

Sustainability and the Zinc Battery Supply Chain

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NAATBatt Zinc Battery Workshop V
Nov. 10, 2022



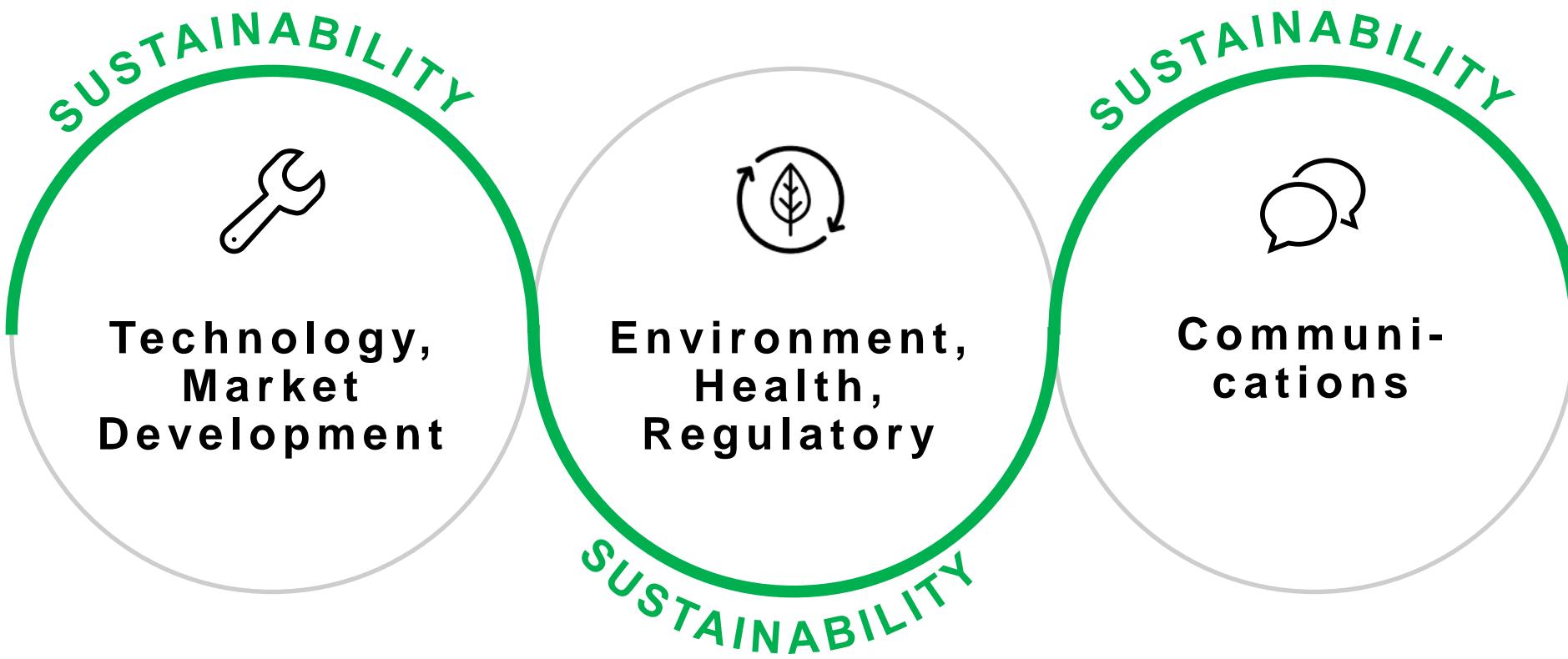


International Zinc Association (IZA)

- 40 full members
- 183 affiliate and associate members
- Offices in North Carolina, Brussels, Delhi, Shanghai

IZA represents the global zinc industry (mining, production, first use production and recycling)

IZA's Core Program Areas



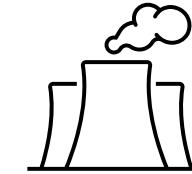


1. Responsible Sourcing

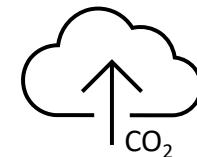
LME Requirements – Joint DD Standard, passport

Full ESG and Assurance - Zinc Mark

Harmonizing Frameworks



2. LCA and Carbon Footprint



3. Climate Action and Energy



4. Circular Economy and Availability



DD Standard, FAQ, tools, videos:

[Joint Due Diligence Standard - The Copper Mark](#)

Complying with LME Responsible Sourcing Requirements

Joint Due Diligence Standard*

- 100% OECD aligned
- LME: Approved Track A standard

* for copper, nickel, lead, and zinc and their by-products

Responsible Sourcing

- From due diligence to ESG*
- Key for market access driven by user groups, financial sector and regulators
- Zinc Mark pilot phase



Partnering for Responsibility

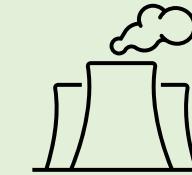
IZA's ambition is to ensure credible responsible sourcing schemes are available for all zinc producers anywhere in the world replying to all regulatory and stakeholder demands.



* ESG: environmental, social and governance aspects



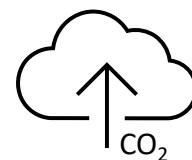
1. Responsible Sourcing



2. LCA and Carbon Footprint

Sector - LMEpassport CF Guidance for SHG Zinc

Material – Profiles at site and global level



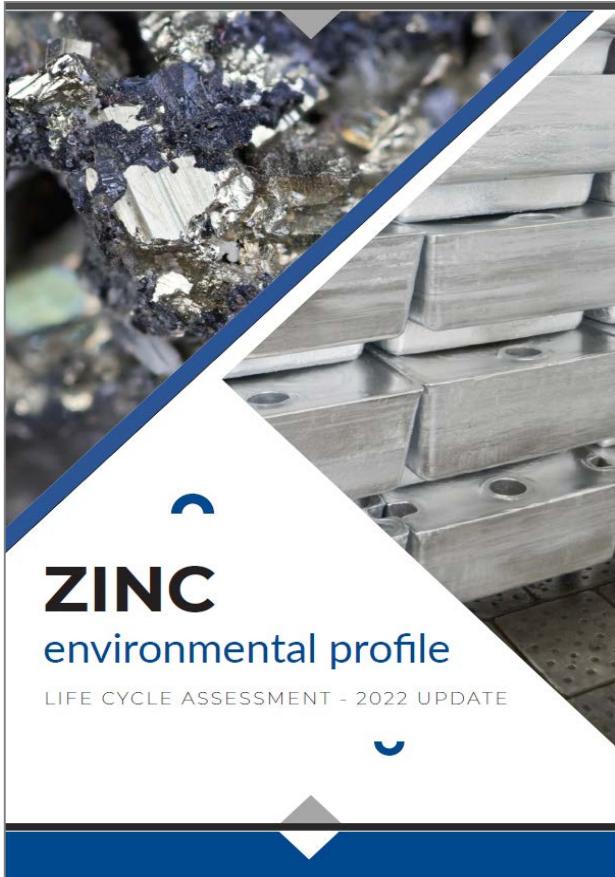
3. Climate Action and Energy



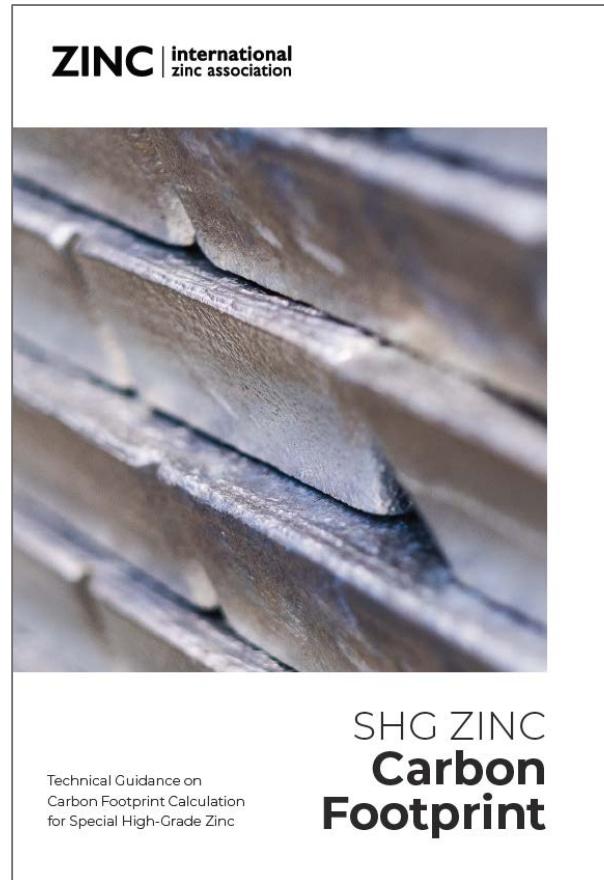
4. Circular Economy and Availability



Zinc Life Cycle Assessment



<https://www.zinc.org/life-cycle-assessment/>



https://www.zinc.org/climate_change/

- LCA updates available via “Zinc Environmental Profile” and relevant LCA data bases.
- Carbon Footprint Guidance for SHG Zinc Production LME approved

