewal. In addition, Section D.3.4 discusses non-power-generating approaches that could also be considered for offsetting a nuclear power plant's existing capacity.

D.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 (GHGs), including carbon dioxide (CO_2) (NRC 2013). 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.

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

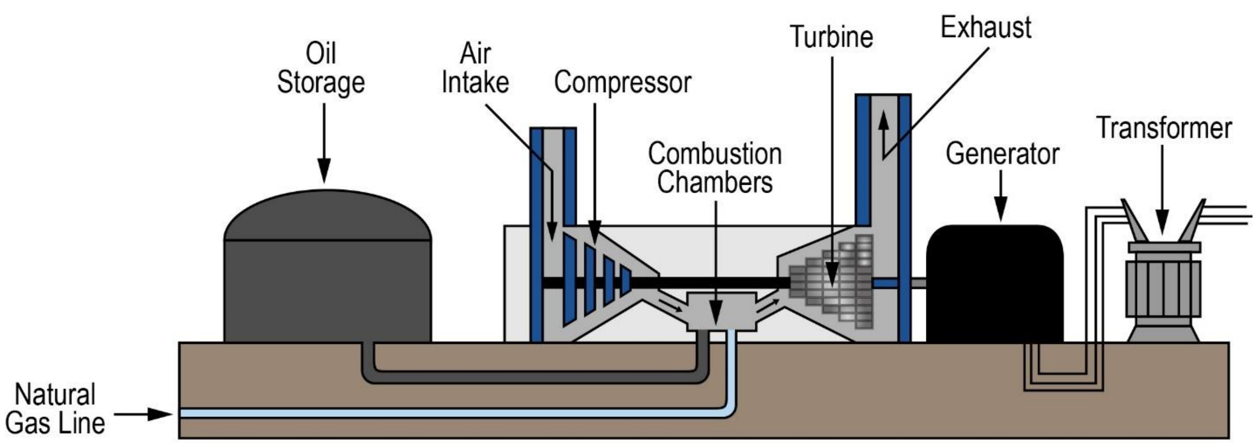


Figure D.3-1 Schematic of a Natural Gas-Fired Plant

D.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 2021a). 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 GHG 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 2022b).

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 [SCPC] 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 D.3-2.

SCPC 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.

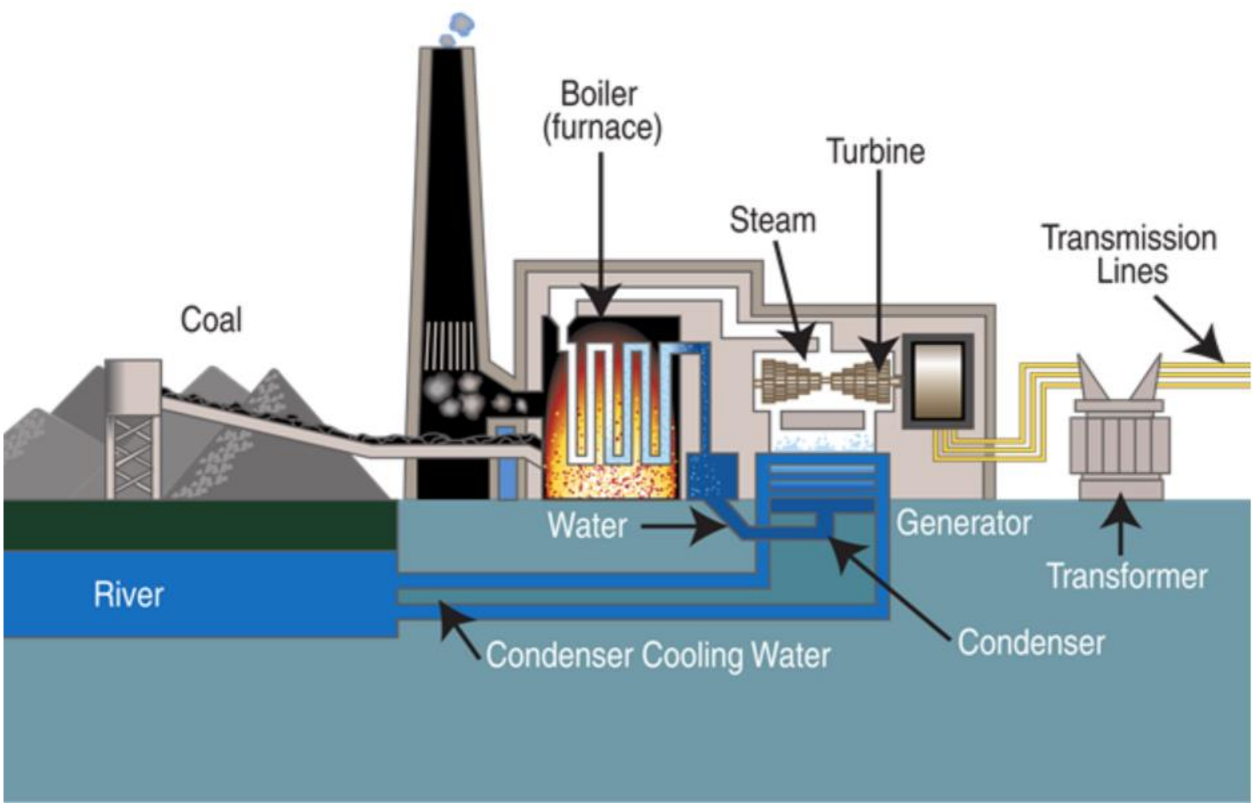


Figure D.3-2 Schematic of a Coal-Fired Power Plant. Source: NETL Undated.

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. § 7401 et seq.) and the Clean Water Act (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 2013). 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 2020).

D.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 more than 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).

D.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 plants to enter service in the United States are Vogtle Units 3 and 4 in Waynesboro, Georgia, which began commercial operation in July 2023 and April 2024, respectively. Prior to that, the last new nuclear power reactor to come online was Watts Bar Unit 2 in 2016 (Georgia Power 2024, DOE/EIA 2022c). 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 2022b). Currently, seven 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), the 1,400 MWe Korean Electric Power Corporation APR 1400 (10 CFR Part 52 Appendix F), and the 600 MWe NuScale Small Modular Reactor (10 CFR Part 52, Appendix G) (NRC 2022, 88 FR 3287).

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 2023a). 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, NRC 2024). 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 light water reactor (LLWR) plants and (2) small modular reactor (SMR) plants.

D.3.2.1 Large Light Water Reactors

LLWR designs feature advanced safety systems and evolutionary operating improvements over existing power reactors. The first of these new LLWR units to be built in the United States (Vogtle Units 3 and 4, see Section D.3.2) represent the initial 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 2022d, DOE Undated-a). A schematic of an LLWR is depicted in Figure D.3-3.

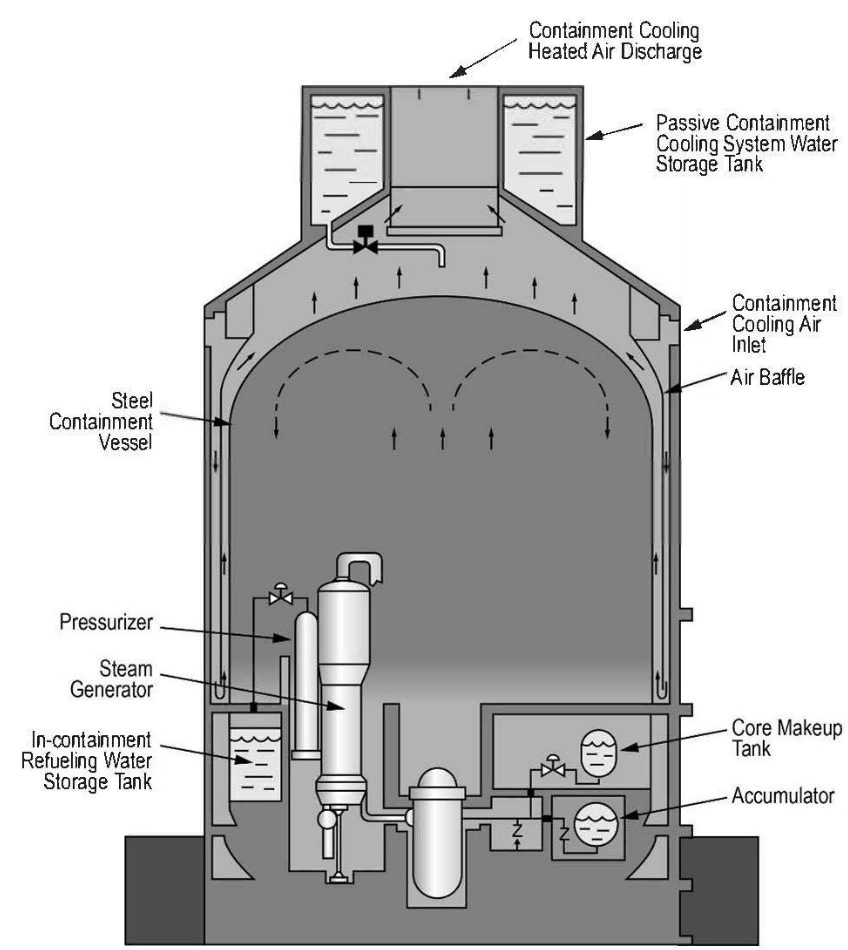
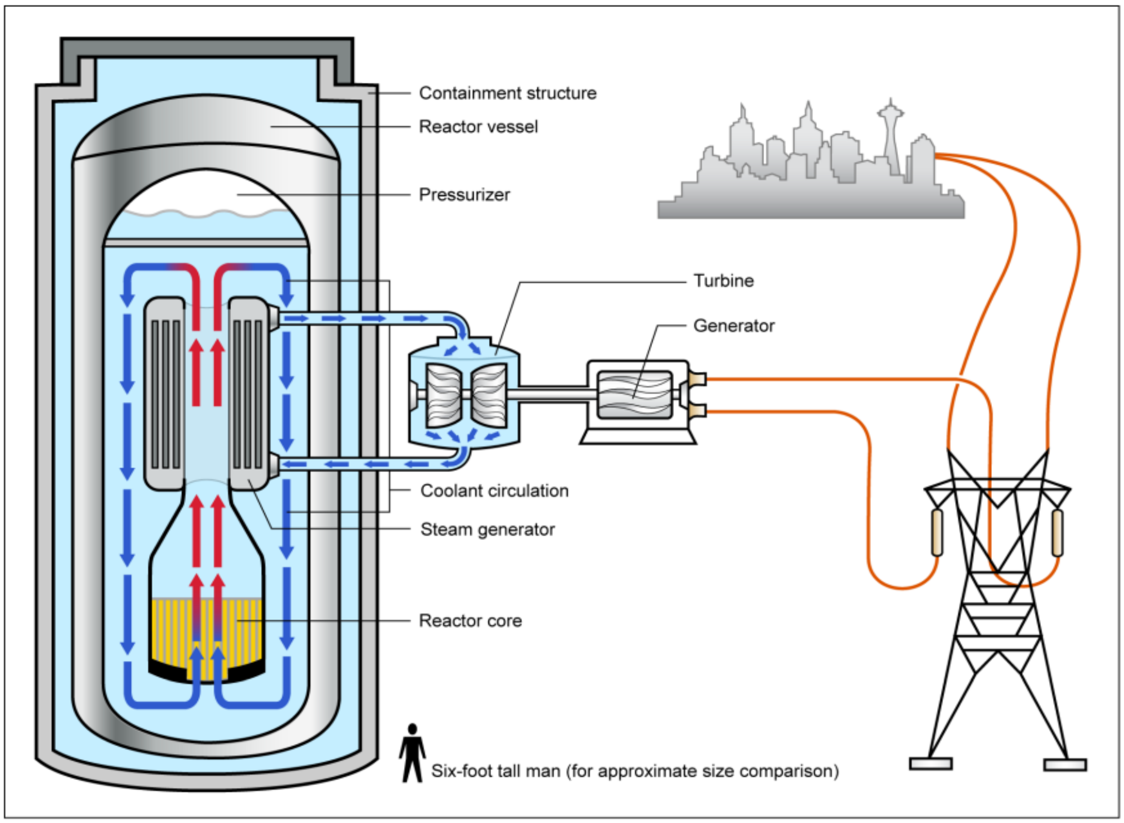


Figure D.3-3 Schematic of a Large Light Water Reactor. Adapted from: NRC 2004.

D.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 light water reactors (LWRs) and LLWRs 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 2018, NRC 2020, 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 D.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 2018). 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 light water reactor units (either conventional LWR or LLWR) 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 2023b). This design, the NuScale SMR, was certified by the NRC in January 2023, and could potentially achieve operation on a commercial scale by 2029 (88 FR 3287, NuScale 2022, NuScale 2023). SMRs could potentially be constructed and operational by the time some existing nuclear power plant licenses expire.



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

Figure D.3-4 Schematic of a Light Water Small Modular Nuclear Reactor. Source: GAO 2015.

D.3.3 Renewable Energy Technologies

The NRC considers the following renewable energy technology alternatives for possible replacement power: solar (both photovoltaic [PV] 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 22 percent of total U.S. electricity generation in 2022, and are projected to account for nearly 60 percent of cumulative generating capacity additions through 2050 (DOE/EIA 2022e, DOE/EIA 2022f). 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 2021b).

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 was negligible prior to 2020, but is expected to increase to 30 gigawatts (GW) by the end of 2025 (DOE/EIA 2022g).

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 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. Compressed air energy storage 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. 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.

D.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 PV and solar thermal, also referred to as concentrating solar power (CSP) (see Figure D.3-5 and Figure D.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.

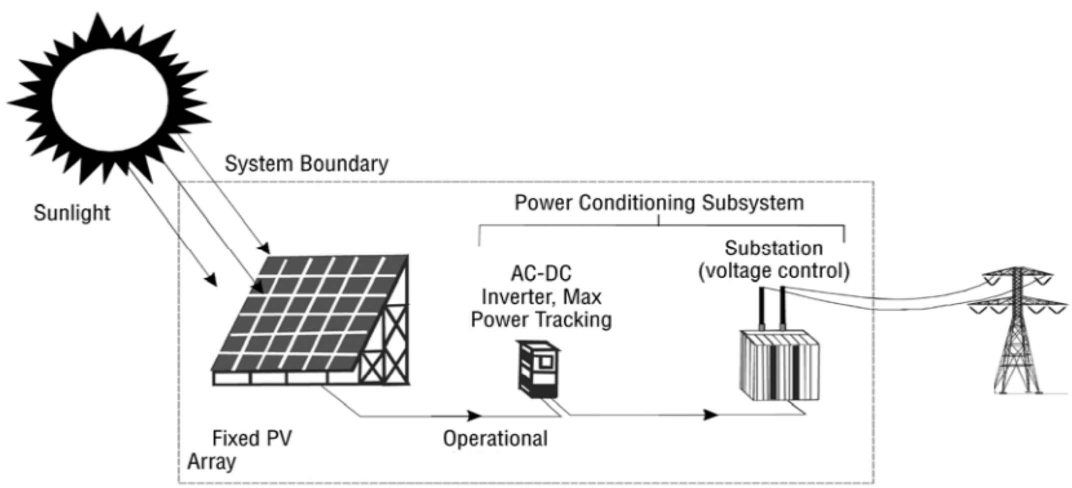


Figure D.3-5 Schematic of Solar Photovoltaic Power Plant. Adapted from: NRC 2013.

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.

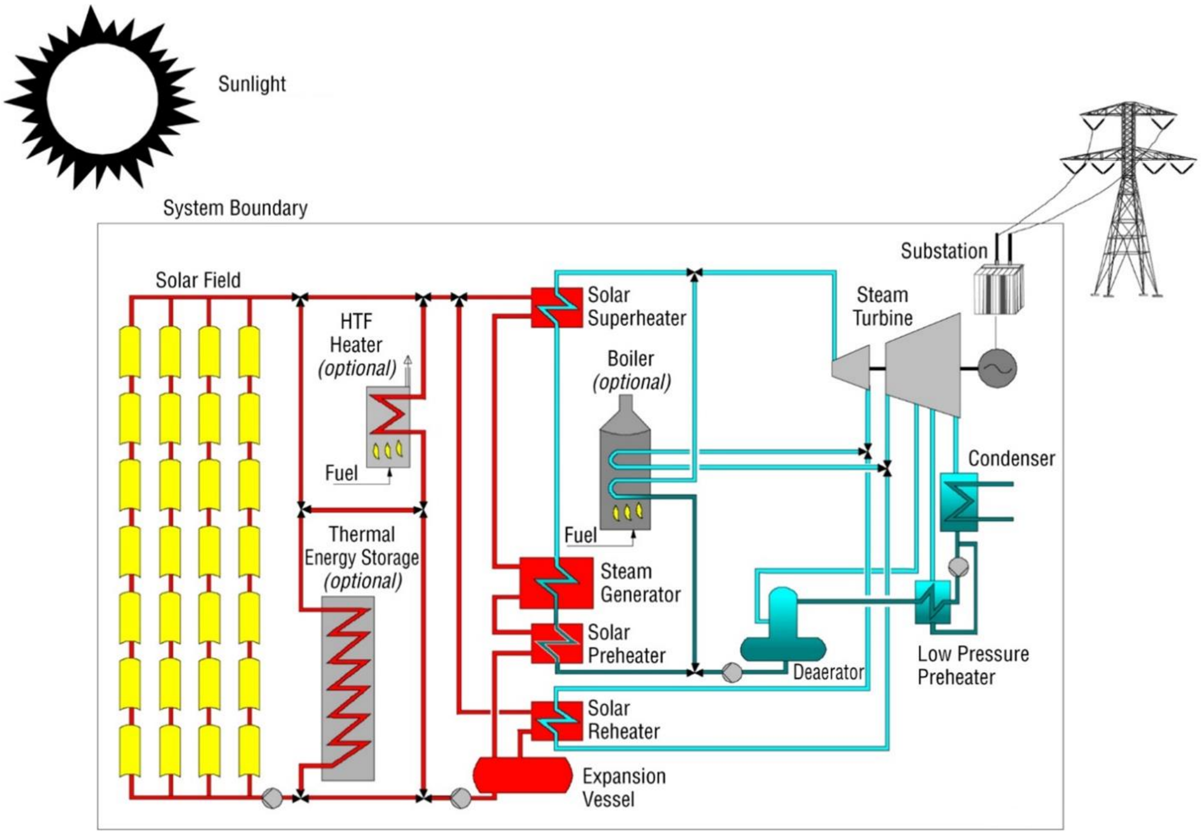


Figure D.3-6 Schematic of Concentrated Solar Power Plant. Adapted from: NRC 2013.

Solar energy technologies produced approximately 3.4 percent of total U.S. electricity generation in 2022, representing approximately 16 percent of total renewable generation (DOE/EIA 2023a). Nationwide, growth in utility-scale solar PV facilities (greater than 1 MW) has resulted in an increase from approximately 1,000 MW in 2011 to approximately 60,000 MW of installed capacity in 2021 (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 2021c). 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 (i.e., having at least 1 MW of electrical generating capacity) that could potentially serve as reasonable replacement energy sources. The remaining 30 percent of these solar additions are projected to come from individually smaller end-use PV sources, such as residential and commercial rooftop solar installations, which do not meet the NRC's utility-scale criterion (DOE/EIA 2022h).

D.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 D.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-b). 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).

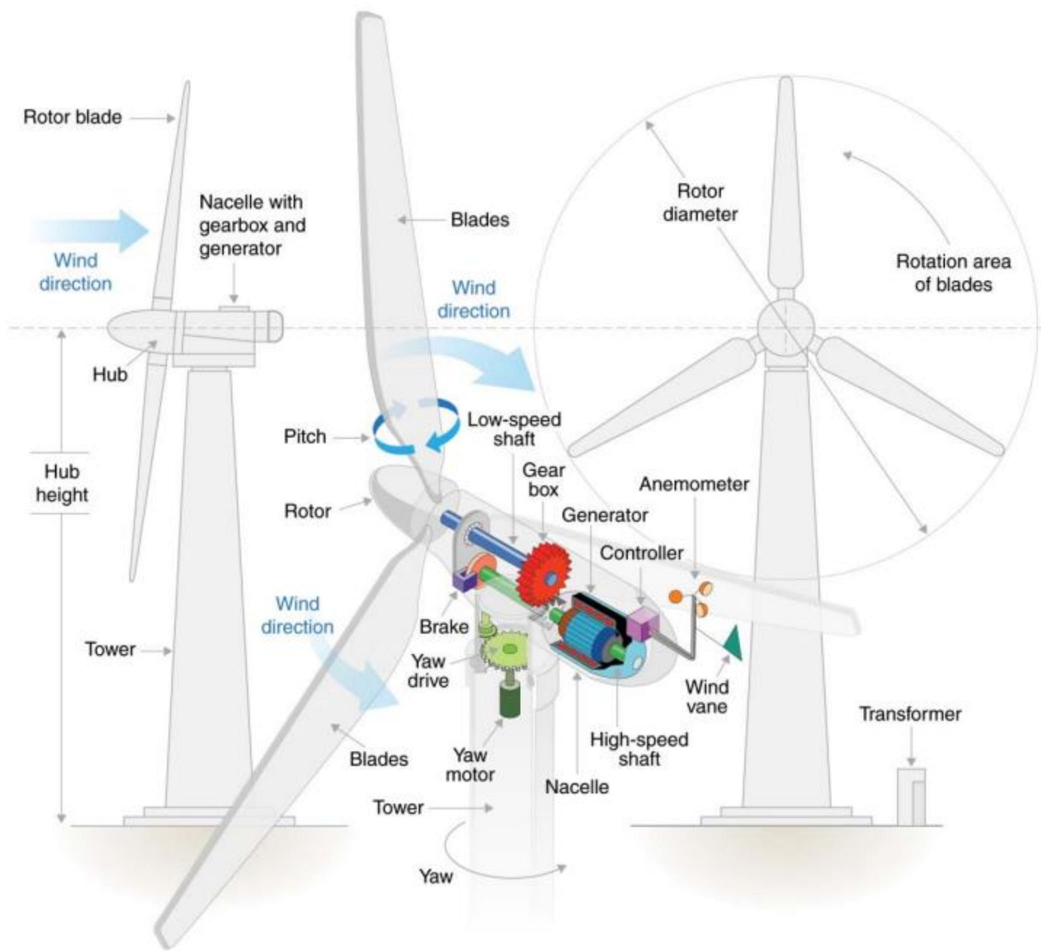


Figure D.3-7 Components of a Modern Horizontal-Axis Wind Turbine. Source: NREL 2012.

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 D.3-8.

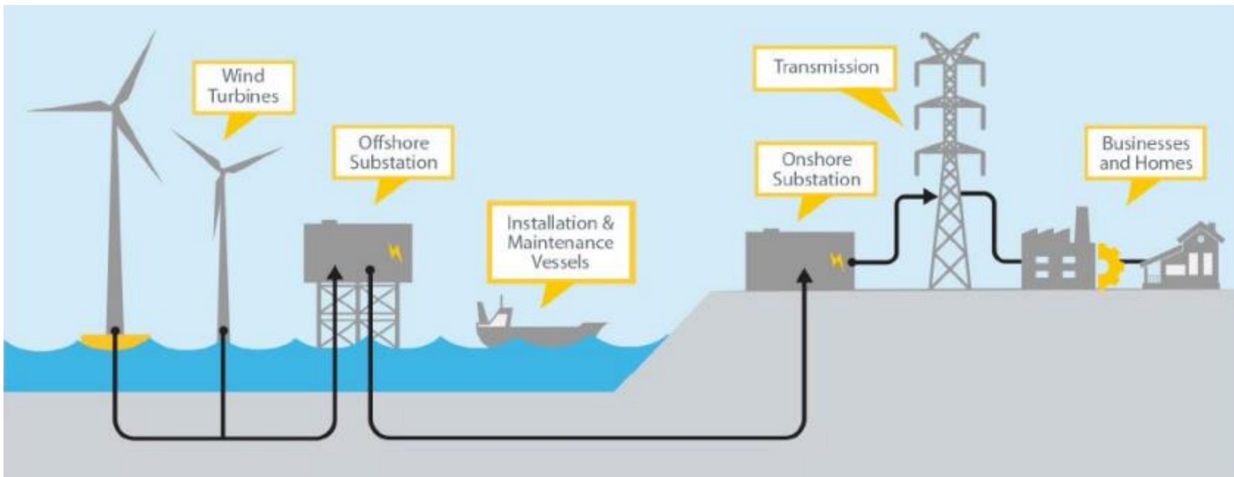


Figure D.3-8 Major Offshore Wind Power Plant and Transmission Elements. Source: DOE 2022b.

The amount of wind electricity generation has grown significantly in the past 30 years. Wind energy was the source of approximately 10 percent of total U.S. electricity generation and about 48 percent of all renewable energy produced in 2022 (DOE/EIA 2023a). 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 2022h).

D.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 D.3-9) (NRC 2013).

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 2021d).

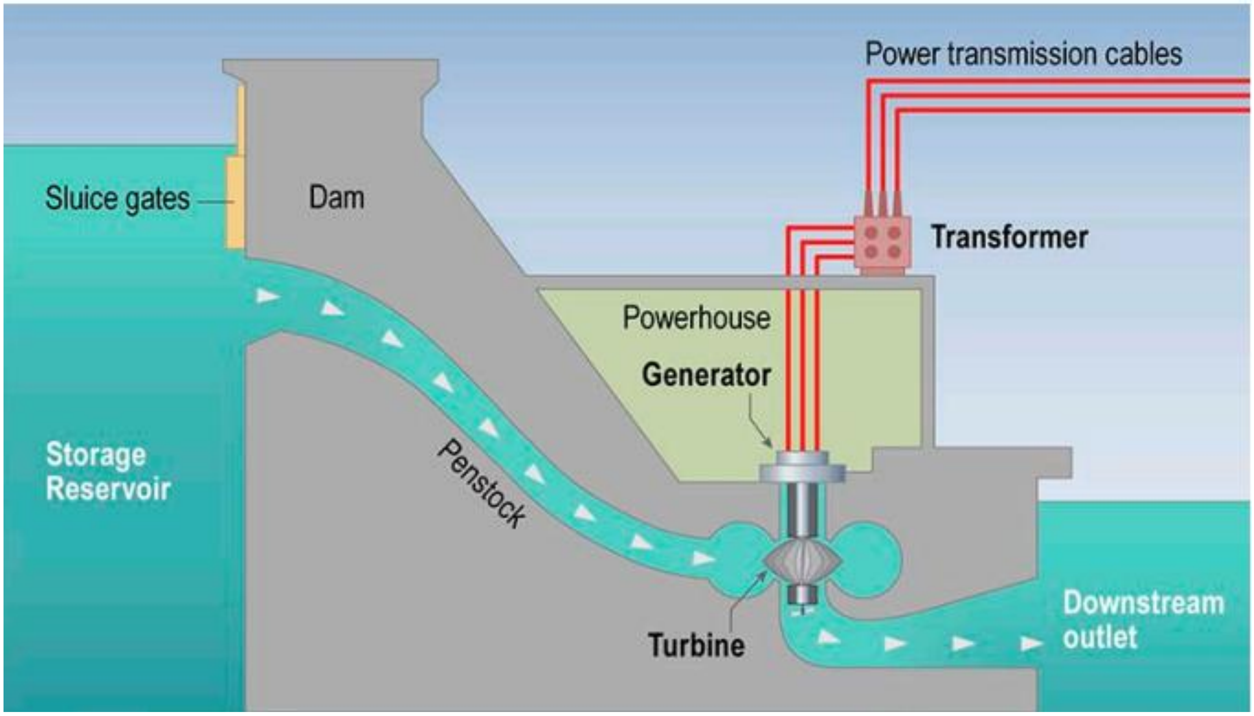


Figure D.3-9 Cross Section of a Large Hydroelectric Plant. Source: NREL 2012.

Large hydroelectric facilities constructed on major rivers can have peak power capacities as high as 10,000 MWe. 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 2013). 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 2022, hydroelectricity accounted for approximately 6.2 percent of total U.S. utility-scale electricity generation and approximately 29 percent of the total utility-scale renewable electricity generation (DOE/EIA 2023a). EIA projects that this level of generation will remain relatively steady through 2050 (DOE/EIA 2022h). 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.

D.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 D.3-10 (NRC 2013).

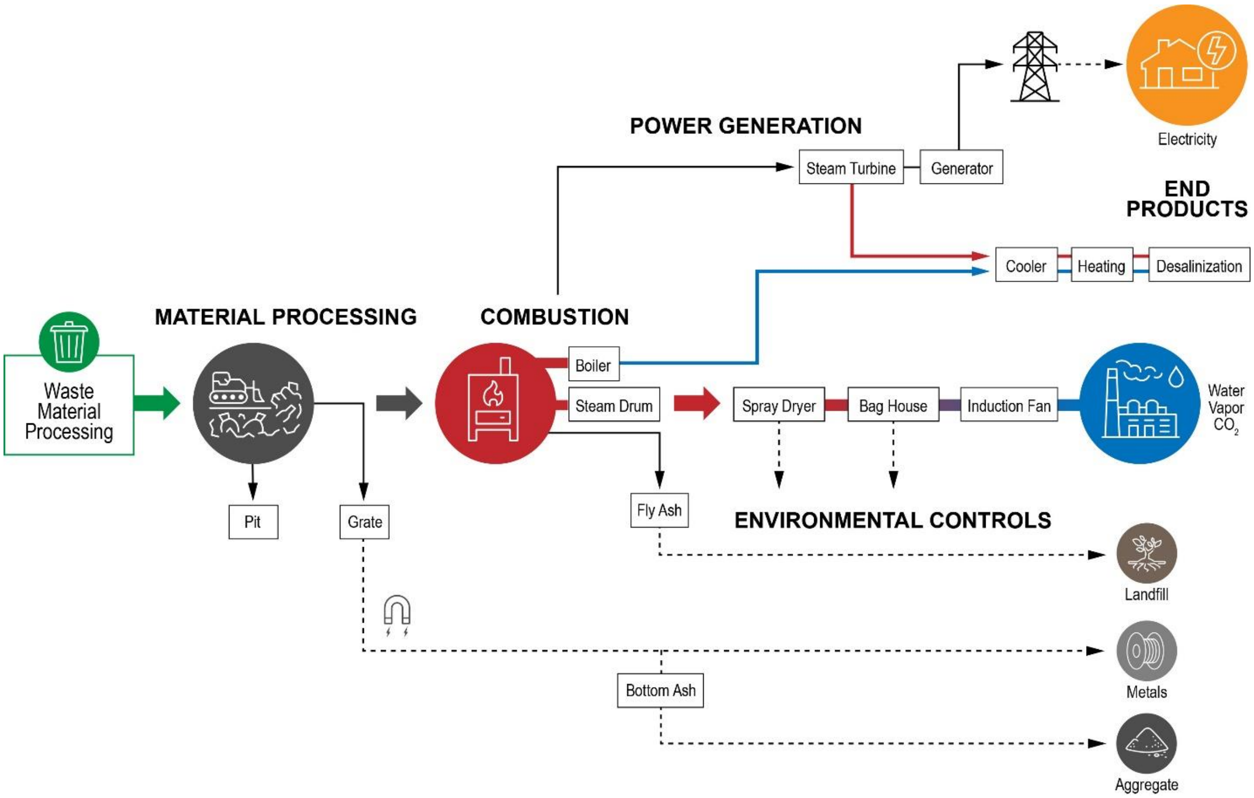


Figure D.3-10 Schematic of a Biomass/Waste-to-Energy Plant

The 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 2022, biomass energy was the source of approximately 1.3 percent of total U.S. electrical generation and approximately 6 percent of the total generation derived from renewable energy sources (DOE/EIA 2023a). This contribution from biomass energy sources is projected to remain largely unchanged through 2050 (DOE/EIA 2022b).

D.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 2013). A schematic of a representative geothermal generating facility is provided in Figure D.3-11.

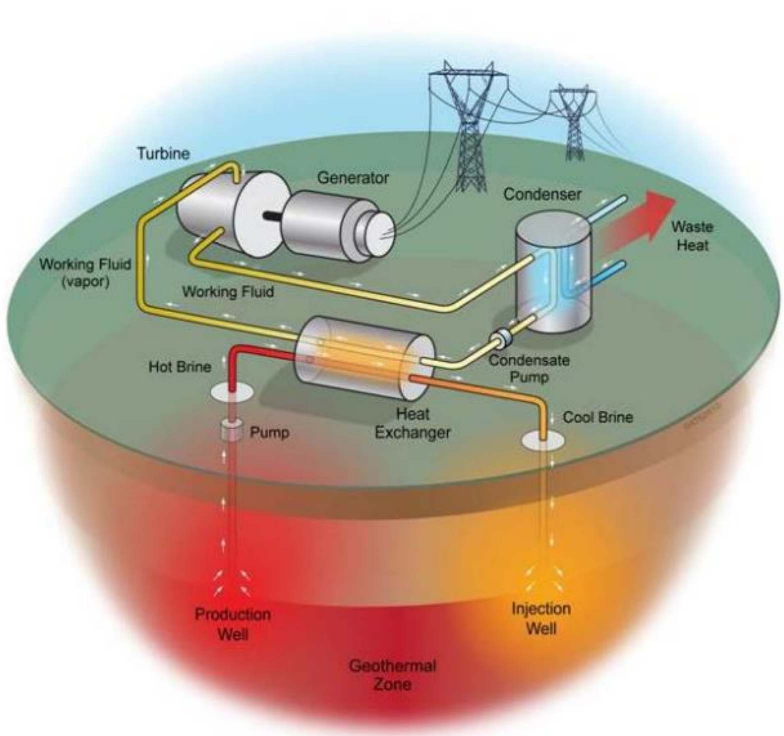


Figure D.3-11 Schematic of a Hydrothermal Binary Power Plant. Source: NREL 2012.

Utility-scale geothermal energy generation requires geothermal reservoirs with a temperature above 200°F (93°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-d, USGS 2008). In 2022, geothermal power plants produced approximately 0.4 percent of total U.S. electrical generation, equivalent to approximately 2.0 percent of total U.S. renewable electricity generation (DOE/EIA 2023a). This contribution from geothermal energy sources is projected to remain largely unchanged through 2050 (DOE/EIA 2022b).

D.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 D.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 (NRC 2013). Some of these technologies are undergoing demonstration testing at commercial scales, but none is currently used to provide baseload power (BOEM Undated).

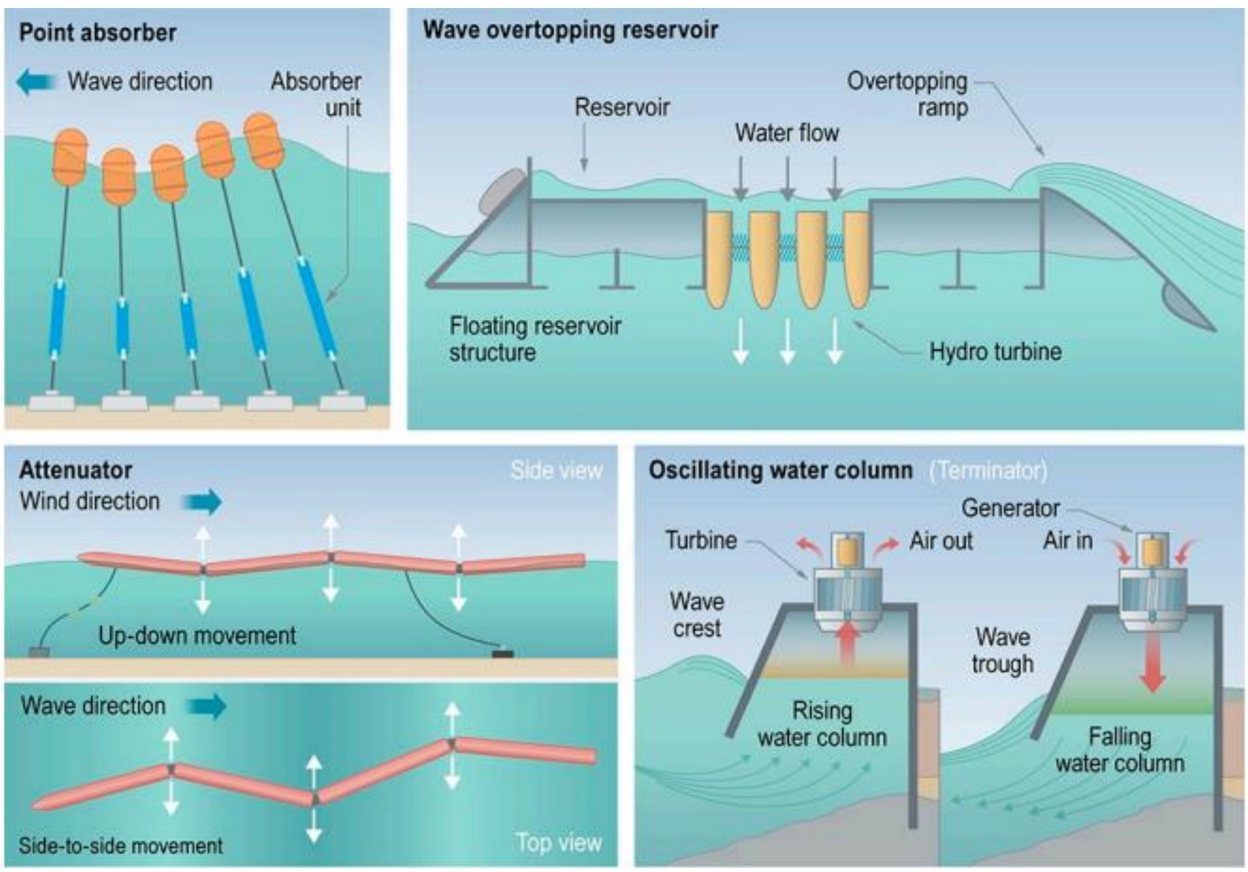


Figure D.3-12 Primary Types of Wave Energy Devices. Source: NREL 2012. Illustrations Not to Scale.

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).

D.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 D.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-e). As of October 2020, the United States had a total of 250 MW of fuel cell generation capacity (DOE/EIA Undated-a).

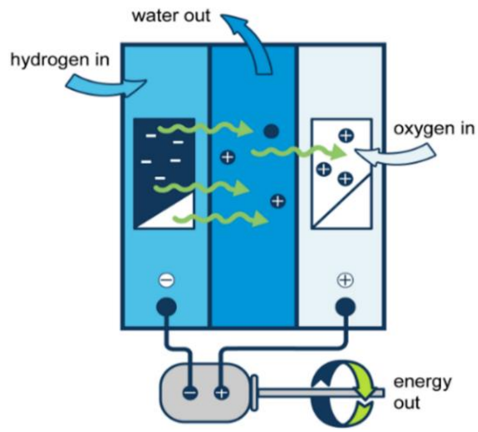


Figure D.3-13 Components of a Hydrogen Fuel Cell. Adapted from: DOE/EIA 2022i.

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 2022j). 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 2021). However, it is unclear to what degree this initiative will lead to increased future development and deployment of fuel cell technologies.

D.3.4 Non-Power-Generating Alternatives

As discussed in Section D.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 power-generating technologies that the NRC considers to be viable candidates as alternatives. However, in addition to these power-generating options, viable non-power-generating 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 DSM measures), delayed retirement of existing non-nuclear plants, and purchased power from other electricity generators within or outside of a region.

D.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 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 2022 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 2022a). 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.

D.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 U.S. Environmental Protection Agency's (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.

D.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.

D.4 Environmental Consequences of Alternatives to the Proposed Action

The no action alternative (see Section D.2) 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 Chapter 4, Section 4.14.2 in this LR GEIS 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 (DSM measures), (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.

The following sections present NRC's detailed consideration and analysis of 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 as compared to the proposed action (license renewal). For each resource area addressed, the range of possible environmental effects of constructing and operating various replacement energy alternatives is generically assessed. Alternatives were selected based on 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 environmental 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 DSM measures, delaying the scheduled retirement of one or more existing power plants, or purchasing an equivalent amount of power from other energy suppliers. As summarized in Chapter 2, Table 2.4-1 through Table 2.4-5, DSM 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 appropriately considered in plant-specific license renewal environmental reviews.

D.4.1 Land Use and Visual Resources

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.

D.4.1.1 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.

D.4.1.2 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.

D.4.1.3 Renewable Alternatives

Construction and Operations – 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 MSW, 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 MSW, 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 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.

D.4.2 Air Quality and Noise

Construction – Construction of a replacement power alternative would result in temporary impacts on local air quality. Air emissions would include criteria pollutants, hazardous air pollutants, and GHGs from construction vehicles and equipment and dust from land clearing and grading. Volatile organic compounds (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 best management practices (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.

D.4.2.1 Fossil Energy Alternatives

Construction – Air quality and noise impacts would be the same as described in Section D.4.2.

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 D.4-1 presents representative emission factors for various fossil fuel power plants. The values presented in Table D.4-1 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 IGCC or SCPC plant.

Table D.4-1 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 = kilogram(s) per megawatt-hour; lb/MWh = pound(s) per megawatt-hour; 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 D.4.2. 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).

D.4.2.2 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 D.4.2. 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 D.4.2. 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.

D.4.2.3 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 D.4.2. 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.

D.4.3 Geologic Environment

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 increase 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.

D.4.3.1 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 and natural gas would involve clearing and grading for drill pads and construction of 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.

D.4.3.2 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.

D.4.3.3 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 groundwater. 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 waterbodies.

D.4.4 Water Resources

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 waterbodies 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) National Pollutant Discharge Elimination System (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.

Operations – Most large electrical power plants require water for cooling. As a result, fossil-fueled and nuclear power plants are generally located near large surface waterbodies, including lakes, rivers, or oceans. Table D.4-2 compares water demands and consumptive use for various technologies. Existing thermoelectric power plants use either once-through or closed-cycle cooling systems (i.e., typically 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 cooling towers. 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 D.4-2 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	22,551 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.

D.4.4.1 Fossil Energy Alternatives

Operations – 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 closed-cycle (recirculating) cooling, but closed-cycle consumptive water use is twice as much or more as that of once-through cooling systems (NREL 2011). As indicated in Table D.4-2, 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.

D.4.4.2 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 waterbody. 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 D.4-2). 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.

D.4.4.3 Renewable Alternatives

The operational impacts of renewable energy technologies on water resources would vary greatly based on the technology (see Table D.4-2).

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 D.4-2) 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 waterbodies. These potential impacts can be mitigated with proper safeguards (DOE 1997).

As shown in Table D.4-2, 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 1997).

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.

D.4.5 Ecological Resources

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 waterbodies. 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 right-of-way (ROW) 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 waterbodies 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 U.S. Army Corps of Engineers 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.

Operations – 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.

D.4.5.1 Fossil Energy Alternatives

The general impacts of the construction and operation of new fossil fuel energy technologies are described above in Section D.4.5. 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 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 trace 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.

D.4.5.2 New Nuclear Alternatives

Many of the impacts of construction and operation of new nuclear technologies are described above in Section D.4.5. 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.

D.4.5.3 Renewable Alternatives

The impacts of renewable 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 MSW 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 waterbodies, 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 (±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 U.S. Fish and Wildlife Service (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 hypoxic 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.

D.4.6 Historic and Cultural Resources

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 area of potential effect and consider the effects of the undertaking on historic properties, in accordance with Section 106 of the National Historic Preservation Act (NHPA; 54 U.S.C. § 300101 et seq.). If historic properties are present and are affected by the undertaking, adverse effects would be assessed, and resolved through the NHPA Section 106 process in consultation with the State Historic Preservation Officer/Tribal Historic Preservation Officer, Indian Tribes that attach religious and cultural significance to identified historic properties, and other parties that have a demonstrated interest in the undertaking. 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 traditional cultural properties. Impacts would vary with plant heights and associated exhaust stacks or cooling towers.

D.4.6.1 Fossil Energy Alternatives

Impacts from operations of a fossil fuel power plant would be the same as those described in Section D.4.6.

D.4.6.2 New Nuclear Alternatives

Impacts from operations of a new nuclear power plant would be the same as those described in Section D.4.6.

D.4.6.3 Renewable Alternatives

Impacts from operations of a new renewable energy facility would be the same as those described in Section D.4.6.

D.4.7 Socioeconomics

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 community's 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.

D.4.7.1 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.

D.4.7.2 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.

D.4.7.3 Renewable Alternatives

Construction and Operations – 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 MSW, 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.

D.4.8 Human Health

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.

D.4.8.1 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 D.4.2.1. 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, electric shock hazards, 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).

D.4.8.2 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 Chapter 3, Section 3.9. In addition to radiological impacts, there are also potential impacts from the same nonradiological hazards as discussed in Section 3.9.2 for current reactors and described in Section D.4.8.1 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 Chapter 4, Section 4.9.1.2 and Appendix E of this LR GEIS. 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.

D.4.8.3 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, MSW, 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, electromagnetic field (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.

D.4.9 Environmental Justice

Construction and Operations – 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. 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 DSM 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.

D.4.10 Waste Management and Pollution Prevention

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.

D.4.10.1 Fossil Energy 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.

D.4.10.2 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. Low-level waste (LLW) disposal is assumed to occur at an offsite location, while spent nuclear fuel would be stored onsite either in spent fuel pool 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 Chapter 4, 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.

D.4.10.3 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 MSW 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 polychlorinated biphenyls or 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.

D.4.11 Greenhouse Gas Emissions and Climate Change

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) releases 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.

D.4.11.1 Fossil Energy Alternatives

Construction – The GHG impacts would be the same as those described in Section D.4.11 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 D.4-3 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.

Table D.4-3 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 = kilogram(s) per megawatt-hour; lb/MWh = pound(s) per megawatt-hour; 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.

D.4.11.2 New Nuclear Alternatives

Construction – The GHG impacts would be the same as those described in Section D.4.11 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.

D.4.11.3 Renewable Alternatives

Construction – The GHG impacts would be the same as those described in Section D.4.11 above. For facilities without a power block (solar PV, onshore, and offshore wind) the amount 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_2eq/MWh (NREL 1997, NREL 2004).

D.4.12 Replacement Energy Alternative Fuel Cycles

Most replacement energy alternatives employ, to varying degrees, a set of steps in the utilization of their fuel sources. These steps may include extraction, transformation, transportation, combustion, storage, and disposal; and result in associated environmental impacts.

D.4.12.1 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 include:

- 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 waterbodies, 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.

D.4.12.2 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 high-level waste (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 (see Chapter 4, 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 (see Chapter 4, Table 4.14-2). Detailed analysis of the uranium fuel cycle is also considered in Chapter 4, Section 4.14.1 of this LR GEIS. Although the uranium fuel cycle analysis is specific to the impacts of license renewal, it is applicable to new nuclear energy alternatives because the new LLWR 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 Chapter 4, Section 4.14.1.5, would still be SMALL.

D.4.12.3 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, MSW, 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 MSW 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 ground disturbing activities in areas 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.

D.4.13 Termination of Operations and Decommissioning of Replacement Power Plants

All electrical power-generating facilities will be shut down and decommissioned after the end of their operating life or after a decision is made to terminate its operation. The termination of operations and decommissioning of power-generating plants using alternative energy sources would result in associated environmental impacts. Some of these impacts would be specific to the alternative energy source employed, while others are anticipated to be common across all technologies.

D.4.13.1 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. Some water use may continue, such as for dust control and potable and sanitary needs during decommissioning. 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.

D.4.13.2 New Nuclear Alternatives

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 Chapter 4, Section 4.14.2.1 of this LR GEIS.

D.4.13.3 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, as applicable:

- 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.

D.5 References

10 CFR Part 50. *Code of Federal Regulations*, Title 10, *Energy*, Part 50, “Domestic Licensing of Production and Utilization Facilities.”

10 CFR Part 51. *Code of Federal Regulations*, Title 10, *Energy*, Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.”

10 CFR Part 52. *Code of Federal Regulations*, Title 10, *Energy*, Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants.”

18 CFR Part 157. *Code of Federal Regulations*, Title 18, *Conservation of Power and Water Resources*, Part 157, "Applications for Certificates of Public Convenience and Necessity and for Orders Permitting and Approving Abandonment Under Section of the Natural Gas Act."

40 CFR Part 125. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 125, "Criteria and Standards for the National Pollutant Discharge Elimination System."

40 CFR Part 257. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 257, "Criteria for Classification of Solid Waste Disposal Facilities and Practices."

85 FR 24040. April 30, 2020. "Notice To Conduct Scoping and Prepare an Advanced Nuclear Reactor Generic Environmental Impact Statement." *Federal Register*, Nuclear Regulatory Commission.

88 FR 3287. January 19, 2023. "NuScale Small Modular Reactor Design Certification." Final Rule, *Federal Register*, Nuclear Regulatory Commission.

Clean Air Act. 42 U.S.C. § 7401 et seq.

Federal Water Pollution Control Act of 1972 (commonly referred to as the Clean Water Act). 33 U.S.C. § 1251 et seq.

BLM (Bureau of Land Management). 2008. *Final Programmatic Environmental Impact Statement for Geothermal Leasing in the Western United States, Volume 1: Programmatic Analysis*. FES08-44, Washington, D.C. October. Accessed April 12, 2023, at https://permanent.fdlp.gov/LPS123922/LPS123922/www.blm.gov/wo/st/en/prog/energy/geothermal/geothermal_nationwide/Documents/Final_PEIS.html.

BOEM (Bureau of Ocean Energy Management). 2019. *National Environmental Policy Act Documentation for Impact-Producing Factors in the Offshore Wind Cumulative Impacts Scenario on the North Atlantic Outer Continental Shelf*. OCS Study, BOEM 2019-036, Washington, D.C. Accessed April 27, 2023, at https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Renewable-Energy/IPFs-in-the-Offshore-Wind-Cumulative-Impacts-Scenario-on-the-N-OCS.pdf.

BOEM (Bureau of Ocean Energy Management). 2020a. *Comparison of Environmental Effects from Different Offshore Wind Turbine Foundations*. OCS Study, BOEM 2020-041, Washington, D.C. Accessed April 27, 2023, at https://www.boem.gov/sites/default/files/documents/environment/Wind-Turbine-Foundations-White%20Paper-Final-White-Paper.pdf.

BOEM (Bureau of Ocean Energy Management, Office of Renewable Energy Programs). 2020b. *Vineyard Wind 1 Offshore Wind Energy Project: Supplement to the Draft Environmental Impact Statement*. OCS EIS/EA BOEM 2020-025. U.S. Department of the Interior, Washington, D.C. Accessed April 27, 2023, at https://www.boem.gov/sites/default/files/documents/renewable-energy/Vineyard-Wind-1-Supplement-to-EIS.pdf.

BOEM (Bureau of Ocean Energy Management). 2021. *Commercial Wind Lease Issuance and Site Assessment Activities on the Atlantic Outer Continental Shelf Offshore North Carolina, Draft Supplemental Environmental Assessment*. Washington, D.C. Accessed April 27, 2023, at https://www.boem.gov/renewable-energy/lease-issuance-wind-ocs-activities-north-carolina-draft-supplemental-ea.

BOEM (Bureau of Ocean Energy Management). Undated. "Renewable Energy on the Outer Continental Shelf: Ocean Wave Energy." Washington, D.C. Accessed April 27, 2023, at https://www.boem.gov/Renewable-Energy-Program/Renewable-Energy-Guide/Ocean-Wave-Energy.aspx.

Ciferno, J.P., and J.J. Marano. 2002. *Benchmarking Biomass Gasification Technologies for Fuels, Chemicals and Hydrogen Production*. Washington, D.C. Accessed April 27, 2023, at https://netl.doe.gov/sites/default/files/netl-file/BMassGasFinal_0.pdf.

DOE (U.S. Department of Energy). 1997. *Renewable Energy Technology Characterizations, Topical Report TR-109496*. Washington, D.C. December. Accessed April 27, 2023, at https://www.nrel.gov/docs/gen/fy98/24496.pdf.

DOE (U.S. Department of Energy). 2021. *Hydrogen Shot: An Introduction*. Office of Energy Efficiency and Renewable Energy, Hydrogen and Fuel Cells Technology Office. Washington, D.C. Accessed April 27, 2023, at https://www.energy.gov/eere/fuelcells/articles/hydrogen-shot-introduction.

DOE (U.S. Department of Energy). 2022a. "Advanced Small Modular Reactors (SMRs): Office of Nuclear Energy." Washington, D.C. Accessed April 27, 2023, at https://www.energy.gov/ne/advanced-small-modular-reactors-smrs.

DOE (U.S. Department of Energy). 2022b. *Offshore Wind Energy Strategies*. Washington, D.C. Accessed April 27, 2023, at https://www.energy.gov/sites/default/files/2022-01/offshore-wind-energy-strategies-report-january-2022.pdf.

DOE (U.S. Department of Energy). Undated-a. "Vogtle Loan Program Office." Washington, D.C. Accessed April 27, 2023, at https://www.energy.gov/lpo/vogtle.

DOE (U.S. Department of Energy). Undated-b. "WINDExchange: Wind Energy State Information." Washington, D.C. Accessed April 27, 2023, at https://windexchange.energy.gov/states.

DOE (U.S. Department of Energy). Undated-c. "Types of Hydropower Plants." Washington, D.C. Accessed April 27, 2023, at https://www.energy.gov/eere/water/types-hydropower-plants.

DOE (U.S. Department of Energy). Undated-d. "Geothermal Basics: Geothermal." Washington, D.C. Accessed April 27, 2023, at https://www.energy.gov/eere/geothermal/geothermal-basics.

DOE (U.S. Department of Energy). Undated-e. "Fuel Cell Basics: Hydrogen and Fuel Cell Technologies Office." Washington, D.C. Accessed April 27, 2023, at https://www.energy.gov/eere/fuelcells/fuel-cell-basics.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2015a. *Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2015*. Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/outlooks/archive/aeo15/pdf/electricity_generation_2015.pdf.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2015b. *Annual Energy Outlook 2015 with Projections to 2040*. DOE/EIA-0383(2015), Washington, D.C. ADAMS Accession No. ML16172A121.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2017. "Today in Energy: Oil-fired Power Plants Provide Small Amounts of U.S. Electricity Capacity and Generation." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/todayinenergy/detail.php?id=31232.

DOE/EIA (U.S. Department of Energy/Energy Information Association). 2019a. "More new natural gas combined-cycle power plants are using advanced designs." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/todayinenergy/detail.php?id=39912.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2019b. "Today In Energy: Demand-side Management Programs Save Energy and Reduce Peak Demand." Washington, D.C. Accessed April 12, 2023, at https://www.eia.gov/todayinenergy/detail.php?id=38872.

DOE/EIA (U.S. Department of Energy/Energy Information Association). 2020. *Annual Energy Outlook 2020, with projections to 2050*. AEO2020. Washington, D.C. Accessed April 12, 2023, at https://www.eia.gov/outlooks/aeo/pdf/AEO2020%20Full%20Report.pdf.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2021a. "Today in Energy: Less Electricity Was Generated by Coal than Nuclear in the United States in 2020." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/todayinenergy/detail.php?id=47196.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2021b. "Today in Energy: U.S. Large-Scale Battery Storage Capacity Up 35% in 2020, Rapid Growth to Continue." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/todayinenergy/detail.php?id=49236.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2021c. "Today in Energy: Solar Generation Was 3% of U.S. Electricity in 2020, But We Project It Will Be 20% by 2050." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/todayinenergy/detail.php?id=50357.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2021d. "Electric Power Monthly with Data for August 2021, Table 6.07.B Capacity Factors for Utility Scale Generators Primarily Using Non-Fossil Fuels." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/electricity/monthly/archive/august2021.pdf

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2022a. *Electric Power Annual 2020*. Washington, D.C. Accessed April 12, 2023, at https://www.eia.gov/electricity/annual/archive/2020/pdf/epa.pdf.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2022b. "Today in Energy: EIA Projects That Renewable Generation Will Supply 44% of U.S. Electricity by 2050." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/todayinenergy/detail.php?id=51698.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2022c. "Nuclear explained, U.S. Nuclear Industry." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2022d. "Today in Energy: U.S. nuclear electricity generation continues to decline as more reactors retire." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/todayinenergy/detail.php?id=51978#.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2022e. "Frequently Asked Questions (FAQS)." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/tools/faqs/faq.php?id=92&t=4.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2022f. "Annual Energy Outlook 2022." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/outlooks/aeo/narrative/electricity/sub-topic-04.php.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2022g. "U.S. battery storage capacity will increase significantly by 2025." Washington, D.C. Accessed May 1, 2023, at https://www.eia.gov/todayinenergy/detail.php?id=54939.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2022h. *Annual Energy Outlook 2022 with Projections to 2050, Narrative*. Washington, D.C. Accessed April 12, 2023, at https://www.eia.gov/outlooks/aeo/pdf/AEO2022_Narrative.pdf.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2022i. "Hydrogen Explained, Use of Hydrogen." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/energyexplained/hydrogen/use-of-hydrogen.php.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2022j. *Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2021*. Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2023a. "What is U.S. electricity generation by energy source?" Washington, D.C. Accessed May 1, 2023, at https://www.eia.gov/tools/faqs/faq.php?id=427&t=3.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). 2023b. "Annual Energy Outlook 2023." Washington, D.C. Accessed May 1, 2023, at https://www.eia.gov/outlooks/aeo/pdf/AEO2023_Narrative.pdf.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). Undated-a. "Electric Power Annual, With Data for 2021, Table 1.2. Summary Statistics for the United States, 2011-2021. Utility Scale Capacity: Solar Photovoltaic." Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/electricity/annual/html/epa_01_02.html.

DOE/EIA (U.S. Department of Energy/Energy Information Administration). Undated-b. *Form EIA-861 Annual Electric Power Industry Report Instructions*. Washington, D.C. Accessed April 27, 2023, at https://www.eia.gov/survey/form/eia_861/instructions.pdf.

Fiscal Responsibility Act of 2023. Public Law No. 118-5, 137 Stat. 10.

GAO (U.S. General Accounting Office). 2015. Technology Assessment, Nuclear Reactors, Status and Challenges in Development and Deployment of New Commercial Concepts. Washington, D.C. July. Accessed April 27, 2023, at https://www.gao.gov/assets/gao-15-652.pdf.

Georgia Power. 2024. "Vogtle Unit 4 Enters Commercial Operation." Atlanta, Georgia. Accessed April 29, 2024, at https://www.georgiapower.com/company/news-hub/press-releases/vogtle-unit-4-enters-commercial-operation.html.

Johnson, D.H., S.R. Loss, K.S. Smallwood, and W.P. Erickson. 2016. "Avian Fatalities at Wind Energy Facilities in North America: A Comparison of Recent Approaches." *Human-Wildlife Interactions* 10(1):7-18. DOI:10.26077/a4ec-ed37. Logan, UT. Accessed April 28, 2023, at https://doi.org/10.26077/a4ec-ed37.

Kagel, A., D. Bates, and K. Gawell. 2005. *A Guide to Geothermal Energy and the Environment*. Geothermal Energy Association, Washington, D.C. Accessed April 28, 2023, at https://doi.org/10.2172/897425.

Kosciuch, K., D. Riser-Espinoza, M. Gerringer, and W. Erickson. 2020. "A Summary of Bird Mortality at Photovoltaic Utility Scale Solar Facilities in the Southwestern U.S." *PLOS ONE* 15(4):e0232034. Accessed April 28, 2023, at https://doi.org/10.1371/journal.pone.0232034.

Kristmannsdottir, H., and H. Armannsson. 2003. "Environmental Aspects of Geothermal Energy Utilization." *Geothermics* 32(4-6):451–461. DOI:10.1016/S0375-6505(03)00052-X. Amsterdam, The Netherlands. Accessed April 28, 2023, at https://doi.org/10.1016/S0375-6505(03)00052-X.

Loss, S.R., T. Will, and P.P. Marra. 2015. "Direct Mortality of Birds from Anthropogenic Causes." *Annual Review of Ecology, Evolution, and Systematics* 46:99–120. DOI:10.1146/annurev-ecolsys-112414-054133. Palo Alto, CA. Accessed May 1, 2023, at https://doi.org/10.1146/annurev-ecolsys-112414-054133.

Maize, K. 2019. "Waste-to-Energy: A Niche Market in Decline?" *POWER*, Rockville, MD. Accessed May 1, 2023, at https://www.powermag.com/waste-to-energy-a-niche-market-in-decline/.

MASCWG (Multiagency Avian-Solar Collaborative Working Group). 2016. *Multiagency Avian-Solar Science Coordination Plan*. Multiagency Avian-Solar Collaborative Working Group, Washington, D.C. Accessed April 14, 2023, at https://blmsolar.anl.gov/related/avian-solar/docs/Final_Avian-Solar_Science_Coordination_Plan.pdf.

Michaels, T., and K. Krishnan. 2019. *Energy Recovery Council, 2018 Directory of Waste-to-Energy Facilities*. Washington, D.C. Accessed February 22, 2024, at https://wtert.org/2018-directory-of-waste-to-energy-facilities-energy-recovery-council/#.

MMS (Minerals Management Service). 2007. *Programmatic Environmental Impact Statement for Alternative Energy Development and Production and Alternate Use of Facilities on the Outer Continental Shelf, Volume II, Chapter 5*. OCS EIS/EA, MMS 2007-046, U.S. Department of the Interior, Washington, D.C. Accessed April 21, 2023 at https://www.boem.gov/sites/default/files/renewable-energy-program/Regulatory-Information/Alt_Energy_FPEIS_VolIIFrontMatter.pdf.

National Environmental Policy Act of 1969, as amended. 42 U.S.C. § 4321 et seq.

National Historic Preservation Act of 1966, as amended. 54 U.S.C. § 300101 et seq.

NETL (National Energy Technology Laboratory). 2019. *Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity*. NETL-PUB-22638, Pittsburgh, PA. Accessed April 21, 2023, at https://www.osti.gov/biblio/1569246.

NETL (National Energy Technology Laboratory). Undated. "High Temperature Material Supply Chain." Pittsburgh, PA. Accessed May 15, 2023, at https://netl.doe.gov/high_temp_materials_supply_chain.

NPCC (Northwest Power and Conservation Council). 2010. *Sixth Northwest Conservation and Electric Power Plan*. Portland, OR. ADAMS Accession No. ML14093A352.

NRC (U.S. Nuclear Regulatory Commission). 2004. "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design (NUREG-1793, Initial Report)." Washington, D.C. Accessed May 1, 2023, at https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1793/initial/index.html.

NRC (U.S. Nuclear Regulatory Commission). 2013. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* [GEIS]. NUREG-1437, Revision 1, Washington, D.C. ADAMS Package Accession No. ML13107A023.

NRC (U.S. Nuclear Regulatory Commission). 2018. *Environmental Impact Statement for an Early Site Permit (ESP) at the Clinch River Nuclear Site, Draft Report for Comment.* NUREG-2226, Volumes 1 and 2, Washington, D.C. ADAMS Accession No. ML18100A220.

NRC (U.S. Nuclear Regulatory Commission). 2020. *2020–2021 Information Digest*. NUREG-1350, Volume 32, Washington, D.C. ADAMS Accession No. ML20282A632.

NRC (U.S. Regulatory Commission). 2022. "Design Certification Application for New Reactors." Washington, D.C. Accessed April 28, 2023, at https://www.nrc.gov/reactors/new-reactors/design-cert.html.

NRC (U.S. Nuclear Regulatory Commission). 2023a. *2022-2023 Information Digest*. NUREG-1350, Volume 34. Washington, D.C. ADAMS Accession No. ML23047A371.

NRC (U.S. Nuclear Regulatory Commission). 2023b. "Design Certification Application – NuScale." Washington, D.C. Accessed May 1, 2023, at https://www.nrc.gov/reactors/new-reactors/smr/nuscale.html.

NRC (U.S. Nuclear Regulatory Commission). 2024. Memorandum from C.M. Safford to R.V. Furstenau, dated April 17, 2024, regarding "Staff Requirements - SECY-21-0098 – Proposed Rule: Advanced Nuclear Reactor Generic Environmental Impact Statement (RIN 3150-AK55; NRC-2020-0101)." Washington, D.C. ADAMS Accession No. ML24108A199.

NREL (National Renewable Energy Laboratory). 1997. *The Environmental Costs and Benefits of Biomass Energy Use in California*. NREL/SR-430-22765, UC Category 600, DE97000254, Golden, CO. Accessed May 1, 2023, at https://doi.org/10.2172/481490.

NREL (National Renewable Energy Laboratory). 2003. *Biopower Technical Assessment: State of the Industry and the Technology*. NREL/TP-510-33123, U.S. Department of Energy, Golden, CO. March. Accessed May 1, 2023, at https://www.nrel.gov/docs/fy03osti/33123.pdf.

NREL (National Renewable Energy Laboratory). 2004. *Biomass Power and Conventional Fossil Systems with and without CO2 Sequestration – Comparing the Energy Balance, Greenhouse Gas Emissions and Economics*. NREL/SR-430-22765, Golden, CO. Accessed May 1, 2023, at https://doi.org/10.2172/15006537.

NREL (National Renewable Energy Laboratory). 2011. *A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies*. NREL/TP–6A20–50900, Golden, CO. ADAMS Accession No. ML14286A088.

NREL (National Renewable Energy Laboratory). 2012. *Renewable Electricity Futures Study*. NREL/TP-6A20-52409, 4 Volumes, Golden, CO. Accessed May 1, 2023, at https://www.nrel.gov/docs/fy13osti/52409-ES.pdf.

NREL (National Renewable Energy Laboratory). Undated. "Concentrating Solar Power." Golden, CO. Accessed May 1, 2023, at https://www.nrel.gov/csp/index.html.

NuScale (NuScale Power LLC). 2022. "Frequently Asked Questions: NuScale FAQS." Portland, OR. Available at https://www.youtube.com/watch?v=NWH01ImMkyk.

NuScale (NuScale Power LLC). 2023. "Standard Power." Portland, OR. Accessed November 9, 2023, at https://www.nuscalepower.com/en/projects.

Orsted. Undated. "Our Offshore Wind Projects in the U.S." Boston, MA. Accessed May 1, 2023, at https://us.orsted.com/wind-projects.

USGS (U.S. Geological Survey). 2008. *Assessment of Moderate- and High-Temperature Geothermal Resources of the United States*. Fact Sheet 2008–3082, Menlo Park, CA. Accessed May 11, 2023, at https://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf.

Weaver, S.P., A.K. Jones, C.D. Hein, and I. Castro-Arellano. 2020. "Estimating bat fatality at a Texas wind energy facility: implications transcending the United States–Mexico border." *Journal of Mammalogy* 101(6):1533–1541. DOI:10.1093/jmammal/gyaa132. Oxford, United Kingdom. Accessed May 11, 2023, at https://dx.doi.org/10.1093/jmammal/gyaa132.

Wiser, R., and M. Bolinger. 2019. *2018 Wind Technologies Market Report.* Office of Energy Efficiency and Renewable Energy, Washington, D.C. Accessed May 11, 2023, at https://www.energy.gov/eere/wind/downloads/2018-wind-technologies-market-report.

Zimmerling, J.R., A.C. Pomeroy, M.V. d'Entremont, and C.M. Francis. 2013. "Canadian Estimate of Bird Mortality Due to Collisions and Direct Habitat Loss Associated with Wind Turbine Developments." *Avian Conservation and Ecology* 8(2):10. DOI:10.5751/ACE-00609-080210. Nova Scotia, Canada. Accessed May 11, 2023, at http://dx.doi.org/10.5751/ACE-00609-080210.

APPENDIX E

ENVIRONMENTAL IMPACT OF POSTULATED ACCIDENTS

APPENDIX E

ENVIRONMENTAL IMPACT OF POSTULATED ACCIDENTS

E.1 Introduction

Under the U.S. Nuclear Regulatory Commission's (NRC's) license renewal rule in Title 10 of the *Code of Federal Regulations*, Part 54 (10 CFR Part 54), applicants for initial license renewal (initial LR) and subsequent license renewal (SLR) must take adequate steps to account for aging during the period of extended operation either through updating time-limited aging analyses or implementing aging management plans. Based on these activities, the NRC expects that operation during an initial LR or SLR term would continue to provide a level of safety equivalent to that during the current license term. Consequently, the following discussions of accident risk, which generally consider the additional risk posed by 20 years of additional operation, would apply to initial LR or SLR.

Chapter 5 of the 1996 *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, NUREG-1437, Volumes 1 and 2 (1996 LR GEIS; NRC 1996, NRC 1999)[1] assessed the impacts of postulated accidents at nuclear power plants on the environment. Postulated accidents include design-basis accidents and severe accidents (e.g., those involving core damage). The impacts considered included the following:

- dose and health effects of accidents (Sections 5.3.3.2 through 5.3.3.4 of the 1996 LR GEIS),
- economic impacts of accidents (Section 5.3.3.5 of the 1996 LR GEIS), and
- effect of uncertainties on the results (Section 5.3.4 of the 1996 LR GEIS).

The estimated impacts were based on the analysis of postulated severe accidents at 28 nuclear power plant sites[2] as reported in the environmental impact statements (EISs) and/or final environmental statements (FESs) 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 of external events qualitatively.[3] The severe accident analysis for the 28 sites was extended to the remainder of plants whose EISs did not consider severe accidents (because such analyses were 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 (UCB) estimates whenever available. This approach provides conservatism to cover uncertainties, as described in Section 5.3.3.2.2 of the 1996 LR GEIS. The 1996

[1] The LR GEIS was originally issued in 1996. 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 1999).
[2] The 28 sites are listed in Table 5.1 of the 1996 LR GEIS. A total of 44 units are included in the list (at the 28 sites), but four of them never operated (Grand Gulf 2, Harris 2, Perry 2, and Seabrook 2). For the purpose of this appendix, the list is referred to as containing 28 nuclear power plants, but when mean values are calculated for this subset of nuclear power plants, all 40 units that operated are considered.
[3] Section 5.3.3.1 of the 1996 LR GEIS includes a brief discussion of the external event risk assessments conducted by the NRC staff prior to 1996, which included assessments for Zion 1 and 2, Indian Point 2 and 3, Limerick 1 and 2, Surry 1, Peach Bottom 2, and Millstone 3.

LR GEIS concluded that the probability-weighted consequences[4] were small compared to other risks to which the populations surrounding nuclear power plants are routinely exposed. Specifically, in Section 5.5.2.5 of the 1996 LR GEIS, the NRC staff concluded that the generic analysis "applies to all plants and 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." The term probability-weighted consequences in the remainder of this revised LR GEIS refers to probability-weighted consequences to the public and environment as a result of a severe accident.

The focus of the 2013 LR GEIS (NRC 2013b) was on severe accidents because the impacts of design-basis accidents are SMALL and, as stated in Section E.3 of the 2013 LR GEIS, the NRC's assessment remains unchanged. Similarly, this LR GEIS revision focuses on severe accidents, because this LR GEIS also concludes that the impacts of design-basis accidents are unchanged as discussed below and therefore would be SMALL for both an initial LR and SLR term.

The NRC's understanding of severe accident risk has evolved since issuance of the 1996 and 2013 LR GEISs due in part to improvements in plant safety, improved plant operational performance, and lessons learned and knowledge gained. This appendix assesses more recent information and updates the analysis presented in Chapter 4.9 and Appendix E of the 2013 LR GEIS regarding severe accidents. This revision considers how these developments would affect the Chapter 5 conclusions in the 1996 LR GEIS and provides comparative data where appropriate. The 1996 LR GEIS provided quantitative estimates of severe accident impacts with estimated population projections, meteorology, and exposure indices to support the conclusions, and the estimates remain unchanged for the purposes of this analysis. This LR GEIS is more focused on SLR since it is assumed that nuclear power plants using this LR GEIS will have had a severe accident mitigation alternative (SAMA) or severe accident mitigation design alternative (SAMDA) analysis approved in an EIS. However, the following analysis would also apply to a plant applying for initial LR; although if the plant had not previously been the subject of a SAMA or SAMDA analysis in a National Environmental Policy Act of 1969, as amended (NEPA) (42 U.S.C. § 4321 et seq.) document, the applicant would need to submit a SAMA analysis.

The format of this appendix follows a format similar to that provided in the 2013 LR GEIS, including a discussion of uncertainties and SAMAs.

E.2 Nuclear Power Plant Accidents

General characteristics of postulated accidents (design-basis and severe accidents) are described in Section 5.2 of the 1996 LR GEIS, which covered

- the general characteristics of accidents
- fission product characteristics
- meteorological considerations

[4] The correct terminology is "frequency-weighted consequences" because the accident consequences are multiplied by the core damage frequency. However, the 1996 LR GEIS used the term "probability-weighted consequences" when referring to frequency-weighted consequences. To avoid confusion, this LR GEIS continues use of the 1996 LR GEIS terminology but also uses these two terms interchangeably.

- exposure pathways
- adverse health effects
- avoiding adverse health effects
- accident experience and observed impacts
- mitigation of accident consequences
- emergency preparedness

These characteristics of postulated accidents are still valid.

Accident experience and observed impacts are described in Section 5.2.2 of the 1996 LR GEIS. The Fukushima Dai-ichi accident information is described in Section E.2.1 of the 2013 LR GEIS and is updated in Section E.2.1 of this appendix. Specifically, the section addresses the Fukushima accident experience, observed impacts, and mitigation since the issuance of the 1996 LR GEIS and 2013 LR GEIS. The discussion provides an example of how NRC initiatives continue to focus on safety (which can improve safety and reduce environmental impacts of releases that may or may not be modeled in probabilistic risk assessment [PRAs]).

