NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Nuclear Power, Generation III+ Reactor Operation

Reference Flow: 1 MWh of Electricity

Brief Description: Encompasses the energy, material, and water use and the emissions and discharges during the operation of a Generation III+ nuclear reactor.

Section I: Meta Data

Geographical Coverage: US **Region:** US

Year Data Best Represents: 2009

Process Type: Energy Conversion (EC)

Process Scope: Gate-to-Gate Process (GG)

Allocation Applied: Yes

Completeness: Individual Relevant Flows Recorded

Flows Aggregated in Data Set:

☒ Process ☒ Energy Use ☐ Energy P&D ☐ Material P&D

Relevant Output Flows Included in Data Set:

Releases to Air:	☒ Greenhouse Gases	☒ Criteria Air Pollutants	☒ Other
Releases to Water:	☒ Inorganic Emissions	☒ Organic Emissions	☒ Other
Water Usage:	☒ Water Consumption	☒ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

BurnUp	*Mass of the uranium fuel (UO_2) which is used to produced each MWh of electricity*
Water_in	*Water withdrawal*

Tracked Input Flows:

UO2 (fuel assembly) [Intermediate products]	*Fuel assemblies which are loaded into the nuclear reactors for the creation of electricity*

Tracked Output Flows:

Electricity [Operation]	*1 MWh of electricity (the reference flow of this unit process)*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_O_GenIII_Plus_Nuclear_Reactor_2010.01.xls*, which provides additional details regarding calculations, data quality, and references as relevant.

Goal and Scope

This unit process accounts for the operating activities of the United States average proposed Generation III+ nuclear power plant. The process is based on the reference flow of 1 MWh of electricity. The tracked input to the process is the uranium (UO_2) fuel assembly. Water is used for cooling and other process-related utilities; water is assumed to enter the boundaries of this unit process having no upstream resource consumption or environmental emissions. The outputs of this unit process are produced electricity, spent fuel, discarded water, air emissions, water emissions, and solid waste. The output electricity is transmitted to the grid for transportation in LC Stage #4.

Boundary and Description

Figure 1 provides an overview of the boundary of this unit process. Rectangular boxes represent relevant sub-processes, while trapezoidal boxes indicate upstream data that are outside of the boundary of this unit process. As shown, the upstream emissions from the creation of the uranium fuel assemblies are calculated in another unit process which should be added to this to provide an accurate inventory value. Water is assumed to enter the boundary of the unit process with no upstream resources or emissions. The methods for calculating these operating activities are described above.

The model of Generation III+ nuclear power plant operation seeks to represent the industry average of proposed advanced nuclear reactors. Data for establishing this average comes from submitted Environmental Impact Statements (EIS) to the Nuclear Regulatory Commission for all of the proposed plants. The proportion of Pressurized Water Reactors (PWR) to Boiling Water Reactors (BWR) in this average is 67:33. In the calculated operating parameters and plant emissions, the contribution from each proposed plant is weighted according to the relative power output of that plant to the power output of the total proposed fleet. The industry average values for plant parameters for each of the types of reactors and the overall Gen III+ value are provided in **Table 1**.

