Attachment 1: Staff Guidance for Greenhouse Gas and Climate Change Impacts for New Reactor Environmental Impact Statements
COL/ESP-ISG-026

Purpose

The principal purpose of this guidance is to provide the framework for considering and the format and content for presenting the U.S. Nuclear Regulatory Commission (NRC or Commission) staff's evaluation of greenhouse gas (GHG) emissions and climate change in the environmental reviews for new reactors in a manner that implements the Commission's direction. This Interim Staff Guidance (ISG) addresses treatment of GHG emissions and impacts associated with the current environment, building activities, operation, fuel cycle, cumulative impacts, alternative energy and alternative sites.

Background

In recent licensing actions, NRC's Atomic Safety Licensing Board Panels have referred rulings on GHG emissions and climate change to the Commission suggesting that it may want to consider the "… potential generic significance of the issue …" In CLI-09-21 (NRC 2009), the Commission provided additional guidance to the staff. The staff outlined its general plan for implementing the Commission's guidance in a memorandum from M. Johnson to R.W. Borchardt on January 15, 2010 (NRC 2010).

Rationale

This guidance directs the staff's consideration of GHG emissions and the treatment of climate change in environmental reviews for new reactors. A National Environmental Policy Act (NEPA) analysis (Environmental Impact Statement or Environmental Assessment) is the appropriate forum to consider the interface and potential consequences of new projects and the environment. Additionally, this guidance notes that the air quality analysis and requirement to determine if the proposed action conforms to the State Implementation Plan under Title 40 of the *Code of Federal Regulations* (40 CFR) Part 93 described in Environmental Standard Review Plan (ESRP) or NUREG-1555, Sections 2.7 and 4.4.1, should be performed in Environmental Impact Statement (EIS), Chapters 4, 5, 6, 7, and 9. For information on general conformity determinations, refer to the staff guidance memo for conducting general conformity determinations (NRC 2013a) (Agencywide Documents Access and Management System (ADAMS) Accession No.ML12313A190).

Staff Guidance

Definitions

C*arbon dioxide (CO_2) equivalent* is a metric that describes, for a given mixture and amount of greenhouse gas, the amount of CO_2 that would have the same global warming potential (GWP), when measured over a specified timescale (generally, 100 years).

Global warming potential (GWP) is a measure of the total energy that a gas absorbs over a particular period of time (usually 100 years), as compared to CO_2.

NRC-authorized impacts are the impacts from NRC-authorized construction activities identified in Chapter 4 and the operational impacts identified in Chapter 5 of the EIS.

Review Interfaces

The air quality reviewer should obtain input from and provide input to the reviewers for the following EIS chapters, as indicated:

- Chapter 2, Affected Environment. Subject matter experts obtain information on regional climate change for the proposed site location from the U.S. Global Change Research Program (USGCRP) Report. This will form the baseline for the climate change discussion. The staff should consider the effects of a changing climate on air and water resources, ecological resources, and human health issues. Climate change in the affected environment section should cover the project period and resources that are likely to be impacted by climate change during this period.

- Chapters 4 and 5, Construction Impacts at the Proposed Site and Operational Impacts at the Proposed Site. Provide input on estimated air emissions (including GHGs) and mitigation measures or plans to control air emissions from preconstruction/construction and operations, including traffic.

- Chapter 6, Fuel Cycle, Transportation, and Decommissioning. Provide input on GHG emissions from the uranium fuel cycle (including impacts from fossil fuel combustion and decommissioning activities).

- Chapter 7, Cumulative Impacts. Provide input on cumulative GHG emissions from all phases of the proposed action. Provide input on reasonably foreseeable changes in the climate and the associated effects on specific resource areas during the period of the proposed action for the proposed site location cumulative impacts analysis. Each subject area should contain a discussion of climate change impacts on the specific resource being considered.

- Chapter 9, Environmental Impacts of Alternatives. Provide input on GHG emissions from alternative energy sources. Provide input on air quality impacts, including GHG emissions, for each of the alternative sites. Provide input on reasonably foreseeable changes in the climate and the associated effects on specific resource areas during the period of the proposed action for each of the alternative sites.

Data and Information Needs

The following sources of information could be useful for the GHG analysis:

- U.S. Global Change Research Program Report (USGCRP) (http://www.globalchange.gov/) and peer-reviewed assessments from USGCRP.

- Intergovernmental Panel on Climate Change Periodic Report (IPCC 2012).

- U.S. Environmental Protection Agency (EPA) Periodic Report *Inventory of U. S. Greenhouse Gas Emissions and Sinks* (EPA 2012a).

