NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Natural gas energy conversion by GTSC

Reference Flow: 1 MWh of Electricity

Brief Description: The operations of a GTSC plant on the basis of 1 MWh output

Section I: Meta Data

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

Year Data Best Represents: 2010

Process Type: Energy Conversion (EC)

Process Scope: Gate-to-Gate (GG)

Allocation Applied: No

Completeness: Individual Relevant Flows Captured

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:

CCS	*Binary parameter that allows modeling of GTSC with or without CCS; value must equal 0 (without CCS) or 1 (with CCS)*
Net_MW_base	*Net power (in MW) of GTSC plant without CCS*
Net_MW_CCS	*Net power (in MW) of GTSC plant with CCS*
CF	*Capacity factor of GTSC plant; default value is 0.85, which represents an 85% capacity factor.*
Fuel_NG_hour	*Feed rate of natural gas to GTSC plant, not including natural gas used by auxiliary boiler*

Tracked Input Flows:

Natural gas	*Natural gas extraction and delivery to the GTSC plant*
Natural gas combustion in auxiliary boiler	*Natural gas (in kg) that is combusted in an auxiliary boiler*

Tracked Output Flows:

Electricity	*Reference flow; 1 MWh of electricity generation*
Carbon dioxide [coproduct]	*Carbon dioxide that is captured from GTSC emissions and sent to CO_2 recovery*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_O_GTSC_2010.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides a summary of relevant input and output flows associated with the production of electricity by the combustion of natural gas in a GTSC (gas turbine simple cycle) power plant. This unit process can be used for scenarios with and without CCS (carbon capture and sequestration). Key inputs include natural gas and water from surface and ground sources; combustion of natural gas in an auxiliary boiler is an ancillary input. Key outputs include electricity, greenhouse gas emissions to air, and air pollutants such as CO, NOx, and NH_3.

This unit process is designed to represent a GTSC plant with or without CCS. If the value for the “CCS” parameter is 0, then no CO2 is captured. If the value for the “CCS” parameter is 1, then 90 percent of the CO2 emissions from the GTSC plant are shown as a tracked output flow; this tracked output flow feeds into a separate unit process for CO_2 recovery operations.

The reference flow of this unit process feeds into the unit process for the transmission and distribution of electricity (LC Stage #4).

The relevant flows of this unit process are described below and shown in **Figure 1.**

Boundary and Description

The GTSC plant uses two parallel, advanced F-Class natural gas-fired combustion turbines/generators (CTGs). The performance of the GTSC plant was adapted from the NETL baseline of NGCC (Natural Gas Combined Cycle) power by considering only the streams that enter and exit the combustion turbines/generators and not accounting for any process streams related to the heat recovery systems used by combined cycles. The NGCC plant consumes natural gas at a rate of 75,901 kg/hr (NETL 2010). The net output of the GTSC plant without CCS is 360 MW. If a CCS system is used to capture 90 percent of CO_2 emissions, the net output of the GTSC plant is 332 MW. **Table 1** and **Table 2** show the total, net, and auxiliary power of the NGCC plant, and the assumptions for determining the power output of the GTSC plant. **Table 1**shows data for power plants *without* CCS, and **Table 2** shows data for power plants *with* CCS.

