NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Comminution

Reference Flow: 1 kg of solid material, comminuted

Brief Description: This process estimates the electricity use to crush, grind, or mill a solid material

Section I: Meta Data

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

Year Data Best Represents: N/A

Process Type: Manufacturing Process (MP)

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:

feed_size	*[um] Adjustable parameter - Size of the feedstock in micrometers*
prod_size	*[um] Adjustable parameter - Size of the final product in micrometers*
bond_WI	*[kWh/Mg] Adjustable parameter - bond work index for the feedstock*
motor_eff	*[dimensionless] Efficiency of the electric motor(s)*

Tracked Input Flows:

Electricity [Electric Power]	*[Technosphere] Electricity for crushers, grinders, and mills*
Steel	*[Technosphere] Steel grinding media*

Tracked Output Flows:

solid material, comminuted	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *Stage12345_O_Comminution_2014.01.xlsx*, which provides additional details regarding relevant calculations, data quality, and references.

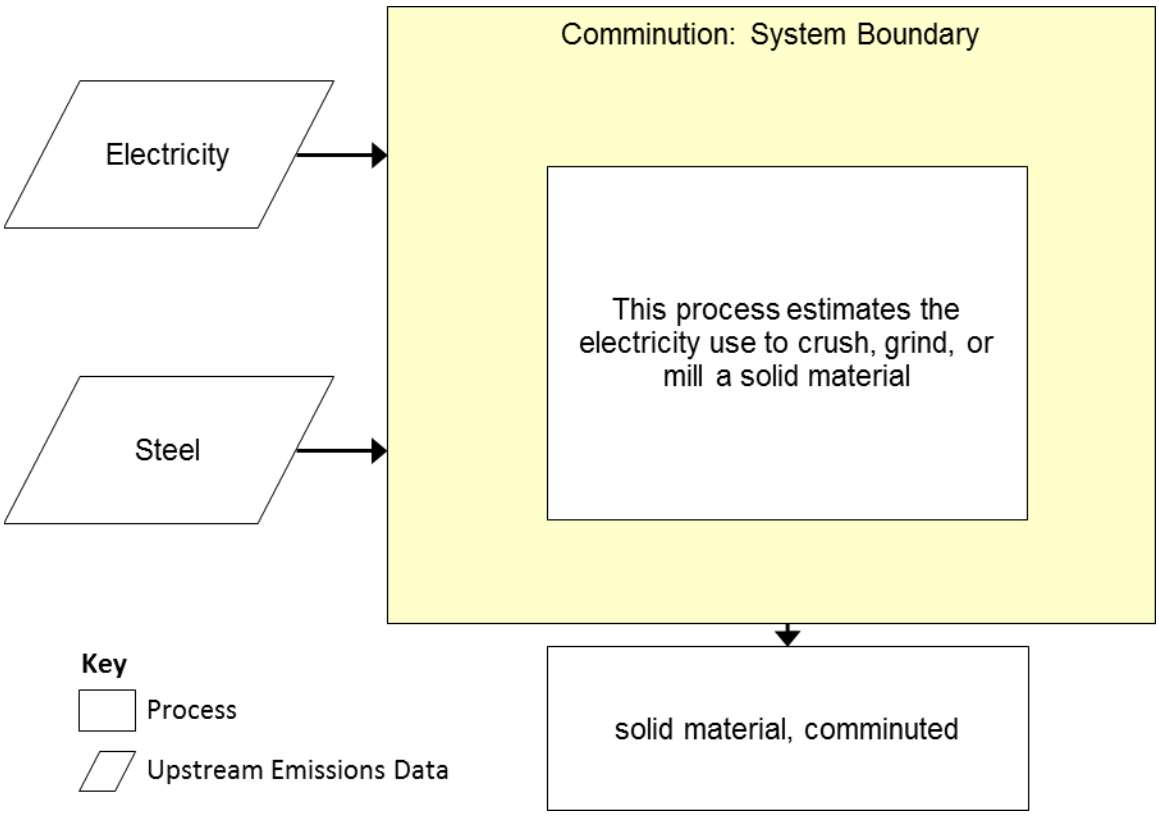
Goal and Scope

This unit process estimates the electricity required to crush, grind, or mill a solid material. The user defines a beginning and end-size which do not need to be restricted to a single step. The user also needs to define the Bond work index for a given material. Examples are provided in this unit process. Emissions from electricity generation are accounted for in upstream processes. The reference flow of this unit process is: 1 kg of solid material, comminuted.

