Kennecott Utah Copper
Molybdenum Oxide
Environmental Profile
Life Cycle Assessment
As a contributor to the economic, social, and environmental future of the Salt Lake Valley, we are committed to integrating sustainable development into everything we do.

Our Approach
At Kennecott Utah Copper, sustainable development is integral to our success as a producer of copper cathode, molybdenum, gold, silver, and sulfuric acid, and to the social and financial investment we have made in our stakeholders and surrounding communities.

Consistent with our sustainable development principles, safety remains one of our core values. We are committed to continually improving health and safety performance in our operations. Currently, our safety record is almost three times better than the industry average, and we aim to continually improve this record with the ultimate goal of achieving a sustained zero incident workplace.

This Molybdenum Environmental Profile is intended to summarize the results of the Life Cycle Assessment of the molybdenum originating from Kennecott’s Bingham Canyon Mine. A more detailed profile can also be obtained upon request to help our customers better understand the environmental impacts of their products or services when conducting their own life cycle studies.

What is Molybdenum?
Molybdenum is primarily used in stainless and low alloy steels. It is highly versatile as an alloy in steel - it improves strength, hardness, toughness, weldability, elevated temperature strength, and corrosion resistance of steel.

One of the first applications of molybdenum was as a cost-effective replacement for tungsten in steels used at high speeds, such as in tools like drills and lathes. (The density of molybdenum is about half that of tungsten so it only takes 1% molybdenum to equal roughly 2% tungsten.)

Now, molybdenum is finding its way into a variety of alloys used in harsh operating environments. Molybdenum’s unique properties also make it ideal for many other applications beyond alloys. For example, molybdenum is used in chemical applications such as catalysts, pigments, corrosion inhibitors, smoke suppressants, lubricants and other chemical applications.
How is it Produced?

Many copper mines contain molybdenum, and the Kennecott Bingham Canyon Mine is no exception. Following extraction and crushing, the ore from Bingham Canyon is sent to the concentrator where it is mixed with an aqueous solution and ground to a face powder consistency. Minerals containing molybdenum, copper, gold and silver are separated using a process known as froth flotation.

In froth flotation, the ore is mixed with water and chemicals that cause a change to the minerals surface. Those minerals containing sulfur (such as molybdenum, copper, etc.) float to the surface of the flotation cells when nitrogen is injected allowing separation of the valuable minerals from the tailings (non-valuable) minerals. This first step is known as bulk flotation.

During the second step, molybdenum is separated from copper by adding chemicals that further alter the copper-bearing mineral surface. Molybdenum disulfide attaches to bubbles and floats to the surface of the flotation cell, separating itself from the copper. The molybdenum sulfide, or concentrate, is then filtered, dried, and packaged in large “super sacks” for shipment.

The concentrate is shipped to roasting facilities that further process the concentrate into the base finished product – molybdenum oxide. Molybdenum oxide can also be converted into ferromolybdenum using a smelting process.

Life Cycle Assessment

Life Cycle Assessment (LCA) studies involve the collection, assessment and interpretation of data from an environmental perspective over a product’s life cycle (production, use, and end-of-life). Studies can evaluate:

- the entire product life cycle, often referred to as cradle-to-grave or cradle-to-cradle studies, or
- parts of a product life cycle, referred to as cradle-to-gate or gate-to-gate studies.

Figure 1

GOAL AND SCOPE

DEFINITION

LIFE CYCLE INVENTORY (LCI)

INTERPRETATION

LIFE CYCLE IMPACT ASSESSMENT (LCIA)

Inputs

Energy – Consumables – Raw Materials – (ore, water, air)

MINING

* Drilling
* Blasting
* Loading

CRUSHING

Hauling

Conveying

CONCENTRATING

Grinding
Flootation

Pipeline

SMELTING

Drying
Furnaces
Anode Casting

REFINING

Cathode Production

Molybdenum Sulfide to Roasters

Sulfuric Acid to Customers

Copper Cathodes or Precious Metals to Customers

Figure 2 – Process Flow – Mining to Refining

Other Outputs

Air Emissions
Water
Tailings

Figure 3 – Molybdenum Oxide Environmental Profile

Life Cycle Assessment

GOAL AND SCOPE

DEFINITION

LIFE CYCLE INVENTORY (LCI)

INTERPRETATION

LIFE CYCLE IMPACT ASSESSMENT (LCIA)
Goal and Scope

The Kennecott LCA project included a complete cradle to gate LCA study for copper cathode, gold, silver, molybdenum oxide and sulfuric acid produced by the mining operation. The methodology used was consistent with ISO 14040 series LCA standards, as shown at a macro level in Figure 1.\(^2\)

LCA provides Kennecott with a systematic, comprehensive method to evaluate and communicate the environmental impacts of its products and processes. This approach helps the company ensure that a change made in one of its processes will not result in an equal or greater increase elsewhere, including the upstream supply chain. LCA also provides Kennecott with a way to benchmark and improve its operational performance from a sustainable development perspective. Finally, LCA provides Kennecott with a broader view of how its products impact the world, both positively and negatively.

