NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Powder River Basin Surface Subbituminous Coal Mine, Operations

Reference Flow: 1 kg of Powder River Basin Subbituminous Coal

Brief Description: Based on a compilation of mines, a surface mine for Powder River Basin subbituminous coal in Wyoming, producing ~6 billion kg of coal per year. Assumes 32,000 scf/kg coalbed methane (CBM) emissions, adjustable CBM capture rates.

Section I: Meta Data

Geographical Coverage: US **Region:** Powder River Basin

Year Data Best Represents: 2008

Process Type: Extraction Process (EP)

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

Allocation Applied: No

Completeness: All Relevant Flows Recorded

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 Pollutants	☒ Other
Releases to Water:	☒ Inorganic Emissions	☒ Organic Emissions	☐ Other
Water Usage:	☒ Water Consumption	☒ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

Coalbed methane emissions (CBM)	*Emissions of coalbed methane (CBM) from the coal mine and from mined coal*

Tracked Input Flows:

Diesel [Crude Oil Products]	*Diesel (from crude oil) usage for mine operations*
Power [Electric Power]	*Electricity usage for mine operations*
Ammonium Nitrate [Inorganic Intermediate Products]	*The amount of ammonium nitrate needed for ammonium nitrate fuel oil (ANFO) explosives*

Light Fuel Oil [Crude Oil Products]	*Light fuel oil (from crude oil) needed for ANFO explosives*

Tracked Output Flows:

PRB Coal [Hard Coal Products]	*Coal mine production flow for Powder River Basin subbituminous coal*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_CoalMine_PRB_2010.02.xls*, which provides additional details regarding calculations, data quality, and references as relevant.

Goal and Scope

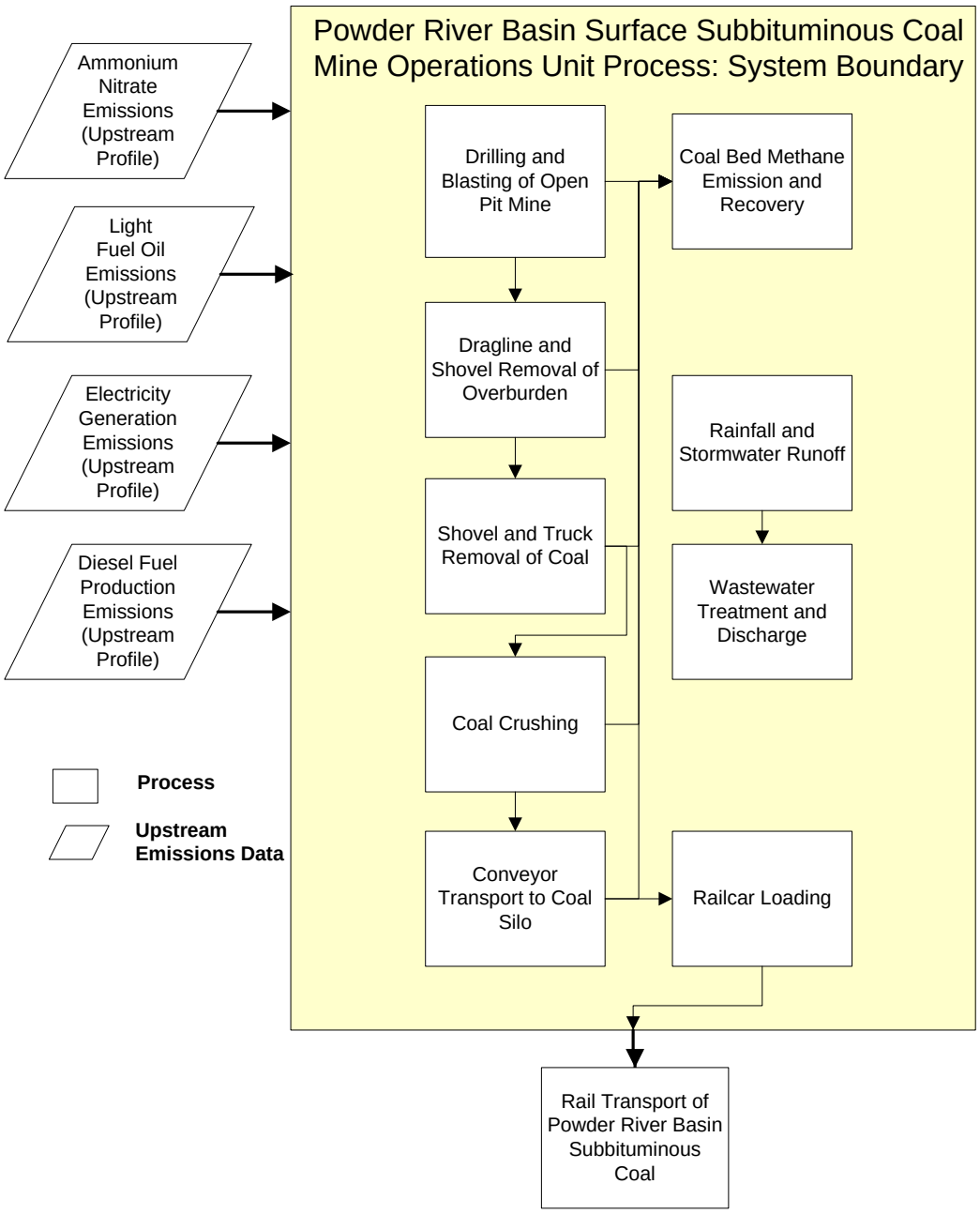
The scope of this process covers the production of coal during operation of a surface mine for Powder River Basin subbitumious coal, from resource extraction to the boundary for LC Stage #2 (e.g., transport of coal). The process is based on the reference flow of 1 kg of cleaned, crushed (to approximately 3 inches) Powder River Basin coal, as described below, and in **Figure 1.** Considered are the consumption of electricity, consumption of diesel, emissions of methane associated with off-gassing from the coal/coal mine, particulate matter emissions associated with fugitive coal dust, water input flows required for mining and cleaning operations, wastewater flows including stormwater, emissions of criteria air pollutants, and air emissions of mercury and ammonia.

