NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Barnett Shale Natural Gas, Water Use and Water Quality

Reference Flow: 1 kg of Natural Gas, Barnett Shale

Brief Description: This unit process quantifies water use and water quality emissions resulting from the production of natural gas from a Barnett Shale natural gas well.

Section I: Meta Data

Geographical Coverage: United States **Region:** Barnett Shale, TX

Year Data Best Represents: 2010

Process Type: Extraction Process (EP)

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:

N/A

Tracked Output Flows:

Natural Gas, Barnett Shale *Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_Water_BarnettShale_NG_2011.02.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process covers produced water and water quality emissions associated with produced water in support of natural gas produced from Barnett Shale extraction activities, as described below. This unit process considers only water and water quality related flows. For an evaluation of energy, materials, and airborne emissions associated with Barnett Shale natural gas extraction, please refer to separate unit processes for natural gas extraction and on-site processing. The calculations presented for this unit process are based on the reference flow of 1 kg of natural gas, Barnett Shale, as described below and shown in **Figure 1**.

This unit process is used under Life Cycle (LC) Stage #1 in support of the extraction of Barnett Shale natural gas. Water use and water quality emissions for other natural gas profiles are contained in separate unit processes. 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 _2011.02.docx. 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

Water is an input to hydrofracing (hydraulic fracturing), which is used for recovering natural gas from tight reservoirs such as Barnett Shale. Based on water use and natural gas production data for Barnett Shale gas, hydrofracture requires the use of approximately 0.49 kg groundwater/kg natural gas, plus approximately 0.32 kg surface water/kg natural gas (calculated based on data available in Tinker, S.W. 2012 and RRC 2013). Approximately 25% of hydrofracture water that is injected into the formation is recovered as flowback water (Ewing 2008). This amounts to approximately 0.20 kg flowback water/kg natural gas, on average, over the lifetime of the production well.

In addition to flowback water, substantial water is produced during NG extraction of Barnett Shale (Texas Water Development Board 2007). However, the produced water is of very poor quality, and is not discharged to the surface or to groundwater supply aquifers. Instead, it is injected to deep aquifers for disposal. Therefore, changes in water quality associated with produced water are considered negligible, since the deep aquifers are assumed to not mix with overlying aquifers. Flowback water is of generally better quality than produced water. Flowback water is hydrofracing water that is released from the well during extraction. Volumes of flowback water are much smaller than produced water, but the water quality of flowback water is still relatively poor. The water quality calculations assume that flowback water is treated before it is discharged (Shramko 2009).

Figure 1 provides an overview of the boundary of this unit process. As shown, groundwater and surface water inputs to the unit process are considered. However, these water sources are assumed to carry negligible environmental and energy burdens; upstream emissions and energy requirements associated with groundwater and surface water acquisition and delivery are assumed to be negligible. Within the

system boundary, water is input in support of hydrofracture, flowback water volume, and flowback water quality emissions to surface water (following treatment) are considered. This unit process is combined with other natural gas extraction unit processes in a natural gas operations assembly unit process.