- Applicant's Environmental Report (ER) – emission estimates, mitigation plans, alternative energy sources emissions.

Appendix A of Attachment 1 presents a generic GHG footprint for a 1000-MW(e) reactor to be scaled by reactor type and number of units proposed to be built. The NRC staff can rely upon the generic analysis as a starting point; however, the unique aspects of each proposal must be reflected in the material included in the air quality sections of the EIS. If a site-specific analysis is provided in the ER, the reviewer should discuss both the applicant's GHG emissions estimates and the staff's emissions estimates scaled from the generic analysis in Appendix A.

I. ACCEPTANCE CRITERIA

Acceptance criteria for the GHG and climate change impacts associated with the proposed activities are the following:

- Title 10 of the *Code of Federal Regulations* (10 CFR) 51.10(a) with respect to NRC policy to voluntarily take account, subject to certain conditions, of the regulations of Council on Environmental Quality (CEQ) implementing NEPA. On February 23, 2010, the CEQ issued (75 FR 8046) draft guidance for public comment on "Consideration of the Effects of Climate Change and Greenhouse Gas Emissions." As of July 2013, this guidance has not yet been finalized.
- 10 CFR 51.45 with respect to the need to discuss the impact of the proposed action on the environment in the ER.
- 10 CFR 51.71 with respect to the need to discuss the environmental effects of the proposed action and alternatives in an EIS.

Technical Rationale

The technical rationale for evaluating GHG impacts associated with the applicant's proposed activities is the draft CEQ guidance (75 FR 8046) on "Consideration of the Effects of Climate Change and Greenhouse Gas Emissions" (CEQ 2010).

The following excerpted text from the CEQ's draft guidance is considered relevant by the NRC staff in shaping its consideration of GHG emissions and the effects of climate change as part of its NEPA reviews of new reactor applications and its preparation of EISs:

> *Because climate change is a global problem that results from global GHG emissions, there are more sources and actions emitting GHGs (in terms of both absolute numbers and types) than are typically encountered when evaluating the emissions of other pollutants. From a quantitative perspective, there are no dominating sources and fewer sources that would even be close to dominating total GHG emissions. The global climate change problem is much more the result of numerous and varied sources, each of which might seem to make a relatively small addition to global atmospheric GHG concentrations. CEQ proposes to recommend that environmental documents reflect this global context and be realistic in focusing on ensuring that useful information is provided to*

decision makers for those actions that the agency finds are a significant source of GHGs.

Under this proposed guidance, agencies should use the scoping process to set reasonable spatial and temporal boundaries for this assessment and focus on aspects of climate change that may lead to changes in the impacts, sustainability, vulnerability and design of the proposed action and alternative courses of action. At the same time, agencies should recognize the scientific limits of their ability to accurately predict climate change effects, especially of a short-term nature, and not devote effort to analyzing wholly speculative effects.

In the agency's analysis of direct effects, it would be appropriate to: (1) quantify cumulative emissions over the life of the project; (2) discuss measures to reduce GHG emissions, including consideration of reasonable alternatives; and (3) qualitatively discuss the link between such GHG emissions and climate change. However, it is not currently useful for the NEPA analysis to attempt to link specific climatological changes, or the environmental impacts thereof, to the particular project or emissions, as such direct linkage is difficult to isolate and to understand. The estimated level of GHG emissions can serve as a reasonable proxy for assessing potential climate change impacts, and provide decision makers and the public with useful information for a reasoned choice among alternatives.

II. REVIEW PROCEDURES

The Commission provided guidance to the staff in CLI-09-21 (NRC 2009) regarding carbon dioxide and other GHGs in its environmental reviews for major licensing actions under NEPA. The Commission's guidance stated that the staff's analysis for reactor applications should evaluate emissions from the uranium fuel cycle as well as from construction and operation of the facility to be licensed.

The staff has previously developed a framework document to address GHG issues and climate change (NRC 2011). This ISG updates and formalizes that framework. Climate change is to be addressed in Chapter 2 as a changing affected environment under the discussion of climate; thereafter, it is to be considered in particular resource areas (air and water resources, ecological resources, and human health areas) as part of the cumulative impacts analysis (reflecting past, present and reasonably foreseeable effects) in Chapter 7 for the proposed site and in Chapter 9 for the alternative sites. CO_2 and other GHG emissions are to be considered as direct, indirect or cumulative impacts on air quality (along with criteria pollutants) in Chapter 4 (Building Impacts), Chapter 5 (Operational Impacts), Chapter 6 (Fuel Cycle and Decommissioning), Chapter 7 (Cumulative Impacts at the Proposed Site), and Chapter 9 (Alternative Energy Sources and Cumulative Impacts at the Alternative Sites). For more information, refer to the updated GHG guidance memo (NRC 2013b) (ADAMS Accession No. ML12356A500).