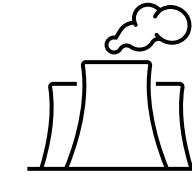


International Zinc Association

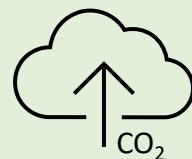




1. Responsible Sourcing



2. LCA and Carbon Footprint



3. Climate Action and Energy

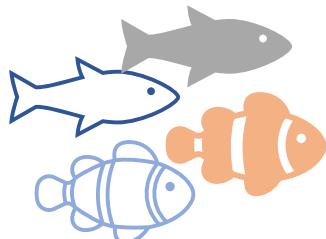
Coordination – IZA Climate Change Task Force

Strategy – Decarbonization Roadmap



4. Circular Economy and Availability

Sector Perspective



- Achieve more as a sector
- Maximize effects along value chains – team up with down stream users
- Represent the sector at regulator and political level

IZA Decarbonization Roadmap



Scoping Report

- Review existing data and information
- Company interviews

Baseline

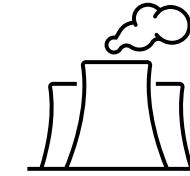
- Calc. model base line CF
- Materiality assessment
- Risk & opportunity analysis

Decarb. scenarios

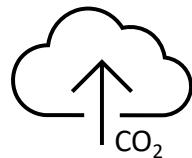
Operationalization



1. Responsible Sourcing



2. LCA and Carbon Footprint



3. Climate Action and
Energy



4. Circular Economy and
Availability

Demand – 2050 scenarios

Supply – Material Flow Analyses

Maximizing Zinc Circularity

ZINC RECYCLING Stocks + Flows

As a material, zinc follows a complex life cycle from ore extraction, through refinement and use in society, to eventual collection and recycling of products at the end of life. This life cycle can be characterized by collecting information at various stages of production, manufacturing, use, and waste management. Information on these "stocks and flows" of material can be used to calculate recycling rates, identify recycling gaps, and impact opportunities for increasing zinc circularity.

Material Flow Analysis

A tool called Material Flow Analysis (MFA) is used to characterize the zinc life cycle, which is based on the mass balance principle. In MFA, a material life cycle is described by identifying the main stages (processes) of a material's life cycle. These stages include the extraction of the stocks from mineral accumulates over time, and its release from these stocks. These processes are interconnected through the generation and use of scrap in different stages and through the flows. Flows are quantified by using a variety of methods, including mass balance. Five main processes characterize the life cycle for zinc (Figure 1): mining & smelting (production), first use production, fabrication & manufacturing (products, use, services), and management and recycling of scrap and waste (end of life).

Figure 1: Anticipated zinc cycle of zinc (Fresenius IIS 2020)

The Dynamic Model of Zinc Global Stocks + Flows

The broad variety of zinc uses and zinc recycling pathways require a wealth of data to visibly describe the global zinc cycle. Zinc production, use, and recycling are closely interconnected with the material cycles of steel, brass, and lead, which adds to the complexity. The dynamic nature of the zinc cycle not only requires current input data, but also long-term data to predict future zinc availability and potential lifetime of 100 years for some applications. The International Zinc Association (IZA) partnered with Fraunhofer IIS Institute, Kiel, Germany to develop a comprehensive dynamic model describing global zinc stocks and flows.

Zinc Circularity

The zinc global stocks + flows model helps quantifying the current zinc circularity:

- ~ 200 Mt of zinc were in the use phase, the so-called exogenic stock, about twenty times the amount of zinc that was mined in the same year (Figure 2). At the end of useful life, zinc will become available for recycling from this urban mine.

ZINC RECYCLING Material Supply

The world is naturally abundant in zinc. Its unique metallurgical and chemical properties make it the material of choice for an extensive range of applications in a modern and greening society. At the end of their useful lives, the zinc recovered from these products can be recycled without loss of its metallurgical properties or value. Further, while the attributes of zinc contribute significantly to sustainability during use, zinc recycling also plays a role in reducing mined zinc demand, energy use, emissions, and minimizing waste disposal.

Zinc is Available from Geological, Mined Sources

There is an estimated 980,000 million metric tons of zinc contained in the earth's crust in such form and amount that economic extraction is currently feasible, or will become feasible by 2050 (accessible crustal content, Figure 3). However, not all of this zinc is immediately available for extraction.

The composition of zinc resources, reserves, and economic considerations dictate extraction of a particular ore body can or should be developed. Due to these factors, 63 billion tons of zinc are estimated as unreliably global zinc resources. Of this, about 250 million tons (Mt) are proven and probable reserves that meet specified criteria for production to achieve current market demands.

Since exploration and mine development are ongoing processes, the amount of zinc reserves is not a fixed number and sustainability of zinc ore supplies cannot be judged by current estimates. The total estimated amount of zinc resources is 1000 Mt.

This concept is evidenced by data from the United States Geological Survey (USGS), which illustrates that although refined zinc production increased 80% between 1900 and 2019, the reserve lifetime for zinc has remained unchanged.

Figure 1: Zinc utilization of zinc resources, reserves, extraction, and use 2019

1. IMA E 2020
2. USGS 2022
3. U.S. Geological Survey 2019
4. International Zinc Study Series 2019

ZINC RECYCLING Closing the Loop

Zinc is an essential element for all living organisms. Its unique metallurgical and chemical properties have also made it the material of choice for an extensive range of applications in modern society. At the end of their useful life, the zinc recovered from these products can be recycled without loss of its characteristics or value.

Current Uses of Zinc

Refined zinc is used in a variety of applications. Galvanizing represents the largest first use of zinc – coating steel to provide corrosion protection (about 60% of total consumption, Figure 1). Other markets for zinc include alloys with copper (brass) or aluminum (the casting), zinc sheet, compounds such as zinc oxide, zinc sulfide, zinc oxide, zinc sulfide, and many other applications. While uses have not significantly changed over time, zinc consumption has more than doubled in the last 40 years. Most of this growth has occurred in applications with long effective lifetimes, such as galvanizing, alloys, and rolled zinc, which are often used in construction and infrastructure. Primary and use markets for these products include building and construction, transportation, industrial, electronic, and agricultural applications.

Sources for Zinc Recycling

A systematic life cycle for zinc is illustrated in Figure 2. Zinc-containing scrap is the main galvanic scrap and a source of zinc for recycling (the end of the useful life of zinc scrap). These products are collected and processed based on scrap availability, metal composition (e.g., pure, alloy, zinc oxide, zinc sulfide, zinc sulfide, and zinc sulfide), and uses during manufacturing and fabrication (e.g., dresses, residues, off-cuts, etc.). Zinc becomes available for recycling during the processing phase ("new scrap"). Depending on the conditions of the recycling source being available, it can either be re-melted or returned to the refining process.

Recycling Rates

Approaches commonly used to assess recycling rates for zinc are Recycled Content (RC), Recycling Input Rate (RIR),

Figure 2: 2020 Zinc recycling rates (Fresenius IIS 2020)

ZINC RECYCLING 2050 Demand + Supply

Metal demand at global level is expected to increase over the next decades. The development is driven by the growing world population and increasing living standards in developing regions, as well as changing use patterns in a greening economy. Zinc contributes to both improved living standards and changing use patterns from its uses in the building sector, infrastructure projects, and renewable energy production and storage. To ensure long-term zinc availability, the International Zinc Association has asked renowned experts to analyse 2050 zinc demand and supply scenarios.

