Introduction

Increasingly the zinc industry is being asked to provide information to downstream users of zinc and zinc containing products on the environmental footprint of the materials it produces. Material specifiers and product engineers in key end-use markets such as construction and transportation are becoming more interested in selecting materials that have the best environmental profile while meeting traditional cost, quality and technical performance criteria.

Understanding the environmental footprint of zinc starts with documenting the resource requirements (energy and non-energy) and environmental releases associated with upstream operations (e.g. mining and refining); but it also involves understanding the impacts and benefits of using zinc during other stages in the product life cycle. These benefits can arise in use (e.g. extending the life of galvanized steel products) and through end-of-life recycling (e.g. by utilizing recycled zinc to create new products).

This environmental profile was developed to provide updated information and life cycle data on primary zinc to stakeholders along the zinc value chain. It can be used to understand and improve the life cycle impacts and benefits of zinc and zinc containing products.

What is Zinc?

First recognized as a metal in 1374, zinc and zinc compounds have been used for centuries for a variety of applications, from making brass to healing wounds. zinc is present naturally in rock and soil, air, water and the biosphere and is essential to human, animal and crop health. When the supply of available zinc in soils is inadequate, crop yields are reduced and the quality of crop products is impaired. Dietary zinc deficiency is a critical problem that affects hundreds of millions of people in many parts of the world.

A very versatile material, zinc also plays a key role in a variety of industrial and product applications. Zinc protects steel from rust – making steel more durable and longer lasting. Less corrosion also means fewer costs and less environmental impact for maintenance. In fact, architectural zinc sheet applications – roofing, gutters and downpipes, etc. – can last longer than the lifetime of the building where they are applied. Like other metals, zinc can be recycled indefinitely without changing its properties.

These inherent characteristics of zinc – natural, essential, durable, recyclable – make it a desirable material for a range of applications in transportation, infrastructure, consumer products and food production.

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1. This profile updates information originally published in Zinc Environmental Profile, 2010.
Where does zinc come from?

Minerals and metals are mostly obtained from the earth’s crust. The average natural level of zinc in the earth’s crust ranges between 10 and 300 mg/kg, (averaging 70 mg/kg). In some areas, zinc has been concentrated to much higher levels by natural geological and geochemical processes (5-15% or 50,000 – 150,000 mg/kg). Such concentrations, found at the earth’s surface and underground, are ore bodies.

Zinc ore deposits are widely spread throughout the world. Zinc ores are extracted in more than 50 countries. China, Peru, Australia, India and Canada are the biggest zinc mining locations. Zinc is normally associated with lead and other metals including copper, gold and silver.

Sustainability Attributes of Zinc

Zinc is Natural
• Zinc is present naturally in rock and soil, air, water and the biosphere

Zinc is Essential
• All living organisms – plants, animals and humans – need Zinc to live

Zinc is Durable
• Zinc extends the life cycle of steel and reduces maintenance costs

Zinc is Sustainable
• Zinc can be recycled indefinitely, without loss of its physical or chemical properties

Zinc is Vital
• Zinc is vital for construction, food production, health, pharmaceuticals, infrastructure, transport... for life itself
How is zinc produced?

Zinc Mining

80% of zinc mines are underground and 20% are open pit mines. Rarely is the ore, as mined, rich enough to be used directly by smelters without first being concentrated. Zinc ores contain 5 to 15% zinc. To concentrate the ore it is first crushed and then ground to enable optimal separation from the other minerals. Typically, a zinc concentrate contains about 55% of zinc with some copper, lead and iron. Zinc concentration is usually done at the mine site to keep transport costs to smelters as low as possible.

How is zinc used?

Worldwide, approximately 13 million tons of zinc are produced annually. Nearly 60% of this amount is used for galvanizing to protect steel from corrosion (Figure 1). About one third is used to produce alloys with copper (brass) and aluminum (die casting). The remainder is used to produce zinc compounds (mainly oxide and sulfate) and semi-manufactures including wire, sheet, and dust.