Figure 1: Unit Process Scope and Boundary

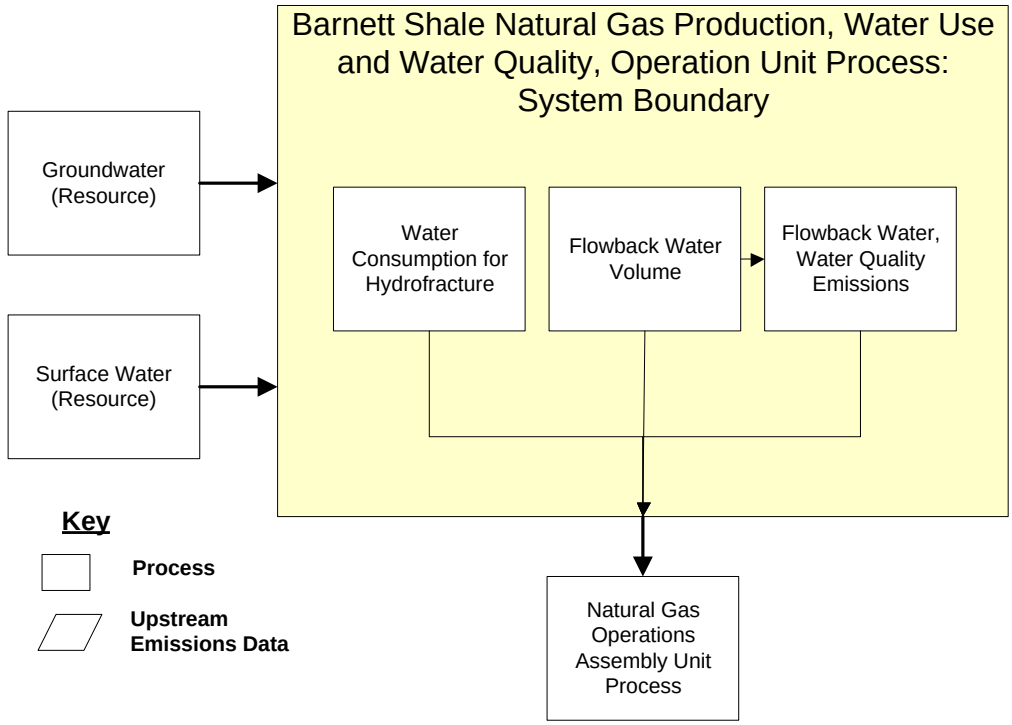

Table 1 summarizes water properties related to Barnett Shale natural gas production that are applied within this unit process. **Table 2** provides a summary of modeled input and output flows. Additional detail regarding input and output flows, including calculation methods, is contained in the associated DS.

Table 1: Water Consumption and Produced Water: Barnett Shale Natural Gas

Flow Name	Value	Units	Reference
Average water use for hydrofracture, Barnett Shale	0.81	kg water/kg natural gas	Tinker, S.W. 2012 and RRC 2013
Estimated percentage of groundwater used for hydrofracture, Barnett Shale	60%	Percent	TWDB 2007
Estimated percentage of surface water used for hydrofracture, Barnett Shale	40%	Percent	TWDB 2007
Estimated percentage of hydrofracture water that is recovered as flowback water	25%	Percent	Ewing 2008

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Water (ground water) [Water]	4.86E-01	kg
Water (surface water) [Water]	3.24E-01	kg
Outputs		
Natural Gas, Barnett Shale	1.00	kg
Water (wastewater) [Water]	2.03E-01	kg
Calcium [Inorganic emissions to water]	1.20E-04	kg
Chloride [Inorganic emissions to water]	1.20E-03	kg
Iron [Inorganic emissions to water]	6.43E-07	kg
Magnesium [Inorganic emissions to water]	1.07E-05	kg
Silica [Inorganic emissions to water]	4.36E-07	kg
Sulfate [Inorganic emissions to water]	4.68E-06	kg
Total Dissolved Solids [Inorganic emissions to water]	2.19E-03	kg

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows. Upstream environmental flows for bolded values were added during the modeling process using GaBi modeling software, as shown in **Figure 1**.

Embedded Unit Processes

None.

References

TWDB 2007 — Texas Water Development Board. 2007. *Northern Trinity/Woodbine GAM Assessment of Groundwater Use in the Northern Trinity Aquifer Due to Urban Growth and Barnett Shale Development*. http://rio.twdb.state.tx.us/RWPG/rpgm_rpts/0604830613_BarnetShale.pdf (Accessed May 14, 2010).

Ewing 2008 — Ewing, J. 2008. *Taking a Proactive Approach to Water Recycling in the Barnett Shale.* http://www.barnettshalenews.com/documents/EwingPres.pdf (Accessed May 14, 2010)

Tinker, S.W. (2012). — Oil & Gas Water Use in Texas: Update to the 2011 Mining Water Use Report. University of Texas at Austin: Austin, TX http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/0904830939_2012Update_MiningWaterUse.pdf (Accessed 4/8/2013)

RRC (2013). — Newark, East (Barnett Shale) Field Discovery Date - 10-15-1981. Railroad Commission of Texas: Austin, TX www.rrc.state.tx.us/data/fielddata/barnettshale.pdf (Accessed 4/8/2013)

Section III: Document Control Information

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04APR2013 Water use updated to newer data

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