Operating experience and lessons learned have contributed to NRC initiatives to provide reasonable assurance of adequate protection of public health and safety and to promote the common defense and security. Based on earlier lessons learned from operating experience and accidents in the 1996 LR GEIS, the Commission noted that all licensees had undergone, or were in the process of undergoing, more detailed site-specific severe accident mitigation or regulatory programs through processes separate from license renewal, specifically the Containment Performance Improvement (CPI), Individual Plant Examination (IPE), and Individual Plant Examination of External Events (IPEEE) programs (61 FR 28467, 28481; June 5, 1996) (lessons learned from the Three Mile Island accident). As discussed in greater detail in Section E.4, in light of these studies and severe accident initiatives outside of license renewal, the Commission stated that it did not expect future SAMA analyses to uncover “major plant design changes or modifications that will prove to be cost-beneficial” (61 FR 28467, 28481; June 5, 1996). The NRC’s experience in reviewing SAMA analyses in plant-specific license renewal proceedings has confirmed this prediction. These plant-specific reviews further illustrate the magnitude of mitigation as a result of the agency’s ongoing and robust safety oversight.

Other examples of mitigation initiatives and regulatory programs to improve safety since publication of the 1996 LR GEIS include the following:

- implementation of plant improvements identified through the IPE program (e.g., improved reliability and/or redundancy of alternating current and direct current power; improved core cooling or injection reliability) (NRC 1997a) and the IPEEE program (e.g., strengthened seismic supports; enhanced fire brigade training) (NRC 2002c)
- NRC staff actions related to generic safety issues and generic issues (e.g., Generic Safety Issue 191 on sump performance, Generic Issue 199 on seismic risk [NRC 2011b])

- implementation of the NRC's Interim Compensatory Measures (ICMs) Orders following the September 2001 terrorist attacks,[5] most of which have subsequently been codified into NRC regulations[6]
- implementation of the NRC Orders and information requests under 10 CFR 50.54(f) (NRC 2012d) following the Fukushima Dai-ichi nuclear power plant accident initiated by the March 2011 Great Tohoku Earthquake and subsequent tsunami; the requirements for two of these Orders have subsequently been incorporated into NRC regulations[7] (see discussion in Section E.2.1)
- implementation of plant improvements and severe accident management guidelines required by 10 CFR 50.155 for mitigation of beyond-design-basis events, including under circumstances associated with loss of large areas of the plant affected by the event, that provide for the maintenance or restoration of core cooling, containment, and spent fuel pool (SFP) cooling capabilities, and for the acquisition and use of offsite assistance and resources to support these functions[8]

The NRC recently presented an assessment of safety trends over the last 20–30 years in currently operating nuclear power plants regulated by the NRC (2022b). The assessment investigated trends in numerous safety indicators, including some of the topics discussed in Section E.3 of this appendix. The result of the assessment was that almost all key trends and developments for the 51 safety measures evaluated, with one exception (loss of offsite power recovery time), are either favorable (i.e., show improved plant safety or performance) or flat (i.e., show no discernible change in plant safety or performance). The assessment concluded that a large reduction in average core damage frequency (CDF) for internal events and a reduction in plant performance issues have also been observed, but external event hazards and uncertainties need to be considered when evaluating safety goal impacts.

These examples of mitigation to improve severe accident risk since publication of the 1996 LR GEIS demonstrate the magnitude of mitigation as a result of the agency's ongoing and robust safety oversight. Furthermore, operating experience and lessons learned from accidents have further contributed to NRC initiatives to provide reasonable assurance of adequate protection of public health and safety and to promote the common defense and security. The discussion of these initiatives provides context and perspective for the analysis and conclusions presented in this appendix.

[5] The safety evaluations for the operating license amendments associated with implementation of Section B.5.b. of Commission Order EA-02-026 provide background related to the implementation of particular portions of the ICMs. As an example, the reader is referred to the safety evaluations associated with Brunswick Steam Electric Plant, Units 1 and 2 (NRC 2007d).
[6] Final Rule on Power Reactor Security Requirements dated March 27, 2009 (74 FR 13926) and Final Rule on Enhancements to Emergency Preparedness Regulations dated November 23, 2011 (76 FR 72560).
[7] The NRC, subsequent to issuance of the NRC Orders, amended its regulations to require mitigation strategies for beyond-design-basis events at nuclear power plants. The Final Rule on Mitigation of Beyond-Design-Basis Events, dated August 9, 2019 (84 FR 39684), makes generically applicable the requirements of Order EA-12-049 (NRC 2012c) and Order EA-12-051 (NRC 2012a).
[8] Implementation of these plant improvements and guidelines is required by 10 CFR 50.155, "Mitigation of beyond-design-basis events."

E.2.1 Fukushima Dai-ichi Nuclear Power Plant Accident

On March 11, 2011, a massive earthquake—referred to as the Great Tohoku Earthquake—that occurred off the eastern coast of Honshu Island, Japan, produced a devastating tsunami that struck the coastal town of Fukushima. The six-unit Fukushima Dai-ichi nuclear power plant was directly impacted by these events. The resulting damage caused the failure of several of the units' safety systems needed to maintain cooling water flow to the reactors. As a result of the loss of cooling, the fuel overheated and major fuel melting occurred in three of the reactors. Damage to the systems and structures containing reactor fuel resulted in the release of radioactive material to the surrounding environment.

In response to the earthquake, tsunami, and resulting reactor accidents at Fukushima Dai-ichi (hereafter referred to as the "Fukushima events"), the Commission directed the NRC staff to convene an agency task force of senior leaders and experts to conduct a methodical and systematic review of the relevant NRC regulatory requirements, programs, and processes, including their implementation, and to recommend whether the agency should make near-term improvements to its regulatory system. As part of the short-term review, the task force (referred to as the Near-Term Task Force [NTTF]), concluded that while improvements are expected to be made as a result of the lessons learned from the Fukushima events, the continued operation of nuclear power plants and licensing activities for new plants do not pose an imminent risk to public health and safety (NRC 2011a).

On July 21, 2011, the NRC staff provided the NTTF report, "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident" to the Commission in SECY-11-0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan" (NRC 2011a). On October 3, 2011, the staff prioritized the NTTF recommendations into three tiers in SECY-11-0137, "Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned" (NRC 2011c). The Commission approved the staff's prioritization, with comment, in the Staff Requirements Memorandum (SRM) to SECY-11-0137 (NRC 2011d). A complete discussion of the prioritization of the recommendations from the NTTF report, additional issues that were addressed subsequent to the NTTF report, and the disposition of the issues that were prioritized as Tier 2 or Tier 3 are provided in SECY-17-0016, "Status of Implementation of Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Subsequent Tsunami" (NRC 2017d).

The NRC undertook the following regulatory activities to address the majority of the Tier 1 recommendations:

- On March 12, 2012, the NRC issued Orders EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," EA-12-050, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents," and EA-12-051, "Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," and a request for information under 10 CFR 50.54(f) (hereafter referred to as the 50.54(f) letter) to licensees (NRC 2012c, NRC 2012h, NRC 2012a, and NRC 2012d, respectively).
- On June 6, 2013, the NRC issued Order EA-13-109, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions" (NRC 2013g), which superseded Order EA-12-050, replacing its requirements with modified requirements.

- In addition to the three orders and the 50.54(f) letter, the NRC completed rulemaking, 10 CFR 50.155, "Mitigation of Beyond-Design-Basis Events," that made generically applicable the requirements of Orders EA-12-049 and EA-12-051. The draft final rule and supporting documentation were provided to the Commission for approval in SECY-16-0142, "Draft Final Rule – Mitigation of Beyond-Design-Basis Events (RIN 3150-AJ49)" (MBDBE) (NRC 2017e, 2017f). The MBDBE rulemaking effort consolidated several of the recommendations from the NTTF report.
- On January 24, 2019, the Commission, via SRM-M190124A (NRC 2019a), approved the final MBDBE rule, with edits. The final rule approved by the Commission contains provisions that make generically applicable the requirements imposed by Orders EA-12-049 and EA-12-051 and supporting requirements. The Commission's direction in the SRM makes it clear that the NRC will continue to follow a site-specific approach to resolving the interaction between the hazard reevaluation and mitigation strategies using information gathered in the 50.54(f) letter process. The NRC staff made conforming changes to the final rule package (NRC 2019b) as directed by the Commission, which included changes to two regulatory guides (NRC 2019c and NRC 2019d). The final rule was published in the *Federal Register* on August 9, 2019 (84 FR 39684), with an effective implementation date of September 9, 2019.
- Subsequent to Commission approval of the final MBDBE rule, the staff engaged with stakeholders to pursue the expeditious closure of the remaining post-Fukushima 50.54(f) letter responses on a timeframe commensurate with each item's safety significance.
- In a draft discussion paper (NRC 2019e), the NRC staff outlined the process to be used to review the reevaluated hazard and mitigation strategies assessment information provided by licensees, considering the differences between the draft final MBDBE rule and the approved final MBDBE rule. Subsequently, the NRC staff provided a screening letter (also called a "binning" letter) for both seismic and flooding hazard reevaluations (NRC 2019f and NRC 2019g), which categorized sites based on available information and the status of any commitments made in prior reports and assessments.

The NRC staff has concluded that each operating nuclear power plant has implemented the NRC-mandated safety enhancements resulting from the lessons learned from the Fukushima Dai-ichi accident through its implementation of Orders EA-12-049 and EA-12-051. The staff further concluded that all licensees have completed their response to the 50.54(f) letter for their nuclear power plants and that no further regulatory decisionmaking is required for nuclear power plants related to the Fukushima lessons learned.

In the context of the LR GEIS, the Fukushima events are considered a severe accident (i.e., a type of accident in which substantial damage is done to the reactor core) and more specifically, a severe accident initiated by an event external to the plant. The 1996 LR GEIS concluded that risks from severe accidents initiated by external events (such as an earthquake) could have potentially high consequences but found that external events are adequately addressed through a consideration of a severe accident initiated by an internal event (such as a loss of cooling water). Section E.3 assesses the impact of new information obtained in the responses to the NTTF recommendations. The conclusion from these assessments of the impact of the new information is that the risk of severe accidents, specifically, probability-weighted consequences reported in the 1996 LR GEIS, remains bounding.

No additional revisions to NRC regulatory requirements are expected as a result of lessons learned from the Fukushima Dai-ichi accident. If additional changes are identified, they would be made applicable to operating nuclear power reactors regardless of whether they have a renewed license. Information collected and mitigation measures implemented as part of the agency's response to the Fukushima event are considered in the section below. If the NRC identifies further information from the Fukushima events or analysis of steps taken in response to those events that constitutes new and significant information with respect to the environmental impacts of license renewal (initial LR or SLR), the NRC will evaluate that information in its plant-specific supplemental EISs (SEISs) to the LR GEIS, as it does with all such new and potentially significant information. Separate from the NRC's license renewal process, the NRC requires all licensees to take into account changes in seismic hazard in order to maintain safe operating conditions at all nuclear power plants.

In conclusion, operating experience and lessons learned from accidents have further contributed to NRC initiatives to provide reasonable assurance of adequate protection of public health and safety, to promote the common defense and security, and to protect the environment outside of NEPA. Because these initiatives have led operating plants to take action to reduce the likelihood of postulated accidents or to mitigate the potential consequences of such accidents, the NRC concludes that these initiatives have likely lowered the overall risk of postulated accidents compared to the assessment of that risk in the 1996 LR GEIS.

Further, as noted above, under Commission policy, license renewal applicants that had not previously completed a SAMA review were required to do so for initial LR. Several severe accident and mitigation programs outside of the environmental review, as described above, were in process but not completed before the implementation of SAMA in the environmental review. Thus, the Commission noted that all licensees had undergone, or were in the process of undergoing, more detailed site-specific SAMA analyses through processes separate from license renewal, specifically the CPI, IPE, and IPEEE programs (61 FR 28467, 28481; June 5, 1996) (Three Mile Island lessons learned). In light of these studies, the Commission stated that it did not expect future SAMA analyses to uncover "major plant design changes or modifications that will prove to be cost-beneficial" (61 FR 28467, 28481; June 5, 1996). The NRC's experience in completed license renewal proceedings has confirmed this prediction as explained in Section E.4. This observation lends further support that ongoing agency activities suggest that the probability-weighted consequences of severe accidents are, if anything, lower than originally estimated in 1996 LR GEIS.

E.3 Accident Risk and Impact Assessment

The environmental impacts of design-basis accidents and severe accidents are assessed in Sections 5.3.2 and 5.3.3 of the 1996 LR GEIS, respectively. As stated in Section 5.3.2, the environmental impact of design-basis accidents was assessed in the individual plant-specific licensing documents at the time of the initial licensing process and determined to be within regulatory limits. Because licensees are required to maintain the plant within acceptable design and performance criteria consistent with the current licensing basis, regardless of initial LR or SLR term, these impacts are not expected to change. Specifically, 10 CFR 54.21(a)(3) requires a license renewal application, for either the initial LR or SLR term, to "demonstrate that the effects of aging will be adequately managed [for structures and components identified in 10 CFR 54.21(a)(1)] so that the intended function(s) will be maintained consistent with the [current licensing basis] for the period of extended operation." Furthermore, 10 CFR 54.29(a)(1) requires that a renewed license may be issued if the Commission, in part, finds that actions have been identified and have been or will be taken with respect to managing the effects of aging during the period of extended operation such that there is reasonable assurance that activities authorized by the renewed license will continue to be conducted in accordance with the current licensing basis. Therefore, additional assessment of the environmental impacts of design-basis accidents is not necessary and the remainder of this evaluation is focused on the environmental impact of severe accidents similar to the analysis in the 1996 LR GEIS.

To assess the impacts of severe accidents from the airborne pathway, representing the most likely pathway for significant doses to the public, the 1996 LR GEIS relied on severe accident analyses provided in the plant-specific licensing documents where available. Table 5.1 in the 1996 LR GEIS lists the 28 nuclear power plants, representing 44 units, that included severe accident analyses in their original (plant-specific) EISs.[9] These original EISs used plant-specific meteorology, land topography, population distributions, and offsite emergency response parameters, along with generic or plant-specific source terms, to calculate offsite health and economic impacts. The offsite health effects included those from airborne releases of radioactive material and contamination of surface water and groundwater.

The 1996 LR GEIS used information from the 28 plant-specific EISs and a metric called the exposure index (EI) to (1) scale up the radiological impact of severe accidents on the population due to demographic changes from the time each original EIS was done until the year representing the mid-license renewal period, and (2) estimate the severe accident environmental impacts for the other plants (whose EISs did not include a quantitative assessment of severe accidents). The EI method uses the projected population distribution around each nuclear power plant site at the middle of its license renewal period and meteorology data for each site to provide a measure of the degree to which the population would be exposed to the release of radioactive material resulting from a severe accident (i.e., the EI method weights the population in each of 16 sectors around a nuclear power plant by the fraction of time the wind blows in that direction on an annual basis; see Section E.3.9.2 of this appendix for further information about population density). The EI metric was also used to project economic impacts at the mid-point of the license renewal period. A more detailed description of the EI method is contained in Appendix G of the 1996 LR GEIS. The plant-specific exposure indices (which are a function of population and wind direction), in conjunction with the plant-specific total probability-weighed consequences or risk values from the original EIS severe accident analyses, were used to predict the 95 percent UCB consequences for 74 nuclear power plants, representing 118 units, from atmospheric releases due to severe accidents. In Section 5.3.3.2.4 of the 1996 LR GEIS, the NRC concluded that the risk of early and latent fatalities from individual nuclear power plants is small. It represents only a small fraction of the risk to which the public is exposed from other sources. The probability-weighted consequences or risk is the product of the probability (i.e., CDF) and the consequences (e.g., total population dose) of a severe accident.

[9] The term “original EIS” describes a plant-specific EIS, FES, or similar environmental review document issued by the NRC that is associated with the issuance of a plant’s original operating license. This term is used in this appendix to differentiate it from a SEIS to the LR GEIS prepared in conjunction with a license renewal environmental review.

Predicted 95 percent UCB values were developed for early fatalities per reactor-year (RY), latent fatalities/RY, and total population dose/RY.[10] The results of this assessment for each plant for each of these impact metrics are provided in 1996 LR GEIS Table 5.10, Table 5.11, and Table 5.6, respectively. These results are repeated in Table E.3-1 in the columns titled "Predicted Total Early Fatalities/RY (95% UCB)," "Non-normalized Predicted Latent Total Fatalities/RY (95% UCB)," and "Non-normalized Predicted Total Dose (person-rem/RY) (95% UCB)," respectively. In Section 5.5.2.5 of the 1996 LR GEIS, the NRC staff concluded that the generic analysis "applies to all plants and 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."

Table E.3-1 Comparison of 1996 LR GEIS-Predicted Risks to License Renewal Estimated Risks

Nuclear Power Plant	LR GEIS Supplement Number	1996 LR GEIS-Predicted Total Early Fatalities/ RY (95% UCB)(a)	1996 LR GEIS Non-normalized Predicted Latent Total Fatalities/RY (95% UCB)(a)	1996 LR GEIS Non-normalized Predicted Total Dose (person-rem/RY) (95% UCB)(a)	License Renewal SAMA Total PDR (person-rem/RY)(b)	Ratio of GEIS 95% UCB Population Dose to License Renewal Total PDR
Calvert Cliffs 1 & 2	1	1.8×10^{-3}	2.3×10^{0}	2,995	69	44
Oconee 1, 2, & 3	2	1.1×10^{-2}	1.0×10^{0}	1,311	5	266
Arkansas 1	3	3.3×10^{-3}	1.7×10^{-1}	238	1	216
Hatch 1 & 2	4	2.6×10^{-3}	5.7×10^{-1}	855	4	244
Turkey Point 3 & 4	5	6.0×10^{-2}	2.0×10^{-1}	278	22	13
Surry 1 & 2	6	1.6×10^{-2}	9.0×10^{-1}	1,200	36	33
North Anna 1 & 2	7	9.4×10^{-4}	1.1×10^{0}	1,496	50	30
McGuire 1 & 2	8	1.0×10^{-2}	1.4×10^{0}	1,806	14	134
Catawba 1 & 2	9	1.7×10^{-2}	1.4×10^{0}	1,880	31	60
Peach Bottom 2 & 3	10	4.2×10^{-3}	2.0×10^{0}	2,950	15	201
St. Lucie 1	11	3.2×10^{-2}	6.3×10^{-1}	2,724	31	89
St. Lucie 2	11	3.2×10^{-2}	6.3×10^{-1}	2,724	28	97
Fort Calhoun	12	1.7×10^{-3}	8.0×10^{-2}	111	20	5
Robinson	13	3.1×10^{-3}	7.0×10^{-1}	926	11	87
Ginna	14	3.9×10^{-3}	1.5×10^{-1}	203	16	12
Summer	15	1.3×10^{-3}	1.0×10^{0}	1,381	2	691
Quad Cities 1 & 2	16	4.5×10^{-3}	1.1×10^{0}	1,588	17	95
Dresden 2 & 3	17	4.6×10^{-3}	1.4×10^{0}	1,991	51	39
Farley 1 & 2	18	1.5×10^{-3}	2.4×10^{-1}	334	4	92
Arkansas 2	19	3.3×10^{-3}	1.7×10^{-1}	238	9	28
D.C. Cook 1 & 2	20	8.4×10^{-3}	1.8×10^{0}	2,311	85	27
Browns Ferry 1 & 2	21	4.3×10^{-3}	9.7×10^{-1}	1,446	3	441

[10] Predicted 95 percent UCB values were also developed for economic impacts from severe accidents. Economic impacts are addressed in later sections.

Nuclear Power Plant	LR GEIS Supplement Number	1996 LR GEIS-Predicted Total Early Fatalities/RY (95% UCB)[a]	1996 LR GEIS Non-normalized Predicted Latent Total Fatalities/RY (95% UCB)[a]	1996 LR GEIS Non-normalized Predicted Total Dose (person-rem/RY) (95% UCB)[a]	License Renewal SAMA Total PDR (person-rem/RY)[b]	Ratio of GEIS 95% UCB Population Dose to License Renewal Total PDR
Browns Ferry 3	21	4.3×10^{-3}	9.7×10^{-1}	1,446	4	371
Millstone 2	22	2.5×10^{-2}	3.1×10^{0}	3,988	23	176
Millstone 3	22	2.5×10^{-2}	3.1×10^{0}	3,988	20	195
Point Beach 1 & 2	23	2.5×10^{-3}	2.3×10^{-1}	309	4	84
Nine Mile Point 1	24	3.8×10^{-3}	6.7×10^{-1}	996	23	44
Nine Mile Point 2	24	3.8×10^{-3}	6.7×10^{-1}	996	51	20
Brunswick 1 & 2	25	3.5×10^{-3}	4.7×10^{-1}	704	59	12
Monticello	26	4.1×10^{-3}	5.0×10^{-1}	730	76	10
Palisades	27	4.2×10^{-3}	1.3×10^{0}	1,691	64	27
Oyster Creek	28	7.4×10^{-3}	1.5×10^{0}	2,125	72	30
Pilgrim	29	3.7×10^{-3}	6.0×10^{-1}	873	68	13
Vermont Yankee	30	4.6×10^{-3}	9.0×10^{-1}	1,314	50	26
FitzPatrick	31	3.8×10^{-3}	5.0×10^{-1}	728	7	112
Wolf Creek	32	4.7×10^{-4}	3.3×10^{-1}	466	7	71
Harris	33	2.8×10^{-3}	7.3×10^{-1}	1,001	58	17
Vogtle 1 & 2	34	1.6×10^{-4}	7.3×10^{-1}	983	3	315
Susquehanna 1 & 2	35	6.0×10^{-3}	2.8×10^{0}	4,010	4	1,055
Beaver Valley 1	36	2.5×10^{-2}	1.3×10^{0}	1,720	58	30
Beaver Valley 2	36	2.5×10^{-2}	1.3×10^{0}	1,720	56	31
Three Mile Island 1	37	2.8×10^{-2}	3.3×10^{0}	4,381	593	7
Indian Point 2	38	6.5×10^{-2}	7.7×10^{0}	9,727	332	29
Indian Point 3	38	6.5×10^{-2}	7.7×10^{0}	9,727	521	19
Prairie Island 1	39	3.7×10^{-3}	1.7×10^{-1}	237	6	40
Prairie Island 2	39	3.7×10^{-3}	1.7×10^{-1}	237	17	14
Kewaunee	40	8.9×10^{-4}	2.2×10^{-1}	303	60	5
Cooper	41	2.6×10^{-3}	6.3×10^{-1}	955	6	149
Duane Arnold	42	8.0×10^{-3}	3.7×10^{-1}	561	46	12
Palo Verde 1, 2, & 3	43	1.1×10^{-4}	2.6×10^{-1}	369	34	11
Crystal River	44	1.5×10^{-3}	5.0×10^{-1}	700	48	15
Salem 1 & 2	45	2.9×10^{-3}	5.0×10^{0}	6,059	156	39
Hope Creek	45	4.1×10^{-3}	2.5×10^{0}	3,604	156	23
Seabrook	46	1.1×10^{-2}	6.0×10^{-1}	819	79	10
Columbia[c]	47	2.3×10^{-3}	4.3×10^{-1}	649	26	25
South Texas 1 & 2	48	3.3×10^{-4}	8.0×10^{-1}	1,063	2	611
Limerick	49	1.1×10^{-2}	3.1×10^{0}	4,461	56[d]	79

Nuclear Power Plant	LR GEIS Supplement Number	1996 LR GEIS-Predicted Total Early Fatalities/ RY (95% UCB)[(a)]	1996 LR GEIS Non-normalized Predicted Latent Total Fatalities/RY (95% UCB)[(a)]	1996 LR GEIS Non-normalized Predicted Total Dose (person-rem/RY) (95% UCB)[(a)]	License Renewal SAMA Total PDR (person-rem/RY)[(b)]	Ratio of GEIS 95% UCB Population Dose to License Renewal Total PDR
Grand Gulf	50	2.8×10^{-3}	9.7×10^{-1}	1,441	7	215
Callaway	51	6.9×10^{-4}	3.6×10^{-1}	509	21	24
Davis-Besse	52	1.4×10^{-3}	1.5×10^{0}	2,021	12	170
Sequoyah 1	53	6.6×10^{-3}	1.1×10^{0}	1,474	131	11
Sequoyah 2	53	6.6×10^{-3}	1.1×10^{0}	1,474	114	13
Byron 1 & 2	54	2.3×10^{-3}	2.2×10^{0}	2,867	92	31
Braidwood 1 & 2	55	3.6×10^{-3}	3.3×10^{0}	4,418	342	13
Fermi 2	56	6.8×10^{-3}	1.9×10^{0}	2,722	54	50
LaSalle 1 & 2	57	3.6×10^{-3}	2.0×10^{0}	2,898	40	73
River Bend	58	4.1×10^{-3}	8.0×10^{-1}	1,168	8	138
Waterford 3	59	1.4×10^{-2}	3.3×10^{-1}	477	61	8
Comanche Peak 1 & 2	N/A	2.3×10^{-3}	3.3×10^{-1}	466	16[(e)]	29
Diablo Canyon 1 & 2	N/A	1.5×10^{-3}	2.5×10^{-1}	346	101[(f)]	3
Watts Bar 1	N/A	1.8×10^{-3}	1.2×10^{0}	1,540	5[(g)]	291
Watts Bar 2	N/A	1.8×10^{-3}	1.2×10^{0}	1,540	46[(h)]	34
Clinton	N/A	3.0×10^{-3}	1.8×10^{0}	2,549	N/A	N/A
Perry	N/A	6.9×10^{-3}	1.7×10^{0}	2,544	N/A	N/A

LR GEIS = Generic Environmental Impact Statement for License Renewal of Nuclear Plants; N/A = not applicable (a license renewal application has not been submitted or was withdrawn); PDR = population dose risk; RY = reactor-year; SAMA = severe accident mitigation alternative; UCB = upper confidence bound.

(a) Data were obtained from NRC 1996.
(b) Data were obtained from the applicable plant-specific supplement to NUREG-1437, unless otherwise noted. Where applicable, the SAMA PDR was adjusted using the external events multiplier.
(c) Referred to as WNP-2 (Washington Nuclear Project 2) in the 1996 LR GEIS.
(d) Data were obtained from the SAMA analysis included in NUREG-0974, Supplement (NRC 1989b), which was then adjusted using the internal events CDF and external events multiplier from NUREG-1437, Supplement 49 (NRC 2014b).
(e) The SAMA PDR is from the severe accident mitigation design alternative (SAMDA) analysis included in NUREG-0775, Supplement (NRC 1989a). No external events multiplier was assumed in the SAMDA analysis.
(f) The SAMA PDR is from PG&E 2015, which was then adjusted using the external events multiplier from this same document.
(g) The SAMA PDR is from the SAMDA analysis included in NUREG-0498, Supplement 1 (NRC 1995b). No external events multiplier was assumed in the SAMDA analysis.
(h) The SAMA PDR is from the SAMDA analysis included in NUREG-0498, Supplement 2 (NRC 2013a), which was then adjusted using the external events multiplier from this same document.

Source: NRC 2022c, unless otherwise noted.

As of 2023, almost all the currently operating nuclear plants have submitted license renewal applications and been approved for initial LR. Per the Commission’s regulations, applicants are required to include a plant-specific SAMA analysis in the environmental report if one has not been previously considered. A SAMA analysis is “a cost-benefit analysis that addresses whether the expense of implementing a mitigation measure not mandated by the NRC is outweighed by the expected reduction in environmental cost it would provide in a core damage event" (*Massachusetts v. NRC*, 708 F.3d 63, 68 [1st Cir. 2013]). Similar to the 1996 LR GEIS, the consequence analysis software that was typically used for the SAMA analysis was the MELCOR Accident Consequence Code System (MACCS) code (SNL 2021).[11] Thus, most operating plants have submitted an initial LR application that includes a more recent plant-specific estimate of the total PDR due to severe accidents, which is an update of the non-normalized predicted total dose (person-rem/RY) (95 percent UCB) consequences provided in the 1996 LR GEIS. This consequence analysis includes plant-specific updated CDFs for internal and, for most plants, external event hazards, plant-specific updated analyses of containment performance under severe accident conditions, and updated consequence analyses using plant-specific information about radionuclide source terms, radionuclide releases, projected population distribution during the license renewal period, meteorological data, and emergency response.

The estimated PDR developed for the SAMA analyses, at a minimum, included the contribution from severe accidents due to internally initiated events, which also generally included events initiated by internal flooding. Several SAMA analyses also included the contribution from externally initiated events in the PDR estimate. Most SAMA analyses, however, accounted for externally initiated events by developing an external events multiplier in accordance with the methodology in Nuclear Energy Institute (NEI) publication NEI 05-01 (NEI 2005), which has been endorsed by the NRC (2013d). The external events multiplier is the ratio of the total plant CDF (both internally initiated and externally initiated) to the CDF for internally initiated events. This multiplier is multiplied by the estimated PDR for internally initiated events to develop the estimate of the total plant PDR that is included in Table E.3-1.[12]

In summary, PDR is the numerical value for the probability-weighted consequences using a Level 3 PRA. As shown in Table E.3-1, the estimated total PDR from the license renewal SAMA analyses, for all plants having available information, is less than the corresponding predicted 95 percent UCB values from the 1996 LR GEIS and, in most cases, is orders of magnitude less. Table E.3-1 demonstrates the 1996 LR GEIS assumption that, "The use of the 95 percent upper prediction confidence bounds provides even greater assurance that the [1996] GEIS does not underestimate potential future environmental impacts." Specifically, the predicted 95 percent UCB population dose values from the 1996 LR GEIS are higher by factors ranging from 3 to over 1,000 and are on average a factor of 120 higher than the corresponding total PDR values from the license renewal SAMA analyses. Thus, the probability-weighted environmental consequences of a severe accident were demonstrated for all plants having a SAMA analysis to be lower than predicted in the 1996 LR GEIS. In isolated cases, updated plant-specific hazard

[11] MACCS was developed at and continues to be maintained by Sandia National Laboratories for the NRC. It is used to model estimates of the health risks and economic impacts of offsite radiological releases from potential severe accidents at nuclear facilities. See Section E.3.9 of this appendix for a relatively recent application by the NRC of the MACCS code for performing a state-of-the art assessment of the consequences of severe accidents at nuclear power plants.

[12] Information from several of the SAMA analyses (i.e., for the Oconee, McGuire, Catawba, and Columbia plants) show that the PDR for different hazards is not linear relative to their contribution to CDF. For example, these analyses show that the relative contribution to total plant PDR is somewhat higher than the relative contribution to total plant CDF for seismic events and is somewhat lower for internal events. This result is consistent with NRC staff experience with the risk results from plant-specific seismic PRAs where the contribution to large early release is generally higher than the corresponding results from internal events PRAs. However, this non-linear relationship likely introduces a small non-conservatism in the total plant PDR. This non-conservatism is not significant to the conclusions of this LR GEIS supplement because of the significant conservatism in the 1996 LR GEIS analyses.

PRAs may show that the 1996 LR GEIS underpredicted a site-specific value. Because of the significant margin below the health criteria and the conservatisms in the overall values in the 1996 LR GEIS, the probability-weighted consequences to the public and environment are still predicted to be SMALL.

The license renewal SAMA analyses did not include estimates of the early fatality risk or latent fatality risk. However, the 1996 LR GEIS 95 percent UCB predicted values for early fatalities and latent fatalities are derived from the estimated radiological doses to the population. Therefore, the NRC staff concludes that the 1996 LR GEIS-predicted 95 percent UCB results for early fatalities and latent fatalities are also very conservative based on the updated information from the license renewal SAMA analyses regarding PDR and the fatality risk results from the state-of-the-art reactor consequence analysis (SOARCA). The plant-specific LR-calculated values presented in Table E.3-1 demonstrate the magnitude of conservatism used in the 1996 LR GEIS-predicted values, both from the standpoint of reduced consequences using more recent plant-specific information and the conservatism built into the 1996 LR GEIS methodology, and demonstrate the conclusion that the probability-weighted consequences due to severe accidents to the public and environment are smaller than predicted in the 1996 LR GEIS.

Since publication of the 1996 LR GEIS and 2013 LR GEIS and the completion of the license renewal SAMA analyses, developments or new information regarding plant operation and accident analysis have occurred that could affect the assumptions made in these analyses. These changes are grouped into the following areas and are each covered in the indicated section of this LR GEIS revision:

- internal event risk (Section E.3.1)
- external event risk (Section E.3.2)
- updates in the quantification of accident source terms (Section E.3.3)
- increases in licensed reactor power levels, i.e., power uprates (Section E.3.4)
- increases in fuel burnup levels (Section E.3.5)
- consideration of reactor accidents at low power and shutdown conditions (Section E.3.6)
- consideration of accidents in SFPs (Section E.3.7)
- the Biological Effects of Ionizing Radiation (BEIR) VII report on the risk of fatal cancers posed by exposure to radiation (Section E.3.8)

Sections discussing uncertainties (Section E.3.9), SAMAs (Section E.4), and conclusions are also provided. New information regarding the above topics is also evaluated in plant-specific license renewal applications to determine its significance. This revised LR GEIS also evaluates new information regarding severe accidents for each of the above topics and considers whether the information would, collectively, change the conclusions in the 1996 LR GEIS and 2013 LR GEIS. As explained below, while several of these factors may result in modest increases to severe accident risk, other new information regarding these factors suggests that the risk of severe accidents may be, on average, substantially lower than previously estimated. As a result, the following analysis further supports the overall findings from the 1996 and 2013 LR GEIS that the probability-weighted consequences of severe accidents would be SMALL.

As discussed in Section 5.3.3.1 of the 1996 LR GEIS, the environmental impacts of security-related events were not considered. As stated, these types of events are addressed via deterministic criteria in 10 CFR Part 73 rather than by risk assessments. The regulatory requirements under 10 CFR Part 73 provide reasonable assurance that the risk from sabotage is small. This section goes on to state:

> Although the threat of sabotage events cannot be accurately quantified, the Commission believes that acts of sabotage are not reasonably expected. Nonetheless, if such events were to occur, the Commission would expect that resultant core damage and radiological releases would be no worse than those expected from internally initiated events.

The NRC continues to take this position. As a result of the terrorist attacks of September 11, 2001, the NRC conducted a comprehensive review of the agency's security program and made further enhancements to security at a wide range of NRC-regulated facilities. These enhancements included significant reinforcement of the defense capabilities of nuclear facilities, better control of sensitive information, enhancements in emergency preparedness to further strengthen the NRC's nuclear facility security program, and implementation of mitigating strategies to deal with postulated events potentially causing loss of large areas of the plant due to explosions or fires, including those that an aircraft impact might create. These measures are outlined in greater detail in NUREG/BR-0314 (NRC 2004), NUREG-1850 (NRC 2006), Sandia National Laboratories' *Mitigation of Spent Fuel Pool Loss-of-Coolant Inventory Accidents and Extension of Reference Plant Analyses to Other Spent Fuel Pools* (SNL 2006), and Section E.3.7.

The NRC routinely assesses threats and other information provided by a variety of Federal agencies and sources. The NRC also ensures that licensees meet appropriate security-level requirements. The NRC will continue to focus on prevention of terrorist acts for all nuclear facilities and will not focus on plant-specific evaluations of speculative environmental impacts resulting from terrorist acts. While these are legitimate matters of concern, the NRC will continue to address them through the ongoing regulatory process as a current and generic regulatory issue that affects all nuclear facilities and many of the activities conducted at nuclear facilities. The issue of security and risk from malevolent acts at nuclear power facilities is not unique to facilities that have requested a renewal of their licenses (NRC 2006).

The NRC's position is that malevolent acts remain speculative and beyond the scope of a NEPA review. NEPA requires that there be a "reasonably close causal relationship" between the Federal agency action and the environmental consequences. The environmental impact of a terrorist attack is too far removed from the natural or expected consequences of a license renewal action to warrant consideration under NEPA. However, as noted above, in the event of a terrorist attack, the consequences of such an attack would be no worse than an internally initiated severe accident, which has already been analyzed.

In a decision dated June 2, 2006, *San Luis Obispo Mothers for Peace v. NRC*, 449 F.3d 1016, 1028 (9th Cir. 2006), the U.S. Court of Appeals for the Ninth Circuit held that the NRC could not categorically refuse to consider the consequences of a terrorist attack under NEPA and remanded the case to the NRC. On remand, the Commission adjudicated the intervenors' claim that the NRC staff had not adequately assessed the environmental consequences of a terrorist attack on the Diablo Canyon Power Plant's proposed facility for storing spent nuclear fuel in dry casks. See *Pacific Gas & Electric Co.,* (Diablo Canyon Power Plant Independent Spent Fuel Storage Installation), CLI-08-26, 68 NRC 509 (PG&E 2008). The Commission ultimately determined that an EIS was not required to address land contamination and latent health effect issues (Diablo Canyon, CLI-08-26, 68 NRC at 521). Further, the Commission concluded that the staff's final, supplemental environmental assessment (EA) and finding of no significant impact, the adjudicatory record of the case, and its supervisory review of the non-public information underlying portions of the staff's analyses satisfied the agency's NEPA obligations (*Id.* at 525-26). The staff had found that even the most severe, plausible terrorist attack of those examined would not cause immediate or latent health effects. The staff also found that such an attack was improbable, but if one occurred, the likelihood of significant radioactive release was very low because the nature of the Diablo Canyon casks and site (*Id.* at 521). The U.S. Court of Appeals for the Ninth Circuit upheld the Commission's determination on appeal. See *San Luis Obispo Mothers for Peace v. NRC*, 635 F.3d 1109, 1120-21 (9th Cir. 2011).

The Commission stated that it will adhere to the Ninth Circuit decision when considering licensing actions for facilities subject to the jurisdiction of that Circuit. See *Pacific Gas and Electric Co.,* (Diablo Canyon Power Plant Independent Spent Fuel Storage Installation), CLI-07-11, 65 NRC 148 (NRC 2007b). However, the Commission decided against applying that holding to all licensing proceedings nationwide. In one such proceeding, *Amergen Energy Co. LLC* (Oyster Creek Nuclear Generating Station), CLI-07-8, 65 NRC 124, 128-29 (NRC 2007b), the New Jersey Department of Environmental Protection contended that NEPA requires an analysis of a terrorist attack. The NRC found that NEPA "imposes no legal duty on the NRC to consider intentional malevolent acts" because such acts are "too far removed from the natural or expected consequences of agency action" (*Id.* at 129 [quoting the Atomic Safety and Licensing Board decision]). The NRC also found that a terrorism review would be redundant because (1) "the NRC has undertaken extensive efforts to enhance security at nuclear facilities," which it characterized as the best mechanism to protect the public (*Id.* at 130); and (2) the LR GEIS had addressed the issue and concluded that "the core damage and radiological release from [terrorist] acts would be no worse than the damage and release to be expected from internally initiated events." On appeal, the Third Circuit agreed with the NRC and denied the petition. See *New Jersey Department of Environmental Protection v. NRC and Amergen Energy Co, LLC* (Case No. 07-2271), 561 F.3d 132 (3rd Cir. 2009). The Court found that, "the NRC correctly concluded that the relicensing of Oyster Creek does not have a 'reasonably close causal relationship' with the environmental effects that would be caused in the event of a terrorist attack" (*Id.*).

The Third Circuit disagreed with the Ninth Circuit's application of the relevant Supreme Court decisions. Instead, as the Commission had originally held, the Third Circuit concluded that the issuance of a facility license—here, the issuance of the 20-year extension for the Oyster Creek license—would not be the "proximate cause" of a terrorist attack on the facility (*Id.* at 141-43).

Moreover, the Third Circuit noted that the 1996 LR GEIS had reviewed the possible impacts of a sabotage event, which is a form of terrorism (*Id.* at 134). The LR GEIS found that the consequences of a sabotage event would be no worse than those expected from an internally initiated severe accident (*Id.* [quoting "Generic Environmental Impact Statement for License Renewal of Nuclear Plants," Final Report, Vol. I (May 1996), at 5-18]). The Third Circuit noted that the petitioner in the case before it (the State of New Jersey) had failed to demonstrate that the results of a terrorist attack would be any different from those of a severe accident, which had already been analyzed (*Id.* at 144). The Third Circuit also noted that the NRC had prepared a plant-specific SEIS addressing the mitigation of severe accidents at Oyster Creek (*Id.* at 143-144). As a result, the Third Circuit found that, even if the Commission were required to analyze the impacts of a terrorist attack, the NRC had prepared both generic and plant-specific analyses of the impacts of a terrorist attack at Oyster Creek, and that the petitioner had not shown that the NRC could evaluate the risks more meaningfully than it had already done (*Id.* at 144).

After the Third Circuit's determination, the Commission overturned the Atomic Safety and Licensing Board's decision to admit a NEPA terrorism contention in the Diablo Canyon License Renewal proceeding, a facility located in the Ninth Circuit. *Pacific Gas & Electric Co.* (Diablo Canyon Nuclear Power Plant), CLI-11-11, 74 NRC 427. The Commission reaffirmed that "the staff's determination in the [LR] GEIS that the environmental impacts of a terrorist attack were bounded by those resulting from internally initiated events, was sufficient to address the environmental impacts of terrorism" (PG&E 2011) (*Id*. at 456).

In sum, the Commission has found that the issuance of a facility license is not the "proximate cause" of a terrorist attack at that facility. Thus, it is not required to prepare an EIS discussion of the potential impacts of a terrorist attack (*Id*. at 455-456). However, due to the decision of the Ninth Circuit, the NRC will prepare an analysis of the environmental impacts of a terrorist attack for licensing actions of facilities within the geographical boundaries of the Ninth Circuit (*Id*. at 456). In addition, the Third Circuit has held that the LR GEIS constitutes such an analysis for license renewals (*Id*. at 455).

NUREG-1935 (NRC 2012g) explained that the NRC did not include security events as part of SOARCA to avoid providing any specific information that may materially assist in planning or carrying out a terrorist attack on a nuclear power plant. However, the NRC has stated that the security-related studies conducted after September 11, 2001, led it to conclude that previous risk studies used conservative radionuclide source terms and that plant improvements, plus improved modeling, would confirm that radionuclide releases and early fatalities were substantially smaller than suggested by earlier studies.

E.3.1 Impact of New Information about Accidents Initiated by Internal Events

With few exceptions, the severe accident analyses formulating the basis for the 1996 LR GEIS were limited to consideration of reactor accidents caused by internal events. The 1996 LR GEIS addressed the impacts of external events qualitatively, and external events are covered in more detail in Section E.3.2 of this LR GEIS revision. The impacts from the 1996 LR GEIS were based on the original EISs for the 28 nuclear power plant sites identified in Table E.3-2 and Table E.3-3. The source terms[13] and their likelihood used in the plant-specific original EISs to calculate the airborne pathway environmental impacts of accidents were, in turn, usually based upon information contained in NUREG-0773 (NRC 1982d). NUREG-0773 updates the source terms used in the original *Reactor Safety Study – An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants* (NRC 1975). These source terms and frequencies were used along with plant-specific meteorology, population distributions, and emergency planning characteristics to calculate the airborne pathway environmental impacts. These EISs were issued in the 1981 to 1986 timeframe. Thus, while the LR GEIS was published in 1996, it was primarily based on information from the 1980s.

Since the publication of NUREG-0773, many additional studies have been completed on the likelihood and consequences of reactor accidents initiated by internal events at full power. These studies include the NRC's risk study of five plants documented in NUREG-1150 (NRC 1990), the NRC's integrated risk assessment to address phenomenology and uncertainty documented in NUREG/CR-5305 (SNL 1992), and licensee responses to Generic Letter 88-20 and associated supplements (i.e., the IPE program), as summarized in NUREG-1560

[13] Source term refers to the magnitude and mix of the radionuclides released from the fuel, expressed as fractions of the fission product inventory in the fuel, as well as their physical and chemical form, and the timing of their release.

(NRC 1997a). Licensees have further updated their IPE-vintage PRA models to support various risk-informed licensing applications and the identification and analysis of potentially cost-effective SAMA alternatives evaluated in plant license renewal applications. In addition, the NRC has developed standardized plant analysis risk models for all operating plants, which can be used to calculate CDFs and large early release frequencies (LERFs) for internal events; completed the SOARCA project, which performed a detailed examination of accident progression, source term, and offsite consequences for select accident scenarios for three nuclear plants (NRC 2012g, NRC 2019h); and started publishing the results of the Level 3 PRA project to develop a full-scope Level 3 PRA[14] for a nuclear plant site using current state-of-practice methods, tools, and data (NRC 2022a).

The purpose of Section E.3.1 is to assess how results from updated internal event information compare to those on which the 1996 LR GEIS was based. The evaluation contained in Sections E.3.1.1 through E.3.1.3 compares the CDFs and offsite doses obtained directly from the 1996 LR GEIS to the updated information for the 28 nuclear power plant sites that included severe accident analyses in their original (plant-specific) EISs. A similar comparison is not made for the other operating nuclear plants because severe accident analyses were not performed in the original (plant-specific) analyses for these other plants. The comparison is done for pressurized water reactors (PWRs) and boiling water reactors (BWRs), and covers each of the plants listed in Table 5.1 of the 1996 LR GEIS. Changes in source terms (i.e., the quantity, form, and timing of radioactive material released to the environment) are assessed in Section E.3.3.

E.3.1.1 Airborne Pathway Impacts

As a first step in the comparison, the internal event-initiated CDFs from the original EISs are compared to the CDFs reported in the plant-specific IPEs and in the license renewal SAMA analyses for the PWRs and BWRs considered by the 1996 LR GEIS. Before making this comparison, it is notable that the CDFs from the original EISs are for severe accidents initiated by internal events, while the CDFs from the IPEs and SAMA analyses, in many cases, also include severe accidents initiated by internal flooding events.[15] Table E.3-2 and Table E.3-3 show these comparisons. The data in these tables show that CDFs have been steadily declining since the original estimates in the EISs. Specifically, as can be seen in Table E.3-2 and Table E.3-3, for many plants, the IPE CDFs are smaller than those from the original EISs, particularly for BWRs. The mean value of the IPE CDFs listed in Table E.3-2 and Table E.3-3 are lower than the corresponding mean of the 1996 LR GEIS CDFs by 30 percent for PWRs and by about a factor of 3.5 for BWRs. Furthermore, the SAMA internal event CDFs are smaller than those from the original EISs for all plants except one and smaller than those from the IPE for most of the plants. Specifically, the mean value of the SAMA CDFs listed in Table E.3-2 and Table E.3-3 are a factor of almost 4 lower than the corresponding mean of the 1996 LR GEIS CDFs for PWRs (i.e., from Table E.3-2, 8.4×10^{-5}/yr for the 1996 LR GEIS mean CDF divided by 2.2×10^{-5}/yr for the SAMA mean CDF) and more than a factor of 6 lower for BWRs (i.e., from Table E.3-3, 5.4×10^{-5}/yr for the 1996 LR GEIS mean CDF divided by 8.7×10^{-6}/yr for the SAMA mean CDF). Information from recent risk-informed license amendment requests (LARs) submitted to the NRC show that these CDFs are, on average, further reduced from what were reported in the license renewal SAMA analyses. Accordingly, the likelihood of an accident that

[14] A Level 3 PRA is an assessment of the offsite public risks attributable to a spectrum of possible accident scenarios involving a nuclear power plant.

[15] Internal events are accidents that are initiated by the failure of plant systems or operator actions. Internal flooding events are accidents that are initiated by a ruptured water pipe inside the plant and for which the resulting water spray or flood damages plant equipment.

leads to core damage, based on just internally initiated events, is significantly less for both PWRs and BWRs than that used as the basis for the 1996 LR GEIS.

Table E.3-2 Pressurized Water Reactor Internal Event (Full Power) Core Damage Frequency Comparison

Nuclear Power Plant	1996 LR GEIS Estimated CDF(a)	IPE CDF(b)	SAMA CDF(c)
Beaver Valley 2	1.0×10^{-4}/yr	1.9×10^{-4}/yr(d)	9.5×10^{-6}/yr(d)
Braidwood 1	1.0×10^{-4}/yr	2.7×10^{-5}/yr(d)	3.6×10^{-5}/yr(d)
Braidwood 2	Same as Unit 1	Same as Unit 1	3.5×10^{-5}/yr(d)
Byron 1	4.8×10^{-5}/yr	3.1×10^{-5}/yr(d)	4.0×10^{-5}/yr(d)
Byron 2	Same as Unit 1	Same as Unit 1	3.8×10^{-5}/yr(d)
Callaway 1	4.8×10^{-5}/yr	5.9×10^{-5}/yr(d)	1.7×10^{-5}/yr
Catawba 1, 2	4.8×10^{-5}/yr	5.8×10^{-5}/yr(d)	4.7×10^{-5}/yr(d)
Comanche Peak 1, 2	4.8×10^{-5}/yr	5.7×10^{-5}/yr(d)	4.8×10^{-5}/yr(e)
Harris 1	4.8×10^{-5}/yr	7.0×10^{-5}/yr(d)	9.2×10^{-6}/yr(d)
Indian Point 2	3.5×10^{-4}/yr	3.1×10^{-5}/yr	1.8×10^{-5}/yr(d)
Indian Point 3	3.4×10^{-4}/yr	4.4×10^{-5}/yr(d)	1.2×10^{-5}/yr(d)
Millstone 3	2.0×10^{-4}/yr	5.6×10^{-5}/yr	2.6×10^{-5}/yr
Palo Verde 1, 2, 3	4.8×10^{-5}/yr	9.0×10^{-5}/yr	5.1×10^{-6}/yr
San Onofre 2, 3	4.8×10^{-5}/yr	3.0×10^{-5}/yr	Not Available(f)
Seabrook 1	4.8×10^{-5}/yr	6.1×10^{-5}/yr(g)	7.8×10^{-6}/yr(d)
South Texas 1, 2	4.4×10^{-5}/yr	4.3×10^{-5}/yr	3.9×10^{-6}/yr
St. Lucie 2	4.8×10^{-5}/yr	2.6×10^{-5}/yr	2.4×10^{-5}/yr(d)
Summer 1	4.9×10^{-5}/yr	2.0×10^{-4}/yr	5.6×10^{-5}/yr
Vogtle 1, 2	1.0×10^{-4}/yr	4.9×10^{-5}/yr(d)	1.6×10^{-5}/yr(d)
Waterford 3	4.8×10^{-5}/yr	1.8×10^{-5}/yr	1.1×10^{-5}/yr
Wolf Creek 1	4.8×10^{-5}/yr	4.2×10^{-5}/yr(d)	3.0×10^{-5}/yr
Mean value	8.4×10^{-5}/yr	5.9×10^{-5}/yr	2.2×10^{-5}/yr
Median value	4.8×10^{-5}/yr	4.9×10^{-5}/yr	1.7×10^{-5}/yr

CDF = core damage frequency; IPE = Individual Plant Examination; LR GEIS = Generic Environmental Impact Statement for License Renewal of Nuclear Plants; SAMA = severe accident mitigation alternative.

(a) The estimated CDF was obtained by summing individual atmospheric release sequences, including intact containment sequences, provided in the original (plant-specific) environment impact statement (EIS). Similar data for the other operating nuclear plants are not available because their original EISs did not include an assessment of severe accidents.
(b) Data were obtained from NRC 1997a, unless otherwise noted.
(c) Data were obtained from the applicable plant-specific supplement to NUREG-1437, unless otherwise noted.
(d) The internal events-initiated CDF value includes contribution from internal flooding events.
(e) Data are from the severe accident mitigation design alternative (SAMDA) analysis included in NUREG-0775, Supplement (NRC 1989a).
(f) The San Onofre plant was permanently shut down in 2012.
(g) Data were obtained from the licensee's Individual Plant Examination of External Events submittal.

Source: NRC 2022c, unless otherwise noted.

Table E.3-3 Boiling Water Reactor Internal Event (Full Power) Core Damage Frequency Comparison

Plant	1996 LR GEIS Estimated CDF[(a)]	IPE CDF[(b)]	SAMA CDF[(c)]
Clinton 1	2.4×10^{-5}/yr	2.7×10^{-5}/yr[(d)]	Not Available[(e)]
Fermi 2	2.4×10^{-5}/yr	5.7×10^{-6}/yr	1.5×10^{-6}/yr[(d)]
Grand Gulf 1	2.4×10^{-5}/yr	1.7×10^{-5}/yr[(d)]	2.9×10^{-6}/yr[(d)]
Hope Creek	1.0×10^{-4}/yr	4.6×10^{-5}/yr[(d)]	4.4×10^{-6}/yr[(d)]
Limerick 1, 2	8.9×10^{-5}/yr	4.3×10^{-6}/yr	3.2×10^{-6}/yr
Nine Mile Point 2	1.1×10^{-4}/yr	3.1×10^{-5}/yr	5.8×10^{-5}/yr[(d)]
Perry 1	2.4×10^{-5}/yr	1.3×10^{-5}/yr[(d)]	Not Available[(e)]
River Bend	9.5×10^{-5}/yr	1.6×10^{-5}/yr	2.8×10^{-6}/yr
Susquehanna 1	2.4×10^{-5}/yr	5.6×10^{-7}/yr[(d,f)]	2.0×10^{-6}/yr[(d)]
Susquehanna 2	2.4×10^{-5}/yr	5.6×10^{-7}/yr[(d,f)]	1.9×10^{-6}/yr[(d)]
Columbia[(g)]	2.4×10^{-5}/yr	1.8×10^{-5}/yr[(d)]	7.4×10^{-6}/yr[(d)]
Mean value	5.4×10^{-5}/yr	1.5×10^{-5}/yr	8.7×10^{-6}/yr
Median value	2.4×10^{-5}/yr	1.45×10^{-5}/yr	3.1×10^{-6}/yr

CDF = core damage frequency; IPE = Individual Plant Examination; LR GEIS = Generic Environmental Impact Statement for License Renewal of Nuclear Plants; SAMA = severe accident mitigation alternative.

(a) Data were obtained by summing individual atmospheric release sequences, including intact containment sequences, provided in the original (plant-specific) environment impact statement (EIS). Similar data for the other operating nuclear plants are not available because their original EISs did not include an assessment of severe accidents.
(b) Data were obtained from NRC 1997a, unless otherwise noted.
(c) Data were obtained from the applicable plant-specific supplement to NUREG-1437, unless otherwise noted.
(d) Internal events-initiated CDF value includes contribution from internal flooding events.
(e) A license renewal application and associated SAMA analysis has not been submitted for this plant.
(f) The IPE CDF was obtained from Appendix G of NRC 2009.
(g) Referred to as WNP-2 (Washington Nuclear Project 2) in the 1996 LR GEIS.

Source: NRC 2022c, unless otherwise noted.

Additional comparisons can be made of the estimated total population dose from severe accidents initiated by internal events, which were estimated in both the 1996 LR GEIS for the 28 nuclear power plant sites that included severe accident analyses in their original (plant-specific) EISs (referred to as the predicted or Expected Total Population Dose – non-normalized) and in the license renewal SAMA analyses. These comparisons are shown in Table E.3-4 and Table E.3-5 for the same PWR and BWR plants, respectively, included in Table E.3-2 and Table E.3-3. The data in these tables show that the estimated PDRs in the SAMA analyses are significantly less than the predicted or expected value estimates in the 1996 LR GEIS. Specifically, as shown in Table E.3-4 and Table E.3-5, the SAMA PDR is less than the expected value of the PDR reported in the 1996 LR GEIS for all of the plants (both PWRs and BWRs), and for most plants the SAMA PDR is substantially less. This is the case even when considering the assumptions included in the SAMA analyses that would, in isolation, increase the PDR relative to the estimates in the 1996 LR GEIS, such as increases in the estimated population surrounding the plant sites, or increases in source terms due to planned or approved power uprates.

The means of the SAMA PDR estimates listed in Table E.3-4 and Table E.3-5 are lower than the corresponding mean of the 1996 LR GEIS expected value PDRs by more than a factor of

30 for PWRs (i.e., from Table E.3-4, 986 person-rem/RY for the 1996 LR GEIS mean population dose divided by 31.3 person-rem/RY for the SAMA mean PDR) and just under a factor of 30 for BWRs (i.e., from Table E.3-5, 577 person-rem/RY for the 1996 LR GEIS mean population dose divided by 19.4 person-rem/RY for the SAMA Internal Event mean PDR), and ranges from a factor of less than 2 (Braidwood 1, 2) to almost 600 (River Bend). Accordingly, the risk of severe accidents that result in core damage and a subsequent offsite release of radioactive materials, based on only the risk of severe accidents initiated by internal events, is significantly less for both PWRs and BWRs than that used as the basis for the 1996 LR GEIS.

Table E.3-4 Pressurized Water Reactor Internal Event (Full Power) Population Dose Risk Comparison

Nuclear Power Plant	1996 LR GEIS Estimated Expected Total Population Dose – Non-normalized (person-rem/reactor-year)[(a)]	SAMA PDR (person-rem/reactor-year)[(b)]
Beaver Valley 2	230	55.8[(c)]
Braidwood 1, 2	180	114[(d)]
Byron 1, 2	218	35.5[(d)]
Callaway 1	126	4.6
Catawba 1, 2	170	31.4[(c)]
Comanche Peak 1, 2	58	16.0[(e)]
Harris 1	114	29.0[(d)]
Indian Point 2	10,400	87.4[(d)]
Indian Point 3	Same as Unit 2	94.8[(d)]
Millstone 3	1,000	12.8
Palo Verde 1, 2, 3	67	13.6
San Onofre 2, 3	380	Not Available[(f)]
Seabrook 1	105	37.8[(g)]
South Texas 1, 2	250	1.74[(h)]
St. Lucie 2	78	14.0[(d)]
Summer 1	130	1.0
Vogtle 1, 2	310	1.56[(d)]
Waterford 3	69	17.1
Wolf Creek 1	99	3.27
Mean value	986	31.3
Median value	175	16.0

LR GEIS = Generic Environmental Impact Statement for License Renewal of Nuclear Plants; PDR = population dose risk; SAMA = severe accident mitigation alternative.
(a) Data were obtained from NRC 1996.
(b) The SAMA PDR was obtained from the applicable plant-specific supplement to NUREG-1437, unless otherwise noted.
(c) Includes the contribution from internal events, internal flooding events, and external events.
(d) Includes the contribution from internal events and internal flooding events.
(e) Data are from the severe accident mitigation design alternative (SAMDA) analysis included in NUREG-0775, Supplement (NRC 1989a).
(f) The San Onofre plant was permanently shut down in 2012.
(g) Includes contribution from internal events, internal flooding events, and some external events.
(h) Includes contribution from internal events and external events.
Source: NRC 2022c, unless otherwise noted.

Table E.3-5 Boiling Water Reactor Internal Event (Full Power) Population Dose Risk Comparison

Nuclear Power Plant	1996 LR GEIS Estimated Expected Total Population Dose – Non-normalized (person-rem/reactor-year)[a]	SAMA PDR (person-rem/reactor-year)[b]
Clinton 1	320	Not Available[c]
Fermi 2	520	4.91[d]
Grand Gulf 1	100	0.61[d]
Hope Creek	1,000	22.9[d]
Limerick 1, 2	1,360	28.2[e]
Nine Mile Point 2	300	50.9[f]
Perry 1	470	Not Available[c]
River Bend	700	1.21
Susquehanna 1, 2	360	1.9[d]
Columbia[g]	99	5.5
Mean value	577	19.4
Median value	415	5.21

LR GEIS = Generic Environmental Impact Statement for License Renewal of Nuclear Plants; PDR = population dose risk; SAMA = severe accident mitigation alternative.
(a) Data were obtained from NRC 1996.
(b) The SAMA PDR was obtained from the applicable plant-specific supplement to NUREG-1437, unless otherwise noted.
(c) A license renewal application and associated SAMA analysis has not been submitted for this plant.
(d) Includes the contribution from internal events and internal flooding events.
(e) Data are from the severe accident mitigation design alternative (SAMDA) analysis included in NUREG-0974, Supplement (NRC 1989b), which was then linearly scaled by the ratio of the CDF reported in NUREG-1437 Supplement 49 (NRC 2014b).
(f) Includes the contribution from internal events, internal flooding events, and external events.
(g) Referred to as WNP-2 (Washington Nuclear Project 2) in the 1996 LR GEIS.
Source: NRC 2022c, unless otherwise noted.

To summarize, based on only the contribution to plant risk from internally initiated events, the general contribution to decreased estimated dose risks are a factor of 4 to 6 lower due to the conservatism in the 1996 LR GEIS estimated CDF values in comparison to license renewal SAMA internal event CDF values. The total decrease in the plant site-specific calculated SAMA PDR values compared to the 1996 LR GEIS-predicted value PDR estimates includes additional conservatism that results in the calculated dose risks from the SAMA analyses being about a factor of about 30 less than those from the 1996 LR GEIS.

E.3.1.2 Other Pathway Impacts

Any change in the likelihood of accidents that release substantial amounts of radioactive material to the environment not only affects the airborne pathway but also the surface water and groundwater pathways, and the resulting economic impacts from any pathway. The information in Table E.3-2, Table E.3-3, Table E.3-4, and Table E.3-5 indicates that the likelihood and impacts of airborne pathway releases are smaller than those used in the 1996 LR GEIS. Because this pathway directly affects the surface water pathway, it is reasonable to conclude that the likelihood of the surface pathway impacts would also be smaller and would continue to be bounded by the airborne pathway. The decreased likelihood of any pathway impacts would indicate the reduced likelihood of any subsequent economic impacts. This assumption is consistent with the results of the 1996 LR GEIS.

Furthermore, some information is available regarding basemat melt-through sequences, which could affect the groundwater pathway:

- WASH-1400 (NRC 1975) used a frequency of 4×10^{-5}/yr for basemat melt-through sequences.
- NUREG-0773 (NRC 1982d) used a generic frequency of 3×10^{-5}/yr and a plant-specific frequency of 1.1×10^{-5}/yr for Indian Point Units 2 and 3.
- NUREG-1150 (NRC 1990) calculated the basemat melt-through frequencies for the Surry and Sequoyah plants to be 2.4×10^{-6}/yr and 1×10^{-5}/yr, respectively.
- A sample of IPE results showed basemat melt-through frequencies ranging from 1×10^{-6}/yr to 4×10^{-6}/yr.
- A sample of license renewal application results showed basemat melt-through frequencies ranging from 2×10^{-7}/yr to 6×10^{-6}/yr.

For the 1996 LR GEIS, a conservative value of 1×10^{-4}/yr was used (see Section 5.3.3.4 of the 1996 LR GEIS), which is higher than any of the values cited above. As such, it is concluded that the basemat melt-through frequencies used in the 1996 LR GEIS to assess the groundwater pathway are bounding.

Basemat melt-through sequences are low contributors to estimates of severe accident risk due to their long-developing nature. In other words, they occur late in accident sequences due to the time required for the melted core to penetrate the basemat, which is several feet thick. By the time a melted core penetrates the basemat, it is anticipated that actions such as providing an alternative water source in accordance with emergency procedures, along with accident mitigation strategies, would mitigate the basemat melt-through sequences and result in a stable configuration within the intact containment.

E.3.1.3 Conclusion

The PWR and BWR internal event accident frequencies that form the basis for the environmental impacts shown in the 1996 LR GEIS are, on average, a factor of 4 for PWRs higher and a factor of 6 for BWRs higher than the updated accident frequencies from the license renewal SAMA analyses (i.e., plant-specific SEISs to NUREG-1437) shown in Table E.3-2 and Table E.3-3. Furthermore, the internal event accident frequencies for these same plants have further decreased as reported in recent risk-informed LARs to the NRC. In addition, the 1996 LR GEIS-predicted or expected PDR estimates presented in Table E.3-4 and Table E.3-5 are, in all cases, higher than the updated PDRs from the license renewal SAMA analyses. On average, the expected PDR estimates in the 1996 LR GEIS are about a factor of 30 higher for both PWRs and BWRs relative to the estimates from the license renewal SAMA analyses. These results demonstrate the conservatism in the 1996 LR GEIS values, both from the standpoint of reduced PDR from more recent estimates and the conservatism built into the 1996 LR GEIS methodology.

E.3.2 Impact of Accidents Initiated by External Events

The 1996 LR GEIS included a qualitative assessment of the environmental impacts of accidents initiated by external events (see Section 5.3.3.1 of the 1996 LR GEIS). The purpose of this section is to consider updated information regarding the contribution to CDF from accidents initiated by external events and potential external event impacts. The sources of information used in this assessment are the SAMA analyses provided by nuclear plant licensees in the environmental reports provided with plant-specific license renewal applications and in the plant-specific SEISs to NUREG-1437. Most of the license renewal SAMA analyses submitted and reviewed by the NRC staff explicitly considered the impact of external events in the assessment of SAMAs.

Typically, the external events that contribute the most to plant risk are seismic and fire events. In some cases, high winds, floods, tornadoes, and other external hazards may also contribute to plant risk; however, these contributions are generally, but not always, much lower than those from seismic and fire events. Therefore, the assessment of the environmental impact from external events provided here explicitly considers seismic and fire events, but also considers the impact of other external events as applicable. This is consistent with the results obtained from the license renewal SAMA analyses.

E.3.2.1 Airborne Pathway Impacts

The assessment in this section is based on the cumulative assessment of the risks and environmental impacts of severe accidents initiated by external events and those initiated by internal events, based on the aforementioned information sources. As with the previous section that addressed updated information with regard to internal events risk, the evaluation contained in this section compares the CDFs that formed the basis for the 1996 LR GEIS, and offsite doses directly from the 1996 LR GEIS, to the newer license renewal SAMA information. The comparison is done for PWRs and BWRs and covers each of the plants listed in Table 5.1 of the 1996 LR GEIS, and in Table E.3-2, Table E.3-3, Table E.3-4, and Table E.3-5.

Level 1 Comparison (CDF)

As was done in Section E.3.1 for internally initiated events, the first step in the evaluation is to compare the internal events initiated CDFs considered in the 1996 LR GEIS for the 28 nuclear power plant sites that included analyses in their original (plant-specific) EISs to the CDFs reported in the license renewal SAMA analyses for the same PWRs and BWRs. For the comparison in this section, the total plant CDF (referred to as the All Hazards CDF) is used from the SAMA analyses, which is the summation of the CDFs for internally initiated events, including internal flood events, and external events. For a small number of early SAMA analyses, the contribution to CDF from external events was not explicitly provided for each hazard type but rather was reported as being approximately the same as the CDF contribution from internal events. In these cases, the internal events CDF was multiplied by 2 to obtain the All Hazards CDF.[16] As noted in Section E.3.1, the CDFs from the original plant EISs are for severe accidents initiated by internal events. However, it was the NRC staff's judgment in these original EISs that the additional risk of severe accidents initiated by natural events is within the uncertainty of risks presented for the sequences considered.[17] It is therefore appropriate to compare the All Hazards CDF from the SAMA analyses with the CDFs from the original EISs. Table E.3-6 and Table E.3-7 show these comparisons for the PWRs and BWRs, respectively.

[16] This was the case for St. Lucie Unit 2 and Summer Unit 1 in Table E.3-6 and Limerick Units 1 and 2 and Susquehanna Units 1 and 2 in Table E.3-7.
[17] See, for example, Section 5.9.4.5 of NUREG-0895, the FES related to the operation of Seabrook Station Units 1 and 2 (NRC 1982a), and Section 5.9.4.1.4.2 of NUREG-0854, the FES related to the operation of Clinton Power Station Unit 1 (NRC 1982c).

The data in these tables show that after accounting for the CDF contribution from all hazards, the total plant CDFs are generally lower than the original estimates in the EISs, which only considered internal events. Specifically, as can be seen in Table E.3-6 and Table E.3-7, the All Hazards CDFs are smaller than those from the original EISs for over 50 percent of the PWR units and all but one BWR unit. In the most sensitive case (Summer Unit 1), the All Hazards CDF exceeds the original estimate in the EIS by a factor of about 2.2. In the positive direction, the largest reduction in All Hazards CDF compared to the original estimate in the EIS for PWRs occurred at Indian Point Units 2 and 3, where the reduction was over a factor of 4, and for BWRs occurred at Limerick Units 1 and 2, where the reduction was over a factor of 10. The mean of the All Hazards CDFs listed in Table E.3-6 and Table E.3-7 is lower than the corresponding mean of the CDFs used in the 1996 LR GEIS, by 40 percent for PWRs and by more than 60 percent for BWRs. Accordingly, the likelihood of an accident that leads to core damage, including accounting for the contribution from external events, is generally less for both PWRs and BWRs than the likelihood used as the basis for the 1996 LR GEIS, and all are appreciably less than the highest estimated CDF used in the 1996 LR GEIS.

Table E.3-6 Pressurized Water Reactor All Hazards (Full Power) Core Damage Frequency Comparison

Nuclear Power Plant	1996 LR GEIS Estimated CDF[(a)]	SAMA All Hazards CDF[(b)]
Beaver Valley 2	1.0×10^{-4}/yr	2.4×10^{-5}/yr
Braidwood 1, 2	1.0×10^{-4}/yr	1.05×10^{-4}/yr
Byron 1, 2	4.8×10^{-5}/yr	1.0×10^{-4}/yr
Callaway 1	4.8×10^{-5}/yr	7.6×10^{-5}/yr
Catawba 1, 2	4.8×10^{-5}/yr	5.9×10^{-5}/yr
Comanche Peak 1, 2	4.8×10^{-5}/yr	Not Available[(c)]
Harris 1	4.8×10^{-5}/yr	2.2×10^{-5}/yr
Indian Point 2	3.5×10^{-4}/yr	6.7×10^{-5}/yr
Indian Point 3	3.4×10^{-4}/yr	6.4×10^{-5}/yr
Millstone 3	2.0×10^{-4}/yr	4.1×10^{-5}/yr
Palo Verde 1, 2, 3	4.8×10^{-5}/yr	1.3×10^{-5}/yr
San Onofre 2, 3	4.8×10^{-5}/yr	Not Available[(d)]
Seabrook 1	4.8×10^{-5}/yr	2.5×10^{-5}/yr
South Texas 1, 2	4.4×10^{-5}/yr	1.0×10^{-5}/yr
St. Lucie 2	4.8×10^{-5}/yr	4.9×10^{-5}/yr
Summer 1	4.9×10^{-5}/yr	1.1×10^{-4}/yr
Vogtle 1, 2	1.0×10^{-4}/yr	2.6×10^{-5}/yr
Waterford 3	4.8×10^{-5}/yr	3.7×10^{-5}/yr
Wolf Creek 1	4.8×10^{-5}/yr	5.8×10^{-5}/yr
Mean value	8.4×10^{-5}/yr	5.1×10^{-5}/yr
Median value	4.8×10^{-5}/yr	4.5×10^{-5}/yr

CDF = core damage frequency; LR GEIS = Generic Environmental Impact Statement for License Renewal of Nuclear Plants; PDR = population dose risk; SAMA = severe accident mitigation alternative.

(a) Data were obtained by summing individual atmospheric release sequences, including intact containment sequences.

(b) Data were obtained from the applicable plant-specific supplement to NUREG-1437. Where applicable, the SAMA PDR was adjusted using the external events multiplier.

(c) The severe accident mitigation design alternative (SAMDA) analysis included in NUREG-0775, Supplement (NRC 1989a) did not account for external events.

(d) The San Onofre plant was permanently shut down in 2012.

Source: NRC 2022c, unless otherwise noted.

Table E.3-7 Boiling Water Reactor All Hazards (Full Power) Core Damage Frequency Comparison

Nuclear Power Plant	1996 LR GEIS Estimated CDF[(a)]	SAMA All Hazards CDF[(b)]
Clinton 1	2.4×10^{-5}/yr	Not Available[(c)]
Fermi 2	2.4×10^{-5}/yr	1.65×10^{-5}/yr
Grand Gulf 1	2.4×10^{-5}/yr	2.2×10^{-5}/yr
Hope Creek	1.0×10^{-4}/yr	3.0×10^{-5}/yr
Limerick 1, 2	8.9×10^{-5}/yr	6.4×10^{-6}/yr
Nine Mile Point 2	1.1×10^{-4}/yr	6.2×10^{-5}/yr
Perry 1	2.4×10^{-5}/yr	Not Available[(c)]
River Bend	9.5×10^{-5}/yr	1.9×10^{-5}/yr
Susquehanna 1, 2	2.4×10^{-5}/yr	3.9×10^{-6}/yr
Columbia[(d)]	2.4×10^{-5}/yr	3.4×10^{-5}/yr
Mean value	5.4×10^{-5}/yr	2.0×10^{-5}/yr
Median value	2.4×10^{-5}/yr	1.8×10^{-5}/yr

CDF = core damage frequency; LR GEIS = Generic Environmental Impact Statement for License Renewal of Nuclear Plants; SAMA = severe accident mitigation alternative.
(a) Data were obtained by summing individual atmospheric release sequences, including intact containment sequences.
(b) Data were obtained from the applicable plant-specific supplement to NUREG-1437, which was then adjusted, if applicable, using the external events multiplier.
(c) A license renewal application and associated SAMA analysis has not been submitted for this plant.
(d) Referred to as WNP-2 (Washington Nuclear Project 2) in the 1996 LR GEIS.
Source: NRC 2022c, unless otherwise noted.

The above comparison of CDF estimates is between those used in the 1996 LR GEIS and those provided in license renewal SAMA analyses. To further show the reduction in CDF estimates over the last 20 to 30 years, Figure E.3-1 provides a comparison of CDF estimates provided in SAMA analyses and risk-informed LAR submittals to CDF estimates provided in the IPE and IPEEE submittals (NRC 2016a). This figure shows more than a factor of 2.5 reduction in the mean of the total CDF estimates between the more recent estimates and the estimates developed for the IPE and IPEEE submittals (the estimates include the contribution from internally initiated events and external events).

