Executive Summary

Prepared for:
International Molybdenum Association
4 Heathfield Terrace, London, W4 4JE
UNITED KINGDOM

tel: + 44 (0) 20 7871 1580
info@imoa.info
www.imoa.info

By:
Four Elements Consulting, LLC
1619 22nd Avenue East
Seattle, WA 98112
USA

2008

Introduction

Life Cycle Assessment (LCA) has become one of the most valuable environmental tools for assessing the environmental footprint of a product or process. LCA provides quantitative and scientific analyses of the environmental impacts of products and their associated industrial systems. Because it assesses each stage of the life of a product, LCA offers valuable information on a product's supply chain and helps to identify environmental attributes and weaknesses of a product.

Over the past 10 years, the non-ferrous and ferrous metals industries have adopted LCA as an environmental tool of choice to supply environmental information to customers, help identify areas for process improvement, and measure environmental performance. In 2000, the International Molybdenum Association (IMOA) completed a Life Cycle Inventory (LCI), the first part of an LCA, for three molybdenum metallurgical products. In 2006, IMOA updated this LCI since it has been more than five years since the production of the original LCI - an ideal timeframe to revisit processes and data, methodological decisions, and invite other molybdenum producers to join the study to enhance its industry representation.

There is an ever-increasing demand for environmental LCA-related information within all industrial sectors. The building and construction industry, which includes the vast array of materials, products, and industries pertaining to the built environment, is embracing LCA as a means to finding green solutions and improvements for new and existing buildings. Materials suppliers use LCA to highlight positive environmental attributes of their products in buildings, and builders and designers are choosing materials based on these environmental attributes.

Outside the building sector, global companies as part of their sustainable and environmental programs are increasingly asking their suppliers for environmental information that often requires LCAs. On the demand side, consumers and purchasers are using environmental criteria to make their purchasing decisions. LCA is also required in some government purchasing programs; for example, the U.S. federal government is requiring product LCAs to be performed on biobased products under its Federal Preferred Procurement program and the European Union uses LCA for policy-making. In short, environmental information based on LCA has become more the norm than the exception.

Goal

The aim of this study was to provide the Molybdenum Industry with LCIs of three molybdenum products, using current, robust data on molybdenum production. The products studied include:

a. technical grade molybdic oxide ("tech oxide") in powder form;

b. tech oxide in a briquette form;

c. ferromolybdenum in chip form.

The LCI is cradle-to-gate, encompassing the processes that include extracting resources from the earth through the point at which the products are ready for shipment to customers. The LCI is based on current data on process technologies, energy and materials consumed, and environmental outputs. The study results may later be used by the molybdenum industry in the evaluation of potential impacts associated with molybdenum products and their applications. This data used with appropriate methodologies such as the ISO 14000 standards can be the basis for industry benchmarking and management of environmental improvement programmes.

The aim of this study is also to provide the stainless steel industry and other data requestors LCI data for use in other LCI studies.

The geographical scope of the study is worldwide production of molybdenum excluding China, Mongolia, and CIS (former USSR).

This project adheres to the LCA guidelines summarized by ISO, which are the most widely accepted worldwide standards for performing LCA. The requirements of this study are summarised in the following:

■ ISO 14040:1997(E), the International Standard of the International Standardisation Organisation, Environmental management — Life cycle assessment — Principles and framework; and

■ ISO 14044:2006, Environmental management — Life cycle assessment — Requirements and guidelines.

This study aims to meet the essential requirements formalised by these ISO Standards. Specifically:

■ The project aims at taking an inventory of the environmental inflows and outflows associated with the cradle-to-gate production of a product;

■ The goal and scope of the project are precisely defined at the beginning of the project;

■ Assumptions are clearly stated, and the methodology is as transparent as allowed with protection of confidential data;

■ System boundaries, functional unit, and allocation rules are rigorously defined and described;

■ Pertinent data are collected and their quality is rigorously assessed; and

■ Reporting requirements are stated.

The consultant, Four Elements, LLC, worked to ensure that the major LCI-related methodological decisions (allocations rules, etc.) were consistent with the EUROFER and other stainless steel-related LCI studies to the extent that the confidentiality of all studies has been respected.

This LCI will be the most comprehensive, current record of environmental inflows and outflows associated with the production of molybdenum products. However, it should be borne in mind that LCA, like any other scientific/quantitative study, is a far from perfect tool. There is inherently some margin of error due to various limitations such as imperfections of data and unavailability of some relevant data.