Boundary and Description

Figure 1 provides an overview of the boundary of this unit process. Rectangular boxes represent relevant sub-processes, while trapezoidal boxes indicate upstream data that are outside of the boundary of this unit process. As shown, the upstream emissions from electricity and steel are calculated in other unit processes. The methods for calculating these operating activities are described below.

Figure 1: Unit Process Scope and Boundary



This process uses the Bond Work Index and Equation [1] to estimate the energy required to crush, grind, or mill any solid (Morrell, 2004). Equation [1] was chosen from other relationships because it accounts for increased energy requirements as the outgoing size gets smaller, and appears accurate over a wider range. The values for the constants were not provided explicitly, but were set by fitting the equation to the same general relationship shown in Morrell, 2004 and to known energy requirements for crushing the ore at the Mountain Pass rare earth mine and for crushing coal. Comparisons of the calculated values to the known values are shown in **Table 1**.

$$W = M_i \cdot K \cdot \left(x_1^{-\left(a+b\cdot x_1^{(1+b)}\right)} - x_2^{-\left(a+b\cdot x_2^{(1+b)}\right)} \right) \quad [1]$$

where,
W: Required work (kWh/tonne)
M_i: Bond work index (kWh/tonne)
K: Constant (set to 20)
x_1: Size of outgoing solid (μm)
x_2: Size of incoming solid (μm)
a: Constant (set to 0.3)
b: Constant (set to 0.00001)

The material use associated with grinding/milling media, specifically steel grinding balls, are estimated using data for the Mountain Pass mine. The unit process will determine whether the grinding/milling media is needed based on whether the final solids size is less than 500 micrometers. Crushing processes are assumed to not have many material losses due to wear.

Particulate matter (PM) emissions are provided for the crushing system as a whole for Mountain Pass ore (ENSR International, 1996) and are the only expected emission from any crushing/grinding system. If this process is used for a product other than Mountain Pass ore, then this parameter should be updated.

Table 2 shows the relevant input and output flows of the comminution unit process.

Table 1: Documented and Calcualted Energy Use

	Documented Energy Use (kWh/kg)	Calculated Energy Use (kWh/kg)
Mountain Pass Ore	4.91E-02 (SRK Consulting, 2010)	4.59E-02
Bituminous Coal Crushing	5.69E-04 (DOE & NMA, 2002)	7.49E-04
Bituminous Coal Grinding	3.01E-02 (DOE & NMA, 2002)	3.30E-02

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Electricity [Electric Power]	4.59E-02	kWh
Steel	8.98E-04	kg
Outputs		
solid material, comminuted	1.00E+00	kg
Dust (PM10) [Particles to air]	4.26E-05	kg

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

Embedded Unit Processes

None.

References

Morrell, S. (2004). An alternative energy–size relationship to that proposed by Bond for the design and optimization of grinding circuits. International Journal of Mineral Processing, 74(1–4), 133-141. doi: http://dx.doi.org/10.1016/j.minpro.2003.10.002

SRK Consulting. (2010). Engineering Study for Re-Start of the Mountain Pass Rare Earth Element Mine and Processing Facility Mountain Pass, California. Retrieved from

http://www.sec.gov/Archives/edgar/data/1489137/000095012310065239/d74323fwfwp.htm

DOE and National Mining Association (2002). Energy and Environmental Profile of the U.S. Mining Industry : Chapter 2 Coal. U.S. Department of Energy. http://www1.eere.energy.gov/manufacturing/resources/mining/pdfs/coal.pdf

ENSR International (1996). Molycorp Mountain Pass Mine Expansion Project, Mountain Pass, California, Draft Environmental Impact Report. Camarillo, CA: ENSR International.

ENSR International (2004). Final Environmental Impact Report for Molycorp, Inc. Mountain Pass Mine 30-Year Plan. Camarillo, CA: ENSR International.

Section III: Document Control Information

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