ZINC

environmental profile

LIFE CYCLE ASSESSMENT

2023 UPDATE BASED ON 2021 INDUSTRY DATA

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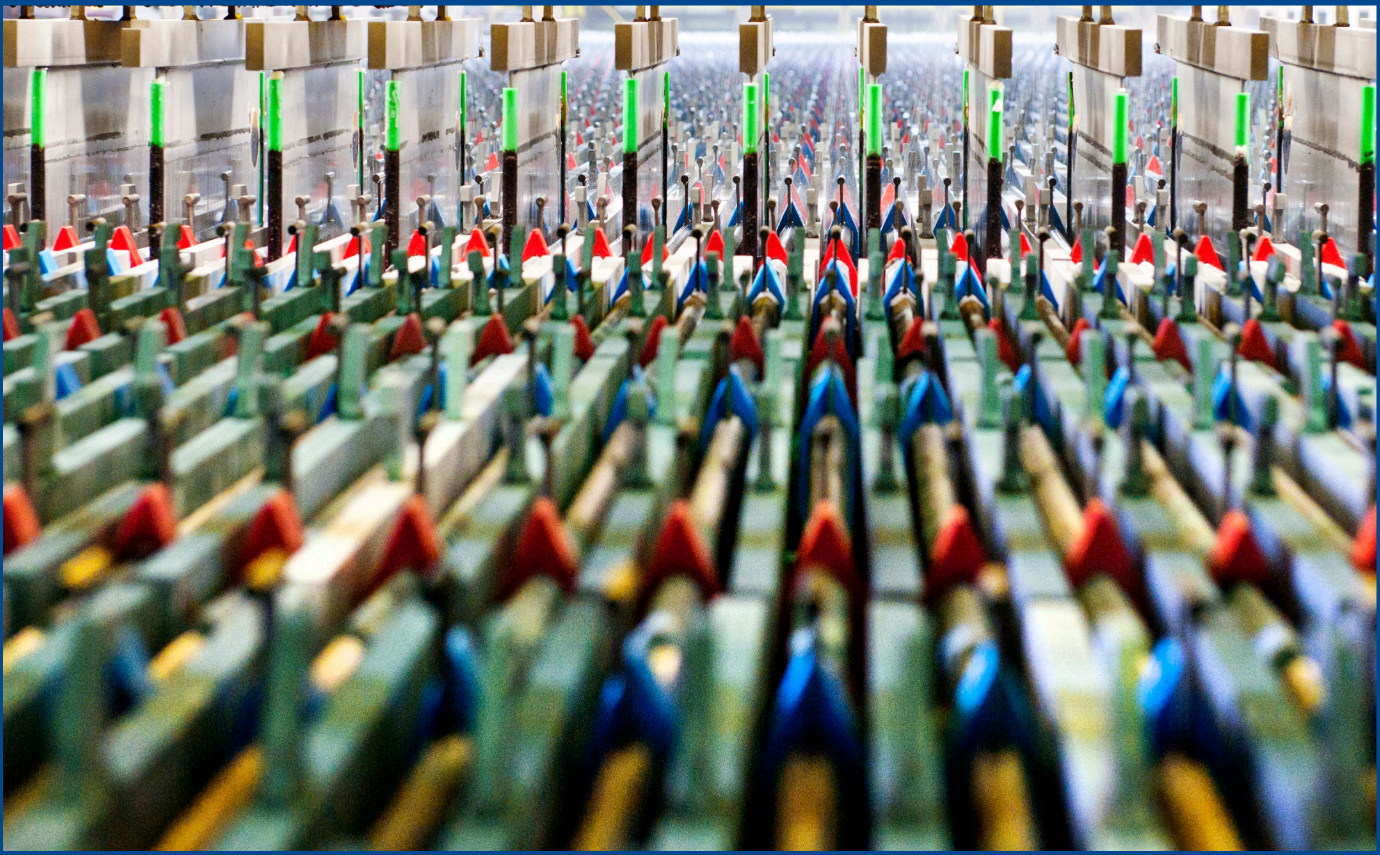
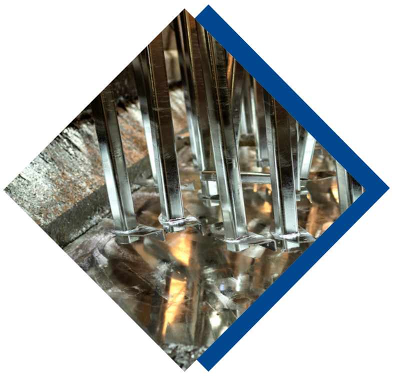