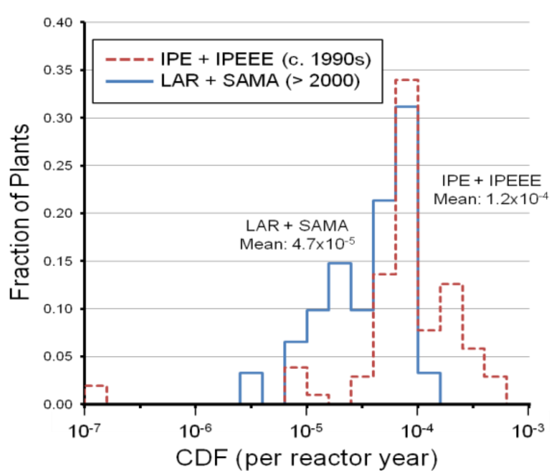


Figure E.3-1 Comparison of Recent and Past Estimates for Total Core Damage Frequency. Source: NRC 2016a.

Level 3 Comparison (Offsite Consequences)

Additional comparisons can be made for the estimated total PDR from severe accidents initiated by internal events and external events, as estimated in the license renewal SAMA analyses, with the estimated total PDR from severe accidents initiated by only internal events, as estimated in the 1996 LR GEIS. For this comparison, the 95 percent UCB PDR estimates from the 1996 LR GEIS are used. The estimated total PDR from the SAMA analyses, in some cases, included the contribution from both internal events and external events directly. For most of the SAMA analyses, however, the PDR estimates reported in the plant-specific SEISs to the LR GEIS were estimated based on the contribution from internal events and internal flooding events only. In these cases, the impact of external events was addressed in the license renewal SAMA analyses by multiplying the plant-specific environmental impacts, which include the estimated PDR in addition to other impacts, by an external events multiplier. The external events multiplier is the ratio of the All Hazards CDF to the internal events CDF, including internal flooding CDF.[18] This approach to addressing external events in the license renewal SAMA analyses is in accordance with the guidance contained in NEI 05-01, Revision A (NEI 2005), which is endorsed by the NRC in Regulatory Guide 4.2, Supplement 1, Revision 1 (NRC 2013d). Given the existing information about the contribution to risk from external events, the approach described in NEI 05-01 continues to be a reasonable approach to addressing the external event risk contribution.

The comparisons are shown in Table E.3-8 and Table E.3-9 for the same PWR and BWR plants included in Table E.3-6 and Table E.3-7, respectively, and assessed in the 1996 LR GEIS. The data in these tables show that the estimated PDR in the SAMA analyses, accounting for the risk from all hazards, is significantly less than the 95 percent UCB estimates in the 1996 LR GEIS. Specifically, as shown in Table E.3-8 and Table E.3-9, the SAMA analyses are more than a factor of 10 less than the corresponding 95 percent UCB estimates for all but one PWR plant (Waterford 3, which is almost a factor of 8 less) and for all but one BWR plant (Limerick, which is a factor of 7 less). For BWRs, excluding the Limerick plant, the All Hazards PDR from the SAMA analyses is more than a factor of 20 less than the corresponding 95 percent UCB estimates for all but one plant (Nine Mile Point 2, which is just under a factor of 20 less). As discussed previously, the PDR estimate for the Limerick plant is from the 1989 SAMDA analysis performed for the original EIS, so it does not reflect updated risk information considered in the license renewal SAMA analyses. Furthermore, the mean All Hazards PDR from the SAMA analyses is substantially less than the 95 percent UCB PDR reported in the original GEIS for all of the plants (both PWRs and BWRs). The means of the All Hazards PDR estimates listed in Table E.3-8 and Table E.3-9 are lower than the corresponding 95 percent UCB 1996 LR GEIS PDR by more than a factor of 20 for PWRs and more than a factor of 17 for BWRs. For BWRs, the reduction factor is over 70 if the PDR estimate for the Limerick plant is not included.

[18] For some SAMA analyses, the internal events CDF did not include the contribution from internal flooding events. In these cases, the contribution to CDF from internal flooding events was included in the determination of the external events multiplier.

Table E.3-8 Pressurized Water Reactor All Hazards (Full Power) Population Dose Risk Comparison

Nuclear Power Plant	1996 LR GEIS Estimated Predicted Total Population Dose – Non-normalized 95% UCB (person-rem/reactor-year)[(a)]	SAMA All Hazards PDR (person-rem/reactor-year)[(b)]
Beaver Valley 2	1,720	55.8
Braidwood 1, 2	4,418	342
Byron 1, 2	2,867	92.3
Callaway 1	509	21.0
Catawba 1, 2	1,880	31.4
Comanche Peak 1, 2	466	16.0[(c)]
Harris 1	1,001	58.0
Indian Point 2	9,727	332
Indian Point 3	9,727	521
Millstone 3	3,988	20.5
Palo Verde 1, 2, 3	369	34.0
San Onofre 2, 3	3,099	Not Available[(d)]
Seabrook 1	819	79.4
South Texas 1, 2	1,063	1.74
St. Lucie 2	2,724	28.0
Summer 1	1,381	2.0
Vogtle 1, 2	983	3.1
Waterford 3	477	61.0
Wolf Creek 1	466	6.5
Mean value	2,294	89.8
Median value	1,222	34.0

LR GEIS = Generic Environmental Impact Statement for License Renewal of Nuclear Plants; PDR = population dose risk; SAMA = severe accident mitigation alternative; UCB = upper confidence bound.

(a) Data were obtained from NRC 1996.

(b) Data were obtained from the applicable plant-specific supplement to NUREG-1437 and multiplied by the external events multiplier from the same plant-specific SEIS to NUREG-1437, if applicable.

(c) The severe accident mitigation design alternative (SAMDA) analysis included in NUREG-0775, Supplement (NRC 1989a) did not account for external events.

(d) The San Onofre plant was permanently shut down in 2012.

Source: NRC 2022c, unless otherwise noted.

Table E.3-9 Boiling Water Reactors All Hazards (Full Power) Population Dose Risk Comparison

Nuclear Power Plant	1996 LR GEIS Estimated Predicted Total Population Dose – Non-normalized 95% UCB (person-rem/reactor-year)[(a)]	SAMA All Hazards PDR (person-rem/reactor-year)[(b)]
Clinton 1	2,549	Not Available[(c)]
Fermi 2	2,722	54.0
Grand Gulf 1	1,441	6.7
Hope Creek	3,604	156
Limerick 1, 2	4,461	48.6[(d)]
Nine Mile Point 2	996	50.9
Perry 1	2,544	Not Available[(c)]
River Bend	1,168	8.5
Susquehanna 1, 2	4,010	3.8
Columbia[(e)]	649	25.9
Mean value	2,718	41.0
Median value	2,636	37.3

LR GEIS = Generic Environmental Impact Statement for License Renewal of Nuclear Plants; PDR = population dose risk; SAMA = severe accident mitigation alternative; UCB = upper confidence bound.
(a) Data were obtained from NRC 1996.
(b) Data were obtained from the SAMA PDR reported in Section E.3.1 and multiplied by the external events multiplier from the applicable plant-specific supplement to NUREG-1437.
(c) A license renewal application and associated SAMA analysis has not been submitted for this plant.
(d) Data were obtained from the severe accident mitigation design alternative (SAMDA) analysis included in NUREG-0974 Supplement (NRC 1989b), which was then linearly scaled by the ratio of the CDF reported in NUREG-1437 Supplement 49 (NRC 2014b).
(e) Referred to as WNP-2 (Washington Nuclear Project 2) in the 1996 LR GEIS.
Source: NRC 2022c, unless otherwise noted.

Accordingly, based on the license renewal SAMA analyses, the risk of severe accidents that result in core damage and a subsequent offsite release of radioactive materials, considering accidents initiated by all hazards, is significantly less for both PWRs and BWRs than that used as the basis for the 1996 LR GEIS.

Fire Events

Since publication of the 1996 LR GEIS, the NRC and nuclear industry collaborated to develop updated PRA standards and guidance (methods, tools, and data) for the development of quality fire probabilistic risk assessment (FPRA) models. The updated guidance was published as NUREG/CR-6850 and Electric Power Research Institute (EPRI) Report 1011989, *EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities* (EPRI/NRC 2005a, EPRI/NRC 2005b), and has subsequently been enhanced by numerous additional reports about specific FPRA and fire modeling topics. The documented methods are intended to support applications of FPRA in risk-informed regulatory applications. Subsequently, FPRAs have been developed for most nuclear power plants using these updated guidance documents. Furthermore, to be used in risk-informed regulatory activities, these FPRAs must be shown to be acceptable to the NRC. Regulatory Guide 1.200, Rev. 3 (NRC 2020a), describes one approach acceptable to the NRC staff for demonstrating the acceptability of PRA models for risk-informed activities.

In recent years, many nuclear plant licensees have submitted to the NRC risk-informed LARs for their plants, in which risk results and risk insights from FPRAs have been included. In addition, since about 2010, many of the SAMA analyses for license renewal applications have included risk results and insights from their newly developed FPRAs. Table E.3-10 provides the plant-specific fire core damage frequencies (FCDFs) obtained from FPRAs summarized in various risk-informed LARs. Results are provided for about three-fourths of the current nuclear reactor operating fleet. Each of the FPRAs for which FCDFs are reported in this table were determined to be technically acceptable by the NRC for specific risk-informed LARs in accordance with Regulatory Guide 1.200 (NRC 2020a). Probabilistic health consequences, such as PDR, are not available because this information is not used in the NRC staff assessment of risk-informed LARs. Table E.3-10 also compares these FCDFs to those used in the license renewal SAMA analyses, where available. The results in Table E.3-10 show that the FCDF values are higher for the FPRAs than in the corresponding license renewal SAMA analyses for about 80 percent of the plants for which both values are available. The results also show that, on average, the FCDF values from the plant-specific FPRAs are about a factor of 2.5 higher than the FCDF values used in the license renewal SAMA analyses. However, given the significant margin between the cumulative PDR results from the license renewal SAMA analyses and the cumulative 95th percentile UCB PDR results from the 1996 LR GEIS, as reported in Table E.3-1, the updated FCDFs do not challenge the 95th percentile estimates used in the 1996 LR GEIS (even if a factor of 2.5 increase in FCDF were uniformly applied to all of the nuclear power units).

Table E.3-10 Fire (Full Power) Core Damage Frequency Comparison

Nuclear Power Plant	SAMA FCDF[a]	FPRA FCDF[b]
Arkansas 1	Not Estimated[c]	3.7×10^{-5}/yr
Arkansas 2	2.8×10^{-5}/yr	4.4×10^{-5}/yr
Beaver Valley 1	4.0×10^{-6}/yr	4.6×10^{-5}/yr
Beaver Valley 2	4.8×10^{-6}/yr	5.9×10^{-5}/yr
Braidwood 1	5.9×10^{-5}/yr	5.5×10^{-5}/yr
Braidwood 2	5.9×10^{-5}/yr	6.6×10^{-5}/yr
Browns Ferry 1	Not Estimated[c]	2.8×10^{-5}/yr
Browns Ferry 2	Not Estimated[c]	3.2×10^{-5}/yr
Browns Ferry 3	Not Estimated[c]	2.7×10^{-5}/yr
Brunswick 1	3.6×10^{-5}/yr	3.2×10^{-5}/yr
Brunswick 2	3.6×10^{-5}/yr	4.0×10^{-5}/yr
Byron 1	5.4×10^{-5}/yr	5.6×10^{-5}/yr
Byron 2	5.4×10^{-5}/yr	6.1×10^{-5}/yr
Callaway 1	2.0×10^{-5}/yr	1.2×10^{-5}/yr
Calvert Cliffs 1	7.3×10^{-5}/yr	4.2×10^{-5}/yr
Calvert Cliffs 2	7.3×10^{-5}/yr	4.0×10^{-5}/yr
Catawba 1	1.2×10^{-6}/yr	2.4×10^{-5}/yr
Catawba 2	1.2×10^{-6}/yr	2.5×10^{-5}/yr
Clinton 1	No SAMA Available	7.8×10^{-5}/yr
Columbia[d]	1.4×10^{-5}/yr	4.1×10^{-5}/yr
Comanche Peak 1	Not Estimated[e]	5.6×10^{-5}/yr
Comanche Peak 2	Not Estimated[e]	4.3×10^{-5}/yr
D.C. Cook 1	3.8×10^{-6}/yr	3.1×10^{-5}/yr

Nuclear Power Plant	SAMA FCDF[(a)]	FPRA FCDF[(b)]
D.C. Cook 2	3.8×10^{-6}/yr	2.6×10^{-5}/yr
Diablo Canyon 1	5.4×10^{-5}/yr[(f)]	4.8×10^{-5}/yr
Diablo Canyon 2	5.4×10^{-5}/yr[(f)]	5.2×10^{-5}/yr
Davis-Besse	2.9×10^{-5}/yr	4.8×10^{-5}/yr
Farley 1, 2	5.0×10^{-5}/yr	7.7×10^{-5}/yr
FitzPatrick	8.5×10^{-6}/yr	1.9×10^{-5}/yr
Ginna	1.1×10^{-5}/yr	3.8×10^{-5}/yr
Harris 1	1.1×10^{-5}/yr	3.2×10^{-5}/yr
Hatch 1	Not Estimated[(c)]	5.7×10^{-5}/yr
Hatch 2	Not Estimated[(c)]	5.0×10^{-5}/yr
Hope Creek	1.7×10^{-5}/yr	3.7×10^{-5}/yr
LaSalle 1	8.9×10^{-6}/yr	1.0×10^{-5}/yr
LaSalle 2	9.4×10^{-6}/yr	7.8×10^{-6}/yr
Limerick 1, 2	Not Reported[(g)]	5.2×10^{-6}/yr
McGuire 1	2.9×10^{-6}/yr	2.8×10^{-5}/yr
McGuire 2	2.9×10^{-6}/yr	3.3×10^{-5}/yr
Monticello	7.8×10^{-6}/yr	5.8×10^{-5}/yr
Nine Mile Point 1	1.3×10^{-5}/yr	3.4×10^{-5}/yr
Nine Mile Point 2	3.7×10^{-6}/yr	3.1×10^{-5}/yr
Oconee 1, 2	4.5×10^{-6}/yr	6.0×10^{-5}/yr
Oconee 3	4.5×10^{-6}/yr	6.1×10^{-5}/yr
Palo Verde 1, 2, 3	2.7×10^{-6}/yr	4.9×10^{-5}/yr
Peach Bottom 2	Not Estimated[(c)]	2.8×10^{-5}/yr
Peach Bottom 3	Not Estimated[(c)]	4.0×10^{-5}/yr
Point Beach 1	1.2×10^{-5}/yr	5.9×10^{-5}/yr
Point Beach 2	1.2×10^{-5}/yr	6.9×10^{-5}/yr
Prairie Island 1, 2	1.0×10^{-5}/yr	6.6×10^{-5}/yr
Robinson 2	Not Estimated[(c)]	4.6×10^{-5}/yr
Sequoyah 1	5.8×10^{-6}/yr	6.2×10^{-5}/yr
Sequoyah 2	5.8×10^{-6}/yr	6.6×10^{-5}/yr
St. Lucie 1	Not Estimated[(c)]	4.2×10^{-5}/yr
St. Lucie 2	Not Estimated[(c)]	3.6×10^{-5}/yr
Summer 1	Not Estimated[(c)]	5.1×10^{-5}/yr
Susquehanna 1	2.0×10^{-6}/yr	5.0×10^{-5}/yr
Susquehanna 2	2.0×10^{-6}/yr	6.3×10^{-5}/yr
Turkey Point 3	Not Estimated[(c)]	8.7×10^{-5}/yr
Turkey Point 4	Not Estimated[(c)]	7.7×10^{-5}/yr
Vogtle 1, 2	1.0×10^{-5}/yr	5.2×10^{-5}/yr
Waterford 3	1.8×10^{-5}/yr	2.0×10^{-5}/yr
Mean value	1.8×10^{-5}/yr	4.5×10^{-5}/yr
Median value	9.4×10^{-5}/yr	4.6×10^{-5}/yr

FCDF = fire core damage frequency; FPRA = fire probabilistic risk assessment; SAMA = severe accident mitigation alternative.

(a) Data were obtained from the applicable plant-specific supplement to NUREG-1437, unless otherwise noted.

(b) Data were obtained from risk-informed license amendment requests.

(c) The FCDF was not provided but was considered to be included within the scope of the external events multiplier (if applicable).
(d) Referred to as WNP-2 (Washington Nuclear Project 2) in the 1996 LR GEIS.
(e) The FCDF was not provided in the severe accident mitigation design alternative (SAMDA) analysis in NUREG-0775, Supplement (NRC 1989a).
(f) Data were from a license renewal application that was later withdrawn.
(g) The FCDF was not separately reported in the NUREG-0974, Supplement (NRC 1989b), but was included in the total CDF of 4.2×10^{-5}/yr that included internal events, internal flooding, and fire.
Source: NRC 2022c, unless otherwise noted.

In February 2002, after the September 11, 2001, terrorist attacks, the NRC issued Order EA-02-026, "Order for Interim Safeguards and Security Compensatory Measures" (NRC 2002b), which modified current operating licenses for commercial power reactor facilities to require compliance with specified interim safeguards and security compensatory measures. The Order required licensees to adopt mitigation strategies using readily available resources to maintain or restore core cooling, containment, and SFP cooling capabilities to cope with the loss of large areas of the facility due to large fires and explosions from any cause, including from both design-basis and beyond-design-basis events. By August 2007, all operating power reactor licensees had implemented the guidance via commitments and in new conditions of their operating licenses. By December 2008, the NRC staff had completed licensing reviews and onsite inspections to verify implementation of the licensee actions as documented by NRC staff in "The Evolution of Mitigating Measures For Large Fire and Explosions" (NRC 2010c).[19]

Additionally, licensees for more than 40 percent of currently operating nuclear power plants submitted LARs to transition the plant-specific fire protection programs from 10 CFR Sections 50.48(a) and (b) to 10 CFR 50.48(c), National Fire Protection Association (NFPA) 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants*, 2001 Edition. In addition to developing FPRAs that were necessary to support this transition, which are all represented in Table E.3-10, many of these licensees committed to making plant modifications to reduce the risk of fires. Based on statements made in subsequent risk-informed LARs, most of these committed plant modifications have been implemented.

When considered in isolation, based on the large margin between the PDR estimates from the SAMA analyses compared to the estimates in the 1996 LR GEIS reported in Table E.3-1, the updated FCDFs reported in Table E.3-10 do not challenge the 95th percentile UCB for population dose estimates used in the 1996 LR GEIS. For this reason, and because of the fire mitigation and plant modifications that have been made to reduce fire risk and to cope with the loss of large areas of the plant due to large fires and explosions that may not be modeled in PRAs, the NRC staff concludes that the new information from the FPRAs is not significant for the purposes of the LR GEIS.

[19] Portions of NRC Order EA-02-026 have been rescinded because those requirements were subsequently incorporated into NRC regulations by the 2009 Final Rule on Power Reactor Security Requirements (79 FR 13926).

Seismic Events

As previously discussed in Section E.2.1, in response to the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami that initiated severe reactor accidents at three units of the Fukushima Dai-ichi nuclear power plant that resulted in major fuel melting, the NRC issued information requests under 10 CFR 50.54(f) (NRC 2012d). With respect to seismic design, licensees were requested to reevaluate the seismic hazards at their sites relative to present-day NRC requirements and guidance (NRC 2012d).

As further background, prior to the Fukushima Dai-ichi accident, the results of NRC staff analyses had determined that the probability of exceeding the safe shutdown earthquake at some currently operating sites in the Central and Eastern United States is higher than previously understood and that, therefore, further study was warranted. As a result, it was concluded that the issue of increased seismic hazard estimates in the Central and Eastern United States should be examined under the NRC's Generic Issues Program (GIP).

GI-199 was established on June 9, 2005 (NRC 2005a). The initial screening analysis for GI-199 suggested that estimates of the seismic hazard for some currently operating plants in the Central and Eastern United States have increased. The NRC staff completed the initial screening analysis of GI-199 and concluded that GI-199 should proceed to the safety/risk assessment stage of the GIP. For the GI-199 safety/risk assessment, the NRC staff evaluated the potential risk significance of the updated seismic hazards on seismic core damage frequency (SCDF) estimates. The changes in the SCDF estimate in the safety/risk assessment for some plants lie in the range of 10^{-4} per year to 10^{-5} per year, which met the numerical risk criterion for an issue to continue to the regulatory assessment stage of the GIP. After the Fukushima Dai-ichi accident, resolution of GI-199 was subsumed into NTTF Recommendation 2.1, which pertained to reassessing seismic hazard.

To implement NTTF Recommendation 2.1, the NRC staff used the general process developed for GI-199. This process asked each licensee to provide information about the current hazard and potential risk posed by seismic events using a progressive screening approach. This screening approach is defined in EPRI Report 1025287 (EPRI 2012), which is endorsed by the NRC (2013c). In the first phase of this screening approach, a seismic hazard reevaluation was performed for each nuclear power plant site, which included development of new plant-specific seismic hazard curves using up-to-date models representing seismic sources, ground motion equations, and site amplification. For screening purposes, a Ground Motion Response Spectrum (GMRS) was developed, which provides an estimate of the structural response of the plant structures (the magnitude of building shaking or movement) to ground motion caused by plant-specific postulated earthquakes. The GMRS estimate was then compared to the plant design-basis safe shutdown earthquake. If the amount by which the GMRS exceeds the safe shutdown earthquake in the 1 to 10 hertz[20] frequency range of the response spectrum and/or peak spectral acceleration was considered significant by the NRC staff, then performance of a detailed seismic risk evaluation was necessary. Furthermore, if these considerations were determined to not be significant, additional consideration was given to a general estimate of the plant's SCDF and on insights related to the conditional containment failure probability for the plant's specific type of containment. If either of these considerations was considered significant by the NRC staff, then performance of a detailed seismic risk evaluation was necessary. Based on the licensee seismic hazard reevaluation submittals provided in response to NTTF

[20] This response spectrum frequency range has the greatest potential effect on the performance of equipment and structures important to safety.

Recommendation 2.1 that addressed each of these considerations, the NRC issued a final determination of which nuclear power plants were required to perform a full power seismic PRA (NRC 2015b).[21]

Table E.3-11 provides the updated plant-specific SCDFs obtained predominantly from these Seismic Probabilistic Risk Assessments (SPRAs). Each of the SPRAs reported in this table have been independently peer reviewed in accordance with NRC guidance (see, for example, NRC 2020a). Probabilistic health consequences, such as PDR, are not available because this information was not requested in the response to NTTF Recommendation 2.1. Table E.3-11 also compares these updated SCDFs to those used in the license renewal SAMA analyses where available. The results in Table E.3-11 show that the SCDF values are higher for the SPRAs than in the corresponding license renewal SAMA analyses for about two-thirds of the plants for which both values are available. The results also show that, on average, the SCDF values from the plant-specific SPRAs are about 70 percent higher than the SCDF values used in the license renewal SAMA analyses. Because these SPRA results are representative of just one-third of the reactor fleet, and specifically those that were determined by the NRC staff to have reevaluated seismic hazards that are potentially risk-significant, these results are inconclusive for the remaining two-thirds of the current operating reactor fleet. Given the significant margin between the cumulative PDR results from the license renewal SAMA analyses and the cumulative 95th percentile UCB PDR results from the 1996 LR GEIS, as discussed in Section E.3, the reevaluated SCDFs do not challenge the 95th percentile estimates used in the 1996 LR GEIS (even if a 70 percent increase in SCDF were uniformly applied to all of the nuclear power units).

Table E.3-11 Seismic (Full Power) Core Damage Frequency Comparison

Nuclear Power Plant	SAMA SCDF[(a)]	SPRA Mean SCDF[(b)]
Beaver Valley 1	1.2×10^{-5}/yr	1.3×10^{-5}/yr
Beaver Valley 2	9.7×10^{-6}/yr	8.8×10^{-6}/yr
Browns Ferry 1	2.5×10^{-6}/yr	1.5×10^{-5}/yr
Browns Ferry 2	2.5×10^{-6}/yr	1.6×10^{-5}/yr
Browns Ferry 3	2.5×10^{-6}/yr	1.7×10^{-5}/yr
Callaway 1	5.0×10^{-6}/yr	7.3×10^{-5}/yr
Columbia[(c)]	4.9×10^{-6}/yr	4.8×10^{-5}/yr
D.C. Cook 1, 2	3.2×10^{-6}/yr	5.5×10^{-5}/yr
Diablo Canyon 1, 2	1.3×10^{-5}/yr	2.8×10^{-5}/yr
Dresden 2	Not Estimated[(d)]	8.8×10^{-6}/yr
Dresden 3	Not Estimated[(d)]	8.7×10^{-6}/yr
Hatch 1	Not Estimated[(d)]	6.8×10^{-7}/yr[(e)]
Hatch 2	Not Estimated[(d)]	5.6×10^{-7}/yr[(e)]
North Anna 1, 2	Not Estimated[(d)]	6.3×10^{-5}/yr
Oconee 1, 2, 3	3.9×10^{-5}/yr	5.7×10^{-5}/yr
Palo Verde 1, 2, 3	4.8×10^{-6}/yr	1.7×10^{-5}/yr[(f)]
Peach Bottom 2, 3	Not Estimated[(d)]	2.1×10^{-5}/yr

[21] Several plants (i.e., Catawba Units 1 and 2, Indian Point Units 2 and 3, McGuire Units 1 and 2, Palisades, and Pilgrim) were subsequently removed from the list requiring SPRAs, because either the plant has permanently ceased operation or the licensee provided additional information that resulted in a revised determination by the NRC staff that a detailed seismic risk assessment was not necessary.

Nuclear Power Plant	SAMA SCDF[(a)]	SPRA Mean SCDF[(b)]
Robinson 2	Not Estimated[(d)]	1.3×10^{-4}/yr
Sequoyah 1	5.1×10^{-5}/yr	1.3×10^{-5}/yr
Sequoyah 2	5.1×10^{-5}/yr	1.5×10^{-5}/yr
Summer 1	Not Estimated[(d)]	4.8×10^{-5}/yr
Vogtle 1, 2	Not Estimated[(d)]	3.6×10^{-6}/yr
Watts Bar 1	Not Estimated[(d)]	3.1×10^{-6}/yr
Watts Bar 2	1.8×10^{-5}/yr[(g)]	3.1×10^{-6}/yr
Mean value	1.7×10^{-5}/yr	3.0×10^{-5}/yr
Median value	7.35×10^{-5}/yr	1.7×10^{-5}/yr

SAMA = severe accident mitigation alternative; SCDF = seismic core damage frequency; SPRA = seismic probabilistic risk assessment.
(a) Data were obtained from the applicable plant-specific supplement to NUREG-1437, unless otherwise noted.
(b) Data were obtained from the applicable licensee-submitted seismic PRA report and NRC staff evaluation, unless otherwise noted.
(c) Referred to as WNP-2 (Washington Nuclear Project 2) in the 1996 LR GEIS.
(d) The seismic CDF was not provided but was considered to be included within the scope of the external events multiplier (if applicable).
(e) Data were obtained from the license amendment request (SN 2021).
(f) Data were obtained from the license amendment request (APS 2018).
(g) Data were obtained from the severe accident mitigation design alternative (SAMDA) analysis included in NUREG-0498, Supplement 2 (NRC 2013a).
Source: NRC 2022c, unless otherwise noted.

In March 2012, after the severe reactor accidents at three units of the Fukushima Dai-ichi nuclear power plant, the NRC issued Order EA-12-049, “Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design Basis External Events” (NRC 2012b). The Order was effective immediately and directed all nuclear power plants to provide diverse and flexible coping strategies (FLEX) to enhance their ability to mitigate conditions resulting from beyond-design-basis external events. The Final Integrated Plans for each nuclear power plant developed in response to the Order provide strategies for maintaining or restoring core cooling, containment cooling, and SFP cooling capabilities for a beyond-design-basis external event. The FLEX strategies and equipment, when coupled with plant procedures, can also provide a safety benefit, or additional mitigation capability, for certain design-basis events. The NRC completed the rulemaking, 10 CFR 50.155, “Mitigation of Beyond-Design-Basis Events,” that made generically applicable the requirements of Orders EA-12-049 and EA-12-051.

Based on its review of each of the SPRA reports submitted in response to NTTF Recommendation 2.1, the NRC staff determined in each case that no further response or regulatory actions, including the need for additional strategies to mitigate seismic events, were necessary with regard to seismic risk.

When considered in isolation, based on the large margin between the PDR estimates from the SAMA analyses compared to the estimates in the 1996 LR GEIS reported in Table E.3-1, the updated SCDFs do not challenge the 95th percentile UCB for population dose estimates used in the 1996 LR GEIS. For this reason, and because of the plant modifications that have been made to reduce seismic risk, the NRC staff concludes that the new information from the SPRAs is not significant for the purposes of the LR GEIS.

The recent SOARCA studies (published 2012–2022) add to the NRC staff's updated understanding of the consequences that may result from seismic initiators. SOARCA did no new work on quantifying CDFs. But SOARCA did analyze the conditional consequences; in other words, it modeled the consequences if a challenging seismic initiating event were to occur. SOARCA analyzed three plants, each representing one of the most common types of operating U.S. nuclear plants: Peach Bottom Atomic Power Station in Pennsylvania, Surry Power Station in Virginia, and Sequoyah Nuclear Power Plant in Tennessee. Peach Bottom is a General Electric-designed BWR with a Mark I containment, Surry is a Westinghouse-designed PWR with a large dry containment, and Sequoyah is a Westinghouse-designed PWR with an ice condenser containment. For Peach Bottom, Surry, and Sequoyah, the team modeled loss of all alternating current electrical power or "station blackout (SBO)" scenarios caused by earthquakes more severe than anticipated in the plant's design—in other words, beyond-design basis earthquakes. The SOARCA reports present results of an earthquake and SBO in terms of radiological releases, which are discussed further and summarized in Section E.3.3, and in terms of individual latent cancer fatality (LCF) risk and early (or prompt) fatality risk, as summarized in Section E.3.9.

Integrated Assessment of New Information on All Hazards

The new information about internal events and external events CDFs discussed above from the license renewal SAMA analyses, risk-informed LARs, and in responses to NTTF Recommendation 2.1 about seismic risk are integrated in this section to develop the current, best available information about total All Hazards CDFs for comparison to the 1996 LR GEIS internal events CDFs and the license renewal SAMA total All Hazards CDFs. This comparison is made for the PWRs and BWRs evaluated in the 1996 LR GEIS that have CDFs and also having updated CDF information for all hazards. For the plants for which a SPRA is not available, the risk-informed LARs report a bounding estimate of the SCDF that is based on the updated seismic hazard, or GMRS, and a plant-level seismic fragility that is generally obtained from the plant-specific IPEEE. Because risk-informed LARs and the responses to NTTF Recommendation 2.1 about seismic risk do not report PDR, the comparison in this section is limited to CDFs, which is an important parameter used in the development of PDR.

The total All Hazards CDF from the LARs is provided in Table E.3-12, as are the internal events CDF from the 1996 LR GEIS and the All Hazards CDF from the license renewal SAMA analyses. The mean of the SAMA All Hazards CDFs listed in Table E.3-12 is less than the corresponding mean of the EIS CDFs by about 30 percent, while the mean of the LAR All Hazards CDFs is essentially the same as the mean of the EIS CDFs. Furthermore, the mean of the LAR All Hazards CDFs is about 35 percent greater than the mean of the SAMA All Hazards CDFs. These are relatively small differences that do not affect the conclusions of the 1996 LR GEIS. Specifically, as discussed previously in Section E.3, on average, the SAMA All Hazards PDR is over a factor of 120 less than the mean of the 95th percentile UCB for population dose estimates reported in the 1996 LR GEIS. Further, in accordance with NEI 05-01 (NEI 2005), which is endorsed by the NRC (NRC 2013d), the impact of external events was addressed in the license renewal SAMA analyses either directly or by multiplying the plant-specific environmental impacts, which includes the estimated PDR in addition to other impacts, by an external events multiplier, which is the ratio of the All Hazards CDF to the internal events CDF. The approach described in NEI 05-01 continues to be a reasonable approach to addressing the external event risk contribution. Based on this, an average 35 percent increase in the All Hazards CDFs reported in the risk-informed LARs will not challenge the 95th percentile UCB for population dose estimates used in the 1996 LR GEIS. Furthermore, because of the plant modifications that have been made to reduce fire and seismic risk and to cope with the loss of large areas of the plant due to large fires and explosions, the NRC staff concludes that the new information from the FPRAs, SPRAs, and risk-informed LARs is not significant for the purposes of this LR GEIS.

Table E.3-12 Pressurized Water Reactor and Boiling Water Reactor All Hazards (Full Power) Core Damage Frequency Comparison

Nuclear Power Plant	1996 LR GEIS Estimated CDF[(a)]	SAMA All Hazards CDF[(b)]	LAR All Hazards CDF[(c)]
Beaver Valley 2	1.0×10^{-4}/yr	2.4×10^{-5}/yr	7.8×10^{-5}/yr
Braidwood 1	1.0×10^{-4}/yr	1.1×10^{-4}/yr	7.1×10^{-5}/yr
Braidwood 2	Same as Unit 1	1.1×10^{-4}/yr	8.2×10^{-5}/yr
Byron 1	4.8×10^{-5}/yr	1.0×10^{-4}/yr	7.5×10^{-5}/yr
Byron 2	Same as Unit 1	1.0×10^{-4}/yr	8.0×10^{-5}/yr
Callaway 1	4.8×10^{-5}/yr	7.6×10^{-5}/yr	8.3×10^{-5}/yr
Catawba 1	4.8×10^{-5}/yr	5.9×10^{-5}/yr	6.3×10^{-5}/yr
Catawba 2	Same as Unit 1	5.9×10^{-5}/yr	5.9×10^{-5}/yr
Clinton	2.4×10^{-5}/yr	Not Available[(e)]	8.8×10^{-5}/yr
Columbia[(d)]	2.4×10^{-5}/yr	9.6×10^{-6}/yr	6.0×10^{-5}/yr
Comanche Peak 1	4.8×10^{-5}/yr	Not Available[(f)]	6.3×10^{-5}/yr
Comanche Peak 2	Same as Unit 1	Not Available[(f)]	5.0×10^{-5}/yr
Harris 1	4.8×10^{-5}/yr	2.2×10^{-5}/yr	3.9×10^{-5}/yr
Hope Creek	1.0×10^{-4}/yr	3.0×10^{-5}/yr	4.3×10^{-5}/yr
Limerick 1, 2	8.9×10^{-5}/yr	6.4×10^{-6}/yr	1.2×10^{-5}/yr
Nine Mile Point 2	1.1×10^{-4}/yr	6.2×10^{-5}/yr	3.3×10^{-5}/yr
Palo Verde 1, 2, 3	4.8×10^{-5}/yr	1.3×10^{-5}/yr	7.2×10^{-5}/yr
St. Lucie 2	4.8×10^{-5}/yr	4.9×10^{-5}/yr	4.1×10^{-5}/yr
Summer 1	4.9×10^{-5}/yr	1.1×10^{-4}/yr	8.9×10^{-5}/yr
Susquehanna 1	2.4×10^{-5}/yr	3.9×10^{-6}/yr	5.4×10^{-5}/yr
Susquehanna 2	Same as Unit 1	3.9×10^{-6}/yr	6.6×10^{-5}/yr
Vogtle 1, 2	1.0×10^{-4}/yr	2.6×10^{-5}/yr	7.8×10^{-5}/yr
Waterford 3	4.8×10^{-5}/yr	3.7×10^{-5}/yr	2.8×10^{-5}/yr
Mean value	6.1×10^{-5}/yr	4.4×10^{-5}/yr	6.1×10^{-5}/yr
Median value	4.8×10^{-5}/yr	2.8×10^{-5}/yr	6.6×10^{-5}/yr

CDF = core damage frequency; EIS = environmental impact statement; LAR = license amendment request; LR GEIS = Generic Environmental Impact Statement for License Renewal of Nuclear Plants; SAMA = severe accident mitigation alternative.

(a) Data were estimated by summing individual atmospheric release sequences, including intact containment sequences.
(b) Data were obtained from the applicable plant-specific supplement to NUREG-1437.
(c) Data were obtained from the applicable risk-informed LAR.
(d) Referred to as WNP-2 (Washington Nuclear Project 2) in the 1996 LR GEIS.
(e) A license renewal application and associated SAMA analysis has not been submitted for this plant.
(f) The severe accident mitigation design alternative (SAMDA) analysis included in NUREG-0775, Supplement (NRC 1989a) did not account for external events.

Source: NRC 2022c, unless otherwise noted.

E.3.2.2 Other Pathway Impacts

With respect to the other pathways (open bodies of water and groundwater), the IPEEE, NUREG-1150, NUREG/CR-5305, and later analysis (e.g., SOARCA) did not address their impacts on human health. The 1996 LR GEIS estimated these impacts for reactor accidents from full power (internal events only) using the results from plant-specific site information about surface water and groundwater areas, volumes, flow rates, and geology to assess contamination of water by comparing the plant-specific site characteristics information to that used in NUREG-0440 (NRC 1978), which assessed the contamination of surface water and groundwater from reactor accidents.

With the airborne pathway impacts from external events being less than or similar to the internal event airborne pathway impacts in the 1996 LR GEIS, it is reasonable to conclude that the probability-weighted impact of accidents caused by external events on surface water and groundwater contamination would also be much less than the impacts contained in the 1996 LR GEIS. Because of the longer time before the population is exposed and the effects of the interdiction of contaminated food, only latent cancer fatalities are expected to result from these pathways. Therefore, the environmental impacts of surface and groundwater contamination caused by accidents initiated by external events are bounded by the impacts stated in the 1996 LR GEIS. This same conclusion can also be drawn with respect to the economic impacts that are caused by the environmental contamination.

E.3.2.3 Conclusion

In summary, it is concluded that the CDFs from severe accidents initiated by all hazards (i.e., internal and external events), as quantified in recent risk-informed LARs and the other sources cited above, are, in some cases, higher than the internal events CDFs that formed the basis for the 1996 LR GEIS and, on average, are about 35 percent higher than the All Hazards CDFs used in the license renewal SAMA analyses. However, the environmental impacts from events initiated by all hazards (specifically, consequence-weighted population dose) are generally significantly lower (one to two orders of magnitude) than those used in the 1996 LR GEIS. In addition, as cited above, plant improvements made in response to NRC Orders and industry initiatives have contributed to the improved safety of all plants during both power operation and low power and shutdown operation. The NRC staff concludes that the new information from the external events PRAs is not significant for the purposes of this LR GEIS revision, that external event risk is being effectively addressed and reduced by the various NRC Orders and other initiatives, and therefore, external event risk is not expected to challenge the 1996 LR GEIS 95th percentile UCB risk metrics during the initial LR or SLR time period.

E.3.3 Impact of New Source Term Information

The 1996 LR GEIS used information from 28 original plant-specific EISs to project the environmental impact from all 118 plants analyzed (see Table 5.5 in the 1996 LR GEIS). The 28 sites chosen were those for which the impacts from severe accidents were analyzed in their plant-specific EISs. As stated in Section 5.3.3.1 of the 1996 LR GEIS, the accident source terms (i.e., the magnitude, timing, and characteristics of the radioactive material released to the environment) used in the EIS analyses for the 28 sites (and subsequently used to estimate the environmental impacts from all plants) were generally based on those documented in NUREG-0773 (NRC 1982d). The NUREG-0773 source terms represented an update (re-baseline) of the source terms used in WASH-1400 (NRC 1975). The source terms in NUREG-0773 were developed for PWRs and BWRs and are shown in Tables 13 and 14A, respectively, of that document. NUREG-0773 states that the provided source terms are based on models that have "known deficiencies which would tend to give overestimates of the magnitude of the releases." The 1996 LR GEIS used updated WASH-1400 source terms taken from the Byron FES (NRC 1982b) to be representative of PWRs and updated WASH-1400 source terms taken from the Clinton FES (NRC 1982c) to be representative of BWRs.

Since completion of NUREG-0773, additional information about source terms has been developed through experimental and analytical programs. The purpose of this section is to assess the impact of new source term information about the environmental impacts described in the 1996 LR GEIS. In the 2013 LR GEIS, using source term information in NUREG-1150 (NRC 1990) as updated and simplified in NUREG/CR-6295 (NRC 1997e), the NRC staff concluded the following:

> More recent source term information indicates that the timing from dominant severe accident sequences, as quantified in NUREG/CR-6295 (NRC 1997b), is comparable to the analysis forming the basis of the 1996 GEIS. In most cases, the release frequencies and release fractions are significantly lower for the more recent estimate. Thus, the environmental impacts used as the basis for the 1996 GEIS (i.e., the frequency-weighted consequences) are higher than the impacts that would be estimated using the more recent source term information.

This LR GEIS revision confirms the 2013 source term conclusions by comparing the historical source term information with more recent realistic source term information developed in the NRC's SOARCA research project.

E.3.3.1 Airborne Pathway Impact

SOARCA calculated the realistic outcomes of severe nuclear power plant accidents that could release radioactive material into the environment for three representative plants: Peach Bottom and Surry, which are representative of a BWR and PWR, respectively, and Sequoyah, which is representative of a PWR with an ice condenser containment. The SOARCA-developed source terms for these plants are compared to the re-baselined WASH-1400 largest source term category, referred to as siting source term 1 (SST1),[22] provided in NUREG/CR-2239, *Technical Guidance for Siting Criteria Development*, commonly referred to as the 1982 Siting Study (Aldrich et al. 1982). SST1 assumes severe core damage, loss of all safety systems, and loss of containment after 1.5 hours (hrs).

The computer models that produced the SOARCA calculations incorporated decades of research into reactor accidents as well as the current design and operation of nuclear power plants. The NRC considers SOARCA a state-of-the-art project because (1) it models accidents with the latest plant-specific and associated site characteristics information, (2) it uses an improved understanding of how radioactive material behaves during an accident, (3) it examines emergency response comprehensively, and (4) it combines modern computer-modeling capabilities and detailed computerized plant models. The SOARCA project sought to focus its resources on the more important severe accident scenarios for Peach Bottom and Surry. The project narrowed its approach by using an accident sequence's possibility of damaging reactor fuel, or CDF, as a surrogate for risk. The SOARCA scenarios were selected from the results of

[22] NUREG/CR-2239 defines a spectrum of five source term categories—SST1 through SST5. Category SST1 is the largest source term category of the five categories in that it represents the radiological releases from severe core damage accident sequences in which essentially all installed safety features are assumed to be lost (not functional) and there is a direct breach of the containment.

existing PRAs. Unlike the modeling of SST1 from NUREG/CR-2239, SOARCA modeled mitigation measures, including those in emergency operating procedures, severe accident management guidelines (SAMGs), and the additional equipment and strategies required by 10 CFR 50.155 for the mitigation of beyond-design-basis events.

For both Peach Bottom and Surry, the SOARCA modeled loss of all AC electrical power, referred to as SBO, caused by earthquakes more severe than anticipated in the plant's design and by flood and fire scenarios. Two SBO scenarios were analyzed: (1) the LTSBO (long-term SBO) where it is assumed that backup battery systems are available to operate safety systems for several hours until the batteries are exhausted, and (2) the STSBO (short-term station blackout) where it is assumed that all safety systems become inoperable immediately and core damage occurs in the short-term. For the Peach Bottom plant, the STSBO scenario is analyzed assuming a reactor core isolation cooling blackstart is successful and assuming a reactor core isolation cooling blackstart is not successful. In addition, SOARCA analyzed two scenarios for Surry in which radioactive material could potentially reach the environment by bypassing containment features: (1) an interfacing systems loss-of-coolant accident in which a random failure of valves ruptures low-pressure system piping outside containment that connects with the high-pressure reactor system inside containment, and (2) a thermally induced steam generator tube rupture, which is a low-probability variation of STSBO, in which a steam generator (SG) tube is ruptured due to overheating and boiling of reactor coolant system water.

Brief descriptions of the source terms (timing and duration of atmospheric release of radioactive material, and integral release fractions or fractional release to the environment of the original core inventory by chemical class[23]) for each of the Peach Bottom and Surry accident scenarios are provided in Table 7-1 of the respective SOARCA studies, which are reproduced, respectively, in Table E.3-13 (NRC 2013e) and

Table E.3-14 (NRC 2013f). For comparison, the largest source term, SST1, from the 1982 Siting Study, or NUREG/CR-2239, is also shown. The radionuclide inventory used in these analyses is presented in Appendix A of the Peach Bottom SOARCA report and Appendix B of the Surry SOARCA report. The inventory data were evaluated specifically for the SOARCA work and reflect realistic fuel cycle data from the two plants.

In comparison, the SST1 source term is significantly larger in magnitude, especially for the cesium chemical class, than all but one of the Peach Bottom source terms (i.e., barium) for the STSBO without blackstart) and all of the Surry source terms. Moreover, the release begins just 1.5 hrs after accident initiation, which is much earlier than for any of the SOARCA scenarios.

[23] The chemical classes are defined in Appendix A of the Peach Bottom SOARCA report and in Appendix B of the Surry SOARCA report.

Table E.3-13 Brief Source Term Description for Unmitigated Peach Bottom Accident Scenarios and the SST1 from the 1982 Siting Study[(a)]

Scenario	CDF (Events/yr)	Xe	Cs	Ba	I	Te	Ru	Mo	Ce	La	Start (hr)	End (hr)
PB LTSBO	3×10^{-6}	0.978	0.005	0.006	0.020	0.022	0.000	0.001	0.000	0.000	20.0	48.0
PB STSBO w/RCIC BS	3×10^{-7}	0.979	0.004	0.007	0.013	0.015	0.000	0.001	0.000	0.000	16.9	48.0
PB STSBO w/o RCIC BS	3×10^{-7}	0.947	0.017	0.095	0.115	0.104	0.000	0.002	0.007	0.000	8.1	48.0
SST1	1×10^{-5}	1.000	0.670	0.070	0.450	0.640	0.050	0.050	0.009	0.009	1.5	3.5

Ba = barium; BS = blackstart; CDF = core damage frequency; Ce = cerium; Cs = cesium; hr = hour; I = iodine; La = lanthanum; LTSBO = long-term station blackout; Mo = molybdenum; PB = Peach Bottom Atomic Power Station; RCIC = reactor core isolation cooling; Ru = ruthenium; SST = siting source term; STSBO = short-term station blackout; Te = tellurium; Xe = xenon; yr = year.

(a) The integral release fractions are presented by chemical class. Also presented are the atmospheric release timing start and end times.

Table E.3-14 Brief Source Term Description for Unmitigated Surry Accident Scenarios and the SST1 from the 1982 Siting Study[(a)]

Scenario	CDF (Events/yr)	Xe	Cs	Ba	I	Te	Ru	Mo	Ce	La	Start (hr)	End (hr)
Surry STSBO	2×10^{-6}	0.518	0.001	0.000	0.006	0.006	0.000	0.000	0.000	0.000	25.5	48.0
Surry STSBO w/TISGTR	4×10^{-7}	0.592	0.004	0.000	0.009	0.007	0.000	0.001	0.000	0.000	3.6	48.0
Surry Mitigated STSBO w/ TISGTR	4×10^{-7}	0.085	0.004	0.000	0.005	0.004	0.000	0.001	0.000	0.000	3.6	48.0
Surry LTSBO	2×10^{-5}	0.537	0.000	0.000	0.003	0.006	0.000	0.000	0.000	0.000	45.3	72.0
Surry ISLOCA	3×10^{-8}	0.983	0.020	0.000	0.154	0.132	0.000	0.003	0.000	0.000	12.8	48.0
SST1	1×10^{-5}	1.000	0.670	0.070	0.450	0.640	0.050	0.050	0.009	0.009	1.5	3.5

Ba = barium; CDF = core damage frequency; Ce = cerium; Cs = cesium; hr = hour; I = iodine; ISLOCA = interfacing systems loss-of-coolant accident; La = lanthanum; LTSBO = long-term station blackout; Mo = molybdenum; Ru = ruthenium; STSBO = short-term station blackout; SST = siting source term; Te = tellurium; TISGTR = thermally induced steam generator tube rupture; Xe = xenon; yr = year.

(a) The integral release fractions are presented by chemical class. Also presented are the atmospheric release timing start and end times.

These same source term results for the iodine (I) and cesium (Cs) chemical classes are shown graphically in Figure E.3-2 and Figure E.3-3, respectively (which are reproduced Figures ES-1 and ES-2 from the Peach Bottom and Surry SOARCA studies). In addition to showing the significant delayed radiological releases relative to the 1982 Siting Study SST1 case, the SOARCA study demonstrates that the amount of radioactive material released is much smaller for both Peach Bottom and Surry. The cesium (predominantly Cs-137) and iodine (predominantly I-131) chemical classes were chosen for this comparison because of their generally recognized importance to total risk from severe reactor accidents that result in core damage.

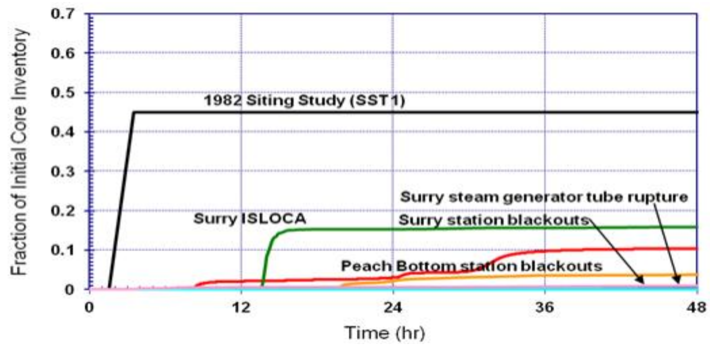


Figure E.3-2 Iodine Release to the Environment for SOARCA Unmitigated Scenarios and the 1982 Siting Study SST1 Case. Source: NRC 2012g.

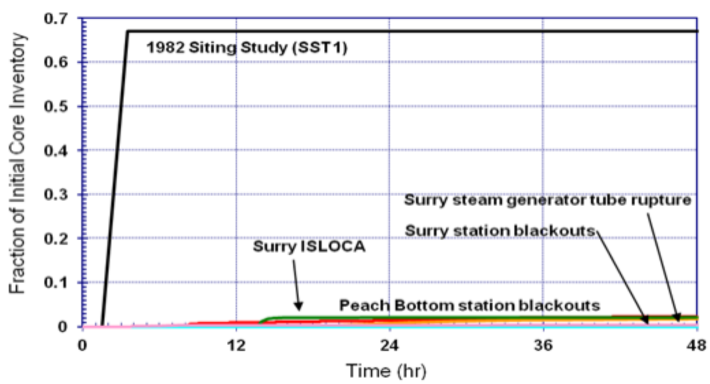


Figure E.3-3 Cesium Release to the Environment for SOARCA Unmitigated Scenarios and the 1982 Siting Study SST1 Case. Source: NRC 2012g.

Figure E.3-4 compares the cesium and iodine source terms from these studies with those from the older severe accident studies and with the 1982 Siting Study SST1 case (NRC 2020c). As was observed for the earlier SOARCA studies, the SOARCA unmitigated release of Cs-137 and I-131, for each of the modeled scenarios, are much smaller than estimated in the earlier 1982 Siting Study SST1 case. Figure E.3-4 also compares the source terms relative to the source terms released during the historical severe accidents at Chernobyl and Three Mile Island. All the releases from the SOARCA studies are much smaller than those from the Chernobyl accident.[24]

[24] The Chernobyl accident release data are estimated at 20–40 percent for Cs-137 and 50–60 percent for I-131. The Three Mile Island accident released an extremely small quantity of I-131 (~ 15 curies) and zero Cs-137. The Fukushima Dai-ichi accident releases are estimated to be approximately one-tenth of releases from the Chernobyl accident. Source: NRC 2020c.

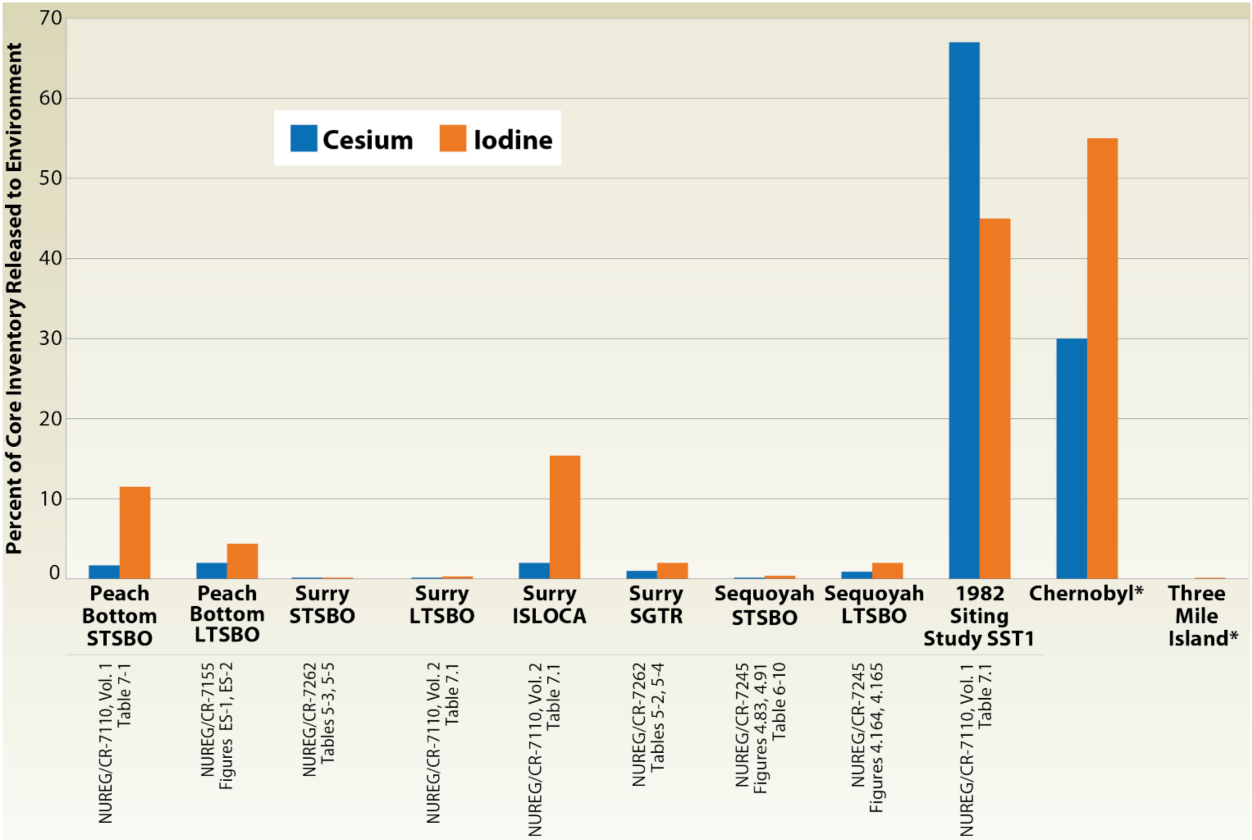


Figure E.3-4 Percentages of Cesium and Iodine Released to the Environment for SOARCA Unmitigated Scenarios, the 1982 Siting Study SST1 Case, and Historical Accidents. Source: NRC 2020c.

As discussed previously, the SOARCA project's offsite consequence analyses focused on the same radiation-induced fatality risks as those defined by the quantitative health objectives (QHOs), namely the risk of early fatalities from radiation exposure and the risk of long-term cancer fatalities from radiation exposure. All mitigated cases for the Peach Bottom and Surry SOARCA scenarios, except for one, result in prevention of core damage and/or no offsite release of radioactive material. The only mitigated case still leading to an offsite release was the Surry thermally induced steam generator tube rupture scenario. In this scenario, mitigation is still beneficial in that it keeps most radioactive material inside containment and delays the onset of containment failure by about 2 days. For the Sequoyah analyses, only hydrogen igniters after core damage were considered. The Sequoyah results show that early containment failure caused by hydrogen burns can be eliminated if igniters are operational within 3 hrs. As a result, the mitigated scenarios show zero risk of early fatalities from radiation exposure and result in either zero risk or very small risk of a long-term cancer fatality for an individual.

The unmitigated scenarios result in very low risk of early fatality for an individual. Although these unmitigated scenarios result in core damage and release of radioactive material to the environment, the release is often delayed, which allows the population to take protective actions (including evacuation and sheltering). Therefore, the public would not be exposed to concentrations of radioactive material in excess of NRC regulatory limits. This result holds even when uncertainties are considered—all three uncertainty analyses continued to show extremely low risk of early fatalities.

For the unmitigated scenarios, the individual risk of a long-term cancer fatality is calculated to be very small—regardless of which distance interval (e.g., 0–10 mi, 0–20 mi, 0–50 mi) is considered. This result holds even when uncertainties are considered.

Table E.3-15 summarizes the results for the mitigated and unmitigated scenarios based on the linear-no-threshold (LNT) dose-response model[25] for estimating the risk of a long-term cancer fatality for individuals located within 10 mi of each plant (NRC 2020c).

Table E.3-15 SOARCA Results: Long-Term Cancer Fatality Risk

Accident Scenario	About how likely is the accident to occur?	Mitigated Case[(a)]	Unmitigated Case[(a)]	Approximate Range of Uncertainty[(a,b)]
Peach Bottom LTSBO	1 event in 300,000 reactor years	Zero	1 in 3 billion	1 in 1 billion to 1 in 11 billion
Peach Bottom STSBO	1 event in 3 million reactor years	Zero	1 in 20 billion	Not Estimated
Surry LTSBO	1 event in 50,000 reactor years	Zero	1 in 1 billion	Not Estimated
Surry STSBO	1 event in 500,000 reactor years	Zero[(c)]	1 in 6 billion	1 in 3 billion to 1 in 7 billion
Surry Steam Generator Tube Rupture	1 event in 3 million reactor years	1 in 10 billion	1 in 10 billion	Not Estimated
Surry ISLOCA	1 event in 30 million reactor years	Zero	1 in 100 billion	Not Estimated
Sequoyah LTSBO	1 event in 100,000 reactor years	Zero[(d)]	1 in 200 million	Not Estimated
Sequoyah STSBO	1 event in 500,000 reactor years	Zero[(d)]	1 in 6 billion	1 in 3 billion to 1 in 50 trillion

ISLOCA = interfacing-system loss-of-coolant accident; LTSBO = long-term station blackout; STSBO = short-term station blackout.

(a) Estimated risks below 1 in 10 million reactor years should be viewed with caution because of the potential impact of events not studied in the analyses and the inherent uncertainty in very small, calculated numbers.

(b) Values shown represent the 5th–95th percentile range for uncertainty in accident progression and offsite consequences. The SOARCA did not evaluate uncertainty in accident frequency. Uncertainty analyses were performed for the three identified scenarios only.

(c) For the mitigated Surry STSBO, the reactor vessel would fail; however, the containment would not fail until about 66 hrs after the blackout. A review of available resources and emergency plans shows that adequate mitigation measures could be brought onsite within 24 hrs and connected and functioning within 48 hrs. Therefore, 66 hrs would allow time for mitigation via equipment brought to the site from offsite, and this mitigation would avert containment failure such that radioactive material would not be released to the environment.

(d) Although not explicitly modeled in the Sequoyah SOARCA, the response is expected to be similar to the mitigated Surry SOARCA assuming backup generators and pumps are available to restore core cooling.

SOARCA results, while specific to the Peach Bottom, Surry, and Sequoyah plants, may be generally applicable to plants of similar designs. Additional work would be needed to confirm this, however, because differences exist in plant-specific designs, procedures, and emergency response characteristics. The SOARCA results for the three plants analyzed are as follows:

[25] The LNT model is based on the conclusion that any amount of radiation dose (no matter how small) can incrementally increase cancer risk. It is a basic assumption used in many regulatory limits, including the NRC's regulations and past assessments.

- When operators are successful in using onsite equipment during the accidents analyzed in the SOARCA, they can prevent the reactor from melting, or delay or reduce releases of radioactive material to the environment.
- SOARCAs indicate that all modeled accident scenarios, even if operators are unsuccessful in stopping the accident, progress more slowly and release smaller amounts of radioactive material than calculated in earlier studies.
- As a result, public health consequences from severe nuclear power plant accidents modeled in SOARCAs are smaller than previously calculated.
- The delayed releases calculated provide more time for emergency response actions such as evacuating or sheltering for affected populations. For the scenarios analyzed, SOARCA shows that emergency response programs, if implemented as planned and practiced, reduce the risk of public health consequences.
- Both mitigated (operator actions are successful) and unmitigated (operator actions are unsuccessful) cases of all modeled severe accident scenarios in SOARCA cause very low risk of fatality during or shortly after the accident.
- SOARCAs results for longer-term cancer fatality risks for the accident scenarios analyzed are millions of times lower than the general U.S. cancer fatality risk.

Because SOARCA is based on decades of research and uses improved modeling tools, the SOARCAs generate more realistic results than past efforts such as the 1982 Siting Study. The past studies were based on then-existing plant descriptions and knowledge of how severe accidents would occur. However, it is known that the predictions from these past studies are out-of-date for realistically understanding severe accident consequences. The current understanding of accident progression has led to a very different characterization of release signatures than was assumed for the 1982 Siting Study.

Based on the SOARCA results, the impacts (i.e., the frequency-weighted consequences) from the airborne pathway using the updated source term information would be expected to be much lower than previously predicted in either the 1996 LR GEIS or the license renewal SAMA analyses.

E.3.3.2 Other Pathway Impacts

Because the comparison of the new source term information to that used in the 1996 LR GEIS environmental impact projection shows that the amount of release of radioactive material in a severe accident is estimated to be less than that estimated in the 1996 LR GEIS, the environmental impacts from the other pathways (contamination of open bodies of water, groundwater contamination, and the resulting economic impacts from any pathway) will also be less than those estimated in the 1996 LR GEIS.

E.3.3.3 Conclusion

More recent and more realistic source term information indicates that the anticipated release timing and release fractions from severe accident sequences are significantly lower than earlier studies (e.g., the 1982 Siting Study) and the more conservative source term information that formed the basis of the 1996 LR GEIS. Furthermore, while the SOARCAs were focused on the most risk-significant accident scenarios and did not evaluate all scenarios, the SOARCA offsite consequence calculations for the three sites evaluated are generally smaller than those reported in earlier studies. Specifically, the SOARCA results show extremely low early fatality risk for the three sites and show a very low individual risk of cancer fatalities for the populations close to the plants (i.e., well below the NRC Safety Goal of two long-term cancer fatalities annually in a population of one million individuals). Thus, the environmental impacts estimated using the more recent and realistic source term information are expected to be much lower than the impacts used as the basis for the 1996 LR GEIS (i.e., the frequency-weighted consequences).

E.3.4 Impact of Power Uprates

The NRC regulates the maximum power level at which a commercial nuclear power plant may operate. This power level is used, with other data, in many of the licensing analyses that demonstrate the safety of the plant. This power level is included in the license and technical specifications for the plant. The NRC controls any change in a license or technical specification, and the licensee may only change these documents after the NRC approves the licensee's application for change. Power uprates are defined as the process of increasing the maximum power level at which a nuclear power plant may operate. Although power uprates have been approved by the NRC since 1977, the effects of power uprates since 1996 were not taken into account in the 1996 LR GEIS. Extended power uprates began to be approved in 1998. The purpose of this section is to provide an assessment of the impact of power uprates on the risk of severe accidents. This section also addresses anticipated increases in fuel enrichment.

Utilities have been using power uprates since the 1970s as a way to increase the power output of their nuclear power plants. To increase the power output of a reactor, typically more highly enriched uranium fuel and/or more fresh fuel is used. This enables the reactor to produce more thermal energy and therefore more steam, driving a turbine generator to produce electricity. To accomplish this, components such as pipes, valves, pumps, heat exchangers, electrical transformers, and generators must be able to accommodate the conditions that would exist at the higher power level. For example, a higher power level usually involves higher steam and water flow through the systems used in converting the thermal power to electric power. These systems must be capable of accommodating the higher flows. In some instances, licensees will modify and/or replace components to accommodate a higher power level.

There are three categories of power uprates:

- measurement uncertainty recapture power uprates
- stretch power uprates (SPUs)
- extended power uprates (EPUs).

Measurement uncertainty recapture power uprates are less than 2 percent and are achieved by implementing enhanced techniques for calculating reactor power. This involves the use of state-of-the-art feedwater flow measurement devices to more precisely measure feedwater flow, which is used to calculate reactor power. More precise measurements reduce the degree of uncertainty in the power level, which is used by analysts to predict the ability of the reactor to be safely shut down under postulated accident conditions.

SPUs are typically up to 7 percent and are within the design capacity of the plant. The actual value for the percentage increase in power a plant can achieve and stay within the stretch power uprate category is plant-specific and depends on the operating margins included in the design of a particular plant. Stretch power uprates usually involve changes to instrumentation setpoints, but do not involve major plant modifications.

EPUs are greater than SPUs and have been approved for increases as high as 20 percent. These uprates require significant modifications to major balance-of-plant equipment such as the high-pressure turbines, condensate pumps and motors, main generators, and/or transformers.

An increase in plant power level will affect the source term available for release in a severe accident (see previous section) and, thus, the quantified risk of severe accidents. Power uprates generally affect the source term radionuclide magnitude and mix due to small changes in fuel burnup (higher burnup requires increased uranium enrichment in the fuel), the amount of fuel used, and isotopic concentrations of the radionuclides in the irradiated fuel relative to the original level of burnup. To accommodate the increased power level and associated source term, facility modifications and technical specification changes are made, which lower allowable leakage to the environment to ensure that the NRC's acceptance criteria for radiological consequences analyses continue to be met for normal plant operations and for design-basis accidents.

With regard to severe accidents, potential risk increases are also associated with implementing a power uprate due to the increased heat loads at higher power levels and the resulting reductions in the times available to perform specific accident response actions. In addition, there can be impacts on the equipment loads and the potential for an increase in the frequency of reactor scrams due to these increased loads and tighter operating margins. For small power uprates (i.e., measurement uncertainty recaptures and SPUs), the risk increases are expected to be exceedingly small, so LARs for these power uprates do not generally include an assessment of the change in risk. For EPUs, however, notwithstanding any plant modifications that could reduce risk, some increase in risk is expected. Depending on the type of plant-specific modifications necessary to implement the larger power uprates, these power uprates have the potential to significantly increase plant risks, so an assessment of the impact on CDF and LERF is included with EPU LARs (NRC 2003).

The purpose of this section is to assess the impact of power uprates on severe accident risk that have been approved by the NRC since issuance of the 1996 LR GEIS. In the 2013 LR GEIS, using power uprate risk information up to that point in time, the NRC staff concluded the following:

> Power uprates would result in a small to (in some cases) moderate increase in the environmental impacts from a postulated accident. However, taken in combination with the other information presented in this appendix, the increases would be bounded by the 95 percent UCB values in Tables 5.10 and 5.11 of the 1996 GEIS.

This LR GEIS revision confirms the 2013 conclusions by considering risk information from power uprate LARs.

E.3.4.1 Airborne Pathway Impacts

Power uprates require using fuel that has a higher percentage of uranium-235 or additional fresh fuel in order to derive more energy from the operation of the reactor. This results in a larger radionuclide inventory (particularly short-lived isotopes, assuming no change in burnup limits) in the reactor core, than the same core at a lower power level. The larger radionuclide inventory represents a larger source term for accidents and can result in higher doses to offsite populations in the event of a severe accident. Typically, short-lived isotopes are the main contributor to early fatalities. As stated in NUREG-1449 (NRC 1993), short-lived isotopes make up 80 percent of the dose following early release.

The NRC uses LERF as a surrogate for the individual early fatality risk QHO. Thus, the impact of a power uprate on early fatalities can be gauged by considering the impact of the uprate on the LERF metric. To this end, Table E.3-16 presents the change in LERF calculated by licensees who have been granted an EPU. As shown, the change in LERF ranges from decreases[26] to increases of up to 32 percent (with a mean of 5.7 percent). Relative to the substantial decreases in probability-weighted consequences since issuance of the 1996 LR GEIS discussed previously with respect to new information on internal and external events and on source term, this increase due to EPUs is judged to be small.[27] Additional discussion of new information about early fatality risk is provided in Section E.3.9 with regard to the results of the SOARCA study. SOARCA found the individual early fatality risk to be in the 1×10^{-14}/RY range, or essentially zero, for the risk-significant scenarios evaluated for three plants.

Table E.3-16 Changes in Large Early Release Frequencies for Extended Power Uprates

Nuclear Power Plant	Percent Increase in Power	Percent Increase in Internal Event LERF
Arkansas 2	7.5	24
Beaver Valley 1	8	5.6
Beaver Valley 2	8	4.1
Browns Ferry 1	14.3	9.7
Browns Ferry 2	14.3	8.3
Browns Ferry 3	14.3	7.5
Brunswick 1, 2	15	4.5
Clinton	20	5.5
Dresden 2, 3	17	10
Duane Arnold	15.3	16
Ginna	16.8	19
Hope Creek	15	30
Monticello	12.9	7.8
Nine Mile Point 2	15	5.1
Peach Bottom 2, 3	12.4	2.8
Point Beach 1, 2	17	-33[a]

[26] The negative impacts reflect regulatory commitments to make specific plant improvements prior to implementation of the EPU.
[27] It is noted that a few of these EPUs were accounted for in the license renewal SAMA analyses previously discussed in this appendix (e.g., Beaver Valley, Brunswick, Waterford).

Nuclear Power Plant	Percent Increase in Power	Percent Increase in Internal Event LERF
Quad Cities 1, 2	17.8	4
St. Lucie 1	11.9	-20[(a)]
St. Lucie 2	11.9	-0.1[(a)]
Susquehanna 1, 2	13	<1
Turkey Point 3	15	30
Turkey Point 4	15	32
Vermont Yankee	20	5
Waterford	8.0	4.6
Mean	14.3	5.7

LERF = large early release frequency.
(a) The reduction in LERF reflects plant improvements that result in a risk reduction that is greater than the increase in risk due to the extended power uprate.
Source: NRC 2022c, unless otherwise noted.

E.3.4.2 Other Pathway Impacts

As discussed in previous sections, the change in impacts due to other pathways is considered to be bounded by the change in the airborne pathway, consistent with the results obtained in the 1996 LR GEIS.

E.3.4.3 Conclusion

Power uprates would result in a small increase in the environmental impacts from a postulated accident. However, taken in combination with the other information presented in this appendix, the increases would be bounded by the 95 percent UCB values in the 1996 LR GEIS and represented in Table E.3-1 of this appendix.

E.3.5 Impact of Higher Fuel Burnup

An EA was published by the NRC in 1988 about the effects of increased peak burnup (to 60 gigawatt-days [units of energy] per metric tonne [GWd/MT], 5 percent by weight uranium-235). NUREG/CR-5009 (Baker et al. 1988) is the basis for the EA. NUREG/CR-6703 (Ramsdell et al. 2001) is a more current analysis using updated designs and data, and peak burnup up to 75 GWd/MT. The purpose of this section is to include the updated information from NUREG/CR-6703 in this LR GEIS revision to account for the effect of current and possible future increased fuel burnup on postulated accidents.

The history of fuel utilization for BWRs and PWRs has seen a gradual progression toward higher fuel discharge burnups and increased enrichments to allow for more efficient utilization of the fuel and longer operating cycles. The current fuel burnup limits differ slightly among fuel vendors and fuel products, but fuel assemblies are generally limited to a maximum rod-average burnup of 62 GWd/MTU. However, some potential applicants are interested in raising this limit up to 75 GWd/MTU rod-average. Burnup limits are not specified in any regulations. Burnup limits are incorporated into power reactor licenses once they are reviewed and approved by the NRC staff in safety evaluations based on approved topical reports. As such, the NRC has continuously evaluated the impact of higher fuel burnups and increased enrichments on the various regulatory source terms.

All currently operating nuclear power plants were licensed in accordance with the original 1962 reactor site criteria (10 CFR Part 100), which for the purposes of licensing nuclear power plants require that radionuclide releases to reactor containments associated with a “substantial meltdown” of the reactor core be postulated. To meet the Part 100 siting regulation, facilities were originally designed and sited with a historical regulatory source term published in 1962 by the U.S. Atomic Energy Commission in Technical Information Document (TID) 14844, *Calculation of Distance Factors for Power and Test Reactors* (DiNunno et al. 1962). This source term was based on results of experiments involving the heatup of irradiated fuel fragments in a furnace with relatively low burnup rates and enrichments. This source term formed the basis for the early Regulatory Guides 1.3 (AEC 1974a) and 1.4 (AEC 1974b), which have been used to determine compliance with the NRC's reactor site criteria set forth in 10 CFR Part 100 and to evaluate other important plant performance requirements.

After the Three Mile Island Unit 2 meltdown, the NRC initiated a major research effort in the area of severe accidents. A motivation for this effort was the differences in the observed radionuclide behavior during the accident and various aspects of the TID-14844 source term such as aerosol physics and radionuclide release and transport through the plant systems. The culmination of this work with respect to commercial nuclear power plant severe accident risk assessment was published by the NRC in NUREG-1150, *An Assessment for Five U.S. Nuclear Power Plants* (NRC 1990). From this body of research, a new set of generic “regulatory accident source terms” for representative BWR and PWR nuclear plants was derived and published in NUREG-1465, *Accident Source Terms for Light-Water Nuclear Power Plants* (NRC 1995a). This report provided more realistic estimates of the source term release into containment in terms of timing, nuclide types, quantities, and chemical form, given a severe core-melt accident.

In December 1999, the NRC issued a new regulation, 10 CFR 50.67, “Accident Source Term,” which provided a mechanism for licensed power reactors to voluntarily replace the traditional TID-14844 accident source term used in their design-basis accident analyses with an alternative source term more consistent with the results published in NUREG-1150 and NUREG-1465. Regulatory guidance for the implementation of the alternative approach is provided in Regulatory Guide 1.183, *Alternative Radiological Source Terms for Evaluating Design-Basis Accidents at Nuclear Power Reactors*, Revision 0 (NRC 2000). Regulatory Guide 1.183, Footnote 10, limits the use of this source term for light water reactor fuel with peak burnups of up to 62 GWD/MTU. To date, nearly all commercial nuclear power plant licensees have adopted the Accident Source Term as their licensing and design-basis by applying the methodologies of Regulatory Guide 1.183.