Boundary and Description

Operations of the coal mine are based on operations from a compilation of the three largest producers of Powder River Basin coal (Peabody Energy's North Antelope-Rochelle mine, Arch Coal, Inc.'s Black Thunder Mine, and Kennecott Energy's Cordero Rojo Operation) to produce an average annual rate of 60.8 billion kilograms (NMA 2009). The Powder River Basin is located in the southeast portion of Montana and the northeast portion of Wyoming. Sources reviewed in assessing coal mine operations include facility and equipment needs, production raters, electricity usage, particulate air emissions, methane emissions, explosives usage, and additional governmental publications on coal and mines.

Figure 1 provides an overview of the boundary of this unit process. As shown, upstream emissions associated with the production and delivery of electricity and diesel fuel, ammonium nitrate, and light fuel oil are accounted for outside of the boundary of this unit process.

Figure 1: Unit Process Scope and Boundary



Coal is extracted from a surface Powder River Basin coal seam through an open pit mining process. Blasting with ammonium nitrate fuel oil (ANFO) explosives occurs in drilled holes to remove the overburden and expose the coal seam for extraction. The removal of the overburden occurs with the use of draglines, powered by electricity, which pile the overburden in a different location to enable extraction of the coal. After the dragline has removed as much as possible, large electric shovels are used for the removal of the remaining overburden. The coal is removed using a truck and shovel approach. The trucks move the coal 3.2 km (2 miles) to the preparation facility for grinding and crushing to the proper size for transport. No cleaning of the coal occurs

based on the coal properties. A conveyor belt carries the crushed coal from the preparation facility to the loading silo. The coal is then loaded into rail cars for transport (LC Stage #2) to the plant (LC Stage #3).

Coalbed methane emissions from the coal mine, and from the extracted coal during processing and storage, were estimated based on U.S. EPA estimates of methane release for coal mines (U.S. EPA 2008). An 80 percent methane capture rate was used based on data for existing and potential recovery rates (U.S. EPA 2008), which resulted in a coalbed methane emission factor of 7 standard cubic feet per short ton of coal. For a sensitivity analysis, one may assume that no coalbed methane capture method was employed, by updating the appropriate adjustable parameter. It was assumed that all emitted methane was released to the atmosphere. The average Powder River Basin coal deposit has 30-40 standard cubic feet per short ton. Other types of coal may have up to 360 standard cubic feet per short ton of emissions.

Electricity and diesel use were based on data points published by Peabody Energy in reference to their North Antelope Rochelle Mine in Wyoming (Burley 2008 and Peabody 2005). The data were scaled such that they were applicable to the size of the mine being modeled.

Emissions of criteria pollutants were based on emissions associated with the use of diesel. U.S. EPA Tier 4 diesel standards for non-road diesel engines were used, since these standards would go into effect within a few years of commissioning of the mine for this study (U.S. EPA 2004). Diesel is assumed to be ultra low sulfur diesel (ULSD; 15 ppm sulfur). Emissions of particulate matter included those due to the combustion of diesel, as well as fugitive coal dust from the mining process. Total coal dust emissions were obtained from the EPA's AP 42's Mineral Products Industry section (EPA 2009).

Water use was estimated based on an environmental impact study completed on West Antelope II mine located in the Powder River Basin of Wyoming (BLM 2008) with other sources used to calculate fraction ground or surface fresh or saline water fractions and maximum and minimum values for uncertainty (USGS 2000a; USGS 2000b; EIA 2013; HKM 2002). An option was also added to calculate fresh and saline ground water use given a user-defined fresh surface water usage. If the fresh and saline ground water use is not calculated, then the user is responsible for ensuring that the total fractions add up to 1 and are within the maximum and minimum values.

Water emissions, including flows and concentrations of relevant inorganic constituents and solids entering the waterstream, were taken from available National Pollutant Discharge Elimination System permit reporting documentation (NPDES 2009).

Properties of Powder River Basin coal relevant to this unit process are indicated in **Table 1**. **Table 2** provides a summary of modeled input and output flows. Additional details regarding input and output flows, including calculation methods, are contained in the associated DS sheet.

