NETL Life Cycle Inventory Data
Process Documentation File

Process Name:	Natural Gas Dehydration
Reference Flow:	1 kg of Natural Gas
Brief Description:	This unit process evaluates the natural gas fuel use and gaseous emissions that result from the dehydration of natural gas during natural gas production, at the natural gas extraction site, for all natural gas types.

Section I: Meta Data

Geographical Coverage:	United States	**Region:**	N/A
Year Data Best Represents:	2010		
Process Type:	Auxiliary Process (AP)		
Process Scope:	Gate-to-Gate Process (GG)		
Allocation Applied:	No		
Completeness:	All 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:

N/A

Tracked Input Flows:

Natural Gas [Intermediate Product]	*Natural gas extracted within previous unit process*

Tracked Output Flows:

Natural Gas, [Intermediate Product]	*Reference flow*
Vented gas [Intermediate Product]	*Vented methane gas*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_NG_Dehydration_2011.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process covers natural gas dehydration in support of natural gas extraction activities, as described in greater detail below. Natural gas dehydration is the process of removing excess water from raw natural gas, in order to make it suitable for transport and use. This unit process considers energy use (natural gas) as well as emissions of carbon dioxide, methane, nitrous oxide, and vented gas, associated with the natural gas dehydration process. Vented methane from the dehydration process is considered within this unit process, but airborne emissions are accounted for within a separate unit process, DF_Stage1_O_NG_Flaring_2011.01.doc. The calculations presented for this unit process are based on the reference flow of 1 kg of natural gas, as described below and shown in **Figure 1**.

This unit process is used under Life Cycle (LC) Stage #1 to assist in the extraction of natural gas from a variety of natural gas extraction profiles, including conventional onshore, conventional offshore, associated gas, Barnett Shale gas, Marcellus Shale gas, and coal bed methane. This unit process is combined with other relevant equipment for LC Stage #1 in a separate operations assembly process, DF_Stage1_O_Assembly_Natural_Gas _2011.01.doc. The assembly process quantifies the relevant flows and emissions associated with each portion of the natural gas extraction profile being modeled, in order to complete extraction and in-field processing of 1 kg of natural gas.

Boundary and Description

Dehydration is necessary to remove water from raw natural gas, which makes it suitable for pipeline transport and increases its heating value. The configuration of a typical dehydration process includes an absorber vessel in which glycol-based solution comes into contact with a raw natural gas stream, followed by a stripping column in which the rich glycol solution is heated in order to drive off the water and regenerate the glycol solution. The regenerated glycol solution (the lean solvent) is recirculated to the absorber vessel. The methane emissions from dehydration operations include combustion and venting emissions. Thus, this analysis estimates the fuel requirements and venting losses of dehydration in order to determine total methane emissions from dehydration, as well as combustion related emissions for carbon dioxide and nitrous oxide.

The fuel requirements of dehydration are a function of the reboiler duty. Due to the heat integration of the absorber and stripper streams, the reboiler, which is heated by natural gas combustion, is the only equipment in the dehydration system that consumes fuel. The reboiler duty (the heat requirements for the reboiler) is a function of the flow rate of glycol solution, which, in turn, is a function of the difference in water content between raw and dehydrated natural gas. The typical water content for untreated natural gas is 49 lbs/MMCF. In order to meet pipeline requirements, the water vapor must be reduced to 4 lbs/MMCF of natural gas (EPA 2006). The flow rate of glycol solution is 3 gallons per pound of water removed (EPA 2006), and the heat required to regenerate glycol is 1,124 BTU/gal (EPA 2006). By factoring the change in water content, the glycol flow rate, and boiler heat requirements, the energy requirements for dehydration are 152,000 BTU/MMCF of dehydrated natural gas (as shown by the equations below). Assuming that the reboiler is fueled entirely by natural gas, this translates to 1.48E-04 kg of natural gas combusted per kg of dehydrated natural gas (as shown by the equations below). The emission factor for the combustion of natural gas in boiler equipment produces 2.3 lb CH4/million scf natural gas (API 2009). After converting to common units, the above fuel consumption rate and methane emission factor translate to 8.09E-09 kg CH4/kg NG treated.

