NETL Life Cycle Inventory Data
Process Documentation File

Process Name:	Gas Lift Petroleum Extraction
Reference Flow:	1 kg of Raw Petroleum Mixture
Brief Description:	Petroleum production by injecting gas into production tubing

Section I: Meta Data

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

Year Data Best Represents: N/A

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:

☐ 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:

Field_age	*[yrs] Age of the oil field*
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.*
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)*
GLIR	*[scf/bbl] Gas lifting injection ratio - scf of gas per bbl of produced liquid*
inj_N2	*Adjustable parameter - mole fraction of nitrogen in the injection gas*
inj_CO2	*Adjustable parameter - mole fraction of carbon dioxide in the injection gas*
inj_C1	*Adjustable parameter - mole fraction of methane in the injection gas*
inj_C2	*Adjustable parameter - mole fraction of ethane in the injection gas*
inj_C3	*Adjustable parameter - mole fraction of propane in the injection gas*
inj_C4_plus	*Adjustable parameter - mole fraction of butane and higher hydrocarbons in the injection gas*
inj_H2S	*Adjustable parameter - mole fraction of hydrogen sulfide in the injection gas*
GOR_UI	*[scf/bbl] Ratio of gas to oil. Leave as 0 if the value is not known and a relationship developed by OPGEE will be used.*
N2	*Adjustable parameter - mole fraction of nitrogen in associated gas stream*

CO2	*Adjustable parameter - mole fraction of carbon dioxide in associated natural gas stream*
C1	*Adjustable parameter - mole fraction of methane in associated natural gas stream*
C2	*Adjustable parameter - mole fraction of ethane in associated natural gas stream*
C3	*Adjustable parameter - mole fraction of propane in associated natural gas stream*
C4_plus	*Adjustable parameter - mole fraction of butane and higher hydrocarbons in associated natural gas stream*
H2S	*Adjustable parameter - mole fraction of hydrogen sulfide in associated natural gas stream*
inj_depth	*[dimensionless] Fraction of reservoir depth*
extra_pressure	*[psi] Additional pressure for injected gas*
npsh	*[psia] Pressure at the compressor inlet*
num_stages	*[dimensionless] The number of stages in the compressor. Adjust this number until the pressure ratio is less than 5*
ratio_cp_cv	*[dimensionless] Ratio of isobaric and isochoric heat capacities*
stage1_in_T	*[ºF] Compressor stage 1 inlet temperature*
comp_eff	*[Dimensionless] Compressor efficiency*
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, combusted in engine [Natural gas products]	*[Technosphere] Natural gas for pump prime mover*
LPG, combusted in engine [Natural gas products]	*[Technosphere] Natural gas liquids for pump prime mover*
Electricity [Electric Power]	*[Technosphere] Electricity for pump prime mover*
Thermal Energy from Diesel Combusted in Industrial Equipment [Valuable substances]	*[Technosphere] Natural gas for pump prime mover*
Natural gas, combusted in turbine [Natural gas products]	*[Technosphere] Natural gas for pump prime mover*
LPG, combusted in turbine [Natural gas products]	*[Technosphere] Natural gas for pump prime mover*

Tracked Output Flows:

