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 scf/ton 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 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 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 Combustion, Mobile Sources, Truck [Refinery products]	*Diesel from crude oil, combusted in trucks*
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_2010.03.xls*, which provides additional details regarding calculations, data quality, and references as relevant.

Goal and Scope

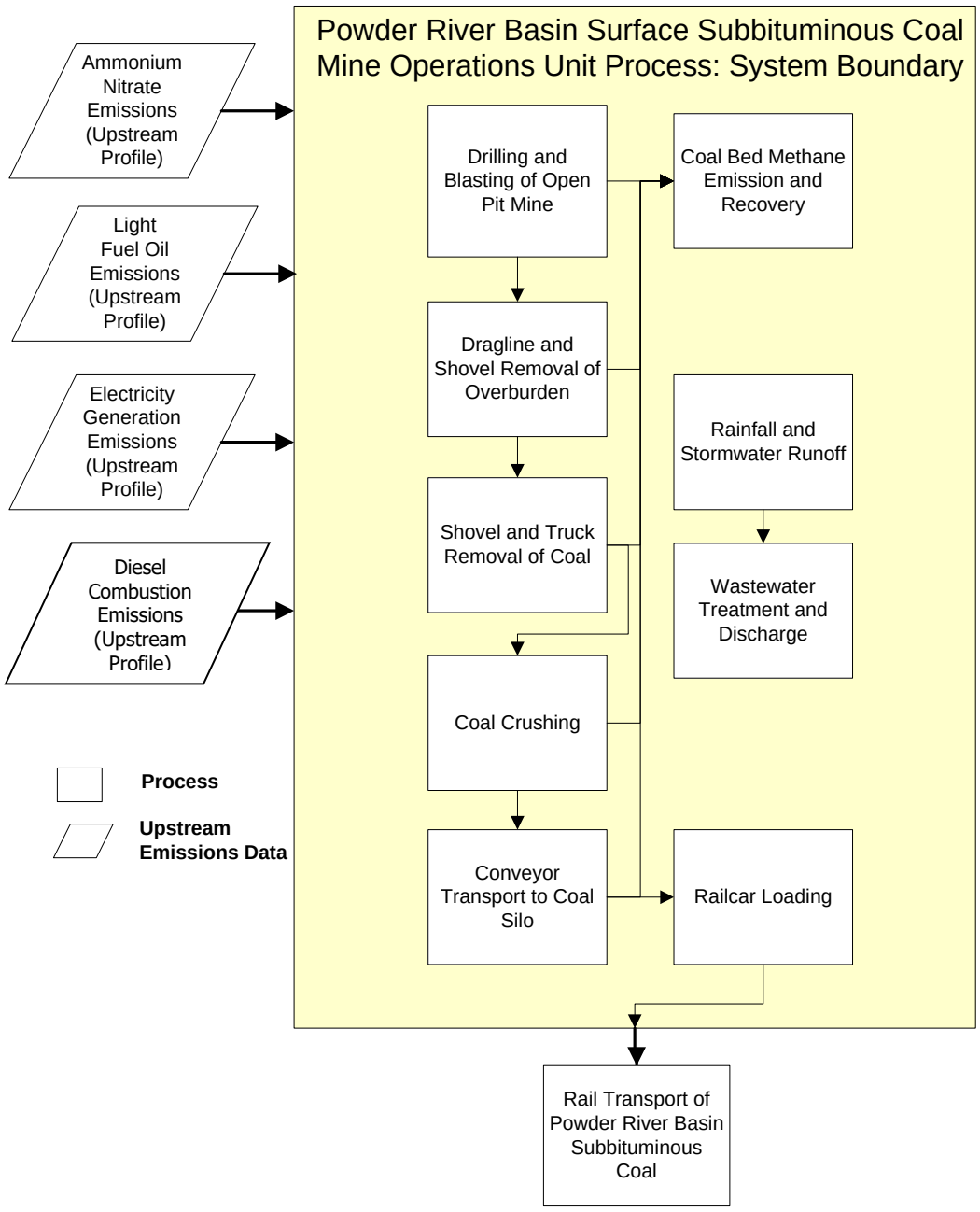
The scope of this process covers the production of coal during operation of a surface mine for Powder River Basin subbitumious coal, from resource extraction to the boundary for LC Stage #2 (e.g., transport of coal). The process is based on the reference flow of 1 kg of cleaned, crushed (to approximately 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. The consumption of diesel is modeled as a tracked input flow in which the associated emissions from diesel combustion are accounted for in an externally linked unit process.