Table 1: Power Summary for NGCC and GTSC Plants Without CCS

	NGCC	GTSC	Assumption
Gas Turbine Power	362,200	362,200	No adaptation necessary
Steam Turbine Power	202,500	0	The GTSC plant does not have a steam cycle
TOTAL POWER, kWe	564,700	362,200	Sum of gas and steam turbine power
AUXILIARY LOAD SUMMARY, kWe			
Condensate Pumps	170	0	The GTSC plant does not have a steam cycle
Boiler Feedwater Pumps	2,720	0	The GTSC plant does not have a steam cycle
Amine System Auxiliaries	0	0	No adaptation necessary
CO_2 Compression	0	0	No adaptation necessary
Circulating Water Pump	2,300	0	The GTSC plant does not have a steam cycle
Ground Water Pumps	210	0	The GTSC plant does not have a steam cycle
Cooling Tower Fans	1,190	0	The GTSC plant does not have a steam cycle
SCR	10	10	No adaptation necessary; NOx is from the gas turbine
Gas Turbine Auxiliaries	700	700	No adaptation necessary
Steam Turbine Auxiliaries	100	0	The GTSC plant does not have a steam cycle
Miscellaneous Balance of Plant	500	500	Miscellaneous systems are the same for NGCC and GTSC.
Transformer Losses	1,720	1103	Transformer losses are directly proportional to power output
TOTAL AUXILIARIES, kWe	9,620	2,313	
NET POWER, kWe	555,080	359,887	
Net Plant Efficiency (HHV)	50.20%	32.55%	Net Plant Efficiency = (Net Power/Thermal HHV Input)*100%
Net Plant Efficiency (LHV)	55.70%	36.10%	Net Plant Efficiency = (Net Power/Thermal LHV Input)*100%
Net Plant Heat Rate (HHV), kJ/kWhr	7,172	11,062	Net Plant Heat Rate (HHV) = (3600 kJ/kWhr)/Net Plant Efficiency (HHV)
Net Plant Heat Rate (LHV), kJ/kWhr	6,466	9,973	Net Plant Heat Rate (LHV) = (3600 kJ/kWhr)/Net Plant Efficiency (LHV)
CONSUMABLES			
Natural Gas Feed Flow, kg/hr	75,901	75,901	No adaptation necessary
Thermal Input (HHV), kW_{th}	1,105,812	1,105,812	No adaptation necessary
Thermal Input (LHV) , kW_{th}	997,032	997,032	No adaptation necessary
Raw Water Withdrawal, m^3/min	8.9	0	GTSC plant does not have process water requirements
Raw Water Consumption, m^3/min	6.9	0	GTSC plant does not have process water requirements

Table 2: Power Summary for NGCC and GTSC Plants with CCS

POWER SUMMARY FOR NGCC AND GTSC SYSTEMS WITH CCS			
	NGCC	GTSC	Assumption
Gas Turbine Power	362,200	362,200	No adaptation necessary
Steam Turbine Power	148,800	0	The GTSC plant does not have a steam cycle
TOTAL POWER, kWe	511,000	362,200	Sum of gas and steam turbine power
AUXILIARY LOAD SUMMARY, kWe			
Condensate Pumps	80	0	The GTSC plant does not have a steam cycle
Boiler Feedwater Pumps	2,710	0	The GTSC plant does not have a steam cycle
Amine System Auxiliaries	9,600	9,600	No adaptation necessary
CO_2 Compression	15,200	15,200	No adaptation necessary
Circulating Water Pump	4,360	1,790	Scaled according to relative water withdrawal of NGCC and GTSC
Ground Water Pumps	360	148	Scaled according to relative water withdrawal of NGCC and GTSC
Cooling Tower Fans	2,250	924	Scaled according to relative water withdrawal of NGCC and GTSC
SCR	10	10	No adaptation necessary; NOx is from the gas turbine
Gas Turbine Auxiliaries	700	700	No adaptation necessary
Steam Turbine Auxiliaries	100	0	The GTSC plant does not have a steam cycle
Miscellaneous Balance of Plant	500	500	Miscellaneous systems are the same for NGCC and GTSC.
Transformer Losses	1,560	1,106	Transformer losses are directly proportional to power output
TOTAL AUXILIARIES, kWe	37,430	29,978	
NET POWER, kWe	473,570	332,222	
Net Plant Efficiency (HHV)	42.80%	30.04%	Net Plant Efficiency = (Net Power/Thermal HHV Input)*100%
Net Plant Efficiency (LHV)	47.50%	33.32%	Net Plant Efficiency = (Net Power/Thermal LHV Input)*100%
Net Plant Heat Rate (HHV), kJ/kWhr	8,406	11,983	Net Plant Heat Rate (HHV) = (3600 kJ/kWhr)/Net Plant Efficiency (HHV)
Net Plant Heat Rate (LHV), kJ/kWhr	7,579	10,804	Net Plant Heat Rate (LHV) = (3600 kJ/kWhr)/Net Plant Efficiency (LHV)
CONSUMABLES			
Natural Gas Feed Flow, kg/hr	75,901	75,901	No adaptation necessary
Thermal Input (HHV), kW_{th}	1,105,812	1,105,812	No adaptation necessary
Thermal Input (LHV) , kW_{th}	997,032	997,032	No adaptation necessary
Raw Water Withdrawal, m^3/min	15.1	6.2	CCS water is the difference between total water requirements of NGCC with CCS and NGCC w/o CCS cases.
Raw Water Consumption, m^3/min	11.3	4.4	CCS water is the difference between total water requirements of NGCC with CCS and NGCC w/o CCS cases.

