NETL Life Cycle Inventory Data
Process Documentation File

Process Name:	Conventional Hydropower, Operation
Reference Flow:	1 MWh of Electricity
Brief Description:	This unit process quantifies the emissions that result from the operation of a large scale conventional hydropower plant and reservoir.

Section I: Meta Data

Geographical Coverage: US **Region:** N/A

Year Data Best Represents: 2003

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:

CAPACITY_FAC	*Capacity factor expressed as a proportion; varies regionally within the U.S.*
CAPACITY_GEN	*Electricity generation capacity of the hydropower plant*
SURF_AREA_CAP	*Surface area of reservoir when water levels are at capacity*
RES_MEAN_CAP	*Proportion of capacity water volume contained in the reservoir, on average*

ALLOC_HYDROELEC	*Proportion of reservoir allocated to hydroelectric power production, as opposed to other uses*
RES_EVAP	*Mass of water evaporated per MWh of power produced*

Tracked Input Flows:

None.

Tracked Output Flows:

Electricity [Electric power]	*Electricity generated by the conventional hydropower dam*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_O_Conventional_Hydropower_Dam_2011.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process encompasses power generated from a conventional hydropower dam, rated to at least 100 MW of nameplate power production capacity. The unit process considers water consumption associated with evaporation from the reservoir, and carbon dioxide and methane emissions from the reservoir surface, which occur during operation of the hydroelectric reservoir. The type of dam used in support of this unit process is not specified, except that it must be large enough to support at least 100 MW of nameplate generation capacity. An allocation factor is also included in the unit process, which allows the user to allocate a proportion of total water consumption and airborne emissions to other uses that are common to reservoirs (water supply, flood control, etc.). The process is based on the reference flow of 1 megawatt hour (MWh) of conventional hydroelectric power, as described below, and as shown in **Figure 1.**

This process functions in tandem with a conventional hydropower construction unit process for LC Stage #3. Because no fuel production or transport occurs for hydropower, there are no LC Stage #1 or #2 unit processes that are applied in support of the conventional hydropower LCA. Flows from this unit process are combined with inputs and emissions associated with conventional hydropower construction (evaluated in a separate unit process), in order to evaluate the total environmental burdens associated with conventional hydropower production.

Boundary and Description

This unit process models reservoir emissions and evaporation rates associated with large scale conventional hydropower construction. The intent of this unit process is to provide evaporation and emission values that are applicable regionally across the United States. Therefore, six adjustable parameters have been included in this unit process. Default parameter values are discussed below.

Default values for the capacity factor parameter (CAPACITY_FAC) were evaluated based on data available within the Velocity Suite Database (Ventyx 2011). Capacity factor is a key adjustable parameter in support of this unit process, because it strongly influences the amount of electricity that can be generated over any given period. Capacity factor was calculated based on regional average capacity factors for the U.S. West, Southwest, South, Midwest, and Northeast. Location and capacity factor were queried for approximately 150 U.S. reservoirs, having nameplate capacities of at least 100 MW. Data were acquired for 2002 through 2010, and average capacity factors were generated for each U.S. region. These are as follows: Northeast, 52.0 percent; West, 42.7 percent; Midwest, 41.9 percent; Alaska, 36.3 percent; South, 29.5 percent; and Southwest, 26.3 percent.

The generation capacity parameter (CAPACITY_GEN) refers to the total nameplate generation capacity of the dam being modeled. Alternatively, the user can select an average or other representative nameplate capacity if a number of dams are being modeled collectively. The DS includes nameplate generation capacities for a handful of dams located in the U.S., but data from other facilities could also be used.

Reservoir surface area, measured at reservoir capacity (SURF_AREA_CAP), is also parameterized. Reservoir surface area is a key factor used in support of the evaluation of carbon dioxide and methane emissions from the reservoir. Literature values for these emission factors (see **Table 1**) are provided based on emissions from a single square meter during one day. Therefore, the surface area parameter scales these emission factors to account for reservoir surface area.