Zinc in Modern Society

About 60% of all zinc produced is used to protect steel from corrosion by galvanizing. Steel is the main material needed for all projects, from basic tools to complex industrial structures. Protecting steel from corrosion is a valuable natural resource and energy, while at the same time increasing and preserving the living standard of societies worldwide.

Renewable energy production is at the core of climate friendly economies. Zinc not only is involved in galvanizing steel structures that support wind and solar power generation, but zinc batteries also support long-duration grid/timescale storage, transforming intermittent energy generation (wind and solar) into constant energy supply.

Zinc 2050 Demand Scenario

Using the global stocks and flows model, Fraunhofer IIS, Kiel, Germany developed a 2050 demand scenario based on population growth and global GDP developments as described by OECD (Global Material Resources Outlook to 2050). As a result, the total zinc demand is projected to increase from 175 Mt in 2019 to 280 Mt in 2050. The energy storage market is forecasted to consume an additional 2.8 Mt of zinc by 2050 (Figure 3). Demand expectations estimated by Fraunhofer IIS are well in line with the zinc recycling rates (Figure 2) over the past ten years and for various time horizons. Unforeseen changes in societies' use patterns to support carbon neutrality and unknown new uses for zinc will also modify scenarios in the coming years.

Figure 3: 2050 Zinc demand scenario (Fresenius IIS 2020)

Fact Sheets

- Zinc Stocks and Flows ([link](#))
- 2050 Supply and Demand ([link](#))
- Material Supply ([link](#))
- Closing the Loop ([link](#))

International Zinc Association



ZINC international zinc association



Zinc Batteries are Versatile



Zinc has been developed across a wide range of chemistries and applications.

Hybrid systems offer potential for zinc to meet most critical needs.

SILVER
ZINC

NICKEL
ZINC

ZINC
ION

MANGANESE
ZINC

ZINC
BROMINE
FLOW & NON

ZINC
AIR

High power density;
Short duration storage

High energy capacity;
Long duration storage

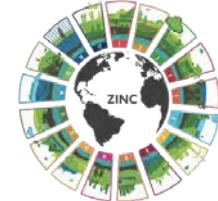


Advantages of Zinc Batteries go Beyond Performance



SAFETY

Zinc batteries are non-flammable and non-toxic.



SUSTAINABLE

Zinc is abundant, recyclable, and has the lowest GHG emissions.



SECURE SUPPLY

Mined in 50+ countries globally, fully integrated supply chains in major regions.

④ Long life (15-20 years)

④ Flexible operating temps (-35°C to +75°C)*

④ Low operating cost

④ Non-hazardous transport

* Depending on Zn-tech used

Single-use versus Rechargeable

Primary (single-use):

Zinc Carbon – AAA, AA, C, D, 9V



Zinc Manganese (alkaline) – AAA, AA, C, D, 9V

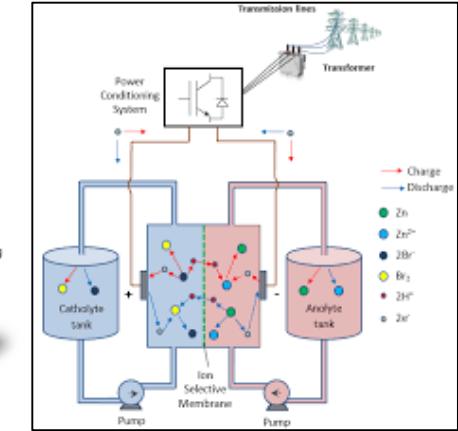


Zinc air – button or coin cells

Rechargeable (secondary):

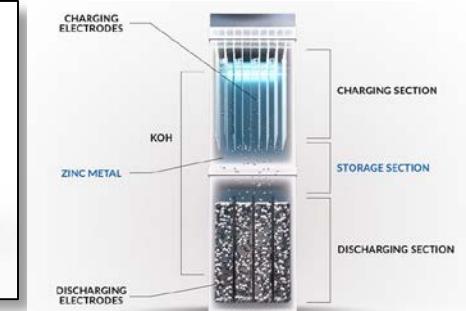
Zinc Bromine – flow

Nickel Zinc – cell



Zinc ion (sulphate electrolyte) – cell

Zinc Manganese (alkaline electrolyte) – cell



Zinc air – cell or flow

Zinc Starter Materials for Batteries

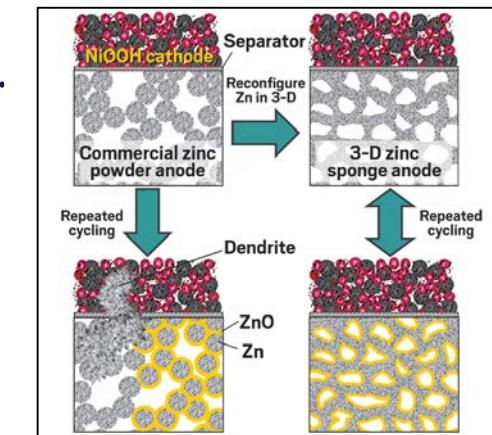
Primary (single-use):

- Alkaline:
Zinc powder,
alloyed with Bi, In, Al, Mg,
and/or Ca (50-500ppm)
Typical size 200-300 μ m
- ZnC:
Zinc sheet, for battery case

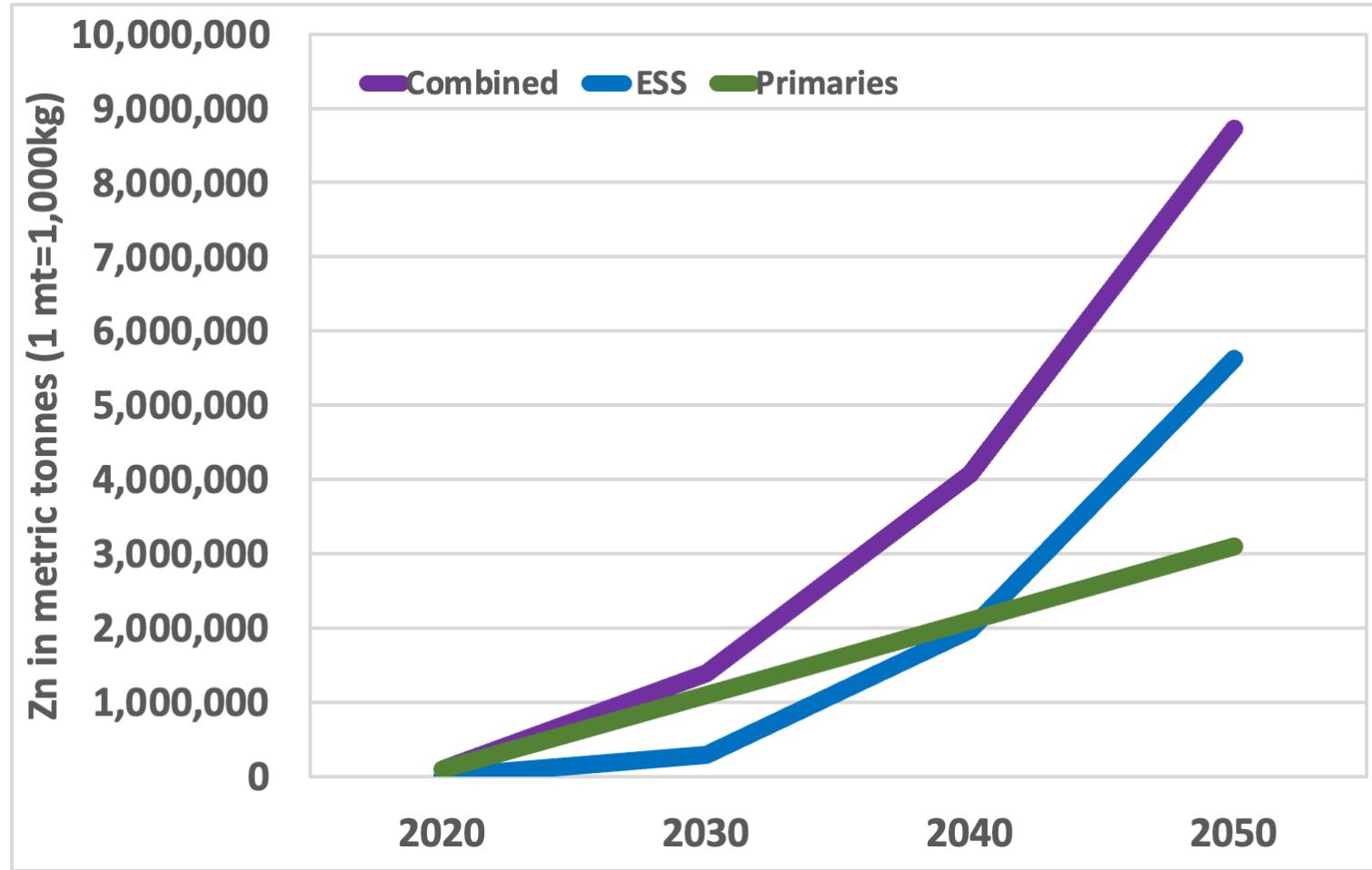


Rechargeable (secondary):

