NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Surface Coal Mining – Overburden Removal, Extraction, and Reclamation

Reference Flow: 1 kg of Coal

Brief Description: The Energy and non-combustion emissions for the operation of a surface coal mine.

Section I: Meta Data

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

Year Data Best Represents: 1989-2011

Process Type: Extraction Process (EP)

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

Allocation Applied: No

Completeness: Individual 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:

PM25	*[kg/kg] Mass of total PM2.5 emissions per unit of coal produced for reference mine*
PM25_total	*[kg/kg] Mass of total PM2.5 emissions per unit of coal produced*
PM25_unmit	*[kg/kg] Mass of unmitigated PM2.5 emissions per unit of coal produced*

PM_25to10	*[kg/kg] Mass of total PM2.5 to PM10 emissions per unit of coal produced for reference mine*
PM_25to10_total	*[kg/kg] Mass of total PM2.5 to PM10 emissions per unit of coal produced*
PM_25to10_unmit	*[kg/kg] Mass of unmitigated PM2.5 to PM10 emissions per unit of coal produced*
VOC_Ref	*[kg/kg] Mass of VOC emissions per unit of coal produced for reference mine*
Elec_Ref	*[MWh/kg] Amount of electricity input per unit of coal produced for reference mine*
D_Ref_great750	*[kg/kg] Amount of diesel energy input per unit of coal produced for reference mine; equipment with engines > 750 horsepower*
D_Ref_less750	*[kg/kg] Amount of diesel energy input per unit of coal produced for reference mine; equipment with engines < 750 horsepower*
TierIV_Switch	*[dimensionless] Switch to turn on or off TierIV Requirements (0 = off; 1 = on)*
NH3NO3_Ref	*[kg/kg] Mass of ammonium nitrate per unit of coal produced for reference mine*
FO_Ref	*[kg/kg] Mass of light fuel oil per unit of coal produced for reference mine*
percent_mit	*[dimensionless] Fraction of PM emissions that are mitigated*
Nox	*[kg/kg] Mass of NOx emissions from overburden blasting per unit of coal produced*
NOx_total	*[kg/kg] Mass of NOx emissions per unit of coal produced*
Strip_Ratio_Ref	*[dimensionless] Ratio of overburden removal to coal extracted for reference mine*

Strip_Ratio_UI	*[dimensionless] Ratio of overburden removal to coal extracted for modeled mine*
SR_Scaler	*[dimensionless] Ratio of strip ratios used to scale inputs and outputs*
VOC_Scale	*[kg/kg] Mass of VOC emissions per unit of coal produced*
Elec_Scale	*[MWh/kg] Amount of electricity input per unit of coal produced*
D_Scal_great750	*[kg/kg] Amount of diesel energy input per unit of coal produced; equipment with engines > 750 horsepower*
D_Scal_less750	*[kg/kg] Amount of diesel energy input per unit of coal produced; equipment with engines < 750 horsepower*
D_Scal_total	[kg/kg] Amount of diesel energy input per unit of coal produced; all equipment
NH3NO3_Scale	*[kg/kg] Mass of ammonium nitrate per unit of coal produced*
FO_Scale	*[kg/kg] Mass of light fuel oil per unit of coal produced*
Dies_Eff_Scaler	*[dimensionless] Scaler to adjust diesel consumption to account for manual operations at Indonesian mine*
Elec_Switch	*[dimensionless] Switch to turn electricity on/off depending on mining country (0 = no elec; 1 = elec)*
OB_switch	*[dimensionless] Switch to turn strip ratio scalar on/off depending on activity type (0 = coal extraction or reclamation; 1 = OB removal)*
Ext_switch	*[dimensionless] Switch to indicate if scenario is set to coal extraction (1 = yes; 0 = no); utilized for coal mine methane.*

Tracked Input Flows:

