NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Downhole Pump

Reference Flow: 1 kg of Downhole pump extraction

Brief Description: Energy use for extraction of crude oil with a downhole pump

Section I: Meta Data

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

Year Data Best Represents: N/A

Process Type: Extraction Process (EP)

Process Scope: Cradle-to-Gate Process (CG)

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	☐ 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:

API	*[deg API] API of the crude oil being produced. Heavy Venezuelan crude has an API of just over 10, and Bakken crude can be around 42.*
Production_vol	*[bbl/day] Production volume. For all wells in the field. U.S. productivity per well is lower than the world average*

WOR	*[bbl water/bbl oil] Water cut, the ratio of water to oil. A relationship with field age was developed for OPGEE (1.706*EXP(0.036*Field_age)-1.706), which might be low for U.S. fields. The default value is the average of U.S. onshore and offshore from 2007.*
TDS	*[mg/L] Total dissolved solids in the produced water*
res_depth	*[ft] Depth of the reservoir. See Figure 3.6. Min and Max represent one standard deviation from the median, which is lower than the mean.*
Well_diam	*[in] Diameter of the production tubing. API tubing can actually vary from 1.050 to 4.5 in (OD).*
press_grad	*[psi/ft] The pressure gradient of the formation. The default assumes that a field started at hydrostatic and pressure has been reduced by half.*
Res_pressure	*[psi] Pressure of the reservoir*
Well_head_press	*[psi] Pressure at the well head*
bbl_per_well	*[bbl/well-d] The OPGEE default value is for non-US producers (183 bbl/well-d), which have a higher productivity. The default value here is for global production (82 bbl/well-d)*
Num_wells	*[well-d] Number of production wells.*
Prod_index	*[bbl/psi-day] Productivity index*
Friction_factor	*[dimensionless] Moody friction factor. The default value is an estimate from OPGEE. Min and Max values are likely estimates calculated using equations from OPGEE, but may not represent extreme cases.*
Pump_eff	*[dimensionless] Pump efficiency*
GOR	*[scf/bbl] Ratio of gas to oil. The relationship with API was developed for OPGEE.*

N2	*[dimensionless] Adjustable parameter - mole fraction of nitrogen in associated gas stream*
CO2	*[dimensionless] Adjustable parameter - mole fraction of carbon dioxide in associated natural gas stream*
C1	*[dimensionless] Adjustable parameter - mole fraction of methane in associated natural gas stream*
C2	*[dimensionless] Adjustable parameter - mole fraction of ethane in associated natural gas stream*
C3	*[dimensionless] Adjustable parameter - mole fraction of propane in associated natural gas stream*
C4_plus	*[dimensionless] Adjustable parameter - mole fraction of butane and higher hydrocarbons in associated natural gas stream*
H2S	*[dimensionless] Adjustable parameter - mole fraction of hydrogen sulfide in associated natural gas stream*
NG_engine	*[Btu/bhp-hr] NG engine prime mover fuel consumption. The default value can be changed to correspond with the appropriate engine size in the "Drivers" tab. Fuel consumption is based on the engine size, which is determined by the brake horsepower value.*
Elec_motor	*[kWh/bhp-hr] Electric motor prime mover fuel consumption. The default value can be changed to correspond with the appropriate engine size in the "Drivers" tab. Fuel consumption is based on the engine size, which is determined by the brake horsepower value.*
Diesel_engine	*[Btu/bhp-hr] Diesel engine prime mover fuel consumption. The default value can be changed to correspond with the appropriate engine size in the "Drivers"*

	tab. Fuel consumption is based on the engine size, which is determined by the brake horsepower value.
NG_turbine	*[Btu/bhp-hr] NG turbine prime mover fuel consumption. The default value can be changed to correspond with the appropriate engine size in the "Drivers" tab. Fuel consumption is based on the engine size, which is determined by the brake horsepower value.*
Prime_nge	*[dimensionless] Adjustable parameter - Select 1 to use as prime mover type, or enter fraction of pumps powered by natural gas engines*
Prime_elec	*[dimensionless] Adjustable parameter - Select 1 to use as prime mover type, or enter fraction of pumps powered by electric motors*
Prime_diesel	*[dimensionless] Adjustable parameter - Select 1 to use as prime mover type, or enter fraction of pumps powered by diesel engines*
Prime_ngt	*[dimensionless] Adjustable parameter - Select 1 to use as prime mover type, or enter fraction of pumps powered by natural gas turbines*
NG_fuel	*[dimensionless] Adjustable parameter - Select 1 to use natural gas fuel for NG engines and turbines*
NGL_fuel	*[dimensionless] Adjustable parameter - Select 1 to use NGL (butane or propane) fuel for NG engines and turbines*

Tracked Input Flows:

Natural gas engine	*[Technosphere] Natural gas for pump prime mover*
Natural gas engine with NGL	*[Technosphere] Natural gas liquids for pump prime mover*
Electricity [Electric Power]	*[Technosphere] Electricity for pump prime mover*

Diesel engine	*[Technosphere] Natural gas for pump prime mover*
Natural gas turbine	*[Technosphere] Natural gas for pump prime mover*
Natural gas turbine with NGL	*[Technosphere] Natural gas for pump prime mover*

Tracked Output Flows:

Downhole pump extraction	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_Downhole_pump_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 the use of a downhole pump to aid in extraction of crude oil. The process calculates the power and necessary fuel required to operate the pump and extract 1 kg of petroleum mixture. The reference flow of this unit process is: 1 kg of Downhole pump extraction

Boundary and Description

A downhole pump is used as a means to provide artificial lift when the natural pressure of a petroleum reservoir is no longer enough for production. The pump is powered by a prime mover, which can take the form of an engine, natural gas turbine, or electric motor. Energy use is calculated assuming that the entire difference in pressure – accounting for the elevation head, friction head, reservoir pressure, and well head pressure – is overcome by the downhole pump. If both gas lift and a downhole pump are used in the extraction process then it will be necessary to adjust parameters so as to reduce the flowing gradient of the fluid.