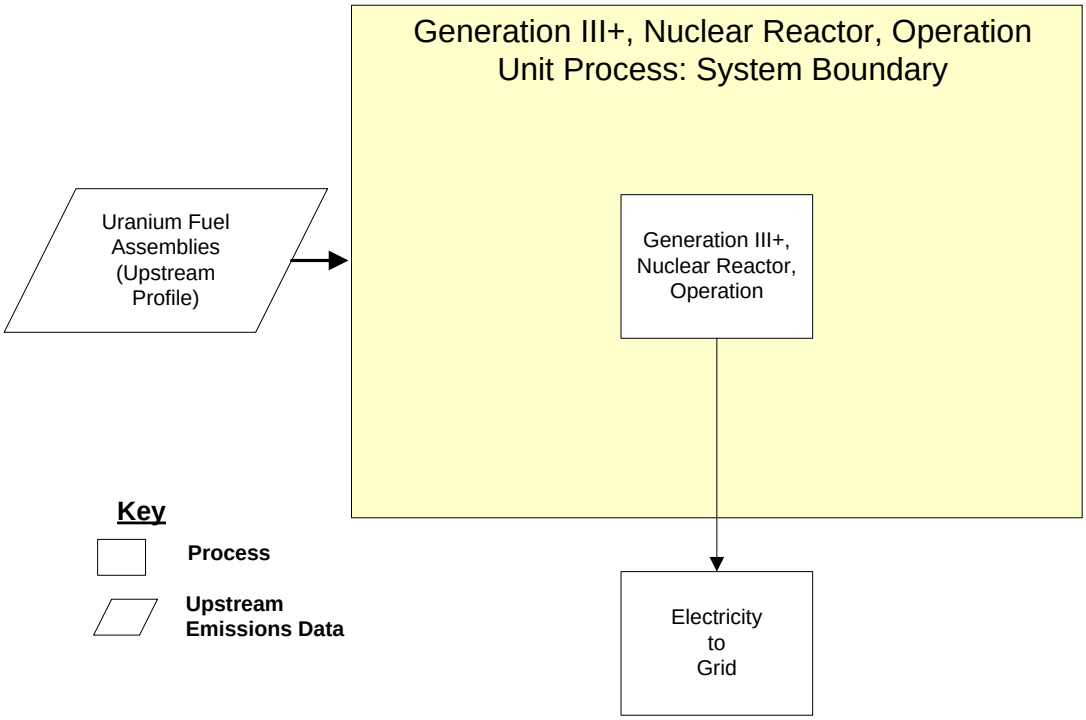

Figure 1: Unit Process Scope and Boundary

Table 1. Proposed Industry Average Generation III+ Nuclear Power Plant Operating Parameters

Parameter	**PWR Reactors Average Proposed Plant (calculated on sheet "PWR Reactors")**	**BWR Reactors Average Proposed Plant (calculated on sheet "BWR Reactors")**	**Overall Gen III+ Average**
Single Reactor Output (MW)	1251	1508	1336
Capacity Factor	93.4	95	94.0
Thermal Efficiency	33.9	34.7	34.2
Effective electric output (MW)	1174	1438	1261
Plant Lifetime (years)	60	60	60
Calculated net electrical generation (MWh/ year)	1.71E+07	1.68E+07	1.70E+07
Fuel Burn-up (kg uranium fuel/ MWh electricity produced)	8.41E-04	9.06E-04	8.63E-04
Average water withdrawal (m^3/kWh)	4.42	3.33	4.06
Water discharge (m^3/MWh)	1.45	1.21	1.37
Mixed waste (m^3/MWh)	1.60E-07	3.96E-08	1.20E-07

The proposed plant EIS's provide plant operating parameters, fuel burnup, water withdrawal and discharge, and mixed waste (mixed hazardous and radioactive waste).

For the important parameters of fuel use and water withdrawal, the variability between maximum and minimum of all reported values is recorded with adjustable parameters. GHG Emissions produced during normal reactor operation are assumed to be negligible.

A data limitation exists for Generation III+ nuclear power plant air and water emissions. Therefore, existing nuclear fleet operational data is used as a surrogate. Air and water emissions are representative of emissions from the U.S. average nuclear power industry for one year, and as such, an adjustment is made to the emissions to account for increased thermal efficiency of Gen III+ reactors over Gen II reactors. Emissions are then normalized by electricity output of Gen III+ plants, thus incorporating the increased capacity factor of GenIII+ plants over Gen II plants.

Emissions are directly adjusted to account for the increased thermal efficiency of Gen III+ plant as described on the 'Average Operations' worksheet. Air emissions data for the Gen II average is taken from US EPA nuclear industry emission factors categorized under the North American Industry Classification System (NAICS) code 221113 (EPA 2005). A list of criteria air emissions and hazardous air emissions inventoried by NAICS is available on the 'Average Operations' worksheet of the DS sheet.

Water emissions were collected from the US EPA's *Enforcement & Compliance History Online* report. Reported emissions are separated by cooling type used at the proposed plant: closed-loop and once-through (ECHO 2009).

Radioactive emissions to air were compared from two sources: the Westinghouse AP 1000 (PWR) environmental report (Westinghouse 2009) and the Generic Environmental Impact Statement for License Renewal of Nuclear Plants (NUREG-1437 Vol. 1). The higher of the two values was reported by Westinghouse 2009, thus this value was used as the more conservative estimate. Radioactive water emissions were also taken from Westinghouse.

Table 2 provides a summary of modeled input and output flows for the Gen III+ nuclear reactor. Additional details regarding input and output flows, including calculation methods, are contained in the associated DS sheet.

