*SCRREEN2*

*This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211.*

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FACTSHEETS UPDATES **BASED ON THE EU FACTSHEETS 2020**

**ZINC**

AUTHOR(S):

# TABLE DES MATIÈRES



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# ZINC

## OVERVIEW

Zinc (chemical symbol Zn) is the fourth most used nonferrous metal, after iron, aluminIum and copper. Zinc has a specific weight of 7.13 g/cm$^3$ and its melting and boiling points are 419 °C and 906 °C, respectively. It alloys readily with other metals (like brass or spelter) and is chemically active. Zinc is an essential element for the growth of living organisms.

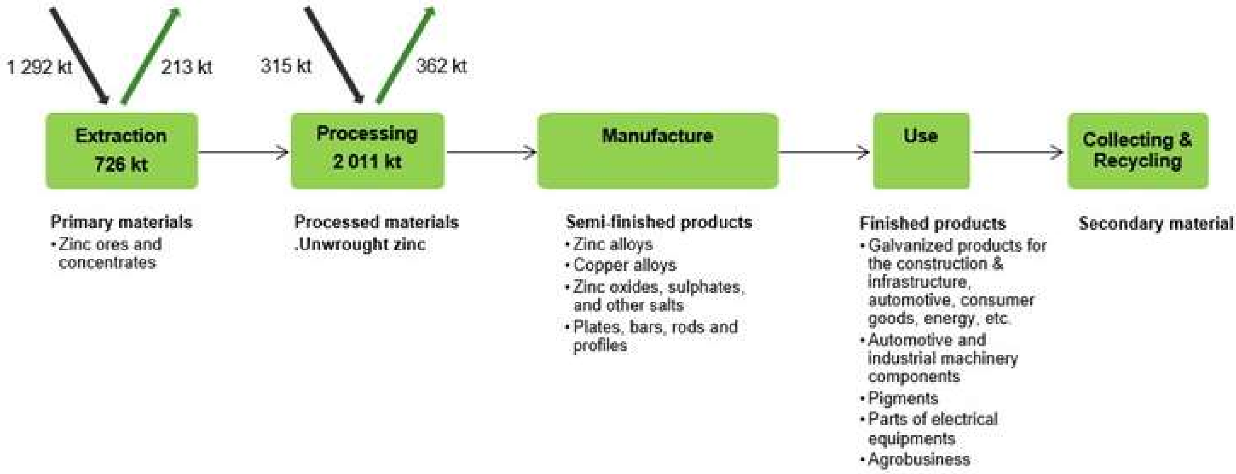


**Figure 1. Simplified value chain for zinc in the EU[1]**

**Table 1. Zinc supply and demand (extraction) in metric tonnes, 2016-2020 average**

| Global production | Global Producers | EU consumption | EU Share | EU Suppliers | Import reliance |
|---|---|---|---|---|---|
| **12.14 Mtonnes** | China 32% | 1.9 Mtonnes | 14.1% | Peru 13% | 56% |
| | Peru 12% | | | Sweden 13% | |
| | Australia 9% | | | USA 10% | |
| | India 6% | | | Australia 8% | |
| | Mexico 6% | | | Ireland 7% | |
| | USA 6% | | | Mexico 7% | |
| | Bolivia 4% | | | Portugal 7% | |
| | Canada 3% | | | Bolivia 6% | |
| | Kazakhstan 3% | | | Spain 5% | |
| | Russia 2% | | | Turkey 4% | |
| | Sweden 2% | | | Finland 3% | |

[1] JRC elaboration on multiple sources (see next sections)

