**Process Name:** Onshore Associated Natural Gas Production, Water Use and Water Quality

**Reference Flow:** 1 kg of Natural Gas, Conventional Onshore Associated

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

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**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:**

- [x] Process
- [ ] Energy Use
- [ ] Energy P&D
- [ ] Material P&D

**Relevant Output Flows Included in Data Set:**

- Releases to Air: [ ] Greenhouse Gases
- [x] Criteria Air Pollutants
- [ ] Other
- Releases to Water: [x] Inorganic Emissions
- [x] Organic Emissions
- [ ] Other
- Water Usage: [x] Water Consumption
- [x] 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 Associated  

*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_Associated_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 associated 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 associated 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 associated, 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 associated 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 associated 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 associated natural gas extraction results in a greater volume of produced water than consumed water, for a net release of water.

Water produced from an associated 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 associated 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 Associated Natural Gas**

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

**Table 2: Unit Process Input and Output Flows**

<table>
<thead>
<tr>
<th>Flow Name</th>
<th>Value</th>
<th>Units (Per Reference Flow)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (ground water) [Water]</td>
<td>3.06E-01</td>
<td>kg</td>
</tr>
<tr>
<td>Water (surface water) [Water]</td>
<td>3.06E-01</td>
<td>kg</td>
</tr>
<tr>
<td>Natural Gas, Conventional Onshore Associated</td>
<td>1.00</td>
<td>kg</td>
</tr>
<tr>
<td>Water (wastewater) [Water]</td>
<td>1.15</td>
<td>kg</td>
</tr>
<tr>
<td>Boron [Inorganic emissions to water]</td>
<td>1.83E-06</td>
<td>kg</td>
</tr>
<tr>
<td>Chloride [Inorganic emissions to water]</td>
<td>3.60E-04</td>
<td>kg</td>
</tr>
<tr>
<td>Total Dissolved Solids [Inorganic emissions to water]</td>
<td>3.75E-03</td>
<td>kg</td>
</tr>
<tr>
<td>Sulfates [Inorganic emissions to water]</td>
<td>1.45E-03</td>
<td>kg</td>
</tr>
<tr>
<td>Hydrocarbons [Organic emissions to water]</td>
<td>2.56E-05</td>
<td>kg</td>
</tr>
</tbody>
</table>

*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


Section III: Document Control Information

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