$$\frac{3.00\ gal\ glycol}{lb\ water} * \frac{1{,}124\ BTU}{gal\ glycol} * \frac{(49-4)\ lb\ water}{MMCF\ NG} = \frac{152{,}000\ BTU}{MMCF\ NG} \quad \text{(Equation 1)}$$

$$\frac{152{,}000\ BTU}{MMCF\ NG} * \frac{MMCF\ NG}{10^6\ scf\ NG} * \frac{1\ scf\ NG}{1027\ Btu} = \frac{1.48\times10^{-4}\ lb\ NG\ fuel}{lb\ NG\ product} \quad \text{(Equation 2)}$$

In addition to absorbing water, the glycol solution also absorbs methane from the natural gas stream. This methane is lost to evaporation during the regeneration of glycol in the stripper column. Flash separators can be used to capture methane emissions from glycol strippers; however, this analysis assumes that flash separators are not used, resulting in methane emissions. The emission of methane from glycol dehydration is based on emission factors developed by the Gas Research Institute (API 2009). Based on this emission factor, 3.4E-04 kg of methane is released for every kilogram of natural gas that is dehydrated.

Figure 1 provides an overview of the boundary of this unit process. As shown, natural gas that is extracted within upstream unit processes is input to natural gas dehydration operations. Energy (natural gas) consumption is then quantified for glycol dehydration process. Other energy use is presumed to be negligible. GHG emissions from natural gas combustion and venting from the glycol solution are then evaluated, in order to quantify overall carbon dioxide, methane, and nitrous oxide emissions to the atmosphere, and evaluate the mass of methane that is vented, where venting emissions to the atmosphere are evaluated in a separate unit process. This unit process is then combined with other natural gas extraction operations unit processes in a downstream natural gas operations assembly unit process.

Figure 1: Unit Process Scope and Boundary

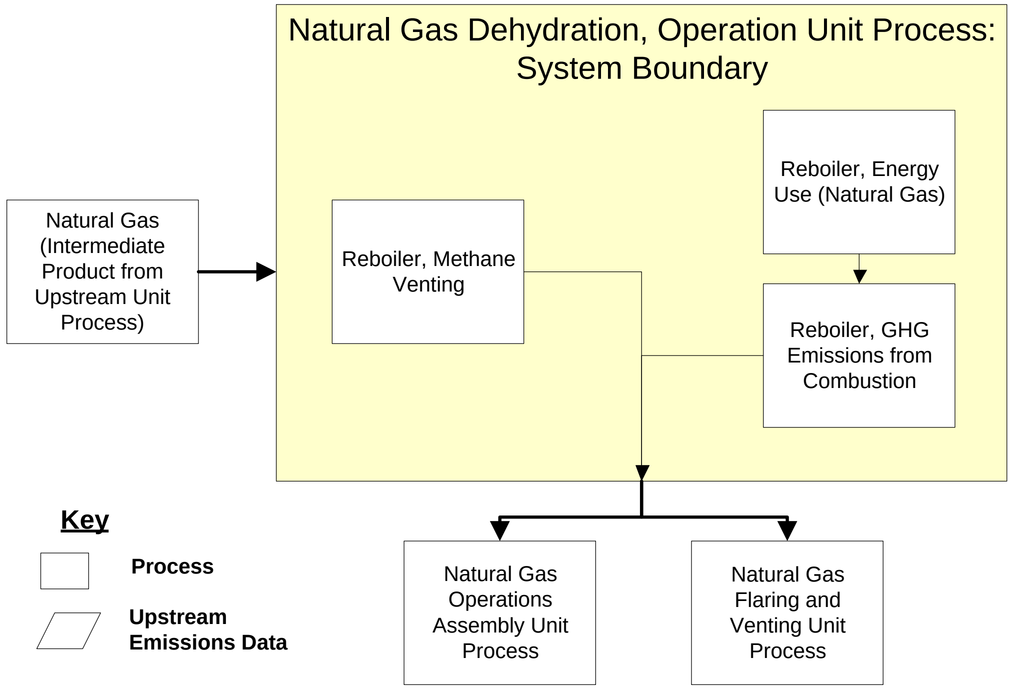

Table 1 summarizes natural gas dehydration airborne emissions factors and energy inputs and outputs that are applied within this unit process. **Table 2** provides a summary of modeled input and output flows. Additional detail regarding input and output flows, including calculation methods, is contained in the associated DS.

