NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Hydraulic Fracturing Water Delivery

Reference Flow: 1 kg of delivered water

Brief Description: Water sourcing and delivery to a Marcellus shale well.

Section I: Meta Data

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

Year Data Best Represents: 2011

Process Type: Transport Process

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:

distance	*Adjustable parameter for the distance for the source of water to the natural gas well*
diesel_rate	*Diesel use rate, in terms of volume of diesel required for the transport of 1 kg of water a distance of 1 km*

Tracked Input Flows:

Diesel [Crude oil products]	*Diesel used for transportation of cargo*

Tracked Output Flows:

Delivered water	*Water delivered to natural gas well*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_watertruck_2011_01.doc*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process accounts for the transport of water from a surface or ground source to a Marcellus Shale gas well to be used for hydraulic fracturing (hydrofracking). The only tracked input is diesel fuel, and the key outputs are diesel combustion emissions. The reference flow of this unit process is the delivery of one kilogram of water as described below and shown in **Figure 1**. This unit process is used within Life Cycle (LC) Stage #1 of NETL's model of Marcellus Shale natural gas extraction.

Boundary and Description

This unit process accounts for the transport of water from a surface or ground source to a Marcellus Shale gas well to be used for hydraulic fracturing (hydrofracking). The only tracked input is diesel fuel, and the key outputs are diesel combustion emissions. The reference flow of this unit process is the delivery of one kilogram of water.

The default transport distance for the transport of hydrofracking water is 100 km (one way). The truck has an energy consumption rate of 16.84 MJ/km (25,690 Btu/mile) (Wang, 1999). The truck has a water tank that can hold 12,700 to 19,900 liters (3,360 to 5,250 gal) (Camex Equipment Sales & Rentals, 2011), for an average payload 16,300 liters (or 16,300 kg). When the energy consumption rate of the truck is divided by its average payload, the energy consumption per unit of transport is 1.033 E-03 MJ/(kg-km). A liter of diesel has a lower heating value of 35.8 MJ/L (128,450 Btu/gal) (Wang, 1999); applying this lower heating value to the energy consumption per unit of transport (calculated above) results in a diesel consumption rate of 2.904E-05 L/kg-km of water transport.

The air emissions from diesel combustion in combination trucks are based on emission factors from the greenhouse gases, regulated emissions, and energy use in transportation (GREET) model, a life cycle model for transportation (Wang, 1999). These emission factors include greenhouse gases (GHGs) and criteria air pollutants. The combustion of one liter of diesel in a heavy duty truck produces 2.65 kg CO_2, 5.28E-05 kg CH_4,and 6.79E-05 kg of N_2O. The emission of criteria air pollutants are on the magnitude of 1E-03 or lower.

Figure 1 provides an overview of the boundary of this unit process. There are two inputs to this unit process. Diesel is an upstream input; the energy and material flows for the production and delivery of diesel are not included in this unit process, but the

emissions from the combustion of diesel are included in this unit process. There is one tracked output for this unit process: the transport of 1 kg of water.

