Greenhouse Gas Emissions for the Fossil Fuel Sources Identified in Table S-3

Brad Harvey, NRO/DSEA/RHMB

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Table S-3 of 10 CFR 51.51 provides the basis for evaluating the contribution of the environmental effects of the uranium fuel cycle in licensing nuclear power plants. According to Table S-3, the annual fossil fuel use required to support the uranium fuel cycle for a reference 1000 MWe reactor includes 118,000 metric tons (MT) of coal to generate 323,000 MWh of electrical energy and 135,000,000 standard cubic feet (scf) of natural gas to generate process heat. The intent of this document is to estimate the greenhouse gas (GHG) emissions from these two fossil fuel sources.

This document also estimates the entire lifecycle assessment for the reference 1000 MWe reactor (including building, operating, and decommissioning the facility) in terms of grams of CO_2eq released per kWh of electric energy produced by the reference reactor.

Fuel Cycle GHG Emissions from Burning Coal

An EPA document on calculating GHG emissions from stationary combustion sources (Reference 1) provides an emission factor of 1,885 kg of carbon dioxide (CO_2) emissions per ton of coal and coke used by electric utilities (Table B-5 of Reference 1). Assuming the amount of coal burned per year is 118,000 MT, the annual amount of CO_2 emitted is:

$$(1{,}885 \text{ kg } CO_2/\text{ton coal}) \times (\text{MT}/10^3 \text{ kg}) \times (118{,}000 \text{ MT coal/yr}) \times (1.1023 \text{ tons/MT})$$

$$= 2.45 \times 10^5 \text{ MT } CO_2/\text{yr}$$

The combustion of fossil fuel also emits the greenhouse gases methane (CH_4), and nitrous oxide (N_2O). Table A-1 of Reference 1 provides CH_4 and N_2O emission factors of 1 g/mmBtu and 1.6 g/mmBtu, respectively, for electric generation using coal and Table B-1 of Reference 1 states that the heat content of coal and coke used by electric utilities is 19.95 mmBtu/ton. Again, assuming the amount of coal burned per year is 118,000 MT, the annual amount of CH_4 emitted is:

$$(1 \text{ g } CH_4/\text{mmBtu}) \times (19.95 \text{ mmBtu/ton coal}) \times (118{,}000 \text{ MT coal/yr})$$

$$\times (\text{MT}/10^6 \text{ g}) \times (1.1023 \text{ tons/MT})$$

$$= 2.59 \text{ MT } CH_4/\text{yr}$$

and the annual amount of N_2O emitted is:

$$(1.6 \text{ g } N_2O/\text{mmBtu}) \times (19.95 \text{ mmBtu/ton coal}) \times (118{,}000 \text{ MT coal/yr})$$

$$\times (\text{MT}/10^6 \text{ g}) \times (1.1023 \text{ tons/MT})$$

$$= 4.15 \text{ MT } N_2O/\text{yr}$$

Conversion to CO_2eq is achieved by multiplying the individual GHG emissions by the respective gas global warming potential or GWP. Table ES-1 of Reference 2 lists the 100-year GWP for CO_2, CH_4, and N_2O as 1, 21, and 310, respectively. Therefore, the CO_2eq emissions resulting from burning 118,000 metric tons of coal per year are:

$$(2.45 \times 10^5 \text{ MT } CO_2/\text{yr}) \times (1) + (2.59 \text{ MT } CH_4/\text{yr}) \times (21) + (4.15 \text{ MT } N_2O/\text{yr}) \times (310)$$

$$= 2.46 \times 10^5 \text{ MT } CO_2eq/\text{yr}$$

Fuel Cycle GHG Emissions from Burning Natural Gas

Table B-5 of Reference 1 provides an emission factor of 0.0546 kg of CO_2 emissions per scf of natural gas combustion. Assuming 135,000,000 scf of natural gas is burned per year, the annual amount of CO_2 emitted is:

$$(0.0546 \text{ kg } CO_2/\text{scf}) \times (\text{MT}/10^3 \text{ kg}) \times (1.35 \times 10^8 \text{ scf/yr})$$