Introduction

The environmental footprint of a material today is one of the key performance indicators for market access. Material specifiers and product engineers in end-use markets, such as construction and transportation, select materials with optimal environmental profiles while meeting traditional cost, quality, and technical performance criteria. Downstream users rely on environmental footprints when defining the positive difference their product makes and regulators increasingly use environmental footprints for setting goals and targets.

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 steel products by galvanizing) 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 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 and nutritional quality are reduced. Dietary zinc deficiency is a critical problem that affects over one billion 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 lower lifetime costs and less environmental impact during maintenance. In fact, architectural zinc sheet applications – roofing, gutters, and downpipes, etc. – can last longer than the lifetime of the building itself. Like other metals, zinc can be recycled over and over again without changing its properties.

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

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 called ore bodies.

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

How Is Zinc Used?

Worldwide, approximately 13.5 million tons of refined primary 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.

How Is Zinc Used? ...cont.

First use consumers then convert zinc into in a broad range of products for end use. Main end use applications include construction (45%), transport (25%), consumer goods & electrical appliances (23%) and general engineering (7%).

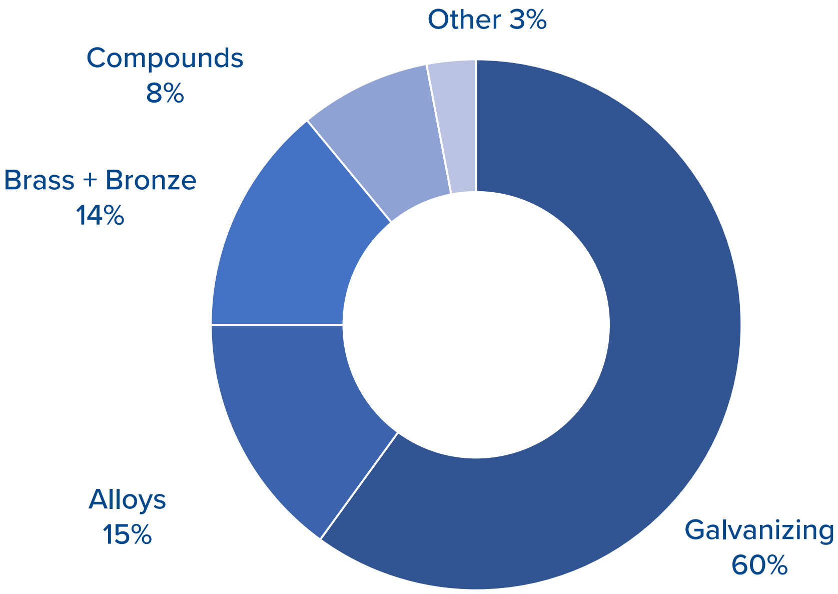
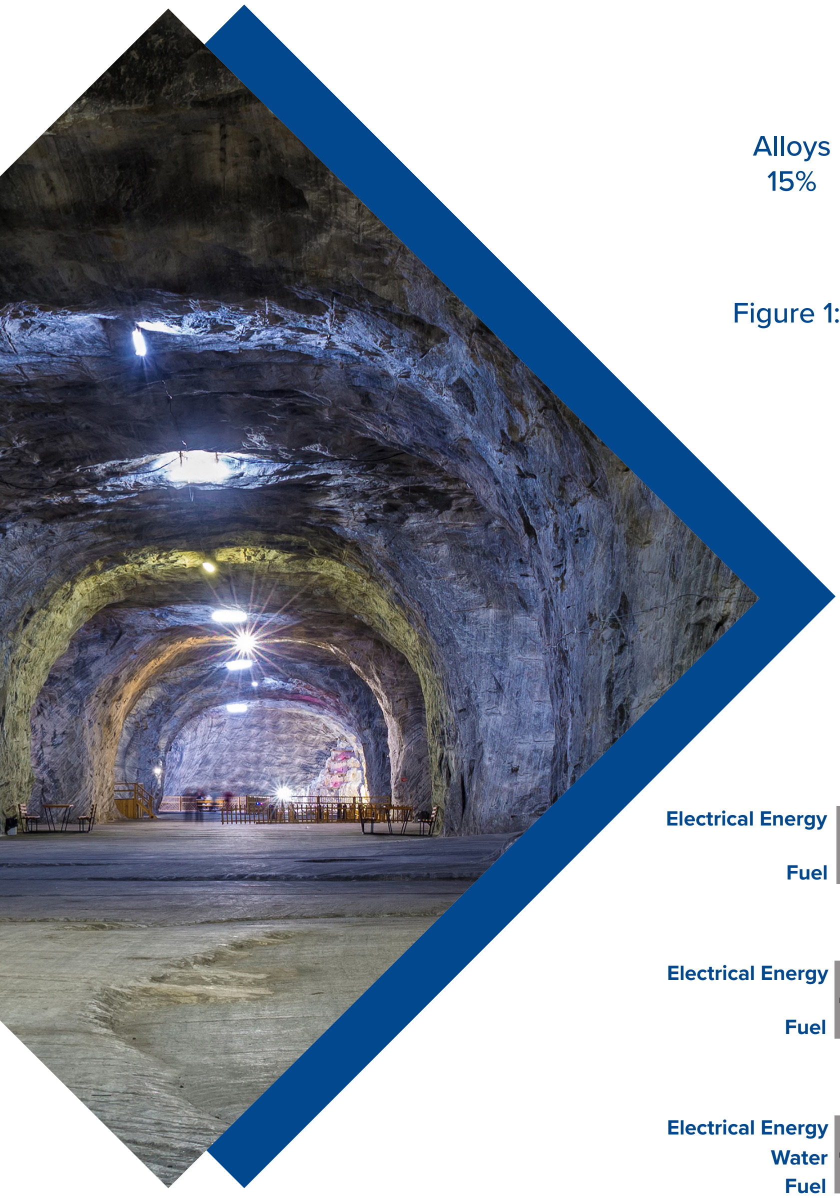