These first use consumers then convert zinc into a broad range of products for end use. Main end use application areas are: construction (45%), transport (25%), consumer goods & electrical appliances (23%) and general engineering (7%).

Figure 1: Major First Uses of Zinc

Figure 2: Schematic illustration of the zinc concentrate production
Zinc Metal Refining

Over 95% of the world’s zinc is produced from zinc blende (ZnS). Apart from zinc the concentrate contains 25-30% sulphur as well as different amounts of iron, lead and silver and other minerals. Before metallic zinc can be recovered, by using either hydrometallurgical or pyrometallurgical techniques, sulphur in the concentrate must be removed. This is done by roasting or sintering. The concentrate is brought to a temperature of more than 900°C where zinc sulphide (ZnS) converts into the more active zinc oxide (ZnO). At the same time sulphur reacts with oxygen to produce sulphur dioxide, which subsequently is converted to sulphuric acid – an important commercial by-product.

Over 90% of zinc is produced hydrometallurgically in electrolytic plants. Figures 2 and 3 show the basic steps in the production of special high grade zinc using the electrometallurgical zinc smelting process.

“Global Warming Potential has decreased by 18%... Primary Energy Demand by 25%.”

Teck Resources Zinc Refinery in Trail, British Columbia, Canada

Zinc Environmental Profile - 2015 Update

Figure 3: Schematic illustration of the Special High Grade Zinc production
How is LCA used?

Typically LCA is used to evaluate the environmental implications of materials and products although services have also been studied using this tool. According to the ISO Standard on LCA it can assist in:

- Identifying opportunities to improve the environmental aspects of product systems at various points in the life cycle
- Making decisions in industry, governmental or non-governmental organizations (e.g., strategic planning, priority setting, product or process design or redesign)
- Selecting relevant indicators of environmental performance, including measurement techniques
- Marketing (e.g., an environmental claim, eco-labeling scheme or environmental product declaration)

Various software tools and databases are available that enable the user to track materials flows, energy flows and emissions from any industrial system. Typically the databases provide generic information on materials, energy supply options, transportation options and end-of-life management.

A product manufacturer (typically an engineer or product designer) can add in data and put together a comprehensive set of information on the entire product system. Scenario analysis can then be conducted to determine the implications of changes to the systems. In some cases short screening level studies are done that can quickly help the user understand where potential “hot spots” in the product system exist.

Primary zinc LCA overview

The specific goal for this life cycle project was to update the LCA information for zinc production gathered from the previous global assessment conducted in 2009 (reference year was 2005) as part of the Zinc for Life program. This up-to-date data for primary zinc (mine to ingot at refinery gate; Figure 5) is made available to LCA practitioners and end use markets, and to support LCA projects on zinc containing products.

Data for the study was provided by IZA members. The participating members represented mining and smelting operations in Asia (Korea and some data from China), Australia, Europe, North America, South Africa, and South America. As a result, participating members represented 4.9Mt of zinc concentrate production and 3.4Mt of Special High-Grade Zinc (SHGZ) production. This data coverage represented 38% of the global zinc mine production and 27% of the global zinc production volume for the reference year 2012. This number is considered high for a global study, therefore the resulting final LCI on primary zinc production is considered representative of the industry.
Study results

To support the study, IZA members provided data on energy use, materials use and environmental releases from the extraction of the zinc ore at the mine site to the production of primary zinc and shipment of zinc ingot from the gate of facility where it is produced.

Primary data for the main unit processes of zinc production and secondary data, from a variety of sources, was used to model upstream materials production (fuel, auxiliary materials, electricity, etc.). The study also looked at five impact categories: primary energy consumption, global warming potential, acidification potential, eutrophication potential and photochemical oxidant creation potential.

