NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Conventional Onshore Natural Gas, Water Use and Water Quality

Reference Flow: 1 kg of Natural Gas, Conventional Onshore

Brief Description: This unit process quantifies water use and water qualtiy emissions resulting from the production of natural gas from a conventional onshore natural gas well.

Section I: Meta Data

Geographical Coverage: United States **Region:** N/A

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, Conventional Onshore *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_Conventional_Onshore _2011.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process covers water use, produced water, and water quality emissions associated with produced water in support of conventional onshore natural gas extraction activities, as described in greater detail below. This unit process considers only water and water quality related flows. For an evaluation of energy, materials, and airborne emissions associated with conventional onshore 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, conventional onshore, 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 conventional onshore 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 _2011.01.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

Conventional onshore natural gas production both requires water and results in the generation of produced water during operation. Based on available water use data (Younos et al 2009; US DOE 2006), the extraction of associated natural gas requires inputs of approximately 3 gallons of water per MMBtu of natural gas extracted. Assuming that 50% of that water is derived from surface water, and the remaining 50% from groundwater, this is equivalent to approximately 0.31 kg of surface water plus 0.31 kg of groundwater per kg of natural gas extracted. Produced water volumes per kg of conventional onshore associated natural gas were derived from a combination of US total produced water data (ANL 2004), historic domestic natural gas production rates (EIA 2010a), and historic domestic crude oil production rates (EIA 2010b). These values were taken from 2002, due to both availability of data during that year, and also because shale gas had not yet escalated to be a major contributor to US natural gas production at that time. Thus, the water use and produced water considered in this unit process are generally relevant to average conditions in the US, rather than representing a specific natural gas field or extraction area.

To calculate produced water volume per kg of natural gas, produced water flows were apportioned to either natural gas or petroleum, in proportion to the energy content of natural gas or petroleum produced across the US. The calculated water production rate was found to be approximately 4.0 kg water/kg natural gas. Approximately 71 percent of produced water is recycled back into the formation in support of additional oil and natural gas production (USDOE 2006). This results in a total discharge of approximately 1.1 kg water/kg natural gas. Note that onshore natural gas extraction results in a greater volume of produced water than consumed water, for a net release of water.

Water produced from a conventional natural gas well typically contains elevated levels of ionic species, minerals, and may also contain elevated levels of oils and other hydrocarbons. Produced water that was not recycled was presumed to be discharged to surface waters, as is customary in many areas of the United States. Available data (Ramirez 2002) indicate elevated levels of total dissolved solids, boron, chloride, sulfate, and oil/grease in produced water from natural gas production.

Figure 1 provides an overview of the boundary of this unit process. As shown, groundwater and surface water enter the unit process boundary without consideration of upstream emissions or energy/equipment use. Within the system boundary, water consumption, produced water, and water quality emissions are considered and quantified. 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

