NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Pipeline NG Operation

Reference Flow: 1 kg of natural gas transport by pipeline

Brief Description: The energy consumption and air emissions for the pipeline transport of natural gas.

Section I: Meta Data

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

Year Data Best Represents: 2009

Process Type: Transport Process (TP)

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:

DISTANCE	*Distance of natural gas transport*
SHARE_RECIP	*Fraction of total compression supplied by reciprocating compressors*
SHARE_TURBINE	*Fraction of total compression supplied by gas-powered centrifugal compressors*
SHARE_MOTOR	*Fraction of total compression supplied by electrically-powered compressors*
NG_FUEL_RATE	*Natural gas used as compressor fuel*

Tracked Input Flows:

Electricity	*Electricity used for electrically-driven compressors*
Natural gas	*Natural gas input to pipeline*

Tracked Output Flows:

Natural gas transport by pipeline	*Reference flow; 1 kg of transported natural gas*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage2_O_NG_Pipeline_2010.02.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process encompasses the relevant inputs and outputs associated with the operation of a natural gas transmission pipeline. This unit process accounts for environmental emissions that are directly released by the natural gas transmission pipeline operations, including fugitive methane emissions and compressor fuel combustion emissions. The generation of electricity used by this unit process occurs upstream, and thus the emissions from electricity generation are not included in the boundaries of this unit process. The output of this unit process is natural gas that is suitable for combustion by utilities, industry, or consumers. Natural gas distribution by pipeline, which occurs downstream of transmission, is not accounted for in this unit process. The relevant flows of this unit process are described below and shown in **Figure 1.**

Boundary and Description

The U.S. has an extensive natural gas pipeline network that connects natural gas supplies in the South (including Texas and the Gulf Coast) to markets in the Midwest. Compressor stations are necessary every 50 to 100 miles along the natural gas transmission pipelines in order to boost the pressure of the natural gas. Compressor stations consist of centrifugal and reciprocating compressors.

Most natural gas compressors are powered by natural gas, but, when electricity is available, electrically-powered compressors are used. A 2008 paper published by the Interstate Natural Gas Association of America (INGAA) provides data from the 2004 INGAA database, which shows that the U.S. pipeline transmission network has 5,400 reciprocating compressors and over 1,000 gas turbine compressors (Hedman 2008). Further, based on written communication from El Paso Pipeline Group, approximately three percent of transmission compressors are electrically driven (EPPG 2011). El Paso Pipeline Group has the highest transmission capacity of all natural gas pipeline companies in the U.S., and it is thus assumed that the share of electrically-powered compressors in their fleet is representative of the entire natural gas transmission network. Based on written communication with El Paso Pipeline Group (EPPG

2011), the share of compressors on the U.S. natural gas pipeline transmission network is approximately 78 percent reciprocating compressors, 19 percent turbine-powered centrifugal compressors, and 3 percent electrically-powered compressors.

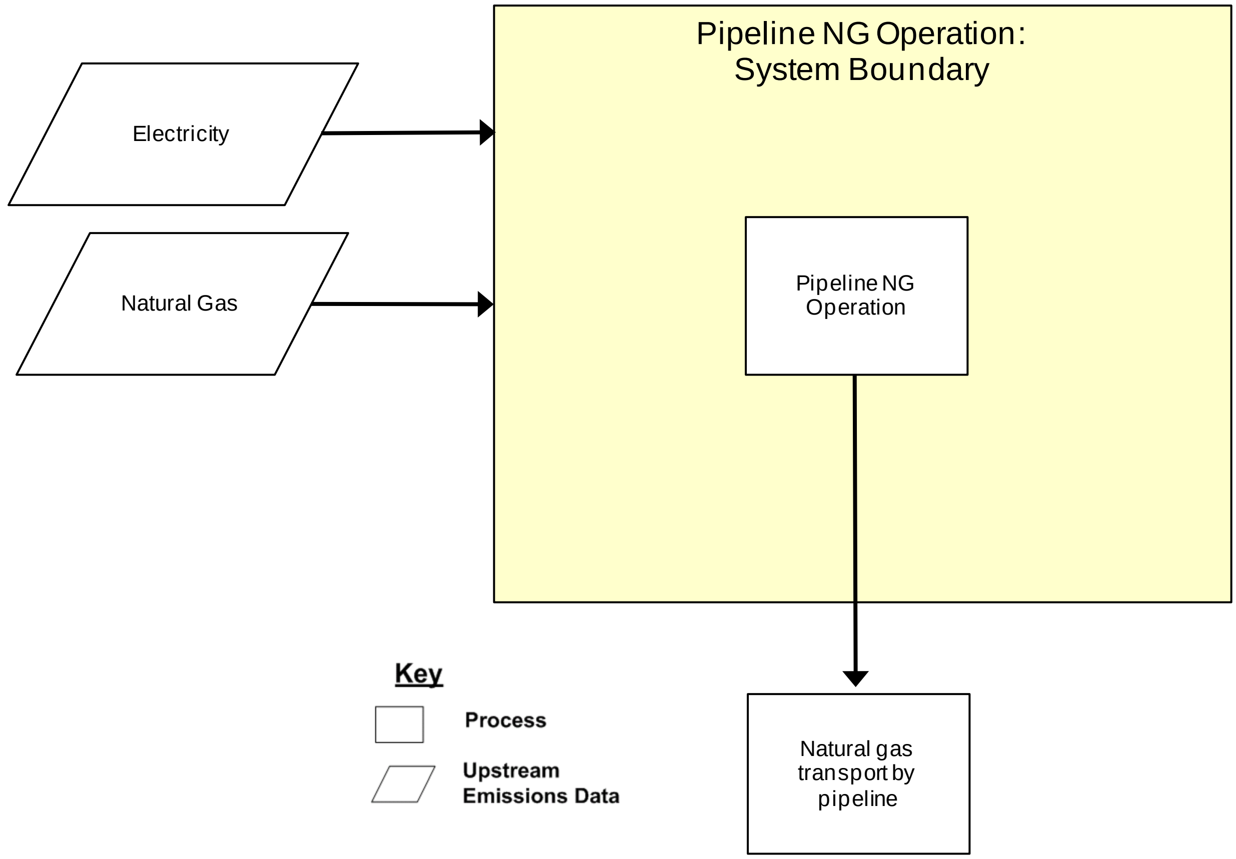
The use rate of natural gas for fuel in transmission compressors was calculated from the FERC Form 2 database, which is based on an annual survey of gas producers and pipeline companies. The 28 largest pipeline companies were pulled from the FERC Form 2 database. These 28 companies represent 81 percent of NG transmission in 2008. The FERC data for 81 percent of US NG transmission is assumed to be a representative sample of the fuel use rate of the entire transmission network. This data shows that 0.96 percent of natural gas product is consumed as compressor fuel. This fuel use rate was converted to a basis of kg of natural gas consumed per kg of natural gas transported by multiplying it by the total natural gas delivered by the transmission network in 2008 (EIA 2011) and dividing it by the annual tonne-km of pipeline transmission in the U.S. (Dennis 2005). The total delivery of natural gas in 2008 was 21 TCF, which is approximately 400 billion kg of natural gas. The annual tonne-km of natural gas transmission was steady from 1995 through 2003, at approximately 380 billion tonne-km per year. More recent transportation data are not available, and thus this analysis assumes the same tonne-km rate for 2008 as shown from 1995 through 2003.

