NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Water Use for Marcellus Shale Gas Extraction

Reference Flow: 1 kg of Natural Gas from Marcellus Shale

Brief Description: Water withdrawal and discharge data for the extraction of natural gas from a Marcellus Shale formation.

Section I: Meta Data

Geographical Coverage: United States **Region:** Northeast, U.S.

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:

NG_product	*[kg/(well-life)] Total natural gas produced during life of well*
Wateruse_drill	*[kg/(well life)] Water used for Marcellus Shale well drilling*
Wateruse_1frac	*[kg/well-treatment] Water use for development of one Marcellus Shale gas well*
NumFrac	*[dimensionless] Number of hydrofracking treatments per life of a Marcellus Shale gas well*

Tracked Input Flows:

Hydraulic Fracturing Water, Groundwater	*Groundwater used for hydrofracking*

Hydraulic Fracturing Water, Groundwater	*Surface water used for hydrofracking*
Hydraulic Fracturing Water Delivery	*Delivery of hydrofracking water by truck*

Tracked Output Flows:

Natural Gas from Marcellus Shale	*Water delivered to natural gas well*
Wastewater to WWTP	*Wastewater that is sent to a municipal wastewater treatment plant*
Wastewater to crystallization	*Wastewater that is sent to a crystallization process*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_WaterUse_MarcShale_NG_2011.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides a summary of relevant inputs and outputs associated with the water withdrawal and discharge for the extraction of natural gas from a Marcellus Shale formation. The scope of the unit process accounts for the amount of water from ground, surface, and recycled sources and the amount of water discharged to a water treatment plant. Emissions from wastewater treatment, including hauling of wastewater, and also hauling of water, is accounted for in separate unit processes. 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 Marcellus Shale natural gas. 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

This unit process provides a summary of relevant inputs and outputs associated with the water withdrawal and discharge for the extraction of natural gas from a Marcellus Shale formation. The scope of the unit process accounts for the amount of water from ground, surface, and recycled sources and the amount of water discharged to a water

treatment plant. Emissions from wastewater treatment, including hauling of wastewater, and also hauling of water, is accounted for in separate unit processes.

Based on data available from (NETL, 2009), drilling of a single Marcellus Shale natural gas well requires approximately 80,000 gallons of water. This water is used in support of the drilling process, in order to cool the bit and to provide a medium for transporting tailings to the surface. Substantially greater volumes of water are utilized during the hydraulic fracturing (hydrofracking). Hydrofracking involves the injection of pressurized water containing various chemicals and proppants (often sand) into the formation, in order to fracture the formation and allow natural gas to escape. Hydrofracking of a single horizontal Marcellus Shale well requires approximately 3.8 million gallons of water. Thus, construction plus hydrofracking of a single Marcellus Shale natural gas well requires nearly 3.9 million gallons of water. The sources of water used in Marcellus Shale drilling and hydrofracking include groundwater, surface water, reuse of flowback water, municipal water, and other water supplies (Hayes, 2010).

Following the hydrofracking process, pressure is released from the well, and natural gas, along with a portion of the injected hydrofracking water, is released from the well. The water that flows back out of the well, termed 'flowback water,' is produced from the well most rapidly directly after well completion, and tails off over time. Available data indicate than an average flowback water production rate of approximately 34.6 percent is typical within the Marcellus shale, although this rate may vary among wells or among regions (Dempsey, 2010). In areas where several wells or well pads are being installed in close proximity, flowback water from one well is sometimes used in support of hydrofracking at another, nearby well. Reuse of flowback water for additional hydrofracking accounts for approximately 3 percent of the total water used for Marcellus Shale hydrofracking.

Flowback water is generally of poor quality, and typically has elevated loads of total suspended solids, total dissolved solids, nitrogen, ammonia, and total organic carbon, among other constituents (Hayes, 2009). In many regions, low quality flowback waters and other produced waters are disposed of via deep well injection. However, the geologic formations that underlie most of the Marcellus Shale region are not amenable to deep well injection. Therefore, for Marcellus Shale, other disposal methods must be utilized for flowback waters. Water having sufficient quality (i.e., without very high levels of total dissolved solids levels or other pollutants) may be conveyed to a municipal wastewater treatment facility, treated via the facility's process, and discharged to surface waters. Crystallization is another option for treating flowback water.