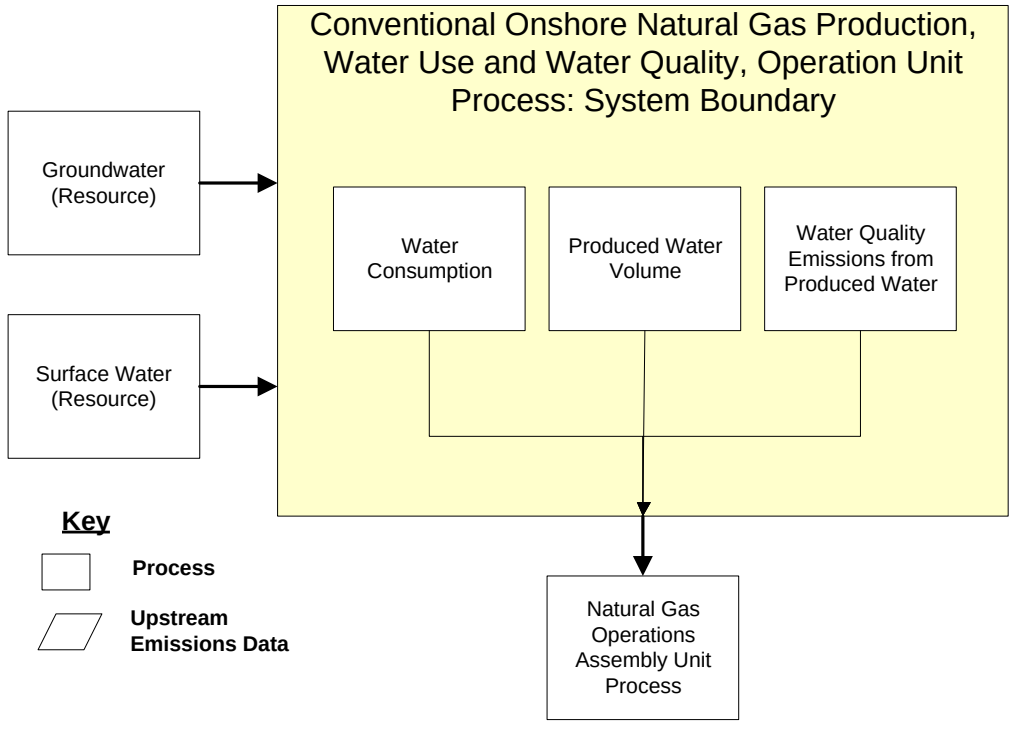

Table 1 summarizes conventional onshore natural gas water consumption and produced water emissions that are applied within this unit process. **Table 2** provides a summary of modeled input and output flows. Additional detail regarding input and output flows, including calculation methods, is contained in the associated DS.

Table 1: Water Consumption and Produced Water: Conventional Onshore Natural Gas

Flow Name	Value	Units	Reference
Surface Water Consumption	0.306	kg water/kg NG	Younos 2009; USDOE 2006
Groundwater Consumption	0.306	kg water/kg NG	ANL 2004; EIA 2010a; EIA 2010b
Produced Water (gross)	3.95	kg water/kg NG	ANL 2004; EIA 2010a; EIA 2010b
Produced Water (net discharge)	1.15	kg water/kg NG	ANL 2004; EIA 2010a; EIA 2010b; USDOE 2006
Fraction of Produced Water that is Recycled	71%	Percent	USDOE 2006
Fraction of Produced Water that is Discharged	29%	Percent	NETL Engineering Calculation

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Water (ground water) [Water]	3.06E-01	kg
Water (surface water) [Water]	3.06E-01	kg
Outputs		
Natural Gas, Conventional Onshore	1.00	kg
Water (wastewater) [Water]	1.15	kg
Boron [Inorganic emissions to water]	1.83E-06	kg
Chloride [Inorganic emissions to water]	3.60E-04	kg
Total Dissolved Solids [Inorganic emissions to water]	3.75E-03	kg
Sulfates [Inorganic emissions to water]	1.45E-03	kg
Hydrocarbons [Organic emissions to water]	2.56E-05	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

ANL 2004 — Argonne National Laboratory. 2004. A White Paper Describing Produced Water from Production of Crude Oil, Natural Gas, and Coal Bed Methane. National Energy Technology Laboratory.

EIA 2010a — U.S. Energy Information Administration. 2010. Natural Gas Gross Withdrawals and Production. Available at: http://www.eia.doe.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_a.htm (Accessed June 30, 2010).

EIA 2010b — U.S. Energy Information Administration. 2010. Petroleum Navigator: Crude Oil Production. Available at: http://www.eia.doe.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm (Accessed June 30, 2010)

Ramirez 2002 — Ramirez, P. 2002. Oil Field Produced Water Discharges into Wetlands in Wyoming. U.S. Fish and Wildlife Service. August, 2002.

USDOE 2006 — U.S. Department of Energy. 2006. Energy Demands on Water Resources; Report to Congress on the Interdependency of Energy and Water. U.S. Department of Energy. December, 2006.

Younos et al 2009 — Younos, T, Hill, R, Poole, H. 2009. Water Dependency of Energy Production and Power Generation Systems. Virginia Polytechnic Institute and State University, Blacksburg, Virginia. July, 2009.

Section III: Document Control Information

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