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Table 2: Zinc supply and demand (processing) in metric tonnes, 2016-2020 average

| Global production | Global Producers | EU consumption | EU Share | EU Suppliers | Import reliance |
|---|---|---|---|---|---|
| **13,592,760** | China 45%<br>South Korea 7%<br>Canada 5%<br>India 5%<br>Spain 4%<br>Japan 4%<br>Australia 3%<br>Mexico 3%<br>Belgium 2%<br>Brazil 2%<br>Finland 2%<br>Kazakhstan 2%<br>Netherlands 2%<br>Peru 2%<br>Russia 2% | 2,006,408 | 14.8% | Spain 22%<br>Finland 13%<br>Belgium 11%<br>Netherlands 11%<br>Germany 8%<br>France 7%<br>Poland 7%<br>Italy 6%<br>Norway 4%<br>Bulgaria 3%<br>Peru 4%<br>Namibia 2% | 0% |

**Prices:** Current Zinc price is much lower than the high price in 2018 as the market prices in Chinese demand show weakness and the there is a rising prospect of European recession. It is expected that the falling demand might continue to create a falling price trend in the short term.

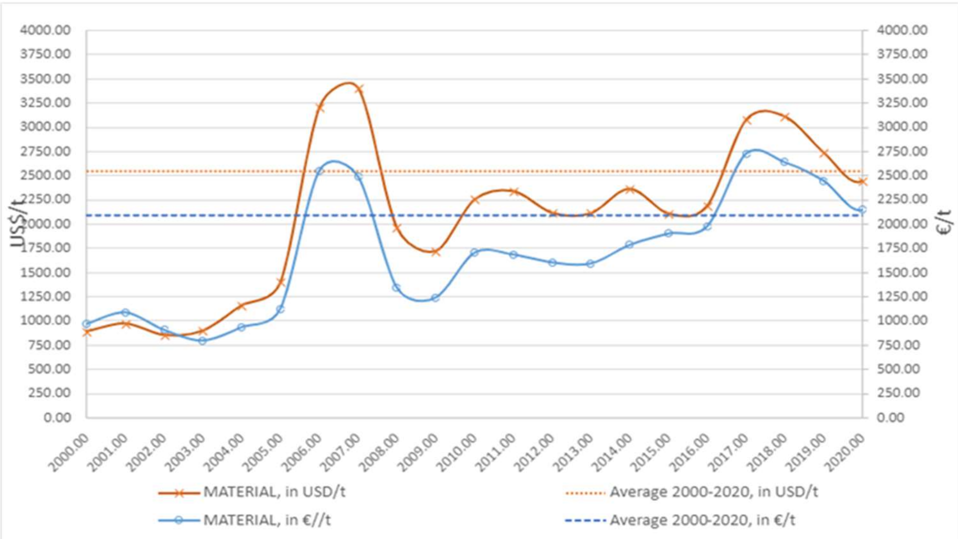


Figure 2. Annual average price of zinc between 2000 and 2020 ( USGS, 2021)[2].

**Primary supply:** China is the larger producer representing over the 32% of world production in 2020 (WMD, since 1984). Peru, Australia, Unites States, Mexico, Bolivia and India consist also major zinc producers

[2] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

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representing together about the 40% of the world production. EU represents about the 4% of the global zinc production by primary resources.

**Secondary supply:** Over the past decade (2010–2019), zinc recycling doubled while zinc mining remained at a constant level. This has improved the indicators such as the Recycling Input Rate (RIR) or the End-of-Life Recycling Rate (EoL RR) that is currently 39%.