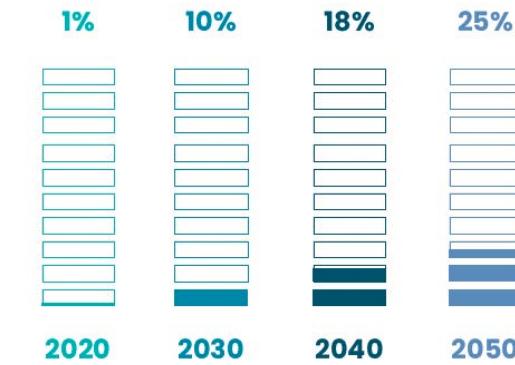
- Zinc bromide solution - ZnBr_2 (aq.)
- Zinc oxide - ZnO
- Zinc hydroxide - Zn(OH)_2
- Zinc powder, alloyed,
finer than primary batt.
- Zinc sheet or foil
- Zinc sponge
- Mixtures of the above



Cumulative Battery Zinc Demand Forecast



Zn Market Share Forecast in ESS'



- ▷ Zinc tonnage forecast for Primary Batteries based on EverZinc estimate and a 0% annual growth rate.
- ▷ Energy storage demand based on BloombergNEF NEO 2022 GWh forecast for storage batteries, percentage of zinc market share estimates based on consultation from Avicenne Energy, and an average zinc intensity of use of 2.5mt Zn/MWh for ESS.



Availability of Zinc



Mt = million tons

1. "Zinc resources – a state of knowledge" by Eric Pirard, 2021
(5 km mineable depth scenario)
2. IZA and Fraunhofer ISI 2021 zinc stocks and flows update
(based on 2019 data)
3. U.S. Geological Survey, 2021
4. International Lead Zinc Study Group. 2019
5. IZA and Fraunhofer ISI 2021 update, post- and pre-consumer scrap
6. IZA and Fraunhofer ISI 2021, zinc entering first use stage

**Accessible
crustal content**
198,000,000 Mt¹

*7X from prev. update at
28,000,000 Mt*

**Extractable global
resources**
63,000 Mt¹

*22X from prev. update
at 2,800 Mt*

Zinc currently
in use

247 Mt²

Proven and
Probable
reserves

250 Mt³

World zinc use/y

20 Mt⁶

Mined zinc/y

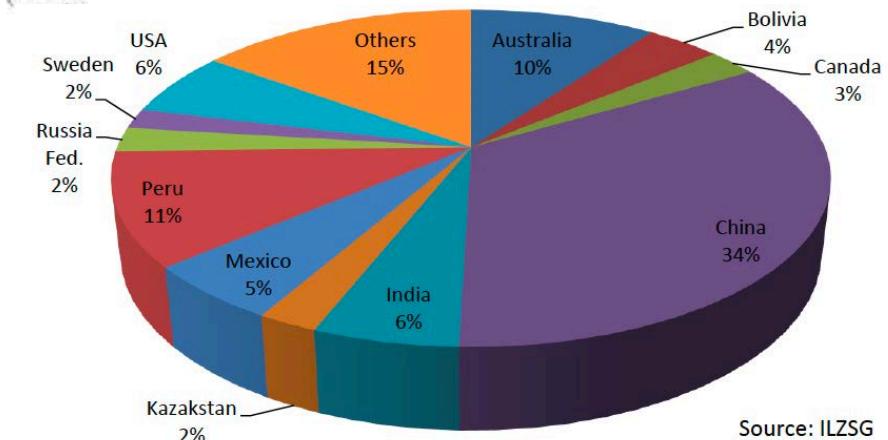
12.8 Mt⁴

Zinc recycled/y

7.6 Mt⁵



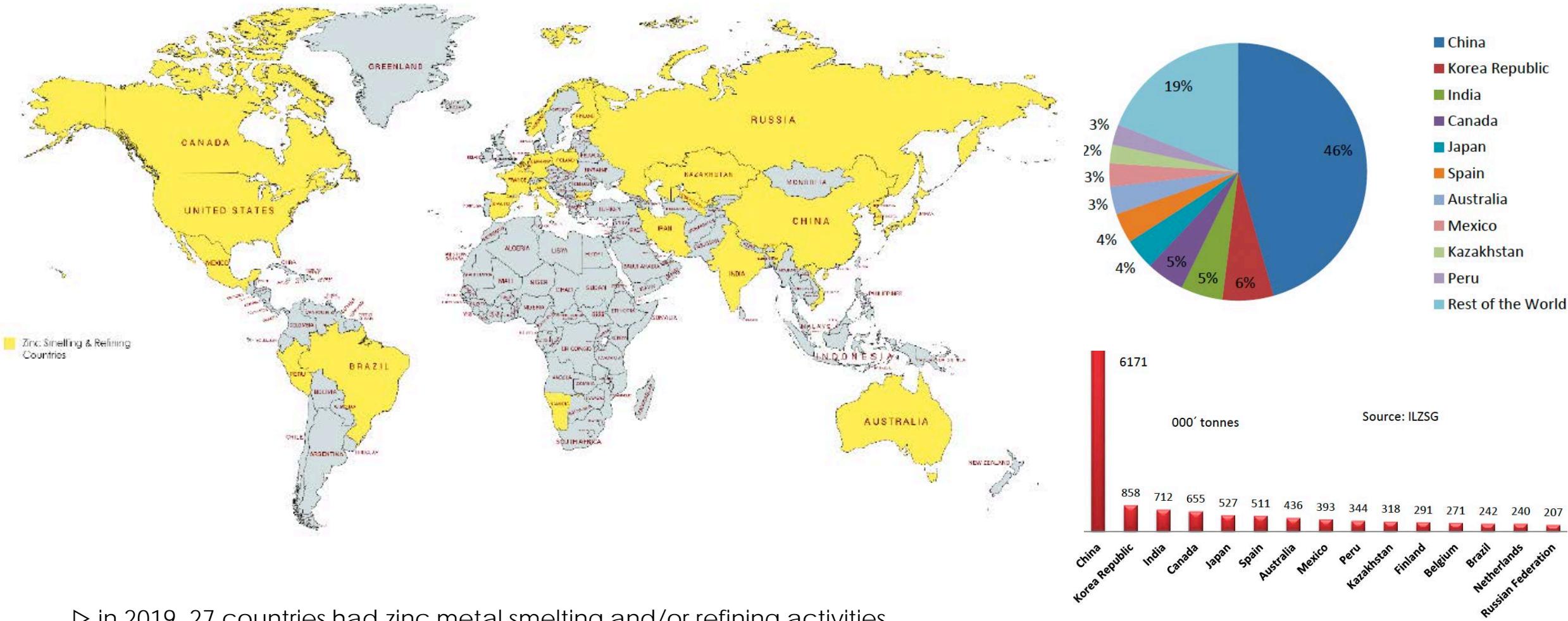
Zinc Mining Countries in 2019



- ▷ Since 1960 over 60 countries have mined zinc ore
- ▷ In 2019, 51 countries were actively mining zinc
- ▷ Top 5 mining countries are China, Peru, Australia, USA and India
- ▷ Top 10 mining companies contributed to 41% of the world concentrate production capacity