Table 1: Natural Gas Dehydration Emission Factors

Air Emission Factors (per MMBtu of reboiler fuel)			
Flow Name	**Value**	**Units**	**Reference**
CO_2	2.86	kg CO_2/kg NG fuel	API 2009[1]
N_2O	1.52E-05	kg N_2O/kg NG fuel	API 2009[2]
CH_4 (combustion)	5.48E-05	kg CH_4/kg NG fuel	API 2009[2]
Energy inputs and outputs			
Flow Name	**Value**	**Units**	**Reference**
Reboiler energy	1.52E-01	BTU/scf NG product	API 2009
Reboiler fuel	1.48E-04	kg NG fuel/kg NG product	calculated
Air Emissions (per kg of natural gas produced)[5]			
Flow Name	**Value**	**Units**	**Reference**
CO_2	4.24E-04	kg CO_2/kg NG product	calculated
N_2O	2.26E-09	kg N_2O/kg NG product	calculated
CH_4 (combustion)	8.10E-09	kg CH_4/kg NG product	calculated
CH_4 (venting)[6]	3.37E-04	kg CH_4/kg NG product	API 2009[6]

[1] API combustion emissions for CO_2 were converted from the basis of tonnes/MMBTU to kg/NG fuel using the following factors: 1 tonne = 1,000 kg, 1 scf NG = 0.042 lb NG, and 1 kg = 2.205 lb.

[2] API combustion emissions for N_2O and CH_4 were converted from the basis of lb/MMCF to kg/MMCF using the following factors: 1 scf NG = 0.042 lb NG, and 1 kg = 2.205 lb

[3] The energy used for dehydration is based on 3 gallons of glycol per lb of water removed, a reboiler duty of 1,124 BTU per gal of glycol regenerated, and 45 lbs of water removed per MMCF of natural gas produced.

[4] The reboiler energy input was converted to the mass of fuel input using a heating value of 1,027 BTU/scf NG.

[5] Combustion air emissions are the product of the emission factors per MMBTU of fuel and the use rate of reboiler fuel.

[6] Methane venting factor assumes that no flash separator is used to control venting emissions. API venting rates were converted from the basis of tonnes CH4/million m3 to kg CH4/kg NG product using the following factors: 1 tonne = 1,000 kg, 1 m3 = 35.3 scf, 1 scf NG = 0.042 lb NG, and 1 kg = 2.205 lb

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Natural gas [Intermediate Product]	**1.0005**	**kg**
Outputs		
Natural Gas [Intermediate Product]	**1.00**	**kg**
Carbon dioxide [Inorganic emissions to air]	4.23E-04	kg
Methane [Organic emissions to air (group VOC)]	8.09E-09	kg
Vented gas [intermediate product]	**3.37E-04**	**kg**
Nitrous oxide (laughing gas) [Inorganic emissions to air]	2.25E-09	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 1.

Embedded Unit Processes

None.

References

EPA 2006 United States Environmental Protection Agency. 2006. Replacing Glycol Dehydrators with Desiccant Dehydrators, EPA, October 2006, Washington DC. http://www.epa.gov/gasstar/documents/ll_desde.pdf (Accessed June 1, 2010).

API 2009 American Petroleum Institute. 2009. "Compendium of Greenhouse Gas Emissions for the Oil and Natural Gas Industry." 2009. Available at:

http://www.api.org/ehs/climate/new/upload/2009_GHG_COMPENDIUM.pdf (Accessed May 18, 2010).

Section III: Document Control Information

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Revision History:

Original/no revisions

How to Cite This Document: This document should be cited as:

NETL (2011). *NETL Life Cycle Inventory Data – Unit Process: Natural Gas Dehydration.* U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: April 2011 (version 01). www.netl.doe.gov/energy-analyses (http://www.netl.doe.gov/energy-analyses)

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