Specifically, the analysis examined how the production of copper, gold, silver, molybdenum and sulfuric acid impacts environmental indicators, such as smog, acid rain, energy, and greenhouse gases from a cradle to gate perspective. Data gathered for the study represents operations at Kennecott’s facilities during the 2006 calendar year. The study was undertaken for internal use by Kennecott and the absolute numbers are only communicated in a confidential, aggregated manner to select customers and LCA database providers. The functional units for the study were 1000 kg each of copper, molybdenum and sulfuric acid, and 1 kg each of gold and silver.

Life Cycle Inventory: LCI

Life cycle inventory (LCI) is a key step in the LCA process. The LCI catalogs all the environmental inputs and outputs of a product system. Data may be collected first-hand from measurements and estimates of key activities, or the data will be based on information drawn from existing LCA databases. At Kennecott, the majority of inventory data was collected on-site and modeled using GaBi 4.0™ LCA software. Data included or excluded from the study was dependent on the system boundaries identified during the goal and scope definition. The LCA system boundaries for the study are described in Table 1 and Figure 3.

An allocation based on mass was performed in the concentrator model in order to divide the burden in the system to that point between molybdenum and copper concentrate. The copper concentrate is eventually refined into copper, gold and silver. The inputs and outputs of the concentrator as well as all preceding processes (back to earth) were allocated proportionally based on the mass of each product leaving the unit process. For example, if a product accounts for 20% of the total mass of all the products, 20% of the inputs and outputs are assigned to it.

Because Kennecott uses off-site roasting facilities to process the concentrate into molybdenum oxide, it was not possible to collect primary data on this operation. Molybdenum roasting data was provided by the IMoA (International Molybdenum Association), as documented in the February 2008 IMoA report “Life Cycle Inventory of Metallurgical Molybdenum Products: Update Study Final Report.” The worldwide production average for molybdenum roasting presented in this report was adapted to the energy supply at the specific locations Kennecott uses for off-site roasting.

A critical review, or independent verification, was not carried out for this study given the goal definition outlined previously and the requirements of ISO 14040. However, internal reviews were carried out by project team members at both Kennecott and PE Americas. The PE Americas reviewers included Johannes Gediga and Marc Binder, internationally recognized experts in the field of LCA.

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Table 1 – LCA SYSTEM BOUNDARY

<table>
<thead>
<tr>
<th>INCLUDED</th>
<th>EXCLUDED</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Ore and overburden mining</td>
<td>• Capital equipment and maintenance, with the exception of mining equipment</td>
</tr>
<tr>
<td>• Maintenance and operation of mining equipment</td>
<td></td>
</tr>
<tr>
<td>• Internal transportation of materials</td>
<td></td>
</tr>
<tr>
<td>• Extraction, beneficiation and processing of materials</td>
<td></td>
</tr>
<tr>
<td>• Manufacture of raw and processing materials*</td>
<td>• Overhead (heating, lighting) of off-site administrative facilities</td>
</tr>
<tr>
<td>• Transportation of raw and processing materials to Kennecott</td>
<td>• Transportation of finished product from the Kennecott site</td>
</tr>
<tr>
<td>• Off-site molybdenum roasting process**</td>
<td></td>
</tr>
<tr>
<td>• On and off-site power generation</td>
<td></td>
</tr>
<tr>
<td>• On and off-site waste management and disposal</td>
<td></td>
</tr>
<tr>
<td>• Overhead (heating, lighting) of on-site administrative and manufacturing facilities</td>
<td></td>
</tr>
</tbody>
</table>

*LCI data was included for process materials from the GaBi 4 Software database.
**Molybdenum roasting data was provided by the IMoA (International Molybdenum Association), as documented in the February 2008 IMoA report
"Life Cycle Inventory of Metallurgical Molybdenum Products: Update Study Final Report:"