Figure 1: Global Refined Zinc Consumption by First Use.



How Is Zinc Produced?

Zinc Mining

90% of zinc mines are underground and 10% are open pit mines. Zinc ores contain 5 to 15% zinc. Typical accompanying elements are copper, lead, cadmium, and silver but also indium, germanium. To concentrate the metals in the ore, it is first crushed and then ground to enable optimal separation from the other minerals that are concentrated in their respective concentrates (Figure 2). Most mines are multi-metal mines producing more than one concentrate type. Typically, zinc concentrate (55% zinc) is prepared at the mine site to keep transport costs to smelters as low as possible.

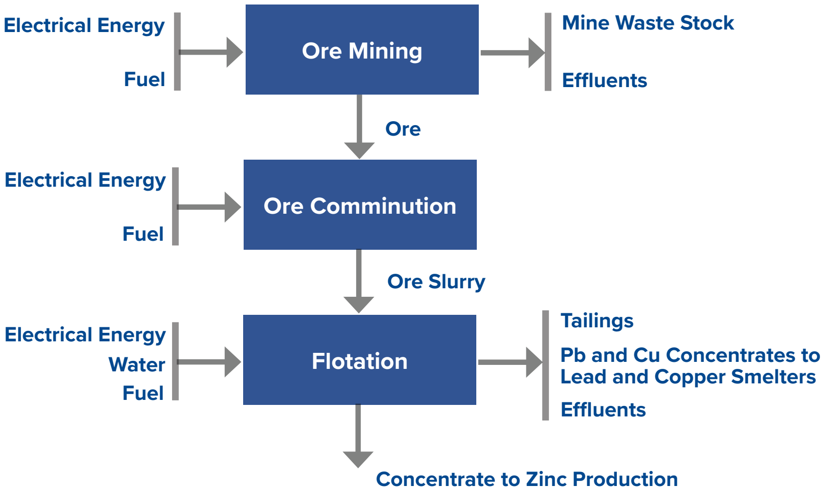


Figure 2: Schematic Illustration of Zinc Concentrate Production.