With the purpose of informing decision-making, CEQ proposes in its 2010 draft NEPA guidance on "Consideration of the Effects of Climate Change and Greenhouse Gas Emissions" (CEQ 2010) that the NEPA process should incorporate consideration of both the impact of an agency action on the environment through the mechanism of GHG emissions and the impact of changing climate on that agency action (75 FR 8046). CEQ recommends that GHG emissions can be used as a "proxy" for assessing climate change impacts. For new reactor licensing actions where an EIS is being prepared to

fulfill its responsibilities under NEPA, the NRC staff should consider (1) the potential impacts of the proposed action on the environment and (2) the changes in significant resource areas that may occur during the lifetime of the proposed action as a result of a changing climate.

Steps to perform the resource specific analysis

AFFECTED ENVIRONMENT (EIS Chapter 2)

The initial discussion of climate change effects is based on the historical record for the area being considered. Following this discussion, climate change in the affected environment section should cover the project period and resources that are likely to be impacted by climate change during this period. The reviewer should recognize the uncertainty with predicting climate change effects in the short-term. Agencies should be clear about the basis for projecting the changes from the existing environment to the reasonably foreseeable affected environment, including what would happen under this scenario and the probability or likelihood of this future condition (CEQ 2010). Reviewers should also consider the particular impacts of climate change on vulnerable communities where this may affect the design of the action or the selection among alternatives (CEQ 2010). This could include environmental justice communities, especially American Indian and Alaska Native peoples who have a special spiritual and cultural link to their environment, communities using subsistence farming or fishing practices, or projects located in coastal areas that could be impacted by sea level rise. Information regarding the estimated changes in climate conditions on a regional basis is provided in the USGCRP report. A convenient source for this information is the Regional Climate Information tab from the USGCRP website home page. Additionally, peer-reviewed literature discussing regional climate change impacts may be available for the area being considered. It is appropriate to consider the anticipated changes in precipitation, temperature, frequency and severity of storms, sea level, floods and droughts during the period of the proposed action. The EIS discussion should be commensurate in scope and depth with the discussion of current climate conditions.

ENVIRONMENTAL CONSEQUENCES (EIS Chapters 4, 5, 6, 7 and 9)

- Carbon Dioxide and Other Greenhouse Gas Emissions

The reviewer should evaluate air quality conditions (i.e., status with regard to National Ambient Air Quality Standards) and potential emissions from sources and activities associated with building and operating a new nuclear power plant. In addition to consideration of the traditional criteria pollutants, air conformity reviews, visibility impairment in Prevention of Significant Deterioration Class I areas, etc., the NRC Staff considers the emission of CO_2 and other GHGs as an important air quality issue consistent with CEQ's draft guidance; i.e., "[T]his is not intended as a 'new' component of NEPA analysis, but rather as a potentially important factor to be considered within the existing NEPA framework." Consequently, discussions related to the consequences of CO_2 and other GHG emissions should be included within the context of air quality issues in EISs for new reactor application reviews. The generic GHG footprint presented in Appendix A should be referenced and adjusted according to the proposed action (number of units, electrical output).

- Environmental Consequence Analyses

The Commission directed in CLI-09-21 (NRC 2009) that the NRC staff's NEPA analysis for reactor applications should "… encompass emissions from the uranium fuel cycle as well as

from construction and operation of the facility to be licensed." For new reactor EISs, the NRC Staff encompasses the direction outlined by the Commission and considers CO_2 and the other GHG as CO_2 equivalent emissions in the following air quality analyses:

1) the direct and indirect impacts of building[a] the nuclear power plant (excluding the manufacturing of components);

2) the direct and indirect impacts of operating the nuclear power plant;

3) the indirect impacts of fuel cycle activities (i.e., uranium mining and milling, enrichment, fuel fabrication, and transportation);

4) the direct and indirect impacts of decommissioning the nuclear power plant;

5) the incremental impacts of the proposed project within the cumulative impacts analysis;

6) the comparison of the proposed project impacts at the proposed site to alternative energy source impacts that meet the purpose and need (i.e., baseload power generation); and

7) the comparison of the proposed project impacts at the proposed site to potential impacts at alternative sites in the context of cumulative impacts.