The air emissions from the combustion of natural gas by compressors are estimated by applying EPA emission factors to the natural gas consumption rate of the compressors (EPA 1995). Specifically, the emission profile of gas-powered, centrifugal compressors is based on emission factors for gas turbines; the emission profile of gas-powered, reciprocating compressors is based on emission factors for 4-stroke, lean burn engines. For electrically-powered compressors, this analysis assumes that the indirect emissions are representative of the U.S. average fuel mix for electricity generation.

The average power of electrically-driven compressors for U.S. NG transmission is assumed to be the same as the average power of all compressors on the transmission network. An average compressor on the U.S. natural gas transmission network has a power rating of 14,055 horsepower (10.5 MW) and a throughput of 734 million cubic feet of natural gas per day (583,000 kg NG/hr) (EIA 2007). Electrically-driven compressors have efficiencies of 95 percent (DOE 1996; INGAA 2008). This efficiency is the ratio of mechanical power output to electrical power input. Thus, approximately 1.05 MWh of electricity is required per MWh of compressor energy output.

In addition to air emissions from combustion processes, pipeline leaks result in the methane emissions to air. Based on pipeline transportation statistics (Dennis 2005) and EPA's national inventory of greenhouse gas emissions (EPA 2010) the emission of methane from U.S. natural gas transmission pipelines is 5.4E-06 kg of natural gas per kg-km of pipeline transport.

Figure 1: Unit Process Scope and Boundary



Default parameters for this unit process are shown in **Table 1.** The inputs and outputs of this unit process (representative of the default values of **Table 1**) are summarized in **Table 2.**

Table 1: Default Values for Natural Gas Pipeline Transport

Property	Value	Units	References
Transport distance	971	km	default
Share of reciprocating compressors for U.S. pipelines	78	percent	El Paso Pipeline Group 2011
Share of gas-power centrifugal compressors for U.S. pipelines	19	percent	
Share of electric centrifugal compressors for U.S. pipelines	3	percent	
Pipeline consumption rate of natural gas for compressor fuel	1.01E-05	kg/kg-km	calculated

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs		
Electricity	**4.26E-07**	**MWh**
Natural gas	**1.015**	**kg**
Outputs		
Natural gas transport by pipeline	1.00E+00	kg
Carbon dioxide [Inorganic emissions to air]	2.57E-02	kg
Methane [Organic emissions to air (group VOC)]	5.22E-03	kg
Nitrous oxide (laughing gas) [Inorganic emissions to air]	1.37E-07	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

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El Paso Pipeline Group, 2011. Personal Written Communication: Compressor Profile of EPPG Transmission Network. July 2011.

Hedman, B.A., 2008. Waste Energy Recovery Opportunities for Interstate Natural Gas Pipelines. Interstate Natural Gas Association of America. February 2008. http://www.ingaa.org/File.aspx?id=6210 (Accessed July 25, 2011)

Section III: Document Control Information

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