NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Surface coal extraction

Reference Flow: 1 kg of Coal

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

Section I: Meta Data

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

Year Data Best Represents: 1989-2011

Process Type: Extraction Process (EP)

Process Scope: Gate-to-Gate Process (GG)

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_blast	*[kg/kg] Mass of PM2.5 emissions per unit of coal produced from blasting*
PM25_dragline	*[kg/kg] Mass of PM2.5 emissions per unit of coal produced from dragline*
PM25_grading	*[kg/kg] Mass of PM2.5 emissions per unit of coal produced from grading*
PM25_storage	*[kg/kg] Mass of PM2.5 emissions per unit of coal produced from storage*

PM10_blast	*[kg/kg] Mass of PM10 emissions per unit of coal produced from blasting*
PM10_dragline	*[kg/kg] Mass of PM10 emissions per unit of coal produced from dragline*
PM10_grading	*[kg/kg] Mass of PM10 emissions per unit of coal produced from grading*
PM10_storage	*[kg/kg] Mass of PM10 emissions per unit of coal produced from storage*
MoistContent	*[dimensionless] Fraction of water in coal (for example 0.1=10%); bituminous=11.12%, subbitumionous=25.77%, and lignite=32%*
VOC_bit	*[kg/kg] Mass of VOC emissions per unit of bituminous coal produced*
VOC_subbit	*[kg/kg] Mass of VOC emissions per unit of subbituminous coal produced*
VOC_lig	*[kg/kg] Mass of VOC emissions per unit of lignite coal produced*
Coaltype	*[Logical operators] 1=bituminous, 2=subbituminous, 3=lignite*
diesel	*[kg/kg] Amount of diesel energy input per unit of coal produced*
Lightfueloil	*[kg/kg] Mass of light fuel oil per unit of coal produced*
NH3NO3	*[kg/kg] Mass of ammonium nitrate per unit of coal produced*
percent_mit	*[dimensionless] Fraction of PM emissions that are mitigated*

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.*

Thermal Energy from Diesel Fuel [Energy resources]	*[Technosphere] Amount of diesel required for equipment used in blasting coal from a surface mine.*
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_Surface_2013.01.xlsx*, which provides additional details regarding relevant calculations, data quality, and references.