The electrical energy that is used to produce and manage the fuel for a nuclear power plant is highly likely to require the combustion of fossil fuels; this is considered in the analysis of the indirect GHG emissions associated with fuel cycle activities for a nuclear power plant. Table S-3, Table of Uranium Fuel Cycle Environmental Data, in 10 CFR 51.51 provides the NRC a framework for assessing the contribution of the environmental effects of uranium mining and milling, the production of uranium hexafluoride, isotopic enrichment, fuel fabrication, reprocessing of irradiated fuel, transportation of radioactive materials and management of low-level wastes and high-level wastes related to uranium fuel cycle activities to the environmental costs of licensing the nuclear power plant.

Table S-3 did not consider GHG emissions explicitly. However, the staff uses the annual electrical energy and process heat needs and the amount of fossil fuels consumed to generate the necessary electrical power and process heat to estimate the annual GHG emissions associated with the uranium fuel cycle. Appendix A presents a generic GHG footprint of CO_2 and other GHG emissions, reported as CO_2 equivalent emissions. The generic GHG footprint should be referenced in an EIS for a new reactor application. If a site-specific analysis is provided in the ER, the reviewer should discuss both the applicant's GHG emissions estimates and the staff's emissions estimates scaled from the generic analysis in Appendix A. When using the generic GHG footprint in Appendix A, certain values may need to be scaled by activity, number of units, electrical output, or capacity factor. The analysis is to be made unique to the project using project-specific adjustment factors without departure from the underlying generic analysis; therefore, this approach is analogous to the use of Table S-3.

[a] Building includes both preconstruction and NRC-authorized construction as defined in 10 CFR 50.10.

The emission estimates in Appendix A are for a 1000-MW(e) large light-water reactor. If the proposed action involves a small modular reactor rather than a large light-water reactor, the emissions associated with construction and preconstruction activities may be less than the Appendix A estimates due to the smaller footprint associated with small modular reactors. However, emissions from building activities are a small fraction of those from the entire nuclear power plant lifecycle, and a reduction in construction and preconstruction emissions may not have a significant impact on the resulting lifecycle emissions.

Chapter 4: Construction and Preconstruction Emissions.

The total emissions from construction and preconstruction activities for a 1000-MW(e) reactor are estimated in the generic GHG footprint in Appendix A. From Appendix A, Table A-3, this value is the sum of the emissions from the construction equipment plus the workforce. This value is 39,000 MT CO_2(eq) plus 43,000 MT CO_2(eq), for a total lifetime estimate of 82,000 MT CO_2(eq) for a 1000-MW(e) reactor.

Chapter 5: Operations Emissions.

From Appendix A, Table A-3, this value is the sum of the emissions from nuclear power plant operations plus the operations workforce. This value is 181,000 MT CO_2(eq) plus 136,000 MT CO_2(eq), for a total lifetime estimate of 317,000 MT CO_2(eq) for a 1000-MW(e) reactor.

Chapter 6: Uranium Fuel Cycle and Decommissioning Emissions.

From Appendix A, Table A-3, this value is 10,100,000 MT CO_2(eq) for the uranium fuel cycle. The decommissioning emissions estimate is the sum of the emissions from the decommissioning equipment and the decommissioning workforce. This value is 19,000 MT CO_2(eq) plus 8,000 MT CO_2(eq) for a total lifetime estimate of 27,000 MT CO_2(eq) for a 1000-MW(e) reactor. The SAFSTOR emissions value in Table A-3 may be added if the reviewer chooses to discuss this decommissioning option in the EIS.

For more information, refer to the updated GHG guidance memo (NRC 2013b) (Adams Accession No. ML12356A500).

Chapter 7: Cumulative Impacts.

The reviewer should discuss the total GHG emissions from all phases of the proposed action in the cumulative impacts analysis, drawing from the generic GHG footprint in Appendix A of this Attachment. This would also be the sum of the impacts addressed in EIS Chapters 4, 5, and 6. From Appendix A, Table A-3, the total nuclear power plant lifetime GHG footprint is 10,500,000 MT CO_2(eq) for a 1000-MW(e) reactor. This is equal to approximately 37.5 g CO_2eq/kWh (Harvey 2013). The proposed action's emissions should be discussed along with GHG emissions from other past, present, and reasonable foreseeable future activities, including the development of associated support infrastructure such as roads, housing, and schools. The total GHG emissions from the proposed action should be put into context for decision makers. For more information on putting total GHG emissions into context for the cumulative impacts analysis, refer to the updated GHG guidance memo (NRC 2013b) (ADAMS Accession No. ML12356A500).

CEQ recommends that GHG emissions can be used as a "proxy" for assessing climate change impacts. The updated GHG guidance memo provides information on addressing climate

change in the cumulative impacts analysis. The Chapter 7 climate change discussions for each subject area should focus on reasonably foreseeable conditions; the subject area reviewers may reference the USGCRP report and available peer-reviewed literature for regional impacts.