To complete the calculation of reservoir surface area, a second adjustable parameter that accounts for the mean amount of water in the reservoir is also provided (RES_MEAN_CAP). The volume of water contained in a reservoir varies based on a combination of water inflow to the reservoir, evaporation, and outflow from the reservoir. Most large reservoirs only reach full capacity during limited periods, such as near the end of the annual wet season or snowmelt season. During prolonged drought, large western reservoirs used for water supply may be reduced to 40 percent capacity of less. However, reservoirs located in the south and Midwest, where water is more consistently available and there are not prolonged dry seasons, may have substantially less variability, operating at 70 to 90 percent capacity most of the time. Therefore, based on a preliminary review of reservoir storage data, boundary values of 35 percent to 85 percent capacity have been selected for mean aquifer volume, with a best estimate value of 70 percent.

Finally, most large reservoirs used for conventional hydroelectric power generation serve multiple uses. These may include water supply, flood control, recreation, environmental purposes, navigation, and various other functions. As a result, some systems may be more effectively modeled by allocating a portion of the total environmental burdens of conventional hydropower to other uses. The parameter, ALLOC_HYDROELEC allows the user to allocate only a portion of total environmental burdens to the hydroelectric use. By default, no allocation is assumed, and a default parameter value of 1.0 is included.

Evaporation occurs as a natural process along rivers and other waterways. When water is held in a reservoir that would otherwise have been allowed to pass downstream, additional evaporation occurs within the reservoir during the time period when the water is withheld. Presumably, following release from the reservoir, water would travel down the remainder of the river, where evaporation rates would be similar to natural baseline values. NREL (2003) quantified water evaporation rates from reservoirs, in support of power generation. NREL's data include reservoirs across five U.S. regions, as shown in **Table 1**, with evaporation rates varying from approximately 23,300 (Northeast) to 340,000 kg/MWh (Southwest) of power generated. These values were calculated based on data from individual reservoirs within each region. The relevant evaporation rate can be input into the unit process via the RES_EVAP parameter.

Figure 1 provides an overview of the boundary of this unit process. As shown, steel plate, cold rolled steel, and concrete are considered as upstream emission profiles that are input into the unit process. Emissions associated with earthen dam construction are calculated within the boundary of the unit process. Emissions associated with the use of cranes and other construction activities, in support of the concrete dam, were not considered. Upstream emissions from the production of raw materials used for the construction of the turbine and associated components (e.g., steel plate, cold rolled steel, and concrete) are calculated outside the boundary of this unit process, based on proprietary profiles available within the GaBi model.

Table 1 shows relevant properties and assumptions used to estimate materials flows and emissions that would result from the construction of a conventional hydropower dam. **Table 2** provides a summary of modeled input and output flows. Additional detail regarding input and output flows, including calculation methods and values for alternative adjustable parameter values, is contained in the associated DS.