The emission profile for the GTSC plant is identical to the emission profile for the NGCC plant. However, due to the relatively lower power output of the GTSC plant, the emissions per MWh of electricity generation are higher for the GTSC plant than for the NGCC plant. The emissionof CO_2 and NO_x from the GTSC plant were calculated by scaling the NGCC CO_2 and NO_x emissions by the relative power outputs of the NGCC and GTSC systems.

The emissions profile shown in the NETL baseline (NETL 2010) does not include a comprehensive list of criteria air pollutants and other air emissions of concern. In particular, CO emissions are not reported in the NETL baseline. Factors from EPA's AP-42 documentation (EPA 1998) were used to calculate CO emissions from the GTSC plant. This

calculation included the assumption that CO emissions from natural gas-fired turbines are not controlled.

The NETL baseline (NETL 2010) shows negligible mercury emissions from the NGCC plant, and thus this analysis assumes that the GTSC plant produces negligible mercury emissions. Additional searches on the EPA's National Emissions Inventory confirmed that natural gas power plant do not produce significant mercury emissions. Therefore, no mercury emissions are estimated for the GTSC plant. Similarly, this analysis assumes that negligible lead emissions are produced from natural gas combustion in a GTSC plant.

Ammonia emissions to air are not inventoried in the baseline report (NETL 2010). However, due to the use of selective catalytic reduction (SCR) for NO_X control, some ammonia is emitted. The baseline report states a 10 ppmv ammonia slip rate (through the stack) at the end of the catalyst life. Further investigation showed that as the SCR catalyst degrades, the ammonia slip increases; once new catalyst is added to the system the slip rate goes to zero. To simplify the calculation of an ammonia emission rate: the 10 ppmv rate was is the maximum rate at the end of the catalyst life, each layer (in the two layer catalyst system) has a two year lifetime, and the slip rate is linear to catalyst activity. Using the available data and assumptions, a 5 ppmv average slip rate was calculated for the lifetime of the plant.

The GTSC system does not have a steam cycle, nor does it require process cooling water. Thus, this analysis assumes that the GTSC does not withdraw or consume water. Furthermore, no emissions to water are generated from GTSC operations. However, if a GTSC plant includes a CCS system, process water is required for CO_2 compression and amine auxiliaries.

An 85 percent capacity factor is modeled for the GTSC system. The GTSC operation data used for this analysis is not dependent on the capacity factor, but this capacity factor is used for apportioning the construction and installation requirements of the GTSC plant to the basis of 1 MWh of electricity generation.

There is evidence that the thermal efficiency (MMBTU natural gas input per MWh electricity output) of the gas turbine goes down as output is turned down. Further, oxidation efficiency may be reduced, increasing the rate of CO relative to CO_2, and NOx emissions may increase. The effect that GTSC operating characteristics have on these emissions is beyond the capability of LCA and is not accounted for in this analysis.