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.

Diesel is assumed to be ultra low sulfur diesel (ULSD; 15 ppm sulfur). The emissions associated with the combustion of diesel are accounted for in an externally linked unit process.

Emissions to air from ammonium nitrate and fuel oil (ANFO) based explosives were calculated using Emission Estimation Technique Manual for Explosives Detonation and Firing Ranges (NPI, 1999). A combustion efficiency of 98 percent was assumed. Unspecified VOCs were calculated as the difference in accounted for VOCs and total VOCs using the weighted average molecular weight of accounted for VOCs for the molecular weight of unspecified VOCs. CO_2 emissions from ANFO combustion were determined by assuming that all unaccounted for carbon in combusted ANFO become CO_2.

Emissions of particulate matter included those due to fugitive coal dust from the mining process are calculated as PM10 and PM2.5. Total coal dust emissions were obtained from the EPA's AP 42's Mineral Products Industry section (EPA 2009). A PM2.5/PM10 ratio was not available for fugitive dust from storage piles so it was assumed to be the same ratio as that of truck loading. It was further assumed that there was an 85 percent reduction of fugitive waste emissions due to remediation efforts.

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)	DQI
Inputs			
Ammonium nitrate [Inorganic intermediate products]	**1.45E-03**	**kg**	2,2
Diesel Combustion, Mobile Sources, Truck [Refinery products]	**8.93E-04**	**kg**	2,2
Light fuel oil [Crude oil products]	**1.01E-04**	**kg**	2,2
Power [Electric power]	**1.40E-03**	**kWh**	2,2
Water (ground water, fresh) [Water]	1.44E-02	L	2,2
Water (ground water, saline) [Water]	1.09E-02	L	2,2
Water (surface water, fresh) [Water]	5.08E-03	L	2,2
Outputs			
PRB Coal (NETL) [Hard coal products]	1	kg	2,2
Carbon dioxide [Inorganic emissions to air]	6.752E-02	kg/kg coal	1,1
Carbon monoxide [Inorganic emissions to air]	1.051E-05	kg/kg coal	1,1
Sulphur dioxide [Inorganic emissions to air]	1.481E-06	kg/kg coal	1,1
Methane [Organic emissions to air (group VOC)]	1.471E-04	kg/kg coal	1,2
Nitrogen dioxide [Inorganic emissions to air]	3.723E-05	kg/kg coal	1,1
NMVOC (unspecified) [Group NMVOC to air]	6.678E-06	kg/kg coal	1,1
Hexane [Group NMVOC to air]	3.339E-03	kg/kg coal	1,1
Benzene [Group NMVOC to air]	2.039E-04	kg/kg coal	1,1
Toluene [Group NMVOC to air]	6.678E-08	kg/kg coal	1,1
Ethylbenzene [Group NMVOC to air]	4.770E-02	kg/kg coal	1,1
Xylene [Group NMVOC to air]	4.046E-03	kg/kg coal	1,1
Cumene [Group NMVOC to air]	1.126E-02	kg/kg coal	1,1
Dust (PM10) [Particles to air]	5.279E-05	kg/kg coal	1,1
Dust (PM2.5) [Particles to air]	3.731E-06	kg/kg coal	1,1
Aluminium [Heavy metals to fresh water]	2.51E-10	kg/kg coal	2,2
Arsenic (+V) [Heavy metals to fresh water]	3.53E-11	kg/kg coal	2,2
Barium [Inorganic emissions to fresh water]	8.88E-10	kg/kg coal	2,2
Biological oxygen demand (BOD) [Analytical measures to fresh water]	7.97E-08	kg/kg coal	2,2
Boron [Inorganic emissions to fresh water]	4.86E-09	kg/kg coal	2,2
Cadmium (+II) [Heavy metals to fresh water]	1.59E-12	kg/kg coal	2,2
Calcium (+II) [Inorganic emissions to fresh water]	1.14E-06	kg/kg coal	2,2
Total organic carbon, TOC (Ecoinvent) [ecoinvent long-term to fresh water]	9.65E-08	kg/kg coal	2,2
Chemical oxygen demand (COD) [Analytical measures to fresh water]	2.69E-07	kg/kg coal	2,2
Chromium (unspecified) [Heavy metals to fresh water]	1.59E-10	kg/kg coal	2,2
Copper (+II) [Heavy metals to fresh water]	7.81E-11	kg/kg coal	2,2
Cyanide [Inorganic emissions to fresh water]	1.13E-10	kg/kg coal	2,2