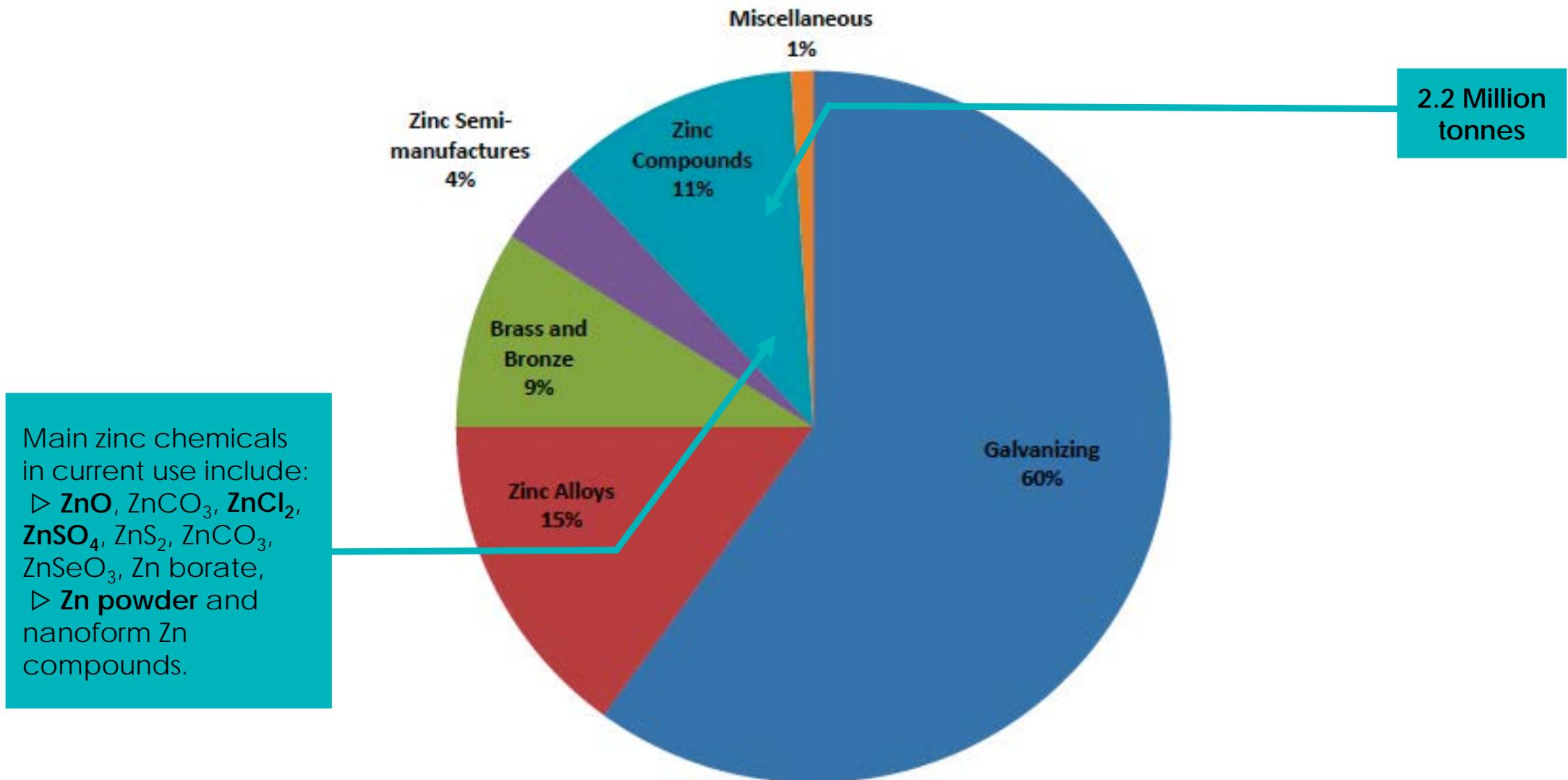
Zinc Metal Producing Countries in 2019



- ▷ in 2019, 27 countries had zinc metal smelting and/or refining activities
- ▷ Top 10 refined zinc metal producing countries contributed 81% of world total output



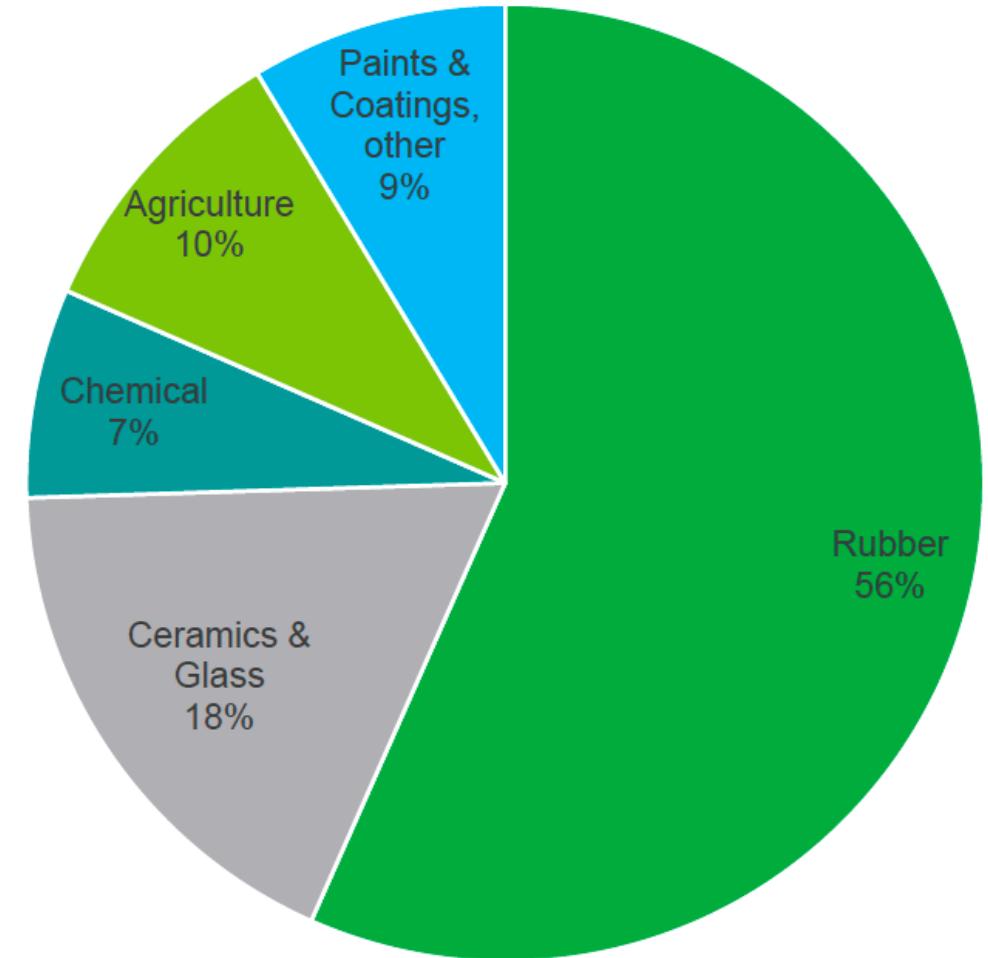
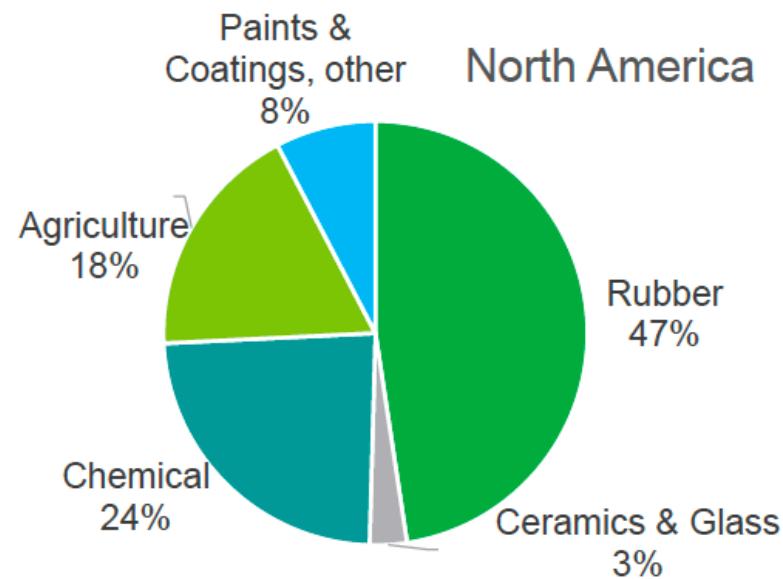
Zinc First Uses in 2019