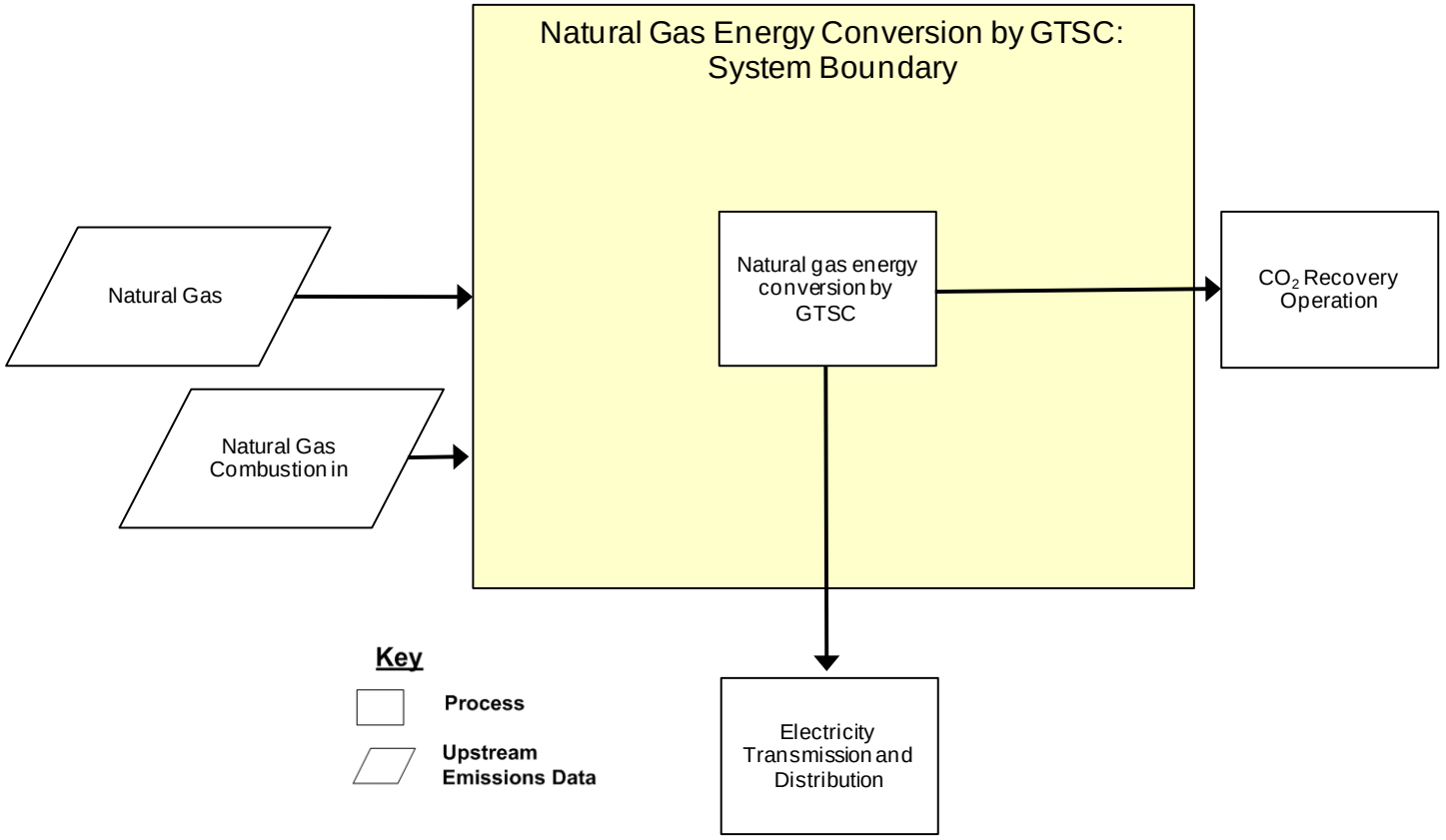

Figure 1: Unit Process Scope and Boundary

Default parameters for this unit process are shown in **Table 3.** The inputs and outputs of this unit process (representative of the default values of **Table 3**) are summarized in **Table 4.**

Table 3: Emission Factors for GTSC Operation

Variable	GTSC without CCS	GTSC with CCS	Units	References
GTSC net power	360	332	MW	NETL 2010
Natural gas feed rate to GTSC	75,901	75,901	kg/hr	NETL 2010
Default capacity factor	85%	85%	%	NETL 2010
Water withdrawal	0	372,000	kg/hr	NETL 2010
Water discharge	0	108,000	kg/hr	NETL 2010
CO_2 capture rate	0	90%	%	NETL 2010

Table 4: Unit Process Input and Output Flows

Flow Name*	GTSC without CCS	GTSC with CCS	Units (Per Reference Flow)
Inputs			
Natural gas USA [Natural gas (resource)]	**211**	**229**	kg
Natural gas combustion in auxiliary boiler	**0.25**	**0.27**	kg
Water (surface water)	0.00	560	kg
Water (ground water)	0.00	560	kg
Outputs			
Electricity	1.00	1.00	kg
Carbon dioxide [coproduct]	0.00	499	kg
Carbon dioxide [Inorganic emissions to air]	560	61.0	kg
Nitrogen oxides [Inorganic emissions to air]	0.04	0.04	kg
Carbon monoxide [Inorganic emissions to air]	0.42	0.46	kg
Ammonia [Inorganic emissions to air]	0.03	0.03	kg
Water (wastewater) [Water]	0.00	325	kg

* **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 2.

Embedded Unit Processes

None.

References

EPA (1998). AP 42 Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion, Supplement D. Available from: http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s04.pdf.

NETL (2010). *Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity Report*. National Energy Technology Laboratory. DOE/NETL-2010/1397. Pittsburgh, PA. March 2010.

Section III: Document Control Information

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