NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Well hydraulic fracture completion

Reference Flow: 1 pcs of Hydraulic fracturing completion

Brief Description: Hydraulic fracturing (fracking) of a horizontal well

Section I: Meta Data

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

Year Data Best Represents: 2012

Process Type: Extraction Process (EP)

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	☐ Organic Emissions	☐ Other
Water Usage:	☐ Water Consumption	☐ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

lateral_len	*[m] length of lateral*
fracture_len	*[m] length of fracture stage*
man_num_stage	*[stages] Number of fracture stages, manually specified*
man_auto	*[binary] 0 - manual number of stages, 1 - auto calculate number of stages based on fracture length*
num_stage	*[stages] Number of fracture stages*

treat_press	*[MPa] Pressure of the treatment*
gravity	*[m/s^2] Gravitational acceleration (sea-level)*
vol_flow_rate	*[m³/sec] Volumetric flow rate*
density	*[kg/m³] Density of slurry (assume density of water)*
pump_eff	*[Dimensionless] Efficiency of pump - assume triplex, positive displacement*
time_per_stage	*[hrs/stage] Time required to pump fluid during fracture treatment for each fracture stage*
ch4_em	*[kg/pcs] Total methane emissions during flowback period*
fract_ch4_em	*[dimensionless] Fraction of total available methane that is emitted to atmosphere*

Tracked Input Flows:

Fracturing fluid	*[Technosphere] Fracturing fluid*
Mechanical Energy [Mechanical energy]	*[Technosphere] Shaft energy*

Tracked Output Flows:

Hydraulic fracturing completion	*Reference flow*
Methane	*Emission*
Methane	*Technosphere*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_C_Lateral_hydraulic_fracture_2015.01.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 fracturing a natural gas or oil well. Inputs include fracturing fluid and the energy for the pumps. Emissions include methane emissions. The reference flow of this unit process is: 1 pcs of Hydraulic fracturing completion

Boundary and Description

Figure 1 provides an overview of the boundary of this unit process. In order to generate the necessary parameter values for this unit process, three calculations were performed:

Stage length (parameter frac_length) values were obtained from three separate sources (Range Resources, 2014; PTTC, 2011; Grieser *et al.* 2009). These values can be found within the Stage_Length tab in the DS file for this unit process. These values were used to generate a representative range of natural gas well stage lengths.

Pump power values were retrieved from multiple sources (ASME, 2012; DI, 2014; Halliburton, 2010) to generate a list of hydraulic pump horsepower typically found in use for shale hydraulic fracture completions. However, as an alternative to using the nominal horsepower ratings of the completion equipment above, the amount of hydraulic horsepower required was calculated based on flow rate and required pressure. For this method, it is assumed that fracking fluid must be raised from atmospheric pressure to the stated treatment pressure. This method supplies a more generic process that still falls in line with the nominal powers provided by the source above: the power calculated by the default parameters - 9.2 MW and the range specified by the sources above - 1.1 to 37 MW.

The next step in estimating the energy required is to look at how long the high power requirements are needed. Treatment plot data (see the Pump_power tab in the corresponding DS file) obtained from Lohoefer et al. (2006) and Borstmayer et al. (2011) show that open hole packing stimulation only requires 3-4 hours/stage; however, it makes some sense that a typical plug and perforate completion would pump for the same amount of time. The assumed key difference between the technologies is the actual time it takes between stages. Therefore, 3-4 hours/stage can be used to estimate the operating time for all pumping equipment, assuming that pumps are triplex, positive-displacement pumps. The treatment plot data can also be used to estimate fracture fluid requirements per stage. Note that the amount of slurry used is fairly consistent for these Barnett wells (~15,000 - 16,000 bbl/stage). Therefore the fluid pumping rate and assumed time on station can be used to estimate water use. The resultant water use (3.528 million gal/completion) can be checked with typical water demands of the Barnett shale, 3-5 million gallons/well.

Methane emissions & capture data were retrieved from Allen et al. (2013), and include a 95% confidence interval for the average methane emissions. This confidence interval was obtained by randomly sampling 1,000 sets of 24 and then taking the average of each set to form a larger sample population (bootstrapping). This process was repeated within the corresponding DS file for reference. However, in order to provide a 95% confidence for the fraction of potential methane emissions that are emitted, the process was repeated for the total methane available and the sum of emissions was divided by the sum of potential methane. Excel is then used to provide the 2.5 and 97.5 percentiles of the resulting 1,000 fractions. The Excel functions (randombetween) have been replaced by static values in the random number section. This process served to provide a realistic boundary of uncertainty around the expected value provided by Allen et al. (2013).