ENERGY ALTERNATIVES AND ALTERNATIVE SITES (EIS Chapter 9)

- Energy Alternatives

The reviewer should discuss the emissions from competitive energy alternatives that are capable of meeting the purpose and need of the proposed action in Section 9.2.2 (Alternatives Requiring New Generating Capacity) of the EIS.

To put emissions into context for decision makers, the EIS should include a comparison of emissions from competitive energy alternatives. The Intergovernmental Panel on Climate Change (IPCC) Special Report on Renewable Energy Sources and Climate Change Mitigation (IPCC 2012) contains a comparison of lifecycle GHG emissions in $gCO_2(eq)/kWh$ for various energy alternatives in Figure SPM.8 and Table A.II.4. This may be a useful resource for the reviewer. The reviewer should maintain awareness of subsequent IPCC reports. If IPCC does not publish subsequent reports in the future, the reviewer should consider using other published reports referenced by the CEQ and Federal programs and agencies charged with the responsibility to assess and report on the science of climate change (e.g., USGCRP).

- Alternative Sites

Impacts to air quality from criteria pollutants and impacts from GHG emissions at each alternative site are addressed in the same manner as in Chapters 4, 5, and 6 for the proposed site. Cumulative impacts are addressed in the same manner as in Chapter 7 for the proposed site.

EVALUATION FINDINGS

For Chapters 4 and 5:

Wording of the conclusion in the section will depend on whether the impacts are SMALL or MODERATE or LARGE. Use words below:

If impact is SMALL – Provide the reason for the conclusion, then state, “As a result, the NRC staff concludes that the impacts on air quality would be SMALL, and no further mitigation is warranted.”

If impact is MODERATE or LARGE - Summarize why the basis for the conclusion (the full explanation should be provided in the preceding analysis). In the next paragraph, state the NRC-authorized impact and provide a discussion as to whether the NRC-authorized activity is a significant contributor to MODERATE or LARGE impact. Sufficient information should be provided to show whether the NRC-authorized activity caused the impact to go from SMALL to MODERATE or MODERATE to LARGE. For example, if the NRC-authorized increment is SMALL, but the current environment is degraded or the impacts from preconstruction are the principal contributors to the MODERATE rating, state this. For other than a SMALL impact, discuss if, and to what extent, the NRC-authorized increment contributes to the “other than

SMALL" impact. For guidance on considering mitigation in impact determinations, refer to ISG-026 cover memo.

For Chapter 6:

Provide a basis for the fossil fuel impacts from the uranium fuel cycle and decommissioning, and make a conclusion for the impact on air quality.

If the reactor design is one that is addressed in NUREG-0586 Supplement 1 (NRC 2002), determine if the impacts are bounding for the proposed project. Provide a basis for the conclusion for the impact on air quality, and determine if the impact is SMALL, MODERATE or LARGE.

For Chapter 7:

Provide a basis for the cumulative impacts to air quality including GHG emissions, and the impact from the projects listed in Table 1 in the cumulative impacts portion of this ISG (Attachment 4). State the incremental impact from NRC-authorized activities and provide a discussion as to whether the NRC-authorized activity is a significant contributor to the impact. If, for example, the purpose and need for the project includes replacing large GHG-emitting fossil fuel facilities with a lower GHG-emitting nuclear power plant, the incremental impact of the project would be beneficial and would reduce GHG emissions and the resulting contribution to climate change for those resource areas affected. In addition, consider reductions in criteria pollutants if a fossil fuel facility is being replaced by a nuclear power plant.

For more information, refer to the updated GHG guidance memo (NRC 2013b) (ADAMS Accession No. ML12356A500).

For Chapter 9:

9.2.2.x (Energy Alternatives): Provide a basis and conclusion for the impact on air quality of SMALL, MODERATE or LARGE for each competitive energy alternative.

9.2.5 (Summary Comparison of Alternatives): Provide a conclusion regarding whether any of the competitive energy alternatives are preferable to the proposed action of building and operating a new nuclear power plant, including consideration of GHG emissions.

9.3.x (Alternative Sites): Provide a basis and conclusion for the impact on air quality of SMALL, MODERATE or LARGE for the building and operation of a nuclear power plant at each alternative site, and the cumulative impacts on air quality at each alternative site. State the incremental impact from NRC-authorized activities and provide a discussion as to whether the NRC-authorized activity is a significant contributor to the impact.