Zinc Metal Production

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

Roasting is followed by leaching and purification before zinc being recovered by electrolysis to produce zinc of a special high-grade quality (SHG; 99.995%). Over 90% of all zinc worldwide is produced in this type of hydrometallurgical process. The remainder involves pyrometallurgical technologies such as the Imperial Smelting furnace.

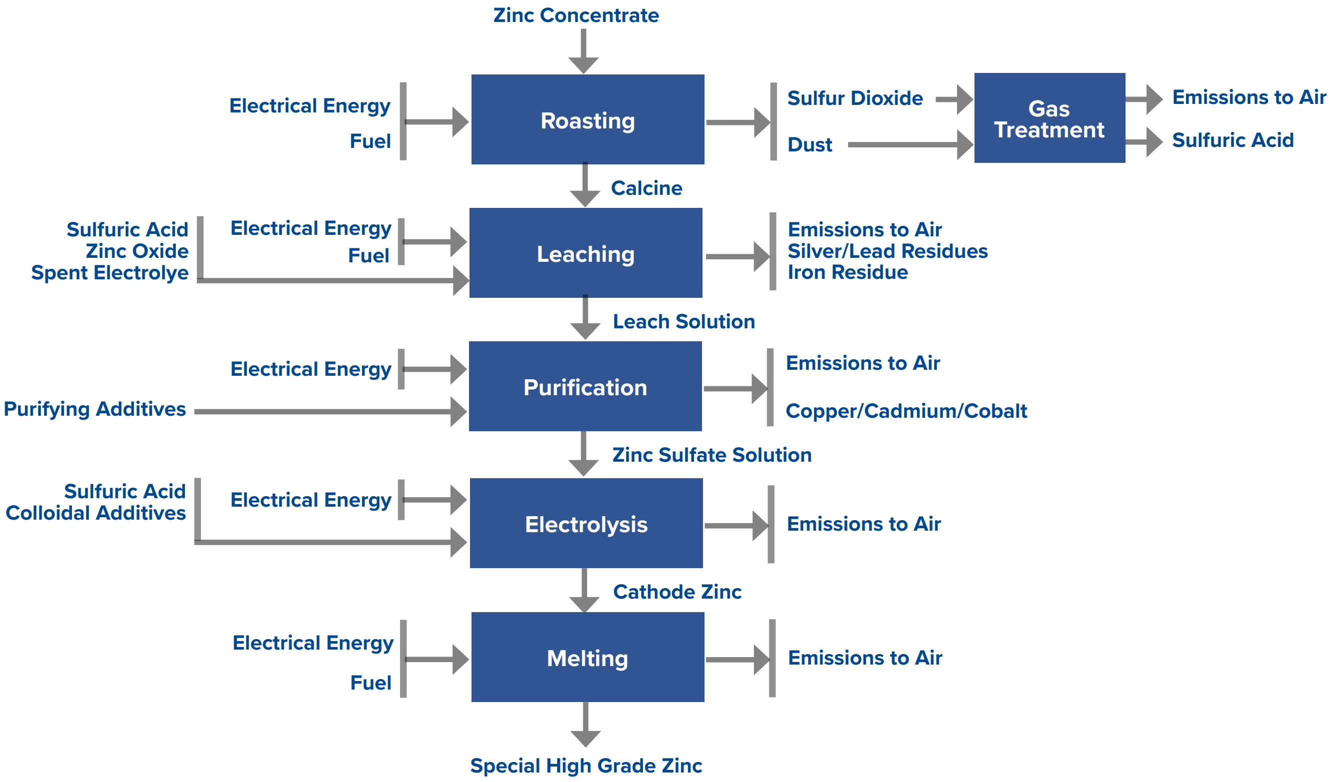


Figure 3: Schematic Illustration of the Hydrometallurgical Special High-Grade (SHG) Zinc Production