Figure 1 provides an overview of the boundary of this unit process. As shown, water is delivered to the system boundary by a water truck (the operation of the water truck is accounted for by another unit process). Within the boundary of this unit process, water is used for well construction and hydrofracking. Flowback water is an output of this unit process, and is either sent to a municipal wastewater treatment plant or a wastewater crystallization process. The consumption of water, which is the difference between water input and flowback water, is accounted for within the boundary of this unit

process. 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

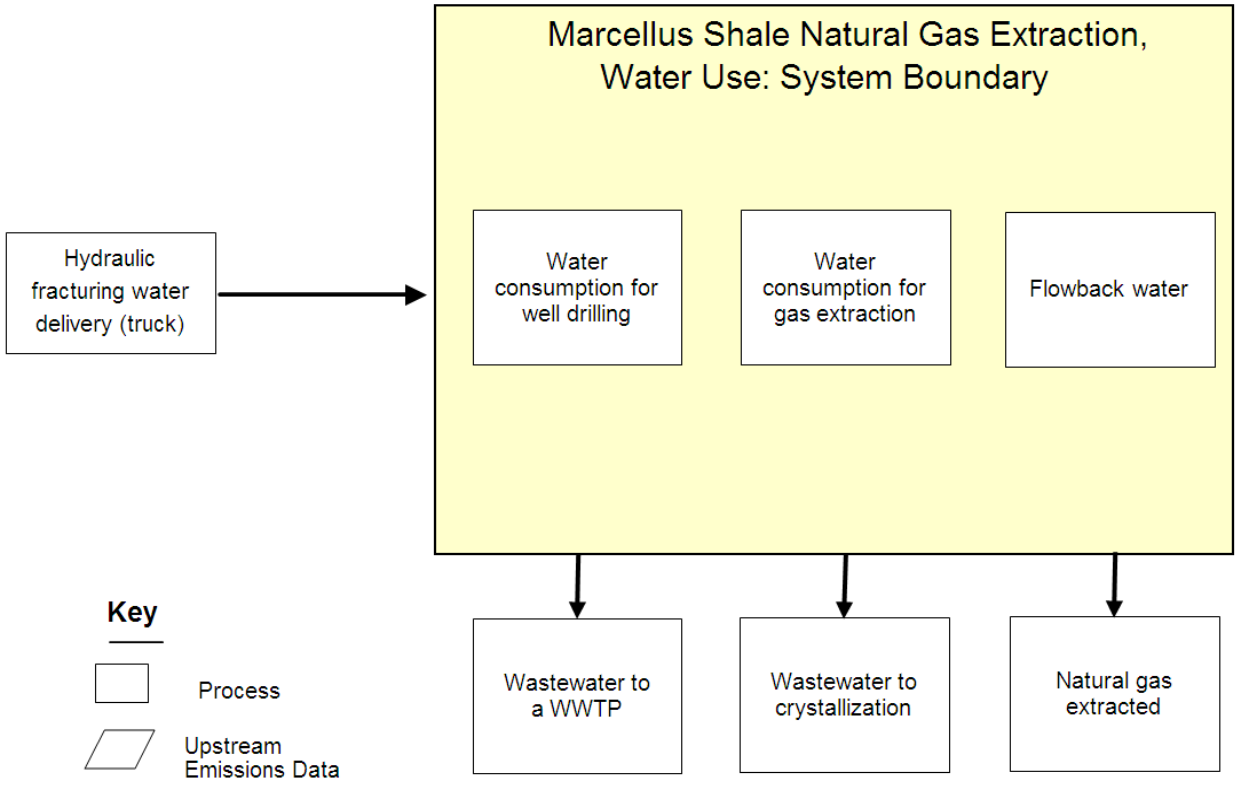

Table 1 summarizes water sources related to Marcellus Shale natural gas extraction that are applied by this unit process. **Table 2** provides a summary of modeled input and output flows. Additional detail regarding input and output flows, including calculation methods, is contained in the associated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

Table 1: Marcellus Shale Input Water Profile

Flow Name	Value	Reference
Groundwater	2%	Hayes, 2010
Surface Water	78%	Hayes, 2010
Reuse of Flowback Water	3%	Hayes, 2010
Municipal	15%	Hayes, 2010
Other	2%	Hayes, 2010

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units
Inputs		
Hydraulic Fracturing Water, Groundwater	1.060E-02	kg/kg NG
Hydraulic Fracturing Water, Surface Water	6.746E-01	kg/kg NG
Hydraulic Fracturing Water Delivery	6.852E-01	kg/kg NG
Outputs		
Natural Gas, Marcellus Shale	1.000	kg
Water Discharged from WWTP (wastewater) [Water]	9.263E-02	kg/kg NG
Water to Crystallizer (wastewater) [Water]	9.263E-02	kg/kg NG

* **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

Hayes 2009 — Hayes, T. *Sampling and Analysis of water Streams Associated with the Development of Marcellus Shale Gas*. Gas Technology Institute. December 31, 2009.

NETL 2009 — *Modern Shale Gas Development in the United States, A Primer*. http://www.barnettshalenews.com/documents/EwingPres.pdf (Accessed May 14, 2010)

Section III: Document Control Information

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