III. IMPLEMENTATION

The method described in this guidance should be used by the staff in evaluating conformance with NRC requirements, except in those cases in which the applicant proposes an acceptable alternative for complying with specified portions of the requirements.

IV. REFERENCES

1. 10 CFR 51.10, *Code of Federal Regulations*, Title 10, *Energy*, "Purpose and scope of subpart; application of regulations of Council on Environmental Quality."

2. 10 CFR 51.45, *Code of Federal Regulations*, Title 10, *Energy,* "Environmental report."

3. 10 CFR 51.51: Code of Federal Regulations, Title 10, *Energy,* "Table S–3, Table of Uranium Fuel Cycle Environmental Data."

4. 10 CFR 51.71, *Code of Federal Regulations*, Title 10, *Energy,* "Draft Environmental Impact Statement - Contents."

5. 40 CFR Part 93, *Code of Federal Regulations*, Title 40, *Protection of Environment,* "Determining Conformity of Federal Actions to State or Federal Implementation Plans."

6. Council on Environmental Quality (CEQ). 2010: 75 FR 8046. February 18, 2010. Memorandum for Heads of Federal Departments and Agencies. Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions. *Federal Register*. Council on Environmental Quality.

7. Environmental Protection Agency (EPA). 2009: 74 FR 66496. December 15, 2009. Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act. *Federal Register.* U.S. Environmental Protection Agency, Washington, D.C

8. Environmental Protection Agency (EPA). 2012a. *Inventory of U. S. Greenhouse Gas Emissions and Sinks: 1990-2010*. EPA 430-R-12-001. U.S. Environmental Protection Agency, Washington, D.C.

9. Environmental Protection Agency (EPA). 2012b. U.S. Environmental Protection Agency, Clean Energy: Calculations and References. Accessed October 10, 2012 at http://www.epa.gov/cleanenergy/energy-resources/refs.html.

10. Harvey B. 2013. "Greenhouse emissions for the fossil fuel sources identified in Table S-3." Office of New Reactors, U.S. Nuclear Regulatory Commission, Washington, D.C. Agencywide Documents Access and Management System (ADAMS) Accession No. ML12299A401.

11. Intergovernmental Panel on Climate Change (IPCC). 2012: *Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change.* Intergovernmental Panel on Climate Change. Cambridge University Press, 2012.

12. National Environmental Policy Act of 1969, as amended (NEPA). 42 U.S.C. 4321, *et seq*

13. Nuclear Regulatory Commission (NRC). 2002: *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities: Supplement 1.* NUREG-0586, Supplement 1, Washington, D.C.

14. Nuclear Regulatory Commission (NRC). 2009: Memorandum and Order (CLI-09-21) In the Matter of Duke Energy Carolinas, LLC, and Tennessee Valley Authority. (Combined License Application for Williams States Lee III Nuclear Station, Units 1 and 2 and Bellefonte Nuclear Power Plant, Units 3 and 4), November 3, 2009. Docket Nos. 52-014-COL, 52-015-COL, 52-018-COL, 52-019-COL. Washington, D.C. ADAMS Accession No. ML093070689.

15. Nuclear Regulatory Commission (NRC). 2010: Memorandum from Michael Johnson to R.W. Borchardt. "Consideration of Certain Environmental Impacts Relevant to Greenhouse Gas Emissions." January 15, 2010. ADAMS Accession No. ML093520734.

16. Nuclear Regulatory Commission (NRC). 2011: Memorandum from Brent Clayton to Scott Flanders. "Revision 1- Addressing The Construction and Preconstruction Activities, Greenhouse Gas Issues, General Conformity Determinations, Environmental Justice, the Need For Power, Cumulative Impact Analysis And Cultural/Historical Resources Analysis Issues in Environmental Impact Statements." March 4, 2011. ADAMS Accession No. ML110380369.

17. Nuclear Regulatory Commission (NRC). 2013a. Memorandum from Ryan Whited to Scott Flanders. "Revision to Staff Guidance for Conducting General Conformity Determinations." April 25, 2013. Washington, D.C. ADAMS Accession No. ML12313A190.

18. Nuclear Regulatory Commission (NRC). 2013b. Memorandum from Stacey Imboden to Ryan Whited. "Staff Guidance to Support ISG regarding Greenhouse Gas and Climate Change Impacts." April 29, 2013. Washington, D.C. ADAMS Accession No. ML12356A500.

Appendix A

Greenhouse Gas Footprint Estimates for a Reference 1000-MW(e) Reactor

The review team has estimated the GHG footprint of various activities associated with nuclear power plants. These activities include building, operating, and decommissioning a nuclear power plant. The estimates include direct emissions from the nuclear facility and indirect emissions from workforce transportation and the fuel cycle.