Light fuel oil [Refinery Products]	*[Technosphere] Amount of light fuel oil required for explosives used in blasting coal from a surface mine.*
Ammonium nitrate [Inorganic intermediate products]	*[Technosphere] Amount of ammonium nitrate required for explosives used in blasting coal from a surface mine.*
Electricity [Electric power]	*[Technosphere] Amount of electricity input per unit of coal produced*
Diesel Combustion, Non-Road Engine, > 750 hp, EPA Tier IV Compliance [Refinery products]	*[Technosphere] Amount of diesel required for equipment used in blasting coal from a surface mine; equipment with engines > 750 horsepower*
Diesel Combustion, Non-Road Engine, 175 ≤ hp ≤ 750, EPA Tier IV Compliance [Refinery products]	*[Technosphere] Amount of diesel required for equipment used in blasting coal from a surface mine; equipment with engines < 750 horsepower*D_Scal_total *Diesel Combustion, Reciprocating, Industrial, Uncontrolled [Refinery products]*
Coal, surface [Resource]	*[Resource] Amount of coal extracted*
Coal, mine methane [Intermediate Product]	*[Technosphere] Connection with coal mine methane unit process*
PRB Coal Surface Mine [Valuable substances]	*[Technosphere] Connection with surface coal mine construction*
PRB comm [Valuable substances]	*[Technosphere] Connection with surface coal mine commissioning/decommissioning*

Tracked Output Flows:

Coal, surface, extracted [Intermediate Product]	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_Extraction_Handling_Surface_2013.02.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 extraction of coal from a surface mine. This includes the amount of electricity and fuel required to power equipment and the direct particulate matter (PM) and volatile organic compound (VOC) emissions from operating equipment and using explosives. Combustion emissions are not included in this unit process. The reference flow of this unit process is: 1 kg of coal.

Boundary and Description

This UP is parameterized into mining stages: Overburden removal, coal extraction, and mine reclamation. This UP is based on a reference Western mine. A strip ratio from any mine can be applied to scale the impacts of the overburden removal scenario. The reference strip ratio is 5:1 and represents a reference Western mine. This UP has a diesel scalar and electricity switch to account for mines that use all diesel equipment (e.g., Indonesia).

For energy calculations, the mining equipment was separated into electrically powered equipment and diesel powered equipment. For all calculations, the equipment was separated into mining stage: overburden removal, coal extraction, and mine reclamation.

The diesel requirements were calculated using the Energy and Environmental Profile of the U.S. Mining Industry developed by the U.S. Department of Energy's Energy Efficiency and Renewable Energy division and the National Mining Association (U.S. Department of Energy and National Mining Association, n.d.). Chapter Two of the source focused on coal; description of coal types, overview of coal mining, energy requirements for underground and surface mines, and emissions from coal mining. The data source provides energy data for specific mining activities such as coal handling, extraction, and grinding. BCS, Incorporated (BCS) developed the data by integrating the U.S. Department of Energy's Energy Information Administration's 1997 Coal Industry data into the Western Mining Engineering, Inc.'s SHERPA Mine Cost Software to create 2002 estimates. BCS also used Mine and Mill Equipment Cost, An Estimator's Guide to develop the data. Newer data for specific coal mining processes are not available. This unit process parameterizes key variables to allow for evaluation of data uncertainty when used in a life cycle model.

Equipment that uses diesel fuel is split into two categories by engine type: Engines greater than 750 horsepower (hp) and engines less than 750 hp. This allows the diesel inputs to be linked to scenarios in the diesel combustion unit process that have emission factors for non-road engines that comply with the U.S. Environmental Protection Agency's (EPA's) Tier IV regulations (Miller, 2015; EPA, 2005).

The reference flow for this unit process is one kg of coal. To calculate the amount of diesel needed, the sum of the equipment's energy requirements, in Btu per ton, was divided by the appropriate conversion to convert tons to kg and then divided by the high heating value of diesel (U.S. Energy Information Administration, 2011), in Btu per kg, to obtain the diesel requirement in kg of diesel per kg of coal.