Scope and Methodology

LCA is an analytical tool used to comprehensively quantify and interpret the environmental flows (to and from the environment, including air emissions, water effluents, solid waste, and the consumption/depletion of energy and other resources), over the life cycle of a product or process. In LCA, the system boundaries may encompass production and extraction of raw materials, manufacturing of intermediate products, transportation, distribution, use, and a final "end-of-life" stage which often includes multiple parallel paths such as recycling, incineration, landfilling, etc.

An LCA involves three main phases according to ISO 14040:1997(E), Section 3:

1. Life Cycle Inventory (LCI), the "phase of the LCA involving the compilation and quantification of inputs and outputs, for a given product system throughout its life cycle." This phase includes:

- defining the project system boundaries as specified by the goal and scope of the project (i.e., defining which steps are included in the system and which are not);
- collecting data required for each step included in the system; and
- calculating the final inventory.

2. Life Cycle Impact Assessment (LCIA) is the part of the LCA "aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system." The LCIA stage involves categorising inventory flows and characterising those flows according to their overall impact to the category, and examples include global warming potential, natural resources depletion, and eutrophication potential. LCIA was not included in this work.

3. Life Cycle Interpretation is the LCA stage in which the "findings of either the inventory analysis or the impact assessment, or both, are combined in line with the defined goal and scope in order to reach conclusions and recommendations." Examples of life cycle interpretation include contribution analyses and scenario analyses, both of which are used to help understand the results of this study. This study included interpretation.

ISO's representation of LCA actually identifies a process preceding the inventory analysis phase: *Goal and Scope Definition*. Individualising *Goal and Scope Definition* as a separate stage was specially intended as a reminder that the key project objective parameters should be carefully established and clearly stated at the outset of an LCA, and that they guide the subsequent stages. All stages of an LCA should be scoped by the particular use or uses for which the study is intended, and that use of the results may entail some results interpretation.

The three products included in the study are tech oxide in powder form and in briquette form; and ferromolybdenum. Twenty-one sites in eight countries worldwide, including primary and byproduct mines and conversion facilities, participated in the study.

Companies in Europe and the Americas were well represented, and a typical range of operating configurations was included. Aggregation of production data included:

- rigorous data checks;
- application of methodological rules that adhered to the ISO 14040 set of standards;
- calculation of weighted averages of facility data; and
- reporting of statistical information for each LCI flow monitored.

LCI models were built in SimaPro, a commercially-available LCA software, and utilized comprehensive and well-accepted databases which include EcoInvent and the U.S. LCI database.

Results

The LCI results provide industry-average cradle-to-gate data for the defined set of energy and material inputs, air emissions, water effluents and solid wastes for the three molybdenum products studied.

Data from facilities around the world were collected to represent the molybdenum industry. The molybdenum data included in the study represents 52 percent of the total molybdenum produced in the world and 75 percent of production excluding China, Mongolia, and CIS. The cut-off criteria of 99.5 percent of the mass of inputs were exceeded.

Additional information reviewed by study participants over the course of the study includes the geographical location and number of sites contributing to the average, minimum, maximum, and standard deviation for each LCI flow monitored. This level of coverage, coupled with robust upstream input data on materials, makes IMOA's molybdenum LCI one of the most representative LCI studies carried out for these products and provides a sound basis for LCA studies relating to molybdenum.

IMOA proposes to review and update the LCI data on a regular basis to take into account expanding and improved monitoring procedures. Where possible this review will include the broadening of the geographical coverage and number of participating companies.

Availability of Data

Applications for LCI data are to be made through IMOA which will designate an LCI manager from one of the participating companies according to geographical location, to liaise with the applicant.

The normal procedure is to complete a questionnaire describing the intended application of the data and to discuss this with that LCI Manager. This will help to ensure that the IMOA methodology and results can be applied appropriately and will be compatible with the goals of the study.

Conclusions

The IMOA LCI study has generated a large, rigorous and representative database. With an understanding of the limitations of the study, the results can be used to assist decision-making and evaluating the performance of molybdenum products through their life cycle (i.e., through use and end-of-life) in the context of sustainable development and practices.

The results also provide the opportunity for participating companies to benchmark and evaluate improvement measures to their processes and product systems.

Industry expertise has been enhanced by involvement in the study and the industry is now better equipped to provide technical support to customers and users of molybdenum products on LCA issues.

The goal of IMOA's LCI programme is to keep the database current and further enhance the methodology and understanding of the study. Recommendations for improvement concerning both the documentation and the data are welcome.

For LCA to be used as a reliable tool for decision-making, high quality data, sound methodology and transparent reporting are essential. This study is a major step towards enhancement of these standards and the molybdenum industry intends to continue and encourage this trend in its future programme of work.

IMOA®

4 Heathfield Terrace, London, W4 4JE
UNITED KINGDOM

FOUR ELEMENTS LLC