NETL Life Cycle Inventory Data
Process Documentation File

Process Name:	Oil Sands Surface Mining
Reference Flow:	1 kg of Recovered and Extracted Dilbit, Synbit, or Upgrader Feed
Brief Description:	Energy use, feedstock, and emissions from production of 1 kg Dilbit, Synbit, or SCO upgrader feed

Section I: Meta Data

Geographical Coverage: Canada **Region:** Alberta

Year Data Best Represents: 2010

Process Type: Energy Conversion (EC)

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:

Cogen	*[Dimensionless] 0 = Extraction facility without cogen; 1 = Extraction facility with cogen*
Diesel_Comb	*[kg/kg] Diesel input for bitumen recovery equipment*
Fugitive_CH4	*[kg/kg] Fugitive emissions from bitumen extraction processes*

Flared_CO2	*[kg/kg] Flared emissions from bitumen extraction processes*
NG_Input_Cogen	*[kg/kg] Natural gas input for bitumen extraction processes with cogen unit*
NG_Input_NoCo	*[kg/kg] Natural gas input for bitumen extraction processes without cogen unit*
Finished_Prod	*[Dimensionless] Determination of ultimate product; 0 = dilbit; 1 = synbit; 2 = to upgrader (diluent used for transport)*
Diluent	*[Dimensionless] Diluent used for produced Dilbit; 0 = naphtha; 1 = NGL*
Naphtha_Dil_m	*[kg/kg] Naphtha diluent input per unit bitumen*
NGL_Dil_m	*[kg/kg] NGL diluent input per unit bitumen*
SCO_Syn_m	*[kg/kg] SCO diluent input per unit bitumen*
Naphtha_SCO_T	*[kg/kg] Naphtha diluent input per unit bitumen - blended for transport to upgrader*
Elec_req	*[MWh/kg] Electricity required for a unit without cogen*
Elec_prod	*[MWh/kg] Electricity produced for a unit with cogen*

Tracked Input Flows:

Diesel [Refinery products]	*[Technosphere] Combusted diesel input*
Natural Gas US Mix - NETL [Natural gas (resource)]	*[Technosphere] Combusted natural gas input*
Naphtha [Organic intermediate products]	*[Technosphere] Naphtha input*
Natural Gas Liquids [Natural Gas Products]	*[Technosphere] NGL input*
SCO [Crude Oil Products]	*[Technosphere] SCO input*
Electricity [Electric Power]	*[Technosphere] Electricity input*

Tracked Output Flows:

Surface Mined Bitumen plus Diluent to Upgrader [Crude Oil Products]	*Reference flow*
Dilbit [Crude Oil Products]	*Reference flow*
Synbit[Crude Oil Products]	*Reference flow*
Electricity [Electric Power]	*Co-product*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *Stage1_O_Oil_Sands_Surface_Mining_2014.01.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 surface mining of Canadian Oil Sands. The processes allows the user to choose the type of product produced (i.e. dilbit, synbit, or upgrader feed), which thereby determines the diluent type and amount. Units that include cogeneration facilities also export electricity. The reference flow of this unit process is: 1 kg of Recovered and Extracted Dilbit, Synbit, or Upgrader Feed

Boundary and Description

There are two main techniques for extracting oil sands: surface mining and in situ recovery. This unit process applies specifically to the first technique. Surface mining involves the extraction of the material by utilizing diesel-powered shovels and trucks. The mined material is transported to a recovery facility where the bitumen is separated by utilizing hot water (Bergerson et al. 2012). Following bitumen recovery it can be blended to produce an immediately saleable product or transported to an upgrading facility. Recovered bitumen must be diluted prior to sale or transport to reduce the viscosity to the point where it can be transported via pipeline. The material used to dilute the bitumen is referred to as the diluent. If the desired product is diluted bitumen (or dilbit), then the most common diluents are naphtha and natural gas liquids (NGLs). Conversely, if the producer wishes to produce synthetic bitumen (or synbit), the bitumen is diluted with synthetic crude oil (SCO) from an oil sands upgrading facility. Finally, if the bitumen will be sent to an upgrader, it is blended with naphtha so that it can be transported via pipeline.

Figure 1 shows all of the process inputs and outputs, along with the system boundary for surface mining of oil sands. The parameter values utilized to scale the inputs and outputs are detailed in **Table 1**. The basis for these parameter values is the GreenHouse gas emissions of current Oil Sands Technologies (GHOST) model developed by the Universities of Calgary and Toronto (Bergerson et al. 2012 and

Charpentier et al. 2011). GHOST is a life cycle model which tracks greenhouse gas emissions all the way from the extraction of oil sands up to the entrance to a refinery.

The direct emissions accounted for in this process include the flaring of associated gas as well as fugitive gas emissions from the mine face, tailings pond, and other miscellaneous leakage points (Bergerson et al. 2012). Direct emissions which are part of the overall system, but not accounted for in this unit process include the combustion of diesel in the mining vehicles and the combustion of natural gas to generate steam for bitumen recovery. Indirect emissions which are also part of the overall system, but not accounted for in this process include the supply chain emissions associated with the production of diesel, natural gas, electricity, and the diluent (naphtha, NGLs, or SCO depending on the desired product).

GHOST includes both no cogeneration (boiler only) and cogeneration cases for the surface mining recovery operations. In the no cogeneration case, all of the electricity required for the operation is sourced from the grid. In the cogeneration case, natural gas is imported and combusted in a gas turbine to generated electricity. The exhaust gas is sent to a heat recovery steam generator (HRSG) where the necessary steam is produced. Any excess electricity leaves the boundary as a co-product.