Preconstruction/construction equipment estimates listed in Table A-1 are based on hours of equipment use estimated for a single nuclear power plant at a site requiring a moderate amount of terrain modification (UniStar 2007).

Preconstruction/construction equipment carbon monoxide (CO) emission estimates were derived from the hours of equipment use and carbon dioxide (CO_2) emissions were then estimated from the CO emissions using a scaling factor of 172 tons of CO_2 per ton of CO. The scaling factor is based on the ratio of CO_2 to CO emission factors for diesel fuel industrial engines as reported in Table 3.3-1 of AP-42 (EPA 2012a). A CO_2 to total GHG equivalency factor of 0.991 is used to account for the emissions from other GHGs such as methane (CH_4) and nitrous oxide (N_2O). The equivalency factor is based on non-road/construction equipment (Chapman et al. 2012). Equipment emissions estimates for decommissioning are assumed to be one half of those for preconstruction/construction. Data on equipment emissions for decommissioning are not available; the one-half factor is based on the assumption that decommissioning would involve less earth moving and hauling of material, and fewer labor hours, as compared to preconstruction/construction.

Table A-1. GHG Emissions from Equipment Used in Preconstruction/Construction and Decommissioning (MT CO_2(eq))

Equipment	Preconstruction/Construction Total[(a)]	Decommissioning Total[(b)]
Earthwork and Dewatering	12,000	6,000
Batch Plant Operations	3,400	1,700
Concrete	5,400	2,700
Lifting and Rigging	5,600	2,800
Shop Fabrication	1,000	500
Warehouse Operations	1,400	700
Equipment Maintenance	10,000	5,000
TOTAL[(c)]	39,000	19,000

(a) Based on hours of equipment usage over 7-year period
(b) Based on equipment usage over 10-year period
(c) Results are rounded

Table A-2 lists the review team's estimates of the CO_2 equivalent emissions associated with workforce transportation. Workforce estimates for new plant preconstruction/construction are conservatively based on estimates in various combined license applications (Chapman et al. 2012), and the operational and decommissioning workforce estimates are based on Supplement 1 to NUREG-0586 (NRC 2002). The table lists the assumptions used to estimate total miles traveled by each workforce and the factors used to convert total miles to metric tons (MT) CO_2 equivalent. The workers are assumed to travel in gasoline-powered passenger vehicles (cars, trucks, vans, and sport utility vehicles) that get an average of 21.6 miles per gallon of gas (FHWA 2012). Conversion from gallons of gasoline burned to CO_2 equivalent is based on EPA emission factors (EPA 2012b).

Table A-2. Workforce GHG Footprint Estimates

	Preconstruction/ Construction Workforce	**Operational Workforce**	**Decommissioning Workforce**	**SAFSTOR Workforce**
Commuting Trips (round trips per day)	1,000	550	200	40
Commute Distance (miles per round trip)	40	40	40	40
Commuting Days (days per year)	365	365	250	365
Duration (years)	7	40	10	40
Total Distance Traveled (miles)[(a)]	102,000,000	321,000,000	20,000,000	23,000,000
Average Vehicle Fuel Efficiency[(b)] (miles per gallon)	21.6	21.6	21.6	21.6
Total Fuel Burned[(a)] (gallons)	4,700,000	14,900,000	900,000	1,100,000
CO_2 emitted per gallon[(c)] (MT CO_2)	0.00892	0.00892	0.00892	0.00892
Total CO_2 Emitted[(a)] (MT CO_2)	42,000	133,000	8,000	10,000
CO_2 equivalent factor[(c)] (MT CO_2/ MT CO_2(eq))	0.977	0.977	0.977	0.977
Total GHG Emitted[(a)] (MT CO_2 (eq))	43,000	136,000	8,000	10,000

(a) Results are rounded
(b) FHWA (2012)
(c) EPA (2012b)

10 CFR 51.51(a) states that every environmental report prepared for the combined license stage of a light-water-cooled nuclear power reactor shall take Table S-3 from 10 CFR 51.51(b) as the basis for evaluating the contribution of the environmental effects of the uranium fuel cycle in licensing the nuclear power reactor. 10 CFR 51.51(a) further states that Table S-3 shall be included in the environmental report and may be supplemented by a discussion of the environmental significance of the data set forth in the table as weighted in the analysis for the proposed facility.