In January 2011, in support of the NRC staff, Sandia National Laboratories published the report SAND 2011-0128, *Accident Source Terms for Light-Water Nuclear Power Plants Using Higher-Burnup or MOX Fuel* (SNL 2011), to assess the impacts on the NUREG-1465 source term for facilities using higher-burnup and mixed-oxide fuels. That report documents a series of MELCOR calculations to compare source terms for low burnup fuel (26–38 GWd/MTU core average discharge burnup, which varied depending on the plant analyzed) vs. high burnup fuel in BWRs and PWRs (59 GWd/MTU maximum assembly-averaged burnup corresponding to 62 GWd/MTU peak rod-average burnup). The calculations accounted for cycle-specific information, fuel assembly design, core inventories, and decay heat. They also accounted for higher fission product diffusivity for the high burnup fuel based on experimental results from the

VERCORS program in France.[28] The diffusion coefficient is based on VERCORS test RT-6, which used a uranium dioxide pellet irradiated to 72 GWd/MTU in a commercial PWR.[29] Important differences among the accident source terms derived and reported in SAND2011-0128 (SNL 2011) and NUREG-1465 (NRC 1995a) are not attributable to either fuel burnup or use of mixed-oxide fuel. Rather, differences among the source terms are due predominantly to improved understanding of the physics of core meltdown accidents. Heat losses from the degrading reactor core prolong the process of in-vessel release of radionuclides. Improved understanding of the chemistries of tellurium and cesium under reactor accidents changes the predicted behavior characteristics of these radioactive elements relative to what was assumed in the derivation of the NUREG-1465 source term. An additional radionuclide chemical class had also been defined to account for release of cesium as cesium molybdate, which enhances molybdenum release relative to other metallic fission products.

The May 13, 2020, NRC Memorandum, “Applicability of Source Term for Accident Tolerant Fuel, High Burn Up and Extended Enrichment” (NRC 2020b), assessed the applicability of Regulatory Guide 1.183’s use of the NUREG-1465 source term for:

- burnups of up to 68 GWd/MTU, excluding potential impacts related to fuel fragmentation, relocation, and dispersal;
- enrichment between 5–8 percent; and
- near-term accident tolerant fuel designs for chromium-coated cladding and chromia-doped fuel.

The memo recommended the use of accident source terms from SAND2011-0128 (SNL 2011) and non-loss-of-coolant accident source terms based on Fuel Analysis under Steady-state and Transients code calculations to serve as a basis for a future Regulatory Guide 1.183 update. This recommendation is based on the limited impact of burnup effects between 38 GWd/MTU and 62 GWd/MTU, where it was found to be reasonable to extrapolate the conclusion for fuel with a 68 GWd/MTU peak rod-average discharge burnup.

In 2022, NRC revised Regulatory Guide 1.183, Revision 0, to expand its applicability to encompass fuel burnup extensions of up to 68 GWd/MTU (rod-average) and enrichments of up to 8 weight-percent uranium-235 based on recommendations from the May 13, 2020, NRC Memorandum (NRC 2020b).

E.3.5.1 Airborne Pathway Impacts

The increased environmental impacts of accidents where high burnup fuel is being used (assuming no change in plant power level) are due to the effects of an increased inventory of long-lived fission products. Long-lived fission products contribute primarily to latent health effects. Because latent health effects are directly scalable to dose, the assessment is based upon the increase in population dose due to the use of high burnup fuel.

---

[28] The VERCORS program studied the release of fission products from irradiated uranium dioxide pellets in a furnace under simulated severe accident conditions. For more information about this program and its results, please refer to the article by G. Ducros et al., “Fission product release under severe accidental conditions: general presentation of the program and synthesis of VERCORS 1–6 results,” Nuclear Engineering and Design 208.2 (2001): 191-203 (Ducros et al. 2001).
[29] See SAND2010-1633, *Synthesis of VERCORS and Phebus Data in Severe Accident Codes and Applications* (SNL 2010) for further information.

Table E-15 of the 2013 LR GEIS, which is represented in Table E.3-17 below, provides the dose to an individual located at the exclusion area boundary and the mean total population dose from NUREG/CR-6703 (Ramsdell et al. 2001). The exclusion area boundary dose includes contributions from inhalation and external dose. The total population dose also includes contributions from contaminated foods. Table E.3-17 provides the estimated total population dose assuming an accident because NUREG/CR-6703 only provided the population dose, whereas other sections of this appendix provide the estimated PDR that accounts for the likelihood of an accident. The increase in population dose is 38 percent from 42 to 75 GWd/MT for PWRs. For BWRs, the net increase in population dose is 8 percent. Although the analysis in NUREG/CR-6703 is for design-basis accidents, the percentage increase in impacts would be generally similar for severe accidents. Even though there are increases in plant population dose (factor of <1.4) because of increased burnup, the increase is significantly less than the reduction in the estimated PDR since the publication of the 1996 LR GEIS (see Table E.3-17).

Table E.3-17 Loss-of-Coolant Accident Consequences as a Function of Fuel Burnup

Reactor Type	Peak Rod Burnup (GWd/MT)	Individual Dose at 0.8 km[(a)] (rem)[(b)]	Mean Total Population Dose (person-rem)[(b)]
PWR	42	10	940,000
PWR	50	10	1,100,000
PWR	60	10	1,200,000
PWR	62	10	1,200,000
PWR	65	11	1,200,000
PWR	70	11	1,300,000
PWR	75	11	1,300,000
BWR	60	10	1,300,000
BWR	62	10	1,300,000
BWR	65	10	1,300,000
BWR	70	11	1,400,000
BWR	75	11	1,400,000

BWR = boiling water reactor; GWD/MT = gigawatt-days (units of energy) per metric tonne; PWR = pressurized water reactor.
(a) Unit conversion: 0.8 km = 0.5 mi.
(b) Note that these doses are on a per event basis, not a frequency (per year) basis.

E.3.5.2 Other Pathway Impacts

As discussed in previous sections, the change in impacts due to other pathways is considered bounded by the change in the airborne pathway, consistent with the results obtained in the 1996 LR GEIS.

E.3.5.3 Conclusion

Increased peak fuel burnup from 42 to 75 GWd/MT for PWRs and 60 to 75 GWd/MT for BWRs results in small increases (up to 38 percent) in the environmental impacts in the event of a severe accident. However, taken in combination with the other information presented in this appendix, the increases would be bounded by the 95 percent UCB values in the 1996 LR GEIS, which are represented in Table E.3-1 of this appendix, and would be very small increases in environmental impact relative to the large decreases in PDR (orders of magnitude) since the publication of the 1996 LR GEIS.

E.3.6 Impact from Accidents at Low Power and Shutdown Conditions

The 1996 LR GEIS did not include an assessment of the environmental impacts of accidents initiated under low power or shutdown conditions. These conditions include operating at power levels less than 5 percent, shutdown configurations (with or without maintenance or plant modifications under way), and fuel handling activities. The safety concern under these conditions is that plant configurations may be established where not all plant safety systems and features would be operable (e.g., containment integrity may not be required) and activities (e.g., plant modification) could be under way that could not be accomplished while at full power. Accordingly, accidents initiated under such conditions may have different initiators, progress differently, and have different consequences than those initiated under full power conditions. In addition, operating experience has shown that events affecting fuel cooling do occur during shutdown operations. Therefore, the industry implemented a number of voluntary measures in response to NRC generic letters and bulletins and in 1991 developed guidelines for the assessment of shutdown management and implementation of safety improvements (NUMARC 1991). As discussed in SECY-97-168 (NRC 1997c), these voluntary industry initiatives resulted in improved safety.

On July 19, 1999, the NRC issued a final rulemaking modifying the Maintenance Rule (64 FR 38551). This rulemaking established requirements under 10 CFR 50.65(a)(4) for the assessment and management of risk associated with maintenance activities and clarified the applicability of the Maintenance Rule to all modes of plant operation, including full power operations, low power operations, and plant shutdown configurations. The assessments are to be used so that the increase in risk that may result from maintenance activities will be managed to ensure that the plant is not inadvertently placed in a condition of significant risk or a condition that would degrade the performance of safety functions to an unacceptable level. Guidance on the implementation of a Maintenance Rule program acceptable to the NRC is provided in NUMARC 93-01, the current version of which is Revision 4F (NEI 2018). This guidance is endorsed by the NRC staff in Regulatory Guide 1.160, Revision 4 (NRC 2018b).

NUMARC 93-01 specifies that the scope of the systems, structures, and components to be addressed by the assessment for shutdown conditions are those systems, structures, and components necessary to support the following key safety functions for preventing or mitigating severe accidents:

- Decay heat removal capability – The ability to maintain reactor coolant system temperature and pressure, and SFP temperature, below specified limits following a shutdown.
- Inventory control – Measures established to ensure that irradiated fuel remains covered with coolant to maintain heat transfer and shielding requirements.
- Power availability – Measures to ensure the availability of electrical power sources required to operate the systems, structures, and components necessary to provide the key safety functions during shutdown.
- Reactivity control – Measures established to preclude inadvertent dilutions, criticalities, power excursions, or losses of shutdown margin and to predict and monitor core behavior.
- Containment (primary/secondary) – Measures to secure primary (PWR) or secondary (BWR) containment and its associated systems, structures, and components as a FUNCTIONAL barrier to accidental release of radiological material under existing plant conditions.

As discussed previously, after the March 11, 2011, accident at the Fukushima Dai-ichi nuclear power plant, the NRC issued Order EA-12-049, "Issuance of Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," dated March 12, 2012 (NRC 2012c). This Order requires that licensees be capable of implementing the strategies in all modes of plant operation, including full power operations, low power operations, and plant shutdown configurations. Regulatory guidance on this requirement contained in NEI 12-06, Revision 4, *Diverse and Flexible Coping Strategies (FLEX) Implementation Guide*, issued December 2016 (NEI 2016), Section 3.2.3, as endorsed by the NRC staff in JLD-ISG-2012-01, Revision 2, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," dated February 2017 (NRC 2017c), specifies that licensees would enhance existing shutdown risk processes and procedures through incorporation of FLEX equipment acquired to meet the Order requirements. This includes maintaining the equipment necessary to support shutdown, assuring that risk processes and procedures remain readily available, and determining how the equipment can be deployed or pre-deployed (pre-staged) to support maintaining or restoring the key safety functions during a loss of shutdown cooling. The NRC required licensees to comply with the Order by December 31, 2016. All operating power reactor licensees have complied with the portions of the Order that affect the shutdown risk processes.

All nuclear power plant licensees are obligated to comply with the Maintenance Rule, including 10 CFR 50.65(a)(4) for the assessment and management of risk associated with maintenance activities, including during low power operations and plant shutdown configurations. All nuclear power plant licensees have implemented the guidance in NUMARC 93-01, Revision 4F, as endorsed by the NRC in Regulatory Guide 1.160, Revision 4 (NRC 2018b), for implementing the Maintenance Rule. Promulgation of 10 CFR 50.65(a)(4) to require licensees to assess and manage the increase in risk that may result from the proposed maintenance activities and industry's implementation of NUMARC 93-01 have further enhanced the NRC staff's ability to oversee licensee activities related to shutdown risk.

E.3.6.1 Airborne Pathway Impacts

This section provides an assessment of the risk from postulated severe accidents under low power and shutdown conditions relative to the risk from postulated severe accidents under full power conditions, including a comparison to the findings in the 1996 LR GEIS.

The conditions assessed are as follows:

- plant operation at power levels between 0 and 5 percent;
- shutdown with containment open and containment closed; and
- fuel handling inside the containment structure.

In 1997, the NRC staff recommended a proposed rule be considered to address shutdown conditions. Although the Commission did not approve going forward with the proposed rule (see SRM-97-168, NRC 1997d), the technical basis for the proposed rule provides additional useful information. NUREG-1449 (NRC 1993) presents an analysis of actual events that have occurred under low power and shutdown conditions. This analysis includes an estimate of the conditional CDF associated with each event and an overall assessment of the range of total CDFs (mean value) that could result from events under low power and shutdown conditions. This range was from 10^{-5}/yr to 10^{-4}/yr.

In addition, NUREG/CR-6143 (SNL 1995) and NUREG/CR-6144 (BNL 1995) provide low power and shutdown risk assessments for two plants (Grand Gulf Unit 1, a BWR, and Surry Unit 1, a PWR). In both studies, a screening analysis was first performed of several plant operational states, each representing different potential plant configurations during low power and shutdown conditions. Based on the results of the screening analyses, a subset of plant operational states was selected for detailed risk analysis. For both risk assessments, the plant operational states selected were for plant configurations that were determined to have a significant contribution to plant low power and shutdown risk.[30] For the Grand Gulf plant, the mean CDF stated in NUREG/CR-6143 is 2×10^{-6}/yr for internal events, with the contribution from internal flooding events, internal fire events, and seismic events each being less than 1×10^{-7}/yr. For the Surry plant (NUREG/CR-6144), the mean CDF is 5×10^{-6}/yr for internal events, with the contributions from internal flooding events also being 5×10^{-6}/yr, from internal fire events being 2×10^{-5}/yr, and from seismic events being less than 1×10^{-7}/yr. However, such CDFs need to be considered with respect to their consequences. The consequences of severe accidents during low power and shutdown conditions can vary substantially depending on the plant operating configuration. For example, during low power operation, the initiating events and configuration of mitigating systems are essentially the same as for full power operation. Since the plant is in a low power configuration much less often than it is at full power, the risk during low power operation is less than at full power. However, for certain shutdown configurations, such as for mid-loop operation in a PWR wherein the reactor coolant inventory is reduced, the consequences and risk of an accident may be higher than during power operations.

NUREG/CR-6143 (SNL 1995) and NUREG/CR-6144 (BNL 1995) also provide estimates of the offsite airborne pathway consequences on human health from accidents (internal events only) under low power and shutdown conditions. Table E.3-18 provides these estimates in terms of probability-weighted consequences for the Grand Gulf and Surry plants for three metrics also used in the 1996 LR GEIS, namely, PDR, total early fatality risk, and total LCF risk. For comparison purposes, also shown for each plant are the airborne pathway offsite probability-weighted consequence results for accidents at full power from NUREG-1150 (NRC 1990) (internal events only), which is a vintage risk assessment similar to the low power and shutdown risk assessments. The results show that latent fatality risk is a factor of four higher for low power and shutdown operations than that for full power operations for both the Grand Gulf ($4 \times 10^{-3}/1 \times 10^{-3}$) and Surry ($2 \times 10^{-2}/5 \times 10^{-3}$) plants. However, for Surry, early fatality risk is a factor of 40 ($2 \times 10^{-6}/5 \times 10^{-8}$) lower and PDR is a factor of 75 (30/0.4) lower for low power and shutdown operations compared to full power operations. For Grand Gulf, early fatality risk and PDR are essentially the same for low power and shutdown operations and for full power operations.

[30] For Grand Gulf Unit 1, the plant operational state evaluated was a refueling outage (cold shutdown as defined by the plant-specific technical specifications). For Surry Unit 1, the plant operational states evaluated were for mid-loop operation (the reactor coolant system is lowered to the mid-plane of the hot leg).

Table E.3-18 Airborne Impacts of Low Power and Shutdown Accidents (Internal Events Initiators)

Nuclear Power Plant	Impact	Low Power/ Shutdown Accidents (mean values)[a]	Full Power Accidents – Internal Events (mean values)[b]	Full Power Accidents – All Hazards (point estimate values)[c]	Full Power Accidents (95% UCB values)[d]
Grand Gulf 1	CDF	2×10^{-6}/yr	4.0×10^{-6}/yr	3.2×10^{-5}/yr	2.4×10^{-5}/yr
Grand Gulf 1	PDR (person-rem per year)	8.7	~6	6.7	1,441
Grand Gulf 1	Total Early Fatality Risk	$\sim 1 \times 10^{-8}$/yr	$\sim 1 \times 10^{-8}$/yr	Not Estimated	2.8×10^{-3}/yr
Grand Gulf 1	Total Latent Cancer Fatality Risk	$\sim 4 \times 10^{-3}$/yr	$\sim 1 \times 10^{-3}$/yr	Not Estimated	1.0/yr
Surry 1	CDF	5×10^{-6}/yr	4.0×10^{-5}/yr	7.6×10^{-5}/yr	Not Estimated
Surry 1	PDR (person-rem per year)	0.4	~30	36	1,200
Surry 1	Total Early Fatality Risk	$\sim 5 \times 10^{-8}$/yr	$\sim 2 \times 10^{-6}$/yr	Not Estimated	1.6×10^{-2}/yr
Surry 1	Total Latent Cancer Fatality Risk	$\sim 2 \times 10^{-2}$/yr	$\sim 5 \times 10^{-3}$/yr	Not Estimated	0.9/yr

CDF = core damage frequency; PDR = population dose risk; UCB = upper confidence bound.

(a) Data for Grand Gulf are from NUREG/CR-6143 (SNL 1995); data for Surry are from NUREG/CR-6144 (BNL 1995).

(b) Data are from NUREG-1150 (NRC 1990).

(c) Data for Grand Gulf are from NUREG-1437, Supplement 50 (NRC 2014c); data for Surry are from NUREG-1437, Supplement 6 (NRC 2002a).

(d) Data for PDR, Early Fatality Risk, and Latent Fatality Risk are from the 1996 LR GEIS and are represented in Table E.3-1 of this appendix. Data for CDF were obtained by summing individual atmospheric release sequences, including intact containment sequences from the original plant-specific EISs, and are represented in Table E.3-2 and Table E.3-3 of this appendix.

In summary, based on the early 1990s-vintage studies, the total LCF risk for low power and shutdown operations is about a factor of 4 higher compared to full power operations, while the total early fatality risk and PDR for low power and shutdown operations are either comparable to or less than that for full power operations. However, there are compelling reasons for why the risks from low power and shutdown events relative to full power operations are expected to be lower today:

- One of the NRC staff conclusions in NUREG-1449 (discussed above) was that “a well-planned, well-reviewed, and well-implemented outage is a major contributor to safety” (NRC 1993, p. 6-2). The report further noted findings where improvements could be made, compared to the current practices at that time (early 1990s). As noted above in Section E.3.6, the NRC Maintenance Rule, NRC Order EA-12-049, and industry initiatives have implemented many of these improvements for safety, resulting in an expected risk reduction from potential low power and shutdown events today compared to the early 1990s.

- Nuclear power plants today spend a much smaller fraction of time in low power and shutdown operations compared to the early 1990s. Since risk from low power and shutdown events is proportional to the percentage of time spent in low power and shutdown operating states, spending less time in low power and shutdown conditions reduces its relative contribution to risk (all else being equal). This can be seen in the capacity factor trends over the years, which show ~60–70 percent time at full power operations in the 1980s to early 1990s, versus over 90 percent today.[31]

Given these additional considerations, the NRC anticipates that the probability-weighted impacts of an accident during low power and shutdown operations would be on the same order as full power if calculated today.

Table E.3-18 also compares these results to the hazards risk results developed from the license renewal SAMA analyses for these same two plants (these results account for external events as previously discussed in Section E.3.2). Even after accounting for external events, the SAMA PDR results are similar to the NUREG-1150 results and the low power and shutdown risk results. The other two metrics (i.e., early fatality risk and LCF risk) were not estimated in the SAMA analyses.

Lastly, Table E.3-18 compares the low power and shutdown risk results to the 95 percent UCB risk results from the 1996 LR GEIS. For Surry, the 95 percent UCB values from the 1996 LR GEIS for the PDR are a factor of 3,000 times (1,200/0.4) greater than those for low power and shutdown accidents, the early fatality risk is a factor of 320,000 times ($1.6 \times 10^{-2}/5 \times 10^{-8}$) greater than that for the low power and shutdown accidents, and the latent fatality risk is a factor of 45 times ($0.9/2 \times 10^{-2}$) greater than that for the low power and shutdown accidents. For Grand Gulf, the 95 percent UCB values from the 1996 LR GEIS for the PDR are a factor of 166 times (1,441/8.7) greater than those for low power and shutdown accidents, the early fatality risk is a factor of 280,000 times ($2.8 \times 10^{-3}/1 \times 10^{-8}$) greater than that for the low power and shutdown accidents, and the latent fatality risk is a factor of 250 times ($1.0/4 \times 10^{-3}$) greater than that for the low power and shutdown accidents. For all three metrics for both Surry Unit 1 and Grand Gulf Unit 1 nuclear power plants, the environmental impact in terms of probability-weighted consequences estimated in the 1996 LR GEIS bounds by a significant margin the estimated probability-weighted consequences from the NUREG/CR-6143 (Grand Gulf Unit 1 [SNL 1995]) and NUREG/CR-6144 (Surry Unit 1 [BNL 1995]) studies. Thus, even though the 1996 LR GEIS estimates regarding the airborne pathway environmental impact are for full power only, the conservatism in these estimates bounds the impacts from accidents under low power and shutdown configurations.

E.3.6.2 Other Pathway Impacts

For the impacts from surface water and groundwater contamination from accidents under low power and shutdown conditions, the estimates for accidents from full power (internal events only) in the 1996 LR GEIS can be used for comparison. In the 1996 LR GEIS, for the surface water pathways, it was estimated that the impacts from the drinking water pathway would be a small fraction of those from the airborne pathway. The risk associated with the aquatic food pathway was found to be also relatively small compared to the risks associated with the airborne pathway for most sites and essentially the same as the atmospheric pathway for the few sites with large annual aquatic food harvests. With the airborne impacts from accidents under low power and shutdown conditions in NUREG/CR-6143 (SNL 1995), NUREG/CR-6144

[31] See for example, Figure 1 in ANS (2020).

(BNL 1995), and NUREG-1150 (NRC 1990) estimated to be considerably less than the impacts from accidents at full power in the 1996 LR GEIS, the surface water pathway impacts should likewise be less, and thus, the risks reported in the 1996 LR GEIS should be bounding.

Section 5.3.3.4 of the 1996 LR GEIS concluded that the contribution of risk from the groundwater pathway for at-power accidents "generally contributes only a small fraction of that risk attributable to the atmospheric pathway but in a few cases may contribute a comparable risk." Groundwater contamination due to basemat melt-through would be less likely than for accidents at full power, due to the lower decay heat associated with low power and shutdown events. Thus, the risks portrayed in the 1996 LR GEIS are considered to be bounding.

E.3.6.3 Conclusion

In summary, the NRC staff concluded that the environmental impacts from accidents at low power and under shutdown conditions are generally comparable to those from accidents at full power when comparing the NUREG/CR-6143 (SNL 1995) and NUREG/CR-6144 (BNL 1995) values to NUREG-1150 (NRC 1990) values. Furthermore, even after accounting for external events, the license renewal SAMA results are on the same order of magnitude as the NUREG-1150 results and the low power and shutdown risk results. Although the impacts under low power and shutdown conditions could be somewhat greater than for full power conditions (for certain metrics), the 1996 LR GEIS estimates of the environmental impact of severe accidents bound the potential impacts from accidents at low power and shutdown conditions with significant margin. In addition, as cited above and discussed in SECY-97-168 (NRC 1997c), industry initiatives taken during the early 1990s have also contributed to the improved safety of low power and shutdown operations. Finally, promulgation of 10 CFR 50.65(a)(4) to require licensees to assess and manage the increase in risk that may result from the proposed maintenance activities and industry's implementation of NUMARC 93-01 have further enhanced the NRC staff's ability to oversee licensee activities related to shutdown risk. The NRC staff concludes that the information from the low power and shutdown PRAs is not significant for the purposes of this LR GEIS revision, that low power and shutdown risk is effectively managed by NRC required Maintenance Rule programs and therefore, low power and shutdown risk is not expected to challenge the 1996 LR GEIS 95 percent UCB risk metrics during the SLR time period.

E.3.7 Impact from Accidents at Spent Fuel Pools

The 1996 LR GEIS did not include an explicit assessment of the environmental impacts of accidents at the SFPs located at each reactor site. The 1996 LR GEIS did, however, discuss qualitatively (see Section 5.2.3.1) the reasons why the impact of accidents at SFPs would be much less than that from reactor accidents. Thus, in Table B-1 of 10 CFR Part 51, it was concluded that the impacts from severe accidents would be SMALL, including the accidents at SFPs, and which could be classified as Category 1 and not require further analysis in support of license renewal. This was primarily because the resolution of Generic Safety Issue 82, "Beyond Design Basis Accidents in Spent Fuel Pools," concluded that the risk from accidents at SFPs was low and, accordingly, no additional regulatory action was necessary. The analysis supporting this conclusion is contained in NUREG-1353 (NRC 1989c).

Since issuance of the 1996 LR GEIS, additional analysis of the risk from SFP accidents has been performed and documented. These analyses and associated regulatory actions provide further justification for the conclusion that risk from accidents at SFPs is low. For example, in 2001, the NRC published NUREG-1738 (NRC 2001), which evaluated SFP risk during decommissioning. Additionally, further analysis has been performed on SFP security as a result of the September 11, 2001, terrorist attacks. However, much of this analysis contains security-related information and is not publicly available.

The 2013 LR GEIS considered the risk from severe accidents in SFPs relative to the risk from severe accidents in reactors, including a comparison to the findings in the 1996 LR GEIS. The 2013 LR GEIS concluded that the environmental impacts from accidents at SFPs, as quantified in NUREG-1738 (NRC 2001), can be comparable to those from reactor accidents at full power, as estimated in NUREG-1150 (NRC 1990). Mitigative measures employed since 2001 have further lowered the risk of this class of accidents. In addition, even the conservative estimates from NUREG-1738 are much less than the impacts from full power reactor accidents as estimated in the 1996 LR GEIS.

More recent analysis demonstrates even lower risk and safety improvements. For example, the NRC performed a consequence study in NUREG-2161, *Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor* (NRC 2014a), referred to as the SFP Study, to continue its examination of the risks and consequences of postulated SFP accidents. As directed by the Commission in SRM-SECY-12-0025, dated March 9, 2012 (NRC 2012e), after the severe accident at the Fukushima Dai-ichi nuclear power plant, the NRC staff has undertaken regulatory actions that originated from the NTTF recommendations to enhance reactor and SFP safety. On March 12, 2012, the staff issued Order EA-12-051 (NRC 2012a), which requires that licensees install reliable means of remotely monitoring SFP levels to support effective prioritization of event mitigation and recovery actions in the event of a beyond-design-basis external event. In addition, the staff issued Order EA-12-049 (NRC 2012c), which requires that licensees develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and SFP cooling capabilities after a beyond-design-basis external event. Upon full implementation of these Orders, SFP safety was anticipated to be significantly increased.

The NRC issued Order EA-12-049, “Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events,” (NRC 2012c) in March 2012 after the accident at the Fukushima Dai-ichi nuclear plant (NRC 2012f). This Order was effective immediately and directed the nuclear power plants to provide FLEX in response to beyond-design-basis external events. The nuclear power plants’ Final Integrated Plans provide strategies for maintaining or restoring core cooling, containment cooling, and SFP cooling capabilities for a beyond-design-basis external event. The FLEX strategies and equipment, when coupled with plant procedures, provide a safety benefit, or additional mitigation capability, for certain design-basis events, not just the beyond-design-basis events. The most common application of FLEX is its inclusion in Total Loss of AC Power Event (SBO) Emergency Procedures. The NRC has subsequently amended its regulations to include 10 CFR 50.155, “Mitigation of Beyond-Design-Basis Events,” which made the requirements of Orders EA-12-049 and EA-12-051 (84 FR 39684) generically applicable.

As a result of the terrorist attacks of September 11, 2001, the NRC issued EA-02-026, “Order for Interim Safeguards and Security Compensatory Measures” (NRC 2002b), referred to as the ICMs Orders, dated February 25, 2002. The ICMs Orders modified then-operating licenses for commercial power reactor facilities to require compliance with specified interim safeguards and security compensatory measures. Section B.5.b of the ICMs Orders requires licensees to adopt mitigation strategies using readily available resources to maintain or restore core cooling, containment, and SFP cooling capabilities to cope with the loss of large areas of the facility due to large fires and explosions from any cause, including beyond-design-basis aircraft impacts.

Information about the historical evolution of mitigating measures implemented in response to the ICMs Orders is described in the NRC memorandum dated February 4, 2010 (NRC 2010a).[32]

NUREG-2161 (NRC 2014a) provides publicly available consequence estimates of a hypothetical SFP accident initiated by a low-likelihood seismic event at a specific reference plant. The study compares high-density and low-density loading conditions and assesses the benefits of post-9/11 mitigation measures. Past risk studies have shown that storage of spent fuel in a high-density configuration is safe and that the risk of a large release due to an accident is very low. The NUREG-2161 results are consistent with earlier research conclusions that SFPs are robust structures that are likely to withstand severe earthquakes without leaking. The NRC continues to believe, based on this study and previous studies, that high-density storage of spent fuel in pools protects public health and safety.

The purpose of this section is to consider the additional risk from severe accidents in SFPs, which was not considered in the 1996 LR GEIS. This is done by comparing the risk from severe accidents in SFPs to the risk from severe accidents in reactors, including a comparison to the findings in the 1996 LR GEIS.

The environmental impacts of accidents at the spent fuel dry cask storage facilities located at most reactor sites are not explicitly addressed in the 1996 LR GEIS. However, dry cask safety is addressed under 10 CFR Part 72. In general, comparison of the NUREG-2161 (NRC 2014a) SFP risk results to those from dry cask storage studies, specifically NUREG-1864 (NRC 2007a) and supplemental analyses in NUREG-2161, indicates that in some circumstances, the conditional individual LCF risk within 0 to 10 mi would be similar due primarily to the conservative upper bound estimate of the dry cask release as well as the expected effectiveness of protective actions in response to an SFP release. However, conditional results for metrics such as population dose or condemned or interdicted lands are several orders of magnitude lower for dry cask scenarios than the low end of consequences of pool accidents, due to the substantially smaller amount of released material (NUREG-2161; NRC 2014a).

E.3.7.1 Airborne Pathway Impacts

The analysis contained in NUREG-1738 (NRC 2001) assessed the impacts from accidents at a typical SFP at decommissioning nuclear power plants. The impacts assessed include those associated with the airborne pathway impact on human health. The analysis covers a range of decay times for the fuel stored in the SFP, a number of initiating events, and some variations in emergency evacuation times, fission product releases, and seismic hazard. The initiating events included in the analysis are listed below:

- seismic (for central and eastern U.S. sites)[33]

---

[32] Portions of NRC Order EA-02-026 have been rescinded because those requirements were subsequently incorporated into NRC regulations by the 2009 Final Rule on Power Reactor Security Requirements (79 FR 13926).

[33] The seismic risk analysis performed in NUREG-1738 was based on plant-specific seismic hazard estimates for nuclear power plants in the central and eastern United States found in NUREG-1488, *Revised Livermore Seismic Hazard Estimates for 69 Nuclear Power Plant Sites East of the Rocky Mountains* (NRC 1994). As such, nuclear power plants in the western United States, such as Diablo Canyon, San Onofre, and Columbia, were not specifically considered in this study. Nothing in NUREG-1738, or the staff's reliance on it here, undermines the staff's initial conclusion in the 1996 LR GEIS that the impacts of SFP severe accidents will be comparable to reactor severe accidents for all facilities.

- cask drop
- loss of offsite power
- internal fire
- loss of pool cooling
- loss of pool coolant inventory
- accidental aircraft impact (although not deliberate impacts)
- tornado missile

Additional details regarding these airborne pathway impacts are provided in Section E.3.7.1 of the 2013 LR GEIS.

The analysis conducted in NUREG-1738 assumed the plant was in its decommissioning phase and, thus, had fewer protective features for the prevention or mitigation of SFP accidents. Therefore, the impact analysis contained in NUREG-1738 is considered conservative from this perspective. Table E.3-19 summarizes the airborne pathway impact on human health from a severe accident in a SFP (from the NUREG-1738 analysis; NRC 2001) for a time period of 1 month to 2 years following shutdown of the reactor (i.e., a typical refueling outage lasts up to 30 days or longer and, occasionally, a maintenance outage lasts for several months). Ranges are given to account for differences in emergency planning and seismic hazard assumptions. The site characteristics used in NUREG-1738 were those derived from the Surry plant. Thus, Table E.3-19 also presents Surry's plant-specific results from NUREG-1150 (NRC 1990) and from the 1996 LR GEIS.

Table E.3-19 Impacts of Accidents at Spent Fuel Pools from NUREG-1738[(a)]

Impact	Spent Fuel Pools[(b)] (1 month to 2 years decay time) Low Ru Release (range of means)	Spent Fuel Pools[(b)] (1 month to 2 years decay time) High Ru Release (range of means)	Reactors NUREG-1150 Surry (mean)	Reactors NUREG-1150 Surry (95th percentile)	Reactors 1996 LR GEIS Surry (95% UCB)
Individual risk - EF[(c)] (1 mi)	2×10^{-9} to 7×10^{-9}/yr	6×10^{-8} to 1×10^{-7}/yr	1.5×10^{-8}/yr	4×10^{-8}/yr	Not Estimated
Individual risk - LF[(d)] (10 mi)	1×10^{-8}/yr	2×10^{-7}/yr	1.5×10^{-9}/yr	1×10^{-8}/yr	Not Estimated
Total person-rem per year	2.5 to 12 (50 mi)	8 to 60 (50 mi)	6 (50 mi) 30 (entire region)	30 (50 mi) 150 (150 mi)	1,200 (150 mi)
Total early fatality risk	2×10^{-7} to 6×10^{-6}/yr	1×10^{-5} to 5×10^{-4}/yr	1×10^{-6}/yr	3×10^{-6}/yr	1.6×10^{-2}/yr

EF = early fatality risk; LF = latent fatality risk; LR GEIS = Generic Environmental Impact Statement for License Renewal of Nuclear Plants; Ru = ruthenium; UCB = upper confidence bound.

(a) All values are approximate.

(b) Data were obtained from Figures 3.7-3, 3.7-4, 3.7-7, and 3.7-8 of NUREG-1738 (NRC 2001).

(c) The individual early fatality risk within 1 mi (1.6 km) is the frequency (per year) that a person living within 1 mi (1.6 km) of the site boundary will die within a year due to the accident. The entire population within 1 mi (1.6 km) is considered to obtain an average value.

(d) The individual latent cancer fatality risk within 10 mi (16 km) is the frequency (per year) that a person living within 10 mi (16 km) of the plant will die many years later from cancer due to radiation exposure received from the accident. The entire population within 10 mi (16 km) is considered to obtain an average value.

As can be seen in Table E.3-19, the impacts from SFP accidents at the Surry plant (as calculated in NUREG-1738 [NRC 2001]) are generally comparable to or smaller than the analogous NUREG-1150 (NRC 1990) internal event reactor accidents when using the low ruthenium release source term.[34] For the high ruthenium release source term, the NUREG-1738 results are generally higher than the accompanying reactor results from NUREG-1150. For either source term, the NUREG-1738 impacts are much less than the conservative estimates of full power reactor accidents at Surry as estimated in the 1996 LR GEIS.

The impacts stated in NUREG-1738 (NRC 2001) are also similar to those calculated for the resolution of Generic Safety Issue 82, in which NUREG-1353 (NRC 1989c) calculated a best-estimate population dose of 16 person-rem per year.[35] While the NUREG-1738 results are for the Surry plant, individual risk metrics for early fatalities and latent fatalities should be relatively insensitive to the plant-specific surrounding population (see pg. 3-28 of NUREG-1738) because these metrics reflect doses to the close-in population. In addition, while results are presented for both the low and high ruthenium source term, the low ruthenium source term is still viewed as being the more accurate representation. Therefore, the risk and environmental impact from fires in SFPs as analyzed in NUREG-1738 are expected to be comparable to or lower than those from reactor accidents and are bounded by the 1996 LR GEIS.

Since the issuance of NUREG-1738 (NRC 2001), and after the terrorist attacks of September 11, 2001, significant additional analyses have been performed that support the view that the risk of a successful terrorist attack (i.e., one that results in a zirconium fire) is very low at all plants. These analyses were conducted by Sandia National Laboratories and are collectively referred to herein as the “Sandia studies.” The Sandia studies contain sensitive, security-related information and are not available to the public. The Sandia studies considered spent fuel loading patterns and other aspects of a PWR SFP and a BWR SFP, including the role that the circulation of air plays in the cooling of spent fuel. The Sandia studies indicated that there may be a significant amount of time between the initiating event (i.e., the event that causes the SFP water level to drop) and the spent fuel assemblies becoming partially or completely uncovered. In addition, the Sandia studies indicated that for conditions where air cooling may not be effective in preventing a zirconium fire, there is a significant amount of time between the spent fuel becoming uncovered and the possible onset of such a zirconium fire, thereby providing a substantial opportunity for both operator and system event mitigation.

The Sandia studies, which more fully accounted for relevant heat transfer and fluid flow mechanisms, also indicated that air cooling of spent fuel would be sufficient to prevent SFP zirconium fires at a point much earlier following fuel offload from the reactor than previously considered (e.g., in NUREG-1738). Thus, the fuel is more easily cooled, and the likelihood of a zirconium fire is therefore reduced.

Furthermore, additional mitigation strategies implemented after September 11, 2001, enhance spent fuel coolability and the potential to recover the SFP water level and cooling prior to a potential zirconium fire. The Sandia studies also confirmed the effectiveness of these additional mitigation strategies in maintaining spent fuel cooling in the event the pool is drained and its

---

[34] Due to a concern about the potential release of ruthenium isotopes from the spent fuel stored in the SFP, two sensitivity cases were analyzed in NUREG-1738: one with a ruthenium release fraction of 2×10^{-5} (called the base case or the low ruthenium release case) and another with a ruthenium release fraction of 1.0 (called the high ruthenium release case).

[35] Taken from the Executive Summary of that report: total dose = 8×10^{6} person-rem; event frequency = 2×10^{-6} per year.

initial water inventory is reduced or lost entirely. Based on the more rigorous accident progression analyses, the recent mitigation enhancements, and NRC site evaluations of every SFP in the United States, the risk of an SFP zirconium fire initiation is expected to be less than that reported in NUREG-1738 (NRC 2001) and previous studies.

NUREG-2161, Appendix D (NRC 2014a), used information contained in the *Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor* (SFP Study), to evaluate whether there is a benefit at the reference plant in the study to change from high- to low-density spent fuel storage configurations in the SFP. The analysis in NUREG-2161 calculates the potential benefit per RY resulting from expedited fuel transfer by comparing the safety of high-density spent fuel pool storage relative to low-density fuel pool storage. The comparison uses the initiating frequency and consequences from the SFP Study as an indicator of any changes in the NRC's understanding of safe storage of spent fuel. The staff also used calculated results from previous SFP studies (i.e., NUREG-1353 and NUREG-1738) to extend the applicability of this evaluation to include other initiators that could challenge SFP cooling or integrity. NUREG-2161 concluded that past SFP risk studies have shown that storage of spent fuel in a high-density configuration is safe and the associated risk is low. The NUREG-2161 study is consistent with earlier research conclusions that SFPs are robust structures that are likely to withstand severe earthquakes without leaking. The study estimated that the likelihood of a radiological release from the SFP resulting from the selected severe seismic event analyzed in the study is on the order of one time in 10 million years or lower.

For the hypothetical releases studied (conditional consequences), no early fatalities attributable to acute radiation exposure were predicted and individual LCF risks are projected to be low, but extensive protective actions may be needed. Comparisons of the calculated individual LCF risk within 10 mi to the NRC Safety Goal are provided in Figure E.3-5 (NRC 2014a) to provide context that may help the reader understand the contribution to cancer risks from the accident scenarios that were studied. The NRC Safety Goal for LCF risk from nuclear power plant operation (i.e., 2×10^{-6} or two in one million per year) is set 1,000 times lower than the sum of cancer fatality risks resulting from all other causes (i.e., $\sim 2 \times 10^{-3}$ or two in 1,000 per year). Comparing the study results to the NRC Safety Goal does involve important limitations. First, the safety goal is intended to encompass all accident scenarios for a nuclear facility, whether a reactor or spent fuel pool. This study does not examine all scenarios that would need to be considered in a PRA for a SFP, although seismic contributors are considered the most important contributors to SFP risk. Also, this study represents a mix of limited probabilistic considerations with a deterministic treatment of mitigating features. All analytical techniques, both deterministic and probabilistic, have inherent limitations in scope and method, and also have uncertainty of varying degrees and types. As a result, comparison of the scenario-specific calculated individual LCF risk to the NRC Safety Goal is incomplete. However, it is intended to show how multiple SFP scenarios' risk results are low, in the one in a trillion (10^{-12}) to one in 10 billion (10^{-10}) per year LCF range. While the results of this study are scenario-specific and related to a single SFP, the NRC staff concludes that because these risks are several orders of magnitude smaller than the 2×10^{-6} (two in one million) individual LCF risk that corresponds to the safety goal for LCFs, it is unlikely that the results here would contribute significantly to a risk that would challenge the Commission's safety goal policy (51 FR 30028).

The study results demonstrated that in a high-density loading configuration, a more favorable fuel pattern or successful mitigation generally prevented or reduced the size of potential releases. Low-density loading reduced the size of potential releases but did not affect the likelihood of a release. When a release is predicted to occur, individual early and latent fatality risks for individuals within 10 mi do not vary significantly between the scenarios studied because protective actions, including relocation of the public and land interdiction, were modeled to be effective in limiting exposure. The beneficial effects in the reduction of offsite consequences between a high-density loading scenario and a low-density loading scenario are primarily associated with the reduction in the potential extent of land contamination and associated protective actions. The results of the SFP Study show that the overall level of safety with respect to spent fuel storage in a SFP currently achieved at the reference plant is high and that the level of risk at the reference plant is very low. Applying the NRC's regulatory analysis guidelines to analyze the results of the SFP Study with respect to the quantitative benefits attributable to expedited transfer of spent fuel at the reference plant, and the risk reduction attributable to expedited transfer against the NRC's Safety Goals, the NRC concluded the incremental safety (including risk) reduction associated with expedited transfer of spent fuel at the reference plant is not warranted in light of the added costs involved with expediting the movement of spent fuel from the pool to achieve low-density fuel pool storage. Therefore, an NRC requirement mandating expedited transfer of spent fuel from pools to dry cask storage containers at the reference plant was not justified.

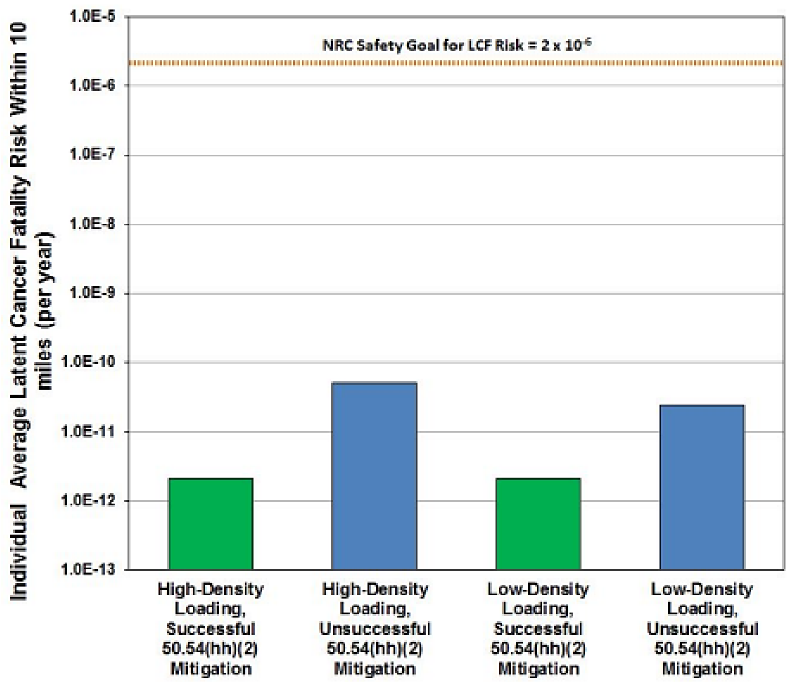


Figure E.3-5 Comparison of Population-Weighted Average Individual Latent Cancer Fatality Risk Results from NUREG-2161 to the NRC Safety Goal. Source: NRC 2014a.[36]

[36] Since publication of NUREG-2161 (NRC 2014a) the requirements formerly in 10 CFR 50.54(hh)(2) have been moved to 10 CFR 50.155(b)(2) as a result of the "Final Rule on Mitigation of Beyond-Design-Basis Events" dated September 9, 2019 (84 FR 39684).

Individual Early Fatality Risk

For all scenarios evaluated in the SFP Study (NRC 2014a), no offsite early fatalities attributable to acute radiation exposure are predicted to occur. Due to radioactive decay, SFPs tend to have significantly fewer shorter-lived radionuclides (e.g., I-131) than reactors. Despite this, in at least one case that was analyzed, doses close to the site did reach levels that can induce early fatalities. Therefore, the potential (although remote) for early fatalities exists. However, emergency response as treated in the SFP Study effectively prevents any early fatality risk from acute radiation exposure, at least in part because the modeled accident progression results in releases that are long compared to the implementation of emergency response in the areas of most concern.

The projection of no early fatalities in the SFP Study is lower than that reported in some previous studies of risks from SFP accidents, such as NUREG/CR-6451 (NRC 1997b) and NUREG-1738 (NRC 2001). This projection is consistent with the earlier studies documented in NUREG-1353 (NRC 1989c). Tables 4.1 and 4.2 of NUREG/CR-6451 project anywhere from approximately 1 to 100 early fatalities within a 500 mi radius in the event of an accident involving the full SFP, with the higher values being associated with high release fractions. NUREG-1738 (Table 3.7-1 and Table 3.7-2) reported similar values, ranging from no fatalities for low ruthenium source terms with early evacuation to up to 192 early fatalities for an accident shortly (30 days) after shutdown with high ruthenium source terms and late evacuation. NUREG-1353 does not provide quantitative estimates of early fatality risk but states that "…there are no 'early' fatalities and the risk of early injury is negligible." On balance, the scenarios analyzed in the SFP Study are consistent with the lower end of the reported range from previous studies, in that no early fatalities are projected to occur.

Individual Latent Cancer Fatality Risk

Despite the large releases under certain circumstances in the SFP Study (NRC 2014a), the risk of LCF to the average individual within 10 mi of the plant is low. When averaged over the likelihood of different event timings and leak sizes, the conditional risks (assuming an event has occurred) within 10 mi are in the 1×10^{-4} to 1×10^{-3} range for cases both with and without successful mitigation and for high-density and low-density cases, when using a LNT dose-response model. This range does not appreciably increase even if the releases for different leak sizes or operating cycle phases are shown separately.

Individual LCF risk is low for the following reasons:

- The predicted release frequency of this event is very small.
- Protective actions, especially those for long-term chronic doses, are estimated to avert significant amounts of public exposure.

Because of the nature of the event, this risk is predominantly from long-term chronic exposures. With effective long-term protective measures (e.g., temporary and permanent land interdiction), essentially no individuals receive any long-term risks greater than those associated with the dose limits for protective actions. Therefore, independent of the release magnitude of the event, these dose limits form an upper limit to individual long-term risk. In addition, emergency response is assumed to be very effective in evacuating and relocating the public. For instance, individuals within the 0 to 10 mi distance (representative of the plume exposure pathway emergency planning zone [EPZ]) essentially only receive LCF risk if they return to low risk, habitable areas. The conditional individual LCF risks within 10 mi are comparable to or lower than the projections from earlier studies of SFP accident risk. For example, NUREG-1738 (NRC 2001) reports conditional individual LCF risks ranging from 8×10^{-4} to 8×10^{-2} for a range of initiating events where large seismic events contributed the most to the overall estimate of risk. These conditional risks were driven largely by the previous estimates of ruthenium volatility and by the effectiveness of evacuation.

When the release frequency is considered, the LCF risks from the events analyzed in the SFP Study are very small—in the 2×10^{-12} to 5×10^{-11} per year range—when using an LNT dose-response model. For perspective, the Commission’s safety goal policy related to the cancer fatality QHO represents a 2×10^{-6} per year objective for an average individual within 10 mi of the nuclear plant site. While the results of the SFP Study are scenario-specific and related to a single SFP, the NRC staff concludes that because these risks are several orders of magnitude smaller than the QHO, it is unlikely that the results would contribute significantly to a risk that would challenge the Commission’s safety goal policy.

Because the health effects that would be induced by low dose radiation are uncertain, the NRC staff performed a sensitivity analysis to understand how the risks would change if computed health risks were limited to those arising from higher doses. The upper truncation level (5 rem annually and 10 rem lifetime) used in this sensitivity analysis corresponds to a treatment consistent with the Health Physics Society's position statement that there is a dose below which, because of uncertainties, a quantified risk should not be assigned. The second truncation level (620 mrem annually) corresponds to the average annual dose to the public from medical and background radiation exposures in the United States. The LCF risks for these truncation levels are even smaller, ranging from 1×10^{-16} to 2×10^{-14} per year.

Subsequent to the regulatory analysis reported in Appendix D of NUREG-2161, the Commission agreed with the NRC staff’s recommendation that no further generic evaluations of SFP risk should be pursued; instead, it directed the staff to evaluate the NRC process for seismic hazard reevaluations, conducted in response to the lessons learned from the Fukushima Dai-ichi accident, with respect to the SFP (NRC 2014d). The NRC staff determined that these seismic hazard reevaluations also include an evaluation of the seismic adequacy of SFPs. These evaluations have been submitted to the NRC for all nuclear power plants. The NRC staff has concluded that each nuclear power plant has implemented the NRC-mandated safety enhancements resulting from the lessons learned from the Fukushima Dai-ichi accident, that all licensees have completed their responses to the 50.54(f) letter for their nuclear power plants, and that no further regulatory decisionmaking is required for nuclear power plants related to the Fukushima lessons learned. Furthermore, with the promulgation of the final MBDBE rule, which addressed certain NTTF recommendations related to SFPs and SBOs, the NRC staff has completed all NTTF recommendations related to SFPs (NRC 2017g).

E.3.7.2 Other Pathway Impacts

Neither the analyses in NUREG-1738 (NRC 2001) nor those in the NUREG-2161 (NRC 2014a) addressed the impacts with respect to the other pathways (open bodies of water and groundwater). The 1996 LR GEIS estimated these impacts for reactor accidents from full power (internal events only) using the results from plant-specific reactor accident analysis to assess the contamination of open bodies of water and from the Liquid Pathway Generic Study (NUREG-0440; NRC 1978) to assess the contamination of groundwater from basemat melt-through accidents.

In both cases, the impacts on human health from surface water and groundwater contamination are only a small fraction of impacts from the airborne pathway, except in a few cases where the impacts are comparable. With the impacts from the airborne pathway associated with SFP accidents (as stated in NUREG-1738) being comparable to the impacts from reactor accidents, as stated in NUREG-1150 (NRC 1990), the impacts from SFP-related surface water and groundwater contamination may also be comparable, even though the SFP fuel inventory is several times that of the reactor. This is due to the lower probability of occurrence of SFP accidents, the effects of decay of the fission products on the radionuclide inventory, and the lower energy density of the fuel inventory, which makes basemat melt-through more unlikely.

The same conclusion can also be drawn with respect to the economic impacts. These impacts are related to the likelihood of the accidents and the cost of cleanup and food interdiction. Even with higher fuel inventories, the lower likelihood of accidents in the SFP reduces the economic impacts. For example, the UCB economic impact identified in Table 5-31 in the 1996 LR GEIS from full power reactor accidents at the Surry plant is approximately $1.1 million/yr. The worst-case economic impacts estimated in past studies for SFP accidents ranged from approximately $18,000/yr to $120,000/yr.[37]

An issue related to the groundwater pathway that has received significant attention since the issuance of the 1996 LR GEIS is leakage of water from SFPs (or related systems) at Salem Unit 1, Indian Point Units 1 and 2, and the Seabrook plant. Instances of this kind are adequately monitored and addressed via existing regulatory programs and do not fall within the scope of this accidents analysis, but the topic of radionuclides released to groundwater is addressed in Sections 4.5.1.2.7 of this LR GEIS. For more information about this topic, the reader is referred to NUREG-0933, Supplement 35, Section 3, Issue 202 (NRC 2011b) and (NRC 2008).

E.3.7.3 Conclusion

In summary, the NRC staff concluded in the 2013 LR GEIS that the environmental impacts from accidents at SFPs, as quantified in NUREG-1738 (NRC 2001), can be comparable to those from reactor accidents at full power, as estimated in NUREG-1150 (NRC 1990). Mitigative measures employed since 2001 have further lowered the risk of this class of accidents. In addition, even the conservative estimates of impacts from NUREG-1738 are much less than those from full power reactor accidents as estimated in the 1996 LR GEIS. NUREG-2161 (NRC 2014a), *Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor*, reinforced the results of earlier studies of the safety of U.S. commercial nuclear power plant SFPs. FLEX capabilities include SFP cooling, which contributes to the plant safety for events involving total loss of AC power. Therefore, the environmental impacts stated in the 1996 LR GEIS continue to bound the impact from SFP accidents.

E.3.8 Impact of the Use of BEIR VII Risk Coefficients

Section 5.3.3.2.2 from the 1996 LR GEIS discussed adverse health effects from exposure to radiation and referenced several National Academy of Sciences reports (BEIR I, III, and V; National Research Council 1972, National Research Council 1980, National Research Council 1990) as sources of risk coefficients for fatal cancers (i.e., latent fatalities) associated with radiation exposure. Benchmark evaluations of the EI methodology employed by the

---

[37] The former estimate uses information from Tables C.95 and C.101 of NUREG/BR–0184 (NRC 1997f), while the latter uses information from Tables 5.1.1 and 5.1.2 of NUREG-1353 (NRC 1989c).

1996 LR GEIS were conducted using the MACCS code, as described in Section 5.3.3.2.3 of the 1996 LR GEIS. The MACCS code version used in 1996 LR GEIS was a predecessor of the MACCS code version currently in use, and it represented the state-of-the-art for assessing risks associated with postulated severe reactor accidents at that time. A MACCS code-to-code comparison used a linear cancer model based on the BEIR V report (National Research Council 1990). The code-to-code comparisons suggest that latent fatality values in the original EISs are an order of magnitude too low. Therefore, to account for this, the latent fatality results predicted from the original EIS values were multiplied by a factor of 10 to obtain the final predicted latent fatality results in the 1996 LR GEIS. This adjustment, in combination with the use of 95th percentile UCB values, ensured that the basis for health effects would be conservative.

In 2006, the National Research Council's Committee on the 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 (see Section 3.9.1.4 and Appendix D of the 2013 LR GEIS for more information). The BEIR VII report estimates that the fatal cancer risk coefficient is approximately 20 percent higher than the International Commission on Radiological Protection recommendation (as described in ICRP 1991). The difference of 20 percent is within the margin of uncertainty associated with these estimates (see Appendix D.8.1.4 of the 2013 LR GEIS for a detailed discussion of the BEIR VII report). SOARCA demonstrated a considerable reduction in predicted fatal cancer fatalities, as provided in Section E.3.9.

The NRC staff completed a review of the BEIR VII report and documented its findings in SECY-05-0202 (NRC 2005b). In that paper, the NRC staff 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 staff agreed with the BEIR VII report's major conclusion that current scientific evidence is consistent with the hypothesis that there is a LNT dose-response relationship between exposure to ionizing radiation and the development of cancer in humans. 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. Therefore, the environmental impacts stated in the 1996 LR GEIS continue to be bounding.

E.3.9 Uncertainties

Section 5.3.4 in the 1996 LR GEIS provides a discussion of the uncertainties associated with the analysis in the LR GEIS and the original EISs used to estimate the environmental impacts of severe accidents. The uncertainties discussed covered the following:

- the probability of an accident
- the quantity and chemical form of radioactivity released
- atmospheric dispersion modeling for the radioactive plume transport, including:
  - duration, energy release, and in-plant radionuclide decay time
  - meteorological sampling scheme used
  - emergency response effectiveness and warning time
  - dose conversion factors and dose-response relationships for early health consequences
  - dose conversion factors and dose-response relationships for latent health consequences

- chronic exposure pathways and
- economic data and modeling

- assumption of normality for random error components
- the EI method
  - selection of EI parameters
  - selection of distances
  - regressing early fatalities for only large plants and
  - normalization of plants for latent fatalities, costs, and dose

The 1996 LR GEIS recognized that the uncertainties in the estimated impacts could be large (i.e., from a factor of 10 to 1,000). In an attempt to help compensate for uncertainties, the 1996 LR GEIS used very conservative estimates of environmental impacts. These included use of:

- the 95th percentile confidence values in estimating airborne pathway and economic impacts;
- plant-specific analysis for estimating surface water pathway impacts; and
- NUREG-0440 (NRC 1978) results to bound the estimated groundwater pathway impacts.

The staff concluded that even with uncertainties, the environmental impacts estimated in the 1996 LR GEIS were adequate for use.

Many of these same uncertainties also apply to the analysis used in this updated LR GEIS. However, as discussed in Sections E.3.1 through E.3.8 of this LR GEIS revision, more recent information is used to supplement the estimate of the environmental impacts contained in the 1996 LR GEIS. In effect, the assessments contained in Sections E.3.1 through E.3.8 of this revision provide additional information about and insights into items that could be considered areas of uncertainty associated with the 1996 LR GEIS.

This updated information also provides insights into sources of uncertainty in addition to those discussed in the 1996 LR GEIS. Each of the insights from these additional sources of uncertainty is summarized below.

Since the issuance of the 1996 LR GEIS and 2013 LR GEIS updates, the NRC staff has completed several studies that provide insight into the quantitative effects of uncertainties related to consequences. One set of studies stemmed from a potential rulemaking technical bases analysis on Containment Protection and Release Reduction (CPRR) that covered a subset of potential accident scenarios for a few reactor and SFP designs and sites. A second set of studies is the NRC's SOARCA uncertainty analyses, which treated accident progression, radiological release, and health effect uncertainties for one accident scenario each at three different sites in the United States with different reactor designs. Uncertainty insights from the regulatory analyses and from the three SOARCA uncertainty analyses are discussed and summarized below. The scope of studies discussed here focused on the important class of severe accidents involving SBOs and treated BWRs with two different containment types, PWRs with two different containment types, and eight different sites in the United States.

Containment Protection and Release Reduction Regulatory Analysis (2015)

After the Fukushima Dai-ichi accident, one of the potential rulemakings investigated by the NRC was for CPRR. The objective of the CPRR regulatory basis was to determine what, if any, additional requirements were warranted for filtering strategies and severe accident management for BWRs with Mark I and Mark II containments, assuming the installation of severe accident-capable hardened vents per Order EA-13-109. The NRC staff documented its detailed analyses in SECY-15-0085, "Evaluation of the Containment Protection and Release Reduction for Mark I and Mark II Boiling Water Reactors Rulemaking Activities," dated June 18, 2015 (NRC 2015c), as well as in NUREG-2206, *Technical Basis for the Containment Protection and Release Reduction Rulemaking for Boiling Water Reactors with Mark I and Mark II Containments*, issued March 2018 (NRC 2018c).

Because none of the alternatives considered in the study would affect the frequency of core damage accidents (i.e., the change in CDF for each alternative relative to the regulatory status quo baseline was zero), the safety goal screening criteria in the regulatory analysis guidelines could not be used to determine whether each alternative could result in a substantial increase in overall protection of public health and safety. Instead, the NRC staff analyzed regulatory alternatives to directly compare their potential safety benefits to the QHOs for average individual early fatality risk and average individual LCF risk, using conservatively high estimates, as described below. The QHOs are described in the Commission's Safety Goal Policy Statement (51 FR 30028). This necessitated building a PRA that included the following elements:

- accident scenario selection;
- development of core damage event trees to (1) model the impact of equipment failures and operator actions occurring before core damage that affects severe accident progression and the probability that CPRR strategies are successfully implemented, (2) match the initial and boundary conditions used in the thermal-hydraulic simulation of severe accidents in MELCOR, and (3) probabilistically consider mitigating strategies for beyond-design-basis external events required by Order EA-12-049;
- development of accident progression event trees to model the CPRR strategies;
- severe accident progression and source term analyses using the MELCOR code to model (1) reactor systems and containment thermal-hydraulics under severe accident conditions and (2) assessment of source terms—the timing, magnitude, and other characteristics of fission product releases to the environment, which are necessary to assess the offsite radiological consequences associated with releases of radioactive materials to the environment; and
- offsite consequence analyses using the MACCS code to calculate offsite radiological consequences with plant-specific population, economic, land use, weather, and evacuation data for reference Mark I and Mark II sites.

The NRC staff performed a screening analysis for the average individual LCF risk QHO for the relevant plants—all U.S. BWRs with Mark I containments (a total of 22 units at 15 sites) and Mark II containments (a total of 8 units at 5 sites). For this screening analysis, the NRC staff developed a conservatively high estimate of the frequency-weighted average of an individual LCF risk within 10 mi of the plant using the following parameter values:

- an extended loss of alternating current power (ELAP)[38] frequency value of 7×10^{-5} per RY—which represented the highest value among all BWRs with Mark I and Mark II containments;
- a success probability for FLEX equipment of 0.6 per demand—which assumed the implementation of FLEX will successfully mitigate an accident involving an ELAP 6 out of 10 times; and
- a conditional average individual LCF risk of 2×10^{-3} per event—which represented the highest value among all BWRs with Mark I and Mark II containments from the detailed analyses.

In other words, for each of these factors (ELAP frequency, FLEX success probability, conditional individual LCF risk), the analysis chose the most conservative estimate from the population of affected plants and combined them into one conservatively high estimate. The calculation does not represent any individual plant, but rather bounds the risk from any individual plant. These assumed parameter values resulted in a conservatively high estimate of a frequency-weighted individual LCF risk within 10 mi of approximately 7×10^{-8} per RY (labeled as "High-Level Conservative Estimate" in Figure E.3-6), which is over an order of magnitude less than the QHO for an average individual LCF risk of approximately 2×10^{-6} per RY. This conservatively high estimate did not take credit for any of the accident strategies and capabilities described in the 20 CPRR alternatives and sub-alternatives.

The NRC staff also conducted uncertainty and sensitivity analyses on their baseline analyses. The NRC staff performed a parametric Monte Carlo uncertainty analysis (UA) to gain additional perspective of the uncertainty of the point estimate risk evaluation results. The UA considered seismic hazard curves, seismic fragility curves, random equipment failures, operator actions, and consequences. Table E.3-20 summarizes information used to perform the parametric UA; in other words, which parameters in the risk equation were varied and what distributions were used to describe the uncertainties in these parameters. The base case model for the reference Mark I plant (which had the highest surrounding population density of the three Mark I sites analyzed) was used to calculate the results. Figure E.3-6 shows the results of the UA for individual LCF risk within 10 mi of the nuclear power plant. The vertical line above each regulatory sub-alternative on the X-axis shows the distribution of results for that alternative. Alternate 1 is the "status quo" (or do nothing new) option. As can be seen, the status quo 95th percentile for individual LCF risk for the "do nothing" option is well below—almost an order of magnitude lower than the "High-Level Conservative Estimate."

Staff performed additional MACCS sensitivity calculations to analyze the influence of site-to-site variation. Sensitivity analyses were conducted for the following:

- population (low, medium, high)
- evacuation delay (1 hr, 3 hrs, 6 hrs, no evacuation)
- nonevacuating cohort size (0.5 and 5 percent of EPZ population)
- intermediate phase duration (0, 3 months, and 1 year)
- long-term habitability criterion (500 mrem/yr and 2 rem/yr), which can vary among states in the United States

[38] An ELAP is defined as an SBO that lasts longer than the SBO coping duration specified in 10 CFR 50.63, "Loss of all alternating current power."

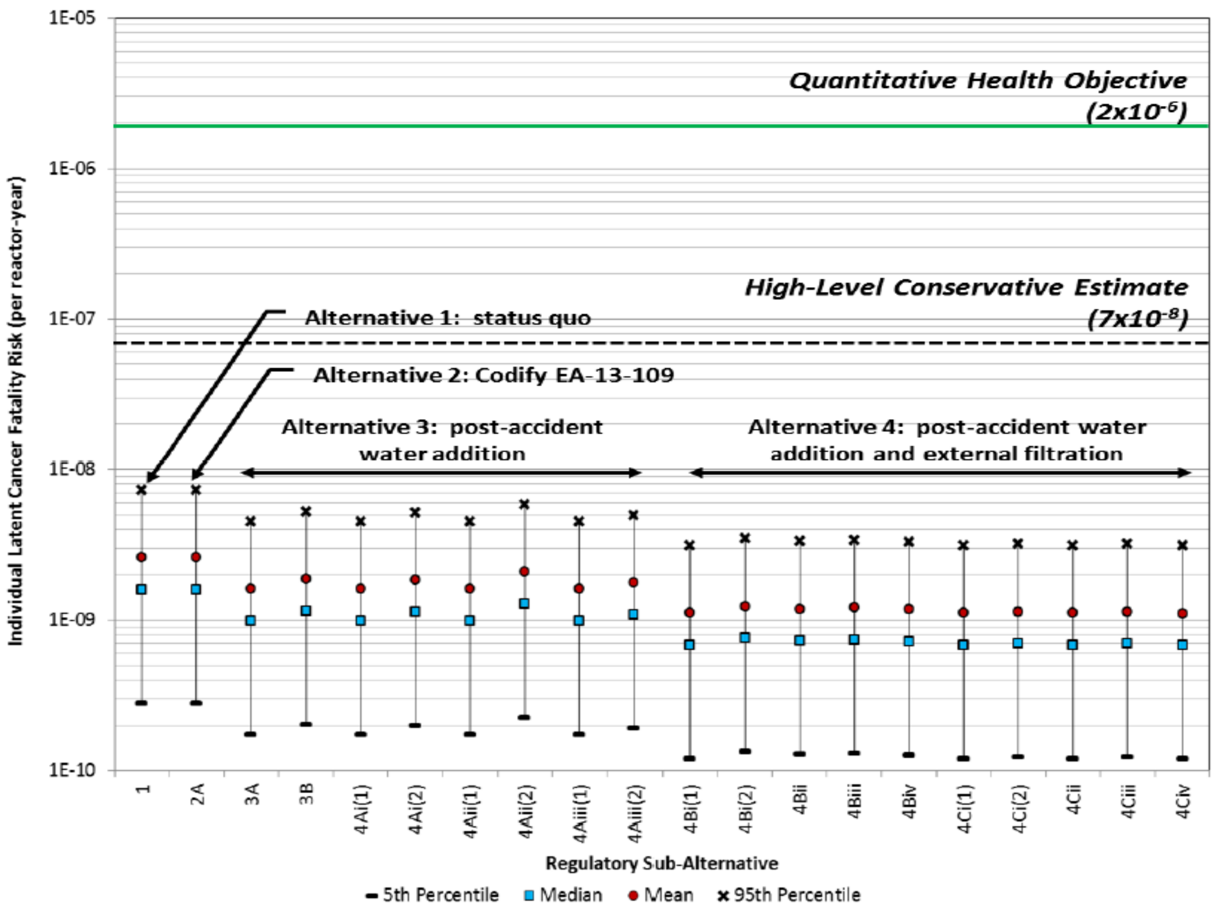


Figure E.3-6 Uncertainty in Average Individual Latent Cancer Fatality Risk (0–10 mi) in the 2015 Containment Protection and Release Reduction Regulatory Analysis. Source: NRC 2015a.

Table E.3-20 Uncertainty Analysis Inputs

Events	Distribution	Remarks
Frequency of ELAPs due to internal events	Lognormal Mean = point estimate Error factor =15	An error factor of 15 maximizes the ratio of the 95th percentile to the mean value. This approach does not explicitly consider the uncertainty in the offsite power recovery curves or the uncertainty in the emergency power system reliability parameters (failure rate and failure-on-demand probability).
Seismic hazard curves	Lognormal	Normal parameters were developed for each point on the seismic hazard curve using the fractile information provided by licensees in their responses to the 10 CFR 50.54(f) information request concerning NTTF Recommendation 2.1.
Seismic fragilities	Double lognormal, using the developed values of C_{50}, β_R, and β_U	Traditional approach to modeling uncertainty in seismic fragility.
Hardware-related failures	Lognormal Mean = point estimate Error factor = 15	An error factor of 15 maximizes the ratio of the 95th percentile to the mean value.

Events	Distribution	Remarks
Human failure events	Constrained non-informative prior	A constrained non-informative prior distribution is a beta distribution with mean = point estimate and α = 0.5.
Conditional consequences	Lognormal Mean = point estimate Error factor = 10	Informed by preliminary results of the SOARCA uncertainty analysis project.

CFR = *Code of Federal Regulations*; ELAP = extended loss of alternating current power; NTTF = Near-Term Task Force; SOARCA = state-of-the-art reactor consequence analysis.
Source: NRC 2018c.

The results of these sensitivity analyses appear in a series of tables in Chapter 4 of NUREG-2206 (NRC 2018c), which report the ratio of the consequences for the sensitivity cases compared to the baseline cases, and to each other. Sensitivity cases were run for each of three different source terms (low, medium, and high) representing cesium releases that spanned four orders of magnitude. Analysis results were most sensitive to the population density surrounding the plants evaluated. Table E.3-21 below shows the results for the different population sensitivity cases on the baseline-case results (i.e., the status quo or do nothing alternative). These tables show the ratio of the risk results for the medium- and high-population cases to the low-population case. For example, the first entry in the “0–10 mi” column under “Individual Latent Cancer Fatality Risk” indicates that the calculated individual LCF risk for 0 to 10 mi from the plant was 1.52 times higher for the medium-population density site compared to the low-population site, and 0.94 times higher for the high-population site compared to the low-population site. The results show that individual LCF risk is relatively insensitive to site data (variations are within 60 percent). Population dose is directly related to population size, so the sensitivity cases show a strong increase in population dose for larger population sites. For example, in the case of the largest difference, for the Mark II high source term case for 0 to 50 mi, the high-population case has a population dose about 11 times larger than the low-population case and about 5 times larger than the medium-population case (i.e., 10.82 divided by 2.06). For all baseline and sensitivity cases, individual early fatality risk is zero.

Of the other sensitivities analyzed, the individual LCF risk was most sensitive to evacuation delay and the long-term habitability criterion. The 0 to 10 mi LCF risk was about a factor of 3 larger compared to the baseline for the most conservative, fastest release source term for the “no evacuation” case. For the alternate long-term habitability criterion, LCF risk showed a maximum increase of a factor of about 2 for the Mark I high-population site file, high source term bin, within 10 mi of the plant. The effects of nonevacuating cohort size and intermediate phase duration on LCF risk were small—within a factor of 20 percent.

Of the other sensitivities analyzed, the population dose was most sensitive to the long-term habitability criterion, for which the 0 to 50 mi population dose showed a maximum increase of 60 percent. The results of the remaining sensitivities on the 0 to 50 mi population dose were very small—within a factor of 10 percent, respectively.

In summary, all of the sensitivity results are well within the large margin for Alternative 1 (status quo) between the 95th percentile to the high-level conservative estimate, and within the even larger margin between the mean estimate and the high-level conservative estimate in Figure E.3-6. In the end, based on the NRC staff’s analyses showing large margins to the QHOs even for the status quo, no new regulatory requirements were imposed for CPRR.

Table E.3-21 Ratio of Consequence Results for Population Density Sensitivity Cases in the 2015 Containment Protection and Release Reduction Regulatory Analysis

Containment Type	Source Term	Population Density Ratio	Individual Latent Cancer Fatality Risk at Distance of 0–10 mi	Individual Latent Cancer Fatality Risk at Distance of 0–50 mi	Individual Latent Cancer Fatality Risk at Distance of 0–100 mi	Population Dose at Distance of 0–50 mi	Population Dose at Distance of 0–100 mi
Mark I	Low	Medium / Low	1.52	0.98	0.90	0.92	1.19
Mark I	Low	High / Low	0.94	0.74	0.96	2.82	2.07
Mark I	Medium	Medium / Low	1.25	0.98	0.97	1.88	2.37
Mark I	Medium	High / Low	1.02	0.83	1.02	5.83	4.00
Mark I	High	Medium / Low	1.23	1.05	1.08	2.26	3.33
Mark I	High	High / Low	1.00	0.89	1.00	6.78	5.04
Mark II	Low	Medium / Low	1.2	0.93	0.49	0.70	1.00
Mark II	Low	High / Low	1.63	1.20	0.69	2.33	2.25
Mark II	Medium	Medium / Low	0.94	9.86	0.49	1.38	1.96
Mark II	Medium	High / Low	1.17	1.03	0.65	6.53	4.82
Mark II	High	Medium / Low	0.89	0.85	0.59	2.06	3.71
Mark II	High	High / Low	1.07	1.04	0.68	10.82	9.32

Source: Table adapted and reproduced from NUREG-2206 (NRC 2018c).

SOARCA Uncertainty Analyses

The NRC, with the assistance of Sandia National Laboratories, conducted three UAs from 2010 to 2019, as part of the SOARCA studies. The SOARCA project was initiated to leverage decades' worth of research into severe accidents and apply modern analytical tools and techniques to develop a body of knowledge about the realistic consequences of severe nuclear reactor accidents (NRC 2012g, NRC 2020c).

