NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Natural Gas Sweetening

Reference Flow: 1 kg of natural gas (sweetened)

Brief Description: Data for the sweetening of natural gas using an amine process for acid gas removal (AGR).

Section I: Meta Data

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

Year Data Best Represents: 2010

Process Type: Basic Process (BP)

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:

Fuel_NG — *Natural gas required for amine reboiler fuel per kg of natural gas sweetened.*

Tracked Input Flows:

Natural gas, unsweetened — *Raw natural gas that has not been processed to remove acid gases (H2S)*

Diethanolamine (DEA) — *Amine used as a solvent for acid gas removal*

Tracked Output Flows:

Natural gas (sweetened) — *Reference flow; 1 kg of sweetened natural gas*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_NG_Sweetening_2010.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process encompasses the energy inputs and material outputs for the processing of natural gas to remove hydrogen sulfide. The unit process is based on the reference flow of 1 kg of sweetened natural gas. The relevant flows of this unit process are described below and shown in **Figure 1.**

The inputs to this unit process are natural gas, ground water, and diethanolamine (DEA) solvent. Ground water is a natural resource and thus enters the boundary of this unit process with no upstream environmental burdens. The inputs of natural gas and diethanolamine represent upstream processes that have material and energy flows that are not included in this unit process but are accounted for by other unit process. The output of this unit process is sweetened natural gas that is suitable for long-distance pipeline transmission and subsequent combustion by utilities, industry, or consumers. This unit process also accounts for environmental emissions that are directly released by the natural gas sweetening operations.

Boundary and Description

Raw natural gas contains varying levels of hydrogen sulfide (H_2S), a toxic gas that reduces the heat content of natural gas and causes fouling when combusted in equipment. The removal of H_2S from natural gas is known as "sweetening". Amine-based processes are the predominant technologies for the sweetening of natural gas.

The H_2S content of raw natural gas is highly variable, with typical concentrations ranging from 5.7E-05 kg of H_2S per kg of natural gas to 0.16 kg of H_2S per kg of natural gas. This analysis assumes an H_2S concentration of 2.3E-05 kg of H_2S per kg of natural gas (which is equivalent to 1 mole of H2S per kg of natural gas).

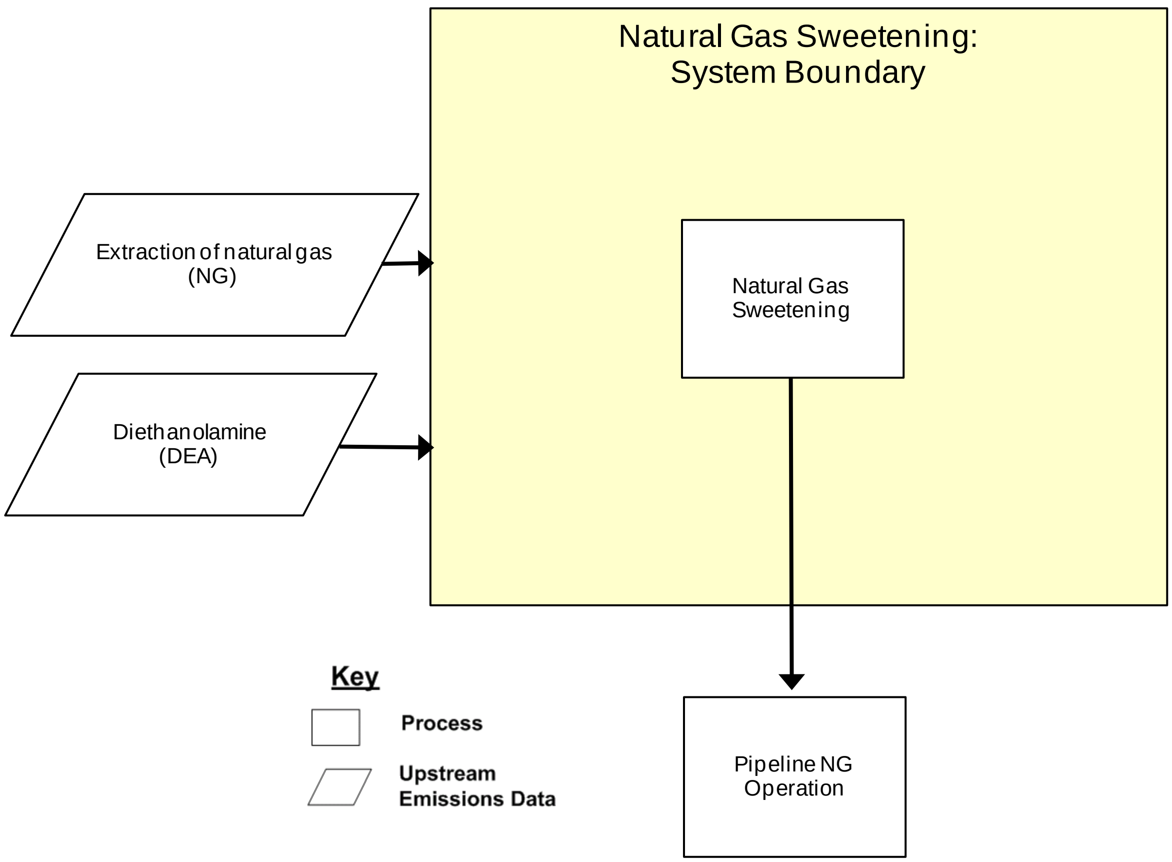
The energy consumed by the amine reboiler accounts for the majority of energy consumed by the sweetening process. Reboiler energy consumption is a function of the amine flow rate, which, in turn, is related to the amount of H_2S removed from natural gas. Approximately 0.30 moles of H_2S are removed per 1 mole of circulated amine solution (Polasek, 2006), and the reboiler duty is approximately 1,000 Btu per gallon of amine (Arnold, 1999).