Fluoride [Inorganic emissions to fresh water]	1.79E-10	kg/kg coal	2,2
Iron [Heavy metals to fresh water]	1.36E-08	kg/kg coal	2,2
Lead (+II) [Heavy metals to fresh water]	1.61E-09	kg/kg coal	2,2
Magnesium (+III) [Inorganic emissions to fresh water]	1.62E-11	kg/kg coal	2,2
Manganese (+II) [Heavy metals to fresh water]	1.40E-06	kg/kg coal	2,2
Mercury (+II) [Heavy metals to fresh water]	2.51E-09	kg/kg coal	2,2
Nickel (+II) [Heavy metals to fresh water]	1.59E-13	kg/kg coal	2,2
Nitrate (as total N) [Inorganic emissions to fresh water]	1.59E-10	kg/kg coal	2,2
Ammonia, as N [Inorganic emissions to fresh water]	9.20E-09	kg/kg coal	2,2
Nitrogen (as total N) [Inorganic emissions to fresh water]	4.77E-09	kg/kg coal	2,2
Phosphorus [Inorganic emissions to fresh water]	1.52E-08	kg/kg coal	2,2
Selenium [Heavy metals to fresh water]	2.39E-08	kg/kg coal	2,2
Sodium (+I) [Inorganic emissions to fresh water]	2.49E-08	kg/kg coal	2,2
Total Dissolved Solids [Analytical measures to fresh water]	2.96E-10	kg/kg coal	2,2
Total Suspended Solids [Analytical measures to fresh water]	2.93E-11	kg/kg coal	2,2
Strontium [Heavy metals to fresh water]	3.46E-06	kg/kg coal	2,2
Sulfates [Inorganic emissions to fresh water]	2.38E-05	kg/kg coal	2,2
Zinc (+II) [Heavy metals to fresh water]	1.62E-07	kg/kg coal	2,2
Water (wastewater) [Water]	1.59E-02	L/kg coal	2,2

* **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.

Inventory items not included are assumed to be zero based on best engineering judgment or assumed to be zero because no data was available to categorize them for this unit process at the time of its creation.

Embedded Unit Processes

None.

References

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Section III: Document Control Information

Date Created: February 10, 2010

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Revision History:

03APR2013 Water use and emissions updated to newer data.

20JAN2015

- Combustion emissions removed and diesel input replaced by "Diesel Combustion, Mobile Source, Truck"
- Speciated fugitive dust emissions by size using PM2.5/PM10 ratio from existing source
- Air emissions from ANFO combustion were added to the Air Emissions Factors and Data Summary tabs
- Added inventory level DQI to Data Summary tab

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