To calculate the amount of ammonium nitrate and fuel oil (ANFO) used to excavate coal, 1994 data specific to the Powder River Basin (PRB) was used (Stump, B., 1995). The average weight percentages for the composition of ANFO were taken from an ANFO material safety data sheet (Maxam North America, 2010). The amount of ammonium nitrate was calculated by multiplying the kg of ANFO per coal produced by the average weight percent of ammonium nitrate. The kg of ANFO per coal produced was multiplied by the average weight percent of light fuel oil to calculate the amount of light fuel oil in kg fuel oil per kg of coal. Particulate matter (PM) and volatile organic compounds (VOCs) are emitted during coal extraction from an underground mine. To calculate the amount of VOC emissions released during the excavation of coal, 1989-1998 data specific to the PRB (McVehil, G.E., 2001) and 2011 coal production data by the National Mining Association (National Mining Association, 2012) was used. The amount of VOCs released, in tons per year, was multiplied by the appropriate conversion and divided by the amount of coal produced, which was also multiplied by the appropriate conversions, to obtain the kg of VOC per kg of coal. The VOC emissions were calculated for the coal types of bituminous, subbituminous, and lignite by using the calculation just described above but replacing the coal produced with the appropriate coal type production value. It was assumed the VOC emissions released were for one year.

The PM emissions were calculated using the U.S. Environmental Protection Agency's AP 42 (U.S. Environmental Protection Agency, 2009). Chapter 11.9 of the source focused on Western surface coal which included emission factor equations and scaling factors. Other factors that were incorporated into these equations, such as coal moisture content, were obtained from a 2012 U.S. Department of Energy document (U.S. Department of Energy, 2012) and a Caterpillar, Inc. equipment specification (Caterpillar). The PM emissions were broken down into extraction processes such as blasting, truck loading, bulldozing, etc. Emission factor equations and conversions were used to calculate the amount of PM emissions based on the reference flow of one kg of coal. Where applicable, the moisture content of coal was used to calculate PM emissions for the coal types of bituminous, subbituminous, and lignite. To obtain the emissions for PM10 and PM2.5, the scaling factor pertaining to each emission was multiplied by the amount of PM emissions per unit of coal for both PM10 and PM25. It

was assumed that PM data not pertaining to coal types was calculated for a surface mine only. For the bulldozer, it was assumed that the equipment operated for 12 hours per day. A five miles per hour grading speed and 20 year lifetime of coal mine for existing mines was assumed in the calculation of the PM emissions for grading. To calculate the unmitigated PM emissions, the sum of the PM10 and PM2.5 emissions were both multiplied by 15 percent, because it was assumed mitigation measures would reduce emissions by 85 percent. The ammonium nitrate, electricity, light fuel oil, PM, and VOC requirements were placed as parameters in the DS file, so the items could be adjusted to measure uncertainties. There are other adjustable parameters such as coal type and moisture content.