The collection of the three SOARCA UAs covers two different types of light water reactors, three different containment designs, and three different locations within the United States. Each UA comprises plant-specific and scenario-specific analyses. The UA for the Peach Bottom plant, a BWR with a Mark I containment, located in Pennsylvania, analyzed the unmitigated LTSBO SOARCA scenario (NUREG/CR–7155, *State of-the-Art Reactor Consequence Analyses (SOARCA) Project: Uncertainty Analysis of the Unmitigated Long-Term Station Blackout of the Peach Bottom Atomic Power Station*, issued in May 2016 [NRC 2016b]). The UA for the Sequoyah plant, a 4-loop Westinghouse PWR, located in Tennessee, analyzed the unmitigated STSBO SOARCA scenario, with a focus on issues unique to the ice condenser containment and the potential for early containment failure due to hydrogen deflagration (NUREG/CR-7245, *State of-the-Art Reactor Consequence Analyses (SOARCA) Project: Sequoyah Integrated Deterministic and Uncertainty Analysis*, issued in October 2019 [NRC 2019h]). The UA for the Surry plant, a three-loop Westinghouse PWR with subatmospheric large dry containment, located in Virginia, analyzed the unmitigated STSBO SOARCA scenario, including the potential for induced SG tube rupture (NUREG/CR-7262, *State-of-the-Art Reactor Consequence Analyses (SOARCA) Project: Uncertainty Analysis of the Unmitigated Short-Term Station Blackout of the Surry Power Station* [NRC 2022d]). A summary of the three UAs is available in NUREG-2254, *Summary of the Uncertainty Analyses for the State-of-the-Art Reactor Consequence Analyses Project* (NRC 2022e).

The SOARCAs were performed primarily using two computer codes, MELCOR for severe accident progression and MACCS (SNL 2021) and its suite of codes for offsite radiological consequences. MELCOR models the following:

- thermal-hydraulic response in the reactor coolant system, reactor cavity (below the reactor vessel), containment, and confinement buildings (e.g., shield building)
- core heatup, degradation (including fuel cladding oxidation, hydrogen production, and fuel melting), and relocation
- core-concrete interaction in the cavity after lower reactor vessel head failure
- hydrogen production, transport, combustion, and mitigation
- fission product transport and release to the environment

The MACCS models the following:

- atmospheric transport and deposition of radionuclides released to the environment
- emergency response and long-term protective actions
- exposure pathways
- acute and long-term doses to a set of tissues and organs

- early and latent health effects for the affected population resulting from the doses[39]

The SOARCA UAs used the existing SOARCA software and models (with some updates) for the three nuclear power plants. In other words, the uncertainty stemming from the choice of conceptual models and model implementation was not explicitly explored, nor was completeness uncertainty (e.g., see NRC's Regulatory Guide 1.174, *An Approach for Using Probabilistic Risk Assessment In Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis*, issued January 2018 [NRC 2018a], or NUREG-1855, *Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decisionmaking*, issued March 2017 [NRC 2017b], for discussion of different types of uncertainty). In addition, the analyses did not include all possible uncertain input parameters. Rather, NRC and Sandia National Laboratories' severe accident experts carefully chose a set of key parameters to capture important influences on the potential release of radioactive material to the environment and on offsite health consequences.

The focus of the UAs was epistemic, or state-of-knowledge, uncertainty in the model parameters. The UAs used a two-step Monte Carlo simulation to propagate parameter uncertainty. From the complete set of MELCOR realizations, a family of radiological source term results was produced. The MACCS sample size (number of realizations) was chosen to match the number of source terms in each UA. The sample sizes for the Peach Bottom, Sequoyah, and Surry plants were 865, 567, and 1,147, respectively. The MACCS results are presented as individual LCF risk and individual early fatality risk, averaged over the random uncertainty stemming from weather (accomplished in the Monte Carlo simulation through a second, inner loop sampling of plant-specific weather conditions in MACCS, for each parameter sample in the outer loop).

Some notable assumptions in the SOARCA UAs include the following:

- Each of the UAs assumed that the accident scenario proceeded without mitigation (e.g., FLEX, 10 CFR 50.155(b), SAMGs, and extensive damage mitigation guidelines are not credited).
- The SOARCA models assume that appropriate planned protective actions (e.g., evacuation, relocation, interdiction, and decontamination of land) will be undertaken and successfully keep doses to the public below habitability criteria in the long-term.
- The SOARCA models assume that 99.5 percent of the population residing in the 10 mi EPZ will evacuate as ordered.
- Shadow evacuations—the voluntary evacuation of members of the public who have not been ordered to evacuate—are also modeled for 10 to 15 mi or 10 to 20 mi radius annular rings around the plants.

Through the use of expert judgment and iteration after interim reviews by the independent technical reviewers (see Appendix B to NUREG-1935; NRC 2012g) and members of the NRC's Advisory Committee on Reactor Safeguards, key MELCOR parameters and key MACCS parameter groups were identified for inclusion in each of the UAs, and distributions were defined for each uncertain parameter (or parameter group).

[39] MACCS can also model economic and societal consequences, such as the population subject to protective actions; however, the SOARCA project did not use them.

The MELCOR uncertainty parameters were selected to capture the following:

- accident sequence issues
- accident progression issues within the reactor vessel
- accident progression issues outside the reactor vessel
- containment behavior issues
- fission product release, transport, and deposition upon plant structures

These broad areas span the severe accident progression over time, ranging from sequence variations to uncertainties in the core damage, melt progression, and fission product transport and release.

The parameters selected from the MACCS consequence model were those that affect (either directly or indirectly) individual LCF risk and individual early fatality risk due to the following:

- cloudshine during radiological plume passage[40]
- groundshine from deposited radionuclides
- inhalation during plume passage and following plume passage from resuspension of deposited radionuclides

Parameters related to emergency response were also varied. Although there is confidence in planned emergency response actions, an emergency is a dynamic event with uncertainties in elements of the response. The following three emergency planning parameter sets were selected:

- hotspot and normal relocation criteria
- evacuation delay
- evacuation speed

Table E.3-22 shows the set of MELCOR parameters that were varied in the three SOARCA UAs. Table E.3-23 shows the set of MACCS parameters that were varied in the three SOARCA UAs; the parameters that were varied in only a subset of the UAs are footnoted.

Table E.3-22 Uncertain MELCOR Parameters Chosen for the SOARCA Unmitigated Station Blackout Uncertainty Analyses

Peach Bottom – BWR with Mark I Containment	Sequoyah – PWR with Ice Condenser Containment	Surry – PWR with Large, Dry Subatmospheric Containment
Sequence-Related: SRV stochastic failure to reclose Battery duration	**Sequence-Related:** Primary SV stochastic number of cycles until failure to close Primary SV open area fraction after failure Secondary SV stochastic number of cycles until failure to close Secondary SV open area fraction after failure	**Sequence-Related:** Primary SV stochastic number of cycles until failure to close Primary SV open area fraction after failure Secondary SV stochastic number of cycles until failure to close Secondary SV open area fraction after failure

[40] This is included in the Peach Bottom UA only.

Peach Bottom – BWR with Mark I Containment	Sequoyah – PWR with Ice Condenser Containment	Surry – PWR with Large, Dry Subatmospheric Containment
		Reactor coolant pump seal leakage Normalized temperature of hottest SG tube SG nondimensional flaw depth Main steam isolation valve leakage
In-Vessel Accident Progression: Zircaloy melt breakout temperature Molten clad drainage rate SRV thermal seizure criterion SRV open area fraction upon thermal seizure Main steam line creep rupture area fraction Fuel failure criterion Radial debris relocation time constants	**In-Vessel Accident Progression:** Melting temperature of the eutectic formed from fuel and zirconium oxides Oxidation kinetics model	**In-Vessel Accident Progression:** Zircaloy melt breakout temperature Molten clad drainage rate Melting temperature of the eutectic formed from fuel and zirconium oxides Oxidation kinetics model
Ex-Vessel Accident Progression and Containment Behavior: Debris lateral relocation—cavity spillover and spreading rate Hydrogen ignition criteria Railroad door open fraction Drywell head flange leakage Drywell liner failure flow area Chemical form of iodine Chemical form of cesium Aerosol density	**Ex-Vessel Accident Progression and Containment Behavior:** Lower flammability limit hydrogen ignition criterion for an ignition source in lower containment Containment rupture pressure Barrier seal open area Barrier seal failure pressure Ice chest door open fraction Aerosol dynamic shape factor	**Ex-Vessel Accident Progression and Containment Behavior:** Hydrogen ignition criteria Containment design leakage rate Containment fragility curve Containment convection heat transfer coefficient Chemical form of iodine Chemical form of cesium Aerosol dynamic shape factor Secondary-side decontamination factor
Time within the Fuel Cycle: Not varied	**Time within the Fuel Cycle:** Time in cycle sampled at three points in the refueling cycle—near beginning of cycle, middle of cycle, and end of cycle	**Time within the Fuel Cycle:** Time in cycle sampled discretely at 14 times from 0.5 days to 550 days

BWR = boiling water reactor; PWR= pressurized water reactor; SG = steam generator; SOARCA = State-of-the-Art Reactor Consequence Analyses Project; SRV = safety relief valve; SV = safety valve.
Source: Ghosh et al. 2021.

Table E.3-23 Uncertain MACCS Parameter Groups Used in the SOARCA Unmitigated Station Blackout Uncertainty Analyses

Epistemic Uncertainty
Dispersion
Crosswind Dispersion Linear Coefficient
Vertical Dispersion Linear Coefficient
Time-Based Crosswind Dispersion Coefficient[(a)]
Deposition
Wet Deposition Coefficient
Dry Deposition Velocities
Emergency Response
Evacuation Delay
Evacuation Speed
Hotspot Relocation Time
Normal Relocation Time
Hotspot Relocation Dose
Normal Relocation Dose
Keyhole Weather Forecast[(b)]
Shielding Factors
Cloudshine Shielding Factors[(c)]
Groundshine Shielding Factors
Inhalation Protection Factors
Early Health Effects
Early Health Effects LD_{50} Parameter
Early Health Effects Exponential Parameter
Early Health Effects Threshold Dose
Latent Health Effects
Dose and Dose Rate Effectiveness Factor
Lifetime Cancer Fatality Risk Factors
Long-Term Inhalation Dose Coefficients
Aleatory Uncertainty
Weather

LD_{50} = median lethal dose; MACCS = MELCOR Accident Consequence Code System; SOARCA = State-of-the-Art Reactor Consequence Analyses Project.
(a) This is included in the Sequoyah and Surry UAs only.
(b) This is included in the Sequoyah UA only.
(c) This is included in the Peach Bottom UA only.
Source: Ghosh et al. 2021.

Conditional (i.e., assuming the severe accident occurred) individual LCF risk and conditional early fatality risks at various distances out to 50 mi from the plant were the offsite consequence metrics reported in the SOARCA UAs. Table E.3-24 shows the LCF risk results for the Peach Bottom UA (NRC 2016b), Figure E.3-7 shows the LCF risk results for the Sequoyah UA (NRC 2019h), and Figure E.3-8 shows the LCF risk results for the Surry UA (NRC 2022d). Note that Table E.3-24 shows results for circular areas—in other words, the results for the 0 to 20 mi radius result column also include 0 to 10 mi radius results, the results for the 0 to 30 mi radius result column also include the 0 to 20 mi radius results, and so on, whereas the annular ring result curves in Figure E.3-7 and Figure E.3-8 are mutually exclusive.

The bimodal nature of the complementary cumulative distribution function curves for Sequoyah plant in Figure E.3-7 derives from the fact that the containment does not fail by 72 hrs (the end of the simulation) in 13 percent of the realizations and does fail before 72 hrs in the remaining 87 percent of the realizations. The cases with no containment failure account for the upper left (very low risk) portion of the complementary cumulative distribution function curves; the cases with containment failure account for the right-hand (relatively higher risk) portion of the complementary cumulative distribution function curves. In Figure E.3-8 for the Surry STSBO UA, the LCF risk distributions also show a bimodal nature. In about 13 percent of the Monte Carlo MELCOR realizations, a consequential SG tube rupture occurred, which accounts for the hump of higher LCF risks in the lower right-hand portion of the graph (corresponding to the portion of the curve below regarding probability of exceedance of 0.13 on the y-axis). These LCF risk results are consistent with the source term results, which showed that the consequential SG tube rupture realizations had the largest and earliest cesium and iodine releases, consistent with containment bypass events (NRC 2022d, NRC 2022e). Traditionally, STSBO accident sequences without and with an induced SG tube rupture would be treated as different categories in a PRA.

The SOARCA UA results show that for populations 0 to 10 mi from the plant, the ratios of the 95th percentile to median LCF risk are about 3 for Peach Bottom, about 3 for Sequoyah, about 10 for Surry STSBO without SG tube rupture, and about 4 for Surry STSBO with induced SG tube rupture. The ratio of the 95th percentile to the mean is lower than the ratio of the 95th percentile to the median because the means of these distributions are skewed to higher percentiles.

Table E.3-24 Population-weighted Individual Latent Cancer Fatality Risk Statistics (based on the linear no-threshold dose-response model) Conditional on the Occurrence of a Long-Term Station Blackout for Five Circular Areas Centered on the Peach Bottom Plant

Statistic Parameter	0–10 mi	0–20 mi	0–30 mi	0–40 mi	0–50 mi
Mean	1.7×10^{-4}	2.8×10^{-4}	2.0×10^{-4}	1.3×10^{-4}	1.0×10^{-4}
Median	1.3×10^{-4}	1.9×10^{-4}	1.3×10^{-4}	8.7×10^{-5}	7.1×10^{-5}
5th percentile	3.1×10^{-5}	4.9×10^{-5}	3.4×10^{-5}	2.2×10^{-5}	1.9×10^{-5}
95th percentile	4.2×10^{-4}	7.7×10^{-4}	5.3×10^{-4}	3.4×10^{-4}	2.7×10^{-4}

Source: NRC 2016b.

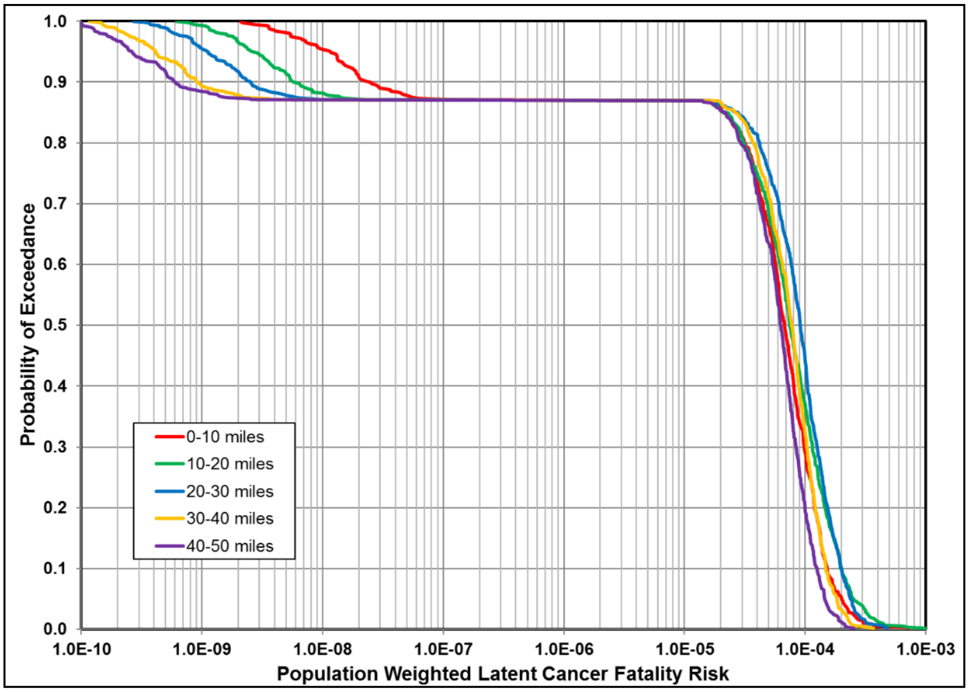


Figure E.3-7 Complementary Cumulative Distribution Functions of Conditional Individual Latent Cancer Fatality Risk within Five Annular Areas Centered on the Sequoyah Plant. Source: NRC 2019h.

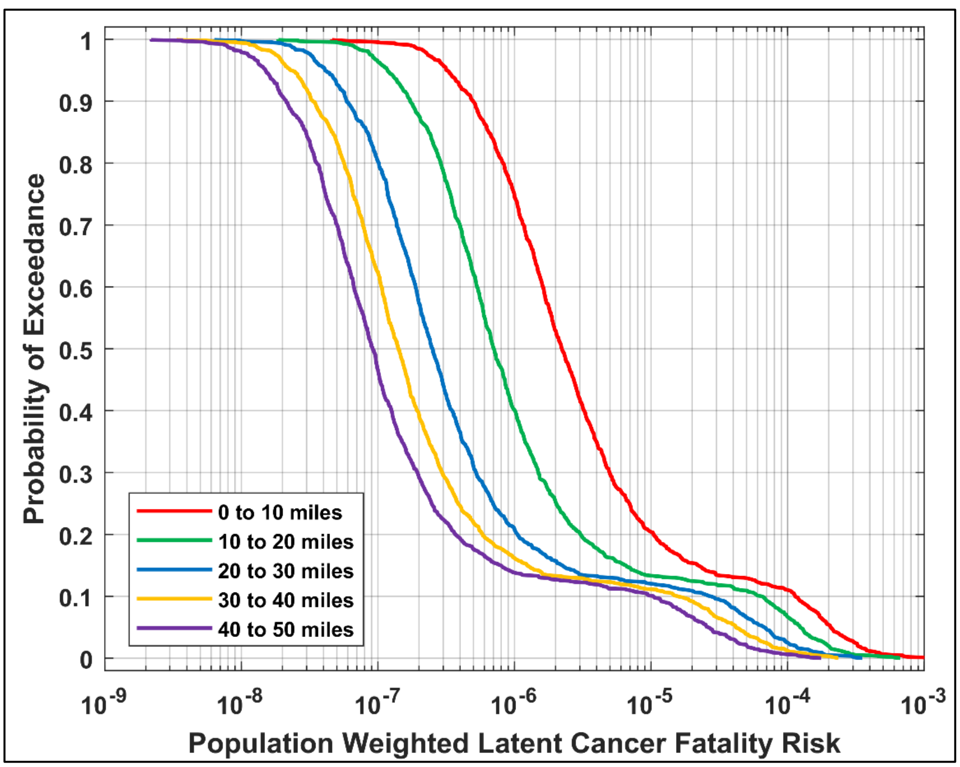


Figure E.3-8 Complementary Cumulative Distribution Functions of Conditional Individual Latent Cancer Fatality Risk within Five Annular Areas Centered on the Surry Plant. Source: NRC 2022d.

Table E.3-25 shows the statistical results for conditional (assuming the severe accident occurred), mean (over weather variability), and individual early fatality risk (per event) from the MACCS UA for the Peach Bottom plant within the specified circular areas. In the SOARCA Peach Bottom UA, the early fatality risks were zero for 87 percent of the 865 realizations, within all specified circular areas. This is because the releases are too low to produce doses large enough to exceed the dose thresholds for early fatalities, even for the 0.5 percent of the population that is modeled as refusing to evacuate. In a minority of realizations, a large-enough source term combined with specific weather trials and uncertain input parameter values resulted in a non-zero computed early fatality risk. At 2.5 mi and beyond in Table E.3-25, the mean result is greater than the 95th percentile. This is due to the few number of non-zero early fatality risks (i.e., less than 5 percent of the realizations) at these distances. This table shows that early fatality risks are negligible (95th percentile less than 6×10^{-12} per RY after considering the scenario frequency), even for the population that resides very close to the plant boundary. The early fatality risks are even lower for the Sequoyah and Surry plants than they are for the Peach Bottom plant.

Table E.3-25 Individual Early Fatality Risk (per Event) Statistics Conditional[(a)] on the Occurrence of a Long-Term Station Blackout for Five Circular Areas with Specified Radii Centered on the Peach Bottom Plant

Statistic Parameter	0–1.3 mi	0–2 mi	0–2.5 mi	0–3 mi	0–3.5 mi
Mean	5×10^{-7}	2×10^{-7}	9×10^{-8}	6×10^{-8}	4×10^{-8}
Median	0.0	0.0	0.0	0.0	0.0
75th percentile	0.0	0.0	0.0	0.0	0.0
95th percentile	2×10^{-6}	7×10^{-7}	4×10^{-8}	5×10^{-10}	0.0

(a) The assessed frequency for this scenario is about 3×10^{-6} per reactor-year.
Source: NRC 2016b.

Conclusions

As noted in the 2013 LR GEIS, the 1996 LR GEIS stated that the uncertainties in the estimated impacts could be large, i.e., from a factor of 10 to 1,000. Since then, the NRC has completed several quantitative analyses for a subset of important severe accident scenarios at nuclear power plants. The CPRR regulatory analysis documented an integrated UA for the Level 1, Level 2, and Level 3 analysis portions of its supporting PRA, and considered a range of different Mark I and Mark II sites encompassing representative low-, medium-, and high-population densities. The SOARCA UAs documented integrated analyses of uncertainties in the Level 2 accident progression and source term and Level 3 offsite consequence analyses (with no new work on Level 1/accident frequencies) for two different PWR containment types and a BWR Mark I plant, encompassing three different sites in total. These detailed quantitative analyses indicate that the 95th percentile bounds of uncertainty are likely to be closer to the lower end of the 1996 projection, about a factor of 10 or less compared to point-estimates, or compared to other central-tendency estimates.

More specifically, for individual LCF risk, recent analyses indicate that there are margins to the LCF risk QHO. The CPRR regulatory analysis and the SOARCA UAs considered integrated uncertainties and sensitivity analyses for the important accident scenarios within the scope of those studies. The results showed an order of magnitude or more margin between the 95th percentile LCF risk results and the QHO (see for example the “Alternative 1: Status Quo” line in Figure E.3-6). The 0 to 10 mi LCF risk metric was within a factor of 3 (of baseline results) in sensitivity analyses for variations in population density and protective action modeling assumptions in the CPRR analysis. The 0 to 10 mi LCF risk metric ratio of the 95th percentile to median was within a factor of 10 in all three SOARCA UAs, which considered integrated uncertainties in the accident progression, source term, and offsite consequence modeling.

For the population dose consequences 0 to 50 mi from the plant, the CPRR regulatory analysis sensitivity results showed a maximum increase of a factor of 5. This maximum factor was the ratio of results for the high-population density site compared to a medium-population density site. The effects of other sensitivities analyzed were even smaller, with maximum increases less than a factor of 2.

In all the studies discussed, early fatality risk was essentially zero or negligible, even considering integrated uncertainties and multiple sensitivities.

E.3.9.1 Emergency Planning

The 1996 LR GEIS (in Section 5.3.4.3) included a discussion of uncertainties associated with emergency planning. However, no quantitative information about the magnitude of these uncertainties was presented. To provide a perspective on the magnitude of the uncertainty, the following information is provided.

NUREG-1150 (NRC 1990) and the SFP accident analysis in NUREG-1738 (NRC 2001) specifically assessed the effect of different emergency planning assumptions on the airborne pathway impacts. NUREG-1150 assessed four alternative emergency response modes in addition to its base case (99.5 percent of the population within 10 mi was evacuated in 4.5 hrs with no sheltering). These alternatives were assessed for reactor accidents from full power, with the Surry and Peach Bottom analyses including seismic and fire-initiated events as well as internal events. For the worst case (no evacuation, no sheltering, or early relocation), the estimated early fatalities per year were approximately a factor of 10 higher than the base case.

The SFP accident analysis in NUREG-1738 also specifically assessed the effect of variations in an emergency evacuation. The variations were assessed relative to the base case used in the NUREG-1150 risk analysis. Doses beyond 20 mi were not calculated. Cases where the evacuation was faster, slower, and where fewer people were evacuated were assessed. As can be expected, improved evacuation scenarios resulted in smaller impacts, and relaxed evacuation scenarios resulted in additional impacts. The impacts associated with relaxed evacuation scenarios increased only a few percent in societal dose (i.e., person-rem) and up to a factor of 10 in early fatalities. However, these impacts are still far below the conservative characterization of the impacts for reactor accidents contained in the 1996 LR GEIS.

More recent analyses have suggested that the significance of the uncertainty in protective actions on health impacts is expected to be a function of the characteristics of the source term being analyzed. In both the CPRR analysis and SOARCA Sequoyah project, the source terms representing the most frequent release categories analyzed were characterized by delayed release, such that protective actions in the early phase effectively limited the doses received. Thus, long-term exposures to lightly contaminated areas after reoccupation tended to be the dominant component of the doses received and thus were suggested to be the most significant contributors to the variation in impacts from uncertainty related to protective actions.

In the CPRR analysis, sensitivity calculations were conducted to estimate the impact that delays in evacuation would have on the LCF risks. Evacuation delays were applied uniformly across evacuation cohorts of 3 hrs, 6 hrs, and a hypothetical situation in which the EPZ population did not evacuate at all, but instead sheltered in place. For the 3-hr evacuation delay, there was no change in LCF risk, whereas the LCF risk for the 6-hr delay doubles LCF risk relative to the base case. For the case in which no evacuation occurs, but instead the population shelters in place, LCF risk increased by 2.5 times over the base case.

The NRC staff noted that these sensitivities simulate "intentionally unrealistic emergency response situations" as detailed emergency response plans are rigorously developed and tested, and it is expected that the plans will be implemented as written.

The SOARCA Sequoyah analysis examined the impact of alternate protective action strategies on conditional LCF. Specifically, sensitivities were performed to look at the implementation of a 12-hr and 48-hr shelter-in-place order prior to evacuation. The conditional mean individual LCF was 2.3 times higher for a 12-hr shelter-in-place order and 3.4 times higher for a 48-hr shelter-in-place order. The NRC staff concludes that the results of new sensitivity analyses for emergency planning are well within the bounds of the quantitative uncertainty results discussed in Section E.3.9 conclusions above.

E.3.9.2 Population Increase

In assessing future airborne and economic impact risks from severe accidents in the 1996 LR GEIS, a composite plant-specific variable called an "exposure index" was introduced and was used to project future risks from previously completed original EISs. The EI values were primarily a function of population distribution around a site and prevailing wind direction, with secondary factors such as terrain, rainfall, and wind stability also considered. As noted in the 1996 LR GEIS, "Because meteorological patterns, including wind direction frequency, tend to remain constant over time, EI changes as populations change or become redistributed." In the 2013 revision of the LR GEIS, the EIs were adjusted from the year 2000 to each plant's mid-year license renewal period based upon population increases to assess the effects of population growth on possible environmental and economic impacts.

The updated estimates of airborne pathway impacts presented in Sections E.3.1 and E.3.2 of this revision are derived from SAMA analyses that were based on population estimates for the initial LR period. By applying the EI framework, the impact of SLR on future PDRs can be approximated by projecting population growth around applicants' sites for this period. The national mean population growth for the 20-year period representing the average SLR years (2040 to 2060) is approximately 20 percent based on U.S. Census Bureau projections (USCB 2021). Plant-specific population changes were estimated from the starting year to the expiration of the subsequent renewal period for the seven sites that have submitted SLR applications from a combination of the information provided in the submitted environmental reports and/or supplemental EISs to NUREG-1437.[41] Applying these growth projections would result in increased impacts ranging from 8 percent to 22 percent over a 20-year period extension, consistent with the national projections.

In summary, the NRC staff concluded that population increase has a minor impact projecting into an SLR period as it would for an initial LR period. However, the environmental impacts from

[41] Where the information was available, offsite population growth was estimated by summing the total increase in the population of counties that lay either partly or completely within 50 mi of the plant sites. Otherwise, population growth was approximated from the information provided in the GEIS supplemental EISs for the "region of influence."

events initiated by all hazards (specifically, consequence-weighted population dose) are generally significantly lower (by one or more orders of magnitude) than those used in the 1996 LR GEIS. In addition, as cited above, plant improvements made in response to NRC Orders and industry initiatives have contributed to the improved safety of all plants during both full power operation and low power and shutdown operation. The NRC staff concludes that the new information from the population projections is not significant for the purposes of this LR GEIS revision, that risk is being effectively addressed and reduced by the various NRC regulatory programs and other initiatives, and therefore, population increases are not expected to challenge the 1996 LR GEIS 95 percent UCB risk metrics during any SLR time period.

E.4 Severe Accident Mitigation Alternatives

Previously, severe accident mitigation under the issue ‘‘Severe accidents’’ was the focus for a plant-specific review because the other aspects of the issue, specifically the offsite consequences, have been adequately addressed in the LR GEIS (61 FR 28467, page 28474). The Statement of Considerations to 61 FR 28467 concluded the [LR] GEIS analysis of severe accident consequences and risk is adequate, and additional plant-specific analysis of these impacts is not required. However, because the ongoing regulatory program related to severe accident mitigation (i.e., IPE and IPEEE) had not been completed for all plants and because consideration of SAMAs had not been included in an EIS or supplemental EIS related to plant operations for all plants, a plant site-specific consideration of SAMAs was required upon license renewal for those plants for which this consideration had not been performed. The Commission expected that if these reviews identified any changes as being cost-beneficial, such changes generally would be procedural and programmatic improvements, with any hardware changes being only minor in nature and few in number (61 FR 28467, page 28481). The NRC staff considerations of SAMAs have now been completed and included in an EIS or SEIS for the vast majority of nuclear power plants (see Table E.3-1). All of these analyses indicate that PDRs have decreased since the staff’s determination in the 1996 LR GEIS that the probability-weighted consequences of a severe accident are SMALL. Also, the CPI, IPE, and IPEEE have been completed for all of these nuclear power plants. Therefore, a plant-specific SAMA need not be performed for these plants for SLR (except for Diablo Canyon, Clinton, and Perry because a final EIS has not been issued for license renewal).

As a result, the 2013 LR GEIS concluded the totality of these studies (the completed SAMA analyses, the IPE, the IPEEE, and the CPI) provides a strong basis for the Commission’s decision to not require applicants to perform an additional SAMA analysis in a license renewal application if the NRC had previously evaluated one for that plant. Therefore, applicants for license renewal of those plants that have already had a SAMA analysis considered by the NRC as part of an EIS, supplemental to an EIS or EA, need not perform an additional SAMA analysis for license renewal. These conclusions in the 2013 LR GEIS were drawn after many but not all of the operating plants had completed their SAMA analysis.

Since the issuance of the 2013 LR GEIS, almost all of the remainder of the operating reactor fleet licensees have applied and been approved for initial LR with a plant-specific SAMA having been performed and documented in the NRC staff’s SEISs. In fact, the NRC expects all license renewal applicants that reference this LR GEIS will have previously completed a SAMA analysis, either at the operating license or initial LR stage. These SAMA analyses further confirmed the Commission’s prediction that it did not expect future SAMA analyses to uncover “major plant design changes or modifications that will prove to be cost-beneficial” (61 FR 28467). Collectively, the studies summarized in this appendix (the completed SAMA analyses, the IPE, the IPEEE, the CPI, the CPRR regulatory analysis, the SOARCA project, implementation of NRC Orders and power reactor security requirements following the September 11, 2001 terrorist attacks, implementation of post-Fukushima orders and information requests, implementation of requirements for mitigation of beyond-design-basis events, completion of SFP Study, etc.) provide a strong basis for the decision to not require any additional SAMA analysis in an SLR application.

Furthermore, when dismissing adjudicatory challenges to the Limerick license renewal, the Commission observed, “the exception in section 51.53(c)(3)(ii)(L) operates as the functional equivalent of a Category 1 issue” (Exelon Generation Company, LLC [Limerick Generating Station, Units 1 and 2], CLI-12-19, 76 NRC 377, 386 [2012]). During the course of that proceeding, the Commission contemplated that the exception in Section 51.53(c)(3)(ii)(L) would also apply to an “application for a subsequent license renewal term” (Exelon Generation Company, LLC [Limerick Generating Station, Units 1 and 2], CLI-13-7, 78 NRC 199, 214 [2013]). The Commission explained that “we did not require license renewal applicants for whom SAMAs were considered previously to provide a supplemental SAMA analysis because we determined that one SAMA analysis would uncover most cost-beneficial measures to mitigate both the risk and the effects of severe accidents, thus satisfying our obligations under NEPA” (*Id*. at 210). On review, the Circuit Court of Appeals for the District of Columbia determined, “Given how extensive the first SAMA analysis is, the Commission found a second analysis would not provide enough value to justify the resource expenditure. This determination is reasonable and so is entitled to deference” (*Natural Resources Defense Council v. NRC*, 823 F.3d 641, 652 [D.C. Cir. 2016]). As discussed elsewhere in this section and previously, the additional safety improvements, risk studies, and experience gained from other license renewal reviews provide further support for this determination.

However, during the course of the Limerick license renewal proceeding the Commission recognized the apparent ambiguity in the NRC license renewal regulations:

> which, on the one hand exempt Exelon and similarly-situated license renewal applicants from including a SAMA analysis in their environmental reports, but on the other hand require an applicant to identify any new and significant information of which it is aware.” (See Exelon Generation Company, LLC [Limerick Generation Station, Units 1 and 2], CLI-13-07, 78 NRC 199, [2013]).

The Commission further recognized the NRC’s continuing duty to take a hard look at new and significant information for each major Federal action to be taken. An acceptable approach to evaluating new and potentially significant information with respect to a prior SAMA analysis is provided in NEI 17-04 (NEI 2019), which is endorsed by NRC in Regulatory Guide 4.2, Supplement 1, Revision 2 (NRC 2024).

In Section 5.4 of the 1996 LR GEIS, the purpose and role of SAMAs in the license renewal process are discussed. SAMAs include cost-effective design alternatives and alternatives that involve changes in procedures and training. With respect to this revision of the LR GEIS, the purpose and objectives of SAMAs remain unchanged.

The purpose of this section is to discuss new information regarding SAMAs, including the consideration of the new information regarding the probability-weighted consequence assessments presented in this revision. It should be noted that since publication of the 1996 and 2013 LR GEISs, many improvements have occurred that have enhanced reactor safety. Some of these improvements are discussed in Sections E.2 and E.3 of this revision and, as can be seen in improved plant performance measures, have been effective.

Even so, the SAMA analyses that have been performed to date have found SAMAs that were cost-beneficial or at least potentially cost-beneficial, subject to further analysis. However, none of the SAMAs identified were related to managing the effects of aging during the period of extended operation. Therefore, they did not need to be implemented as part of license renewal, pursuant to the regulations in 10 CFR Part 54. In general, the cost-beneficial SAMAs were identified for further evaluation by the licensee under the current operating license. In several cases, the applicant has decided to implement the modifications even though they were not related to license renewal (NRC 2006). Furthermore, plant-specific "major" cost-beneficial SAMAs that significantly reduce the risk (Ghosh et al. 2009, NRC 2014b, NRC 2013b) have not been identified in SAMA analyses and almost all currently operating plants having performed a SAMA. This result included consideration of uncertainty, wherein estimated SAMA benefits, developed using the mean point estimate for internal events CDF, were multiplied by an uncertainty factor derived from the ratio of the 95th percentile to the mean point estimate for internal events CDF, which was compared to the estimated implementation cost of the SAMA for the determination of whether it was potentially cost-beneficial. However, as a result of the NRC's ongoing safety oversight, significant improvements in plant safety including reducing the risk of a severe accident initiated by internal or external events have been achieved as a result of processes separate from license renewal such as post-Fukushima Orders for mitigation of beyond-design-basis events. Because these measures have provided additional severe accident mitigation and/or further reduced the risk profile of operating reactors, they decrease the possibility that further SAMA analyses would uncover cost-beneficial SAMAs; as a result, these safety improvements support the NRC's determination that license renewal applicants that have previously completed a SAMA analysis in a NEPA document need not do so again to meet NEPA's rule of reason.

The SAMA analyses performed in support of license renewal focused on the areas of greatest risk (accidents initiated by internal and external events) and on measures that could result in the greatest risk reduction in a cost-beneficial fashion. The environmental impacts of external events are included in an applicant's SAMA analysis for license renewal by following the guidance contained in NEI 05-01, Revision A (NEI 2005). The method described in NEI 05-01 relied upon NUREG/BR-0184 regulatory analysis techniques. The NEI 05-01 guidance (which is endorsed by the NRC in Regulatory Guide 4.2, Supplement 1, Revision 1, *Preparation of Environmental Reports for Nuclear Power Plant License Renewal Applications*, [NRC 2013d]) specifies the consideration of external events when assessing SAMAs. External events are generally considered by multiplying the internal event risk by a factor that accounts for any increase in risk caused by external events (although several SAMA analyses explicitly considered external events). The multiplication factor is determined on a plant-specific basis by considering previous and current external event analyses (e.g., IPEEE). Given the existing information about the contribution to risk from external events, the approach described in NEI 05-01 continues to be a reasonable approach to addressing the external event risk contribution.

This LR GEIS revision has assessed other potential contributors to risk. Therefore, it is reasonable to assess whether those contributors would impact the Commission's prior conclusions on SAMAs or should be included in future SAMA analyses, should an applicant that has not previously conducted a SAMA analysis reference this LR GEIS. Specifically, these contributors are:

- power uprates
- the use of higher-burnup fuel

- accidents during low power and shutdown conditions
- accidents at SFPs
- integrated site risk

With respect to power uprates and the use of higher-burnup fuel, the increased impacts are small compared to the impacts in the 1996 LR GEIS, as indicated in Sections E.3.4 and E.3.5 above, and these factors, as applicable, are included in any severe accident assessment for license renewal. Furthermore, these contributors do not present new accident initiators and are unlikely to result in accident sequences different from those already evaluated in a SAMA evaluation. Lastly, changes in the source term that may result from these contributors are well encompassed within the uncertainty assessment performed for SAMA evaluations. Therefore, no additional SAMA analysis is required.

With respect to severe accidents during low power and shutdown conditions (which are not currently included in SAMA analyses), the risks are generally lower or comparable to those for severe accidents during full power operation depending on the plant configuration. This is in large measure due to nuclear power plants being in a low power or shutdown condition much less frequently compared to full power operation configuration (generally, the frequency is about a factor of 10 less). In addition, NRC and industry initiatives have improved low power and shutdown safety. Specifically, as discussed in Section E.3.6, all nuclear power plant licensees are obligated to comply with the Maintenance Rule, including 10 CFR 50.65(a)(4) for the assessment and management of risk associated with maintenance activities, including during low power operations and plant shutdown configurations. In addition, all licensees are required to comply with NRC Order EA-12-049 (NRC 2012c) to be capable of implementing the mitigating strategies in all modes of plant operation, including full power operations, low power operations, and plant shutdown configurations, and to enhance shutdown risk processes and procedures through incorporation of FLEX equipment acquired to meet the Order requirements. It is also expected that some SAMAs identified as a result of assessing risks from accidents at full power would provide risk reduction benefits for accidents during low power and shutdown conditions. Therefore, the potential for cost-beneficial SAMAs related to low power and shutdown accidents is considered to be less than for accidents at full power. Accordingly, it is reasonable to continue to exclude low power and shutdown conditions from SAMA analysis consideration. Likewise, information regarding low power and shutdown conditions would not change the Commission’s determination to require one SAMA analysis for each facility.

With respect to accidents in SFPs, the risks are substantially less than the population-weighted consequences (radiological dose, early fatalities, latent cancer fatalities) reported in the 1996 LR GEIS and with respect to the NRC safety goals. Additionally, mitigative measures implemented after the attacks of September 11, 2001, and after the accident at the Fukushima Dai-ichi nuclear power plant, have further lowered the risk of this class of accidents, and therefore make the potential for finding cost-effective SAMAs related to SFP accidents substantially less than for reactor accidents. Specifically, as discussed in Section E.3.7, NRC Order EA-12-051 (NRC 2012a) requires that licensees install reliable means of remotely monitoring SFP levels to support effective prioritization of event mitigation and recovery actions in the event of a beyond-design-basis external event. In addition, the staff issued Order EA-12-049 (NRC 2012c), which requires that licensees develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and SFP cooling capabilities after a beyond-design-basis external event. In addition, Section B.5.b of the ICMs Orders requires licensees to adopt mitigation strategies using readily available resources to maintain or restore core cooling, containment, and SFP cooling capabilities to cope with the loss of large areas of the facility due to large fires and explosions from any cause, including beyond-design-basis aircraft impacts. Lastly, while the SFP is not specifically included in the scope of the Maintenance Rule, because of the integral nature of the SFP and the reactor cooling system during reactor shutdown conditions such as refueling, aspects of compliance with the Maintenance Rule also have applicability to the SFP. Specifically, as discussed in Section E.3.6, the scope of the systems, structures, and components to be addressed by the assessment for shutdown conditions include those that are necessary to support the four key safety functions: decay heat removal capability, inventory control, power availability, and reactivity control. Systems, structures, and components associated with the SFP that are necessary to preserve these key safety functions would be included in the scope of the Maintenance Rule (e.g., maintain SFP temperature below specified limits following a shutdown, prevent SFP drain down paths during maintenance activities, support electrical power to maintain cooling to the SFP during shutdown conditions, and preserve reactivity control in the SFP). Therefore, it is reasonable to conclude that accidents at SFPs do not need to be considered in the SAMA analysis. Likewise, information regarding SFP accidents would not change the Commission's determination to require one SAMA analysis for each facility.

Multi-unit and integrated site-level risk was not explicitly addressed in Section E.3 of this appendix. Because the NRC safety goals are expressed on a per-reactor basis, traditional nuclear power plant PRAs assess the risk of a single operating unit only, and separate individual PRAs are developed to assess the risk of each operating unit. As a result, the risk assessment results considered in Section E.3.3 were all for a single unit. Furthermore, the NRC's current risk guidelines in Regulatory Guide 1.174 (NRC 2018a) are applicable to individual units. However, the March 2011 accident at the Fukushima Dai-ichi nuclear power plant highlighted the potential for concurrent severe accidents at multiple co-located nuclear power reactor units. As indicated in Section E.3.3, many nuclear power plant sites in the United States have two operating co-located units and a few have three operating co-located units, all have SFPs, and most have dry cask storage facilities. The NRC Full-Scope Site-Level 3 PRA study, which has not been completed, will be performing an integrated site risk assessment that includes all major site radiological sources, all internal and external initiating event hazards typically considered in internal and external event PRAs, and all modes of plant operation. Major site radiological sources being addressed in this study include reactor cores, SFPs, and dry cask storage.

The Level 3 PRA project is based on a reference site (circa 2012) that includes two Westinghouse four-loop PWRs with large dry containments. The Level 3 PRA project team is leveraging the existing and available information about the reference plant and its licensee PRAs, in addition to related research efforts (e.g., SOARCA), to enhance the study's efficiency. In addition, the Level 3 PRA project is being developed consistent with many of the modeling conventions used for the NRC's standardized plant analysis risk models. Information is available on the NRC's public website at https://www.nrc.gov/about-nrc/regulatory/research/level3-pra-project.htm. The Level 3 PRA project is in an advanced stage, but no results for the integrated site risk assessment have yet been published. In addition to plant CDF and LERF results, the Level 3 PRA project will provide quantitative results for consequences of severe accidents (i.e., Level 3 PRA results), as well as a complete risk profile for a multi-unit site (87 FR 24205). If new and significant information arises out of this project, then that information will need to be considered in license renewal applications. Thus, even though the severe accidents issue is considered to be Category 1, mechanisms are in place to conduct a full plant-specific review if new and significant information warrants such a review.

Mitigative measures implemented after the attacks of September 11, 2001, and the Fukushima Dai-ichi accident are likely to have lowered individual plant risk and integrated site-level risk at nuclear power plants. The implementation of these mitigation methods reduces the potential for finding additional cost-effective SAMAs related to multi-unit or integrated site-level risk. It is also reasonable to expect that some SAMAs identified as a result of assessing risks of accidents at full power would provide risk reduction benefits for multi-unit or integrated site-level accidents. As explained in NEI 05-01 (NEI 2005), SAMA analyses do address multi-unit risk by either assuring that the benefits and implementation costs of SAMAs are on a per-site basis (for example, multiply the maximum benefit of a SAMA for a single unit by the number of units at the site to fully account for its potential benefit) or if SAMA benefits and costs are on a per-unit basis, the impact associated with implementation of the SAMA is reflected in the estimated implementation costs (for example, the estimated cost of a SAMA is divided by the number of units to account for economies of scale in its implementation at each unit). Also, SAMAs that can mitigate risk at all units on the site (e.g., installation of an additional backup power supply) are identified and evaluated. Based on the above discussion, additional information regarding multi-unit risk would not change the Commission's determination to require one SAMA analysis for each facility.

As mentioned above, many severe accident mitigation improvements through processes separate from license renewal (i.e., IPE, the IPEEE, the CPI, implementation of NRC Orders and power reactor security requirements following the September 2001 terrorist attacks, implementation of post-Fukushima Dai-ichi NRC Orders, and information requests etc.) provided plant modifications, procedure changes, and training.

As provided in Section E.2 and elaborated in the paragraphs below, several examples of severe accident mitigations have contributed to improved safety since publication of the 1996 LR GEIS. These actions would lower severe accident risk at NRC-licensed facilities and consequently reduce the likelihood that further SAMA analyses would uncover many cost-beneficial SAMAs that significantly reduce the risk. As a result, they provide further support for the Commission's determination to not require SAMA analyses for facilities that have already performed one.

The IPE and IPEEE specific objective was to develop an appreciation of severe accident behavior, and to identify ways in which the overall probabilities of core damage and fission product releases could be reduced if deemed necessary. In general, the IPEs have resulted in plant procedural and programmatic improvements (i.e., accident management) and, in a few cases, minor plant modifications, to further reduce the risk and consequences of severe accidents (NRC 1996). Examples of plant improvements identified through the IPE program include improved reliability and/or redundancy of AC and direct current power and improved core cooling or injection reliability (NRC 1997a). Examples of plant improvements identified through the IPEEE program include strengthening of seismic supports and enhanced fire brigade training (NRC 2002c). As a result of the IPEEE program, most licensees have made improvements to plant hardware, procedures, or training programs. Although not generally quantified as part of the IPEEE, those improvements are, in many cases, considered to have lowered the reported risk estimates.

The regulatory requirements eventually codified in 10 CFR 50.155(b), formerly 10 CFR 50.54(hh)(2), resulted in enhanced capabilities to "restore core cooling, containment, and SFP cooling capabilities under the circumstances associated with loss of large areas of the plant due to explosions or fire." Under these types of initiating events, the plants now have more diverse capabilities than they did before 2000. Similarly, Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External

Events," dated March 12, 2012 (NRC 2012c), required additional mitigative capabilities associated with the containment function under the conditions of an extended loss of all AC power and loss of normal access to the ultimate heat sink. This NRC Order was effective immediately and directed the nuclear power plants to provide diverse and FLEX in response to beyond-design-basis external events. The nuclear power plant's Final Integrated Plans provide strategies for maintaining or restoring core cooling, containment cooling, and SFP cooling capabilities for a beyond-design-basis external event. The FLEX strategies and equipment, when coupled with plant procedures, provide a safety benefit, or additional mitigation capability, for certain design-basis events, not just the beyond-design-basis events. The magnitude of the FLEX benefit, primarily intended to address LTSBO, is plant-specific and depends on the importance of SBO events in the existing pre-FLEX PRA models.

One of the goals of the original Peach Bottom and Surry SOARCAs was to study the benefits of the then recent 10 CFR 50.54(hh)(2) mitigation measures (formerly "B.5.b") for the accidents analyzed. These mitigation measures include the following for the Peach Bottom (NRC 2013e) and Surry (NRC 2013f) plants:

- portable diesel-fuel powered pumps
- portable generators to provide electricity to power critical instrumentation and to open or close valves
- pre-staged air bottles to open or close air-operated valves
- procedures for controlling steam-turbine-driven pumps without power
- designated makeup water sources

All but one of the SOARCA mitigated scenarios resulted in prevention of core damage, no offsite release of radioactive material, or both. The only mitigated case leading to an offsite release was the Surry STSBO-induced SG tube rupture case. In this case, mitigation was still beneficial in that it kept most radioactive material inside containment and delayed the onset of containment failure by about 2 days (NRC 2020c). The degree to which the 10 CFR 50.54(hh)(2) capabilities are modeled in licensee and agency risk assessments varies widely, and efforts to model the Order EA-12-049 and Order EA-13-109 capabilities are still in progress.

As discussed in Section E.3.9 above, the objective of the CPRR regulatory basis was to determine what, if any, additional requirements were warranted related to filtering strategies and severe accident management for BWRs with Mark I and Mark II containments, assuming the installation of severe accident-capable hardened vents per Order EA-13-109. The results of the NRC staff's detailed analyses are documented in SECY-15-0085, "Evaluation of the Containment Protection and Release Reduction for Mark I and Mark II Boiling Water Reactors Rulemaking Activities," dated June 18, 2015 (NRC 2015c), as well as in NUREG-2206, *Technical Basis for the Containment Protection and Release Reduction Rulemaking for Boiling Water Reactors with Mark I and Mark II Containments*, issued in March 2018 (NRC 2018c). In the end, based on the NRC staff's analyses showing large margins to the QHOs for the baseline and sensitivity cases, no new regulatory requirements were imposed for CPRR.

Other actions to improve safety include identification of specific aging mechanisms (e.g., cables; irradiation-assisted stress corrosion cracking), and development of programs to monitor and control these mechanisms (NRC 2010b, NRC 2017a), and NRC staff actions related to generic safety issues and generic issues (e.g., Generic Safety Issue 191 on sump performance, Generic Issue 199 on seismic risk [NRC 2011b]). The GIP does not formally estimate the holistic, industrywide improvement in nuclear plant safety that results from the implementation of plant changes brought about by the program. However, because the program focuses on potential safety and security issues, regulatory actions that result in plant changes, recommended by the program and approved by the agency, will have a net positive impact on plant and industry safety, despite the lack of quantitative proof. In support of this assertion, NUREG-0933, *Resolution of Generic Safety Issues* (NRC 2011b), provides a historical compilation of all generic safety issues: Three Mile Island Action Plan items (369); Task Action Plan items (142) consisting of Unresolved Safety Issues, legacy Generic Safety Issues, regulatory impact safety issues, licensing issues and environmental issues; “new” generic issues (283); human factors issues (27); and Chernobyl issues (32). Of this total, approximately one-third (281) were resolved with the aid of a regulatory product, including publication of generic letters, revisions to a Regulatory Guide or Standard Review Plan, multi-plant actions, SECYs, policy statements, and staff reports.

In forming its basis for determining which plants needed to submit a SAMA, the Commission noted that all licensees had undergone, or were in the process of undergoing, more detailed plant-specific severe accident mitigation analyses through processes separate from license renewal. Safety improvements were realized from implementation of the NRC Orders[42] and information requests under 10 CFR 50.54(f) (NRC 2012d) after the Fukushima Dai-ichi nuclear power plant accident initiated by the March 2011 Great Tohoku Earthquake and subsequent tsunami. These improvements were for mitigation of beyond-design-basis events that provide for the maintenance or restoration of core cooling, containment, and SFP cooling capabilities and for the acquisition and use of offsite assistance and resources to support these functions.

Developments in the area of SAMGs, which consist of strategies for responding to beyond-design-basis external events, were also enhanced to improve safety. The SAMGs are well-established guidance documents that were developed by the nuclear power industry with substantial NRC involvement and have been implemented by every operating nuclear power reactor licensee. SAMGs were developed using insights and other information from severe accident research and analysis. The intent of SAMGs is to have preplanned strategies that respond to severe accident symptoms based on existing facility equipment and instrumentation with alternatives or compensatory measures as necessary. These strategies focus on stopping the progression of fuel damage and limiting releases to the environment. This guidance improved the technical basis previously issued (e.g., it gave greater consideration to control of combustible gases outside primary containment), but also expanded the scope of that guidance to include accidents during shutdown operations and at SFPs. Thus, the performance and safety record of most nuclear power plants operating in the United States continues to improve. This is also confirmed by analysis, which indicates that, in many cases, improved plant performance and design features have resulted in reductions in initiating event frequency, CDF, and containment failure frequency.[43]

[42] Two of these Orders, EA-12-049 and EA-12-051, were subsequently incorporated into the NRC regulations by the “Final Rule on Mitigation of Beyond-Design-Basis Events” dated September 9, 2019 (84 FR 39684).
[43] This statement is based on industry performance data provided in the NRC’s *2007-2008 Information Digest* (NRC 2007c) and on the NRC’s public website (https://nrcoe.inl.gov/IndustryPerf/), as well as information contained in plant-specific SEIS to NUREG-1437 (https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1437/index.html).

Consequently, the NRC concludes that the information evaluated since the 1996 and 2013 LR GEISs were developed continues to support the Commission's determination that NEPA does not require plants that have already considered SAMAs once in an EA or EIS to do so again. The vast majority, if not all, of the applicants that the NRC expects to apply for license renewal in the coming years will have previously considered SAMAs, either at the initial licensing or initial LR stage. Therefore, to most accurately reflect the agency's NEPA process in most cases, the NRC has determined that severe accidents, including SAMAs, should be classified as a Category 1 issue for facilities that have previously considered SAMAs.

E.5 Summary and Conclusion

The 1996 LR GEIS estimated the environmental impacts on human health and economic factors from full power severe reactor accidents initiated by internal events. Sections E.3.1 through E.3.8 of this LR GEIS revision assessed the impacts of new information and additional accident considerations on the environmental impact of severe accidents contained in the 1996 LR GEIS. In addition, the impact of uncertainties associated with the new information is assessed in Section E.3.9. The purpose of this section is to discuss the aggregate effect of the new information considered in this revised LR GEIS on the environmental impacts and uncertainties stated in the 1996 LR GEIS, and to state what conclusions can be drawn.

The different sources of new information can be generally categorized by their effect of decreasing, not affecting, or increasing the best-estimate environmental impacts associated with postulated severe accidents. Those areas where a decrease in best-estimate impacts would be expected are as follows:

- new internal events information (decreases)
- new source term information (significant decreases)

Areas likely leading to either a small change or no change include the following:

- use of BEIR VII risk coefficients

Lastly, the areas leading to an increase in best-estimate impacts would consist of the following:

- consideration of external events (comparable to internal event impacts)
- low power and shutdown events (could be comparable to at-power event impacts)
- power uprates (small increases)
- higher fuel burnup (small increases)
- new information about SFPs accidents (much less risk than that from full power reactor operations, but is conservatively considered to be comparable to that from full power reactor operations)

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 burnups) 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, was not 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 negligible, or orders of magnitude less than the NRC Safety Goal, and the LCF risk is well below the NRC Safety Goal. However, because the SOARCA 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 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 PDR reported in the 1996 LR GEIS. Because the 1996 LR GEIS did not explicitly consider the contribution from external events in the estimate of the environmental impacts from severe accidents, an explicit consideration would be expected to increase the estimated environmental impacts. However, because the estimates of the probability-weighted consequences reported in the 1996 LR GEIS were intentionally developed to be very conservative, an explicit consideration of the risk from all hazards in this LR GEIS has shown that the probability-weighted dose consequences are bounded by the 1996 LR GEIS estimates. Specifically, 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. Furthermore, the reduction in All Hazards PDR, or probability-weighted dose consequence, ranges from a factor of 3 to over 1,000 and is, on average, about a factor of 120 (or 12,000 percent) less than the corresponding predicted 95 percent UCB values estimated in the 1996 LR GEIS.

The net effect of an increase on the order of 400 to 500 percent and a decrease of more than 10,000 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.

New plant-specific information regarding these conclusions will be assessed for its significance prior to the period of extended operation.

With respect to uncertainties, the 1996 LR GEIS contained an assessment of uncertainties in the information used to estimate the environmental impacts. Section 5.3.4 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, 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 notes that more recent detailed quantitative analyses indicate that the 95th percentile bounds of consequence uncertainty are likely to be closer to the lower end of the 1996 uncertainty range, about a factor of 10 or less, compared to point-estimates or compared to other central-tendency estimates.

Given the discussion in this appendix, the staff concludes that the reduction in environmental impacts from the use of new information (since the 1996 LR GEIS analysis) outweighs any increases resulting from this same information. As a result, the findings in the 1996 LR GEIS remain valid. Therefore, the issue of “Design-basis accidents” is Category 1, and the probability-weighted consequences of severe accidents are SMALL for all plants. In the 2013 LR GEIS, the issue of severe accidents was a Category 2 issue to the extent that only the alternatives to mitigate severe accidents must be considered by license renewal applicants for all plants that have not previously considered such alternatives. This revised LR GEIS provides the technical basis for classifying the issue of “Severe accidents” as Category 1 because SAMA analyses are not likely to be required at the vast majority, if not all, of the facilities that would reference this LR GEIS.

Most license renewal applicants expected to reference this LR GEIS have already completed a SAMA analysis for their nuclear power plants and therefore need not undertake a second analysis per NRC regulations. The totality of the studies and regulatory actions discussed in Section E.4 of this appendix reinforces the Commission’s decision to not require applicants to perform a SAMA analysis in an initial LR or SLR application if the NRC has previously completed a SAMA analysis for their nuclear plant in a NEPA document. Therefore, the impacts of all new information in this update do not contribute sufficiently to the environmental impacts of severe accidents to undermine the Commission’s determination not to require further SAMA analysis because the likelihood of finding cost-effective significant plant improvements is small. Alternatives to mitigate severe accidents still must be considered for all plants that have not considered such alternatives and would be the functional equivalent of a Category 2 issue requiring plant-specific analysis.

Table E.5-1 provides a summary of the conclusions discussed above.

Table E.5-1 Summary of Conclusions

Topic (Section)	Conclusions
New Internal Events Information (Section E.3.1)	New information from the NUREG-1437 supplements about the risk and environmental impacts of severe accidents caused by internal events indicates that PWR and BWR CDFs are significantly less than those forming the basis of the 1996 LR GEIS. On average, internal event CDFs for PWRs have decreased by about a factor of 4 and CDFs for BWRs have decreased by about a factor of 6 compared to the CDFs used in the 1996 LR GEIS. Furthermore, the internal event accident frequencies have further decreased, as reported in recent risk-informed license amendment requests to the NRC. Comparison of PDR risk from newer NUREG-1437 supplements illustrates a reduction in impact by a factor of 2 to 600 compared to the 1996 LR GEIS expected value of the PDR and are, on average, a factor of about 30 lower for both PWRs and BWRs. This would also mean that contamination of open bodies of water and economic impacts would, in most cases, be significantly less. Additionally, the likelihood of basemat melt-through accidents is less than that used in the analysis supporting the 1996 LR GEIS. In general, basemat melt-through sequences are low contributors to estimates of severe accident risk due to their long-developing nature.
Consideration of External Events (Section E.3.2)	The 1996 LR GEIS did not quantitatively consider severe accidents initiated by external events when assessing environmental impacts. New information from the NUREG-1437 supplements about the risk and environmental impacts of severe accidents caused by both internal and external events, from risk-informed license amendment requests submitted by licensees to the NRC, and from licensee responses to the NRC’s Near-Term Task Force (Fukushima) Recommendation 2.1 (NRC 2021) on seismic risk indicates that total PWR and BWR CDFs for all hazards are, on average, about the same as those forming the basis of the 1996 LR GEIS. Furthermore, the environmental impacts from events initiated by all hazards (specifically, probability-weighted population dose) are generally 1 to 3 orders of magnitude lower than those used in the 1996 LR GEIS and, on average, are about a factor of 120 lower than the 1996

Topic (Section)	Conclusions
	LR GEIS 95th percentile upper confidence bound values. In addition, plant improvements made in response to NRC Orders and industry initiatives with respect to reducing the risk of external events have contributed to the improved safety of all plants during both full power operation and low power and shutdown operation. This conclusion would also apply to the contamination of open bodies of water, groundwater, and economic impacts.
New Source Term Information (Section E.3.3)	More recent source term information indicates that the timing from dominant severe accident sequences, as quantified in the SOARCA (NRC 2012g), is much later than the analysis forming the basis of the 1996 LR GEIS. In most cases, the release frequencies and release fractions are significantly lower for the more recent estimate. Furthermore, while the SOARCAs were focused on the most risk-significant accident scenarios and did not evaluate all scenarios, the SOARCA offsite consequence calculations for the three sites evaluated are generally smaller than reported in earlier studies. Specifically, the SOARCA results show essentially zero early fatality risk for the three sites and show a very low individual risk of cancer fatalities for the populations close to the nuclear power plants (i.e., well below the NRC Safety Goal of two long-term cancer fatalities annually in a population of one million individuals). Thus, the environmental impacts estimated using the more recent and realistic source term information are expected to be much lower than the impacts used as the basis for the 1996 LR GEIS (i.e., the frequency-weighted consequences).
Power Uprates (Section E.3.4)	Based on a comparison of the change in LERF for extended power uprates, a small increase in environmental impacts results from the increase in operating power level.
Higher Fuel Burnup (Section E.3.5)	Increased peak fuel burnup from 42 to 75 GWd/MTU for PWRs and 60 to 75 GWd/MTU for BWRs is estimated to result in small increases in the environmental impacts in the event of a severe accident.
Consideration of Low Power and Reactor Shutdown Events (Section E.3.6)	The environmental impacts from accidents under low power and reactor shutdown conditions are generally comparable to those from accidents at full power when comparing the values in SNL 1995 and BNL 1995 to those in the NUREG-1437 supplements. Nonetheless, the 1996 LR GEIS estimates of the environmental impact of severe accidents bound the potential impacts from accidents at low power and reactor shutdown. Finally, safety during low power and shutdown operations has been improved since issuance of the 1996 LR GEIS as a result of (1) industry initiatives taken during the early 1990s, as discussed in SECY-97-168 (NRC 1997c); (2) improved safety of low power and shutdown operation compliance with the Maintenance Rule, including 10 CFR 50.65(a)(4) for the assessment and management of risk associated with maintenance activities, including during low power operations and plant shutdown configurations; and (3) compliance with NRC Order EA-12-049 (NRC 2012c) requiring licensees to be capable of implementing the mitigating strategies for beyond-design-basis external events in all modes of plant operation, including full power operations, low power operations, and plant shutdown configurations.
Consideration of Spent Fuel Pool Accidents (Section E.3.7)	The environmental impacts from accidents at SFPs (as quantified in NUREG-1738; NRC 2001) can be comparable to those from reactor accidents at full power (as estimated in NUREG-1150; NRC 1990). Mitigative measures employed since 2001 have further lowered the risk of this class of accidents. In addition, the conservative estimates from NUREG-1738 (NRC 2001) and NUREG-2161 (NRC 2014a) are much less than the impacts from full power reactor accidents that are estimated in the 1996 LR GEIS.

Topic (Section)	Conclusions
Use of BEIR VII Risk Coefficient (Section E.3.8)	Use of newer risk coefficients such as in BEIR VII is expected to have a small impact on the results presented in the 1996 LR GEIS.
Uncertainties (Section E.3.9)	The impact and magnitude of uncertainties, as estimated in the 1996 LR GEIS, bound the uncertainties introduced by the new information and considerations.
SAMAs (Section E.4)	Most facilities expected to reference this LR GEIS have already completed a SAMA analysis and therefore need not undertake a second per NRC regulations. Moreover, the comprehensive improvements in severe accident risk outside of license renewal have exceeded the current process and scope of SAMA analysis for determining the need for additional mitigative measures.
Summary/ Conclusion (Section E.5)	Given the new and updated information, the reduction in estimated environmental impacts from the use of new internal event and source term information outweighs any increases from the consideration of low power and reactor shutdown risk, external events, power uprates, higher fuel burnup, and SFP risk.

BEIR VII = Biological Effects of Ionizing Radiation report number VII; BWR = boiling water reactor; CDF = core damage frequency; GEIS = generic environmental impact statement; GWd/MTU = gigawatt-day(s) per metric tonne uranium; LERF = large early release frequency; LR = license renewal; NRC = U.S. Nuclear Regulatory Commission; PWR = pressurized water reactor; PDR = population dose risk; SAMA = severe accident mitigation alternative; SOARCA = state-of-the-art consequence analysis.

E.6 References

10 CFR Part 50. *Code of Federal Regulations*, Title 10, *Energy*, Part 50, “Domestic Licensing of Production and Utilization Facilities.”

10 CFR Part 51. *Code of Federal Regulations*, Title 10, *Energy*, Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.”

10 CFR Part 54. *Code of Federal Regulations*, Title 10, *Energy*, Part 54, “Requirements for Renewal of Operating Licenses for Nuclear Power Plants.”

10 CFR Part 72. *Code of Federal Regulations*, Title 10, *Energy*, Part 72, “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste.”

10 CFR Part 73. *Code of Federal Regulations*, Title 10, *Energy*, Part 73, “Physical Protection of Plants and Materials.”

10 CFR Part 100. *Code of Federal Regulations*, Title 10, *Energy*, Part 100, “Reactor Site Criteria.”

51 FR 30028. August 21, 1986. “Safety Goals for the Operation of Nuclear Power Plants; Policy Statement; Republication.” *Federal Register*, Nuclear Regulatory Commission.

61 FR 28467. June 5, 1996. “Environmental Review for Renewal of Nuclear Power Plant Operating Licenses.” *Federal Register*, Nuclear Regulatory Commission.

64 FR 38551. July 19, 1999. “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants.” Final Rule, *Federal Register*, Nuclear Regulatory Commission.

74 FR 13926. March 27, 2009. "Power Reactor Security Requirements." Final Rule, *Federal Register*, Nuclear Regulatory Commission.

76 FR 72560. November 23, 2011. "Enhancements to Emergency Preparedness Regulations." Final Rule, *Federal Register*, Nuclear Regulatory Commission.

79 FR 13926. March 27, 2009. "Power Reactor Security Requirements." Final Rule, *Federal Register*, Nuclear Regulatory Commission.

84 FR 39684. August 9, 2019. "Mitigation of Beyond-Design-Basis Events." Final Rule, *Federal Register*, Nuclear Regulatory Commission.

87 FR 24205. April 22, 2022. "Level 3 Probabilistic Risk Assessment Project Documentation (Volume 3x)." Draft report; request for comment. *Federal Register*, Nuclear Regulatory Commission.

AEC (U.S. Atomic Energy Commission). 1974a. *Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors*. Regulatory Guide 1.3, Revision 2, Washington, D.C. ADAMS Accession No. ML003739601.

AEC (U.S. Atomic Energy Commission). 1974b. *Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors*. Regulatory Guide 1.4, Revision 2, Washington, D.C. ADAMS Accession No. ML003739614.

Aldrich, D.C., J.L. Sprung, D.J. Alpert, K. Diegert, R.M. Ostmeyer, L.T. Ritchie, D.R. Strip, J.D. Johnson, K. Hansen, and J. Robinson. 1982. *Technical Guidance for Siting Criteria Development*. NUREG/CR-2239, SAND81-1549. ADAMS Accession No. ML072320420.

ANS (American Nuclear Society). 2020. "U.S. Nuclear Capacity Factors: Resiliency and New Realities." Nuclear NewsWire, Downers Grove, Il. Accessed November 6, 2023 at https://www.ans.org/news/article-183/us-nuclear-capacity-factors-resiliency-and-new-realities/.

APS (Arizona Public Service). 2018. Letter from M.L. Lacal to NRC dated October 5, 2018, regarding "Palo Verde Nuclear Generating Station Units 1, 2, and 3 Docket Nos. STN 50-528, 50-529, and 50-530 Response to Request for Additional Information for Risk-Informed Completion Times Supplemental Responses for Items 17.f and 21." Washington, D.C. ADAMS Accession No. ML18278A295.

Baker, D.A., W.J. Bailey, C.E. Beyer, F.C. Bold, and J.J. Tawil. 1988. *Assessment of the Use of Extended Burnup Fuel in Light Water Power Reactors*. NUREG/CR-5009, Pacific Northwest Laboratory, Richland, WA. Accessed April 24, 2023, at https://www.osti.gov/biblio/5655949.

BNL (Brookhaven National Laboratory). 1995. *Evaluation of Potential Severe Accidents During Low Power and Shutdown Operations at Surry, Unit 1, Summary of Results*. NUREG/CR–6144, BNL-NUREG-52399, Volume 1, Upton, NY. ADAMS Accession No. ML18151A386.

Commonwealth of Massachusetts v. U.S. Nuclear Regulatory Commission. (Massachusetts v. NRC). 2013. 708 F.3d 63, 68 (1st Cir. 2013). U.S. Court of Appeals First Circuit Decision, February 25, 2013. Accessed May 8, 2023, at https://cite.case.law/f3d/708/63/.

DiNunno, J.J., F.D. Anderson, R.E. Baker, and R.L. Waterfield. 1962. *Calculation of Distance Factors for Power and Test Reactor Sites*. TID-14844, U.S. Atomic Energy Commission, Washington, D.C. ADAMS Accession No. ML021720780.

Ducros, G., P.P. Malgouyres, M. Kissane, D. Boulaud, and M. Durin. 2001. "Fission product release under severe accidental conditions: general presentation of the program and synthesis of VERCORS 1–6 results." *Nuclear Engineering and Design* 208(2):191-203, Elsevier Academic Press, Cambridge, MA. Available at https://doi.org/10.1016/S0029-5493(01)00376-4.

EPRI (Electric Power Research Institute). 2012. *Seismic Evaluation Guidance – Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic.* Report 1025287, Palo Alto, CA. ADAMS Accession No. ML12333A170.

EPRI/NRC (Electric Power Research Institute/U.S. Nuclear Regulatory Commission). 2005a. *EPRI/NRC-RES, Fire PRA Methodology for Nuclear Power Facilities, Volume 1: Summary and Overview*. EPRI - 1011989, NUREG/CR-6850, Final Report, Rockville, MD. Accessed April 24, 2023, at https://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6850/index.html.

EPRI/NRC (Electric Power Research Institute/U.S. Nuclear Regulatory Commission). 2005b. *EPRI/NRC-RES, Fire PRA Methodology for Nuclear Power Facilities, Volume 2: Detailed Methodology*. EPRI - 1011989, NUREG/CR-6850, Final Report, Rockville, MD. Accessed April 24, 2023, at https://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6850/index.html.

Exelon Generation Company, LLC. 2012. *Limerick Generating Station, Units 1 and 2*. CLI-12-19, 76 NRC 377. NUREG-0750. Volume 78, Book II of II. ADAMS Accession No. ML14259A584.

Exelon Generation Company, LLC. 2013. *Limerick Generating Station, Units 1 and 2*. CLI-13-7, 78 NRC 199. NUREG-0750. Volume 78, Book II of II. ADAMS Accession No. ML15183A194.

Ghosh, T., R. Palla, and D. Helton. 2009. *Perspectives on Severe Accident Mitigation Alternatives for U.S. Plant License Renewal.* Organization for Economic Cooperation and Development Workshop on Severe Accident Management, Bottstein, Switzerland. ADAMS Accession No. ML092750488.

Ghosh, S.T., E. Hossein, A. Hathway, N. Bixler, D. Brooks, M. Dennis, D. Osborn, K. Ross, and K. Wagner. 2021. "State-of-the-Art Reactor Consequence Analyses Project: Uncertainty Analyses for Station Blackout Scenarios." *Nuclear Technology,* 207(3):441–451. Washington, D.C. Accessed May 12, 2023, at https://doi.org/10.1080/00295450.2021.1875737.

ICRP (International Commission on Radiological Protection). 1991. "1990 Recommendations of the International Commission on Radiological Protection." ICRP Publication 60, *Ann. ICRP*, 21(1-3). Pergamon Press, New York, NY. Accessed April 24, 2023, at https://www.icrp.org/publication.asp?id=icrp%20publication%2060.

National Environmental Policy Act of 1969 (NEPA), as amended. 42 U.S.C. § 4321 et seq.

National Research Council. 1972. *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation*. The National Academies Press, Washington, D.C. Accessed April 24, 2023, at https://inis.iaea.org/collection/NCLCollectionStore/_Public/37/004/37004410.pdf.

National Research Council. 1980. *Effects on Populations of Exposure to Low Levels of Ionizing Radiation*. 1980. The National Academies Press, Washington, D.C. Accessed April 24, 2023, at https://nap.nationalacademies.org/catalog/21287/effects-on-populations-of-exposure-to-low-levels-of-ionizing-radiation-1980.

National Research Council. 1990. *Health Effects of Exposure to Low Levels of Ionizing Radiation: BEIR V*. The National Academies Press, Washington, D.C. Accessed April 24, 2023, at https://www.ncbi.nlm.nih.gov/books/NBK218704/.

National Research Council. 2006. *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase II*. Washington, D.C. Accessed May 13, 2023, at https://doi.org/10.17226/11340.

Natural Resources Defense Council v. U.S. Nuclear Regulatory Commission. 823 F.3d 641 (D.C. Cir. 2016). Accessed May 8, 2023, at https://cite.case.law/f3d/823/641/5921839/.

NEI (Nuclear Energy Institute). 2005. *Severe Accident Mitigation Alternatives (SAMA) Analysis Guidance Document*. NEI-05-01, Revision A, Washington, D.C. ADAMS Accession No. ML060530203.

NEI (Nuclear Energy Institute). 2016. *Diverse and Flexible Coping Strategies (FLEX) Implementation Guide*. NEI 12-06 [Rev 4]. Washington, D.C. ADAMS Accession No. ML16354B42.

NEI (Nuclear Energy Institute). 2018. Letter from S.J. Vaughn to NRC dated April 27, 2018, regarding “Submittal of NUMARC 93-01, Rev 4f, ‘Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants’ for NRC Endorsement.” Washington, D.C. ADAMS Accession No. ML18120A069.

NEI (Nuclear Energy Institute). 2019. *Model SLR New and Significant Assessment Approach for SAMA*. NEI 17-04, Revision 1, Washington, D.C. ADAMS Accession No. ML19318D216.

New Jersey Department of Environmental Protection v. U.S. Nuclear Regulatory Commission. 561 F.3d 132 (3rd Cir. 2009). Accessed May 8, 2023, at https://cite.case.law/f3d/561/132/.

NRC (U.S. Nuclear Regulatory Commission). 1975. *An Assessment of Accidents Risks in U.S. Commercial Nuclear Power Plants*. NUREG-75/014, Washington, D.C. ADAMS Accession No. ML083570090.

NRC (U.S. Nuclear Regulatory Commission). 1978. *Liquid Pathway Generic Study Impacts of Accidental Radioactive Releases to the Hydrosphere from Floating and Land-Based Nuclear Power Plants*. (NUREG-0440), Washington, D.C. Accessed May 12, 2023, at https://babel.hathitrust.org/cgi/pt?id=mdp.39015095094713&view=page&seq=3.

