NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Oil well drilling and development

Reference Flow: 1 piece of Production or injection well, drilled

Brief Description: Energy use to drill a production or injection well

Section I: Meta Data

Geographical Coverage: World **Region:** N/A

Year Data Best Represents: N/A

Process Type: Auxiliary Process (AP)

Process Scope: Gate-to-Gate Process (GG)

Allocation Applied: No

Completeness: Individual 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	☐ 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:

Well_depth	*[ft] Depth of the well. See Figure 3.6 in the OPGEE documentation. Values for one sd from the median are 3,216 ft and 10,398 ft. This depth does not include additional lateral drilling distance.*
Energy_per_len	*[MMBtu/1000 ft] Energy consumed per 1000 ft drilled. The expected value is an average of low and high intensity operations from OPGEE. Min and Max*

	values represent the low and high intensities with the min and max expected well depth. If the well depth is known, the Min and Max should be adjusted accordingly.
Water_per_len	*[kg] Water use per 1,000 ft of well length drilled.*
casing_density	*[kg/ft] Density of the casing per ft of well length*

Tracked Input Flows:

Diesel, burned in large engine	*[Technosphere] Diesel burned in a large (>600 hp) engine*
Carbon steel	*[Technosphere] Welded steel pipe used for well casing*
Concrete	*[Technosphere] Concrete used for well casing*
Water (ground water) [Water]	*[Resource]*
Water (surface water) [Water]	*[Resource]*

Tracked Output Flows:

Production or injection well, drilled [Construction]	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_Drilling_and_development_2013.01.xlsx*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides a summary of relevant input and output flows associated with operations necessary to drill a production or injection well. Steel and concrete are used for the construction of the well casing; these materials enter the boundaries of this unit process in the form of prefabricated steel pipe and ready-mix concrete. Diesel is used for the internal combustion engines powering the rotary drilling equipment. The air emissions from diesel combustion are accounted for in an upstream process. The energy and material flows for the upstream production and delivery of steel, concrete, and diesel are not included

in this unit process but are accounted for by other unit processes. The reference flow of this unit process is: 1 piece of Production or injection well, drilled.

Boundary and Description

During drilling and development operations, fuel is consumed on site in diesel engines to power mud pumps, apply torque to drill string, pull drill string, pump cement, or raise, lower, and retrieve subsurface monitoring equipment. Furthermore, the amount of fuel required increases per unit of depth drilled since slower drilling occurs as one progresses in depth. Ultimately, an exponential relationship is found between drilling depth and fuel use. The drilling depth considered here is the true drilling depth, which includes horizontal distance, not the vertical depth.

Using a set of data from Canadian drilling operations, El-Houjeiri et al. report high and low energy consumption curves fit to the equation :

$$e_{DR} = a_{DR}\exp(b_{DR}h_W) \text{ [mmBtu/1,000 ft]}$$

where e_{DR} = depth-specific drill rig energy intensity [mmBtu/1,000 ft]; a_{DR} = drill rig energy intensity scaling constant [mmBtu/1,000 ft]; b_{DR} =drill rig energy intensity growth constant [1/1,000 ft]; and h_W = true well depth [1,000 ft] (El-Houjeiri *et al.* 2013).

Water is used as a drilling fluid when drilling a well. The amount of water needed can vary, depending on factors such as the use of air drilling techniques. This unit process uses estimates for water use in Barnett Shale and Fayetteville Shale to calculate water demand per 1,000 feet of true depth (Mantell 2009, Halliburton 2008).

A well is lined with a carbon steel casing that is held in place with concrete. Each well is assumed to have four concentric casing sections of varying diameters and depths (Marcellus Shale Coalition 2014). The amount of casing required for a well was determined by using the casing density of each of the individual well sections as detailed for a typical natural gas well. It was assumed that similar casing configurations are used for an oil well. The total amount of carbon steel is determined by adding the various casing sections together with linear densities based on standard API casing dimensions (Halliburton, 2009). The void between the outer diameter of the carbon steel casing pipe and the drilled hole is filled with concrete. It was assumed for this process that the mass of concrete is equal to the mass of the steel casing. **Table 1** provides the default parameter values for the unit process. The scope and boundary of the unit process are shown in **Figure 1**. The inputs and outputs for the process are shown in **Table 2**.