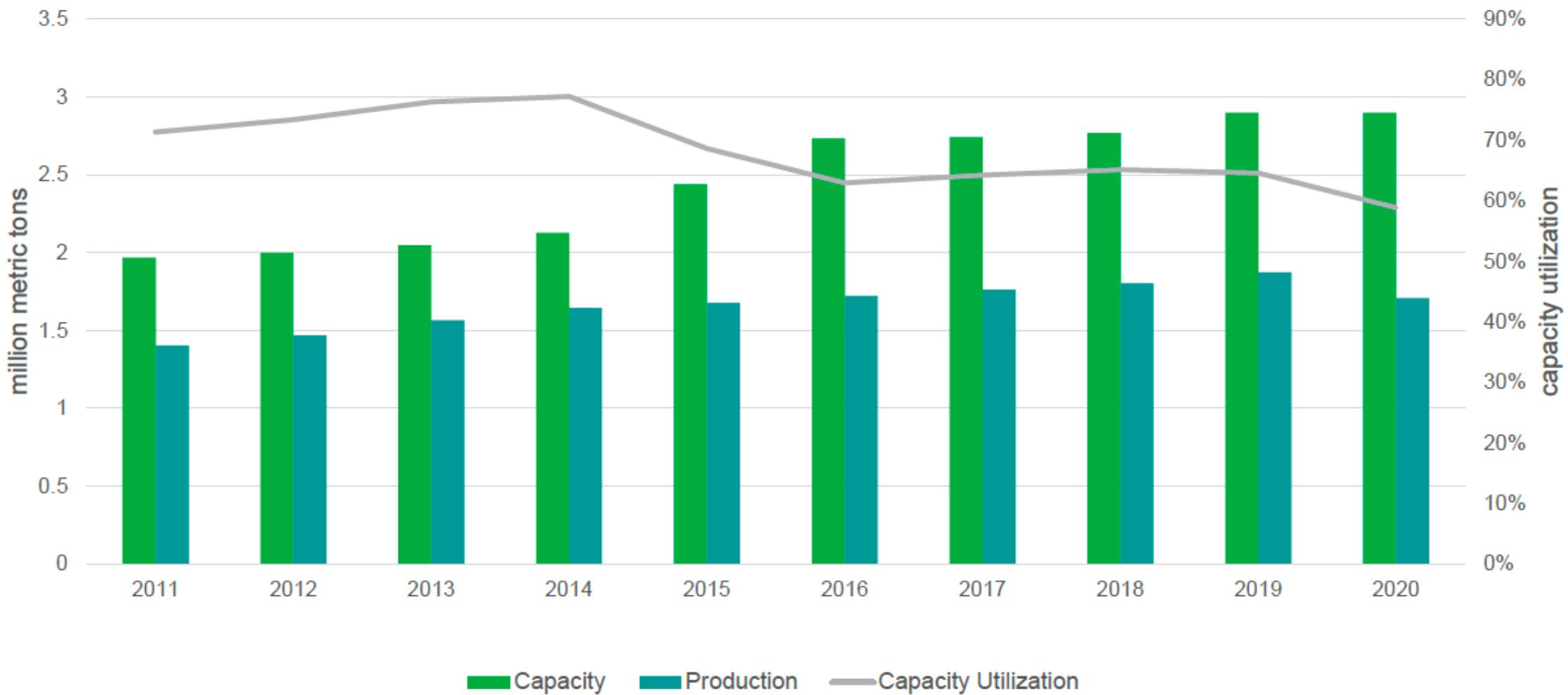
Zinc Oxide Main Uses in 2020

Global demand: 1.7 million metric tons

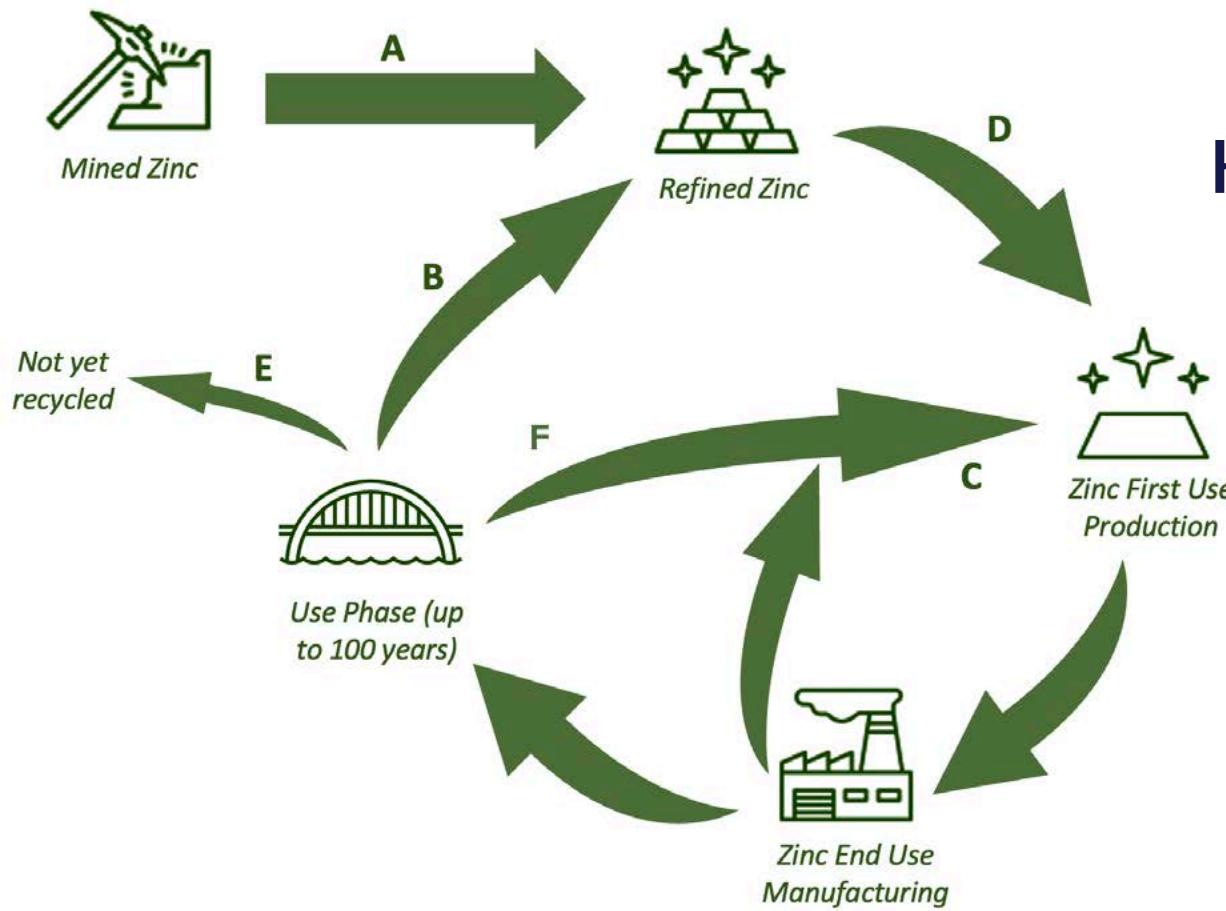
- Rubber compounding remains major end use in all regions
- Ceramics & Glasses is second largest application in all regions but North America