Raw Petroleum Mixture	*Reference flow*

Section II: Process Description

Associated Documentation

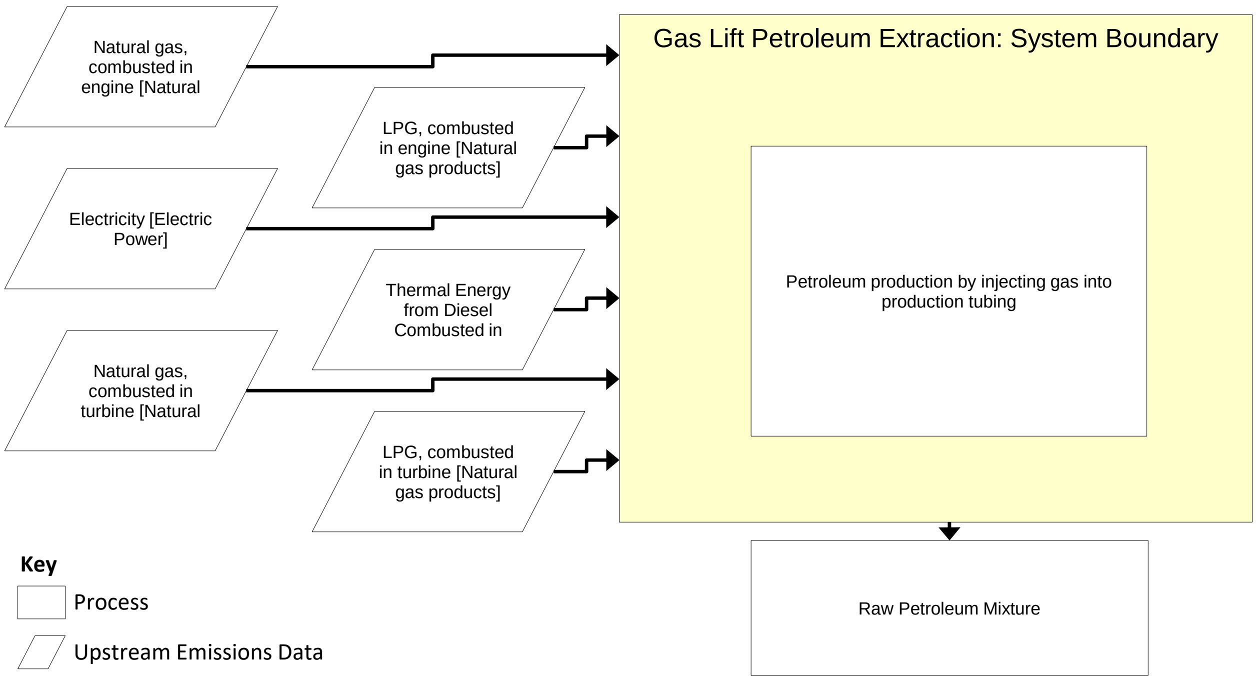
This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_Petroleum_Gas_Lift_2013.01.xlsx*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides a summary of relevant input and output flows associated with petroleum extraction using gas lift. Gas lift involves injecting gas into the production tubing to lower the specific gravity of the produced crude/water/gas mixture. This unit process determines the amount of compressed gas that is needed with electricity or fuel needs provided by the upstream compression process OR this unit process calculates the fuel or electricity needs to power the multi-stage compressor that injects the gas into the production tubing. The reference flow of this unit process is: 1 kg of Raw Petroleum Mixture

Boundary and Description

Figure 1: Unit Process Scope and Boundary



This process describes the energy used to compress gas for injection into production tubing during gas lift. This is a form of artificial lift that can be used in the petroleum extraction model. When gas lift is used the composition of gas extracted is not the same as gas in the reservoir. Instead it is a mix of the reservoir gas and the processed or pipeline gas that is injected at pressure into the fluid column.

Multiple stages of compression may be used, and the user must adjust the number of stages to ensure that the ratio of inlet to outlet pressure for each stage is less than 5. Limiting the ratio of pressure change across each stage allows the gas to be cooled as it is compressed, "making compression less adiabatic and more isothermal" (El-Houjeiri *et al.* 2013). Calculations of work needed for compression in this unit process are taken from OPGEE. Equations for the gas compression ratio and gas compressor suction temperature are given in Sections 3.3.2.4 and 3.3.2.5 of the documentation (El-Houjeiri *et al.* 2013).

The energy for compression can be supplied by an engine burning natural gas, natural gas liquid (NGL), or diesel; an electric motor; or a turbine using natural gas or NGL. Combustion and other emissions are not included in this unit process.

Table 1: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Natural gas, combusted in engine [Natural gas products]	**2.38E-01**	**MJ**
LPG, combusted in engine [Natural gas products]	**0.00E+00**	**MJ**
Electricity [Electric Power]	**0.00E+00**	**MJ**
Thermal Energy from Diesel Combusted in Industrial Equipment [Valuable substances]	**0.00E+00**	**MJ**
Natural gas, combusted in turbine [Natural gas products]	**0.00E+00**	**MJ**
LPG, combusted in turbine [Natural gas products]	**0.00E+00**	**MJ**
Outputs		
Raw Petroleum Mixture	**1.00**	**kg**

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

Embedded Unit Processes

None.

References

El-Houjeiri *et al.* 2005 — 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 Unites 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

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Section III: Document Control Information

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