Figure 3 – LCA System Boundary

ENERGY SOURCES
• Natural Gas
• Diesel
• Gasoline
• Coal

PROCESS MATERIALS
• Steel Drill Bits
• Steel Balls
• Rubber Tires
• Lime
• Limestone
• Blasting Materials
• Sodium Hydrosulfide
• Sodium Hydrosulfide
• Sodium Hydroxide
• Sodium Silicate
• Oxygen
• Floculant
• Ammonium Nitrate
• Others

RAW MATERIALS
• Mine Rock
• Water

Kennecott Utah Copper Corporation

MINING → CONCENTRATING → TAILINGS IMPOUNDMENT → MOLY ROASTING → Molybdenum Oxide

AIR EMISSIONS
• Carbon Dioxide
• Nitrogen Oxides
• Sulfur Dioxide
• Particulate Matter
• Others

WATER EMISSIONS
• Iron
• Strontium
• Manganese
• Lead
• Others

OTHER
• Water Discharge
• Waste Rock
Life Cycle Impact Assessment

Following the LCI, a life cycle impact assessment (LCIA) was completed to help Kennecott determine which process or processes have the greatest adverse environmental impact. LCIA helps Kennecott pinpoint opportunities for improvement within its operations.

Estimates for potential environmental impacts are organized under four main impact categories (shown below in Table 2). These impact categories were selected based on:

- the geographical location of Kennecott’s operations, or
- issues Kennecott currently addresses either through its internal reporting or its Environmental Management System.

### Table 2 – LCIA Categories

<table>
<thead>
<tr>
<th>IMPACT CATEGORY</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Energy Demand</td>
<td>A measure of the total amount of primary energy extracted from the earth, including petroleum, hydropower and other sources, taking into account the efficiency of electric power and heating processes.</td>
</tr>
<tr>
<td>Global Warming Potential</td>
<td>A measure of greenhouse gas emissions, such as CO₂ and methane, calculated using the IPCC 2001 Global Warming Potential Index (GWP100).</td>
</tr>
<tr>
<td>Acidification Potential</td>
<td>A measure of emissions to air known to contribute to atmospheric acid deposition (acid rain).</td>
</tr>
<tr>
<td>Photochemical Oxidant</td>
<td>A measure of emissions of precursors that contribute to low level smog, produced by the reaction of nitrogen potential oxides and VOCs under the influence of UV light.</td>
</tr>
<tr>
<td>Creation Potential</td>
<td></td>
</tr>
</tbody>
</table>

### Primary Energy Demand (PED)

![Figure 4: Breakdown of PED by process group for molybdenum](image)

In molybdenum oxide production, the concentrator contributes most to PED, drawing most of its energy for the milling process.

![Figure 5: Breakdown of PED in the concentrator process for molybdenum processing](image)

Molybdenum roasting is conducted at off-site toll manufacturers in Belgium and Mexico.
Molybdenum Oxide Environmental Profile

Global Warming Potential (GWP)

Consistent with the analysis for PED, the concentrator dominates the GWP results for the molybdenum oxide production system. Emissions associated with the concentrator are the result of greenhouse gases emitted through on-site and off-site electricity production. Diesel combustion and electricity consumption at the mine is the second largest contributor of greenhouse gases in the molybdenum production system. Because the GWP breakdown for the concentrator is similar to the PED breakdown on the previous page, the breakdown for the next most significant contributor, mining, is shown.

Acidification Potential (AP)

The majority of AP emissions are generated during the off-site roasting process. This is a result of SOx emissions from the roasting facility, which are created by the removal of sulfur from the molybdenum sulfide in the roasting process and the combustion of natural gas. A breakdown of emissions within the roasting process has not been provided because detailed data beyond what was made available by IMoA was not available for this process.

Photochemical Oxidant Creation Potential (POCP)

The majority of POCP emissions are generated during the off-site roasting process. This is a result of nitrogen oxide emissions generated at the roasting facilities as a result of the combustion of natural gas in the roasting furnaces. As with AP, a breakdown of emissions within the roasting process is not available because of the lack of Kennecott-generated data on this process and the resulting need to use IMoA data for the off-site roasting model. However, emissions attributed to mining are shown.
Disclaimer: The data reported in this Molybdenum Oxide Profile includes off-site impacts as appropriate for LCA. Consequently, the inclusion of such aspects must be considered when comparing the information included in this Profile to other reported data that does not include off-site life cycle impacts. For more information see Table 1 – LCA BOUNDARY SYSTEM on page 5 of the Profile.

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