$$= 7.37 \times 10^3 \text{ MT } CO_2/\text{yr}$$

Table A-1 of Reference 1 provides CH_4 and N_2O emission factors of 1 g/mmBtu and 0.1 g/mmBtu, respectively, for the industrial use of natural gas and Table B-1 of Reference 1 states that the heat content of natural is 1,029 Btu/scf. Assuming the amount of natural gas burned per year is 135,000,000 scf, the annual amount of CH_4 emitted is:

$$(1 \text{ g } CH_4/\text{mmBtu}) \times (1{,}029 \text{ Btu/scf}) \times (\text{mmBtu}/10^6 \text{ Btu}) \times (1.35 \times 10^8 \text{ scf/yr}) \times (\text{MT}/10^6 \text{ g})$$

$$= 1.39 \times 10^{-1} \text{ MT } CH_4/\text{yr}$$

and the annual amount of N_2O emitted is:

$$(0.1 \text{ g } N_2O/\text{mmBtu}) \times (1{,}029 \text{ Btu/scf}) \times (\text{mmBtu}/10^6 \text{ Btu}) \times (1.35 \times 10^8 \text{ scf/yr}) \times (\text{MT}/10^6 \text{ g})$$

$$= 1.39 \times 10^{-2} \text{ MT } N_2O/\text{yr}$$

Conversion to CO_2eq is achieved by multiplying the individual gas emissions by the respective gas global warming potential or GWP. Table ES-1 of Reference 2 lists the 100-year GWP for CO_2, CH_4, and N_2O as 1, 21, and 310, respectively. Therefore, the CO_2eq emissions resulting from burning 135,000,000 scf of natural gas per year are:

$$(7.37 \times 10^3 \text{ MT } CO_2/\text{yr}) \times (1) + (1.39 \times 10^{-1} \text{ MT } CH_4/\text{yr}) \times (21) + (1.39 \times 10^{-2} \text{ MT } N_2O/\text{yr}) \times (310)$$

$$= 7.38 \times 10^3 \text{ MT } CO_2eq/\text{yr}$$

Fuel Cycle GHG Emissions from the Table S-3 Reference Reactor

The combined 40-year total GHG emissions to support the uranium fuel cycle for the reference 1000 MWe reactor described in Table S-3 includes GHG emissions from (1) 118,000 MT of coal burned per year to generate electricity and (2) 135,000,000 ft^3 of natural gas used per year to generate process heat:

$$[(2.46 \times 10^5 \text{ MT } CO_2\text{eq/yr}) + (7.38 \times 10^3 \text{ MT } CO_2\text{eq/yr})] \times 40 \text{ yrs}$$

$$= 1.01 \times 10^7 \text{ MT } CO_2\text{eq}$$

Lifecycle Assessment

Assuming the reference 1000 MWe reactor operates for 40 years at an 80 percent capacity factor, the amount of electricity generated would be:

$$(1000 \text{ MWe}) \times (8760 \text{ hrs/yr}) \times (40 \text{ yrs}) \times (0.80) \times (1000 \text{ kWe/MWe})$$

$$= 2.8 \times 10^{11} \text{ kWh}$$

Assuming the reference 1000 MWe reactor has a lifetime GHG foot of 10,500,000 MT CO_2eq, the resulting lifecycle assessment in terms of grams of CO_2eq released per kWh is:

$$(1.05 \times 10^7 \text{ MT } CO_2\text{eq}) \times (10^6 \text{ g/MT}) \div (2.8 \times 10^{11} \text{ kWh})$$

$$= 37.5 \text{ g } CO_2\text{eq/kWh}$$

References

1. U.S. Environmental Protection Agency (EPA). 2008. *Direct Emissions from Stationary Combustion Sources.* EPA 430-K-08-003. Office of Air and Radiation, U.S. Environmental Protection Agency. Accession No. ML12292A646.

2. U.S. Environmental Protection Agency (EPA). 2012. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010.* EPA 430-R-12-001. U.S. Environmental Protection Agency, Washington, D.C. Accession No. ML12292A647.