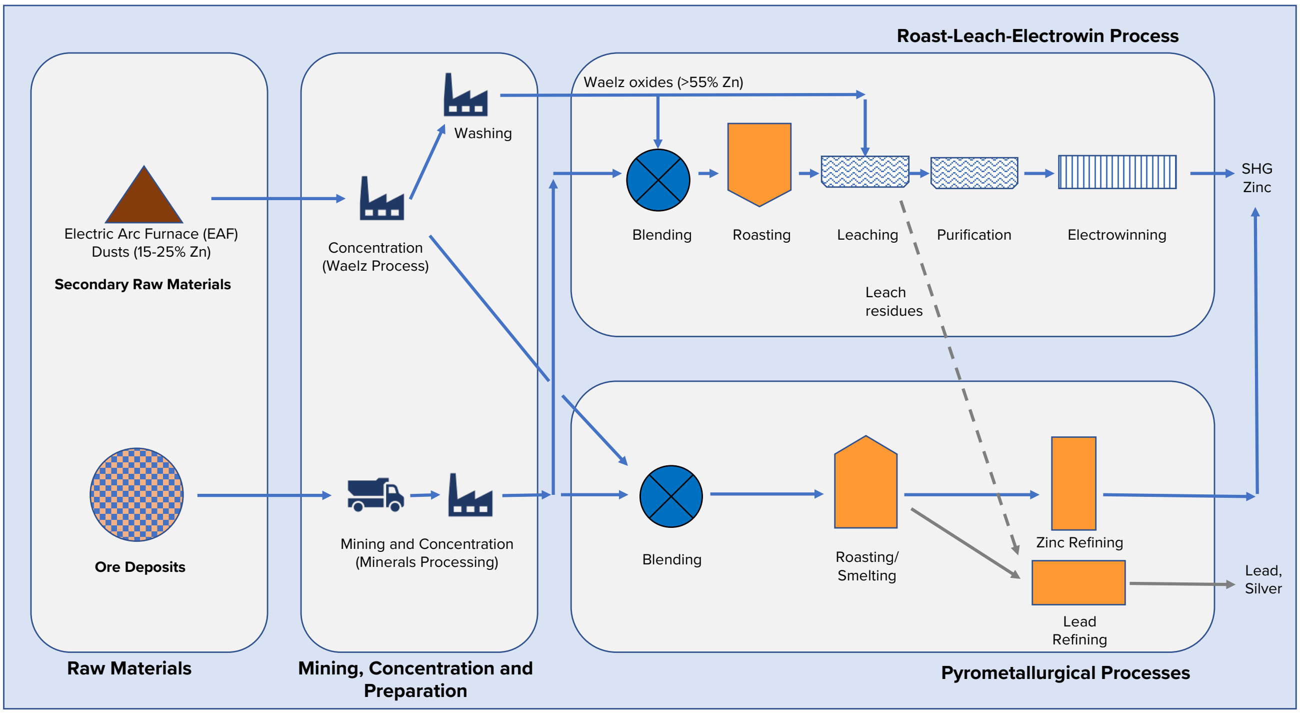
Recycling of Zinc in Primary Zinc Production

Zinc primary production offers the unique opportunity to include zinc containing recycling materials already in the smelting phase. Secondary raw materials used in primary zinc production contain zinc as an oxide. They can be added to the roasting or the leaching stage depending on their chemical quality and the specific technical conditions at the smelter site. The most widely used secondary raw material for SHG zinc production is Waelz oxide, an enriched flue dust coming from steel remelting facilities (electric arc furnace, EAF). When remelting galvanized steel, zinc evaporates and leaves the furnace with the flue dust (EAF dust). However, since EAF dust is not rich enough for direct use in zinc production (15-30% zinc content), Waelzing is a widely used technology for enriching zinc up to levels consistent or above zinc content in concentrates.

