NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Natural Gas Energy Conversion U.S. Fleet Average

Reference Flow: 1 MWh of Electricity

Brief Description: The operations of the U.S. fleet average Natural Gas power generation facilities.

Section I: Meta Data

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

Year Data Best Represents: 2007

Process Type: Energy Conversion (EC)

Process Scope: Gate-to-Gate (GG)

Allocation Applied: No

Completeness: All 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:

Carbon_Factor	*Amount of carbon (in kg) per MJ of natural gas feed to the power plant*
Heat_in	*Heat rate of power plant (in MJ/MWh)*

Tracked Input Flows:

Natural gas	*Natural gas extraction and delivery to the fleet average power plant*

Tracked Output Flows:

Electricity	*Reference flow; 1 MWh of electricity generation*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_O_NG_Fleet_Average_2012.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides fleet average, minimum, and maximum values for various air emissions for representative U.S. natural gas power plant operations based on 1 MWh of electricity production. The scope of this process is restricted to the direct emissions that result from conversion of natural gas to electricity (LC Stage 3 Operations). Key outputs include electricity, greenhouse gas emissions to air, and other air pollutant emissions, specifically carbon monoxide (CO), nitrogen oxides (NO_X), and sulfur dioxide (SO_2). The water consumption and withdrawal values are also reported.

Boundary and Description

The Emissions & Generation Resource Integrated Database (eGRID) provides an inventory of operating data and emissions for U.S. power plants (EPA 2011). The latest edition is eGRID 2010, which contains operating and emissions data for 2007. The Microsoft Excel based version of eGRID allows the user select between a number of different parameters to sort the list of power generation facilities as desired. In the 2010 version, there were a total of 5,172 plants generating power from coal, natural gas, oil, nuclear, hydro, biomass, wind, and solar.

The eGRID data file was filtered to generate a list of facilities that are representative of an average natural gas power plant in the U.S. The first level of filtering involved setting the "primary fuel generation" category to natural gas. Other filtering criteria include nameplate capacity, biomass cofiring, and combined heat and power (CHP); these criteria are discussed in more detail below. Capacity factor was not used as one of the filtering criteria since natural gas plants have a wide range of values since some operate as load following plants as opposed to base load plants. **Table 1** lists the other filtering factors applied for this analysis along with the number of plants that remained after each filter level.

Table 1: eGRID Natural Gas Power Plant Filtering Levels

Filter Level	Number of Plants
0 – Primary Fuel Generation = Natural Gas	1,405
1 – Plant Nameplate Capacity ≥ 250 MW	516
2 – No Use of Biogas/Biomass	513
3 – Not Operated as Combined Heat and Power (CHP)	440
4 - 95% or Greater Annual Power Gen from Gas	390

The first level of filtering was based on the plant nameplate capacity. As shown in **Table 2**, 63.4 percent of the natural gas power plants in the U.S. have a capacity of less than 250 MW and combined generate only 11.1 percent of the total natural gas-based electricity. For this reason, plants with nameplate capacities less than 250 MW were excluded from this analysis.

The second and third levels of filtering criteria were based on the co-firing of biogas/biomass along with natural gas and the operation as a CHP or co-generation facility. CHP or co-generation facilities generate both electricity and heat or steam for industrial or commercial purposes (EPA 2010). As the purpose of this emissions estimate is to characterize the typical natural gas power plant, it was decided to remove those facilities that implement biogas/biomass co-firing and those that operate as CHP facilities. As indicated by **Table 1**, these last two levels of filtering remove 76 plants from the analysis. The majority of natural gas power plants that operate as CHP facilities are typically those that have a much smaller capacity. The final level of filtering was related to the percentage of annual power generation that is attributed to natural gas at the facility. Some of the natural gas power plants co-fired some amount of oil along with the natural gas. To ensure that the emissions were indicative of natural gas power plants, any facility that generated more than 5 percent of its annual power from oil was excluded from the analysis. This final level of filtering removed 50 plants from the list. After applying all the filters, the number of natural gas-powered electricity generation facilities was reduced from 1,405 to 390 plants.