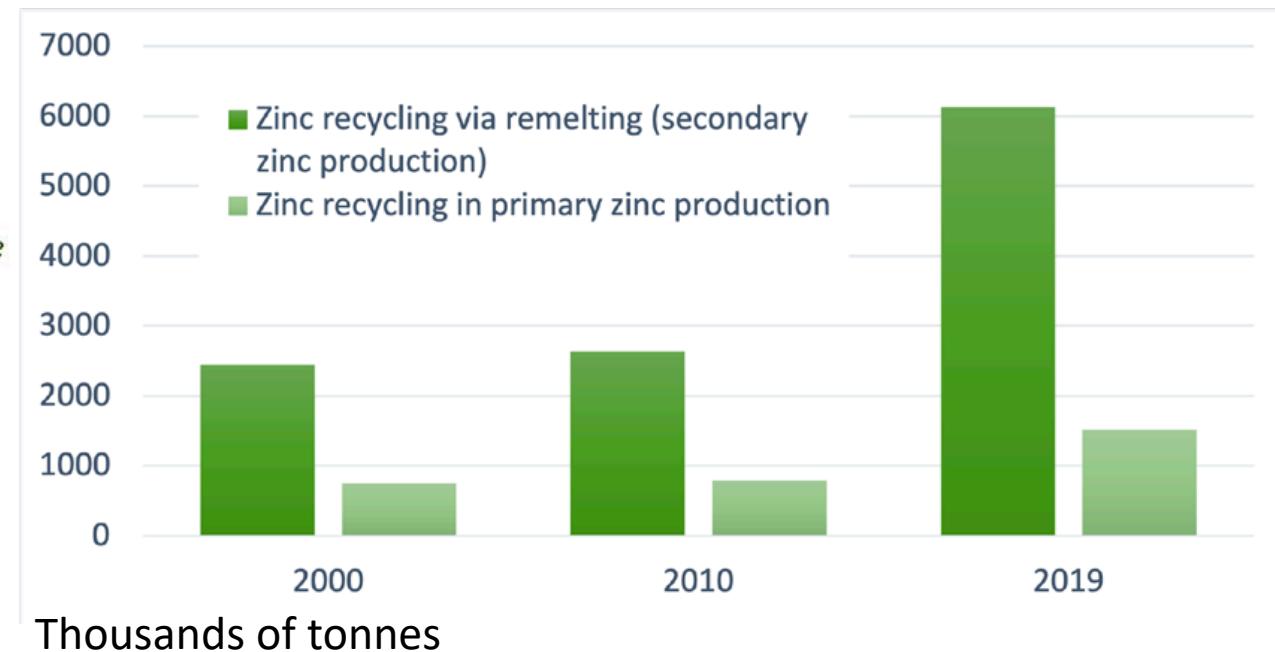
Zinc Oxide Supply



Zinc Circularity - Recycling



How Much Zinc is Recycled Today?

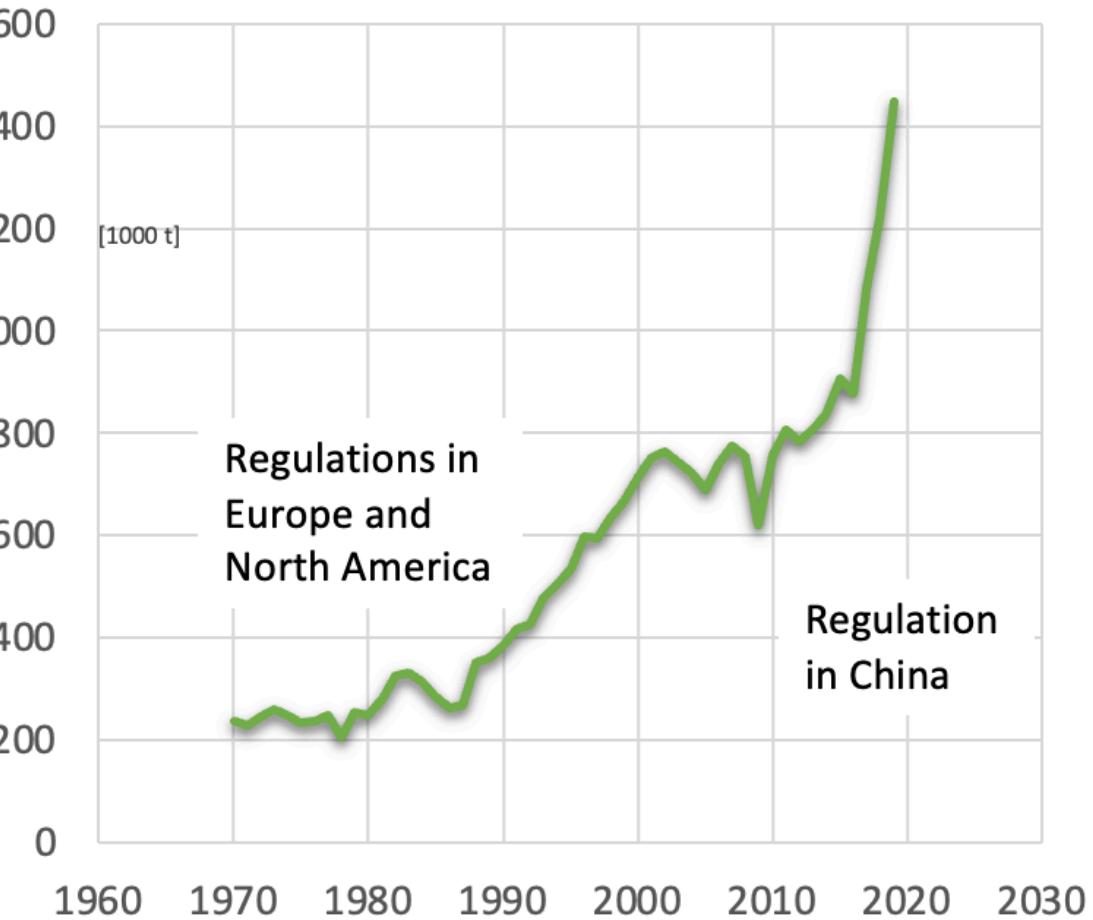
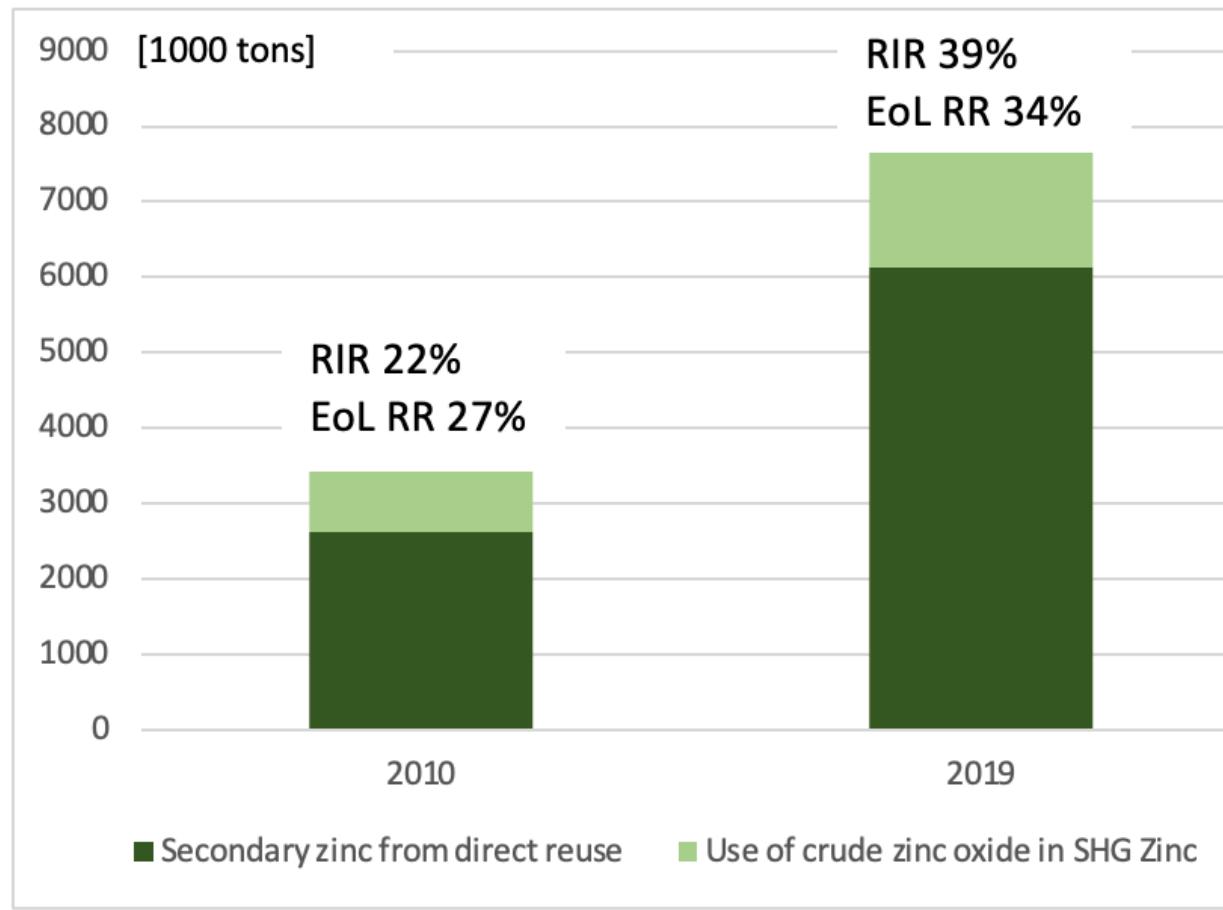


▷ Zinc recycling loops (simplified).