NRC (U.S. Nuclear Regulatory Commission). 1982a. *Final Environmental Statement Related to the Operation of Seabrook Station, Units 1 and 2.* NUREG-0854. Docket No. 50-443 and 50-444. Washington, D.C. ADAMS Accession No. ML102290543.

NRC (U.S. Nuclear Regulatory Commission). 1982b. *Final Environmental Statement Related to the Operation of Byron Station, Units 1 and 2*. NUREG-0848. Docket No. STN 50-454 and STN 50-455. Washington, D.C. ADAMS Accession No. ML13269A184.

NRC (U.S. Nuclear Regulatory Commission). 1982c. *Final Environmental Statement Related to the Operation of Clinton Power Station, Unit No. 1.* NUREG-0854. Docket No. 50-461. Washington, D.C. ADAMS Accession No. ML15098A042.

NRC (U.S. Nuclear Regulatory Commission). 1982d. *The Development of Severe Reactor Accident Source Terms: 1957–1981*. NUREG-0773. U.S. Nuclear Regulatory Commission, Washington, D.C. ADAMS Accession No. ML20070D151.

NRC (U.S. Nuclear Regulatory Commission). 1989a. *Final Environmental Statement related to the operation of Comanche Peak Steam Electric Station, Units 1 and 2.* NUREG-0775 Supplement. Docket Nos. 50-445 and 50-446. Washington, D.C. ADAMS Accession No. ML19332D079.

NRC (U.S. Nuclear Regulatory Commission). 1989b. *Final Environmental Statement related to the operation of Limerick Generating Station, Units 1 and 2 Docket Nos. 50-352 and 50-353, Philadelphia Electric Company*. NUREG-0974, Supplement. Washington, D.C. August. ADAMS Accession No. ML11221A204.

NRC (U.S. Nuclear Regulatory Commission). 1989c. *Regulatory Analysis for the Resolution of Generic Issue 82, "Beyond Design Basis Accidents in Spent Fuel Pools."* NUREG-1353. Washington, D.C. ADAMS Accession No. ML082330232.

NRC (U.S. Nuclear Regulatory Commission). 1990. *Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants*. NUREG-1150, Washington, D.C. ADAMS Accession No. ML040140729.

NRC (U.S. Nuclear Regulatory Commission). 1993. *Shutdown and Low Power Operation at Commercial Nuclear Power Plants in the United States, Final Report*. NUREG-1449. Washington, D.C. ADAMS Accession No. ML20057E700.

NRC (U.S. Nuclear Regulatory Commission). 1994. *Revised Livermore Seismic Hazard Estimates for 69 Nuclear Power Plant Sites East of the Rocky Mountains,* Final Report. NUREG-1488. Washington, D.C. ADAMS Accession No. ML052640591.

NRC (U.S. Nuclear Regulatory Commission). 1995a. *Accident Source Terms for Light-Water Nuclear Power Plants.* NUREG-1465, Washington, D.C. ADAMS Accession No. ML041040063.

NRC (U.S. Nuclear Regulatory Agency). 1995b. *Final Environmental Impact Statement Related to the Operation of Watts Bar Nuclear Plant Units Nos. 1 and 2*. NUREG-0498, Supplement No. 1, Washington, D.C. ADAMS Accession No. ML18023A204.

NRC (U.S. Nuclear Regulatory Commission). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*. Volumes 1 and 2, NUREG-1437, Washington, D.C. ADAMS Accession Nos. ML040690705, ML040690738.

NRC (U.S. Nuclear Regulatory Commission). 1997a. *Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance*. Volume 1, Part 1 Final Summary Report and Volume 2, Parts 2-5, Final Report, NUREG-1560, Washington, D.C. Accessed April 24, 2023, at https://www.osti.gov/biblio/569125.

NRC (U.S. Nuclear Regulatory Commission). 1997b. *A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants*. NUREG/CR-6451, BNL-NUREG-52498. Nuclear Regulatory Commission, Washington, D.C. ADAMS Accession No. ML082260098.

NRC (U.S. Nuclear Regulatory Commission). 1997c. Memorandum from L.J. Callan to The Commissioners, dated July 30, 1997, regarding "Issuance for Public Comment of Proposed Rulemaking Package for Shutdown and Fuel Storage Pool Operation." SECY-97-168, Washington, D.C. Available at: https://www.nrc.gov/reading-rm/doc-collections/commission/secys/1997/secy1997-168/1997-168scy.pdf.

NRC (U.S. Nuclear Regulatory Commission). 1997d. Memorandum from J.C. Hoyle to L.J. Callan, dated December 11, 1997, regarding "Staff Requirements - SECY-97-168 - Issuance for Public Comment of Proposed Rulemaking Package for Shutdown and Fuel Storage Pool Operation." SRM-97-168, Washington, D.C. ADAMS Accession No. ML003752569.

NRC (U.S. Nuclear Regulatory Commission). 1997e. *Reassessment of Selected Factors Affecting Siting of Nuclear Power Plants*. NUREG/CR-6295, BNL-NUREG-52442. ADAMS Accession No. ML20135F947.

NRC (U.S. Nuclear Regulatory Commission). 1997f. *Regulatory Analysis Technical Evaluation Handbook.* NUREG/BR–0184, Washington, D.C. ADAMS Accession No. ML050190193.

NRC (U.S. Nuclear Regulatory Commission). 1999. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Addendum to Main Report, NUREG-1437, Volume 1, Addendum 1.* Washington, D.C. ADAMS Accession No. ML040690720.

NRC (U.S. Nuclear Regulatory Commission). 2000. *Alternative Radiological Source Terms for Evaluating Design-Basis Accidents at Nuclear Power Reactors.* Regulatory Guide 1.183, Washington, D.C. ADAMS Accession No. ML003716792.

NRC (U.S. Nuclear Regulatory Commission). 2001. *Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants*. NUREG-1738, Washington, D.C. ADAMS Accession No. ML010430066.

NRC (U.S. Nuclear Regulatory Commission). 2002a. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants - Supplement 6 Regarding Surry Power Station, Units 1 and 2. Final Report*. NUREG-1437, Supplement 6, Washington, D.C. ADAMS Accession No. ML023310717.

NRC (U.S. Nuclear Regulatory Commission). 2002b. "In the Matter of All Operating Power Reactor Licensees. Order Modifying Licenses (Effective Immediately)." 7590-01-P. EA-02-026. Washington, D.C. ADAMS Accession No. ML020520754.

NRC (U.S. Nuclear Regulatory Commission). 2002c. *Perspectives Gained from the Individual Plant Examination of External Events (IPEEE), Final Report*. NUREG-1742, Vols. 1 and 2. Washington, D.C. April. ADAMS Accession Nos. ML021270070, ML021270122, and ML021270674.

NRC (U.S. Nuclear Regulatory Commission). 2003. *Review Standard for Extended Power Uprates*. RIS-001, Revision 0. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation. Washington, D.C. ADAMS Accession No. ML033640024.

NRC (U.S. Nuclear Regulatory Commission). 2004. *Protecting Our Nation Since 9-11-01: A Report of the U.S. Nuclear Regulatory Commission*. NUREG/BR-0314. ADAMS Accession No. ML042650352.

NRC (U.S. Nuclear Regulatory Commission). 2005a. Memorandum from F. Eltawila, Director Office of Nuclear Regulatory Research, to M.E. Mayfield, Director, Office of Nuclear Reactor Regulation, dated June 9, 2005, regarding "Generic Issue 199, Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States." Washington, D.C. ADAMS Accession No. ML051600272.

NRC (U.S. Nuclear Regulatory Commission). 2005b. *Policy Issue: Staff Review of the National Academies Study of the Health Risks from Exposure to Low Levels of Ionizing Radiation (BEIR VII)*. SECY-05-0202, Washington, D.C. ADAMS Accession No. ML052640532.

NRC (U.S. Nuclear Regulatory Commission). 2006. *Frequently Asked Questions on License Renewal of Nuclear Power Reactors*, Final Report. NUREG-1850, Washington, D.C. March. ADAMS Accession No. ML061110022.

NRC (U.S. Nuclear Regulatory Commission). 2007a. *A Pilot Probabilistic Risk Assessment Of a Dry Cask Storage System At a Nuclear Power Plant*. NUREG-1864. Washington, D.C. ADAMS Accession No. ML071340012.

NRC (U.S. Nuclear Regulatory Commission). 2007b. *Nuclear Regulatory Commission Issuances. Opinions and Decisions of the Nuclear Regulatory Commission with Selected Orders January 1, 2007 - June 30, 2007.* NUREG-0750. Volume 65. ADAMS Accession No. ML090860385.

NRC (U.S. Nuclear Regulatory Commission). 2007c. *2007-2008 Information Digest*. NUREG-1350, Volume 19. Washington, D.C. ADAMS Accession No. ML072960367.

NRC (U.S. Nuclear Regulatory Commission). 2007d. Memorandum from S.N. Bailey, Senior Project Manager, NRC, to J. Scarola, Vice President, Brunswick Steam Electric Plant, dated August 9, 2007, regarding "Brunswick Steam Electric Plant, Units 1 and 2—Conforming License Amendments to Incorporate the Mitigation Strategies Required by Section B.5.b. of Commission Order EA-02-026 and the Radiological Protection Mitigation Strategies Required by Commission Order EA-06-137 (TAC Nos. MD4516 and MD4517)." Washington, D.C. ADAMS Accession No. ML072070375.

NRC (U.S. Nuclear Regulatory Commission). 2008. Letter from M.K. Gamberoni to Entergy Nuclear Operations, Inc., dated May 13, 2008, regarding "Indian Point Nuclear Generating Units 1 & 2 - NRC Inspection Report. Nos. 05000003/2007010 and 05000247/2007010 - Docket Nos. 50-003 and 50-247." Washington, D.C. ADAMS Accession No. ML081340425.

NRC (U.S. Nuclear Regulatory Commission). 2009. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants—Supplement 35 Regarding Susquehanna Steam Electric Station Units 1 and 2. Final Report.* NUREG-1437, Supplement 35, Washington, D.C. ADAMS Accession No. ML090700454.

NRC (U.S. Nuclear Regulatory Commission). 2010a. Memorandum from R.W. Borchardt to Chairman Jaczko, Commissioner Klein, Commissioner Svinicki, dated February 4, 2010, regarding "Documentation of Evolution of Security Requirements at Commercial Nuclear Power Plants With Respect to Mitigation Measures for Large Fires and Explosions." SECY-2008-0648, Washington, D.C. ADAMS Accession No. ML092990438.

NRC (U.S. Nuclear Regulatory Commission). 2010b. *Generic Aging Lessons Learned (GALL) Report, Final Report.* NUREG-1801, Rev. 2. Washington, D.C. ADAMS Accession No. ML103490041.

NRC (U.S. Regulatory Commission). 2010c. *The Evolution of Mitigating Measures for Large Fire and Explosions, A Chronological History From September 11, 2001 Through October 7, 2009*. Washington, D.C. ADAMS Accession No. ML092990417.

NRC (U.S. Nuclear Regulatory Commission). 2011a. *Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident.* SECY-11-0093, NRC Task Force, Washington, D.C. ADAMS Accession No. ML11186A950.

NRC (U.S. Nuclear Regulatory Commission). 2011b. *Resolution of Generic Safety Issues*. NUREG-0933, Main Report with Supplements 1-35, Washington, D.C. Accessed May 12, 2023, at https://www.nrc.gov/sr0933/index.html.

NRC (U.S. Nuclear Regulatory Commission). 2011c. *Prioritization of Recommended Actions to Be Taken in Response to Fukushima Lessons Learned.* SECY-11-0137, NRC Task Force, Washington, D.C. ADAMS Accession No. ML11272A111.

NRC (U.S. Nuclear Regulatory Commission). 2011d. *Staff Requirements – SECY-11-0137 – Prioritization of Recommended Actions to Be Taken in Response to Fukushima Lessons Learned.* SRM-SECY-11-0137, Washington, D.C. ADAMS Accession No. ML113490055.

NRC (U.S. Nuclear Regulatory Commission). 2012a. "In the Matter of All Power Reactor Licensees and Holders of Construction Permits in the Active or Deferred Status. Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation (Effective Immediately)." 7590-01-P, EA-12-051, NRC-2012-0067, Washington, D.C. ADAMS Accession No. ML12056A044.

NRC (U.S. Nuclear Regulatory Commission). 2012b. "In the Matter of All Power Reactor Licensees and Holders of Construction Permits in the Active or Deferred Status. Order Modifying Licenses with Regard to Requirements For Mitigation Strategies For Beyond-Design-Basis External Events (Effective Immediately)." 7590-01-P, EA-12-049, NRC-2012-0068, Washington, D.C. ADAMS Accession No. ML12056A045.

NRC (U.S. Nuclear Regulatory Commission). 2012c. Letter from E. Leeds and M. Johnson to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, dated March 12, 2012, regarding "Issuance of Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events." EA-12-049, Washington, D.C. ADAMS Accession No. ML12054A735.

NRC (U.S. Nuclear Regulatory Commission). 2012d. Letter from NRC to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status dated March 12, 2012, regarding “Request for Information Pursuant to Title 10 of the *Code of Federal Regulations* 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident.” Washington, D.C. ADAMS Accession No. ML12056A046.

NRC (U.S. Nuclear Regulatory Commission). 2012e. Memorandum from A. Vietti-Cook to R.W. Borchardt, dated March 9, 2012, regarding “Staff Requirements – SECY-12-0025 Proposed Orders and Requests for Information in Response to Lessons Learned from Japan’s March 11, 2011, Great Tohoku Earthquake and Tsunami.” SRM-12-0025, Washington, D.C. ADAMS Accession No. ML120690347.

NRC (U.S. Nuclear Regulatory Commission). 2012f. *Policy Issue Notation Vote: Proposed Orders and Requests for Information in Response to Lessons Learned from Japan’s March 11, 2011, Great Tohoku Earthquake and Tsunami*. SECY-12-0025, Washington, D.C. ADAMS Accession No. ML12039A111.

NRC (U.S. Nuclear Regulatory Commission). 2012g. *State-of-the-Art Reactor Consequence Analyses (SOARCA) Report.* NUREG-1935, Washington, D.C. ADAMS Accession No. ML12332A057.

NRC (U.S. Nuclear Regulatory Commission). 2012h. Letter from E. Leeds to All Operating Boiling Water Reactor Licensees with Mark I and Mark II Containments, dated March 12, 2012, regarding “Issuance of Order to Modify Licenses with Regard to Reliable Hardened Containment Vents.” EA-12-050, Washington, D.C. ADAMS Accession No. ML12054A694.

NRC (U.S. Nuclear Regulatory Agency). 2013a. *Final Environmental Impact Statement Related to the Operation of Watts Bar Nuclear Plant Units Nos. 1 and 2.* NUREG-0498, Supplement No. 2, Washington, D.C. ADAMS Accession Nos. ML13144A092, ML13144A093.

NRC (U.S. Nuclear Regulatory Commission). 2013b. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* [GEIS]. NUREG-1437, Revision 1, Washington, D.C. ADAMS Package Accession No. ML13107A023.

NRC (U.S. Nuclear Regulatory Commission). 2013c. Letter from D.L. Skeen to NRC dated February 15, 2013, regarding “Electric Power Research Institute; Seismic Evaluation Guidance.” NRC-0213-0038, Rockville, MD. ADAMS Accession No. ML12324A198.

NRC (U.S. Nuclear Regulatory Commission). 2013d. *Preparation of Environmental Reports for Nuclear Power Plant License Renewal Applications*. Regulatory Guide 4.2, Supplement 1, Revision 1, Washington, D.C. ADAMS Accession No. ML13067A354.

NRC (U.S. Nuclear Regulatory Commission). 2013e. *State-of-the-Art Reactor Consequence Analyses Project Volume 1: Peach Bottom Integrated Analysis.* NUREG/CR-7110, Volume 1, Revision 1, Washington, D.C. ADAMS Accession No. ML13150A053.

NRC (U.S. Nuclear Regulatory Commission). 2013f. *State-of-the-Art Reactor Consequence Analyses Project Volume 2: Surry Integrated Analysis.* NUREG/CR-7110, Volume 2, Revision 1, Washington, D.C*.* ADAMS Accession No. ML13240A242.

NRC (U.S. Nuclear Regulatory Commission). 2013g. Letter from E. Leeds to All Operating Boiling Water Reactor Licensees with Mark I and Mark II Containments, dated June 6, 2013, regarding “Issuance of to Order Modify Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions.” EA-13-109, Washington, D.C. ADAMS Accession No. ML13143A321.

NRC (U.S. Nuclear Regulatory Commission). 2014a. *Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor*. NUREG-2161, Washington, D.C. ADAMS Accession No. ML14255A365.

NRC (U.S. Nuclear Regulatory Commission). 2014b. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 49: Regarding Limerick Generating Station, Units 1 and 2, Chapters 1 to 12, Final Report*. NUREG-1437, Supplement 49, Volumes 1 and 2, Washington, D.C. ADAMS Accession Nos. ML14238A284, ML14238A290.

NRC (U.S. Nuclear Regulatory Commission). 2014c. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 50: Regarding Grand Gulf Nuclear Station, Unit 1, Final Report*. NUREG-1437, Supplement 50, Washington, D.C. ADAMS Accession No. ML14328A171.

NRC (U.S. Nuclear Regulatory Commission). 2014d. Memorandum from R.C. Rochelle to M.A. Satorius, dated May 23, 2014, regarding “Staff Evaluation and Recommendation for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel.” NRC SRM-COMSECY-13-0030, Washington, D.C. ADAMS Accession No. ML14143A360.

NRC (U.S. Nuclear Regulatory Commission). 2015a. *Draft Regulatory Basis for Containment Protection and Release Reduction for Mark I and Mark II Boiling Water Reactors (10 CFR Part 50).* SECY-15-0085. Washington, D.C. ADAMS Accession No. ML15022A214.

NRC (U.S. Nuclear Regulatory Commission). 2015b. Letter from W.M. Dean to All Power Reactor Licensees, dated October 27, 2015, regarding “Final Determination of Licensee Seismic Probabilistic Risk Assessments under the Request for Information Pursuant to Title 10 of the *Code of Federal Regulations* (50.54(f) Regarding Recommendation 2.1 ‘Seismic’ of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident.” Washington, D.C. ADAMS Accession No. ML15194A015.

NRC (U.S. Nuclear Regulatory Commission). 2015c. *Policy Issue Notation Vote: Evaluation of the Containment Protection and Release Reduction for Mark I and Mark II Boiling Water Reactors Rulemaking Activities (10 CFR Part 50) (RIN-3150-AJ26).* SECY-15-0085, Washington, D.C. ADAMS Accession No. ML15005A079.

NRC (U.S. Nuclear Regulatory Commission). 2016a. *Probabilistic Risk Assessment and Regulatory Decisionmaking: Some Frequently Asked Questions*. NUREG-2201, Washington, D.C. ADAMS Accession No. ML16245A032.

NRC (U.S. Nuclear Regulatory Commission). 2016b. *State-of-the-Art Reactor Consequence Analyses Project: Uncertainty Analysis of the Unmitigated Long-Term Station Blackout of the Peach Bottom Atomic Power Station*. NUREG/CR-7155, SAND2012-10702P, Washington, D.C. ADAMS Accession No. ML16133A461.

NRC (U.S. Nuclear Regulatory Commission). 2017a. *Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report: Final Report*. NUREG-2191, Volume 1, Washington, D.C. ADAMS Accession No. ML17187A031.

NRC (U.S. Nuclear Regulatory Commission). 2017b. *Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decisionmaking: Final Report*. NUREG-1855, Revision 1, Washington, D.C. ADAMS Accession No. ML17062A466.

NRC (U.S. Nuclear Regulatory Commission). 2017c. *Revision to JLD-ISG-2012-01, Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events*. JLD-ISG-2012-01, Revision 2, Washington, D.C. ADAMS Accession No. ML17005A182.

NRC (U.S. Nuclear Regulatory Commission). 2017d. *Status of Implementation of Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Subsequent Tsunami.* SECY-17-0016, Washington, D.C. ADAMS Accession No. ML16356A084.

NRC (U.S. Nuclear Regulatory Commission). 2017e. *Draft Final Rule: Mitigation of Beyond-Design-Basis Events.* SECY-16-0142, Washington, D.C. ADAMS Accession No. ML16301A005.

NRC (U.S. Nuclear Regulatory Commission). 2017f. Memorandum from V.M. McCree, Executive Director for Operations, to Chairman Svinicki, Commissioner Baran, and Commissioner Burns, dated July 24, 2017, regarding "Supplement to SECY-16-0142, Draft Final Rule - Mitigation of Beyond-Design-Basis Events (RIN 3150-AJ49)." Washington, D.C. ADAMS Accession No. ML17194A764.

NRC (U.S. Nuclear Regulatory Commission). 2017g. *Policy Issue Notation Vote: Status of Implementation of Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Subsequent Tsunami*. SECY-17-0016, Washington, D.C. ADAMS Accession No. ML16356A045.

NRC (U.S. Nuclear Regulatory Commission). 2018a. *An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis*. Regulatory Guide 1.174, Revision 3, Washington, D.C. ADAMS Accession No. ML17317A256.

NRC (U.S. Nuclear Regulatory Commission). 2018b. *Monitoring the Effectiveness of Maintenance at Nuclear Power Plants.* Regulatory Guide 1.160, Revision 4, Washington, D.C. ADAMS Accession No. ML18220B281.

NRC (U.S. Nuclear Regulatory Commission). 2018c. *Technical Basis for the Containment Protection and Release Reduction Rulemaking for Boiling Water Reactors with Mark I and Mark II Containments*. NUREG-2206, Washington, D.C. ADAMS Accession No. ML18065A048.

NRC (U.S. Nuclear Regulatory Commission). 2019a. *SRM-M190124A: Affirmation Session-SECY-16-0142: Final Rule: Mitigation of Beyond-Design-Basis Events (RIN 3150-AJ49)*, Washington, D.C. ADAMS Accession No. ML19023A038.

NRC (U.S. Nuclear Regulatory Commission). 2019b. *Final Rule: Mitigation of Beyond-Design-Basis Events*, Washington, D.C. ADAMS Accession No. ML19058A006.

NRC (U.S. Nuclear Regulatory Commission). 2019c. *Flexible Mitigation Strategies for Beyond-Design-Basis Events.* Regulatory Guide 1.226, Revision 0, Washington, D.C. ADAMS Accession No. ML19058A012.

NRC (U.S. Nuclear Regulatory Commission). 2019d. *Wide Range Spent Fuel Pool Level Instrumentation.* Regulatory Guide 1.227, Revision 0, Washington, D.C. ADAMS Accession No. ML19037A443.

NRC (U.S. Nuclear Regulatory Commission). 2019e. "NRC Staff Preliminary Process for Treatment of Reevaluated Seismic and Flooding Hazard Information in Backfit Determinations," Washington, D.C. ADAMS Accession No. ML19037A443.

NRC (U.S. Nuclear Regulatory Commission). 2019f. Letter from L. Lund to The Licensees of Operating Power Reactors on the Enclosed List, dated July 3, 2019, regarding "Treatment of Reevaluated Seismic Hazard Information provided under Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident." Washington, D.C. ADAMS Accession No. ML19140A307.

NRC (U.S. Nuclear Regulatory Commission). 2019g. Letter from M. J. Ross-Lee to The Licensees of Operating Power Reactors on the Enclosed List, dated August 20, 2019, regarding "Treatment of Reevaluated Flood Hazard Information provided under Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident." Washington, D.C. ADAMS Accession No. ML19067A247.

NRC (U.S. Nuclear Regulatory Commission). 2019h. *State-of-the-Art Reactor Consequence Analyses (SOARCA) Project: Sequoyah Integrated Deterministic and Uncertainty Analyses*. NUREG/CR-7245, Washington, D.C. ADAMS Accession No. ML19296B786.

NRC (U.S. Nuclear Regulatory Commission). 2020a. *Acceptability of Probabilistic Risk Assessment Results for Risk-Informed Activities*. Regulatory Guide 1.200, Revision 3, Washington, D.C. ADAMS Accession No. ML20238B871.

NRC (U.S. Nuclear Regulatory Commission). 2020b. Memorandum from M. Case to J. Donoghue and M.X. Franovich, dated May 13, 2020, regarding "Applicability of Source Term for Accident Tolerant Fuel, High Burn Up and Extended Enrichment." Washington, D.C. ADAMS Accession No. ML20126G376.

NRC (U.S. Nuclear Regulatory Commission). 2020c. *Modeling Potential Reactor Accident Consequences, State-of-the-Art Reactor Consequence Analyses: Using decades of research and experience to model accident progression, mitigation, emergency response, and health effects*. NUREG/BR-0359, Revision 3, Washington, D.C. ADAMS Accession No. ML20304A339.

NRC (U.S. Nuclear Regulatory Commission). 2021. *Seismic Hazard Evaluations for U.S. Nuclear Power Plants: Near-Term Task Force Recommendation 2.1 Results*. NUREG/KM-0017, Washington, D.C. ADAMS Accession No. ML21344A126.

NRC (U.S. Nuclear Regulatory Commission). 2022a. *U.S. NRC Level 3 Probabilistic Risk Assessment (PRA) Project, Volume 3x: Overview of Reactor, At-Power, Level 1, 2, and 3 PRAs for Internal Events and Internal Floods: Draft Report for Comment*. Washington, D.C. ADAMS Accession No. ML22067A210.

NRC (U.S. Nuclear Regulatory Commission). 2022b. "Perspective on Safety Improvements for Commercial Nuclear Power Plants." *34th Annual Regulatory Information Conference (March 8-10)*. Washington, D.C. ADAMS Accession No. ML22153A343.

NRC (U.S. Nuclear Regulatory Commission). 2022c. Sources of Information Cited in Appendix E, Generic Environmental Impact Statement for License Renewal of Nuclear Plants, NUREG-1437, Revision 2. Washington, D.C. May. ADAMS Accession No. ML22201A061.

NRC (U.S. Nuclear Regulatory Commission). 2022d. *State-of-the-Art Reactor Consequence Analyses (SOARCA) Project: Uncertainty Analysis of the Unmitigated Short-Term Station Blackout of the Surry Power Station*. NUREG/CR-7262. Washington, D.C. ADAMS Accession No. ML22194A066.

NRC (U.S. Nuclear Regulatory Commission). 2022e. *Summary of the Uncertainty Analyses for the State-of-the-Art Reactor Consequence Analyses Project.* NUREG/CR-2254. Washington, D.C. October. ADAMS Accession No. ML22193A244.

NRC (U.S. Nuclear Regulatory Commission). 2024. *Preparation of Environmental Reports for Nuclear Power Plant License Renewal Applications*. Regulatory Guide 4.2, Supplement 1, Revision 2, Washington, D.C. ADAMS Accession No. ML23201A144.

NUMARC (Nuclear Management and Resources Council). 1991. *Guidelines for Industry Actions to Assess Shutdown Management*. NUMARC 91-06, Washington, D.C. ADAMS Accession No. ML14365A203.

PG&E (Pacific Gas & Electric). 2008. *Diablo Canyon Power Plant Independent Spent Fuel Storage Installation*. CLI-08-26, 68 NRC 509. NUREG-0750. Volume 68, Book II of II. ADAMS Accession No. ML120440826.

PG&E (Pacific Gas & Electric). 2011. *Diablo Canyon Power Plant Independent Spent Fuel Storage Installation*. CLI-11-11, 74 NRC 427. NUREG-0750. Volume 74, Book II of II. ADAMS Accession No. ML14028A565.

PG&E (Pacific Gas & Electric). 2015. Letter from Barry S. Allen, Vice President, Nuclear Services to Document Control Desk, U.S. Nuclear Regulatory Commission, dated July 1, 2015, regarding "Diablo Canyon Units 1 and 2 - Diablo Canyon Power Plant License Renewal Severe Accident Mitigation Alternatives Analysis Evaluation of the 2015 Seismic Hazard Results." Avila Beach, CA. ADAMS Accession No. ML15182A303.

Ramsdell, J.V. Jr., C.E. Beyer, D.D. Lanning, U.P. Jenquin, R.A. Schwarz, D.L. Strenge, P.M. Daling, and R.T. Dahowski. 2001. *Environmental Effects of Extending Fuel Burnup Above 60 GWd/MTU*. NUREG/CR-6703, Pacific Northwest Laboratory, Richland, WA. ADAMS Accession No. ML010310298.

San Luis Obispo Mothers for Peace v. Nuclear Regulatory Commission, 449 F.3d 1016 (9th Cir. 2006). Accessed May 10, 2023, at https://cite.case.law/f3d/449/1016/.

San Luis Obispo Mothers for Peace v. Nuclear Regulatory Commission, 635 F.3d 1109 (9th Cir. 2011). Accessed May 10, 2023, at https://cite.case.law/f3d/635/1109/.

SN (Southern Nuclear). 2021. Letter from C.A. Gayheart to NRC dated October 26, 2021, regarding "Edwin I. Hatch Nuclear Plant - Units 1 and 2 License Amendment Request to Revise Technical Specifications to Adopt Risk Informed Completion Times TSTF-505, Revision 2, Provide Risk-Informed Extended Completion Times - RITSTF Initiative 4B." Washington, D.C. ADAMS Accession No. ML21300A153.

SNL (Sandia National Laboratories). 1992. *Integrated Risk Assessment for the LaSalle Unit 2 Nuclear Power Plant*. NUREG/CR–5305, SAND90-2765, Volume 1, RX, Albuquerque, NM. ADAMS Accession No. ML20105C763.

SNL (Sandia National Laboratories). 1995. *Evaluation of Potential Severe Accidents During Low Power and Shutdown Operations at Grand Gulf, Unit 1, Summary of Results*. NUREG/CR–6143, SAND93-2440, Volume 1, Albuquerque, NM. ADAMS Accession No. ML20087K369.

SNL (Sandia National Laboratories). 2006. *Mitigation of Spent Fuel Pool Loss of Coolant Inventory Accidents and Extension of Reference Plant Analyses to Other Spent Fuel Pools*. Sandia Letter Report, Revision 2, Albuquerque, NM. November. ADAMS Accession No. ML120970086.

SNL (Sandia National Laboratories). 2010. *Synthesis of VERCORS and Phebus Data in Severe Accident Codes and Applications*. SAND2010-1633, Albuquerque, NM. April. Accessed May 12, 2023, at https://doi.org/10.2172/983685.

SNL (Sandia National Laboratories). 2011. *Accident Source Terms for Light-Water Nuclear Power Plants Using High-Burnup or MOX Fuel.* SAND2011-0128, Unlimited Release, Albuquerque, NM. Accessed April 24, 2023, at https://www.osti.gov/biblio/1010412.

SNL (Sandia National Laboratories). 2021. *MACCS Theory Manual*. SAND2021-11535, Albuquerque, NM. ADAMS Accession No. ML22118B153.

USCB (U.S. Census Bureau). 2021. "2017 National Population Projections Tables: Main Series." Washington, D.C. Accessed April 24, 2023, at https://www.census.gov/data/tables/2017/demo/popproj/2017-summary-tables.html.

APPENDIX F

LAWS, REGULATIONS, AND OTHER REQUIREMENTS

APPENDIX F

LAWS, REGULATIONS, AND OTHER REQUIREMENTS

F.1 Introduction

It is central to the U.S. Nuclear Regulatory Commission's (NRC's) mission that nuclear power plants are operated in a manner that ensures the protection of public health and safety and the environment through compliance with applicable Federal and State laws, regulations, and other requirements. A number of Federal laws and regulations affect environmental protection, health, safety, compliance, and/or consultation at every NRC-licensed nuclear power plant. In addition, certain Federal environmental requirements have been delegated to State authorities for enforcement and implementation. Furthermore, States have also enacted laws to protect public health and safety and the environment.

This appendix presents a brief discussion of Federal and State laws, regulations, and other requirements that may affect the renewal and continued operation of NRC-licensed nuclear power plants. It provides additional information about environmental laws and regulations that may be applicable to license renewal (initial or subsequent license renewal). These include Federal and State laws, regulations, and other requirements designed to protect the environment, including land and water use, air quality, aquatic resources, terrestrial resources, radiological impacts, waste management, chemical impacts, and socioeconomic conditions.

This appendix is provided as a basic overview to assist the applicant in identifying environmental and natural resources laws that may affect the license renewal process. The descriptions of each of the laws, regulations, executive orders, and other directives are general in nature and are not intended to provide a comprehensive analysis or explanation of any of the items listed. In addition, the list itself is not intended to be comprehensive, and an applicant for license renewal is reminded that a variety of additional Federal, State, or local requirements may apply to a license renewal application for a particular plant site. Depending on the requirement, the NRC or the applicant may need to undergo a new authorization or consultation process, or renew an existing authorization currently granted.

Section F.2 identifies Federal laws and regulations applicable to license renewal. Section F.3 discusses executive orders. Section F.4 identifies applicable NRC regulations and associated guidance. Section F.5 discusses State laws, regulations, and other requirements. Section F.6 discusses operating permits and other requirements that must be issued prior to license renewal. Section F.7 discusses emergency management and response laws, regulations, and executive orders. Section F.8 discusses consultations with agencies and Federally recognized Indian Tribes. Section F.9 provides a list of references cited in this appendix. These regulatory requirements address issues such as protection of public health and the environment, worker safety, historic and cultural resources, and emergency planning.

F.2 Federal Laws and Regulations

The requirements that may be applicable to the operation of NRC-licensed nuclear power plants encompass a broad range of Federal laws and regulations, addressing environmental, historic and cultural, health and safety, transportation, and other concerns. Generally, these laws and regulations are relevant to how the work involved in performing a proposed action would be conducted to protect workers, the public, and environmental resources. Some of these laws and regulations require permits or consultation with other Federal agencies or State, Tribal, or local governments. The Federal laws and regulations that are identified and briefly discussed in this section are presented in alphabetical order.

American Indian Religious Freedom Act of 1978 (42 United States Code [U.S.C.] § 1996) – The American Indian Religious Freedom Act protects Native Americans' rights of freedom to believe, express, and exercise traditional religions.

Antiquities Act of 1906, as amended (54 U.S.C. §§ 320301–320303 and 18 U.S.C. § 1866(b)) – The Antiquities Act protects historic and prehistoric ruins, monuments, and antiquities, including paleontological resources, on Federally controlled lands from appropriation, excavation, injury, and destruction without permission.

Archaeological Resources Protection Act of 1979, as amended (54 U.S.C. § 302107 et seq.) – The Archaeological Resources Protection Act requires a permit for any excavation or removal of archaeological resources from Federal or Indian lands. Excavations must be undertaken for the purpose of furthering archaeological knowledge in the public interest, and resources removed are to remain the property of the United States. Consent must be obtained from the Indian Tribe or the Federal agency having authority over the land, on which a resource is located, before issuance of a permit. The permit must contain terms and conditions requested by the Tribe or Federal agency.

Archeological and Historic Preservation Act of 1974, as amended (54 U.S.C. § 312501 et seq.) – The Archeological and Historic Preservation Act establishes procedures for preserving historical and archaeological resources. Analysis of environmental compliance included assessing the energy alternatives for possible impacts on prehistoric, historic, and traditional cultural resources.

Atomic Energy Act of 1954, as amended (42 U.S.C. § 2011 et seq.) – The 1954 Atomic Energy Act (AEA), as amended, and the Energy Reorganization Act of 1974 (42 U.S.C. § 5801 et seq.) give the NRC the licensing and regulatory authority for nuclear energy uses within the commercial sector. They give the NRC responsibility for licensing and regulating commercial uses of atomic energy and allows the NRC to establish dose and concentration limits for protection of workers and the public for activities under NRC jurisdiction. The NRC implements its responsibilities under the AEA through regulations set forth in Title 10 of the *Code of Federal Regulations* (CFR).

Bald and Golden Eagle Protection Act of 1940, as amended (16 U.S.C. §§ 668–668d) – The Bald and Golden Eagle Protection Act makes it unlawful to take, pursue, molest, or disturb bald and golden eagles, their nests, or their eggs anywhere in the United States. The U.S. Fish and Wildlife Service (FWS) may issue take permits to individuals, government agencies, or other organizations to authorize limited, non-purposeful disturbance of eagles, in the course of conducting lawful activities such as operating utilities or conducting scientific research.

Clean Air Act of 1970, as amended (42 U.S.C. § 7401 et seq.) – The Clean Air Act (CAA) is intended to "protect and enhance the quality of the nation's air resources so as to promote the public health and welfare and the productive capacity of its population." The CAA regulates air emissions from stationary and mobile sources. The CAA establishes regulations to ensure maintenance of air quality standards and authorizes individual States to manage permits. Section 109 of the CAA directs the U.S. Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQSs) for criteria pollutants. The EPA has identified and set NAAQSs for the following criteria pollutants: particulate matter, sulfur dioxide, carbon monoxide, ozone, nitrogen dioxide, and lead. To meet the NAAQSs set forth by the EPA, States are required to create State implementation plans and update the plans periodically. Section 111 of the CAA requires establishment of national performance standards for new or modified stationary sources of atmospheric pollutants. Section 112 requires specific standards for release of hazardous air pollutants (including radionuclides). Section 118 of the CAA requires each Federal agency, with jurisdiction over properties or facilities engaged in any activity that might result in the discharge of air pollutants, to comply with all Federal, State, inter-State, and local requirements with regard to the control and abatement of air pollution. Section 160 of the CAA requires that specific emission increases be evaluated prior to permit approval in order to prevent significant deterioration of air quality. The CAA requires sources to meet standards and obtain permits to satisfy those standards. Nuclear power plants may be required to comply with the CAA Title V, Sections 501–507, for sources subject to new source performance standards or sources subject to National Emission Standards for Hazardous Air Pollutants. Emissions of air pollutants are regulated by the EPA in 40 CFR Parts 50 to 99.

Clean Water Act (33 U.S.C. § 1251 et seq.) – The Clean Water Act (CWA; formerly the Federal Water Pollution Control Act of 1972) was enacted to restore and maintain the chemical, physical, and biological integrity of the Nation’s water. The Act requires all branches of the Federal Government, with jurisdiction over properties or facilities engaged in any activity that might result in a discharge or runoff of pollutants to surface waters, to comply with Federal, State, inter-State, and local requirements.

As authorized by the CWA, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. The NPDES program requires all facilities that discharge pollutants from any point source into waters of the United States to 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. A nuclear power plant may also participate in the NPDES General Permit for Industrial Stormwater due to stormwater runoff from industrial or commercial facilities to waters of the United States. EPA is authorized under the CWA to directly implement the NPDES program, but EPA has authorized many States to implement all or parts of the national program.

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. Section 316(b) of the CWA requires that cooling-water intake structures of regulated facilities must reflect the best technology available for minimizing impingement mortality and entrainment of aquatic organisms. These sections of the CWA are implemented and enforced through the NPDES program.

Section 401 of the CWA requires that an applicant for a Federal license or permit to conduct any activity which may result in any discharge into navigable waters must provide the Federal licensing or permitting agency with a certification from the State or appropriate water pollution control agency in which the discharge originates or will originate. This water quality certification implies that discharges from the activity or project to be licensed or permitted will comply with

CWA requirements, as applicable, including that the discharge will not cause or contribute to a violation of applicable water quality standards. Under this section, the EPA or a delegated agency, as applicable, has the authority to review and approve, condition, or deny all permits or licenses that might result in a discharge to waters of the State, including wetlands. CWA Section 401 [33 U.S.C. 1341(a)(1)] states: “No license or permit shall be granted until the certification required by this section has been obtained or has been waived as provided in the preceding sentence. No license or permit shall be granted if certification has been denied by the State, interstate agency, or the Administrator, as the case may be.” Therefore, the NRC cannot issue its license without a Section 401 Certification or an NRC determination that a waiver has occurred, in accordance with 40 CFR 121.9. In accordance with 10 CFR 50.54(aa), conditions in the Section 401 Certification become a condition of the NRC’s license.

The U.S. Army Corps of Engineers (USACE) is the lead agency for enforcement of CWA wetland requirements (33 CFR Part 320). A Section 404 permit would need to be obtained from the USACE before implementing any action, such as earthmoving activities and certain erosion controls, which could disturb wetlands. Federal and State permits/certifications are obtained using the same form and permit applications for activities affecting waterways and wetlands and are reviewed by the USACE in consultation with the FWS, the Soil Conservation Service, the EPA, and the delegated State agency.

Coastal Zone Management Act of 1972, as amended (16 U.S.C. § 1451 et seq.) – Congress enacted the Coastal Zone Management Act (CZMA) in 1972 to address the increasing pressures of over-development upon the nation’s coastal resources. The National Oceanic and Atmospheric Administration administers the Act. The CZMA encourages States to preserve, protect, develop, and, where possible, restore or enhance valuable natural coastal resources such as wetlands, floodplains, estuaries, beaches, dunes, barrier islands, and coral reefs, as well as the fish and wildlife using those habitats. Participation by States is voluntary. To encourage States to participate, the CZMA makes Federal financial assistance available to any coastal State or territory, including those on the Great Lakes that are willing to develop and implement a comprehensive coastal management program. Section 307(c)(3)(A) of the CZMA requires that applicants for Federal licenses who conduct activities in a coastal zone provide certification that the proposed activity complies with the enforceable policies of the State's coastal zone program.

Comprehensive Environmental Response, Compensation, and Liability Act as amended by the Superfund Amendments and Reauthorization Act (42 U.S.C. § 9601 et seq.) – The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) includes an emergency response program to respond to a release of a hazardous substance to the environment. Releases of source, byproduct, or special nuclear material from a nuclear incident are excluded from CERCLA requirements if the releases are subject to the financial protection requirements of the AEA. CERCLA is intended to provide a response to, and cleanup of, environmental problems that are not covered adequately by the permit programs of the many other environmental laws, including the CAA, CWA, Safe Drinking Water Act (42 U.S.C. § 300(f) et seq.), Marine Protection, Research, and Sanctuaries Act (33 U.S.C. § 1401 et seq.), Resource Conservation and Recovery Act (42 U.S.C. § 6901 et seq.), and AEA. Under Section 120 of CERCLA, each department, agency, and instrumentality (e.g., a municipality) of the United States is subject to, and must comply with, CERCLA in the same manner as any nongovernmental entity (except for requirements for bonding, insurance, financial responsibility, or applicable time period). Under CERCLA, the EPA would have the authority to regulate hazardous substances at a facility in the event of a release or a “substantial threat of a release” of those materials. Releases greater than reportable quantities would be reported to the

National Response Center. Assessment of alternatives for environmental compliance includes consideration of whether hazardous substances, in reportable quantity amounts, could be present at power plants during the license renewal term.

Emergency Planning and Community Right-to-Know Act of 1986 (42 U.S.C. § 11001 et seq.) (also known as "SARA Title III") – The Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA), which is the major amendment to CERCLA (42 U.S.C. § 9601 et seq.), establishes the requirements for Federal, State, and local governments, Indian Tribes, and industry regarding emergency planning and "Community Right-to-Know" reporting on hazardous and toxic chemicals. The "Community Right-to-Know" provisions increase the public's knowledge of and access to information about chemicals at individual facilities, their uses, and releases into the environment. States and communities working with facilities can use the information to improve chemical safety and protect public health and the environment. This Act requires emergency planning and notice to communities and government agencies concerning the presence and release of specific chemicals. The EPA implements this Act under regulations found in 40 CFR Part 355, Part 370, and Part 372.

Endangered Species Act of 1973, as amended (16 U.S.C. § 1531 et seq.) – The Endangered Species Act was enacted to prevent the further decline of endangered and threatened species and to restore those species and their critical habitats. Section 7(a)(2) of the Act requires Federal agencies to consult with the FWS or the National Marine Fisheries Service (NMFS) for Federal actions that may affect listed species or designated critical habitats.

Environmental Standards for Uranium Fuel Cycle (40 CFR Part 190, Subpart B) – These regulations establish maximum doses to the body or organs of members of the public as a result of normal operational releases from uranium fuel cycle activities, including uranium enrichment. These regulations were promulgated by the EPA under the authority of the AEA, as amended, and have been incorporated by reference in the NRC regulations in 10 CFR 20.1301(e).

Federal Insecticide, Fungicide, and Rodenticide Act, as amended (7 U.S.C. § 136 et seq.) – The Federal Insecticide, Fungicide, and Rodenticide Act, as amended, by the Federal Environmental Pesticide Control Act and subsequent amendments, requires the registration of all new pesticides with the EPA before they are used in the United States. Manufacturers are required to develop toxicity data for their pesticide products. Toxicity data may be used to determine permissible discharge concentrations for an NPDES permit.

Fiscal Responsibility Act of 2023 (Public Law 118-5) – The Fiscal Responsibility Act enacted a number of amendments to the National Environmental Policy Act (NEPA), aimed at streamlining the decisionmaking process and codifying existing structures for cooperation between Federal agencies. The Act established page and time limits for the environmental review process. Environmental assessments are limited to 75 pages, not including citations or appendices, while environmental impact statements (EISs) are limited to 150 pages, with a 300-page limit for EISs that address an agency action of "extraordinary complexity," not including citations or appendices. The environmental assessment should take no more than 1 year, while EISs are limited to 2 years. The Act also allows for common categorical exclusions to be used between agencies and codifies agency use of programmatic environmental documents to facilitate the NEPA review process.

Fish and Wildlife Conservation Act of 1980 (16 U.S.C. § 2901 et seq.) – The Fish and Wildlife Conservation Act provides Federal technical and financial assistance to States for the development of conservation plans and programs for nongame fish and wildlife. The Fish and

Wildlife Conservation Act conservation plans identify significant problems that may adversely affect nongame fish and wildlife species and their habitats and appropriate conservation actions to protect the identified species. The Act also encourages Federal agencies to conserve and promote the conservation of nongame fish and wildlife and their habitats.

Fish and Wildlife Coordination Act of 1934, as amended (16 U.S.C. §§ 661–666e) – The Fish and Wildlife Coordination Act requires Federal agencies that construct, license, or permit water resource development projects to consult with the FWS (or NMFS, when applicable) and State wildlife resource agencies for any project that involves an impoundment of more than 10 ac (4 ha), diversion, channel deepening, or other waterbody modification regarding the impacts of that action on fish and wildlife and any mitigative measures to reduce adverse impacts.

Hazardous Materials Transportation Act, as amended (49 U.S.C. § 5101 et seq.) – The Hazardous Materials Transportation Act regulates the transportation of hazardous material (including radioactive material) in and between states. According to the Act, States may regulate the transport of hazardous material as long as their regulation is consistent with the Act or the U.S. Department of Transportation regulations provided in 49 CFR Parts 171 through 177. Other regulations regarding packaging for transportation of radionuclides are contained in 49 CFR Part 173, Subpart I.

Low-Level Radioactive Waste Policy Act of 1980, as amended (42 U.S.C. § 2021b et seq.) – The Low-Level Radioactive Waste Policy Act amended the AEA to improve the procedures for the implementation of compacts providing for the establishment and operation of regional low-level radioactive waste disposal facilities. It also allows Congress to grant consent for certain inter-State compacts. The amended Act sets forth the responsibilities for disposal of low-level waste by States or inter-State compacts. The Act states the amount of waste that certain low-level waste recipients can receive over a set time period. The amount of low-level radioactive waste generated by both pressurized and boiling water reactor types is allocated over a transition period until a local waste facility becomes operational.

Magnuson-Stevens Fishery Conservation and Management Act, as amended (16 U.S.C. § 1801 et seq.) – The Magnuson-Stevens Fishery Conservation and Management Act governs marine fisheries management in U.S. Federal waters. The Act created eight regional fishery management councils and includes measures to rebuild overfished fisheries, protect essential fish habitat, and reduce bycatch. Under Section 305(b) of the Act, Federal agencies are required to consult with NMFS for any Federal actions that may adversely affect essential fish habitat.

Marine Mammal Protection Act of 1972 (16 U.S.C. § 1361 et seq.) – The Marine Mammal Protection Act (MMPA) was enacted to protect and manage marine mammals and their products (e.g., the use of hides and meat). The primary authority for implementing the Act belongs to the FWS and NMFS. The FWS manages walruses, polar bears, sea otters, dugongs, marine otters, and the West Indian, Amazonian, and West African manatees. The NMFS manages whales, porpoises, seals, and sea lions. The two agencies may issue permits under MMPA Section 104 (16 U.S.C. 1374) to persons, including Federal agencies, that authorize the taking or importing of specific species of marine mammals.

After the Secretary of the Interior or the Secretary of Commerce approves a State's program, the State can take over responsibility for managing one or more marine mammals. The MMPA also established a Marine Mammal Commission whose duties include reviewing laws and international conventions related to marine mammals, studying the condition of these mammals, and recommending steps to Federal officials (e.g., listing a species as endangered) that should be taken to protect marine mammals. Federal agencies are directed by MMPA Section 205 (16 U.S.C. 1405) to cooperate with the commission by permitting it to use their facilities or services.

Migratory Bird Treaty Act of 1918, as amended (16 U.S.C. § 703 et seq.) – The Migratory Bird Treaty Act is intended to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. The Act stipulates that, except as permitted by regulations, it is unlawful at any time, by any means, or in any manner to pursue, hunt, take, capture, or kill any migratory bird.

National Environmental Policy Act of 1969, as amended (42 U.S.C. § 4321 et seq.) – NEPA requires, in part, that Federal agencies integrate environmental values into their decisionmaking process by considering the reasonably foreseeable environmental effects (impacts) of proposed Federal actions and a reasonable range of alternatives to those actions. NEPA establishes policy, sets goals (in Section 101), and provides means (in Section 102) for carrying out the policy. Section 102(2) contains action-forcing provisions to ensure that Federal agencies follow the letter and spirit of the Act. For major Federal actions significantly affecting the quality of the human environment, Section 102(2)(C) of NEPA, consistent with the provisions of NEPA except where compliance would be inconsistent with other statutory requirements, requires Federal agencies to prepare a detailed statement that includes the reasonably foreseeable environmental effects of the proposed action and other specified information. This generic environmental impact statement (GEIS) has been prepared in accordance with NEPA requirements and NRC regulations (10 CFR Part 51) for implementing NEPA to ensure compliance with Section 102(2).

National Historic Preservation Act of 1966, as amended (54 U.S.C. § 300101 et seq.) – The National Historic Preservation Act was enacted to create a national historic preservation program, including the National Register of Historic Places and the Advisory Council on Historic Preservation. Section 106 of the Act requires Federal agencies to take into account the effects of their undertakings on historic properties. The Advisory Council on Historic Preservation regulations implementing Section 106 of the Act, are found in 36 CFR Part 800. The regulations call for public involvement in the Section 106 consultation process, including Indian Tribes and other interested members of the public, as applicable.

National Marine Sanctuaries Act of 1966, as amended (16 U.S.C. § 1431 et seq.) – The National Marine Sanctuaries Act (NMSA) establishes provisions for the designation and protection of marine areas that have special national significance. The NMSA authorizes the Secretary of Commerce to designate national marine sanctuaries and establish the National Marine Sanctuary System. Pursuant to Section 304(d) of the NMSA, Federal agencies must consult with the National Oceanic and Atmospheric Administration's Office of National Marine Sanctuaries when their proposed actions are likely to destroy, cause the loss of, or injure a sanctuary resource.

Native American Graves Protection and Repatriation Act of 1990 (25 U.S.C. § 3001) – The Native American Graves Protection and Repatriation Act establishes provisions for the treatment of inadvertent discoveries of Indian remains and cultural objects. When discoveries are made during ground-disturbing activities, the activity in the area must immediately stop, and reasonable protective efforts, proper notifications, and appropriate disposition of the discovered items must be pursued.

Noise Control Act of 1972 (42 U.S.C. § 4901 et seq.) – The Noise Control Act delegates the responsibility of noise control to State and local governments. Commercial facilities are required to comply with Federal, State, inter-State, and local requirements regarding noise control. Section 4 of the Noise Control Act directs Federal agencies to carry out programs in their jurisdictions "to the fullest extent within their authority" and in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health and welfare.

Nuclear Waste Policy Act of 1982, as amended (42 U.S.C. § 10101 et seq.) – The Nuclear Waste Policy Act provides for the research and development of repositories for the disposal of high-level radioactive waste, spent nuclear fuel, and low-level radioactive waste. Title I includes the provisions for the disposal and storage of high-level radioactive waste and spent nuclear fuel. Subtitle A of Title I delineates the requirements for site characterization and construction of the repository and the participation of States and other local governments in the selection process. Subtitles B, C, and D of Title I deal with the specific issues for interim storage, monitored retrievable storage, and low-level radioactive waste.

Occupational Safety and Health Act of 1970 (29 U.S.C. § 651 et seq.) – The Occupational Safety and Health Act establishes standards to enhance safe and healthy working conditions in places of employment throughout the United States. The Act is administered and enforced by the Occupational Safety and Health Administration (OSHA), a U.S. Department of Labor agency. Employers who fail to comply with OSHA standards can be penalized by the Federal Government. The Act allows States to develop and enforce OSHA standards if such programs have been approved by the Secretary of Labor.

Pollution Prevention Act of 1990 (42 U.S.C. § 13101 et seq.) – The Pollution Prevention Act establishes a national policy for waste management and pollution control that focuses first on source reduction, then on environmental issues, safe recycling, treatment, and disposal.

Resource Conservation and Recovery Act as amended by the Hazardous and Solid Waste Amendments (42 U.S.C. § 6901 et seq.) – The Resource Conservation and Recovery Act (RCRA) requires the EPA to define and identify hazardous waste; establish standards for its transportation, treatment, storage, and disposal; and require permits for persons engaged in hazardous waste activities. Section 3006 (42 U.S.C. 6926) allows States to establish and administer these permit programs with EPA approval. EPA regulations implementing the RCRA are found in 40 CFR Parts 260 through 283. Regulations imposed on a generator or on a treatment, storage, and/or disposal facility vary according to the type and quantity of material or waste generated, treated, stored, and/or disposed. The method of treatment, storage, and/or disposal also affects the extent and complexity of the requirements.

Rivers and Harbors Act of 1899, Section 10 (33 U.S.C. § 401 et seq.) – The Rivers and Harbors Act of 1899 (33 U.S.C. § 401 et seq.) requires USACE authorization in order to protect navigable waters in the development of harbors and other construction and excavation. Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. § 403) prohibits the unauthorized obstruction or alteration of any navigable water of the United States. That section provides that the construction of any structure in or over any navigable water of the United States, or the accomplishment of any other work affecting the course, location, condition, or physical capacity of such waters is unlawful unless the work has been authorized by the Secretary of the Army through the USACE. Activities requiring Section 10 permits include structures (e.g., piers, wharves, breakwaters, bulkheads, jetties, weirs, transmission lines) and work such as dredging or disposal of dredged material, or excavation, filling, or other modifications to the navigable waters of the United States.

Safe Drinking Water Act of 1974 (42 U.S.C. § 300(f) et seq.) – The Safe Drinking Water Act (SDWA) was enacted to protect the quality of public water supplies and sources of drinking water and establishes minimum national standards for public water supply systems in the form of maximum contaminant levels for pollutants, including radionuclides. Other programs established by the SDWA include the Sole Source Aquifer Program, the Wellhead Protection Program, and the Underground Injection Control Program. In addition, the Act provides underground sources of drinking water with protection from contaminated releases and spills.

If a nuclear power plant is located within an area designated as a sole source aquifer pursuant to Section 1424(e) of the SDWA, the supplemental environmental impact statement would be subject to EPA review. If the EPA review raises concerns that plant operations are not protective of groundwater quality, specific mitigation recommendations or additional pollution prevention requirements may be required.

Toxic Substances Control Act (15 U.S.C. § 2601 et seq.) – The Toxic Substances Control Act (TSCA) regulates the manufacture, processing, distribution, and use of certain chemicals not regulated by RCRA or other statutes, including asbestos-containing material and polychlorinated biphenyls. Any TSCA-regulated waste removed from structures (e.g., polychlorinated biphenyl-contaminated capacitors or asbestos) or discovered during the implementation phase (e.g., contaminated media) would be managed in compliance with TSCA requirements in 40 CFR Part 761.

F.3 Executive Orders

Executive orders establish policies and requirements for Federal agencies. Executive orders do not have the force of law or regulation. Generally, executive orders are applicable to most Federal agencies, although they may or may not be binding upon independent regulatory agencies such as the NRC.

Executive Order 11514, Protection and Enhancement of Environmental Quality (35 FR 4247) – This Order (regulated by 40 CFR Parts 1500 through 1508) requires Federal agencies to continually monitor and control their activities to (1) protect and enhance the quality of the environment, and (2) develop procedures to ensure the fullest practicable provision of timely public information and understanding of the Federal plans and programs that may have potential environmental impact so that views of interested parties can be obtained.

Executive Order 11593, Protection and Enhancement of the Cultural Environment (36 FR 8921) – This Order directs Federal agencies to locate, inventory, and nominate qualified properties under their jurisdiction or control to the National Register of Historic Places.

Executive Order 11988, Floodplain Management (42 FR 26951) – This Order requires Federal agencies to avoid direct or indirect support of floodplain development whenever there is a practicable alternative. A Federal agency is required to evaluate the potential effects of any actions it may take in a floodplain. Federal agencies are also required to encourage and provide appropriate guidance to applicants to evaluate the effects of their proposals on floodplains prior to submitting applications for Federal licenses, permits, loans, or grants.

Executive Order 11990, Protection of Wetlands (42 FR 26961) – This Order requires Federal agencies to avoid any short- or long-term adverse impacts on wetlands, wherever there is a practicable alternative and to provide opportunity for early public review of any plans or proposals for new construction in wetlands. Federal agencies are required to evaluate the potential effects of any actions they may take on wetlands when carrying out their responsibilities (e.g., planning, regulating, and licensing activities). However, this Executive Order does not apply to the issuance by Federal agencies of permits, licenses, or allocations to private parties for activities involving wetlands on non-Federal property.

Executive Order 12088, Federal Compliance with Pollution Control Standards (43 FR 47707), as amended by Executive Order 12580, Superfund Implementation (52 FR 2923) – This Order directs Federal agencies to comply with applicable administrative and procedural pollution controls standards established by, but not limited to, the CAA, the Noise Control Act, the CWA, the SDWA, the TSCA, and the RCRA.

Executive Order 12148, Federal Emergency Management (44 FR 43239) – This Order transfers functions and responsibilities associated with Federal emergency management to the Director of the Federal Emergency Management Agency. The Order assigns the Director the responsibility to establish Federal policies for, and to coordinate all civil defense and civil emergency planning, management, mitigation, and assistance functions of, Executive agencies.

Executive Order 12580, Superfund Implementation (52 FR 2923), as amended by Executive Order 13308 (68 FR 37691) – This Order delegates to the heads of Executive Departments and agencies the responsibility of undertaking remedial actions for releases or threatened releases that are not on the National Priorities List, and removal actions, other than emergencies, where the release is from any facility under the jurisdiction or control of Executive Departments and agencies.

Executive Order 12656, Assignment of Emergency Preparedness Responsibilities (53 FR 47491) – This Order assigns emergency preparedness responsibilities to Federal departments and agencies.

Executive Order 12856, Right-to-Know Laws and Pollution Prevention Requirements (58 FR 41981) – The Order directs Federal agencies to reduce and report toxic chemicals entering any waste stream; improve emergency planning, response, and accident notification; and meet the requirements of EPCRA.

Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (59 FR 7629) – This Order calls for Federal agencies to address environmental justice in minority populations and low-income populations, and directs Federal agencies to identify and address, as appropriate, disproportionately high and adverse health or environmental effects of their programs, policies, and activities on minority populations and low-income populations. In response to this Executive Order, the NRC has issued a final policy statement on the “Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions” (69 FR 52040) and environmental justice procedures to be followed in NEPA documents.

Executive Order 13007, Indian Sacred Sites (61 FR 26771) – This Order directs Federal agencies, to the extent permitted by law and not inconsistent with agency missions, to avoid adverse effects on sacred sites and to provide access to those sites to Native Americans for religious practices. The Order directs agencies to plan projects, provide protection of, and access to sacred sites to the extent compatible with the project.

Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks (62 FR 19885), as amended by Executive Order 13229 (66 FR 52013), as amended by Executive Order 13296 (68 FR 19931) – This Order requires Federal Executive Branch agencies to make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children and to ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health or safety risks.

Executive Order 13101, Greening the Government through Waste Prevention, Recycling, and Federal Acquisition (63 FR 49643) – This Order requires each Federal agency to incorporate waste prevention and recycling in its daily operations and work to increase and expand markets for recovered materials. This Order states that it is national policy to prefer pollution prevention whenever feasible. Pollution that cannot be prevented should be recycled; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner. Disposal should be employed only as a last resort.

Executive Order 13112, Invasive Species (64 FR 6183) – This Order directs Federal agencies to act to prevent the introduction of, or to monitor and control, invasive (non-native) species, to provide for restoration of native species, to conduct research, to promote educational activities, and to exercise care in taking actions that could promote the introduction or spread of invasive species. During the implementation phase, rehabilitation of disturbed areas would be accomplished by reseeding or revegetating areas with native plants and trees.

Executive Order 13123, Greening the Government through Efficient Energy Management (64 FR 30851) – This Order sets goals for agencies to reduce greenhouse gas emissions from facility energy use, reduce energy consumption per gross square foot of facilities, reduce energy consumption per gross square foot or unit of production, expand use of renewable energy, reduce the use of petroleum within facilities, reduce source energy use, and reduce water consumption and associated energy use.

Executive Order 13148, Greening the Government through Leadership in Environmental Management (65 FR 24595) – This Order requires agencies to develop strategies and goals for environmental compliance, right-to-know, and pollution prevention. It requires all Federal facilities to have an environmental management system, requires compliance or environmental management system audits, and requires that Federal Executive Branch agencies comply with the requirements for toxic chemical release reporting in Section 313 of EPCRA.

Executive Order 13175, Consultation and Coordination with Indian Tribal Governments (65 FR 67249) – This Order directs Federal agencies to establish regular and meaningful consultation and collaboration with Tribal governments in the development of Federal policies that have Tribal implications, to strengthen U.S. government-to-government relationships with Indian Tribes, and to reduce the imposition of unfunded mandates on Tribal governments. On January 9, 2017, the NRC published its Tribal Policy Statement, which describes best practices and principles in conducting the agency's government-to-government interactions with American Indian and Alaska Native Tribes (82 FR 2402).

Executive Order 13990, Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis (86 FR 7037) – This Order lays out a broad policy related to science, public health, environmental protection, environmental justice, and associated job creation. The Order directs Federal agency heads to “immediately” review actions taken during the Trump Administration “that are or may be inconsistent with, or present obstacles to," this policy and to develop and submit to certain Administration officials lists of planned agency actions to rectify the identified issues. The Order also establishes an Interagency Working Group on the Social Cost of Greenhouse Gases and revokes or temporarily suspends a number of prior Orders and other White House issuances related to environmental, infrastructure, and energy issues that were issued by President Trump.

Executive Order 14008, Tackling the Climate Crisis at Home and Abroad (86 FR 7619) – This Order addresses a number of areas related to climate change, including making climate change issues central to U.S. foreign policy and national security and pursuing various government-wide domestic initiatives. The aspects of the Order that have the most direct applicability to the NRC are the provisions addressing the sustainability and climate-related resilience of a Federal agency's own operations. For example, the NRC will submit a draft action plan describing steps the agency can take with regard to its facilities and operations to bolster adaptation and increase resilience to the impacts of climate change and will also release publicly progress reports as updates on the agency's implementation efforts.

F.4 U.S. Nuclear Regulatory Commission Regulations and Associated Guidance

The AEA, as amended, allows the NRC to issue licenses for commercial power reactors to operate up to 40 years. This license is based on adherence of the licensee to NRC's regulations, which are set forth in Chapter 1 of Title 10 of the CFR. The NRC regulations allow for the renewal of the licenses for up to an additional 20 years beyond the initial licensing period. The renewal of the license depends on the outcome of the NRC's safety and environmental reviews of the commercial power reactor license renewal applications. There are no specific limitations in the AEA or NRC regulations restricting the number of times a license may be renewed. The license renewal process includes a set of requirements, which are designed to assure safe operation of nuclear power plants and protection of the environment.

The license renewal process includes two reviews: an environmental review and a safety review. The reviews are based on the regulations published in 10 CFR Part 51 for the environmental review and 10 CFR Part 54 for the safety review. These regulations prescribe the format and content of license renewal applications, as well as the methods and criteria used by NRC staff when evaluating these applications.

The license renewal environmental review relies upon the following regulations and guidance:

- ***Code of Federal Regulations* –** The scope of the environmental review is based on the regulations provided in 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions."
- ***Preparation of Environmental Reports for License Renewal Applications* (Supplement 1 to Regulatory Guide 4.2, Revision 2; NRC 2024c) –** This document outlines the format and content to be used by the applicant to discuss the environmental aspects of its license renewal application. It also defines the information and analyses the applicant must include in its environmental report submitted as part of the application.
- ***Standard Review Plans for Environmental Reviews for Nuclear Power Plants – Supplement 1: Operating License Renewal* (NUREG-1555, Supplement 1, Revision 2; NRC 2024a) –** This document describes how the NRC staff conducts its review of the environmental issues associated license renewal.

- ***Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (NUREG-1437, Revision 2; NRC 2024b) –** This document discusses the environmental impacts from license renewal that are common to all or most nuclear power facilities. The GEIS allows the applicant and NRC to focus on environmental issues specific to each site seeking a renewed operating license. The staff's review results in a plant-specific supplement to the GEIS for each plant site.
- **Nuclear Regulatory Commission License Termination Rule (10 CFR Part 20, Subpart E)** – The AEA assigns the NRC the responsibility for licensing and regulating commercial uses of atomic energy. When a licensed facility has completed its mission, the facility must meet standards for cleanup in order to terminate its license. The License Termination Rule establishes that the NRC will consider a site acceptable for unrestricted use if the residual radioactivity, that is distinguishable from background radiation, results in a total effective dose equivalent to an average member of the critical group that does not exceed 25 mrem/yr, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as is reasonably achievable (ALARA). The critical group is the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.

The License Termination Rule also provides for land use restrictions or other types of institutional controls to allow termination of NRC licenses and releases of sites under restricted conditions if decommissioning criteria for unrestricted use cannot be met. Plus, the License Termination Rule establishes alternate criteria for license termination if the licensee provides assurance that public health and safety would continue to be protected, and that it is unlikely that the dose from all manmade sources combined, other than medical, would be more than 100 mrem/yr.

F.5 State Laws, Regulations, and Other Requirements

The AEA authorizes States to establish programs to assume NRC regulatory authority for certain activities (the NRC's Agreement State Program). The New York State Department of Labor and Department of Environmental Conservation, for example, have established requirements under this Agreement State Program. New York State Department of Labor has jurisdiction in New York over commercial and industrial uses of radioactive material. Under the New York Agreement State Program, New York Department of Environmental Conservation has jurisdiction over discharges of radioactive material to the environment, including releases to the air and water, and the disposal of radioactive wastes in the ground. In addition, States have enacted their own laws to protect public health and safety, and the environment. State laws may supplement or implement various Federal laws for protection of air, water quality, and groundwater. State laws may also address solid waste management programs, locally rare or endangered species, and historic and cultural resources.

In addition, the CWA allows for primary enforcement and administration through State agencies, provided the State program (1) is at least as stringent as the Federal program, and (2) conforms to the CWA. The primary CWA mechanism to control water pollution is the requirement that direct dischargers obtain an NPDES permit or, in the case of States where the authority has been delegated from the EPA, a State-issued permit.

One important difference between Federal regulations and certain State regulations is the definition of waters regulated by the State. Certain State regulations may include underground waters, while the CWA only regulates the navigable waters of the United States. For example, a State permit is required under New York State law for all discharges to both surface waters and groundwater.

F.5.1 State Environmental Requirements

Certain environmental requirements, including some discussed earlier, may have been delegated to State authorities for implementation, enforcement, or oversight. Table F.5-1 through Table F.5-6 provide lists of representative State environmental requirements that may affect license renewal applications for nuclear power plants.

Table F.5-1 State Environmental Requirements for Air Quality Protection

Law/Regulation	Requirements
Title V Permit Rules	Establishes the policies and procedures by which a State will administer the Title V permit program under the CAA. Requires Title V sources to apply for and obtain a Title V permit prior to operation of the source facility.
Permits to Install New Sources of Pollution	Requires a permit prior to the installation of a new source of air pollutants or the modification of an air contaminant source. Discusses exemptions and conditions under which approval will be granted. Also requires an impact analysis to determine whether the air contaminant source will cause or contribute to violations of the NAAQSs.
Air Permits to Operate and Variances	Requires a permit prior to the operation or use of any air contaminant source in violation of any applicable air pollution control law, unless a variance has been applied for and obtained from the State agency.
Accidental Release Prevention Program	Requires the owner or operator of a stationary source, that has more than a threshold quantity of a regulated substance, to comply with all the provisions of the rule, including creating a hazard assessment, risk management plan, a prevention program, and an emergency response program.
General Conformity Rules	Rules on “general conformity” are mandated by the CAA to ensure that Federal actions do not contribute to air quality violations within the State. Discusses which Federal actions are subject to the conformity requirements, the procedures for conformity analysis, public participation/consultation, and the final conformity determination.

CAA = Clean Air Act; NAAQSs = National Ambient Air Quality Standards.

Table F.5-2 State Environmental Requirements for Water Resources Protection

Law/Regulation	Requirements
NPDES Permits	Requires a permit prior to the discharge of pollutants from any point source into waters of the United States. Each permit holder must comply with authorized discharge levels, monitoring requirements, and other appropriate requirements in the permit.
Permits to Install New Sources of Pollution	Requires a permit prior to the installation of a new source of water pollutants or the modification of any pollutant discharge source.

Law/Regulation	Requirements
Water Quality Standards	Establishes water quality standards for surface waters in the State, including beneficial use designations, numeric water quality criteria, and the anti-degradation waterbody classification system. Water quality standards are enforced through the NPDES permit.
Section 401 Water Quality Certifications	Requires a Section 401 water quality certification and payment of applicable fees before the issuance of any Federal permit or license to conduct any activity that may result in discharges to waters of the State.
Public Water Systems Licenses to Operate	Requires a public water system license prior to operating or maintaining a public water system.
Design, Construction, Installation, and Upgrading for Underground Storage Tank Systems	Establishes performance standards and upgrading requirements for underground storage tanks containing petroleum (e.g., diesel fuel) or other regulated substances. Requires an installation or upgrading permit for each location where such installation or upgrading is to occur prior to beginning either an installation or upgrading of a tank or piping comprising an underground storage tank system.
Registration of Underground Storage Tank System	Establishes annual registration requirements for underground storage tanks containing petroleum or other regulated substances.
Flammable and Combustible Liquids	Requires a permit to install, remove, repair, or alter a stationary tank for the storage of flammable or combustible liquids or modify or replace any line or dispensing device.

NPDES = National Pollutant Discharge Elimination System.

Table F.5-3 State Environmental Requirements for Waste Management and Pollution Prevention

Law/Regulation	Requirements
Generator Standards	Requires any person who generates waste to determine whether that waste is hazardous. Requires a generator identification number from EPA or State agency prior to treatment, storage, disposal, transport, or offer for transport of hazardous waste.
Licensing Requirements for Solid Waste, Construction, and Demolition Debris Facilities	Requires an annual license for any municipal solid waste landfill, industrial solid waste landfill, residual solid waste landfill, compost facility, transfer facility, infectious waste treatment facility, or solid waste incineration facility prior to operation. New facilities must obtain a permit to install, prior to construction. Also, requires a license to establish, modify, operate, or maintain a construction and demolition debris facility.
Radiation Generator and Broker Reporting Requirements	Requires completion of a low-level radioactive waste generator report within 60 days of beginning to generate low-level waste. Additionally, requires each generator to submit an annual report on the state of low-level waste activities in their facility and pay applicable fees.
Hazardous Waste Management System Permits	Requires operation permits for any new or existing hazardous waste facility.

EPA = U.S. Environmental Protection Agency.

Table F.5-4 State Environmental Requirements for Emergency Planning and Response

Law/Regulation	Requirements
Hazardous Chemical Reporting	Requires the submission of Material Safety Data Sheets and an annual Emergency and Hazardous Chemical Inventory to local emergency response officials for any hazardous chemicals that are produced, used, or stored at the facility in an amount that equals or exceeds the threshold quantity.
Emergency Planning Requirements of Subject Facilities	Requires any facility having an extremely hazardous substance present in an amount equal to, or exceeding, the threshold planning quantity, to notify the emergency response commission and the local emergency planning committee within 60 days after onsite storage begins. Also requires the designation of a facility representative who will participate in the local emergency planning process as a facility emergency coordinator.
Toxic Chemical Release Reporting	Establishes reporting requirements and schedule for each toxic chemical known to be manufactured (including imported), processed, or otherwise used in excess of an applicable threshold quantity. Applies only to facilities of a certain classification.

Table F.5-5 State Environmental Requirements for Ecological Resources Protection

Law/Regulation	Requirements
State Endangered Plant Species Protection	Establishes criteria for identifying threatened or endangered species of native plants and prohibits injuring or removing endangered species without permission.
State Endangered Fish and Wildlife Species Protection	Establishes and requires periodic update of a State list of endangered fish and wildlife species.
Permits for Impacts to Isolated Wetlands	Requires a general or individual isolated wetland permit prior to engaging in an activity that involves the filling of an isolated wetland.