Table 2: U.S. Natural Gas Power Plant Size and Output for 2007

Plant Nameplate Capacity (MW)	Number of Plants	Percent of Total Plants	2007 Power Gen (MWh)	Percent of Total Generation
0-100	686	48.8%	4.59E+07	5.3%
100-250	205	14.6%	5.05E+07	5.8%
250-500	182	13.0%	1.13E+08	13.0%
500-1,000	242	17.2%	3.62E+08	41.7%
1,000-1,500	61	4.3%	1.43E+08	16.5%
1,500-2,000	14	1.0%	4.75E+07	5.5%
2,000-2,500	9	0.6%	4.68E+07	5.4%
2,500-3,000	5	0.4%	4.38E+07	5.0%
3,000-3,500	0	0.0%	0.00E+00	0.0%
3,500-4,000	0	0.0%	0.00E+00	0.0%
4,000-4,500	1	0.1%	1.68E+07	1.9%
Total	1405	100.0%	8.70E+08	100.0%

Table 3 shows the average, minimum, and maximum air emissions associated with the 390 representative natural gas power plants identified in **Table 1**. Potential outliers were removed from the data set by discarding the top and bottom 5 percent of the individual emissions values when calculating the mean, minimum, and maximum. Entire plants were not excluded based on this 5 percent rule as there was no evidence of a correlation between emissions. For example, a potential outlier in the NO_x category may not be associated with the same plant as a potential outlier in the SO_2 category. **Table 3** also shows the water withdrawal and consumption values to be used for the fleet average natural gas power plant.

These values are based on the Natural Gas Combined Cycle (NGCC) LCA conducted in 2010 (NETL 2010).

Carbon dioxide emissions were calculated utilizing the heat rate of the plant and a carbon emission factor for natural gas. The heat rate of the plant, in MJ/MWh was calculated based on the plants survey in eGRID (EPA 2011). It is important to note that the heat rate is not a baseload efficiency since the plants were not filtered by capacity factor. The carbon emission factor for natural gas was determined based on results from the EIA voluntary reporting of greenhouse gases (2011). The latest edition of eGRID does not contain values for carbon monoxide emissions. Carbon monoxide emissions were based on the value from the NGCC LCA (NETL 2010). It was assumed that the CO emissions would not vary significantly based on the feed since CO is controlled.

Table 3: Unit Process Flows

Flow Name	Average eGRID[1]	Minimum eGRID[1]	Maximum eGRID[1]	Units (Per Reference Flow)
Inputs				
Natural Gas	10,226	7,433	14,907	MJ
Water (surface water)	518.5	518.5	518.5	kg
Water (ground water)	518.5	518.5	518.5	kg
Outputs				
Electricity [Reference flow]	1	1	1	MWh
Carbon dioxide [Inorganic emissions to air]	508	369	740	kg
Carbon monoxide [Inorganic emissions to air]	0.000312	0.000312	0.000312	kg
Methane [Inorganic emissions to air]	0.0103	0.0074	0.0152	kg
Nitrous oxide [Inorganic emissions to air]	0.00103	0.00074	0.00152	kg
Nitrogen oxides [Inorganic emissions to air]	0.274	0.025	1.480	kg
Sulfur dioxide [Inorganic emissions to air]	0.0038	0.0019	0.017	kg
Water (wastewater) [Water]	234	234	234	kg

[1] eGRID average, minimum, and maximum scenarios involve changes in heat rate, methane, nitrous oxide, NO_X, and SO_2 only. Carbon monoxide emissions are constant for all scenarios. Carbon dioxide is production a function of heat rate and carbon factor. The values presented in this table for carbon dioxide assume the average carbon factor, with varying heat rates based on eGRID data.

Embedded Unit Processes

None.

References

EIA 2011 U.S. Energy Information Administration. (2011, January). Voluntary Reporting of Greenhouse Gases Program. Retrieved June 17, 2011, from Fuel Emissions Coefficients: http://www.eia.gov/oiaf/1605/coefficients.html

EPA 2011 U.S. Environmental Protection Agency (2011). The Emissions & Generation Resource Integrated Database (eGRID), 2010. http://www.epa.gov/cleanenergy/energyresources/egrid/index.html (Accessed June 17, 2011)

NETL 2010 NETL (2011). *Life Cycle Analysis: Natural Gas Combined Cycle (NGCC) Power Plant.* September 30, 2010

Section III: Document Control Information

Date Created: May 14, 2012

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

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