Table S-3 does not provide an estimate of GHG emissions associated with the uranium fuel cycle; it only addresses pollutants that were of concern when the table was promulgated in the 1980's. However, Table S-3 does state that 323,000 MW-hour is the assumed annual electric energy use for the reference 1000 MWe nuclear power plant and this 323,000 MW-hour of annual electric energy is assumed to be generated by a 45 MWe coal-fired power plant burning 118,000 MT of coal. Table S-3 also assumes approximately 135,000,000 standard cubic feet (scf) of natural gas is required per year to generate process heat for certain portions of the uranium fuel cycle. The review team estimates that burning 118,000 MT of coal and 135,000,000 scf of natural gas per year results in approximately 253,000 MT of CO_2 equivalent being emitted into the atmosphere per year due to the uranium fuel cycle (Harvey 2013).

The review team estimated GHG emissions related to plant operations from a typical usage of various diesel generators onsite (UniStar 2007). Carbon monoxide emission estimates were derived assuming an average of 600 hrs of emergency diesel generator operation per year (four generators, each operating 150 hours per year) and 200 hrs of station blackout diesel generator operation per year (two generators, each operating 100 hours per year). A scaling factor of 172 was then applied to convert the CO emissions to CO_2 emissions and a CO_2 to total GHG equivalency factor of 0.991 was used to account for the emissions from other GHGs such as methane (CH_4) and nitrous oxide (N_2O).

Given the various sources of GHG emissions discussed above, the review team estimates the total lifecycle GHG footprint for a reference 1000 MW(e) nuclear power plant with an 80 percent capacity factor to be about 10,500,000 metric tons. The components of the footprint are summarized in Table A-3. The uranium fuel cycle component of the footprint dominates all other components. It is directly related to power generated. As a result, it is reasonable to use reactor power to scale the footprint to differently sized reactors.

The IPCC released a special report on renewable energy sources and climate change mitigation in 2012 (IPCC 2012). Annex II of this IPCC report includes an assessment of previously published works on lifecycle GHG emissions from various electric generation technologies, including nuclear energy. The IPCC report included in its assessment only material that passes certain screening criteria for quality and relevance. The IPCC screening yielded 125 estimates of nuclear energy lifecycle GHG missions from 32 separate references. The IPCC-screened estimates of the lifecycle GHG emissions associated with nuclear energy, as shown in Table A.II.4 of the report, ranged more than two orders of magnitude, from 1 to 220 grams (g) of CO_2 equivalent per kWh, with 25 percentile, 50 percentile, and 75 percentile values of 8 g CO_2eq/kWh, 16 g CO_2eq/kWh, and 45 g CO_2eq/kWh, respectively. The range of the IPCC estimates is due, in part, to assumptions regarding the type of enrichment technology employed, how the electricity used for enrichment is generated, the grade of mined uranium ore, the degree of processing and enrichment required, and the assumed operating lifetime of a nuclear power plant.

The review team's lifecycle GHG estimate of approximately 10,500,000 MT CO_2 equivalent for the reference 1000 MWe nuclear plant is equal to about 37.5 g CO_2eq/kWh, which places the review team estimate between the 50 and 75 percentile values of the IPCC estimates in Table A.II.4 of the report.

In closing, the review team considers the footprint estimated in Table A-3 to be appropriately conservative. The GHG emissions estimates for the dominant component (uranium fuel cycle) are based on 30-year old enrichment technology assuming that the energy required for enrichment is provided by coal-fired generation. Different assumptions related to the source of energy used for enrichment or the enrichment technology that would be just as reasonable could lead to a significantly reduced footprint.

Table A-3. Nuclear Power Plant Lifetime GHG Footprint

Source	Activity Duration (yr)	Total Emissions (MT CO_2eq)
Preconstruction/construction Equipment	7	39,000
Preconstruction/construction Workforce	7	43,000
Plant Operations	40	181,000
Operations Workforce	40	136,000
Uranium Fuel Cycle	40	10,100,000
Decommissioning Equipment	10	19,000
Decommissioning Workforce	10	8,000
SAFSTOR Workforce	40	10,000
TOTAL[(a)]		10,500,000

[(a)] Results are rounded

Emissions estimates presented in the body of this EIS have been scaled to values that are appropriate for the proposed project. The uranium fuel cycle emissions have been scaled by reactor power and plant capacity factor using the scaling factor determined in Chapter 6 and by the number of reactors to be built. Plant operations emissions have been adjusted to represent the number of large GHG emissions sources (diesel generators, boilers, etc.) associated with the project. The workforce emissions estimates have been scaled to account for differences in workforce numbers and commuting distance. Finally, equipment emissions estimates have been scaled by estimated equipment usage. As can be seen in Table A-3, only the scaling of the uranium fuel-cycle emissions estimates makes a significant difference in the total carbon footprint of the project.

A.1 References

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