Figure 1: Unit Process Scope and Boundary

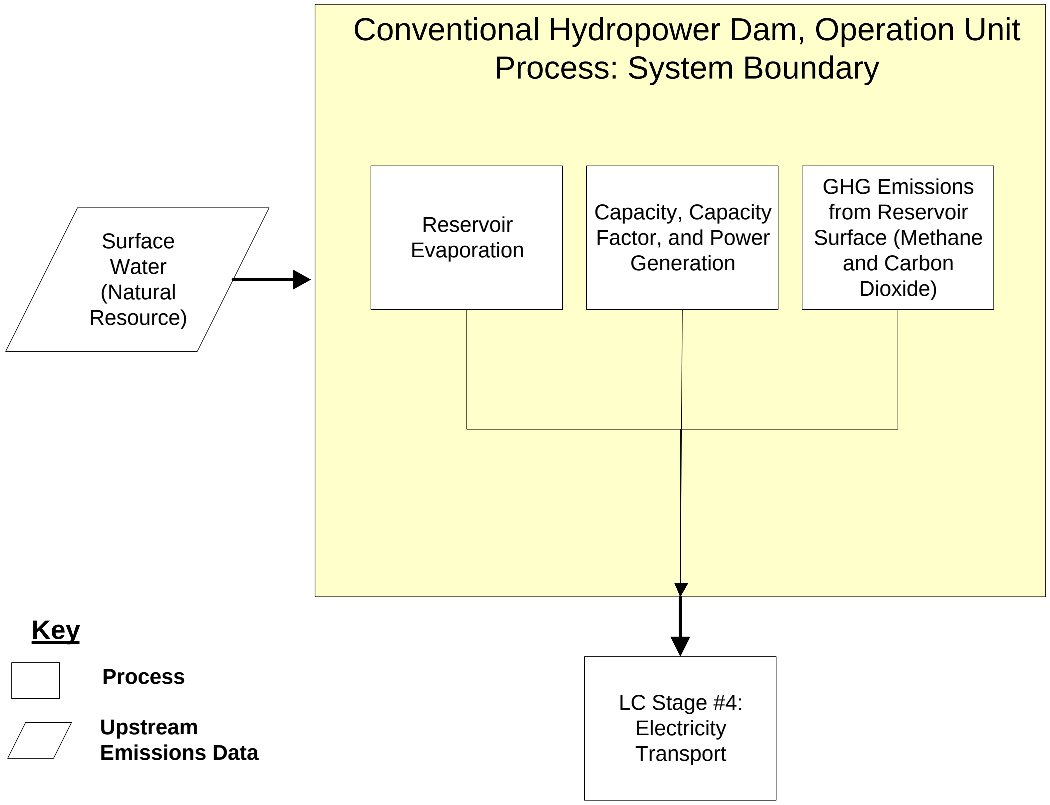

Table 1: Properties of Conventional Hydropower

Item	Weight	Reference
Average CO_2 Reservoir Emissions (g/m^2-day)	0.664	St. Louis *et al.* 2000
Average Methane Reservoir Emissions (g/m^2-day)	0.0092	St. Louis *et al.* 2000
Reservoir Evaporation Rate, Northeast (kg/MWh)	23,361	NREL 2003
Reservoir Evaporation Rate, West (kg/MWh)	157,847	NREL 2003
Reservoir Evaporation Rate, Midwest (kg/MWh)	220,589	NREL 2003
Reservoir Evaporation Rate, South (kg/MWh)	221,431	NREL 2003
Reservoir Evaporation Rate, Southwest (kg/MWh)	340,447	NREL 2003
Reservoir Evaporation Rate, U.S. Average (kg/MWh)	68,137	NREL 2003

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs*		
Water (surface water) [Water]	6.81E+04	kg/MWh
Outputs*		
Electricity [Electric Power]	1.00	kg/MWh
Carbon dioxide [Inorganic emissions to air]	16.9	kg/MWh
Methane [Organic emissions to air (group VOC)]	0.233	kg/MWh

*Values shown are default values for a facility running at 37 percent capacity factor, nameplate capacity of 2080 MW, surface area of 639,727,063 square meters, mean reservoir capacity of 70 percent, no allocation, and an evaporation rate of 68,137 kg per MWh. Adjustable parameters in the associated DS may be varied to determine values for alternate scenarios.

Embedded Unit Processes

None.

References

NREL 2003 — National Renewable Energy Laboratory. 2003. Consumptive Water Use for U.S. Power Production.

St. Louis *et al.* 2000 — Vincent L. St. Louis, Carol A. Kelly, Eric Duchemin, John W. M. Rudd, David M. Rosenburg. 2000. *Reservoir Surfaces as Sources of Greenhouse Gases to the Atmosphere: A Global Estimate.* BioScience 50(9): 766-775. September, 2000.

Ventyx 2011 — Ventyx. 2011. Velocity Suite Databases. Available for purchase at http://www.ventyx.com/velocity/energy-market-data.asp (Accessed May 25, 2011).

Section III: Document Control Information

Date Created: September 7, 2011

Point of Contact: Timothy Skone (NETL), Timothy.Skone@NETL.DOE.GOV

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