Table 1: Properties of Drilling and Development

Property	Value	Source
Well Depth	7,240 [ft]	El-Houjeiri *et al.,* 2013
Average Energy Consumed per 1,000 ft	169 [MMBtu/1000 ft]	El-Houjeiri *et al.,* 2013
Average Water Use per 1,000 ft	185,884 [kg]	Mantell 2009; Halliburton 2008
Casing Density	12.8 [kg/ft]	Marcellus Shale Coalition 2014; Natural Gas.org 2004; EIA 2003; Haliburton 2009

Figure 1: Unit Process Scope and Boundary

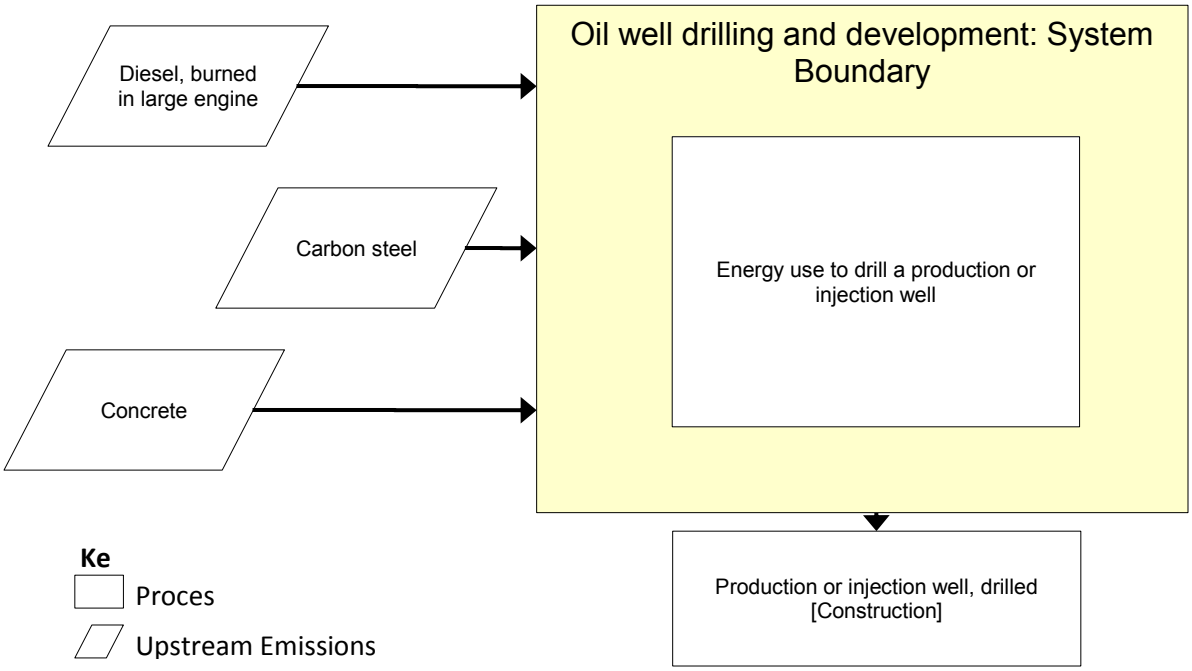

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Diesel, burned in large engine	**1.29E+06**	**MJ**
Carbon steel	**9.29E+04**	**kg**
Concrete	**9.29E+04**	**kg**
Water (ground water) [Water]	6.73E+05	Kg
Water (surface water) [Water]	6.73E+05	Kg
Outputs		
Production or injection well, drilled [Construction]	**1.00**	**Well**

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows.

Embedded Unit Processes

None.

References

EIA 2003	EIA. 2003. Drilling Sideways -- A Review of Horizontal Well Technology and Its Domestic Application. Available at http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/drilling_sideways_well_technology/pdf/tr0565.pdf (Accessed July 6, 2010).
El-Houjeiri *et al.* 2013	El-Houjeiri, H.M., McNally, S., and Brandt, A. R. 2013. *Oil Production Greenhouse Gas Emissions Estimator OPGEE v1.1 DRAFT A: User guide & Technical documentation.*
Haliburton 2008	Halliburton. (2008). U.S. Shale Gas: An Unconventional Resource. Unconventional Challenges. from http://www.halliburton.com/public/solutions/contents/shale/related_docs/H063771.pdf
Halliburton 2009	Halliburton (2009). API Casing Chart. Available at http://www.halliburton.com/public/sdbs/sdbs_contents/Data_Sheets/H03038.pdf (Accessed July 5, 2010).
Mantell 2009	Mantell, M. E. (2009). Deep Shale Natural Gas: Abundant, Affordable, and Surprisingly Water Efficient. Paper presented at the GWPC Water/Energy Sustainability Symposium, Salt Lake City, Utah. http://marcelluscoalition.org/wp-content/uploads/2010/05/MMantell_GWPC_Water_Energy_Paper_Final.pdf
Marcellus Shale Coalition 2014	Marcellus Shale Coalition. 2014. Well Casing. Available at http://marcelluscoalition.org/marcellus-shale/production-processes/casing-the-well/ (Accessed March 17, 2014)
Natural Gas.org 2008	Natural Gas.org. 2004. Well Completion. Available at http://naturalgas.org/naturalgas/well_completion.asp#liftingwell (Accessed July 1, 2010).

Section III: Document Control Information

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