Figure 1: Unit Process Scope and Boundary

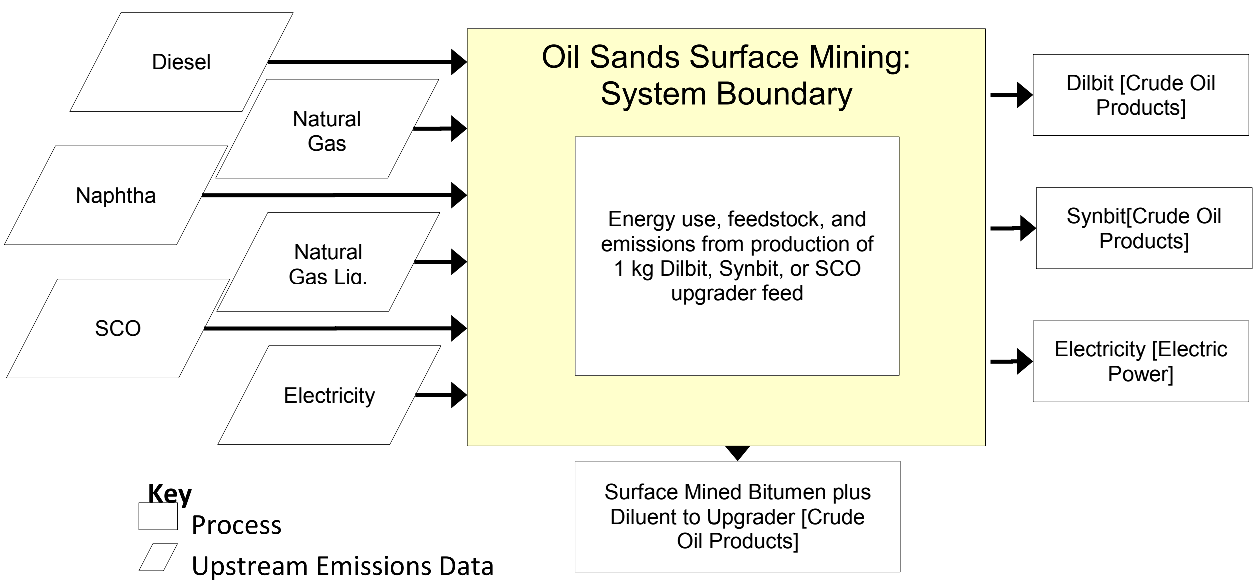

Table 1: Parameter Values for No Cogeneration (Boiler) and Cogeneration Cases (Bergerson et al. 2012, Charpentier et al. 2011)

Parameter	No Cogeneration Cases		Cogeneration Cases		Units (per m^3 bitumen)
	Value	Range	Value	Range	
Utility Requirements					
Electricity	60	50-100	60	50-100	kWh
Diesel	10	7-15	10	7-15	L
Natural Gas	50	20-80	380	N/A	m^3
Electricity Production	N/A	N/A	1,200	240-2,400	kWh
Emissions					
Fugitive Methane	10	3-24	10	3-24	kg CO_2e
Flared Hydrocarbons	2	0-15	2	0-15	kg CO_2e
Diluent					
SCO Pathaway Transport (naphtha)	30%	30%	30%	30%	% by volume
Dilbit Pathway (NGL or naphtha)	25%	25%	25%	25%	% by volume
Synbit Pathway (SCO)	50%	50%	50%	50%	% by volume

Table 2 shows the unit process input and output flows for the case in which dilbit is produced from a surface mine with no cogeneration.

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Diesel [Refinery products]	**6.64E-03**	**kg**
Natural Gas US Mix - NETL [Natural gas (resource)]	**2.65E-02**	**kg**
Naphtha [Organic intermediate products]	**2.01E-01**	**kg**
Natural Gas Liquids [Natural Gas Products]	**0.00E+00**	**kg**
SCO [Crude Oil Products]	**0.00E+00**	**kg**
Electricity [Electric Power]	**4.73E-05**	**MWh**
Outputs		
Surface Mined Bitumen plus Diluent to Upgrader [Crude Oil Products]	0.00E+00	kg
Dilbit [Crude Oil Products]	1.00	kg
Synbit[Crude Oil Products]	0.00E+00	kg
Electricity [Electric Power]	0.00E+00	MWh
Carbon dioxide [Inorganic emissions to air]	1.58E-03	kg
Methane [Organic emissions to air (group VOC)]	3.15E-04	kg

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

Embedded Unit Processes

None.

References

Bergerson et al. 2012	Bergerson, J. A., Kofoworola, O., Charpentier, A. D., Sleep, S., & MacLean, H. L. (2012). Life Cycle Greenhouse Gas Emissions of Current Oil Sands Technologies: Surface Mining and In Situ Applications. Environmental Science & Technology, 46(14), 7865-7874. doi: 10.1021/es300718h
Charpentier et al. 2011	Charpentier, A. D., Kofoworola, O., Bergerson, J. A., & MacLean, H. L. (2011). Life Cycle Greenhouse Gas Emissions of Current Oil Sands Technologies: GHOST Model Development and Illustrative Application. Environmental Science & Technology, 45(21), 9393-9404. doi: 10.1021/es103912m

Section III: Document Control Information

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