Figure 1: Unit Process Scope and Boundary

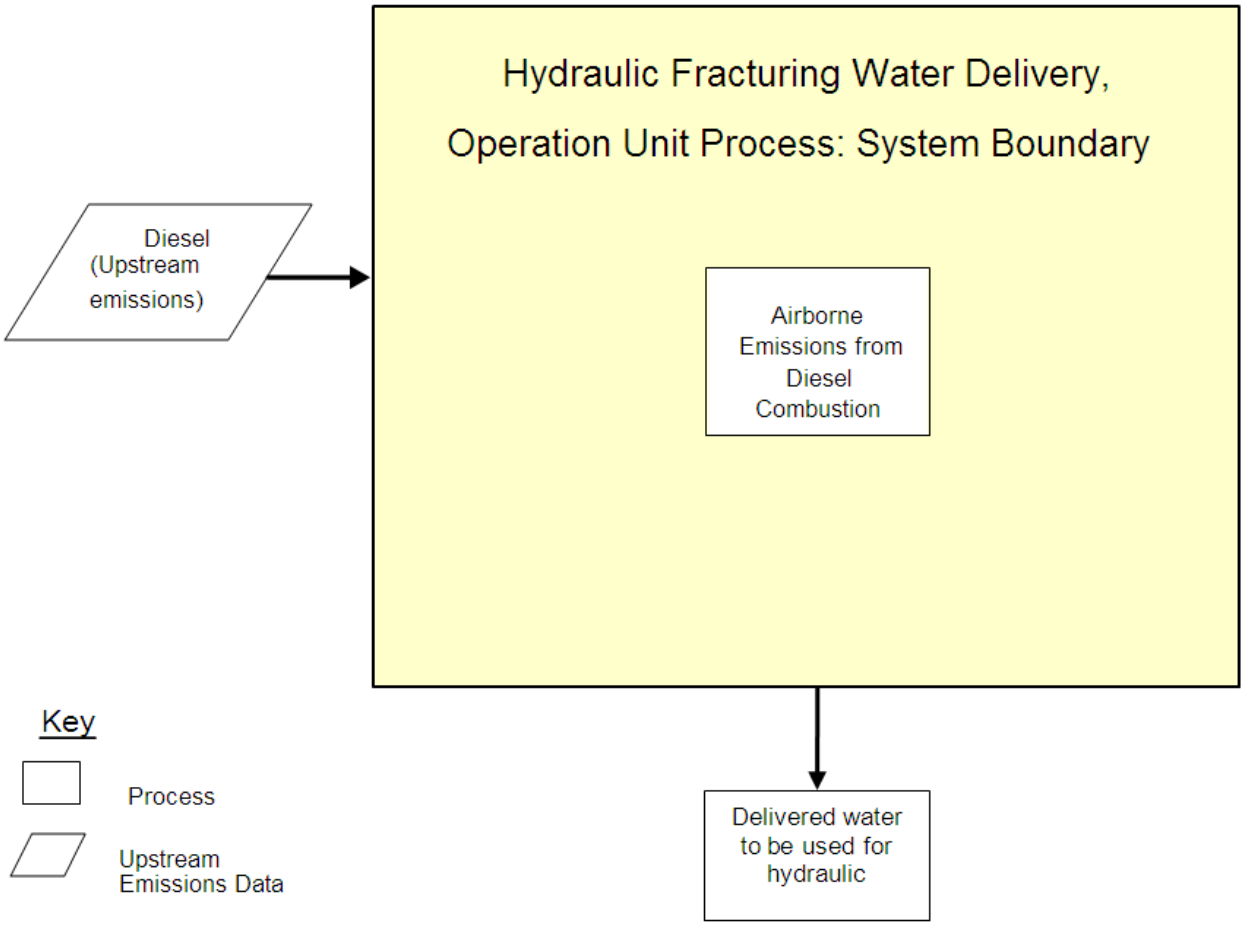

Table 1 summarizes airborne emission factors and other parameters that are relevant to this unit process. **Table 2** provides a summary of modeled input and output flows and shows the energy and emissions for the truck transport water used for hydraulic fracturing. All flows are scaled to the basis of the reference flow (the transport of one kilogram of water). Additional detail regarding input and output flows, including calculation methods, is contained in the associated DS.

Table 1: Emission Factors and Other Relevant Parameters

Flow Name	Value	Units
Emission Factors for Diesel Combustion		
Volatile organic compounds (VOC)	2.787E-04	kg/L diesel
Carbon monoxide (CO)	1.116E-03	kg/L diesel
Nitrogen oxides (NOx)	3.322E-03	kg/L diesel
Particulate Matter (PM10)	1.321E-04	kg/L diesel
Sulfur oxides (SOx)	3.347E-04	kg/L diesel
Methane (CH_4)	5.284E-05	kg/L diesel
Nitrous oxide (N_2O)	6.791E-05	kg/L diesel
Carbon dioxide (CO_2)	2.651	kg/L diesel
Other Parameters		
Energy consumption rate	16.84	MJ/km
Volume of water held by truck	16,300	L
Default water transport distance	100	km
Water transport energy intensity	2.904E-05	L/kg-km
Diesel density	0.832	kg/L

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Diesel	2.416E-03	kg
Outputs		
Delivered water	1.000	kg
Carbon dioxide [Inorganic emissions to air]	7.698E-03	kg
Methane [Organic emissions to air (group VOC)]	1.534E-07	kg
Nitrous oxide (laughing gas) [Inorganic emissions to air]	1.972E-07	kg
Nitrogen oxides [Inorganic emissions to air]	9.647E-06	kg
Sulphur oxides [Inorganic emissions to air]	9.718E-07	kg
Carbon monoxide [Inorganic emissions to air]	3.241E-06	kg
NMVOC (unspecified) [Group NMVOC to air]	8.093E-07	kg
Dust (PM10) [Particles to air]	3.836E-07	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

Wang 1999 — Michael Wang. (1999). GREET 1, Version 1.8d.1. http://greet.es.anl.gov/ (Accessed January 6, 2011).

Camex Equipment Sales & Rentals 2011 — Camex Equipment Sales & Rentals. (2011). Tank Trucks Specifications Sheets. http://www.camex.ca/new-equipment/tank-trucks/tank-truck-specifications-sheets.html (Accessed January 4, 2011).

Section III: Document Control Information

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Section IV: Disclaimer