Figure 1: Unit Process Scope and Boundary

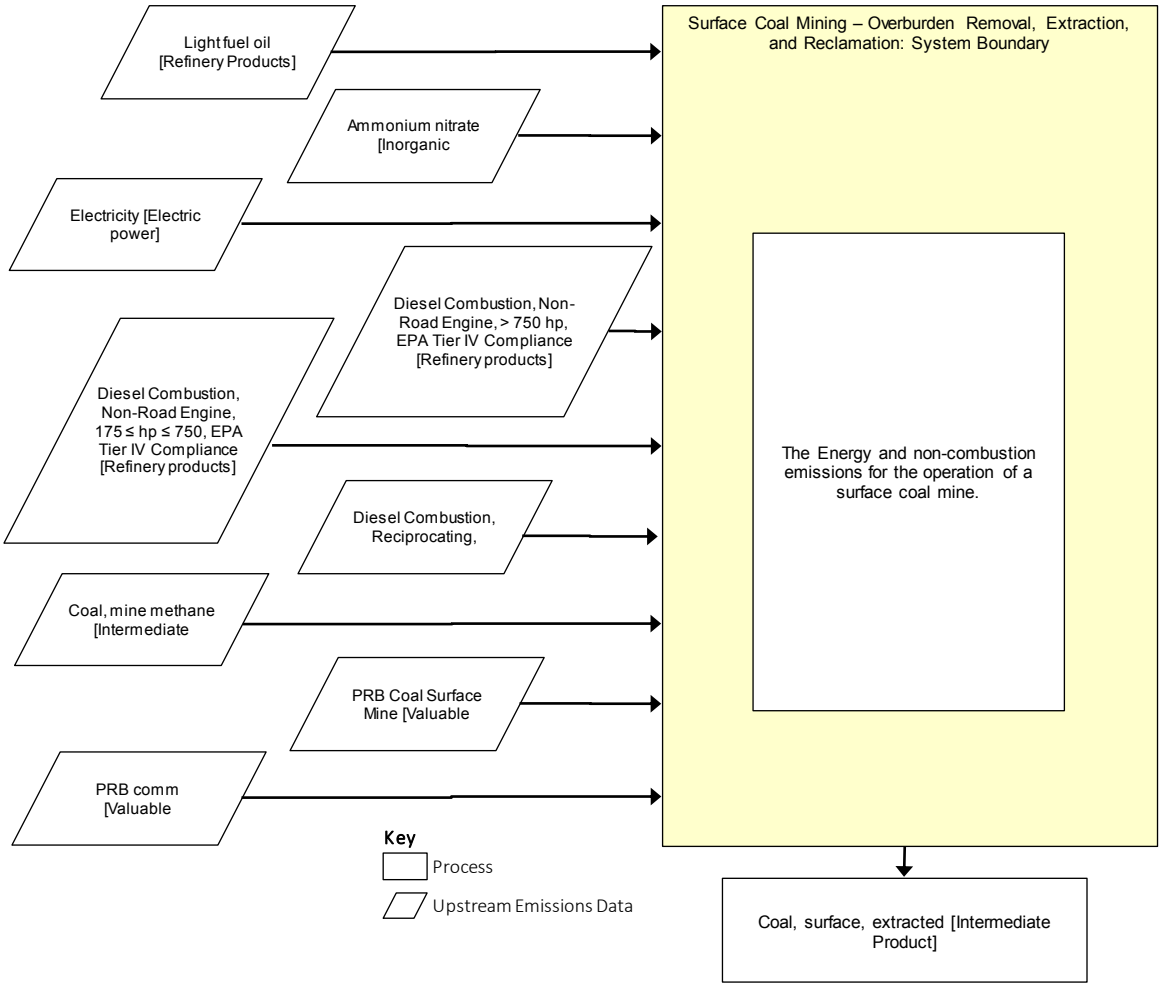

Table 1: Unit Process Input and Output Flows

Flow Name	Value			Units (Per Reference Flow)
	Overburden Removal	Coal Extraction	Mine Reclamation	
Inputs				
Light fuel oil [Refinery Products]	**6.47E-05**	**2.02E-05**	**0.00E+00**	**kg**
Ammonium nitrate [Inorganic intermediate products]	**9.31E-04**	**2.91E-04**	**0.00E+00**	**kg**
Electricity [Electric power]	**8.61E-06**	**7.50E-07**	**0.00E+00**	**kg**
Diesel Combustion, Non-Road Engine, > 750 hp, EPA Tier IV Compliance [Refinery products]	**4.23E-04**	**1.32E-04**	**0.00E+00**	**kg**
Diesel Combustion, Non-Road Engine, 175 ≤ hp ≤ 750, EPA Tier IV Compliance [Refinery products]	**2.56E-04**	**2.67E-05**	**1.05E-04**	**kg**
D_Scal_total	**0.00E+00**	**0.00E+00**	**0.00E+00**	**kg**
Coal, surface [Resource]	1.00E+00	1.00E+00	1.00E+00	kg
Coal, mine methane [Intermediate Product]	**0.00E+00**	**1.00E+00**	**0.00E+00**	**kg**
PRB Coal Surface Mine [Valuable substances]	**1.00E+00**	**1.00E+00**	**1.00E+00**	**pcs**
PRB comm [Valuable substances]	**1.00E+00**	**1.00E+00**	**1.00E+00**	**pcs**
Outputs				
Coal, surface, extracted [Intermediate Product]	**1.00E+00**	**1.00E+00**	**1.00E+00**	**kg**
Dust (PM2.5) [Particles to air]	2.88E-07	7.05E-07	1.45E-07	kg
Dust (PM2.5 – PM10) [Particles to air]	5.07E-06	4.93E-06	8.95E-07	kg
VOC (unspecified) [Organic emissions to air]	1.37E-07	4.28E-08	0.00E+00	kg
Nitrogen oxides [Organic emissions to air (group VOC)]	7.93E-06	1.65E-06	0.00E+00	kg

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

Embedded Unit Processes

None.

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Section III: Document Control Information

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