Secondary Raw Materials in Primary Zinc Production

Recycling secondary raw materials in primary zinc production contributes to resource efficiency and zinc circularity. On average as represented in the IZA LCA update, about 14% of all zinc produced came

Figure 4: Integration of Zinc Recycling in Primary Zinc Production



from secondary sources such as Waelz oxide. Benefits of this recycling pathway include:

- Secondary raw materials such as Waelz oxide boost smelter throughput without increasing the tonnage of iron residue and sulfuric acid typically associated with primary zinc production
- Increasing zinc recycling from steel mill dust makes landfilling of a hazardous waste redundant.
- Zinc production from secondary raw materials causes lower environmental impacts than zinc mining e.g., in the LCA impact categories land-use, water consumption, and resource depletion.

Due to the enforcement of regulations banning the landfill of industrial wastes such as EAF dust in more and more jurisdictions, the global average recycled content of zinc in primary zinc production is expected to further increase.

The carbon footprint of Waelz oxide is higher than the carbon footprint of zinc ore concentrate because carbon is used as a reductant in the enrichment process. Despite the enrichment of zinc in EAF dusts consuming carbon for chemical reduction purposes, the associated carbon footprint does not have a major impact on the overall (cradle-to-cradle, EPD) LCA of a galvanized product. Research aiming at reducing the carbon footprint of Waelz oxide is ongoing at various levels.

Given the complexity of recycling routes for zinc, scenarios must be assessed on a case-by-case basis and decision makers should not rely on individual impact categories for making material or product selections.

Life Cycle Assessment (LCA)

LCA is a decision-making tool to identify environmental burden and evaluate the impact on the environment caused by a material, product, process, or service over its life cycle from cradle to gate (typical for basic raw materials and commodities) or cradle to grave (typical for products and services). LCA has been standardized by the International Organization for Standardization (ISO 14040 and 14044) and forms the conceptual basis for management approaches and standards as well as for regulations and product design.

There are four components to a typical LCA study (Figure 5):

Goal and Scope: Define reference units, scope and boundaries, audience, and uses of the study;

Life Cycle Inventory: Data is collected on all relevant inputs and outputs; physical system is modeled;

Life Cycle Impact Assessment: Potential impacts associated with the system being studied are assessed; and

Interpretation: Results used to help decision-makers understand where the greatest impacts are and to determine the implications of changes to the system (e.g., energy supply or industrial process options).

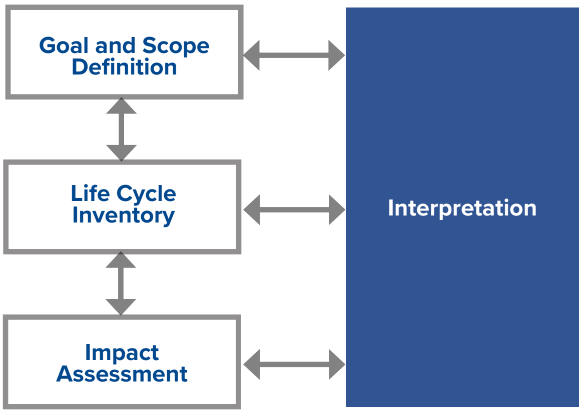


Figure 5:
Life Cycle Assessment Framework

For the impact assessment, impact categories are calculated from the LCI. In the light of Climate Change, the most prominent impact category today is the Global Warming Potential, also referred to as Product Carbon Footprint. Other impact categories of increasing interest are e.g., the Water Footprint or Land Use.

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 assessments conducted by IZA in 2009, 2012 and 2022. This up-to-date data for primary zinc (mine to ingot at refinery gate; Figure 6) is made available to LCA practitioners and end use markets, to support LCA projects on zinc containing products.