Table F.5-6 State Environmental Requirements for Historic and Cultural Resources Protection

Law/Regulation	Requirements
State Registry of Archaeological Landmarks	Establishes a State registry of archaeological landmarks. Prohibits any person from excavating or destroying such land, or from removing skeletal remains or artifacts from any land, placed on the registry without first notifying the State Historic Preservation Office.
Survey and Salvage; Discoveries; Preservation	Directs State departments, agencies, and political subdivisions to cooperate in the preservation of archaeological and historic sites and the recovery of scientific information from such sites. Also, requires State agencies and contractors performing work on public improvements to cooperate with archaeological and historic survey and salvage efforts and to notify the State Historic Preservation Office about archaeological discoveries.

F.6 Operating Permits and Other Requirements

Several operating permit applications may be prepared and submitted, and regulatory approval and/or permits would be received, prior to license renewal approval by the NRC. Table F.6-1 through Table F.6-6 list representative Federal, State, and local permits.

Table F.6-1 Federal, State, and Local Permits and Other Requirements for Air Quality Protection

License, Permit, or Other Required Approval	Responsible Agency	Authority	Relevance and Status
Title V Operating Permit: Required for sources that are not exempt and are major sources, affected sources subject to the Acid Rain Program, sources subject to new source performance standards, or sources subject to National Emission Standards for Hazardous Air Pollutants.	EPA or State agency	CAA, Title V, Sections 501–507 (U.S.C., Title 42, §§ 7661–7661f])	Nuclear power plants are subject to 40 CFR Part 70, “State Operating Permit Programs.”
Risk Management Plan: Required for any stationary source that has a regulated substance (e.g., chlorine, hydrogen fluoride, nitric acid) in any process (including storage) in a quantity that is over the threshold level.	EPA or State agency	CAA, Title 1, Section 112(R)(7) (42 U.S.C. § 7412)	These regulated substances stored in quantities that exceed the threshold levels would require a Risk Management Plan.
CAA Conformity Determination: Required for each criteria pollutant (i.e., sulfur dioxide, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead) where the total of direct and indirect emissions in a nonattainment or maintenance area caused by a Federal action would equal or exceed threshold rates.	EPA or State agency	CAA, Title 1, Section 176(c) (42 U.S.C. § 7506)	CAA conformity determination would be required at nuclear power plants located in nonattainment areas with NAAQSs for criteria pollutants or maintenance areas for any criteria pollutant that would be emitted as a result of license renewal.

CAA = Clean Air Act; EPA = U.S. Environmental Protection Agency; NAAQSs = National Ambient Air Quality Standards.

Table F.6-2 Federal, State, and Local Permits and Other Requirements for Water Resource Protection

License, Permit, or Other Required Approval	Responsible Agency	Authority	Relevance and Status
NPDES Permit: Construction Site Stormwater: Required before making point source discharges of stormwater from a construction project that disturbs more than 2 ha (5 ac) of land.	EPA or State agency	CWA (33 U.S.C. § 1251 et seq.); 40 CFR Part 122	Any plant refurbishment involving construction of more than 2 ha (5 ac) of land would require a Stormwater Pollution Prevention Plan and construction site stormwater discharge permit.

License, Permit, or Other Required Approval	Responsible Agency	Authority	Relevance and Status
NPDES Permit: Industrial Facility Stormwater: Required before making point source discharges of stormwater from an industrial site.	EPA or State agency	CWA (33 U.S.C. § 1251 et seq.); 40 CFR Part 122	Stormwater would be discharged from the nuclear power plants during operations. Stormwater would discharge through existing outfalls covered by a permit.
NPDES Permit: Process Water Discharge: Required before making point source discharges of industrial process wastewater.	EPA or State agency	CWA (33 U.S.C. § 1251 et seq.); 40 CFR Part 122	Process industrial wastewater would be discharged through existing outfalls covered by the permit.
Spill Prevention Control and Countermeasures Plan: Required for any facility that could discharge diesel fuel in harmful quantities into navigable waters or onto adjoining shorelines.	EPA or State agency	CWA (33 U.S.C. § 1251 et seq.); 40 CFR Part 112	A Spill Prevention Control and Countermeasures Plan is required at nuclear power plants storing large volumes of diesel fuel and/or other petroleum products.
CWA Section 401 Water Quality Certification: Required to be submitted to the agency responsible for issuing any Federal license or permit to conduct an activity that may result in a discharge of pollutants into waters of a State.	EPA or State agency	CWA, Section 401 (33 U.S.C. § 1341); 40 CFR 121	Certification for operation of a nuclear power plant may require a Federal license or permit (e.g., a CWA Section 404 Permit).
New Underground Storage Tanks System Registration: Required within 30 days of bringing a new underground storage tank system into service.	EPA or State agency	RCRA, as amended, Subtitle I (42 U.S.C. §§ 6991a–6991i); 40 CFR 280.22	Required if new underground storage tank systems would be installed at a nuclear power plant.
Above Ground Storage Tank: A permit is required to install, remove, repair, or alter any stationary tank for the storage of flammable or combustible liquids.	State Fire Marshal		Required if new aboveground diesel fuel storage tanks would be installed at a nuclear power plant.

ac = acre(s); CFR = *Code of Federal Regulations*; CWA = Clean Water Act; EPA = U.S. Environmental Protection Agency; ha = hectare(s); NPDES = National Pollutant Discharge Elimination System; RCRA = Resource Conservation and Recovery Act.

Table F.6-3 Federal, State, and Local Permits and Other Requirements for Waste Management and Pollution Prevention

License, Permit, or Other Required Approval	Responsible Agency	Authority	License, Permit, or Other Required Approval
Registration and Hazardous Waste Generator Identification Number: Required before a person who generates over 100 kg (220 lb) per calendar month of hazardous waste ships the hazardous waste offsite.	EPA or State agency	RCRA, as amended (42 U.S.C. § 6901 et seq.), Subtitle C	Generators of hazardous waste must notify the EPA that the wastes exist and require management in compliance with RCRA.
Hazardous Waste Facility Permit: Required if hazardous waste will undergo nonexempt treatment by the generator, be stored onsite for longer than 90 days by the generator of 1,000 kg (2,205 lb) or more of hazardous waste per month, be stored onsite for longer than 180 days by the generator of between 100 and 1,000 kg (220 and 2,205 lb) of hazardous waste per month, disposed of onsite, or be received from offsite for treatment or disposal.	EPA or State agency	RCRA, as amended (42 U.S.C. § 6901 et seq.), Subtitle C	Hazardous wastes are usually not disposed of onsite at nuclear power plants. Hazardous wastes generated onsite are not generally stored for more than 90 days. However, should a nuclear power plant store waste onsite for greater than 90 days for characterization, profiling, or scheduling for treatment or disposal, a Hazardous Waste Facility Permit would be required.

EPA = U.S. Environmental Protection Agency; lb = pound(s); kg = kilogram(s); RCRA = Resource Conservation and Recovery Act.

Table F.6-4 Federal, State, and Local Permits and Other Requirements for Emergency Planning and Response

License, Permit, or Other Required Approval	Responsible Agency	Authority	License, Permit, or Other Required Approval
List of Material Safety Data Sheets: Submission of a list of Material Safety Data Sheets is required for hazardous chemicals (as defined in 29 CFR Part 1910) that are stored onsite in excess of their threshold quantities.	State and local emergency planning agencies	EPCRA, Section 311 (42 U.S.C. § 11021); 40 CFR 370.20	Nuclear power plant operators are required to submit a list of Material Safety Data Sheets to State and local emergency planning agencies.
Annual Hazardous Chemical Inventory Report: The report must be submitted when hazardous chemicals have been stored at a facility during the preceding year in amounts that exceed threshold quantities.	State and local emergency response agencies; local fire department	EPCRA, Section 312 (42 U.S.C. § 11022); 40 CFR 370	If hazardous chemicals have been stored at a nuclear power plant during the preceding year in amounts that exceed threshold quantities, then plant operators would be required to submit an annual Hazardous Chemical Inventory Report.

License, Permit, or Other Required Approval	Responsible Agency	Authority	License, Permit, or Other Required Approval
Notification of Onsite Storage of an Extremely Hazardous Substance: Submission of the notification is required within 60 days after onsite storage begins of an extremely hazardous substance in a quantity greater than the threshold planning quantity.	State and local emergency response agencies	EPCRA, Section 304 (42 U.S.C. § 11004); 40 CFR 355.30	If an extremely hazardous substance will be stored at a nuclear power plant in a quantity greater than the threshold planning quantity, plant operators would prepare and submit the Notification of Onsite Storage of an Extremely Hazardous Substance.
Annual Toxics Release Inventory Report: Required for facilities that have 10 or more full-time employees and are assigned certain Standard Industrial Classification Codes.	EPA or State agency	EPCRA, Section 313 (42 U.S.C. § 11023); 40 CFR Part 372	If required, nuclear power plant operators would prepare and submit a Toxics Release Inventory Report to the EPA.
Transportation of Radioactive Wastes and Conversion Products Packaging, Labeling, and Routing Requirements for Radioactive Materials: Required for packages containing radioactive materials that will be shipped by truck or rail.	USDOT	Hazardous Materials Transportation Act (49 U.S.C. § 5101 et seq.); AEA, as amended (42 U.S.C. § 2011 et seq.); 49 CFR Part 172, Part 173, Part 174, Part 177, and Part 397	When shipments of radioactive materials are made, nuclear power plant operators would comply with USDOT packaging, labeling, and routing requirements.

AEA = Atomic Energy Act; CFR = *Code of Federal Regulations*; EPA = U.S. Environmental Protection Agency; EPCRA = Emergency Planning and Community Right-to-Know Act; USDOT = U.S. Department of Transportation.

Table F.6-5 Federal, State, and Local Permits and Other Requirements for Ecological Resource Protection

License, Permit, or Other Required Approval	Responsible Agency	Authority	License, Permit, or Other Required Approval
Threatened and Endangered Species Consultation: Required between the responsible Federal agencies and FWS and/or NMFS to ensure that the project is not likely to: (1) jeopardize the continued existence of any species listed at the Federal or State level as endangered or threatened, or (2) result in destruction of critical habitat of such species.	FWS and NMFS	ESA of 1973, as amended (16 U.S.C. § 1531 et seq.)	For actions that may affect listed species or designated critical habitat, the NRC would consult with the FWS and/or NMFS under Section 7 of the ESA.

License, Permit, or Other Required Approval	Responsible Agency	Authority	License, Permit, or Other Required Approval
Essential Fish Habitat Consultation: Required between the responsible Federal agency and NMFS to ensure that Federal actions authorized, funded, or undertaken do not adversely affect essential fish habitat.	NMFS	MSA, as amended (16 U.S.C. §§ 1801–1891d)	For actions that may adversely affect essential fish habitat, the NRC would consult with NMFS in accordance with 50 CFR Part 600, Subpart J.
CWA Section 404 (Dredge and Fill) Permit: Required to place dredged or fill material into waters of the United States, including areas designated as wetlands, unless such placement is exempt or authorized by a nationwide permit or a regional permit; a notice must be filed if a nationwide or regional permit applies.	USACE	CWA (33 U.S.C. § 1251 et seq.); 33 CFR Parts 323 and 330	Any dredging or placement of fill material into wetlands within the jurisdiction of the USACE at a nuclear power plant would require a Section 404 permit.

CWA = Clean Water Act; ESA = Endangered Species Act; FWS = U.S. Fish and Wildlife Service; MSA = Magnuson-Stevens Fishery Conservation and Management Act; NMFS = National Marine Fisheries Service; NRC = U.S. Nuclear Regulatory Commission; USACE = U.S. Army Corps of Engineers.

Table F.6-6 Federal, State, and Local Permits and Other Requirements for Historic and Cultural Resource Protection

License, Permit, or Other Required Approval	Responsible Agency	Authority	License, Permit, or Other Required Approval
Archaeological and Historical Resources Consultation: Required before a Federal agency approves a project in an area where archaeological or historic resources might be located.	State Historic Preservation Officer and/or Tribal Historic Preservation Officer	National Historic Preservation Act of 1966, as amended (54 U.S.C. § 300101 et seq.); Archeological and Historical Preservation Act of 1974 (54 U.S.C. § 312501 et seq.); Antiquities Act of 1906 (54 U.S.C. § 320301–320303 and 18 U.S.C. § 1866(b)); Archaeological Resources Protection Act of 1979, as amended (54 U.S.C. § 302107)	The NRC would consult with the State and/or Tribal Historic Preservation Officers and representative Indian Tribes regarding the impacts of license renewal and the results of archaeological and architectural surveys at nuclear power plant sites.

F.7 Emergency Management and Response Laws, Regulations, and Executive Orders

This section discusses the response laws, regulations, and executive orders that address the protection of public health and worker safety and require the establishment of emergency plans. These laws, regulations, and executive orders relate to the operation of nuclear power plants. For ease of the reader, certain items are repeated from previous sections in this appendix.

F.7.1 Federal Emergency Management Response Laws

Emergency Planning and Community Right-to-Know Act of 1986 (42 U.S.C. § 11001 et seq.) (also known as "SARA Title III") – EPCRA, which is the major amendment of CERCLA (42 U.S.C. § 9601*)*, establishes the requirements for Federal, State, and local governments, Indian Tribes, and industry regarding emergency planning and "Community Right-to-Know" reporting on hazardous and toxic chemicals. The "Community Right-to-Know" provisions increase the public's knowledge and access to information about chemicals at individual facilities, their uses, and releases into the environment. States and communities working with facilities can use the information to improve chemical safety and protect public health and the environment. This Act requires emergency planning and notice to communities and government agencies concerning the presence and release of specific chemicals. The EPA implements this Act under regulations found in 40 CFR Part 355, Part 370, and Part 372.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (42 U.S.C. § 9604(l)) (also known as "Superfund") – This Act provides authority for Federal and State governments to respond directly to hazardous substance incidents. The Act requires reporting of spills, including radioactive spills, to the National Response Center.

Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 (42 U.S.C. § 5121) – This Act, as amended, provides an orderly, continuing means of providing Federal Government assistance to State and local governments in managing their responsibilities to alleviate suffering and damage resulting from disasters. The President, in response to a State governor's request, may declare an "emergency" or "major disaster" to provide Federal assistance under this Act. The President, in Executive Order 12148 (44 FR 43239), delegated all functions except those in Sections 301, 401, and 409 to the Director of the Federal Emergency Management Agency. The Act provides for the appointment of a Federal coordinating officer who will operate in the designated area with a State coordinating officer for the purpose of coordinating State and local disaster assistance efforts with those of the Federal Government.

Justice Assistance Act of 1984 (34 U.S.C. § 50101 et seq.) – This Act establishes emergency Federal law enforcement assistance to State and local governments in responding to a law enforcement emergency. The Act defines the term "law enforcement emergency" as an uncommon situation that requires law enforcement, that is or threatens to become of serious or epidemic proportions, and with respect to which State and local resources are inadequate to protect the lives and property of citizens or to enforce the criminal law. Emergencies that are not of an ongoing or chronic nature (for example, the Mount St. Helens volcanic eruption) are eligible for Federal law enforcement assistance including funds, equipment, training, intelligence information, and personnel.

Price-Anderson Nuclear Industries Indemnity Act (42 U.S.C. § 2210) – The Price-Anderson Act provides insurance protection to victims of a nuclear accident. The main purpose of the Act is to partially indemnify the nuclear industry against liability claims arising from nuclear incidents while still ensuring compensation coverage for the general public. The Act requires NRC licensees and U.S. Department of Energy contractors to enter into agreements of indemnification to cover personal injury and property damage to those harmed by a nuclear or radiological incident, including the costs of incident response or precautionary evacuation, costs of investigating and defending claims, and settling suits for such damages.

F.7.2 Federal Emergency Management and Response Regulations

Quantities of Radioactive Materials Requiring Consideration of the Need for an Emergency Plan for Responding to a Release (10 CFR 30.72, Schedule C) – This section of the regulations provides a list that is the basis for both the public and private sector to determine whether the radiological materials they handle must have an emergency response plan for unscheduled releases.

Occupational Safety and Health Administration Emergency Response, Hazardous Waste Operations, and Worker Right-to-Know (29 CFR Part 1910) – This regulation establishes OSHA requirements for employee safety in a variety of working environments. It addresses employee emergency and fire prevention plans (Section 1910.38), hazardous waste operations and emergency response (Section 1920.120), and hazards communication (Section 1910.1200) to make employees aware of the dangers they face from hazardous materials in their workplace. These regulations do not directly apply to Federal agencies. However, Section 19 of the Occupational Safety and Health Act (29 U.S.C. § 668) requires all Federal agencies to have occupational safety programs “consistent” with Occupational Safety and Health Act standards.

Emergency Management and Assistance (44 CFR Section 1.1) – This regulation contains the policies and procedures for the Federal Emergency Management Act, National Flood Insurance Program, Federal Crime Insurance Program, Fire Prevention and Control Program, Disaster Assistance Program, and Preparedness Program, including radiological planning and preparedness.

Hazardous Materials Tables and Communications, Emergency Response Information Requirements (49 CFR Part 172) – This regulation defines the regulatory requirements for marking, labeling, placarding, and documenting hazardous material shipments. The regulation also specifies the requirements for providing hazardous material information and training.

F.7.3 Emergency Management and Response Executive Orders

Executive Order 12148, Federal Emergency Management (44 FR 43239) – This Order transfers functions and responsibilities associated with Federal emergency management to the Director of the Federal Emergency Management Agency. The Order assigns the Director the responsibility to establish Federal policies and to coordinate all civil defense and civil emergency planning for the management, mitigation, and assistance functions of Executive agencies.

Executive Order 12656, Assignment of Emergency Preparedness Responsibilities (53 FR 47491) – This Order assigns emergency preparedness responsibilities to Federal departments and agencies.

Executive Order 12938, Proliferation of Weapons of Mass Destruction (59 FR 59099) – This Order states that the proliferation of nuclear, biological, and chemical weapons ("weapons of mass destruction") and the means of delivering such weapons constitutes an unusual and extraordinary threat to the national security, foreign policy, and economy of the United States, and that a national emergency would be declared to deal with that threat.

F.8 Consultations with Agencies and Federally Recognized Indian Tribes

Certain laws, such as the ESA (16 U.S.C. § 1531 et seq.), the Fish and Wildlife Coordination Act (16 U.S.C. § 661 et seq.), and the National Historic Preservation Act (54 U.S.C. § 300101 et seq.), require consultation and coordination by the NRC with other governmental entities including other Federal, State, and local agencies and Federally recognized Indian Tribes. These consultations must occur on a timely basis and are generally required before any land disturbance can begin. Most of these consultations are related to biotic resources, historic properties, cultural resources, and recognize NRC's Federal trust responsibility to Indian Tribes. The biotic resource consultations generally pertain to the potential for activities to disturb sensitive species or habitats. Cultural resource consultations relate to the potential for disruption of important cultural resources and archaeological sites. Consultations with Indian Tribes are conducted on a government-to-government basis.

F.9 References

10 CFR Part 20. *Code of Federal Regulations*, Title 10, *Energy*, Part 20, "Standards for Protection Against Radiation."

10 CFR Part 30. *Code of Federal Regulations*, Title 10, *Energy*, Part 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material."

10 CFR Part 50. *Code of Federal Regulations*, Title 10, *Energy*, Part 50, "Domestic Licensing of Production and Utilization Facilities."

10 CFR Part 51. *Code of Federal Regulations*, Title 10, *Energy*, Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions."

10 CFR Part 54. *Code of Federal Regulations*, Title 10, *Energy*, Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants."

29 CFR Part 1910. *Code of Federal Regulations*, Title 29, *Labor*, Part 1910, "Occupational Safety and Health Standards."

33 CFR Part 320. *Code of Federal Regulations*, Title 33, *Navigation and Navigable Waters*, Part 320, "General Regulatory Policies."

33 CFR Part 323. *Code of Federal Regulations*, Title 33, *Navigation and Navigable Waters,* Part 323, "Permits for Discharge of Dredged or Fill Material into Waters of the United States."

33 CFR Part 330. *Code of Federal Regulations*, Title 33, *Navigation and Navigable Waters*, Part 330, "Nationwide Permit Program."

36 CFR Part 800. *Code of Federal Regulations*, Title 36, *Parks, Forests, and Public Property*, Part 800, "Protection of Historic Properties."

40 CFR Part 70. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 70, “State Operating Permit Programs.”

40 CFR Part 112. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 112, “Oil Pollution Prevention.”

40 CFR Part 121. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 121, “State Certification of Activities Requiring a Federal License or Permit.”

40 CFR Part 122. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 122, “EPA Administered Permit Programs: The National Pollutant Discharge Elimination System.”

40 CFR Part 190. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 190, “Environmental Radiation Protection Standards for Nuclear Power Operations.”

40 CFR Part 280. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 280, “Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST).”

40 CFR Part 355. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 302, “Emergency Planning and Notification.”

40 CFR Part 370. *Code of Federal Regulations*, Title 40, *Protection of Environmen*t, Part 370, “Hazardous Chemical Reporting: Community Right-To-Know.”

40 CFR Part 372. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 372, “Toxic Chemical Release Reporting: Community Right-To-Know.”

40 CFR Part 761. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 761, “Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions.”

40 CFR Parts 50–99. *Code of Federal Regulations*, Title 40, *Protection of the Environment*, Subchapter C, Parts 50–99, “Air Programs.”

40 CFR Parts 239–282. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Parts 239–283, “EPA Regulations Implementing RCRA.”

40 CFR Parts 1500–1508. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Subchapter A, “National Environmental Policy Act Implementing Regulations.”

44 CFR Part 1. *Code of Federal Regulations*, Title 44, *Emergency Management and Assistance*, Part 1, “Rulemaking, Policy, and Procedures.”

49 CFR Part 172. *Code of Federal Regulations*, Title 49, *Transportation*, Part 172, “Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans.”

49 CFR Part 173. *Code of Federal Regulations*, Title 49, *Transportation*, Part 173, “Shippers—General Requirements for Shipments and Packagings.”

49 CFR Part 174. *Code of Federal Regulation*s, Title 49, *Transportation*, Part 174, "Carriage by Rail."

49 CFR Part 177. *Code of Federal Regulation*s, Title 49, *Transportation*, Part 177, "Carriage by Public Highway."

49 CFR Part 397. *Code of Federal Regulation*s, Title 49, *Transportation*, Part 397, "Transportation of Hazardous Materials; Driving and Parking Rules."

49 CFR Parts 171–177. *Code of Federal Regulations*, Title 49, *Transportation*, Subchapter C, "Hazardous Materials Regulations (49 CFR Parts 171–177)."

35 FR 4247. March 7, 1970. "Executive Order 11514 of March 5, 1970: Protection and Enhancement of Environmental Quality." *Federal Register*, Office of the President.

36 FR 8921. May 15, 1971. "Executive Order 11593 of May 13, 1971: Protection and Enhancement of the Cultural Environment." *Federal Register*, Office of the President.

42 FR 26951. May 25, 1977. "Executive Order 11988 of May 24, 1977: Floodplain Management." *Federal Register,* Office of the President.

42 FR 26961. May 25, 1977. "Executive Order 11990 of May 24, 1977: Protection of Wetlands." *Federal Register*, Office of the President.

43 FR 47707. October 17, 1978. "Executive Order 12088 of October 13, 1978: Federal Compliance with Pollution Control Standards." *Federal Register*, Office of the President.

44 FR 43239. July 24, 1979. "Executive Order 12148 of July 28, 1979: Federal Emergency Management." *Federal Register*, Office of the President.

52 FR 2923. January 29, 1987. "Executive Order 12580 of January 23, 1987: "Superfund Implementation." *Federal Register*, Office of the President.

53 FR 47491. November 23, 1988. "Executive Order 12656 of November 18, 1988: Assignment of Emergency Preparedness Responsibilities." *Federal Register*, Office of the President.

58 FR 41981. August 6, 1993. "Executive Order 12856 of August 3, 1993: Federal Compliance With Right-to-Know Laws and Pollution Prevention Requirements." *Federal Register*, Office of the President.

59 FR 7629. February 16, 1994. "Executive Order 12898 of February 11, 1994: Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations." *Federal Register*, Office of the President.

59 FR 59099. November 16, 1994. "Executive Order 12938 of November 14, 1994: Proliferation of Weapons of Mass Destruction." *Federal Register*, Office of the President.

61 FR 26771. May 29, 1996. "Executive Order 13007 of May 24, 1996: Indian Sacred Sites." *Federal Register*, Office of the President.

62 FR 19885. April 23, 1997. "Executive Order 13045 of April 21, 1997: Protection of Children From Environmental Health Risks and Safety Risks." *Federal Register*, Office of the President.

63 FR 49643. September 16, 1998. “Executive Order 13101 of September 14, 1998: Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition.” *Federal Register*, Office of the President.

64 FR 6183. February 8, 1999. “Executive Order 13112 of February 3, 1999: Invasive Species.” *Federal Register*, Office of the President.

64 FR 30851. June 8, 1999. “Executive Order 13123 of June 3, 1999: Greening the Government Through Efficient Energy Management.” *Federal Register*, Office of the President.

65 FR 24595. April 26, 2000. “Executive Order 13148 of April 21, 2000: Greening the Government Through Leadership in Environmental Management.” *Federal Register*, Office of the President.

65 FR 67249. November 9, 2000. “Executive Order 13175 of November 6, 2000—Consultation and Coordination with Indian Tribal Governments.” *Federal Register*, Office of the President.

66 FR 52013. October 11, 2001. “Executive Order 13229 of October 9, 2001: Amendment to Executive Order 13045, Extending the Task Force on Environmental Health Risks and Safety Risks to Children.” *Federal Register*, Office of the President.

68 FR 19931. April 23, 2003. “Executive Order 13296 of April 18, 2003: Amendments to Executive Order 13045, Protection of Children From Environmental Health Risks and Safety Risks.” *Federal Register*, Office of the President.

68 FR 37691. June 24, 2003. “Executive Order 13308 of June 20, 2003: Further Amendment to Executive Order 12580, as amended, Superfund Implementation.” *Federal Register*, Office of the President.

69 FR 52040. August 24, 2004. “Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions.” *Federal Register*, Nuclear Regulatory Commission.

82 FR 2402. January 9, 2017. “Tribal Policy Statement.” *Federal Register*, Nuclear Regulatory Commission.

86 FR 7037. January 25, 2021. “Executive Order 13990 of January 20, 2021: Protecting Public Health and the Environment and Restoring Science To Tackle the Climate Crisis.” *Federal Register*, Office of the President.

86 FR 7619. February 1, 2021. “Executive Order 14008 of January 27, 2021: Tackling the Climate Crisis at Home and Abroad.” *Federal Register*, Office of the President.

33 U.S.C. § 401. U.S. Code Title 33, *Navigation and Navigable Waters*, Section 401, “Construction of Bridges, Causeways, Dams or Dikes, Generally; Exemptions.”

33 U.S.C. § 403. U.S. Code Title 33, *Navigation and Navigable Waters*, Section 403 “Obstruction of Navigable Waters Generally; Wharves; Piers, etc.; Excavations and Filing in.”

33 U.S.C. § 1341. U.S. Code Title 33, *Navigation and Navigable Waters*, Chapter 26, "Water Pollution Prevention and Control," Subchapter IV, *Permits and Licenses*, Section 1341 "Certification."

34 U.S.C. § 50101 et seq. U.S. Code Title 34, *Crime Control and Law Enforcement*, Chapter 501, "Emergency Federal Law Enforcement Assistance."

42 U.S.C. § 6991a–6991i. U.S. Code Title 42, *The Public Health and Welfare*, Section 6991, "Notification" – 6991i, "Operator training."

42 U.S.C. § 7412. U.S. Code Title 42, *The Public Health and Welfare*, Clean Air Act Section 112, "Hazardous Air Pollutants."

42 U.S.C. § 7506. U.S. Code Title 42, *The Public Health and* Welfare, Clean Air Act Section 176, "Limitations on Certain Federal Assistance."

42 U.S.C. § 7661 – 7661f. U.S. Code Title 42, *The Public Health and Welfare*, Clean Air Act Section 7661, "Definitions" – 7661f, "Small business stationary source technical and environmental compliance assistance program."

42 U.S.C. § 9604. U.S. Code Title 42, *The Public Health and Welfare*, Section 9604, "Response authorities."

42 U.S.C. § 11004. U.S. Code Title 42, *The Public Health and Welfare*, Section 11004, "Emergency notification."

42 U.S.C. § 11021. U.S. Code Title 42, *The Public Health and Welfare*, Section 11021, "Material safety data sheets."

42 U.S.C. § 11022. U.S. Code Title 42, *The Public Health and Welfare*, Section 11022, "Emergency and hazardous chemical inventory forms."

42 U.S.C. § 11023. U.S. Code Title 42, *The Public Health and Welfare*, Section 11023, "Toxic chemical release forms."

American Indian Religious Freedom Act, as amended. 42 U.S.C. § 1996 et seq.

Antiquities Act of 1906, as amended. 54 U.S.C. § 320301–320303 and 18 U.S.C. § 1866(b).

Archaeological Resources Protection Act of 1979, as amended. 54 U.S.C. § 302107 et seq.

Archeological and Historic Preservation Act of 1974, as amended. 54 U.S.C. § 312501 et seq.

Atomic Energy Act of 1954, as amended. 42 U.S.C. § 2011 et seq.

Bald and Golden Eagle Protection Act of 1940. 16 U.S.C. § 668-668d et seq.

Clean Air Act of 1970. 42 U.S.C. § 7401 et seq.

Coastal Zone Management Act of 1972. 16 U.S.C. § 1451 et seq.

Comprehensive Environmental Response, Compensation, and Liability Act, as amended. 42 U.S.C. § 9601 et seq.

Emergency Planning and Community Right-to-Know Act of 1986. 42 U.S.C. § 11001 et seq.

Endangered Species Act of 1973. 16 U.S.C. § 1531 et seq.

Federal Insecticide, Fungicide, and Rodenticide Act, as amended. 7 U.S.C. § 136 et seq.

Federal Water Pollution Control Act of 1972 (commonly referred to as the Clean Water Act). 33 U.S.C. § 1251 et seq.

Fiscal Responsibility Act of 2023. Public Law No. 118-5, 137 Stat. 10.

Fish and Wildlife Conservation Act of 1980. 16 U.S.C. § 2901 et seq.

Fish and Wildlife Coordination Act of 1934, as amended. 16 U.S.C. § 661 et seq.

Hazardous Materials Transportation Act. 49 U.S.C. § 5101 et seq.

Justice Assistance Act of 1984. 34 U.S.C. § 50101 et seq.

Low-Level Radioactive Waste Policy Act of 1980. 42 U.S.C. § 2021b et seq. Public Law 96-573.

Magnuson-Stevens Fishery Conservation and Management Act, as amended. 16 U.S.C. § 1801 et seq.

Marine Mammal Protection Act of 1972, as amended. 16 U.S.C. § 1361 et seq.

Marine Protection, Research, and Sanctuaries Act of 1972, as amended. 33 U.S.C. § 1401 et seq.

Migratory Bird Treaty Act of 1918. 16 U.S.C. § 703 et seq.

National Environmental Policy Act of 1969, as amended. 42 U.S.C. § 4321 et seq.

National Historic Preservation Act of 1966, as amended. 54 U.S.C. § 300101 et seq.

National Marine Sanctuaries Act of 1966, as amended. 16 U.S.C. § 1431 et seq.

Native American Graves Protection and Repatriation Act of 1990. 25 U.S.C. § 3001 et seq.

Noise Control Act of 1972. 42 U.S.C. § 4901 et seq.

NRC (U.S. Nuclear Regulatory Commission). 2024a. *Standard Review Plans for Environmental Reviews for Nuclear Power Plants, Supplement 1: Operating License Renewal, Final Report*. NUREG-1555, Revision 2, Washington, D.C. ADAMS Accession No. ML23201A227.

NRC (U.S. Nuclear Regulatory Commission). 2024b. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Final Report*. NUREG-1437, Revision 2, Washington, D.C. ADAMS Package Accession No. ML24087A133.

NRC (U.S. Nuclear Regulatory Commission). 2024c. *Regulatory Guide 4.2 - Supplement 1, Revision 2 to Regulatory Guide 4.2 Preparation of Supplemental Environmental Reports for Applications to Renew Nuclear Power Plant Operating Licenses, Final Report*. Washington, D.C. ADAMS Accession No. ML ML23201A144.

Nuclear Waste Policy Act of 1982, as amended. 42 U.S.C. § 10101 et seq.

Occupational Safety and Health Act of 1970, as amended. 29 U.S.C. § 651 et seq.

Pollution Prevention Act of 1990. 42 U.S.C. § 13101 et seq.

Price-Anderson Act of 1957, as amended. 42 U.S.C. § 2210 et seq.

Resource Conservation and Recovery Act of 1976 (RCRA). 42 U.S.C. § 6901 et seq.

Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988. 42 U.S.C. § 5121 et seq.

Safe Drinking Water Act of 1974, as amended. 42 U.S.C. § 300f et seq.

Toxic Substances Control Act, as amended. 15 U.S.C. § 2601 et seq.

APPENDIX G

TECHNICAL SUPPORT FOR LR GEIS ANALYSES

APPENDIX G

TECHNICAL SUPPORT FOR LR GEIS ANALYSES

This appendix provides additional descriptions of the affected resources, including the description of the nuclear power plant built environment, and region of influence (ROI) that are described in Chapter 3 of this revision of NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (LR GEIS).[1] This appendix also provides additional descriptions of how the impact assessments were conducted in Chapter 4, except for cumulative effects, where the governing methodology is referenced and described in Chapter 4, Section 4.13.

G.1 <u>Nuclear Power Plant Site Facilities and Environs</u>

G.1.1 Description of Affected Resources and Region of Influence

Nuclear power plants contain a number of buildings or structures and other physical infrastructure. These components of the human-built environment interact with the natural and physical environment.

G.1.1.1 Nuclear Power Plant Appearance and Setting

The following list describes typical structures located on most nuclear power plant sites.

- **Containment or reactor building.** The containment or reactor building in a pressurized water reactor (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 boiling water reactor (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 tornadoes, hurricanes, and earthquakes. The containment building's ability

[1] This appendix primarily consists of material relocated from Appendix D in the draft LR GEIS. In addition, the information and analyses included in Section G.1 and Sections G.12.1.1 through G.12.1.7 consist of certain relocated text from Chapter 3 of the draft LR GEIS to address changes to the National Environmental Policy Act (NEPA) (42 U.S.C. § 4321 et seq.) from the Fiscal Responsibility Act of 2023 (Public Law No. 118-5, 137 Stat. 10). The text was relocated to revise the document to be less than the 300-page limit (not including appendices, citations, figures, tables, and other graphics) for environmental impact statements analyzing proposed agency actions of "extraordinary complexity" specified in the revised NEPA statute. Changes made in response to comments in this final LR GEIS, additions of new text, as well as corrective and substantial editorial revisions are marked with a change bar (vertical line) on the side margin of the page where the changes or additions were made. Minor editorial revisions and those limited to formatting are not marked. Text that was simply relocated from Chapter 3 and Appendix D, along with associated references, and not otherwise changed is not marked with a change bar.

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 waterbodies, 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 which are 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.

G.1.1.2 Utility and Transportation Infrastructure

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.

Fuel

An operating 1,000 MWe PWR contains approximately 220,000 pounds (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.

Water

Systems designed to provide cooling water at nuclear power plants are described in Chapter 3, Section 3.1.3 of this LR GEIS. 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, Limerick Generating Station, South Texas Project Electric Generating Station, Byron Station, Braidwood Station, LaSalle County Station, Surry Power Station, North Anna Power Station, and Point Beach Nuclear Plant) and some on surface waterbodies (e.g., nearby rivers and lakes) (e.g., the Columbia Generating Station and Peach Bottom plant) to obtain potable water. An increasing number of plants obtain potable water from public water systems (e.g., Seabrook Station, Enrico Fermi Atomic Power Plant, Sequoyah Nuclear Plant, Waterford Steam Electric Station, River Bend Station, and Turkey Point Nuclear Plant).

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 Chapter 3, Section 3.11.4 of this LR GEIS, 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.

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.

G.1.2 Description of Impact Assessment

Changes in the nuclear power plant physical infrastructure, including utility systems and resource utilization, were considered in terms of assessing potential impacts of nuclear power plant operations and any refurbishment during the initial license renewal (initial LR) and subsequent license renewal (SLR) terms. The U.S. Nuclear Regulatory Commission (NRC) reviewed initial LR and SLR supplemental environmental impact statements (SEISs) prepared since development of the 2013 LR GEIS for new information pertaining to changes in nuclear power plant infrastructure that could contribute to new or different environmental effects during the initial LR or SLR term.

G.2 <u>Land Use and Visual Resources</u>

G.2.1 Description of Affected Resources and Region of Influence

Land use includes the land on and adjacent to each nuclear power plant site, the physical features that influence current or proposed uses, pertinent land use plans and regulations, and land ownership and availability. The ROI for land use impacts varies due to the effects of tax payments to local jurisdictions, land ownership, land use patterns, population and housing development trends, and other geographic or safety considerations but generally includes the site and areas immediately surrounding the power plant site.

Onsite land use that could be affected by the continued operation of the nuclear power plant during the license renewal term (initial LR or SLR) includes all the land within the nuclear plant site boundary and licensee property. For license renewal, current onsite industrial land use is assumed to remain unchanged. Offsite land use includes all land use near the nuclear power plant that could be affected by continued power plant operations and refurbishment activities associated with license renewal. Transmission lines do not preclude the use of land in right-of-ways for other purposes, such as agriculture and recreation. However, certain land use activities in transmission line right-of-ways are restricted.

Visual resources are natural and human-made features that give the landscape its character and aesthetic quality. Landscape character is determined by the visual elements of form, line, color, and texture. All four elements are present in every landscape, but they exert varying degrees of influence. The stronger the influence exerted by these elements in a landscape, the more interesting the landscape. The ROI for visual resources includes the geographic area from which the nuclear power plant may be seen. This would generally involve higher elevations and public roadways. Transmission lines connecting the nuclear plant to the electrical grid are no different from transmission lines connecting any other power plant.

G.2.2 Description of Impact Assessment

License renewal supplemental environmental impact statements (LR SEISs) were examined to determine the extent of onsite and offsite land use and aesthetic impacts from license renewal and refurbishment activities at nuclear power plants. The amount of land disturbed and changes to existing land use were considered to determine potential land use impacts. The LR GEIS generically evaluates potential land use impacts caused by power plant operations both on and off the nuclear plant site. The analysis focuses on the amount of land area affected, changes to existing land use, proximity to special areas, and other factors pertaining to land use. The visual appearance of the nuclear power plant and transmission lines have been well established. These conditions are expected to remain unchanged during the initial LR or SLR term regardless of the number of years of nuclear plant operation.

G.3 Air Quality and Noise

G.3.1 Description of Affected Resources and Region of Influence

Similar to most industrial facilities, nuclear power plants and other fuel-cycle facilities generate air pollutants[2] and propagate noise. Air quality designations (e.g., attainment, nonattainment with respect to National Ambient Air Quality Standards) are typically made at the county level. Therefore, the ROI for air quality is typically the county where the nuclear power plant is located. If a nuclear power plant is located within two counties or near the border of an adjacent county, both counties should be considered as part of the ROI. Sources at nuclear power plants that contribute to criteria air pollutants include backup diesel generators, boilers, fire pump engines, and cooling towers. Fossil fuel-fired equipment is operated intermittently, primarily during testing or outages. Refurbishment activities associated with continued operations that might be necessary to support license renewal terms include fugitive dust from site excavation and grading and emissions from motorized equipment, construction vehicles, and workers' vehicles.

[2] Both radiological and nonradiological (criteria air pollutants) releases are covered in the LR GEIS. See Appendix G.9 for a description of the region of influence and the impact assessment for radiological releases.

Nuclear power plants generate noise primarily from the operation and use of cooling towers, turbine generators, transformers, main steam safety valves, transmission lines, and firing ranges. Noise from nuclear plant operations can often be detected offsite relatively close to the plant site boundary. The ROI for noise impacts includes a 1 mi (1.6 km) radius from the nuclear power plant.

The narrative, figures, and tables provide supplemental data and information in support of the air quality and noise impacts provided in Chapter 3, Section 3.3 and Chapter 4, Section 4.3 of this LR GEIS.

G.3.1.1 Climatology

Continental U.S. maximum and minimum average annual temperatures from 1991 through 2020 are shown in Figure G.3-1 and Figure G.3-2, respectively. The average annual precipitation during the same period is shown in Figure G.3-3.

G.3.1.2 Noise

Table G.3-1 presents common noise sources and their respective noise levels. A whisper is normally 30 A-weighted decibels (dBA) and is considered very quiet. Noise levels can become very annoying at 80 dBA (CDC 2022). Noise levels attenuate rapidly with distance. When distance is doubled from a point source, noise levels decrease by 6 dBA (DOT 2017). Generally, a 3 dBA change over existing noise levels is considered to be a “just noticeable” difference, a 5 dBA increase is readily perceptible, and a 10 dBA increase is subjectively perceived as a doubling in loudness (DOT 2017).

Table G.3-1 Common Sources of Noise and Decibels Levels

Everyday Sounds and Noises	Average Sound Level dB
Normal breathing	10
Soft whisper	30
Refrigerator hum	40
Normal conversation	60
Washing machine	70
City traffic	80–85
Lawnmower	80–85
Motorcycle	95
Approaching subway	100

dB = decibel.
Source: CDC 2022.

There are no Federal Regulations for public exposures to noise. In 1972, Congress passed the Noise Control Act of 1972 (42 U.S.C. § 4901 et seq.) establishing a national policy to promote an environment free of noise that affects the health and welfare of the public. However, in 1982 there was a shift in Federal noise control policy to transfer the responsibility of regulation of noise to State and local governments. The Noise Control Act of 1972 was never rescinded by Congress but remains unfunded (EPA 2023). The Department of Housing and Urban Development considers day-night average sound level outside a residence acceptable if it is less than 65 dBA. The U.S. Environmental Protection Agency (EPA) uses a day-night sound level threshold of 55 dBA in residential areas to prevent activity interference and annoyance.

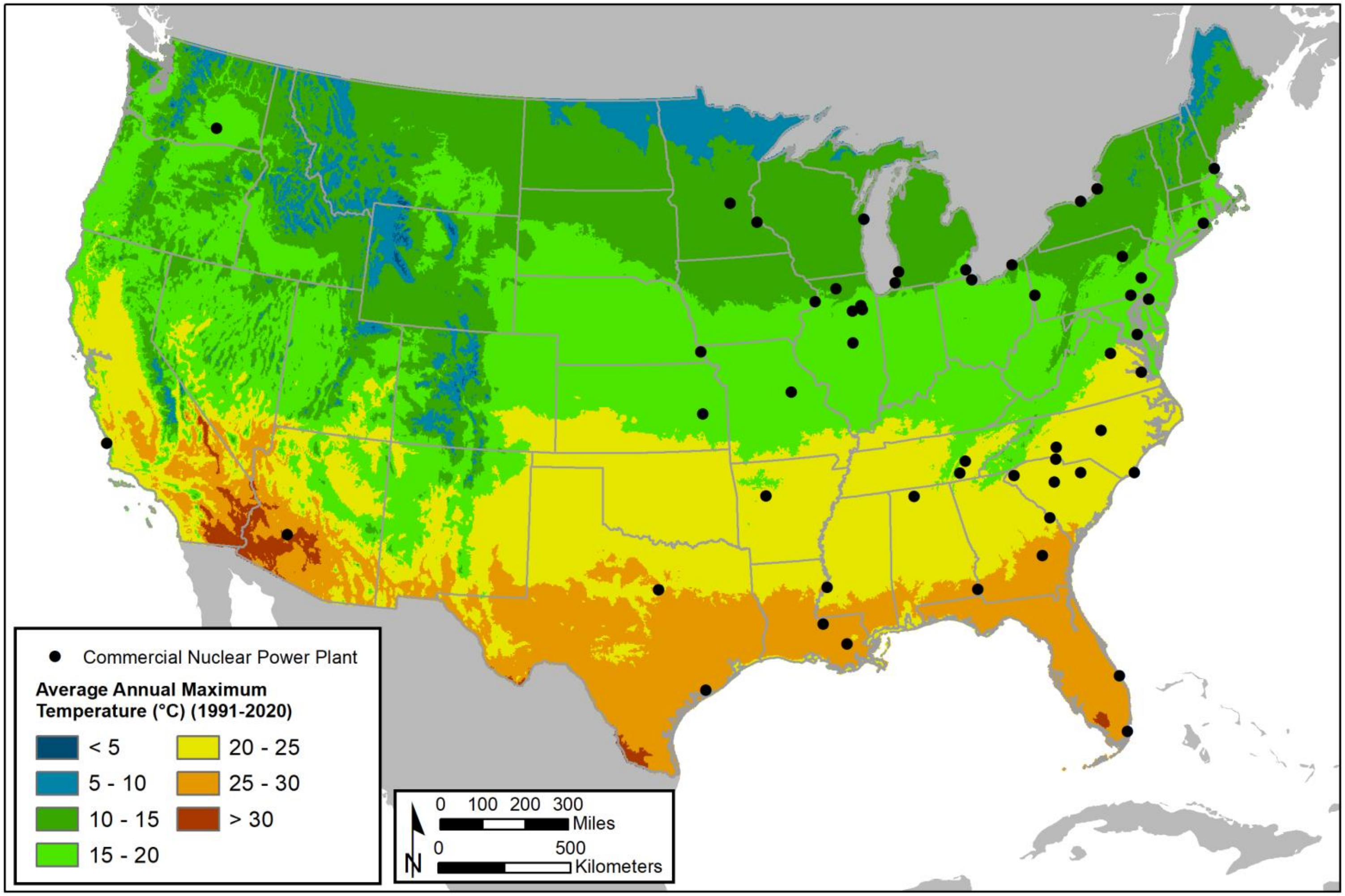


Figure G.3-1 Average Annual Maximum Temperatures across the Continental United States (1991–2020)

(Permission to use this copyrighted material is granted by PRISM Group, Oregon State University)
Copyright © 2022, PRISM Climate Group, Oregon State University, https://www.prism.oregonstate.edu/. Map created April 26, 2022.

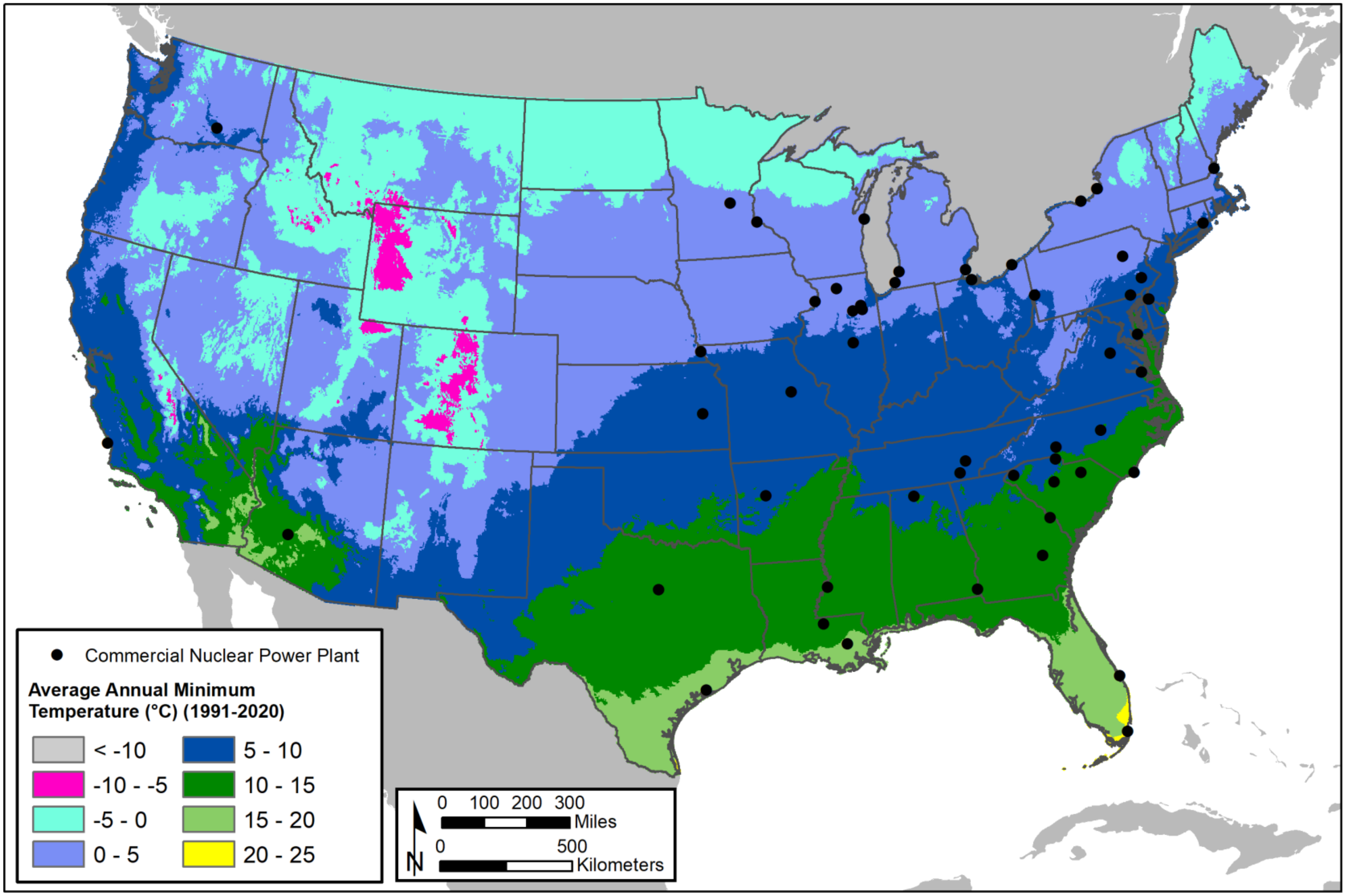


Figure G.3-2 Average Annual Minimum Temperatures across the Continental United States (1991–2020)

(Permission to use this copyrighted material is granted by PRISM Group, Oregon State University)
Copyright © 2022, PRISM Climate Group, Oregon State University, https://www.prism.oregonstate.edu/. Map created April 26, 2022.

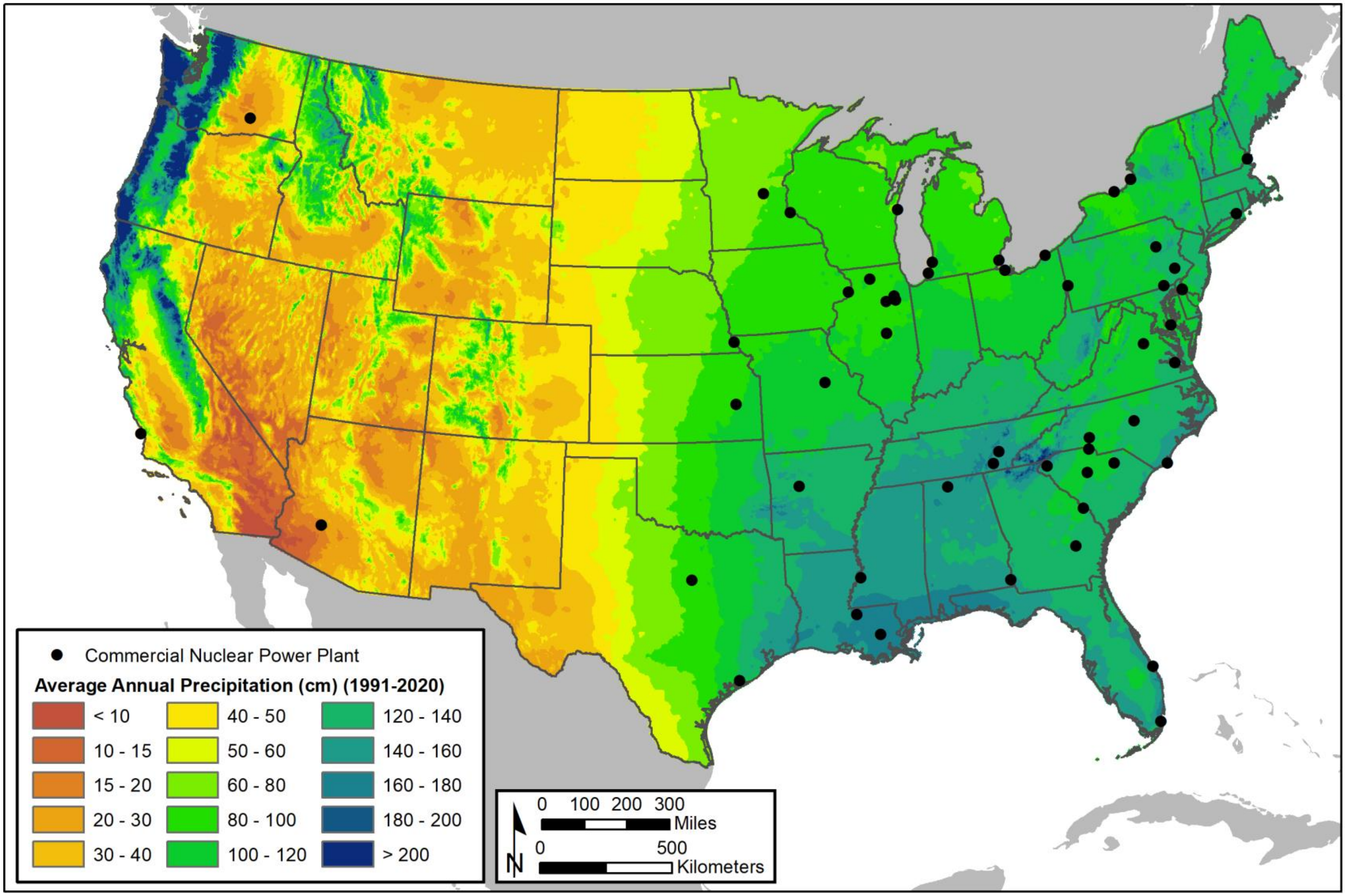


Figure G.3-3 Average Annual Precipitation across the Continental United States (1991–2020)

(Permission to use this copyrighted material is granted by PRISM Group, Oregon State University)

Copyright © 2022, PRISM Climate Group, Oregon State University, https://www.prism.oregonstate.edu/. Map created April 26, 2022.

G.3.2 Description of Impact Assessment

The 2013 LR GEIS identified air quality impacts from continued operations and refurbishment activities as a Category 1 issue. Initial LR and SLR SEISs completed since development of the 2013 LR GEIS were reviewed for new information pertaining to air quality impacts from continued operations and refurbishment activities at nuclear power plants that would indicate different impacts during the initial LR or SLR term, but none were noted. In these SEISs, 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 initial LR or SLR term. SEISs have also concluded that vehicle exhaust emissions during plant refurbishment activities are minor and do not exceed *de minimis* thresholds prescribed in the General Conformity Regulations (40 CFR 93.152(b)).

The 1996 and 2013 LR GEISs (NRC 1996, NRC 2013) determined that the impacts of continued operation on offsite noise levels would be SMALL. Initial LR and SLR SEISs completed since development of the 2013 LR GEIS were reviewed for new information pertaining to noise impacts from continued operations and refurbishment activities at nuclear power plants. In these SEISs, the NRC documented that noise levels near noise-sensitive receptors are below 65 dBA, or noise levels that exceeded 65 dBA were not attributed to operation of the nuclear power plant. Nuclear power plants have received noise complaints associated with operation activities. In response to noise complaints, licensees have provided advance notice to the public about upcoming activities when there is a potential for temporary increase in noise levels. In the 1996 and 2013 LR GEISs, the NRC noted that there have been few noise complaints at power plants and that noise impacts have been found to be small. Initial LR and SLR SEISs completed since development of the 2013 LR GEIS were reviewed to identify any trends or changes in public perception of plant noise.

G.4 <u>Geologic Environment</u>

G.4.1 Description of Affected Resources and Region of Influence

An understanding of geologic and soil conditions, as well as the presence of geologic hazards, has been well established at all nuclear power plants during the current licensing term. Changes in the potential for hazards, such as earthquakes, are not within the scope of this LR GEIS because any such changes during the period of extended operation would not be the result of nuclear reactor operations. The geologic and soil resources considered in this LR GEIS are those that could be affected by an additional 20 years of reactor operation during the initial LR and SLR terms and by any refurbishment activities within the nuclear power plant site property boundaries and nearby offsite areas. Because land and soil disturbance during license renewal could occur in undisturbed and undeveloped areas either onsite or possibly offsite, the locations of power plants relative to areas of important farmland soils (e.g., prime farmland) were considered. In addition, the region of potentially affected geologic resources considered extends to offsite areas because the presence of a nuclear power plant may restrict rock, mineral, and fossil fuel extraction operations beyond the site boundaries.

G.4.2 Description of Impact Assessment

Geologic and soil resources could be affected by construction or any refurbishment projects during the license renewal (initial LR or SLR) term or subsequently during plant decommissioning. These actions would include activities that disturb surface soils, sediments, and underlying geologic strata, resulting in effects such as erosion, loss of soil resources, and increased suspended solids in nearby surface waterbodies.

Initial LR and SLR SEISs completed since development of the 2013 LR GEIS were reviewed for new information pertaining to geologic and soil impacts from continued operations and any refurbishment, as documented in Chapter 4 of this LR GEIS. The magnitude of the impact of potential ground-disturbing activities on geology and soils and local geologic resources would depend on plant-specific factors such as the nature of geologic strata and soils, facility location, construction planning, and site-specific resource mapping.

G.5 Water Resources

G.5.1 Description of Affected Resources and Region of Influence

Most U.S. nuclear power plants are located near significant surface waterbodies that are either natural or human-made. Therefore, the ROI for water resources includes those on and adjacent to each nuclear power plant site that could be affected by water withdrawals, effluent discharges, and spills or stormwater runoff associated with continued operations and refurbishment activities. Thus, the surface water resources considered include those onsite, downstream of the site (in the case of river settings), or throughout some portion of a body of water (in the case of an ocean, lake or Great Lake, bay, reservoir, or pond) adjacent to the site. The ROI for groundwater impacts includes areas both onsite (local water table) and offsite (regional aquifer).

G.5.2 Description of Impact Assessment

Sources of information about surface water and groundwater issues regarding water use, water use conflicts, and water quality included the 1996 and 2013 LR GEISs and plant-specific supplements to the LR GEIS. All SEISs for initial LR and SLR reviews completed since development of the 2013 LR GEIS were reviewed for new information pertaining to water issues.

To analyze the condenser flow rate requirements and consumptive loss associated with specific categories of cooling system technologies (see Chapter 3, Sections 3.1.3 and 3.5.1.1 in this LR GEIS), data and insights retained from the 1996 and 2013 LR GEISs and from recent technical literature, such as from the U.S. Geological Survey (USGS 2019a; Marston et al. 2018), were compiled. The flow rates and consumptive loss rates were normalized by electricity generation or to a specific power capacity to allow comparisons.

Permitting requirements related to surface water withdrawal and groundwater use were summarized, and recent information was reviewed to assess water use quality issues and water use conflicts in the vicinity of specific nuclear power plants.

Initial LR and SLR SEISs completed since development of the 2013 LR GEIS were reviewed for new information related to surface water and groundwater resources, as documented in Chapter 4 of this LR GEIS.

G.6 Ecological Resources

G.6.1 Description of Affected Resources and Region of Influence

Terrestrial resources potentially affected by nuclear power plant operations during the license renewal term (initial LR and SLR) were determined at a broad level by obtaining the Level III ecoregion data (EPA 2013) (Table G.6-1) and land cover data (USGS 2019b) for the vicinity of each operating nuclear power plant. An ecoregion describes a broad landscape in which the ecosystems have a general similarity. It can be characterized by the spatial pattern and composition of biotic and abiotic features, such as vegetation, wildlife, physiography, climate, soils, and hydrology (CEC 1997). The Level I ecoregions of the United States in which the operating nuclear power plants are located are shown in Figure G.6-1. Each ecoregion is subdivided into subregions. Level III ecoregions range from the warm, arid Sonoran Basin and Range ecoregion with cactus-shrub habitats, in which the Palo Verde plant in Arizona is located, to the cool, moist Northeastern Coastal Zone ecoregion with oak and oak-pine forests, which includes the Seabrook plant in New Hampshire. Level III ecoregions in the vicinity of the operating nuclear power plants are presented in Table G.6-2. The ROI for each operating nuclear power plant was considered to be the area within a radius of 5 mi (8 km) as well as the in-scope transmission lines associated with each nuclear power plant.

Within a radius of 5 mi (8 km) of operating nuclear power plants, an average of 23.5 percent of the land area is forested, 4.2 percent is grassland, and 4.2 percent is shrubland, as determined from land cover data (USGS 2019b). Agricultural lands are also present in the vicinity of all operating nuclear power plants with an average of 22.2 percent of the area within 5 mi (8 km) around all nuclear plants designated as cultivated crops or pasture. Wetland types within 5 mi (8 km) of each nuclear power plant were determined by obtaining National Wetland Inventory data (EPA 2013) (Table G.6-3). Open water areas (or deepwater habitats) were assigned to National Wetland Inventory classification based on the National Wetland Inventory classification methodology.

Aquatic habitats and the types of aquatic organisms (including federally protected resources) that could be affected by nuclear power plant operations during the license renewal term (initial LR or SLR) were determined at a broad level based on the location of the plant and the source waterbody of the plant cooling water system. In cases where cooling systems could affect more than one type of system (e.g., freshwater and estuarine), impacts on both systems were considered in the analysis. Similarly, the potential for migratory aquatic species to be affected by a particular nuclear power plant was based on reported occurrences of such species in source waterbodies. In general, impingement and entrainment rates and thermal impacts on aquatic organisms from cooling water systems were considered to be lower for nuclear power plants with cooling towers that operate in a fully closed-cycle mode, because those plants withdraw smaller volumes of water for cooling and discharge comparatively less thermal effluent.

Additional information regarding terrestrial and aquatic resources in the vicinity of specific nuclear power plants was obtained from scientific articles and reports and SEISs for initial LR and SLR reviews completed since development of the 2013 LR GEIS. The NRC staff used this information to describe the general types of nuclear power plant interactions with ecological resources and to illustrate the types of impacts observed at nuclear power plant sites.

Table G.6-1 Level I Ecoregions and Corresponding Level III Ecoregions That Occur in the Vicinity of Operating U.S. Commercial Nuclear Power Plants

Level I Ecoregion	Level III Ecoregion	Level III Description
Eastern Temperate Forests	Arkansas Valley	Forest, pasture, cropland; bottomland deciduous forest on floodplains
Eastern Temperate Forests	Central Corn Belt Plains	Agriculture and cropland; tallgrass prairie, oak-hickory forest
Eastern Temperate Forests	Driftless Area	Agriculture and cropland; prairie, hardwood forest
Eastern Temperate Forests	Eastern Great Lakes and Hudson Lowlands	Agriculture and cropland; mixed coniferous-deciduous forest
Eastern Temperate Forests	Erie Drift Plain	Agriculture; mixed oak and maple-beech-birch forest; wetlands
Eastern Temperate Forests	Huron/Erie Lake Plains	Agriculture and cropland; maple, ash, oak, hickory forest
Eastern Temperate Forests	Interior Plateau	Oak-hickory forest, cropland, pasture; bluestem prairie, cedar glades
Eastern Temperate Forests	Interior River Valleys and Hills	Cropland; pasture; forested valley slopes, bottomland deciduous forest, swamp forest, mixed oak forest, oak-hickory forest
Eastern Temperate Forests	Middle Atlantic Coastal Plain	Pine and oak-hickory-pine forest, swamp, marsh, estuaries; oak, gum, cypress near rivers; cropland; dunes, barrier islands
Eastern Temperate Forests	Mississippi Alluvial Plain	Cropland; bottomland deciduous forest; oxbow lakes and ponds
Eastern Temperate Forests	Mississippi Valley Loess Plains	Cropland; oak-hickory forest and oak-hickory-pine forest; perennial and intermittent streams
Eastern Temperate Forests	North Central Hardwood Forests	Mosaic northern hardwood forest, wetlands and lakes, cropland, pasture
Eastern Temperate Forests	Northeastern Coastal Zone	Oak and oak-pine forest; lakes, streams, wetlands
Eastern Temperate Forests	Northern Piedmont	Agriculture and cropland, Appalachian oak forest, perennial streams
Eastern Temperate Forests	Piedmont	Oak-hickory-pine woodland; cropland; perennial streams

Level I Ecoregion	Level III Ecoregion	Level III Description
Eastern Temperate Forests	Ridge and Valley	Appalachian oak forest, oak-hickory-pine forest, pasture; cropland; streams, springs, caves, reservoirs
Eastern Temperate Forests	Southern Michigan/Northern Indiana Drift Plains	Lakes, marsh; agriculture; oak-hickory forest, northern swamp forest, beech forest; pasture
Eastern Temperate Forests	Southeastern Plains	Mosaic of cropland, pasture, woodland, mixed forest
Eastern Temperate Forests	Southeastern Wisconsin Till Plains	Agriculture; mosaic of hardwood forest, oak savanna, tallgrass prairie
Eastern Temperate Forests	Southern Coastal Plain	Coastal lagoons, marsh, swamp, barrier islands; pine, oak-gum-cypress forest; citrus groves, pasture; lakes
Eastern Temperate Forests	Western Allegheny Plateau	Mixed mesophytic forest, mixed oak forest; pasture, cropland
Great Plains	Central Irregular Plains	Mosaic of grassland, wide riparian forest; cropland
Great Plains	Cross Timbers	Rangeland, pasture; little bluestem grassland with scattered oaks
Great Plains	Western Corn Belt Plains	Cropland, pasture; tallgrass prairie; narrow riparian forest
Great Plains	Western Gulf Coastal Plain	Grassland, cropland
North American Deserts	Columbia Plateau	Arid sagebrush steppe and grassland; agriculture
North American Deserts	Sonoran Basin and Range	Hot climate; creosotebush and bursage; large areas of palo verde-cactus shrub and giant saguaro cactus
Mediterranean California	Southern and Central California Chaparral and Oak Woodlands	Mediterranean climate: hot dry summers, cool moist winters
Tropical Wet Forests	Southern Florida Coastal Plain	Frost-free climate; flat plains with wet soils; marshland, swamp, everglades, palmetto prairie

Sources: EPA 2013; Wiken et al. 2011.

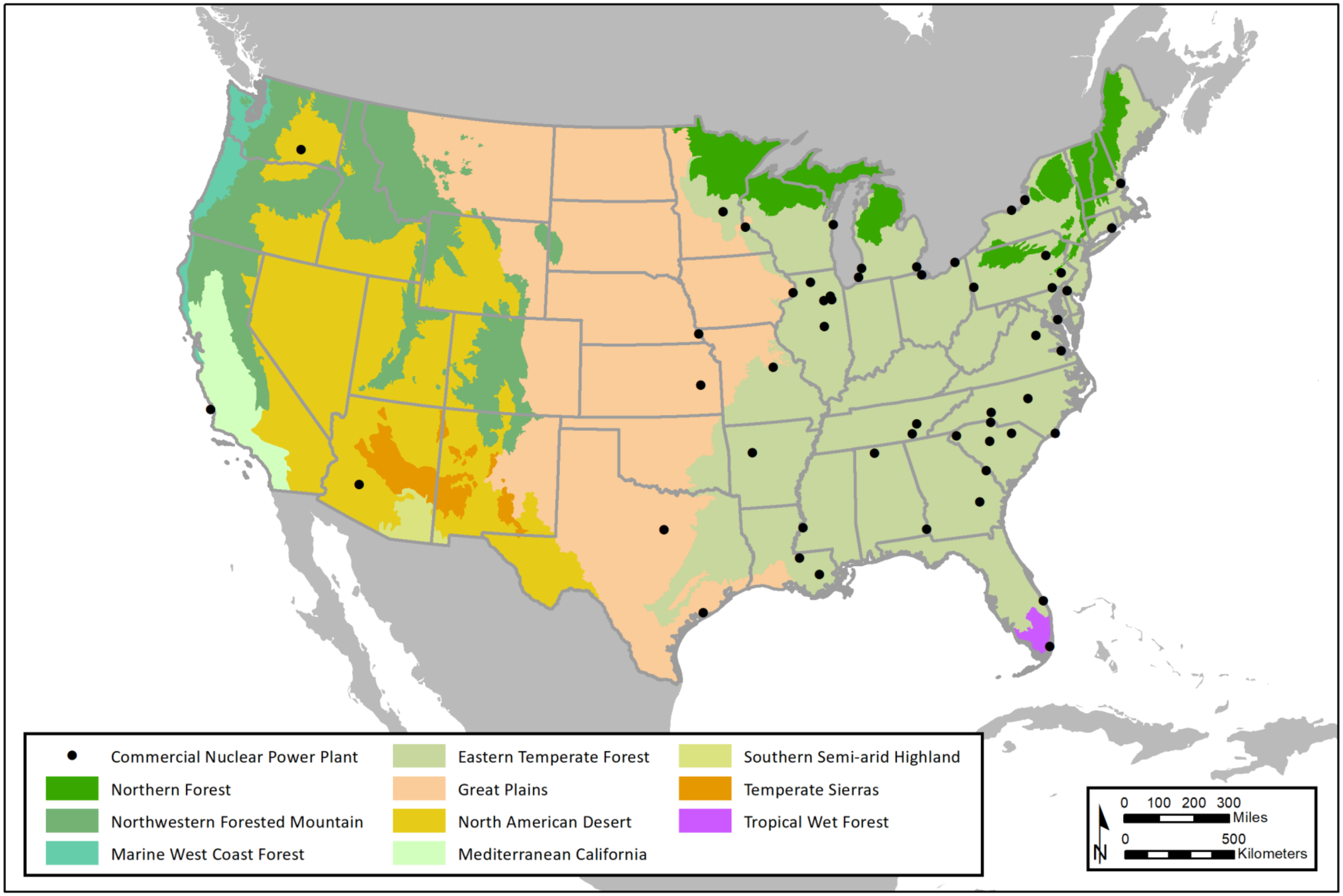


Figure G.6-1 Level I Ecoregions of the United States (EPA 2013)

Table G.6-2 Ecoregions in the Vicinity of Operating U.S. Commercial Nuclear Power Plants

Site Name	Level I Description	Level III Ecoregion(s)
Arkansas	Eastern Temperate Forests	Arkansas Valley
Beaver Valley	Eastern Temperate Forests	Western Allegheny Plateau
Braidwood	Eastern Temperate Forests	Central Corn Belt Plains
Browns Ferry	Eastern Temperate Forests	Interior Plateau
Brunswick	Eastern Temperate Forests	Middle Atlantic Coastal Plain
Byron	Eastern Temperate Forests	Central Corn Belt Plains
Callaway	Eastern Temperate Forests	Interior River Valleys and Hills
Calvert Cliffs	Eastern Temperate Forests	Southeastern Plains, Middle Atlantic Coastal Plain
Catawba	Eastern Temperate Forests	Piedmont
Clinton	Eastern Temperate Forests	Central Corn Belt Plains
Columbia	North American Deserts	Columbia Plateau
Comanche Peak	Great Plains	Cross Timbers
Cooper	Great Plains	Western Corn Belt Plains
Davis-Besse	Eastern Temperate Forests	Huron/Erie Lake Plains
D.C. Cook	Eastern Temperate Forests	S. Michigan/N. Indiana Drift Plains
Diablo Canyon	Mediterranean California	Southern and Central California Chaparral and Oak Woodlands
Dresden	Eastern Temperate Forests	Central Corn Belt Plains
Farley	Eastern Temperate Forests	Southeastern Plains
Fermi	Eastern Temperate Forests	Huron/Erie Lake Plains
FitzPatrick	Eastern Temperate Forests	Eastern Great Lakes and Hudson Lowlands
Ginna	Eastern Temperate Forests	Eastern Great Lakes and Hudson Lowlands
Grand Gulf	Eastern Temperate Forests	Mississippi Valley Loess Plains, Mississippi Alluvial Plain
Harris	Eastern Temperate Forests	Piedmont, Southeastern Plains
Hatch	Eastern Temperate Forests	Southeastern Plains, Southern Coastal Plain

Site Name	Level I Description	Level III Ecoregion(s)
Hope Creek	Eastern Temperate Forests	Middle Atlantic Coastal Plain
LaSalle	Eastern Temperate Forests	Central Corn Belt Plains
Limerick	Eastern Temperate Forests	Northern Piedmont
McGuire	Eastern Temperate Forests	Piedmont
Millstone	Eastern Temperate Forests	Northeastern Coastal Zone
Monticello	Eastern Temperate Forests	North Central Hardwood Forests
Nine Mile Point	Eastern Temperate Forests	Eastern Great Lakes and Hudson Lowlands
North Anna	Eastern Temperate Forests	Piedmont
Oconee	Eastern Temperate Forests	Piedmont
Palisades[a]	Eastern Temperate Forests	S. Michigan/N. Indiana Drift Plains
Palo Verde	North American Deserts	Sonoran Basin and Range
Peach Bottom	Eastern Temperate Forests	Northern Piedmont
Perry	Eastern Temperate Forests	Eastern Great Lakes and Hudson Lowlands, Erie Drift Plain
Point Beach	Eastern Temperate Forests	Southeastern Wisconsin Till Plains
Prairie Island	Eastern Temperate Forests	Driftless Area
Quad Cities	Eastern Temperate Forests and Great Plains	Interior River Valleys and Hills, Western Corn Belt Plains, Central Corn Belt Plains
River Bend	Eastern Temperate Forests	Mississippi Valley Loess Plains, Mississippi Alluvial Plain
Robinson	Eastern Temperate Forests	Southeastern Plains
Salem	Eastern Temperate Forests	Middle Atlantic Coastal Plain
Seabrook	Eastern Temperate Forests	Northeastern Coastal Zone
Sequoyah	Eastern Temperate Forests	Ridge and Valley
South Texas	Great Plains	Western Gulf Coastal Plain
St. Lucie	Eastern Temperate Forests	Southern Coastal Plain
Summer	Eastern Temperate Forests	Piedmont
Surry	Eastern Temperate Forests	Middle Atlantic Coastal Plain, Southeastern Plains

Site Name	Level I Description	Level III Ecoregion(s)
Susquehanna	Eastern Temperate Forests	Ridge and Valley
Turkey Point	Tropical Wet Forests	Southern Florida Coastal Plain
Vogtle	Eastern Temperate Forests	Southeastern Plains
Waterford	Eastern Temperate Forests	Mississippi Alluvial Plain
Watts Bar	Eastern Temperate Forests	Ridge and Valley
Wolf Creek	Great Plains	Central Irregular Plains

(a) Shutdown in May 2022.
Source: EPA 2013.