Table 1: Properties of Powder River Basin Coal (NETL 2011)

Proximate Analysis	Dry Basis, %	As Received, %
Moisture	0	25.77
Ash	11.04	8.19
Volatile Matter	40.87	30.34
Fixed Carbon	48.09	35.7
Total	100	100
Ultimate Analysis	**Dry Basis, %**	**As Received, %**
Carbon	67.45	50.07
Hydrogen	4.56	3.38
Nitrogen	0.96	0.71
Sulfur	0.98	0.73
Chlorine	0.01	0.01
Ash	11.03	8.19
Moisture	0	25.77
Oxygen (Note A)	15.01	11.14
Total	100	100
Heating Value	**Dry Basis, (Dulong Calc.)**	**As Received, %**
HHV, kJ/kg	26,787	19,920
HHV, Btu/lb	11,516	8,564
LHV, kJ/kg	25,810	19,195
LHV, Btu/lb	11,096	8,252

Notes: (A) the proximate analysis assumes sulfur as volatile matter; (B) by difference.

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs		
Ammonium nitrate [Inorganic intermediate products]	**1.45E-03**	**kg**
Diesel [Crude oil products]	**8.93E-04**	**kg**
Light fuel oil [Crude oil products]	**1.01E-04**	**kg**
Power [Electric power]	**1.40E-03**	**kWh**
Water (ground water, fresh) [Water]	1.44E-02	L
Water (ground water, saline) [Water]	1.09E-02	L
Water (surface water, fresh) [Water]	5.08E-03	L
Outputs		
PRB Coal (NETL) [Hard coal products]	1	kg
Carbon dioxide [Inorganic emissions to air]	2.81E-03	kg
Carbon monoxide [Inorganic emissions to air]	6.97E-12	kg
Methane [Organic emissions to air (group VOC)]	1.49E-04	kg
Nitrogen dioxide [Inorganic emissions to air]	2.49E-05	kg
Sulphur dioxide [Inorganic emissions to air]	2.68E-11	kg
Particulate Matter, unspecified [Other emissions to air]	9.45E-05	kg
Volatile Organic Carbons [Organic emissions to air]	3.48E-07	kg
Mercury - Heavy Metals to Air	1.40E-13	kg
Ammonia - Emissions to Air	1.16E-07	kg
Aluminium [Heavy metals to fresh water]	2.51E-10	kg
Arsenic (+V) [Heavy metals to fresh water]	3.53E-11	kg
Barium [Inorganic emissions to fresh water]	8.88E-10	kg
Biological oxygen demand (BOD) [Analytical measures to fresh water]	7.97E-08	kg
Boron [Inorganic emissions to fresh water]	4.86E-09	kg
Cadmium (+II) [Heavy metals to fresh water]	1.59E-12	kg
Calcium (+II) [Inorganic emissions to fresh water]	1.14E-06	kg
Total organic carbon, TOC (Ecoinvent) [ecoinvent long-term to fresh water]	9.65E-08	kg
Chemical oxygen demand (COD) [Analytical measures to fresh water]	2.69E-07	kg
Chromium (unspecified) [Heavy metals to fresh water]	1.59E-10	kg
Copper (+II) [Heavy metals to fresh water]	7.81E-11	kg
Cyanide [Inorganic emissions to fresh water]	1.13E-10	kg
Fluoride [Inorganic emissions to fresh water]	1.79E-10	kg
Iron [Heavy metals to fresh water]	1.36E-08	kg
Lead (+II) [Heavy metals to fresh water]	1.61E-09	kg
Magnesium (+III) [Inorganic emissions to fresh water]	1.62E-11	kg
Manganese (+II) [Heavy metals to fresh water]	1.40E-06	kg
Mercury (+II) [Heavy metals to fresh water]	2.51E-09	kg

Nickel (+II) [Heavy metals to fresh water]	1.59E-13	kg
Nitrate (as total N) [Inorganic emissions to fresh water]	1.59E-10	kg
Ammonia, as N [Inorganic emissions to fresh water]	9.20E-09	kg
Nitrogen (as total N) [Inorganic emissions to fresh water]	4.77E-09	kg
Phosphorus [Inorganic emissions to fresh water]	1.52E-08	kg
Selenium [Heavy metals to fresh water]	2.39E-08	kg
Sodium (+I) [Inorganic emissions to fresh water]	2.49E-08	kg
Total Dissolved Solids [Analytical measures to fresh water]	2.96E-10	kg
Total Suspended Solids [Analytical measures to fresh water]	2.93E-11	kg
Strontium [Heavy metals to fresh water]	3.46E-06	kg
Sulfates [Inorganic emissions to fresh water]	2.38E-05	kg
Zinc (+II) [Heavy metals to fresh water]	1.62E-07	kg
Water (wastewater) [Water]	1.59E-02	L

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows. Upstream environmental flows were added during the modeling process using GaBi modeling software, as shown in Figure 1.

Embedded Unit Processes

None.

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Section III: Document Control Information

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