As shown in **Figure 1**, this unit process has inputs for each of the possible prime movers, and a single output representing the use of a downhole pump. Because this process does not have a mass flow in or out, it is intended to be used in conjunction with a crude oil extraction unit process.

Default values for the parameters used in the calculation of energy requirements are given in **Table 1**. Some parameters, such as the reservoir pressure and the gas to oil ratio (GOR), have "smart default" values that vary based on other factors. These smart defaults should only be used if no information other information is available. **Table 2** shows the inputs and outputs for the process.

Figure 1: Unit Process Scope and Boundary

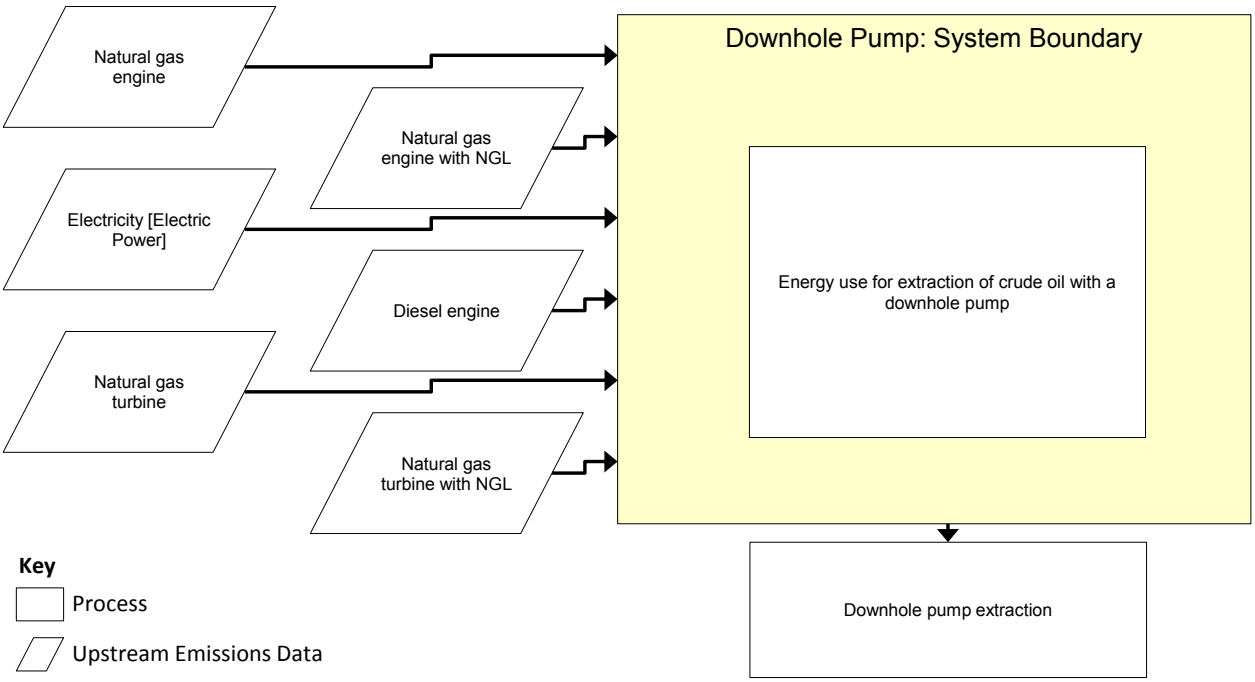

Table 1: Selected Default Parameter Values

Parameter	Value	Units
Number of well-days	18	well-day
Oil Production per Day	1,500	bbl/day
Water to Oil Ratio (WOR)	5.3	bbl water/bbl oil
Well Depth	7,240	ft
Well Diameter	2.775	in
Natural Gas Engine Heat Rate	7,705	btu/bhp-hr
Well Head Pressure	1,000	psi
Reservoir Pressure	1,557	psi
Productivity Index	3.0	bbl liquid/psi-day

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Natural gas engine	**9.08E-02**	**MJ**
Natural gas engine with NGL	**0.00**	**MJ**
Electricity [Electric Power]	**0.00**	**kWh**
Diesel engine	**0.00**	**MJ**
Natural gas turbine	**0.00**	**MJ**
Natural gas turbine with NGL	**0.00**	**MJ**
Outputs		
Downhole pump extraction	**1.00**	

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

Embedded Unit Processes

None.

References

El-Houjeiri *et al.* 2013 — El-Houjeiri, H. M., McNally, S., & Brandt, A. R. (2013). Oil Production Greenhouse Gas Emissions Estimator OPGEE v1.1 DRAFT A: User guide & Technical documentation.

NETL 2009 — NETL. (2009). Produced Water Volumes and Management Practices in the United States. Prepared by C.E. Clark and J.A. Veil, Argonne National Laboratory. Retrieved July 8, 2013, from http://www.netl.doe.gov/technologies/coalpower/ewr/water/pdfs/anl%20produced%20water%20volumes%20sep09.pdf

Section III: Document Control Information

Date Created: October 22, 2013

Point of Contact: Timothy Skone (NETL), Timothy.Skone@NETL.DOE.GOV

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