The amine reboiler combusts natural gas to generate heat for amine regeneration. This analysis applies EPA emission factors for industrial boilers (EPA, 1996) to the energy consumption rate discussed in the above paragraph in order to estimate the combustion emissions from amine reboilers.

The sweetening of natural gas is also a source of vented methane emissions. In addition to absorbing H_2S, the amine solution also absorbs a portion of methane from the natural gas. This methane is released to the atmosphere during the regeneration of the amine solvent. The venting of methane from natural gas sweetening is based on emission factors developed by the Gas Research Institute; natural gas sweetening releases 2.8E-05 per kg of natural gas sweetened (API, 2009).

The loss rate of amine solvent is 2.4E-05 kg per kg of natural gas sweetened (Stewart, 1994). The loss rate of water is 2.8E-03 kg per kg of natural gas sweetened (Lungsford, 2006).

Figure 1: Unit Process Scope and Boundary



Key properties of the amine-based natural gas sweetening technology are summarized in **Table 1.** These properties include the solvent type, energy requirements, and material losses. These variables are expressed on the same bases as reported in literature and do not necessarily match the bases as described above.

The inputs and outputs of this unit process are summarized in **Table 2.**

Table 1: Properties of Amine-Based Natural Gas Sweetening Technology

Property	Value	Source
Solvent type	Diethanolamine	Polasek 2006
Reboiler duty	1,000 Btu/gal amine	Polasek 2006; Arnold 1999
Molar loading	3.3 mol H_2S/mol amine	Polasek 2006
Default H_2S composition of raw natural gas	1 mol H_2S per kg raw natural gas	EPA 1995; TOTAL SA 2006
Amine loss rate	0.1 lb per million cubic feet of natural gas	Stewart 1994
Water loss	115 lb per million cubic feet of natural gas	Lunsford 2006

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs		
Natural gas, unsweetened	**1.0016**	**kg**
Diethanolamine (DEA) [Organic intermediate products]	**2.38E-06**	**kg**
Water (ground water) [Water]	2.75E-03	kg
Outputs		
natural gas (sweetened)	1.00	kg
Carbon dioxide [Inorganic emissions to air]	1.60E-06	kg
Methane [Organic emissions to air (group VOC)]	2.75E-05	kg
Nitrous oxide (laughing gas) [Inorganic emissions to air]	8.73E-09	kg
Nitrogen oxides [Inorganic emissions to air]	3.66E-06	kg
Sulphur dioxide [Inorganic emissions to air]	2.20E-08	kg
Carbon monoxide [Inorganic emissions to air]	3.07E-06	kg
NMVOC (unspecified) [Group NMVOC to air]	2.01E-07	kg
Dust (PM10) [Particles to air]	2.78E-07	kg
Lead (+II) [Heavy metals to air]	1.83E-11	kg
Water (Evaporated) [Water]	2.75E-03	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

API (2009). Compendium of Greenhouse Gas Emissions for the Oil and Natural Gas Industry. API. Washington, DC. 2009. http://www.api.org/ehs/climate/new/upload/2009_GHG_COMPENDIUM.pdf (Accessed May 18, 2010)

Arnold (1999). Surface Production Operations: Design of gas-handling systems and facilities. Gulf Professional Publishing. Houston, Texas. 1999.

EPA (1995). Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42. US EPA Office of Air Quality Planniing and Standards. Research Triangle Park, North Carolina. 1995. http://www.epa.gov/ttnchie1/ap42 (Accessed May 18, 2010)

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.

Lunsford, K. (2006). Optimization of Amine Sweetening Units. Bryan Research and Engineering. 2006.

Polasek (2006). Selecting Amines for Sweetening Units. Bryan Research and Engineering. 2006.

Stewart, E.J. (1994). Reduce Amine Plant Solvent Losses. Hydrocarbon Processing. Gulf Publishing. Houston, Texas. May 1994.

TOTAL S.A., 2006. Sour Gas: A History of Expertise. Paris, France. 2006. http://www.total.com/MEDIAS/MEDIAS_INFOS/225/FR/sour-gas-2007.pdf?PHPSESSID=d16d45165db4253ef2c3d275990ecd96 (Accessed July 1, 2010)

Section III: Document Control Information

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