▷ Zinc recycling



Zinc CircularitY - Recycling



▷ Zinc recycling doubled between 2010 and 2019 while zinc mine production remained constant at 12-13 Mt; RIP: Recycling Input Rate, EoL RR: End-of-Life Recycling Rate

▷ Zinc recycling from steel mill (EAF) dust increases with regulations being enforced (based on ILZSG statistics).

Recycling Paths of Single-use Batteries

Mechanical

- Separation of steel and black mass
- **Steel scrap raw material for new steel**
- **Black mass raw material for agricultural use**, e.g. fertilizers (K, Zn and Mn are micro-nutrients)

Hydrometallurgical

- Hydro treatment follows mechanical separation
- Black mass is processed to Zn^0 , ZnO , $Zn(OH)_2$ or other zinc compounds



Pyrometallurgical

- Treatment of complete spent batteries or after mech. separation
- **Recovery of Fe, Mn (steel) and Zn at processing of complete batteries:**
 - Sumitomo process
 - Inmetco process
 - Special blast furnace
 - EAF (dep. regulations)
- Black mass processed in Waelz Kiln for Zn rec.

30 65.38
Zn
Zinc

26 55.845
Fe
Iron

25 54.938
Mn
Manganese

6 **C**
Carbon
12.011

19 39.098
K
Potassium

17 **Cl**
Chlorine
35.453

7 **N**
Nitrogen



Recycling Paths of Rechargeable Batteries

Mechanical

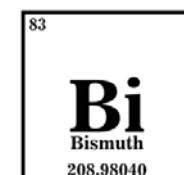
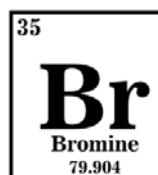
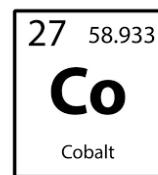
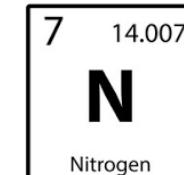
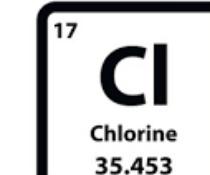
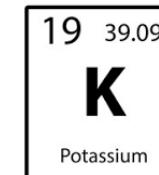
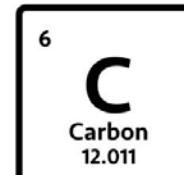
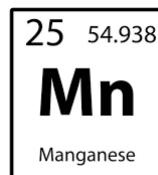
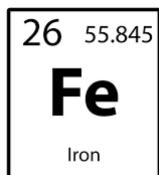
- Flow batteries easy to separate mechanically
- Cell separation of steel and plastics from black mass or paste
- Limited use of black mass or paste as micro-nutrients due to presence of other (eco-)toxic elements

Hydrometallurgical

- Hydro treatment follows mechanical separation
- **Recovery of high-value metals, pot. high recovery rates**
- **Integration in recycling processes of other battery chemistries** (e.g. Li-ion with Co & Ni recovery)

Pyrometallurgical

- Treatment of complete spent batteries vs. after mech. separation
- **Complete batteries processed at Inmetco; Fe, Mn, Ni, Co, Zn rec.**
- Black mass processed in Waelz Kiln for Zn rec.
- Organic materials (plastics, graphite) are lost eventually



Recycling needs to be Economic

Metal	USD price/mt	Exchange, Closing
Cobalt	\$51,955	LME, 29Sep2022
Lithium hydroxide monohydrate	\$78,600	LME, 29Sep2022
Nickel	\$22,348	LME, 29Sep2022
Copper	\$7,542	LME, 29Sep2022
MnO ₂ (EMD)	\$2,394	SMM, 30Sep2022
Zinc	\$2,930	LME, 29Sep2022

31 Source: London Metal Exchange - LME, cash bid closing price; Shanghai Metals Market - SMM for Mn



Challenges to Close the Loop for Zinc Batteries

- **Zinc batteries are versatile:** For all battery chemistries, sizes and designs, not one way of recycling is available.
- **Precondition of recycling is collection and sorting:** Collection of consumer zinc batteries remains a challenge. Industrial battery collection schemes may become more effective.
- **Recycling needs to be economic:** Zinc is not always the most valuable metal in a battery, recycling may not always be economic (like Li in Li-ion)
- **Closed-loop vs open-loop recycling:** Zinc battery materials are likely to be recycled in a form and shape not always suitable for use as new starting materials.
- **Metallurgy is never about one metal alone:** Recycling of primary and rechargeable zinc batteries is often/will often be for the purpose of recovering many metals and materials, such as steel, Mn, Ni, Co and/or Cu – and of course zinc.



Responsible

Essential

Life Saving

Durable

Sustainable

Summary

- ***Sustainability***

- IZA spearheading Decarbonization, LCA, Stocks & Flow, Zn secondary raw materials, ESG and Due Diligence Standard for global zinc industry

- ***Zinc is a plentiful raw material with huge Extractable Global Reserves***

- World EGR – 63,000 million tonnes → @12.5Mt/yr = 5,040 yrs.
- Economic reserves – 250 million tonnes → @12.5Mt/yr = 20 yrs.
- Demand estimate of apprx. 9 million tonnes cumulative by 2050 easily met

- ***Zinc has a diverse, secure global supply chain***

- 50+ countries actively mining zinc; 27 countries actively smelting/refining zinc
- Lower carbon footprint than Lithium and Lead

- ***Zinc recycling***

- Zinc is versatile and multiple ways of recycling available
- Recycling needs to be economic for widespread implementation

ZBI - Zinc Battery Initiative

A Partnership to Advance Zinc-based Battery Technologies

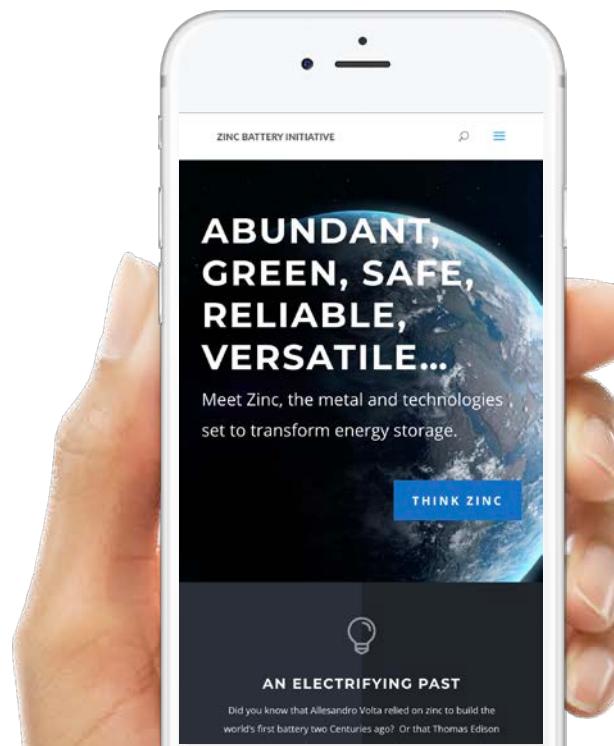
The ZBI serves to champion zinc batteries and ensures that all potential customers and other stakeholders understand the value and advantages of zinc-based power and energy storage products.





ZBI – Status

- ❖ Formed in late 2020 to promote the new wave rechargeable zinc batteries' remarkable story and encourage further adoption of these products.
- ❖ Principal sponsor is the Int'l Zinc Association.
- ❖ Grown to 11 members / battery producers.
- ❖ Engaged PR firm Silverline Communication to reach out to a variety of media channels in the clean energy / energy storage field
 - ❖ Secured press coverages and articles are publishing raising awareness for zinc-based batteries
 - ❖ More in pipeline



CALL FOR MEMBERSHIP!

Join IZA's ZBI – the voice of the zinc battery industry

Thank You!

PLEASE VISIT OUR WEBSITES

www.ZincBatteryInitiative.com

www.zinc.org

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