G.6.2 Description of Impact Assessment

A wide range of issues related to the potential impacts of license renewal on ecological resources were evaluated by considering how continued operations would affect ecological resources compared to current conditions. Potential impacts on terrestrial and aquatic resources were identified and evaluated, in part, through the NRC staff's review of published literature related to power facility operation and SEISs for initial LR and SLR reviews completed since development of the 2013 LR GEIS, and from documents associated with interagency consultations with the U.S. Fish and Wildlife Service and National Marine Fisheries Service (e.g., biological assessments, biological opinions, and essential fish habitat assessments). Although some of the impacts identified were specific to nuclear power plant operation (e.g., effects of radionuclides on biota), the staff also reviewed impacts associated with other types of power facilities (e.g., the effects of bird collisions with cooling towers and plant structures or the effects of impingement, entrainment, and thermal effluents on fish and other aquatic organisms). The NRC staff also considered new information concerning nuclear power plant operations during an initial LR or SLR term that is presented in SEISs since development of the 2013 LR GEIS.

The NRC staff evaluated the potential impacts of exposure of terrestrial and aquatic organisms to radionuclides from normal operations of nuclear power plants by reviewing Radiological Environmental Monitoring Program (REMP) reports (primarily annual radiological environmental operating reports) for the year 2020 for a subset of operating PWR and BWR plants[3] selected to determine radionuclide levels present in environmental media. 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 (LLDs) stated in NUREG-1301 and NUREG-1302 (NRC 1991a, NRC 1991b), the NRC staff obtained site-specific radionuclide concentrations and LLDs in water, sediment, and soils when available from the REMP reports.

[3] 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.

Table G.6-3 Percent of Area Occupied by Wetland and Deepwater Habitats within 5 Miles of Operating Nuclear Power Plants

Nuclear Power Plant	Estuarine and Marine Deepwater[(a)]	Estuarine and Marine Wetland	Freshwater Emergent Wetland	Freshwater Forested/ Shrub Wetland	Freshwater Pond	Lake[(a)]	Riverine[(a)]	Other[(b)]	Total Wetland[(c)]	Total Deepwater Habitats
Arkansas	0	0	0	0.4	0.5	0.2	0.7	0	0.9	0.9
Beaver Valley	0	0	0.2	0.1	0.2	1.7	4.3	0	0.5	6
Braidwood	0	0	1.1	1	1.8	8	1.8	0	3.9	9.8
Browns Ferry	0	0	0.9	10.9	0.2	26.1	0.2	0	11.9	26.3
Brunswick	25.2	14.1	1	16.6	0.6	0.3	0.3	0	32.3	25.8
Byron	0	0	0.6	1	0.1	1.9	0.9	0	1.8	2.8
Callaway	0	0	0.9	1.8	0.5	0.4	1.9	0	3.3	2.3
Calvert Cliffs	53.1	0.4	0.3	1.3	0.2	0.4	0.1	0	2.1	53.6
Catawba	0	0	0	0.4	0.4	12.2	0.9	0	0.7	13.1
Clinton	0	0	0.1	0.4	0.2	8.4	0.4	0	0.7	8.7
Columbia	0	0	0.1	0.1	0	5.5	0	0	0.3	5.6
Comanche Peak	0	0	0.1	0.6	0.4	0	1.4	0	1.1	1.4
Cooper	0	0	0.9	3.2	0.3	0.1	3.4	0	4.4	3.5
Davis-Besse	0	0	8	2.8	0.7	52.6	2.8	0	11.6	55.4
D.C. Cook	0	0	0.5	2.3	0.3	49.6	0.2	0	3.1	49.8
Diablo Canyon	0	0.3	0	0.5	0	0	0.1	0	0.7	0.2
Dresden	0	0	5.4	3.6	1.8	10.9	0.9	0	10.7	11.8
Farley	0	0	0.9	10.3	0.5	1.6	0.4	0	11.8	2
Fermi	0	0	4	1.7	0.4	47.3	1	0	6	48.4
FitzPatrick	0	0	0.1	3.1	0.1	59.6	0.2	0	3.4	59.8

Nuclear Power Plant	Estuarine and Marine Deepwater(a)	Estuarine and Marine Wetland	Freshwater Emergent Wetland	Freshwater Forested/ Shrub Wetland	Freshwater Pond	Lake(a)	Riverine(a)	Other(b)	Total Wetland(c)	Total Deepwater Habitats
Ginna	0	0	0.2	3.7	0.4	49.5	0.6	0	4.3	50.2
Grand Gulf	0	0	0	24.9	0.3	2.3	12.7	0	25.3	15
Harris	0	0	0	3.5	0.4	9.4	0.6	0	3.9	10
Hatch	0	0	0.6	20	0.9	0	2.3	0	21.4	2.3
Hope Creek	46.3	33.9	1.6	1.5	0.3	0	0.2	0	37.4	46.5
LaSalle	0	0	0.1	0.2	0.3	5.1	0.8	0	0.6	5.9
Limerick	0	0	0.1	0.5	0.3	0	1.8	0	1	1.8
McGuire	0	0	0.1	1.7	0.3	21	0.4	0	2.1	21.4
Millstone	1.9	1.3	0.2	2.8	0.2	0.4	0.2	0	4.5	2.6
Monticello	0	0	0.5	1	0.1	0	0.3	0	1.6	0.3
Nine Mile Point	0	0	0.1	3.1	0.1	58.1	0.2	0	3.4	58.3
North Anna	0	0	0.2	3.1	0.3	18.6	0.4	0	3.6	19
Oconee	0	0	0.2	0.4	0.1	22.2	0.6	0	0.8	22.8
Palisades(d)	0	0	0.9	8.7	0.4	48.5	0.2	0	10	48.7
Palo Verde	0	0	0	0	0.1	1.6	1.9	0	0.1	3.5
Peach Bottom	0	0	0.2	0.3	0.2	14.5	0.6	0	0.6	15.1
Perry	0	0	0	1.7	0.4	48.4	0.5	0	2.1	48.9
Point Beach	0	0	0.2	4.3	0.1	44.6	0.3	0	4.6	44.8
Prairie Island	0	0	7.1	10.9	0.5	5.7	5.6	0	18.5	11.3
Quad Cities	0	0	2	9.2	0.9	6.6	3.1	0	12.1	9.7
River Bend	0	0	0.9	15.8	1	1	8.2	0	17.7	9.2
Robinson	0	0	0.3	8.9	0.4	4.4	0.3	0	9.6	4.7

Nuclear Power Plant	Estuarine and Marine Deepwater[a]	Estuarine and Marine Wetland	Freshwater Emergent Wetland	Freshwater Forested/ Shrub Wetland	Freshwater Pond	Lake[a]	Riverine[a]	Other[b]	Total Wetland[c]	Total Deepwater Habitats
Salem	47.2	34.6	1.6	1.3	0.3	0	0.1	0	37.9	47.4
Seabrook	23.9	13.3	1.5	6	0.4	0.1	0.3	0	21.2	24.2
Sequoyah	0	0	0	0.1	0.4	15.4	0.9	0	0.5	16.3
South Texas	0	0	2.9	3.1	0.2	14.2	1.4	2.3	6.2	15.6
St. Lucie	60.9	3.5	4.1	1	0.9	0.6	0.2	0	9.5	61.7
Summer	0	0	0.3	1.9	0.2	17.6	1.3	0	2.5	18.9
Surry	34.3	2.8	3.8	2.8	0.3	0.9	17.2	0	9.6	52.3
Susquehanna	0	0	0.1	1	0.3	0.2	3.8	0	1.4	4
Turkey Point	50.5	15	15.4	9.2	0.1	0	0.4	0	39.7	51
Vogtle	0	0	1.6	24.6	0.3	0.3	1.2	0	26.5	1.5
Waterford	0	0	11.9	45.3	1.1	1.7	7.7	0	58.3	9.4
Watts Bar	0	0	0.2	1.1	0.2	9.9	1.2	0	1.5	11.1
Wolf Creek	0	0	0.8	0.5	0.9	12.7	0.9	0	2.1	13.6
AVERAGE	-	-	-	-	-	-	-	-	9.3	21.2

(a) Deepwater habitats are permanently flooded and lie below the deepwater/wetland boundary (Cowardin et al. 1979; FGDC 2013).
(b) Includes land that was once palustrine wetland habitat that is now farmed, but if farming were discontinued wetland habitat would be reestablished; classified as Palustrine-Farmed. Does not include deepwater habitats.
(c) Does not include deepwater habitats.
(d) Shutdown in May 2022.
No entry is denoted by "-".
Sources: National Wetlands Inventory (FWS 2022); Pacific Northwest National Laboratory calculations.

To estimate radiological dose to ecological receptors, the NRC staff used the RESRAD-BIOTA dose evaluation model (DOE 2004) to calculate estimated dose rates to biota. 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 are below detection limits. Potassium-40 was excluded from this analysis because it is a common naturally occurring radionuclide. The list of radionuclides included in the RESRAD-BIOTA analysis included any radionuclide that was detected in a surface water or sediment/soil sample, as well as the most common radionuclides included in the REMP reports where either a regulatory LLD or site-specific minimum detectable activity was available as a surrogate conservative value. The staff then aggregated these values to form a single RESRAD-BIOTA analysis run.[4] 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). Furthermore, it is conservative because it is an aggregated run of every maximum media measurement from all of the subset of plants.

The RESRAD-BIOTA code was developed at Argonne National Laboratory based on the U.S. Department of Energy's (DOE's) graded approach for evaluating radiation doses to aquatic and terrestrial biota (DOE 2002). The RESRAD-BIOTA code includes three levels corresponding to a graded approach. The NRC staff conducted the evaluation presented in Chapter 4, Section 4.6.1.1.2 of this LR GEIS using RESRAD-BIOTA Level 2. Because RESRAD-BIOTA default B_{iv} values (bioaccumulation transfer factors) for certain radionuclides are relatively high for screening purposes, the staff replaced the transfer factors for zinc-65, cesium-134, and cesium-137 with the maximum value from the wildlife parameter transfer database (IAEA/IUR 2020). These values represent the maximum values used in international publications and in estimates of radiological impacts on the International Commission on Radiation Protection's (ICRP) Reference Animals and Plants, as described in ICRP 108 (ICRP 2008a).

For all ecological receptors, the NRC staff used RESRAD-BIOTA's default bioaccumulation factors and dose limits.[5] The NRC staff evaluated radionuclides at the selected nuclear power plants by comparing the sum of the total estimated dose to the default dose limits (i.e., the DOE guidance dose rates of riparian animal, 0.1 rad/d; terrestrial animal, 0.1 rad/d; terrestrial plant, 1.0 rad/d; and aquatic organisms, 1.0 rad/d). Estimated doses that were less than the default dose limits were determined to represent an acceptable radiological risk to the receptor, whereas estimated doses above the dose limit were determined to represent an unacceptable radiological risk to the receptor.

Additionally, the NRC staff estimated doses to a riparian animal using the ICRP biota dose calculator for a small subset of reactors.[6] The NRC staff used the ICRP calculator 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

[4] RESRAD-BIOTA does not include all radionuclides; radionuclides not available in RESRAD-BIOTA were excluded from analysis.
[5] More information about the RESRAD-BIOTA code, including instructions for using the model, can be found at https://resrad.evs.anl.gov/codes/resrad-biota/.
[6] The subset of plants includes Comanche Peak, Columbia, and Callaway.

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; ICRP 2008b).

The staff developed the DCs using the ICRP’s BiotaDC v.1.5.2, which incorporates the radionuclide decay data of ICRP 107 (ICRP 2008b). The staff’s specific assumptions for these DCs include the following:

- External DCs for aquatic (water) calculations presumed uniform isotropic (4 pi) exposure. This means that the dose rate is constant through the medium being evaluated.
- The ICRP calculator determines the absorbed fraction from external and internal sources based on the shape and mass of the organism (ICRP 2017).
- Absorbed dose rate (mean radiation energy absorbed per unit mass per time) was calculated; no radiation weighting factors were used to weight the DCs for radionuclides selected for this calculation (all were beta/gamma emitters).
- Internal tissue DCs were derived based on simple ellipsoid geometry. For purpose of developing the DCs in this analysis, the animal is assumed to have dimensions of 1:1:0.6 (an oblate spheroid).
- For this analysis, the organism was assumed to burrow into the soil and be exposed under these conditions for 100 percent of the time. The ICRP calculator calculation assumes that the burrowed organism is in the “middle of a 50-cm thick source” (ICRP 2017). This is a conservative estimate of dose.
- For this analysis, the organism was also assumed to be completely surrounded by water 100 percent of the time. This is a conservative estimate of dose.
- Total dose rate was calculated as the product of the media- and organism-specific DC (e.g., tissue, water, or sediment/soil in $\mu Gy\ h^{-1}$ per $Bq\ kg^{-1}$ for the 0.016 kg organism) and a relevant media activity concentration (tissue, water, or soil, in $Bq\ kg^{-1}$), and summed over the external and internal contributors to dose.
- No air submersion calculations were considered, as this is presumed to be substantially less than water or sediment dose rates.
- Internal dose rates were estimated based on maximum reported tissue concentrations for each analyzed nuclear power plant or the LLD when samples were below detection limits. This is a conservative estimate of dose.
- External dose rates from water were calculated based on the assumption of radionuclide concentrations occurring at the reported limits of detection. This is a conservative assumption as the majority of the REMP findings were below the LLDs.
- Reported sediment limits for specific sites in the REMP reports were used when available, or a substitute value from another site or regulatory value was used in cases when they were unavailable in the REMP reports.
- The sediment concentrations were reported as dry weight; no dilution was used in estimating the wet weight concentrations, as this is highly variable, and could range from about 50 percent to less than 10 percent of the reported dry weight concentration. This approach is conservative.
- The radioactivity was assumed uniformly distributed in organism tissue and in the environment.

This approach to determining the potential radiological dose rate to a hypothetical riparian organism is conservative. Chapter 4, Section 4.6.1.1.2 of this LR GEIS presents the results of the NRC staff's RESRAD-BIOTA analysis and ICRP biota dose calculator analysis described above. Additionally, Chapter 4, Section 4.6.1.2.8 of this LR GEIS briefly summarizes these results.

G.7 Historic and Cultural Resources

G.7.1 Description of Affected Resources and Region of Influence

The NRC considers historic and cultural resources as an all-inclusive term that includes precontact (i.e., prehistoric), historic, traditional cultural properties and historic properties. In this revision, the definitions of precontact and historic eras were updated. The National Historic Preservation Act (NHPA; 54 U.S.C. § 300101 et seq.) requires agencies to take into account the effects of their undertakings on historic properties, in consultation with the appropriate consulting parties as defined in 36 CFR 800.2(c). The National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. § 4321 et seq.) requires the consideration of the cultural environment, which includes "aesthetic, historic, and cultural resources as these terms are commonly understood, including such resources as sacred sites" (CEQ and ACHP 2013). Thus, the issue is termed "Historic and Cultural Resources." The NRC uses the NEPA process to comply with NHPA Section 106 review and consultation requirements pursuant to 36 CFR 800.8(c) to conduct a plant-specific site assessment. Refer to Chapter 3, Section 3.7 of this LR GEIS for expanded definitions of historic property and historic and cultural resources.

The ROI is the area of potential effects (APE). The license renewal (initial LR and 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 (see Chapter 3, Section 3.7 of this LR GEIS). The NRC is required to identify historic and cultural resources located within the defined APE.

G.7.2 Description of Impact Assessment

LR SEISs were examined to identify any trends concerning impacts from continued operation and refurbishment activities on historic and cultural resources. Historic and cultural resources were identified as resources to be considered for license renewal in the 1996 and 2013 LR GEISs, where they were identified as a Category 2 issue. The current assessment is in agreement with this categorization. Due to geographic, cultural, and historic differences, a plant-specific assessment of historic and cultural resources must be performed. Refer to Chapter 4, Section 4.7 of this LR GEIS for an expanded discussion of how initial LR and SLR can affect historic properties and historic and cultural resources located in the APE.

G.8 Socioeconomics and Environmental Justice

G.8.1 Description of Affected Resources and Region of Influence

Socioeconomic impacts are defined in terms of changes in the economic characteristics and social conditions of a region. For example, the number of jobs created by the proposed action could affect regional employment, income, and expenditures. Job creation is characterized by two types: (1) refurbishment (construction-related) jobs, which are transient, short in duration, and less likely to have a long-term socioeconomic impact; and (2) operation-related jobs in support of nuclear power plant operations, which have the greater potential for permanent, long-term socioeconomic impact.

Nuclear power plant operations and refurbishment activities affect socioeconomic conditions in communities near the nuclear plant, including the county in which the nuclear plant is located and the counties where the majority of nuclear plant workers reside. The socioeconomic ROI is determined by where the majority of nuclear plant operations workers and their families reside, spend income, and obtain goods and services. This reflects a residential location preference by current nuclear plant employees and is used to estimate the distribution of new workers associated with refurbishment (construction) activities and operation under the replacement energy alternatives. The economic data used in the LR GEIS update were derived from SEISs prepared for both initial LR and SLR reviews since development of the 2013 LR GEIS (NRC 2018a, NRC 2018b, NRC 2019a, NRC 2019b, NRC 2019c, NRC 2021a, NRC 2021b). These NEPA documents were used to describe the socioeconomic environment at 12 nuclear power plants (Table G.8-1).

Table G.8-1 Definition of Regions of Influence at 12 Nuclear Plants

Plant	Counties in Region of Influence	State
Davis-Besse	Ottawa	Ohio
Comanche Peak	Somervell	Texas
Cooper	Cass, Johnson, Nemaha, Otoe, and Richardson	Nebraska
Ginna	Wayne	New York
North Anna	Louisa and Orange	Virginia
Peach Bottom	Lancaster and York	Pennsylvania
Point Beach	Brown and Manitowoc	Wisconsin
River Bend	East Baton Rouge and West Feliciana parishes	Louisiana
South Texas	Matagorda	Texas
Surry	Isle of Wight and Surry	Virginia
Turkey Point	Miami-Dade	Florida
Waterford	St. Charles and Jefferson parishes	Louisiana

Sources: NEI 2015a, NEI 2015b, NEI 2015c, NEI 2018; NRC 2018a, NRC 2018b, NRC 2019a, NRC 2019b, NRC 2019c, NRC 2021a, NRC 2021b.

G.8.2 Estimation of Direct and Indirect Economic Effects

Nuclear power plants provide employment and income in communities near the nuclear plant and tax revenue to State and local governments. The demand for goods and services by nuclear power plant workers and their families creates additional employment and income opportunities in the local, regional, and State economies. The magnitude of the economic effect is determined by the extent of changes in employment and demand for goods and services during the license renewal term and refurbishment activities at each nuclear plant.

Workforce requirements of power plant operations were evaluated in order to measure their possible effect on socioeconomic conditions in the region. Estimates for the ROI were combined with projected workforce requirements to determine the extent of impacts on regional economic and demographic (population) characteristics, including levels of demand for housing, community services, and local transportation impacts.

The socioeconomic effects of reactor operations and refurbishment-related activities vary based on the size of the workforce, expenditures at each nuclear power plant, and economic conditions in the region. To assess the socioeconomic impact, nuclear power plants were classified according to whether they are located in rural or urban areas.

G.8.3 Environmental Justice Assessment Methods

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," (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 the Executive Order, the NRC Chairman, in a March 1994 letter to the President, committed the NRC to endeavoring to carry out its measures "… as part of the NRC's efforts to comply with the requirements of NEPA" (NRC 1994).

The 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 during the NEPA review. Minority and low-income populations, Indian Tribes, and environmental justice issues are different at each nuclear power plant site.

The analysis considers minority populations, low-income populations, and Indian Tribes within a 50 mi (80 km) radius of a nuclear power plant. Data on these populations are collected and analyzed at the census block group level.

Minority individual(s) 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. Census forms allow individuals to designate multiple population group categories to reflect their ethnic or racial origin. The term minority includes all persons who do not classify themselves as White alone.

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 a geographically dispersed or transient set of individuals, such as migrant workers or American Indians, who, as a group, experience common conditions of environmental exposure or effect. The appropriate unit of geographic analysis may be a political jurisdiction, county, region, or State or other similar unit that is chosen so as not to artificially dilute or inflate the affected minority population.

Low-income populations are comprised of people and families whose annual income falls 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. Poverty thresholds take into account family size and the age of individuals. For any given family below the poverty line, all family members are considered as being below the poverty line for the purposes of analysis. Low-income populations are identified using the Census Bureau's American Community Survey 5-year Estimates (American Community Survey Tables B17002 [USCB 2023a] and C17002 [USCB 2023b]). Low-income populations may be communities of individuals living in close geographic proximity to one another, or a set of individuals, such as migrant workers or Native Americans, who, as a group, experience common conditions of environmental exposure or effect.

Adverse health effects are measured in terms of the risks and rates of fatal or nonfatal exposure to an environmental hazard. Adverse health effects may include bodily impairment, infirmity, illness, or death. Disproportionately high and adverse human health effects occur when the risk or rate of exposure to an environmental hazard for 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 exposure rate for the general population or for another appropriate comparison group, and when they occur in a minority population, low-income population, or Indian Tribe affected by cumulative or multiple adverse exposures from environmental hazards (CEQ 1997).

Disproportionately high and adverse environmental effects occur when an impact on the natural or physical environment 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 with impacts on the natural or physical environment. Disproportionately high and adverse environmental effects occur when 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 when they occur or would occur in a minority population, low-income population, or Indian Tribe affected by cumulative or multiple adverse exposures from environmental hazards (CEQ 1997).

G.9 Human Health

G.9.1 Description of Affected Resources and Region of Influence

The NRC considers human health an all-inclusive term that includes both radiological and nonradiological human health effects for both occupational workers and members of the public. Both of these human health effects are discussed in this section.

Low doses of radiation can cause a variety of health effects. The most significant of these are induced cancer incidence. As discussed in the 1996 and 2013 LR GEISs in detail, the National Research Council's Committee on the Biological Effects of Ionizing Radiation has prepared a series of reports about the health consequences of radiation exposure, as presented in Chapter 3, Section 3.9 of this LR GEIS. Since the development of the 2013 LR GEIS, the NRC has determined that the linear, no-threshold model continues to provide a sound regulatory basis for minimizing the risk of unnecessary radiation exposure to both members of the public and radiation workers; three petitions for rulemaking to move away from the linear, no-threshold model were denied in 2021 (86 FR 45923).

Radiological exposures from nuclear power plants include offsite doses to members of the public and onsite doses to members of the workforce. Nuclear power plants must be licensed by the NRC and comply with NRC regulations and conditions specified in the license. The licensees are required to comply with 10 CFR Part 20, Subpart C, “Occupational Dose Limits,” and 10 CFR Part 20, Subpart D, “Radiation Dose Limits for Individual Members of the Public” (see Chapter 3, Section 3.9 of this LR GEIS). Individual occupational doses are measured by NRC licensees as required by the basic NRC radiation protection standard, 10 CFR Part 20 (see Chapter 3, Section 3.9 of this LR GEIS). This standard includes requirements for summing internal and external dose equivalents to yield the total effective dose equivalent. For this LR GEIS revision, worker dose information was obtained from the 53rd annual report titled *Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities 2020* (NRC 2022). The report summarizes the occupational exposure data maintained by the NRC’s Radiation Exposure Information and Reporting System. The licensees submit occupational radiation exposure records for each monitored individual.

Commercial nuclear power plants, under normal operations, release small amounts of radioactive materials to the environment. The effluent releases (gaseous and liquid) 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 Part 50.36a, and 40 CFR Part 190) and conditions specified in the operating license (see Chapter 3, Section 3.9 of this LR GEIS). Appendix I to 10 CFR Part 50 provides numerical values for radioactive effluent design objectives. In addition, each plant license contains technical specification requirements for controlling and limiting the discharge of radioactive gaseous and liquid effluents.

Every year licensees submit two reports to the NRC: an annual radiological environmental monitoring report and an annual radioactive effluent release report. For this LR GEIS update, public doses from gaseous and liquid effluent releases were obtained from a series of annual radioactive effluent release reports.

Nonradiological hazards considered for this human health assessment include chemical hazards, microbiological hazards, electromagnetic fields, and physical hazards (i.e., hazardous physical conditions and electric shock). 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, and heavy metals leached from cooling system piping and condenser tubing. Human health impacts from chemicals were assessed based on information provided in the 1996 and 2013 LR GEISs, published literature, and SEISs published to date.

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). These issues were evaluated by reviewing the information in the 1996 and 2013 LR GEISs and published literature about organisms that could be enhanced by plant operation. SEISs were also reviewed for new information pertaining to microbiological issues.

Electromagnetic fields are generated by any electrical equipment. All nuclear power plants have electrical equipment and power transmission systems associated with them. Occupational workers or members of the public near transmission lines may be exposed to electromagnetic fields produced by the transmission lines. As described in the 2013 LR GEIS, it should be noted that the scope of the evaluation of transmission lines includes only transmission lines that connect the plant to the switchyard where electricity is fed into the regional power distribution system (encompassing 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.

Nuclear power plants are industrial facilities that have many of the typical occupational hazards found at any other electric power generation facility. Workers at or around nuclear power plants would be involved in some maintenance activities, electrical work, electric power line maintenance, and repair work and would be subject to potentially hazardous physical conditions (excessive heat, cold, pressure, etc.). The human health impact from occupational hazards was not discussed in the 1996 LR GEIS but was considered in the 2013 LR GEIS (Section 3.9.5). The physical hazards to workers were 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 (see Chapter 3, Section 3.9 of this LR GEIS). The workers and general public located at or around nuclear power plants and along the transmission lines are exposed to the potential for acute electrical shock from transmission lines. The shock hazard was evaluated by referring to the National Electric Safety Code.

G.9.2 Description of Impact Assessment

Sources of information about radiological and nonradiological hazards to human health were included in the 1996 LR GEIS and 2013 LR GEIS and plant-specific supplements to the LR GEIS. Potential impacts on human health were reviewed for new information through the review of published literature related to power facility operation, SEISs for initial LR and SLR reviews completed since development of the 2013 LR GEIS, and radiological monitoring reports including environmental and occupational, as required by facility license.

The only minor change in this revision is under microbiological hazards to include discharge to waters of the United States accessible to the public to ensure that both fresh and salt waterbodies are reviewed for potential impacts from plant operation on microbiological hazards. The microbiological organisms of concern for public and occupational health were also updated based on SEISs for initial LR and SLR reviews completed since development of the 2013 LR GEIS updates to remove Salmonella and Shigella and add organisms that produce toxins that affect human health (e.g., dinoflagellates [*Karenia brevis*] and blue-green algae).

G.10 <u>Waste Management and Pollution Prevention</u>

G.10.1 Description of Affected Resources and Region of Influence

Similar to most industrial facilities, nuclear power plants and other fuel-cycle facilities generate waste during their operation. The waste materials are often shipped offsite by truck, train, or in some cases by barge, either for disposal or for processing. The wastes that are sent to a processing facility may be reused or recycled or they may be sent to a disposal facility after processing. The processing and handling that occur at the site of generation, including any packaging and loading of the wastes onto conveyance vehicles for shipment offsite, are considered part of the normal operations at that site, and the impacts associated with them are assessed as part of the normal operational impacts. Impacts associated with transportation and offsite processing and disposal are considered under the waste management impacts.

The primary resource affected by the disposal of waste materials is the land that is used for disposal. This land is assumed to be an irreversibly and irretrievably committed resource. The resources that are affected during processing and disposal of the wastes are similar to the resources affected during operation of any nuclear fuel-cycle facility, including nuclear power plants. As discussed in Chapter 4 of this LR GEIS, these resources include land use and visual resources, air quality and noise, geology and soils, hydrology, ecology, historic and cultural resources, socioeconomics, human health and safety, and environmental justice. During transportation, the main resources affected are human health and safety, air quality and noise, and socioeconomics. The impact assessment methodologies and the ROIs for these resource areas are covered in other sections of this appendix.

G.10.2 Description of Impact Assessment

Historical data and experience were used to estimate the characteristics and quantities of wastes generated at nuclear power plants. These values are discussed in the main body of this document under waste management (see Chapter 3, Section 3.11 and Chapter 4, Section 4.11 of this LR GEIS). Table 4.14-1 in this LR GEIS was the main source for waste generation numbers at other nuclear fuel-cycle facilities. The assessment of impacts associated with transportation of waste materials to and from a nuclear power plant relied on the information provided in Table 4.14-2, whereas the impacts of transportation among other nuclear fuel-cycle facilities are addressed as part of Table 4.14-1 and discussed in Section 4.14.1. The impacts at the offsite processing and disposal facilities are not explicitly evaluated in this document because each of these facilities would be operated pursuant to a permit or license issued by either a Federal or State agency. The impacts at those facilities would be addressed as part of the permitting or licensing process for those facilities. All operations including disposal activities at the disposal facilities would be within the bounds of analyses conducted to obtain the facility's permit or license. For example, the waste shipped to the disposal facility would have to meet that facility's waste acceptance criteria.

The issues associated with the availability of disposal facilities for low-level waste are discussed in Chapter 4, Section 4.11.1.1 of this LR GEIS. Section 4.11.1.2 of this LR GEIS discusses the onsite storage of spent nuclear fuel during the licensing term of a reactor. For all other waste types, it is assumed that permitted processing and/or disposal facilities will be available when needed. Historical evidence suggests that this assumption is valid.

Pollution prevention and waste minimization practices generally employed at the nuclear power plant sites are discussed in Chapter 3, Section 3.11.5 of this LR GEIS. These practices are based on the requirements placed on the licensees by the NRC, EPA, or other Federal or State agencies and the licensee's own efforts to minimize the emissions to the environment and minimize the quantities of wastes generated or sent offsite for treatment or disposal.

G.11 <u>Alternative Energy Sources</u>

To ensure that the analysis of replacement power alternatives focused only on realistic options, the NRC staff used data published by the DOE's Energy Information Administration to identify the current and projected contributions made to the commercial electric power sector by various fossil fuel, new nuclear, and renewable energy technologies. The staff reviewed Federal and State regulations, as well as applicable information from Federal and State regulatory agencies and State coalitions, to identify current and anticipated energy trends and environmental externalities that would most likely also influence alternative energy technology selections. As a result of these reviews, staff identified three fossil fuel energy technologies, two nuclear energy technologies, and seven renewable energy technologies as possible alternatives for replacing the existing generating capacity of a retiring nuclear reactor.

In addition, the NRC staff considered three non-power generating approaches for offsetting, rather than replacing, existing generating capacity. Alternatives include 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.

The environmental consequence analyses for the fossil fuel, new nuclear, and renewable energy technologies identified as possible alternatives are summarized in Chapter 2 and further described in Appendix D and are based on data from a variety of sources. Engineering and environmental performance data for fossil fuel technologies were obtained from reports published by DOE's Energy Information Administration, National Energy Technology Laboratory, and the EPA. Published environmental impact statements, regulatory guidance, early site permit applications, and public information provided by reactor developers provided the basis for the environmental consequence analysis of the nuclear energy alternatives. Reports and technology overviews published by DOE's Energy Information Administration, Office of Energy Efficiency and Renewable Energy, and the National Renewable Energy Laboratory, along with the Department of Interior's United States Geographic Survey and Bureau of Land Management, served as the principal sources of data about the environmental impacts of the selected renewable energy technologies. Additional data regarding the environmental consequences of renewable energy technologies were obtained from environmental impact statements published by Federal and State agencies and from other sources within the open literature.

G.12 Greenhouse Gas Emissions and Climate Change

G.12.1 Description of Affected Resources

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). The Earth's climate responds to changes in the concentrations of GHGs in the atmosphere because these gases affect the amount of energy absorbed and heat trapped by the atmosphere. Increasing concentrations of these gases in the atmosphere generally increase the Earth's surface temperature. Carbon dioxide, methane, nitrous oxide, and fluorinated gases (termed long-lived 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). Therefore, the extent and nature of climate change are not specific to where GHGs are emitted, and the impact of a GHG emission source on climate is global. Operations at nuclear power plants release GHG emissions 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). In 2020, U.S. gross GHG emissions totaled 6,692 million tons (5,981 million MT) of CO_2eq (EPA 2022). 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 2022). As noted by the Council on Environmental Quality (CEQ) (88 FR 1196), while the effects of GHG emissions are global and broad, a global or national-level ROI assessment is not beneficial in determining the GHG emission impacts on climate change. GHG emissions of a proposed action would represent a very small percentage of global or national GHG emissions. Therefore, the NRC defines the ROI for GHG emissions to not be greater than the county where the nuclear power plant is located, and the quantified GHG emissions from license renewal (whether initial LR or SLR) should be considered within context of quantified GHG emissions from operations of alternative energy sources.

Climate change and its impacts on resources can vary regionally. Observed climate change indicators and resource impacts have not been uniform across the United States, and climate model projections indicate that changes in climate will differ across the United States. To provide localized information, the United States Global Change Research Program'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, Hawaii, and U.S. Pacific Islands. Therefore, the NRC defines the ROI for climate change impacts on environmental resources as the United States Global Change Research Program region where the power plant is located. The discussions below provide a summary of the observed climate changes by the contiguous U.S. region, with a focus on regions in which operating nuclear power plants are located.

G.12.1.1 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 to 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 a sea level rise along the New York State coastline of 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 2018c). 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 2018c, NRC 2015).

G.12.1.2 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 2013b; 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 2013b). 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 2013b; 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 2019d). 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 2020). 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).

G.12.1.3 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 2013c). 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 2013c). 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 2021a). In the Fermi initial LR SEIS, the NRC staff obtained modeled monthly Lake Erie surface water temperatures from the National Oceanic and Atmospheric Administration'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 2016).

G.12.1.4 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).

G.12.1.5 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).

G.12.1.6 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) from 1900 to 2016 (USGCRP 2017). In July 2015, water temperature in the lower Columbia River and tributaries was 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 2012). The 2015 record temperatures led to a high rate of mortality for endangered sockeye and threatened Chinook in the Columbia River (USGCRP 2018).

G.12.1.7 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 2013d; USGCRP 2014). The Southwest region experienced the wettest conditions in the 1980s and 1990s, which coincide with El Niño-Southern Oscillation events (NOAA 2013d). El Niño-Southern Oscillation events involve periodic warming in sea surface temperatures in the central and eastern tropical Pacific Ocean that influence global and regional precipitation and are 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).

G.12.2 Description of Impact Assessment

GHG emissions associated with nuclear power plant operations and climate change impacts on environmental resources were not identified as either generic or plant-specific issues in the 2013 LR GEIS. GHGs and climate change impacts were identified and evaluated through the NRC staff’s review of initial LR and SLR SEISs completed since development of the 2013 LR GEIS, U.S. Global Climate Change Program National Climate Assessment reports, and Intergovernmental Panel on Climate Change assessment reports.

To analyze GHG emissions and impacts on climate change, the NRC compiled direct and indirect GHG emissions from operations at nuclear power plants presented in initial LR and SLR SEISs. The contribution to GHG emissions during the license renewal term serves as a proxy when assessing the impact from continued power plant operation on climate change. Observed changes in climate by U.S. geographic region were summarized from various climate change reports, including the U.S. Global Climate Change Program, EPA climate indicator, National Oceanic and Atmospheric Administration, and Intergovernmental Panel on Climate Change. To analyze climate change impacts on environmental resources, the NRC summarized and compared differences in projected climate change effects across the United States and the associated impacts on environmental resources areas (e.g., land use, air quality, water resources, etc.) that could also be affected by the continued operation of nuclear power plants as assessed in initial LR and SLR SEISs.

G.13 References

10 CFR Part 20. *Code of Federal Regulations*, Title 10, *Energy*, Part 20, "Standards for Protection Against Radiation."

10 CFR Part 50. *Code of Federal Regulations*, Title 10, *Energy*, Part 50, "Domestic Licensing of Production and Utilization Facilities."

36 CFR Part 800. *Code of Federal Regulations*, Title 36, *Parks, Forests, and Public Property*, Part 800, "Protection of Historic Properties."

40 CFR Part 93. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 93, "Determining Conformity of Federal Actions to State or Federal Implementation Plans."

40 CFR Part 190. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations."

59 FR 7629. February 16, 1994. "Executive Order 12898 of February 11, 1994: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations." *Federal Register*, Office of the President.

86 FR 45923. August 17, 2021. "Linear No-Threshold Model and Standards for Protection Against Radiation." Petition for Rulemaking; Denial, *Federal Register*, Nuclear Regulatory Commission.

88 FR 1196. January 9, 2023. "National Environmental Policy Act Guidance on Consideration of Greenhouse Gas Emissions and Climate Change." Notice of interim guidance; request for comments, *Federal Register*, Council on Environmental Quality.

Bromirski, P.D., D.R. Cayan, N. Graham, R.E. Flick, and M. Tyree. 2012. *Coastal Flooding Potential Projections: 2000-2100*. CEC-500-2012-011, California Energy Commissions, Sacramento, CA. Accessed April 27, 2023, at https://escholarship.org/uc/item/8887j9br.

CDC (Centers for Disease Control and Prevention). 2022. "What Noises Cause Hearing Loss?" Atlanta, GA. Accessed May 12, 2023, at https://www.cdc.gov/nceh/hearing_loss/what_noises_cause_hearing_loss.html#:~:text=A%20whisper%20is%20about%2030,immediate%20harm%20to%20your%20ears.

CEC (Commission for Environmental Cooperation). 1997. *Ecological Regions of North America, Toward a Common Perspective*. Montreal, Quebec, Canada. Accessed April 24, 2023, at http://www.cec.org/files/documents/publications/1701-ecological-regions-north-america-toward-common-perspective-en.pdf.

CEQ (Council on Environmental Quality). 1997. *Environmental Justice Guidance under the National Environmental Policy Act*. Washington, D.C. ADAMS Accession No. ML103430030.

CEQ and ACHP (Council on Environmental Quality and Advisory Council on Historic Preservation). 2013. *NEPA and NHPA: A Handbook for Integrating NEPA and Section 106*. Washington, D.C. ADAMS Accession No. ML14172A044.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. *Classification of Wetlands and Deepwater Habitats of the United States*. FWS/OBS-79/31, Fish and Wildlife Service, Washington, D.C. ADAMS Accession No. ML18019A904.

DOE (U.S. Department of Energy). 2002. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*. DOE-STD-1153-2002, Washington, D.C. ADAMS Accession No. ML21140A436.

DOE (U.S. Department of Energy). 2004. *RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation.* ISCORS Technical Report 2004-02, Interagency Steering Committee on Radiation Standards, Washington, D.C. ADAMS Accession No. ML21140A412.

DOT (U.S. Department of Transportation). 2017. *Highway Traffic Noise Analysis and Abatement Policy and Guidance*. Federal Highway Administration, Washington, D.C. ADAMS Accession No. ML13023A373.

EPA (U.S. Environmental Protection Agency). 2013. *Level III and IV Ecoregions of the Continental United States*. Washington, D.C. ADAMS Accession No. ML18023A341.

EPA (U.S. Environmental Protection Agency). 2016. *Climate Change Indicators in the United States 2016*. Fourth Edition, EPA 430-R-16-004, Washington, D.C. Accessed May 12, 2023, at https://www.epa.gov/sites/default/files/2016-08/documents/climate_indicators_2016.pdf.

EPA (U.S. Environmental Protection Agency). 2022. *Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2020*. EPA 430-R-22-003. Washington, D.C. Accessed May 12, 2023, at https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-text.pdf.

EPA (U.S. Environmental Protection Agency). 2023. *EPA History: Noise and the Noise Control Act*. Washington, D.C. Accessed May 12, 2023, at https://www.epa.gov/history/epa-history-noise-and-noise-control-act.

Fiscal Responsibility Act of 2023. Public Law No. 118-5, 137 Stat. 10.

FGDC (Federal Geographic Data Committee). 2013. *Classification of Wetlands and Deepwater Habitats of the United States.* FGDC-STD-004-2013, Second Edition. Wetlands Subcommittee, Federal Geographic Data Committee and U.S. Fish and Wildlife Service. Washington, D.C. Accessed April 24, 2023, at https://www.fgdc.gov/standards/projects/wetlands/nwcs-2013.

FWS (U.S. Fish and Wildlife Service). 2022. *National Wetlands Inventory, Wetlands Data Layer*. Washington, D.C. Accessed May 5, 2022, at https://www.fws.gov/program/national-wetlands-inventory/wetlands-data.

IAEA/IUR (International Atomic Energy Agency & International Union of Radioecologists). 2020. “Wildlife Transfer Parameter Database.” Accessed May 12, 2023, at https://www.wildlifetransferdatabase.org/mainpage.asp.

ICRP (International Commission on Radiological Protection). 2008a. “Environmental Protection -– the Concept and Use of Reference Animals and Plants.” ICRP Publication 108, Annals of the ICRP 38(4-6), Ottawa, Canada. Accessed May 12, 2023 at https://www.icrp.org/publication.asp?id=icrp%20publication%20108.

ICRP (International Commission on Radiological Protection). 2008b. "Nuclear Decay Data for Dosimetric Calculations." ICRP Publication 107, *Ann. ICRP* 38(3):7-96, Ottawa, Canada. Accessed April 24, 2023, at https://www.icrp.org/publication.asp?id=ICRP%20Publication%20107.

ICRP (International Commission on Radiological Protection). 2017. "Dose Coefficients for Non-human Biota Environmentally Exposed to Radiation." ICRP Publication 136, *Ann. ICRP* 46(2). Ottawa, Canada. Accessed April 24, 2023, at https://www.icrp.org/publication.asp?id=ICRP%20Publication%20136.

Marston, L., Y. Ao, M. Konar, M.M. Mekonnen, and A.Y. Hoekstra. 2018. High-Resolution Water Footprints of Production of the United States. *Water Resources Research* 54:2288-2316, American Geophysical Union, Washington, D.C. Accessed May 12, 2023, at https://doi.org/10.1002/2017WR021923.

National Environmental Policy Act of 1969, as amended. 42 U.S.C. § 4321 et seq.

National Historic Preservation Act of 1966, as amended. 54 U.S.C. § 300101 et seq.

NEI (Nuclear Energy Institute). 2015a. *Economic Impacts of the Davis-Besse Nuclear Power Station*. Washington, D.C. Accessed April 21, 2023, at https://www.nei.org/resources/reports-briefs/economic-impacts-davis-besse-nuclear-power-station#:~:text=Davis%2DBesse's%20operation%20results%20in,local%2C%20state%20and%20federal%20governments.

NEI (Nuclear Energy Institute). 2015b. *Economic Impacts of the R.E. Ginna Nuclear Power Plant*. Washington, D.C. Accessed April 21, 2023, at http://large.stanford.edu/courses/2018/ph241/green1/docs/nei-feb15.pdf.

NEI (Nuclear Energy Institute). 2015c. *The Economic Benefits of Texas' Nuclear Power Plants*. Washington, D.C. Accessed April 21, 2023, at https://silo.tips/download/the-economic-benefits-of-texas-nuclear-power-plants.

NEI (Nuclear Energy Institute). 2018. *Economic Impacts of the Cooper Nuclear Station an Analysis by the Nuclear Energy Institute.* Washington, D.C. Accessed April 21, 2023, at https://www.nei.org/resources/reports-briefs/%E2%80%8Beconomic-impacts-of-the-cooper-nuclear-station.

NOAA (National Oceanic and Atmospheric Administration). 2013a. *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 2. Climate of the Southeast U.S.* Technical Report NESDIS 142-2. Washington, D.C. Accessed April 24, 2023, at https://scenarios.globalchange.gov/sites/default/files/NOAA_NESDIS_Tech_Report_142-2-Climate_of_the_Southeast_U.S_0.pdf.

NOAA (National Oceanic and Atmospheric Administration). 2013b. *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 9. Climate of the Contiguous United States*. Technical Report NESDIS 142-9. Washington, D.C. Accessed April 24, 2023, at https://nesdis-prod.s3.amazonaws.com/migrated/NOAA_NESDIS_Tech_Report_142-9-Climate_of_the_Contiguous_United_States.pdf.

NOAA (National Oceanic and Atmospheric Administration). 2013c. *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 3. Climate of the Midwest U.S.* Technical Report NESDIS 142-3. Washington, D.C. Accessed April 24, 2023, at https://scenarios.globalchange.gov/sites/default/files/NOAA_NESDIS_Tech_Report_142-3-Climate_of_the_Midwest_U.S_0.pdf.

NOAA (National Oceanic and Atmospheric Administration). 2013d. *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 5. Climate of the Southwest U.S.* Technical Report NESDIS 142-5. Washington, D.C. Accessed April 24, 2023, at https://scenarios.globalchange.gov/sites/default/files/NOAA_NESDIS_Tech_Report_142-5-Climate_of_the_Southwest_U.S_0.pdf.

Noise Control Act of 1972. 42 U.S.C. § 4901 et seq.

NRC (U.S. Nuclear Regulatory Commission). 1991a. *Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors (Generic Letter 89-01, Supplement No. 1)*. NUREG-1301, Washington, D.C. ADAMS Accession No. ML091050061.

NRC (U.S. Nuclear Regulatory Commission). 1991b. *Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Boiling Water Reactors (Generic Letter 89-01, Supplement No. 1)*. NUREG-1302, Washington, D.C. ADAMS Accession No. ML091050059.

NRC (U.S. Nuclear Regulatory Commission). 1994. Letter from I. Selin to The President dated March 31, 1994, regarding "…Executive Order 12898 and the accompanying Memorandum For the Heads of all Departments and Agencies…" Washington, D.C. ADAMS Accession No. ML033210526.

NRC (U.S. Nuclear Regulatory Commission). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*. Volumes 1 and 2, NUREG-1437, Washington, D.C. ADAMS Accession Nos. ML040690705, ML040690738.

NRC (U.S. Nuclear Regulatory Commission). 2012. Letter from D. Morey, Chief, to A. Javorik, Vice President, dated April 6, 2012, regarding "Notice of Availability of the Final Plant-Specific Supplement 47, Volume 1 and 2, to the Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding Columbia Generating Station (TAC No. ME3121)." Washington, D.C. ADAMS Package Accession No. ML12097A267.

NRC (U.S. Nuclear Regulatory Commission). 2013. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*. NUREG-1437, Revision 1, Washington, D.C. ADAMS Package Accession No. ML13107A023.

NRC (U.S. Nuclear Regulatory Commission). 2015. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 46: Regarding Seabrook Station, Final Report.* NUREG-1437, Supplement 46, Volumes 1 and 2, Washington, D.C. ADAMS Accession Nos. ML15209A575, ML15209A870.

NRC (U.S. Nuclear Regulatory Commission). 2016. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 56: Regarding Fermi 2 Nuclear Power Plant, Final Report, Chapter 1 to 8*. NUREG-1437, Volume 1, Washington, D.C. ADAMS Accession No. ML16259A103.

NRC (U.S. Nuclear Regulatory Commission). 2018a. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 58: Regarding River Bend Station, Unit 1 Final.* NUREG-1437, Supplement 58, Washington, D.C. ADAMS Accession No. ML18310A072.

NRC (U.S. Nuclear Regulatory Commission). 2018b. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 59: Regarding Waterford Steam Electric Station, Unit 3, Final Report.* NUREG-1437, Supplement 59, Washington, D.C. ADAMS Accession No. ML18323A103.

NRC (U.S. Nuclear Regulatory Commission). 2018c. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 38: Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, Final*. NUREG-1437, Supplement 38, Volume 5, Washington, D.C. ADAMS Accession No. ML18107A759.

NRC (U.S. Nuclear Regulatory Commission). 2018d. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 59: Regarding Waterford Steam Electric Station, Unit 3. Final Report.* NUREG-1437, Supplement 59, Washington, D.C. ADAMS Accession No. ML18323A103.

NRC (U.S. Nuclear Regulatory Commission). 2019a. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 10, Second Renewal: Regarding Subsequent License Renewal for Peach Bottom Atomic Power Station, Units 2 and 3, Draft Report for Comment.* NUREG-1437, Supplement 10, Second Renewal, Washington, D.C. ADAMS Accession No. ML19210D453.

NRC (U.S. Nuclear Regulatory Commission). 2019b. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 5, Second Renewal: Regarding Subsequent License Renewal for Turkey Point Nuclear Generating Unit Nos. 3 and 4*. NUREG-1437, Supplement 5, Second Renewal, Washington, D.C. ADAMS Accession No. ML19290H346.

NRC (U.S. Nuclear Regulatory Commission). 2019c. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Supplement 6, Second Renewal: Regarding Subsequent License Renewal for Surry Power Station, Units 1 and 2, Draft Report for Comment.* NUREG-1437, Supplement 6, Second Renewal, Washington, D.C. ADAMS Accession No. ML19274C676.

NRC (U.S. Nuclear Regulatory Commission). 2019d. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 5, Second Renewal: Regarding Subsequent License Renewal for Turkey Point Nuclear Generating, Unit Nos. 3 and 4, Final Report*. NUREG-1437, Supplement 5, Second Renewal, Washington, D.C. ADAMS Accession No. ML19290H346.

NRC (U.S. Nuclear Regulatory Commission). 2020. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 6, Second Renewal: Regarding Subsequent License Renewal for Surry Power Station Units 1 and 2, Final Report*. NUREG-1437, Supplement 6, Second Renewal, Washington, D.C. ADAMS Accession No. ML20071D538.

NRC (U.S. Nuclear Regulatory Commission). 2021a. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 23: Second Renewal Regarding Subsequent License Renewal for Point Beach Nuclear Plant, Units 1 and 2, Draft Report for Comment.* NUREG-1437, Supplement 23, Second Renewal, Washington, D.C. ADAMS Accession No. ML21306A226.

NRC (U.S. Nuclear Regulatory Commission). 2021b. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 7, Second Renewal: Regarding Subsequent License Renewal for North Anna Power Station, Units 1 and 2, Draft Report for Comment.* NUREG-1437, Supplement 7, Second Renewal, Washington, D.C. ADAMS Accession No. ML21228A084.

NRC (U.S. Nuclear Regulatory Commission). 2022. *Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities 2020, Fifty-Third Annual Report*. NUREG-0713, Volume 42, Washington, D.C. ADAMS Accession No. ML22276A269.

OSU (Oregon State University). 2022. "PRISM Climate Data." PRISM Climate Group, Oregon State University, Corvallis, OR. Accessed July 24, 2023, at https://www.prism.oregonstate.edu/.

Partridge, T.F., J.M. Winter, E.C. Osterberg, D.W. Hyndman, A.D. Kendall, and F.J. Magilligan. 2018. "Spatially Distinct Seasonal Patterns and Forcings of the U.S. Warming Hole." *Geophysical Research Letters* 45(4):2055–2063. DOI: 10.1002/2017GL076463. Washington, D.C. Accessed May 17, 2023, at https://doi.org/10.1002/2017GL076463.

RESRAD (RESRAD Family of Codes). 2016. "RESRAD-BIOTA." Version 1.8, Argonne National Laboratory, Lemont, IL. Accessed October 16, 2023, at https://resrad.evs.anl.gov/codes/resrad-biota/.

Smith, J. 1999. "*Zapus hudsonius* Meadow Jumping Mouse." Animal Diversity Web, Ann Arbor, MI. Accessed May 12, 2023, at https://animaldiversity.org/accounts/Zapus_hudsonius/.

Thorne, J.H., R. Boynton, L. Flint, A. Flint, and T. N'goc Le. 2012. *Development and Application of Downscale Hydroclimatic Predictor Variable for Use in Climate Vulnerability and Assessment Studies*. CEC-500-2012-010. California Energy Commission, Sacramento, CA. Accessed May 11, 2023, at https://escholarship.org/uc/item/160016sh.

USCB (U.S. Census Bureau). 2023a. American Community Survey; Ratio of Income to Poverty Level in the Past 12 Months, Table B17002. Washington, D.C. Accessed May 12, 2023, at https://data.census.gov/cedsci/table?text=b17002.

USCB (U.S. Census Bureau). 2023b. American Community Survey; Ratio of Income to Poverty Level in the Past 12 Months, Table C17002. Washington, D.C. Accessed May 12, 2023, at https://data.census.gov/cedsci/table?text=c17002.

USGCRP (U.S. Global Change Research Program). 2009. *Global Climate Change Impacts in the United States*. T.R. Karl, J.M. Melillo, and T.C. Peterson (editors). Cambridge University Press, New York, NY. ADAMS Accession No. ML100580077.

USGCRP (U.S. Global Change Research Program). 2014. *Climate Change Impacts in the United States: The Third National Climate Assessment*. J.M. Melillo, T.C. Richmond, and G.W. Yohe (eds.). U.S. Government Printing Office, Washington, D.C. ADAMS Accession No. ML14129A233.

USGCRP (U.S. Global Change Research Program). 2017. *Climate Science Special Report: Fourth National Climate Assessment*. Volume I. D.J. Wuebbles, D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.). Washington, D.C. ADAMS Accession No. ML19008A410. DOI: 10.7930/J0J964J6.

USGCRP (U.S. Global Change Research Program). 2018. *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*. Volume II. D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.). Washington, D.C. ADAMS Accession No. ML19008A414.

USGS (U.S. Geological Survey). 2019a. “Withdrawal and Consumption of Water by Thermoelectric Power Plants in the United States, 2015.” M.A. Harris and T.H. Diehl (eds). *Scientific Investigations Report* 2019–5103, Reston, VA. Accessed May 12, 2023, at https://pubs.usgs.gov/sir/2019/5103/sir20195103.pdf.

USGS (U.S. Geological Survey). 2019b. “NLCD 2019 Land Cover (CONUS).” Multi-Resolution Land Characteristics Consortium Project. Sioux Falls, SD. Accessed May 12, 2023, at https://www.mrlc.gov/data/nlcd-2019-land-cover-conus.

Wiken, E., F. Jiménez Nava, and G. Griffith. 2011. *North American Terrestrial Ecoregions-Level III.* Commission for Environmental Cooperation, Montreal, Canada. Accessed May 12, 2023 at http://www3.cec.org/islandora/en/item/10415-north-american-terrestrial-ecoregionslevel-iii-en.pdf.

APPENDIX H

LIST OF PREPARERS

APPENDIX H

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 H-1) with assistance from other NRC organizations, and Pacific Northwest National Laboratory (Table H-2).

Table H-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; 27 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; 18 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; over 40 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; 22 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; 32 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; 35 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 and Climate Change
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; 37 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	A.M., Earth and Planetary Science; B.S., Earth and Environmental Science; 11 years of experience in environmental impact analysis	Greenhouse Gas Emissions and Climate Change; Meteorology, Air Quality, and Noise; Socioeconomic Resources; Environmental Justice; Water Resources
Don Palmrose	Ph.D., Nuclear Engineering; M.S., Nuclear Engineering; B.S., Nuclear Engineering; 37 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	M.R.P., Regional Environmental Planning; M.S., Development Economics; B.A., English; 44 years of combined industry and Government experience in NEPA compliance for DOE Defense Programs/NNSA and Nuclear Energy, DoD, and DOI; project management; socioeconomics and environmental justice impact analysis, historic and cultural resource impact assessments, consultation with American Indian tribes, and comprehensive land-use and development planning studies	Land Use; Socioeconomics; Environmental Justice; Alternatives; Cumulative Effects; Termination of Reactor Operations and Decommissioning

A.M. or M.A. = Master of Arts; B.A. = Bachelor of Arts; B.S. = Bachelor of Science; DoD = U.S. Department of Defense; DOE = U.S. Department of Energy; DOI = U.S. Department of Interior; M.B.A. = Master of Business Administration; M.R.P. = Master of Regional Planning; M.S. = Master of Science; NEPA = National Environmental Policy Act of 1969; NNSA = National Nuclear Security Administration; NRC = U.S. Nuclear Regulatory Commission; Ph.D. = Doctor of Philosophy.

Table H-2 Pacific Northwest National Laboratory[a] Preparers

Name	Education/Expertise	Contribution
Dave Anderson	M.S., Forest Economics; B.S., Forest Resources; 27 years of experience in NEPA compliance, socioeconomics, and environmental justice impact analysis	Socioeconomic Resources; Environmental Justice
Teresa Carlon	B.S., Information Technology; 27 years SharePoint Administrator and database experience	Reference Coordinator
Garill Coles	B.S., Mechanical Engineering, 32 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	Ph.D., Radiation Health Physics; B.S., Environmental Health and Industrial Hygiene; 5 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]	B.J., Journalism; more than 40 years of experience in full-spectrum communications and document production services	Document production, technical editing/formatting
Julia Flaherty	M.S., Environmental Engineering; B.S., Civil Engineering; 19 years of experience in boundary layer meteorology, emergency response, project management, and NEPA	Meteorology, Air Quality, and Noise
Harish Gadey[b]	Ph.D., Nuclear Engineering (Health Physics Minor); M.S., Nuclear Engineering; B.S., Mechanical Engineering; 8 years of experience in radiation detection, simulations, and spent fuel analysis	Human Health; Waste Management/Fuel Cycle; Decommissioning
Dave Goodman	J.D., Law; B.S., Economics; 14 years of experience in NEPA compliance, land use and visual resources, noise, and alternatives	Land Use and Visual Resources; Noise; Alternatives
Ellen Kennedy[b]	M.A., Anthropology; B.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; 22 years of experience in NEPA compliance, project management, and human health	Deputy Team Lead; Human Health
Hayley McClendon	B.S., Environmental Science; 1 year of experience in NEPA compliance, 6 years of experience in environmental regulatory compliance	Reference Coordinator

Name	Education/Expertise	Contribution
Philip Meyer	Ph.D., Civil Engineering; M.S., Civil Engineering; B.A., Physics; 32 years of experience in the application of hydrologic principles to the solution of environmental and engineering problems, including 15 years of NEPA experience in water, soil, and geological resources impact evaluations	Groundwater Resources; Geological Environment; Cooling Water Systems
Ann Miracle	Ph.D., Molecular Genetics; M.S., Population Genetics; B.A., Biology; 14 years of experience in NEPA compliance and 27 years in ecological resources	Ecological Resources
Sadie Montgomery	B.S., Mathematics; 14 years of experience in GIS data processing, visualizations, and mapping	Geographic Information Systems
Jon Napier	Ph.D. and M.S. in Radiation Health Physics; B.S., Environmental Science; 5 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	M.B.A., Business Administration; B.A., Anthropology; 32 years of experience in 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; 27 years of experience copyediting, document design, and formatting, and 22 years of experience in technical editing	Technical Editing
Rajiv Prasad	Ph.D., Civil and Environmental Engineering; Master in Technology, Hydraulic and Water Resources Engineering; B.E., Civil Engineering; 27 years of experience in applying hydrologic principles to water resources engineering, hydrologic design, flooding assessments, environmental engineering, and impacts assessment including 17 years of experience in NEPA environmental assessments of surface water resources	Water Resources
Bo Saulsbury[(b)]	M.S., Planning; B.A., History; 37 years of experience in NEPA environmental assessment, land use, socioeconomics, and alternatives	Alternatives

Name	Education/Expertise	Contribution
Kacoli Sen	Diploma in Environmental Law; Ph.D., Cancer Biology; M.S., Zoology (Ecology specialization); B.S., Zoology; 3 years post-doctoral experience in cancer nanotherapeutics; and 5 years of editing experience	Document Production; Technical Editing/Formatting; References
Steven Short	M.S., Nuclear Engineering; M.B.A., Business Administration; B.S., Nuclear Engineering; 40 years of experience including nuclear safety analysis, probabilistic risk assessment, technical reviews of risk-informed license amendment requests and severe accident mitigation alternative analyses	Postulated Accidents; Severe Accident Mitigation Alternatives
Isaiah Steinke	Ph.D., Electrical Engineering; M.S., Data Analytics; B.S., Materials Science and Engineering; 10+ years of technical and scientific editing	Technical Editing
Kazi Tamaddun	Ph.D., Civil and Environmental Engineering; M.B.A., Business Administration; M.S., Civil and Environmental Engineering; B.S., Civil Engineering; 10 years of experience in hydrologic, hydraulic, ecosystem, and water systems modeling; hydro-climatology; climate change modeling and analysis	Water Resources
Kenneth Thomas	M.S., Mathematics; B.S., Mathematics; 37 years of experience in operations in Navy nuclear and conventional powered surface ships, and teaching at Naval Nuclear Power Training Command; training, operations, and emergency preparedness at two commercial nuclear power plants; nuclear reactor licensing, policy and rulemaking at the NRC; and emergency management policy at NNSA	Senior Advisor; Nuclear power plant operations and infrastructure
In Memoriam: Matthew Urie	LL.M., Environmental Law; J.D., Law; B.A., Political Science; 40 years in the practice of law, including litigation in State and Federal courts; 35 years of experience in the practice of environmental law with the Federal Energy Regulatory Commission, the DOI, the Department of Justice, and the DOE.	Team Lead
Katie Wagner	M.S., Biology; B.S., Biology; 14 years of experience in project management and aquatic ecology; 10 years of experience in NEPA compliance and ecological resources	Team Lead; Ecological Resources

Name	Education/Expertise	Contribution
Anita Waller	M.A., American Studies; B.A., English; 20+ years of experience in reference management, developmental and copyediting, and document production.	Technical Editing

A.M. or M.A. = Master of Arts; B.A. = Bachelor of Arts; B.J. = Bachelor of Journalism; B.S. = Bachelor of Science; DOE = U.S. Department of Energy; DOI = U.S. Department of Interior; GIS = geographic information system; J.D. = Juris Doctor; M.B.A. = Master of Business Administration; M.R.P. = Master of Regional Planning; M.S. = Master of Science; NEPA = National Environmental Policy Act of 1969; NHPA = National Historic Preservation Act; NNSA = National Nuclear Security Administration; NRC = U.S. Nuclear Regulatory Commission; Ph.D. = Doctor of Philosophy.

(a) Pacific Northwest National Laboratory is managed for the U.S. Department of Energy by Battelle Memorial Institute.

(b) Staff formerly with Pacific Northwest National Laboratory.

APPENDIX I

DISTRIBUTION LIST

APPENDIX I

DISTRIBUTION LIST

The U.S. Nuclear Regulatory Commission (NRC) notified the individuals and/or organizations listed below (where contact information was provided by the individuals or organizations) of the issuance and availability of this revision of NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (LR GEIS). Notification was also provided to individuals who submitted a generic campaign letter sponsored by the Nuclear Information and Resource Service (see Accession Numbers ML23135A775, ML23135A776, ML23135A777, and ML23135A779). The NRC will provide hard copies to interested individuals and organizations upon request.

Paul Aitken	Dominion Energy (Dominion)
Richard Arnold	Tribal Radioactive Materials Transportation Committee
Ellery Baker	Dominion
Tony Banks	Dominion
Joseph Bashore	Tennessee Valley Authority (TVA)
Mavis Belisle	Dallas Peace and Justice Center
Reed Bilz	Member of the Public
Jana Bergman	Curtiss-Wright
Stephanie Bilenko	Nuclear Energy Information Service (NEIS)
Jan Boudart	NEIS
George Brozowski	U.S. Environmental Protection Agency (EPA), Region 6
Andrew Burgess	Ameren Missouri
Lon Burnam	Citizens for Fair Utility Regulation
Chip Cameron	Prairie Island Indian Community (PIIC)
Jonathan Carson	Member of the Public
Rafael Casals	Town of Cutler Bay, FL
Daniel Cassiere	Member of the Public
Candice Chou	Kinectrics
LaVonne Cockerell	Member of the Public
Charlotte Collins	Member of the Public
Charlotte Connelly	Member of the Public
Glenn Corbin	Texas Department of State Health Services, Radiation Control Program
Carolyn Croom	Member of the Public
Diane Curran	Harmon, Curran, Spielberg & Eisenberg, LLP

Cliff Custer	Preferred Licensing Services, Inc.
Michael Davis	NextEra Energy
Jim DeLano	Southern Nuclear Operating Company
Anthony Devoe	Member of the Public
Ted Evgeniadis	Lower Susquehanna Riverkeeper Association
Geoffrey Fettus	Natural Resources Defense Council
Earl Fordham	Washington Department of Health, Office of Radiation Protection
Meshelle Francis	Member of the Public
Harrison Frankl	Member of the Public
Michael Gallagher	Member of the Public
Lloyd Generette	EPA, Region 4
Susybelle Gosslee	Member of the Public
Dan Green	TVA
Paul Gunter	Beyond Nuclear
Karen Hadden	Sustainable Energy and Economic Development (SEED) Coalition
Beki Halpin	Member of the Public
Laurie Hernandez	Tribal Radioactive Materials Transportation Committee
Jeremy Hutar	Member of the Public
Johnny Johnson	PIIC
Timothy Judson	Nuclear Information and Resource Service
Glen Kaegi	Constellation Energy Generation, LLC
Arun Kapur	Duke Energy
Laurence Kirby	Member of the Public
Peter Kissinger	Nuclear Energy Institute (NEI)
Elliott Korb	Radiant Industries, Inc.
David Kraft	NEIS
Nicci Lehto	PIIC
Anne Leidich	Pillsbury Winthrop Straw Pittman
Gary Lee	Member of the Public
Thomas Lentz	Energy Harbor
Tony Leshinskie	Vermont Public Service Department
Charles Lippert	Mille Lacs Band of Ojibwe, Department of Natural Resources
Brian Littleton	EPA
Leigh Lloveras	The Breakthrough Institute
Jeff Luse	Generation Atomic

Donald Macleod	Jensen Hughes
Beckie Maddox	Exelon
Brian Magnuson	Member of the Public
Matthew Marzano	Idaho National Laboratory
Lisa Matis	Tetra Tech
Janet Mattern	Member of the Public
Katrina Mcmurrian	Nuclear Waste Strategy Coalition
Kristin Meek	Constellation Energy Generation (Constellation)
Alexandra McCleary	San Manuel Band of Mission Indians, California
Kathy McCorry	South County Chambers of Commerce
Clif McReynolds	Member of the Public
Larry Nicholson	Certrec
Martin O’Neill	NEI
Masato Ono	NRA JAPAN
Richard Orthen	Member of the Public
Rebecca Ramsay	Member of the Public
Thomas Ray	Duke Energy
Bettina Rayfield	Virginia Department of Environmental Quality
Caroline Reiser	Natural Resources Defense Council
Laura Reynolds	Everglades Coalition
Elizabeth Riebschlaeger	Member of the Public
Bonnie Rippingille	Ocean Reef Community Association
Britsy Rizo	Member of the Public
Joseph Rustick	EPA
Maggie Sager	National Oceanic and Atmospheric Administration (NOAA) Fisheries
Jay Santillan	EPA
Steven Schoedinger	Key Largo Utility Corporation
Daniel Schultheisz	EPA
Alberto Sifuentes	Federal Emergency Management Agency
Rachel Silverstein	Miami Waterkeeper
Stephen Sollom	Xcel Energy
Amanetta Somerville	EPA, Region 4
Lisa Spadafina	Miami-Dade County Division of Environmental Resources Management

Allison Stalker	Constellation
Adam Stein	The Breakthrough Institute
Kevin Stewart	California Department of Public Health
Philip Stoddard	City of South Miami
Dianne Strand	Florida Power & Light Company
Akira Tanaka	Japan Electric Power Information Center USA (JEPIC-USA)
Kevin Taylor	AECOM
Brett Titus	NEI
Robert Tomiak	EPA, Office of Federal Activities
Jackie Toth	Good Energy Collective
Rachel Turney-Work	Enercon Services, Inc.
Jennifer Uhle	NEI
Steve Vance	Cheyenne River Sioux Tribe
Heather Westra	PIIC
Jessica York	Loving Endeavors 3
Jason Zorn	Constellation

APPENDIX J

GLOSSARY

APPENDIX J

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 ACHP 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 (i.e., the no action alternative, which is the only alternative to the proposed action that is within the U.S. Nuclear Regulatory Commission's [NRC's] decision-making authority); (2) replacing existing nuclear generating capacity with other energy sources (including fossil fuel, new nuclear, and renewable energy); (3) offsetting existing nuclear generation capacity by using demand-side management (conservation), delayed retirement, or purchased 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 waterbody that is representative of typical conditions unaffected by human activities (e.g., the temperature of the surface waterbody 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, related 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 effects (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 license renewal (LR) (initial LR or subsequent LR [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 (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 NRC, “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 (PWRs), the fuel storage facility. The facility’s control room is often located in the auxiliary building.

avian: Of, related 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. 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 (3.7×10^{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, related 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; 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.

carbon sequestration: See carbon capture and storage.

carbonaceous: Consisting of, containing, related to, or yielding carbon.

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 related 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 BWR also generally contains the spent fuel pool and the new fuel pool. The reactor building for both PWRs 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 human-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 waterbodies, 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 pounds per hour (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 waterbodies. 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 based on 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 based on 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 effects: The effects (impacts) 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. Cumulative effects can result from actions with individually minor but collectively significant effects taking place over a period of time (40 CFR 1508.1(i)(3)).

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 (3.7×10^{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 waterbody.

dose: The absorbed dose, given in rads (or in international system [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 waterbody 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.

effects (or impacts): Changes to the human environment from the proposed action or alternatives that are reasonably foreseeable and include the following: (1) Direct effects, which are caused by the action and occur at the same time and place. (2) Indirect effects, which are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include growth-inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems. (3) Cumulative effects, which are 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. Cumulative effects can result from actions with individually minor but collectively significant effects taking place over a period of time. (4) Effects include ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health, such as disproportionate and adverse effects on communities with environmental justice concerns, whether direct, indirect, or cumulative. Effects also include effects on Tribal resources and climate change related effects, including the contribution of a proposed action and its alternatives to climate change, and the reasonably foreseeable effects of climate change on the proposed action and its alternatives. Effects may also include those resulting from actions which may have both beneficial and adverse effects, even if on balance the agency believes that the effects will be beneficial (40 CFR 1508.1(i)(1)–(4)).

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 (1) meet the requests of Congress, other elements within the DOE, Federal Energy Regulatory Commission, and Executive Branch; (2) meet 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 of different greenhouse gases without directly calculating the changes in atmospheric concentrations. The global warming potential of a particular greenhouse gas is 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. The larger the global warming potential, the more that a given gas warms the Earth compared to carbon dioxide over that time period.

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 (GHGs): 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 human-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.

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.

in situ: In its original place.

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.

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: That period of time, either an initial license renewal or the first subsequent license renewal, 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-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 (NAAQS). 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.

mitigation: A method or process by which impacts from actions can be made less injurious to the environment through appropriate protective measures (see also 40 CFR 1508.1(y)).

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.

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 (NESC): 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. NESC 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 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.

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 waterbody or smokestack into the atmosphere.

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.

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 https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/index.html, 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 (ROW): The land and legal right to use and service the land along which a transmission line is located. Transmission line ROWs are usually acquired in widths that vary with the kilovolt (kV) size of the line.

riparian: Related 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 human-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 watts per square meter.

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 fuel pool: An underwater storage and cooling facility for spent fuel elements that have been removed from a reactor.

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.

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 homogeneous supercritical fluid. The supercritical point for water is 22.1 megapascals (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 plant-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.

universal waste: A special class of hazardous waste consisting of commonly used and yet hazardous materials: batteries, pesticides, mercury-containing equipment, and lamps.

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.

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 include the regulation of 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 staggered five-year terms.

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 waterbodies 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 waterbody. 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 quality: The condition of water with respect to the amount of impurities in it.

water table: The boundary between the unsaturated zone and the deeper, saturated zone. The upper surface of an unconfined aquifer.

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.

NRC FORM 335 (12-2010) NRCMD 3.7 — U.S. NUCLEAR REGULATORY COMMISSION	1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)
BIBLIOGRAPHIC DATA SHEET *(See instructions on the reverse)*	NUREG-1437, Volume 3, Revision 2 Final Report
2. TITLE AND SUBTITLE Generic Environmental Impact Statement for License Renewal of Nuclear Plants Appendices Final Report	3. DATE REPORT PUBLISHED MONTH: August — YEAR: 2024 4. FIN OR GRANT NUMBER
5. AUTHOR(S) See Appendix H of this Report.	6. TYPE OF REPORT Technical 7. PERIOD COVERED (Inclusive Dates)

8. PERFORMING ORGANIZATION - NAME AND ADDRESS (If NRC, provide Division, Office or Region, U. S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)

Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

9. SPONSORING ORGANIZATION - NAME AND ADDRESS (If NRC, type "Same as above", if contractor, provide NRC Division, Office or Region, U. S. Nuclear Regulatory Commission, and mailing address.)

Same as 8 above.

10. SUPPLEMENTARY NOTES

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, 59 nuclear power plants (96 reactor units) have undergone license renewal environmental reviews and have received renewed licenses (either an initial license renewal [initial LR] or subsequent license renewal [SLR]), 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 LR and SLR 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 initial LR and one term of SLR.

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)	13. AVAILABILITY STATEMENT
Generic Environmental Impact Statement for License Renewal of Nuclear Plants LR GEIS NUREG-1437, Revision 2 National Environmental Policy Act NEPA License Renewal Initial LR Subsequent License Renewal SLR	unlimited 14. SECURITY CLASSIFICATION *(This Page)* unclassified *(This Report)* unclassified 15. NUMBER OF PAGES 16. PRICE

Printed
on recycled
paper

Federal Recycling Program

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, DC 20555-0001

OFFICIAL BUSINESS

@NRCgov