NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Petroleum Gas Injection

Reference Flow: 1 scf of Injected gas

Brief Description: Injection of associated gas back into a petroleum reservoir

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:

Res_pressure	*[psi] Pressure of the reservoir*
inj_gas	*[scf/day] Gas injection rate (should not be changed from value of 1)*
disch_pressure	*[psia] Required injection compressor discharge pressure. Equation is from OPGEE, with no explanation in the documentation.*
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. Calculate externally for most accurate results.*
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*
MMbtu_to_MJ	*[MJ/MMbtu] Conversion factor for million btu to MJ*

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 Fuel [Energy resources]	*[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:

Injected gas	*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_Injection_2013.01.xlsx*, which provides additional details regarding relevant calculations, data quality, and references.

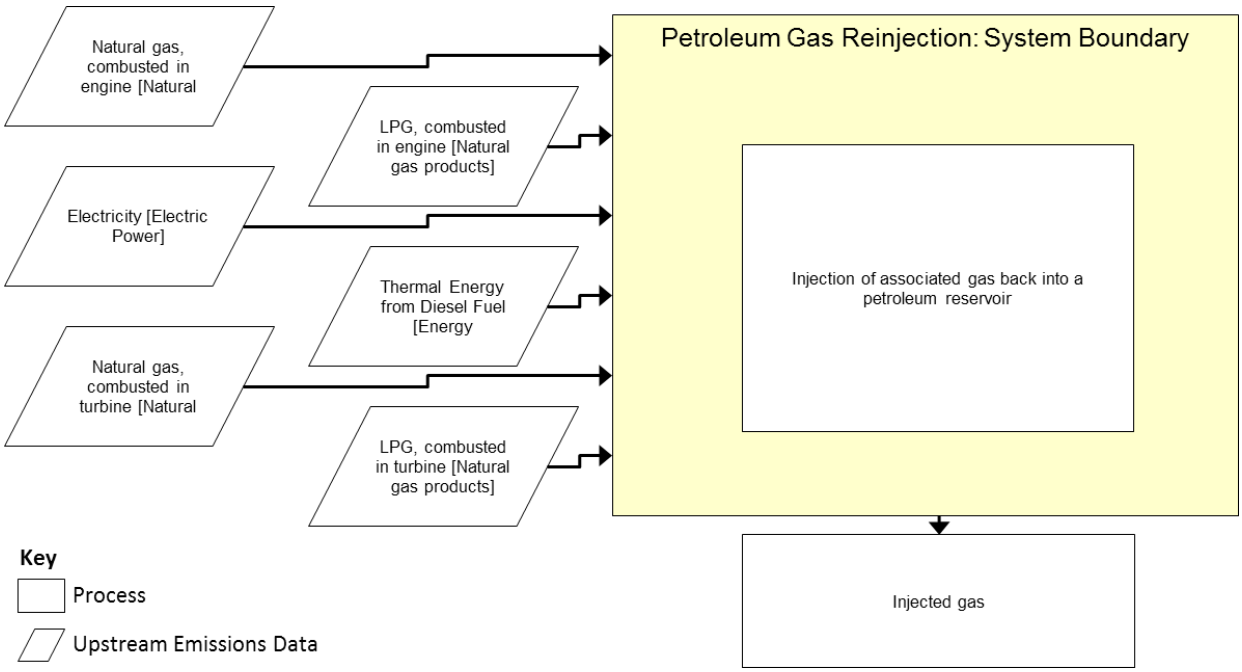
Goal and Scope

This unit process provides a summary of relevant input and output flows associated with reinjecting associated gas. This process is calculated for 1 scf of injected gas, which is then scaled by a separate extraction process. The reservoir pressure, inlet pressure, and driver/fuel types should be adjusted as necessary for the reservoir or group of reservoirs under consideration. The reference flow of this unit process is: 1 scf of Injected gas

Boundary and Description

Figure 1 provides an overview of the boundary of this unit process. Rectangular boxes represent relevant sub-processes, while trapezoidal boxes indicate upstream data that are outside of the boundary of this unit process. As shown, the upstream emissions from natural or associated gas and water are calculated in another unit process. The methods for calculating these operating activities are described below.

Figure 1: Unit Process Scope and Boundary



This process describes the energy used to compress gas for injection into a petroleum reservoir. 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: Sample Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Natural gas, combusted in engine [Natural gas products]	**0.05**	**MJ**
LPG, combusted in engine [Natural gas products]	**0.00E+00**	**MJ**
Electricity [Electric Power]	**0.00E+00**	**MJ**
Thermal Energy from Diesel Fuel [Energy resources]	**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		
Injected gas	**1.00**	**scf**

* **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.

NIST 2013 — NIST (2013). Thermophysical Properties of Fluid Systems. Accessed on October 23, 2013 from http://webbook.nist.gov/chemistry/fluid/

Section III: Document Control Information

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