NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Water reinjection

Reference Flow: 1 kg of Water injected

Brief Description: Produced water reinjection during extraction operations

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:

Prod_volume	*[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.*

WOR_add	*[bbl water/bbl oil] Extra amount of water to oil ratio required for water flooding - Default value is 1 additional bbl of water/bbl of oil*
TDS	*[mg/L] Total dissolved solids in the produced water*
TDS_add	*[mg/L] Total dissolved solids in the additional water used for water flooding*
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 injection tubing. API tubing can actually vary from 1.050 to 4.5 in (OD).*
Reinject_water	*[dimensionless] Fraction of water to reinjection*
Suction_press	*[psi] Net positive suction head at the reinjection pump*
Water_loss	*[bbl/day] The amount of fugitive water losses*
press_grad	*[psi/ft] The pressure gradient of the formation. The mininum assumes only water is above the formation. The max is rock.*
Res_pressure	*[psi] Pressure of the reservoir*
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	*Number of production wells*
Inject_wells	*Number of water injection wells*
Inject_index	*[bbl/psi-d] Injectivity index. These values can vary widely based on the reservoir and underlying geology.*
Friction_factor	*[dimensionless] Moody friction factor. The default value is an estimate from*

	OPGEE. Min and Max values are likely estimates but may not represent extreme cases.
Pump_eff	*[dimensionless] Pump 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	*Adjustable parameter - Select 1 to use as prime mover type, or enter fraction of pumps powered by natural gas engines*
Prime_elec	*Adjustable parameter - Select 1 to use as prime mover type, or enter fraction of pumps powered by electric motors*

Prime_diesel	*Adjustable parameter - Select 1 to use as prime mover type, or enter fraction of pumps powered by diesel engines*
Prime_ngt	*Adjustable parameter - Select 1 to use as prime mover type, or enter fraction of pumps powered by natural gas turbines*
NG_fuel	*Adjustable parameter - Select 1 to use natural gas fuel for NG engines and turbines*
NGL_fuel	*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 burned in an engine for power*
Natural gas engine with NGL	*[Technosphere] NGLs burned in an engine for power*
Electricity	*[Technosphere] Electricity used to power a motor*
Diesel engine	*[Technosphere] Diesel burned in an engine for power*
Natural gas turbine	*[Technosphere] Natural gas burned in a turbine for power*
Natural gas turbine with NGL	*[Technosphere] NGLs burned in a turbine for power*

Tracked Output Flows:

Water injected	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_Water_reinjection_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 injecting produced or fresh water during crude oil extraction. This unit process models both water reinjection and water flooding. If the water required for injection is greater than the water-to-oil ratio, then it is considered water flooding and necessitates bringing in additional water. The default parameter values should be replaced where appropriate to model a specific reservoir or group of reservoirs. The reference flow of this unit process is: 1 kg of Water injected

Boundary and Description

This unit process is intended to fit within a larger model of petroleum extraction based on the Oil Production Greenhouse Gas Emissions Estimator (OPGEE). The reference flow, 1 kg of water injected, does not easily relate to a given amount of petroleum extracted. Instead, the amount of water injected is determined within the larger context of the field in question. This process helps to quantify the energy use and emissions associated with water injected (or reinjected) into reservoirs. It uses engineering calculations to determine energy use, based on the specified values for parameters such as well depth, pipe diameter, and reservoir pressure. Unlike in OPGEE, this process is used for both reinjection and water flooding operations.

Because parameter values may vary significantly between formations, only a few examples have been provided in **Table 1**. Additionally, the flow values provided in **Table 2** should not be considered definitive. Users should choose appropriate values in the DS to obtain process flow values.

Figure 1: Unit Process Scope and Boundary

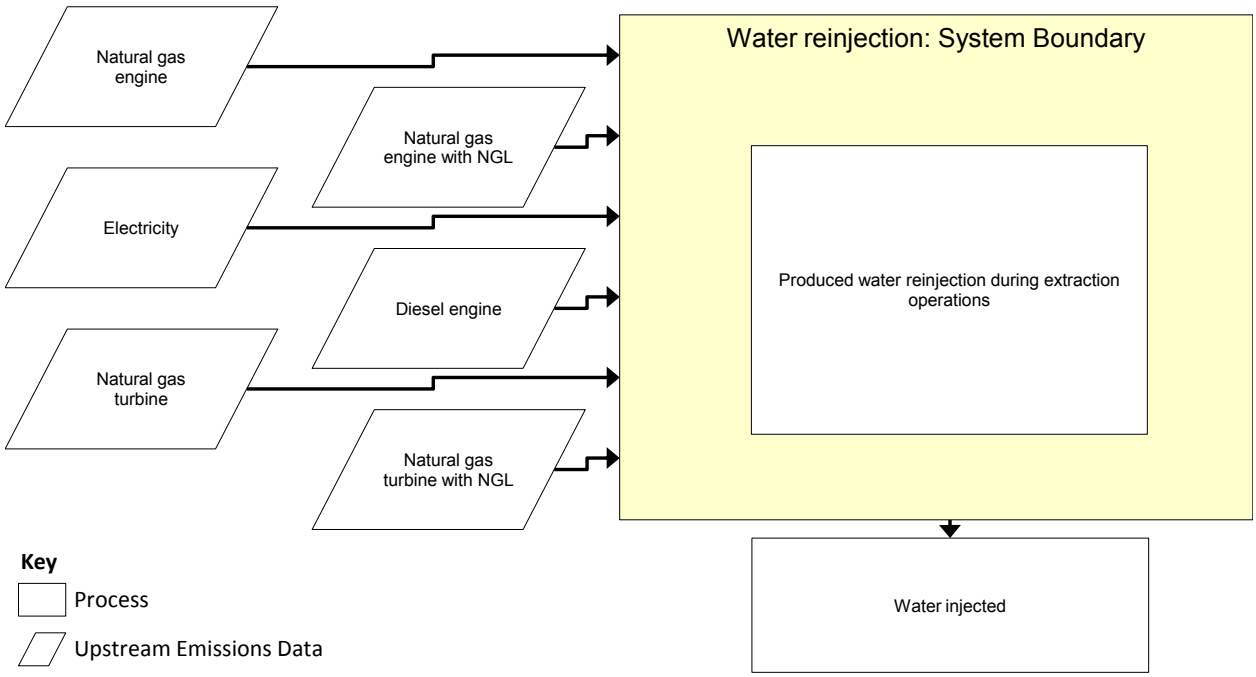

Table 1: Sample Parameter Values

Parameter	Sample Value	Unit
Well Diameter	2.775	inches
Water Oil Ratio (WOR)	5.3	bbl water/ bbl oil
Reservoir Pressure	1,557	psi

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Natural gas engine	**0.00E+00**	**MJ**
Natural gas engine with NGL	**0.00E+00**	**MJ**
Electricity	**0.00E+00**	**kWh**
Diesel engine	**0.00E+00**	**MJ**
Natural gas turbine	**0.00E+00**	**MJ**
Natural gas turbine with NGL	**0.00E+00**	**MJ**
Water [Water]	0.00E+00	kg
Outputs		
Water injected	**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.

Section III: Document Control Information

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