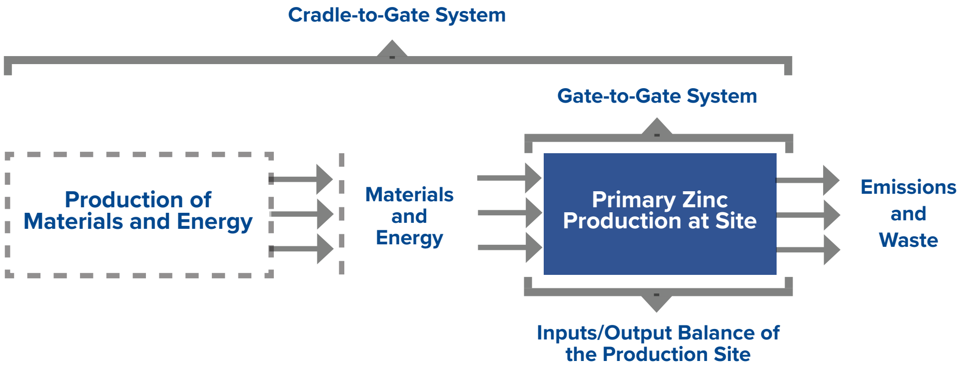


Figure 6: Schematic Illustration of the "Cradle-to-Gate" and the "Gate-to-Gate" System of Primary Zinc Production.

Data for the study was provided by IZA members. The participating members represented mining and smelting operations in Asia, Australia, Europe, North America. As a result, participating members represented 3.9 Mt of mined zinc and 4.3 Mt of Special High-Grade Zinc (SHGZ) production. This data coverage represented 30% of the global zinc mine production and 31% of the global refined zinc production volume for the reference year 2021. 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, 25 mines and 24 smelters from the IZA membership 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. Zinc smelters operating Waelz kilns on site have included these in the data collection process.

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 relevant and fully developed impact categories: global warming potential (GWP), primary energy demand non-renewable (PEDnr), acidification (AP) and eutrophication (EP) potential, photochemical ozone creation potential (POCP), abiotic resource consumption. Anticipating an increasing interest in water footprint for the future, three different types of water-related impact categories were included: blue water consumption, water scarcity index (WSI), and available water remaining (AWaRe).

To account for valuable metals in intermediate products of zinc production, mass allocation was used. For non-metal co-products such as sulfuric acid, system expansion was applied (Table 1).

Table 1: Selected LCIA Parameters Based on 2021 Industry Data per Metric Ton of Product (SHG Zinc), Using Mass Allocation for Valuable Metals in By-Products and System Expansion (Credits) for Sulfuric Acid.

Impact Category [ref. CML2001 - Aug. 2016]	Unit per metric ton of zinc	Global average		European average	
		Primary zinc production	Primary zinc production with 14% recycled content	Primary zinc production	Primary zinc production with 14% recycled content
Global Warming Potential (GWP)	kg CO2 eq.	3500	3800	2000	2500
Acidification Potential (AP)	kg SO2-eq	29	33	15	20
Eutrophication Potential (EP)	kg PO43--eq	1.3	1.3	1.1	1.0
Photochemical Ozone Creation Potential (POCP)	kg C2H4-eq	1.3	1.5	0.7	1.0
Primary Energy Demand, Total (PED)	MJ	58000	63000	51000	58000
Primary Energy Demand, Non-Renewable (PEDnr)	MJ	43000	48000	31000	39000
Blue Water Consumption	L water	76000	74000	71000	62000
Representation of Global/European (Incl. Norway) Production	%	31	31	94	94

Results from this update based on 2021 industry data are in the same order of magnitude as in the previous update which was based on industry data from 2018. However, a direct comparison of both studies is not recommended. Changes to the LCA indicators for primary zinc production since the last update occurred for multiple reasons::

- Market and geographic representation;
- LCA methodologies for characterizing impact categories have changed;
- Characteristics of country specific power grid mixes (primary energy demand) have been refined to better reflect local energy efficiencies.

Evaluating the performance of the global zinc industry will occur through ongoing annual updates to the Life Cycle Inventory.

Outlook

IZA member companies recognize the importance of understanding and minimizing their carbon footprint at company level as well as for the whole of the zinc sector. At the same time, it is the ambition of the zinc industry to provide the best possible and most recent data to zinc users, designers, and regulators. The global average LCA data sets for SHG zinc production are updated more frequently now with an increasing global and regional representation.

Sustainability Attributes of Zinc

Zinc is Natural - and 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 - extending the life cycle of steel and reduces maintenance costs.

Zinc is Circular - and can be recycled from technical applications, without loss of its physical or chemical properties.

Zinc is Vital - for construction, food production, health, pharmaceuticals, infrastructure, transport... for life itself.

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