Relative to the previous LCA for primary zinc, this update concluded that primary energy demand and emissions to air decreased by at least 15% (Table 1). In fact, the 24% reduction in Primary Energy Demand (from 49,134 Mj in 2005 to 37,444 Mj in 2012) was accompanied by a 34% increase in the use of renewable energy resources (hydro, wind, solar). Similarly, all Life Cycle Impact Assessment (LCIA) indicators, except for a relatively stable result for Eutrophication Potential, also decreased by up to 26% (Table 1). In particular, Global Warming Potential decreased 15% (from 3,124 Kg CO2 equivalents in 2005 to 2,660 Kg CO2 equivalents in 2012) since the previous global LCA for primary zinc was conducted.

Changes to the LCA indicators for primary zinc production occurred for two reasons. First, changes to the characteristics of country specific power grid mixes (primary energy demand) have occurred, which affects energy efficiency. Second, additional representation in production and geography improved indicators due to inclusion of integrated operations and better allocation methodologies for coproducts.

Figure 5: Schematic illustration of the “cradle-to-gate” and the “gate-to-gate” system of primary zinc production
As with any material, the inputs, environmental emissions and LCIA indicators for zinc are best understood in relation to the products it is used in. For example zinc’s anti-corrosion properties can extend the life of a variety of steel products and reduce the overall impact of those products, therefore making them more sustainable.

**Table 1:** Illustration of the “cradle-to-gate” system of primary zinc production. Selected LCIA parameters (GWP, AP, EP, POCP, and ODP) estimated based on impact methodology CML 2001 (April 2013).

<table>
<thead>
<tr>
<th>Selected LCI Parameters of Special High Grade Zinc</th>
<th>Inventory Results per Metric Ton (2009)</th>
<th>Inventory Results per Metric Ton (2014)</th>
<th>Change from 2009 to 2014</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Primary energy demand</td>
<td>49,134</td>
<td>37,444</td>
<td>-24%</td>
<td>MJ</td>
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<tr>
<td>Non-renewable energy resources</td>
<td>41,644</td>
<td>27,301</td>
<td>-34%</td>
<td>MJ</td>
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<td>Renewable energy resources</td>
<td>7,489</td>
<td>10,143</td>
<td>+35%</td>
<td>MJ</td>
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<td>Carbon dioxide</td>
<td>3,041</td>
<td>2,541</td>
<td>-16%</td>
<td>kg</td>
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<td>Sulfur dioxide</td>
<td>9.2</td>
<td>5.87</td>
<td>-36%</td>
<td>kg</td>
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<td>Global Warming Potential (GWP)</td>
<td>3,124</td>
<td>2,660</td>
<td>-15%</td>
<td>kg CO₂-eq</td>
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<td>Acidification Potential (AP)</td>
<td>23.5</td>
<td>17.5</td>
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<td>kg SO₂-eq</td>
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<td>Eutrophication Potential (EP)</td>
<td>2.45</td>
<td>2.55</td>
<td>+4%</td>
<td>kg PO₄³⁻-eq</td>
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<td>Photochemical Ozone Creation Potential (POCP)</td>
<td>1.27</td>
<td>0.932</td>
<td>-26%</td>
<td>kg C₂H₄-eq</td>
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<td>Ozone Layer Depletion Potential (ODP), steady state</td>
<td>0.0003</td>
<td>-8.3 E-08*</td>
<td>-99%</td>
<td>kg R11-eq</td>
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</tbody>
</table>

*Net negative impact results have occurred due to the energy credit associated with waste incineration and should not be interpreted in a way that an increase in consumption of the products under study will lead to any ‘reversal’ of environmental burden elsewhere.

**Summary**

The information provided herein represents an update of the global zinc Life Cycle Inventory (LCI) originally conducted by IZA in 2010. Results showed a significant improvement in virtually all measured metrics in the study. The study data has been submitted to the leading global LCI databases used by LCA practitioners, specifiers, and others to make informed material decisions when using zinc. The data has also been made available to our industry partners from the steel, galvanizing, sheet, and die casting industries and could further benefit IZA members in benchmarking their own operations against the global average.