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units
Inputs		
Uranium Fuel Assemblies (UO2) [Intermediate product]	**2.53E-03**	**kg**
Water (surface water) [Water]	**4.06E+00**	**m^3**
Outputs		
Electricity [Operation]	1.00E+00	MWh
Spent fuel (UO2)	2.53E-03	kg/MWh
Radionuclides [Radioactive emissions to air]	6.02E+05	Bq/MWh
Radionuclides [Radioactive emissions to water]	2.05E+06	Bq/MWh
Carbon dioxide [Inorganic emissions to air]	0.00E+00	kg/MWh
Methane [Organic emissions to air (group VOC)]	0.00E+00	kg/MWh
Nitrous oxide (laughing gas) [Inorganic emissions to air]	0.00E+00	kg/MWh
Nitrogen oxides [Inorganic emissions to air]	5.09E-04	kg/MWh
Sulphur dioxide [Inorganic emissions to air]	7.83E-05	kg/MWh
Carbon monoxide [Inorganic emissions to air]	9.78E-05	kg/MWh
NMVOC (unspecified) [Group NMVOC to air]	4.14E-05	kg/MWh
Dust (PM10) [Particles to air]	2.00E-04	kg/MWh
Dust (PM2.5) [Particles to air]	1.27E-04	kg/MWh
Lead (+II) [Heavy metals to air]	3.68E-09	kg/MWh
Mercury (+II) [Heavy metals to air]	5.49E-11	kg/MWh
Ammonia [Inorganic emissions to air]	6.70E-06	kg/MWh
Selenium [Heavy metals to air]	2.53E-10	kg/MWh
Chromium (unspecified) [Heavy metals to air]	5.07E-11	kg/MWh
Manganese (+II) [Heavy metals to air]	1.02E-10	kg/MWh
Nickel (+II) [Heavy metals to air]	5.41E-11	kg/MWh
Arsenic (+V) [Heavy metals to air]	6.76E-11	kg/MWh
Cadmium (+II) [Heavy metals to air]	5.07E-11	kg/MWh
Aluminum (+III) [Inorganic emissions to fresh water]	8.21E-04	kg/MWh
Chlorine (dissolved) [Inorganic emissions to fresh water]	1.39E-04	kg/MWh
Iron [Heavy metals to fresh water]	5.99E-04	kg/MWh
Oil (unspecified) [Hydrocarbons to fresh water]	6.63E-03	kg/MWh
Phosphorus [Inorganic emissions to fresh water]	7.41E-04	kg/MWh
Solids (suspended) [Particles to fresh water]	1.46E-02	kg/MWh
Ammonia (NH3)	3.58E-04	kg/MWh
Total Nitrogen (N)	1.69E-03	kg/MWh
Oxidants	9.25E-05	kg/MWh
Barium	9.58E-05	kg/MWh
Boron	4.09E-04	kg/MWh
Fluoride	4.63E-04	kg/MWh
Chromium, Total	2.62E-06	kg/MWh
Copper, total recoverable	3.96E-05	kg/MWh
Mercury, total	5.49E-09	kg/MWh
Zinc	1.92E-04	kg/MWh
Water (river water) [Water]	1.37E+00	m3/MWh
Waste (solid) [Waste for disposal]	4.26E-05	kg/MWh
Mixed Waste (Hazardous or Radioactive)	1.20E-07	m3/MWh

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows. Upstream environmental flows were added during the modeling process using GaBi modeling software, as shown in Figure 1.

Embedded Unit Processes

None.

References

EPA 2005	EPA, 2005. 2005 *National Emissions Inventory Data & Documentation, NAICS Summaries.* U.S. Environmental Protection Agency. January 2009. http://www.epa.gov/ttnchie1/net/2005inventory.html (Accessed July 18, 2010).
ECHO 2009	*Enforcement & Compliance History Online (ECHO): Integrated Compliance Information System - National Pollutant Discharge Elimination System*. U.S. Environmental Protection Agency. August 2009. http://www.epa-echo.gov/echo/compliance_report_water.html (Accessed July 18, 2010).
Westinghouse 2009	Westinghouse, 2009. UK AP1000 Environment Report. UKP-GW-GL-790. Revision 3. 2009. https://www.ukap1000application.com/PDFDocs/UKP-GW-GL-790%20Rev%201%20PDF%20Files%20-%20Public/UKP-GW-GL-790%20Rev%201.pdf (Accessed July 18, 2010).

Section III: Document Control Information

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