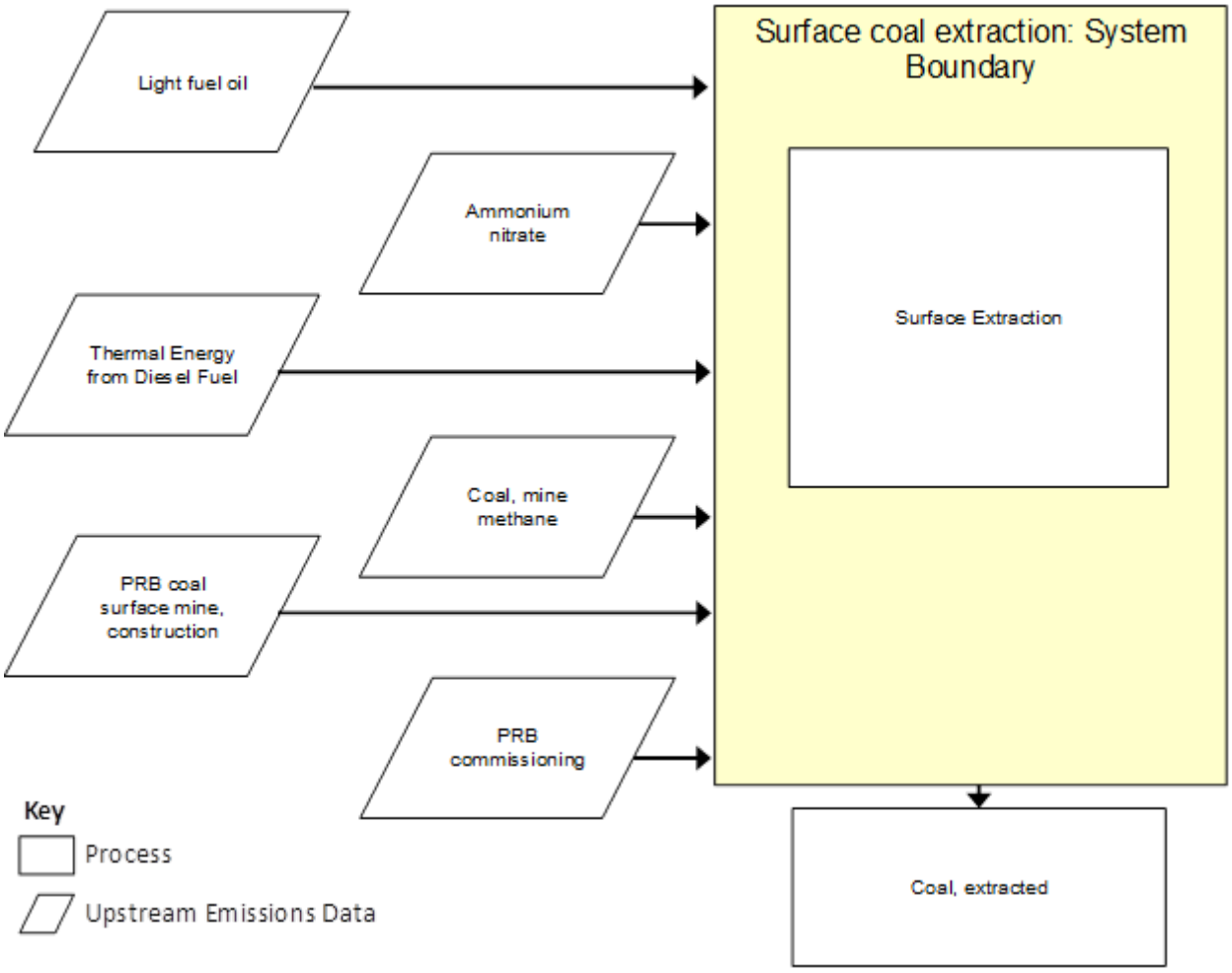
Goal and Scope

This unit process provides a summary of relevant input and output flows associated with the amount of electricity required to power equipment used in the extraction of coal from a surface mine. This equipment includes drills and graders. Fuel and non-combustion emissions for the operation for a surface coal mine are also included. Key inputs include light fuel oil, ammonium nitrate, diesel, and coal. Light fuel oil, ammonium nitrate, and diesel are also adjustable parameters to measure uncertainties. Extracted coal, Dust (PM10 and PM2.5), and VOCs are key outputs. All of these outputs except extracted coal are also adjustable parameters to measure uncertainties. There are various other parameters such as coal moisture content. The unit process is based on the reference flow of one kg of coal. The relevant flows of this unit process are described below and shown in **Figure 1**.

Boundary and Description

Figure 1 provides an overview of the boundary of this unit process.

Figure 1: Unit Process Scope and Boundary



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, 2002). 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, which allow for evaluation of data uncertainty when used in a life cycle model.

Cable shovels (western)/hydraulic shovels (interior), rotary drills, water tankers, pumps, and graders were the pieces of equipment used for extracting coal from a surface mine; it was assumed that all equipment uses diesel. The reference flow for this unit process is one kg of coal. To calculate the amount of diesel needed, the sum of the equipments' 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. The diesel requirement was placed as a parameter in the DS file, so the item could be adjusted to measure uncertainties. Minimum and maximum values for diesel were also included in the parameter section. The maximum value was calculated by dividing the sum of the energy requirements for an interior surface mine (U.S. Department of Energy and National Mining Association, 2002), in Btu/ton, 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. The minimum value was the average of the western and interior mine data energy requirements, in Btu per ton, divided by the appropriate conversion and 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 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 ammonium nitrate and fuel oil in 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., 1998) and 2011 coal production data by the National Mining Association (National Mining Association, 2008) 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 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 emissions 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 PM emissions unmitigated, the sum of the PM10 and PM2.5 emissions were both multiplied by 15 percent since 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.

Table 1 shows the input and output flows of this unit process. Additional details regarding input and output flows, including calculation methods, are contained in the associated DS sheet.

Table 1: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Light fuel oil [Refinery Products]	1.01E-04	kg/kg
Ammonium nitrate [Inorganic intermediate products]	1.45E-03	kg
Thermal Energy from Diesel Fuel [Energy resources]	2.68E-04	kg
Coal, surface [Resource]	1.00	kg
Coal, mine methane [Intermediate Product]	1.00	kg
PRB Coal Surface Mine [Valuable substances]	1.00	pcs
PRB comm [Valuable substances]	1.00	pcs
Outputs		
Coal, surface, extracted [Intermediate Product]	1.00	kg
Dust (PM10) [Particles to air]	9.90E-05	kg
Dust (PM2.5) [Particles to air]	2.62E-05	kg
VOC (unspecified) [Organic emissions to air]	1.94E-07	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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