Figure 1: Unit Process Scope and Boundary

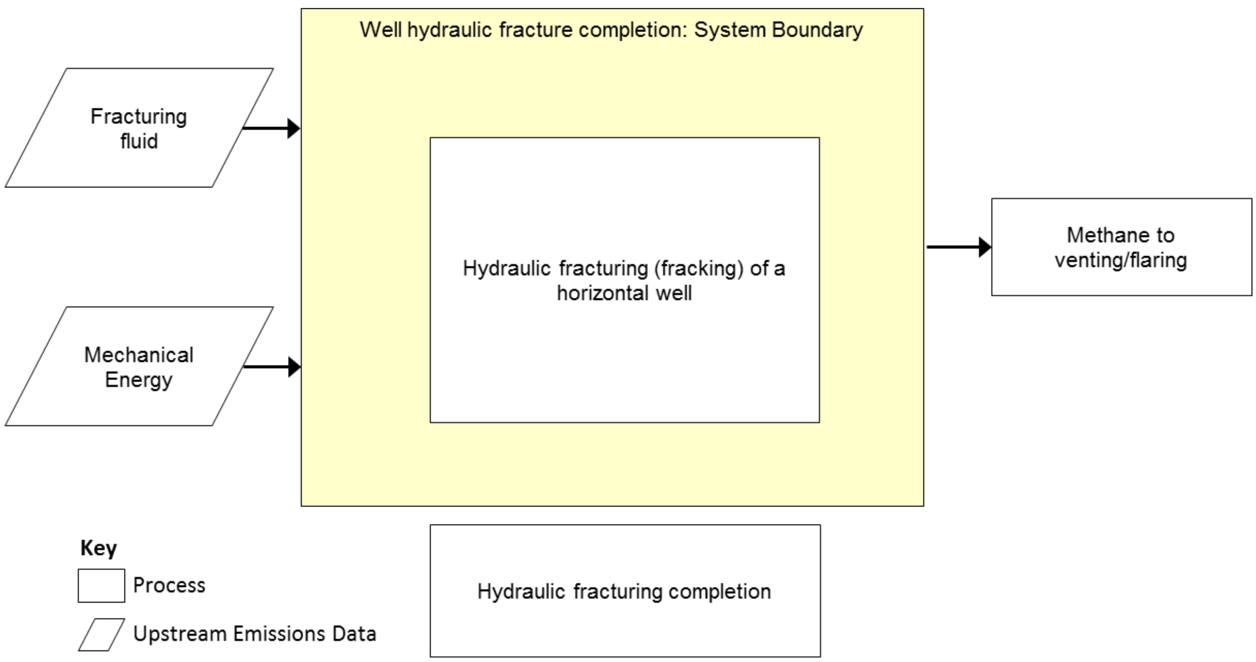

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Fracturing fluid	**3.34E+04**	**m^3**
Mechanical Energy [Mechanical energy]	**4.04E+02**	**MWh**
Outputs		
Hydraulic fracturing completion	**1.00E+00**	
Methane [Organic emissions to air (group VOC)]	1.70E+03	kg
Methane [Intermediate product]	**1.20E+05**	**kg**

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

Embedded Unit Processes

None.

References

Range Resources, 2014	Waller, R., Amend, D., Sando, L., Freeman, M. 2014. Range Resources Corporation Company Presentation. Range Resources. Available at < http://media.corporate-ir.net/media_files/IROL/10/101196/presentations/11.10.2014_Company_Presentation.pdf>
PTTC, 2011	McKeon, M. 2011. Horizontal Fracturing in Shale Plays. Halliburton. Available at < http://www.thepttc.org/workshops/eastern_062111/eastern_062111_McKeon.pdf>
Grieser *et al.* 2009	Grieser, W. V., Shelley, R. F., & Soliman, M. Y. 2009. Predicting Production Outcome From Multi-stage, Horizontal Barnett Completions. Society of Petroleum Engineers. doi:10.2118/120271-MS
ASME, 2012	MacRae, M. 2012. Fracking: A Look Back. ASME. Available at: <https://www.asme.org/engineering-topics/articles/fossil-power/fracking-a-look-back>

DI, 2014	Triepke, J. 2014. Well Completion 101 Part 3: Well Stimulation. DrillingInfo. Available at: http://info.drillinginfo.com/well-completion-well-stimulation/
Halliburton, 2010	Halliburton. 2010. Haynesville Shale. Halliburton. Available at: http://www.halliburton.com/public/solutions/contents/Shale/Brochures/10_B144_011_Haynesville_shale_bro_web.pdf
Lohoefer, 2006	Lohoefer, D. S., Seale, R. A., & Athans, J. 2006. New Barnett Shale Horizontal Completion Lowers Cost and Improves Efficiency. http://dx.doi.org/10.2118/103046-MS
Borstmayer, 2011	R. Borstmayer, N. Stegent, A. Wagner, J. Mullen. 2011. Approach Optimizes Completion Design. Halliburton. Available at: http://www.halliburton.com/public/pe/contents/Papers_and_Articles/web/A_through_P/Eagle%20Ford%20-%20Approach%20Optimizes%20Completion%20Design.pdf
Allen, 2013	Allen, D.T., Torres, V.M., Thomas, J., Sullivan, D.W., Harrison, M., Hendler, A., Herndon, S. C., Kolb, C.E., Fraser, M.P., Hill, A.D., Lamb, B.K., Miskimins, J., Sawyer, R.F., Seinfeld, J.H. 2013. Measurements of methane emissions at natural gas production sites in the United States. PNAS. Available at: http://www.pnas.org/content/110/44/17768.abstract

Section III: Document Control Information

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Revision History:

Original/no revisions

How to Cite This Document: This document should be cited as:

NETL (2015). NETL Life Cycle Inventory Data – Unit Process: Well hydraulic fracture completion – Version 01. U.S. Department of Energy, National Energy Technology Laboratory. Retrieved [date] from www.netl.doe.gov/LCA

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