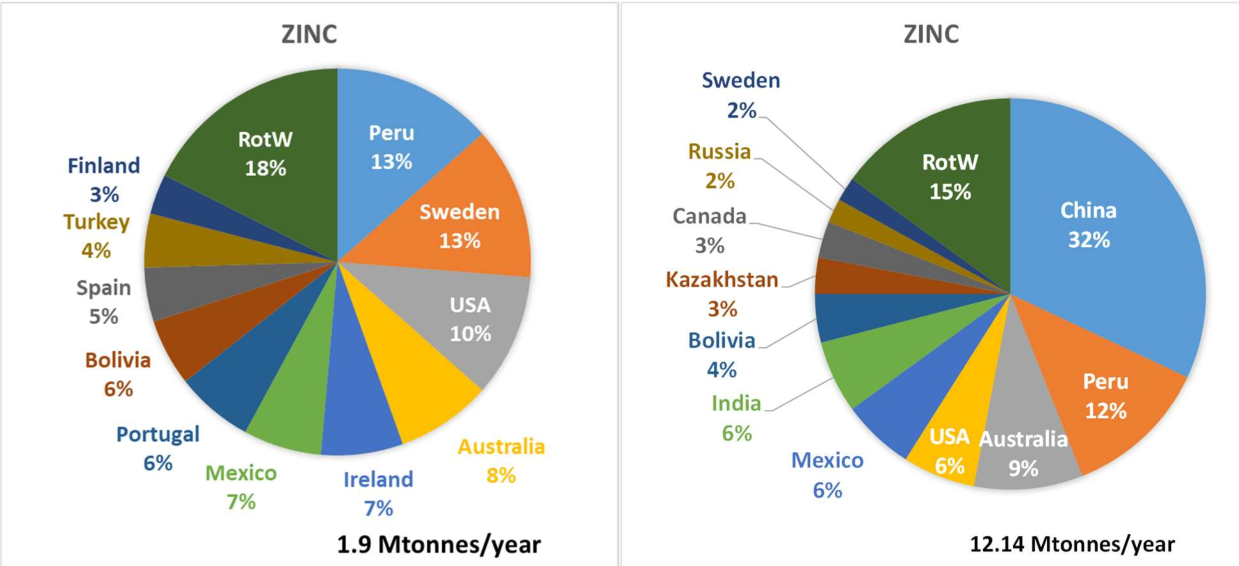


**Figure 3. EU sourcing of zinc (extraction) and global mine production (2016-2020)**

**Uses:** Zinc is used to galvanize steel products, to produce zinc base alloys, brass and bronze, chemical compounds as well as semi manufactures like zinc sheet and wire. There is no up-to-date data available for the European uses and end use shares of zinc since 2015. At this time, the EU uses were aligned with the global uses

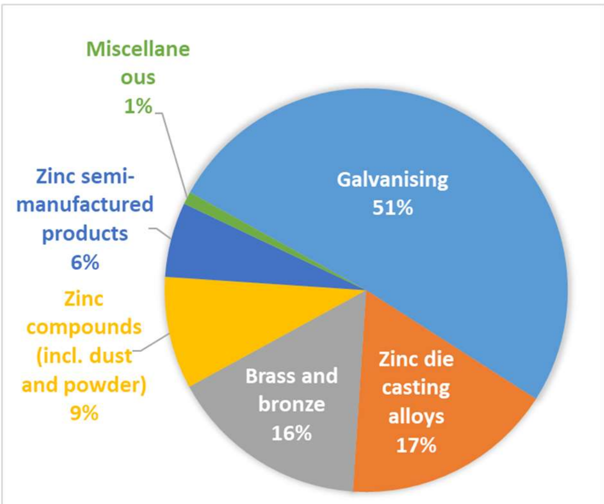


**Figure 4: EU uses of zinc (ILZSG, 2017)**

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**Substitution:** For corrosion protection, zinc coating is substituted by aluminium alloys (less effective), cadmium, paint and plastic coatings (less durable). Galvanised plates, e.g., in automobiles, can be replaced by aluminium, steel or plastics. Aluminium, magnesium as well as their alloys, and plastics are major competitors for parts of zinc-based die-casting alloys (USGS, 2022). Plastics and stainless steel can serve as a substitute of brass used e.g., in plumbing applications such as fittings, pipes and fasteners. Silver and gold can be used for music instruments but have much higher price compared to brass.

**Table 3. Uses and possible substitutes**

| Application | Share | Substitutes | SubShare | Cost | Performance |
|---|---|---|---|---|---|
| Galvanising | 51% | Aluminium | 10% | Similar or lower costs | Similar |
| | 51% | Zn/Al/Mg/Si alloys | 10% | Slightly higher costs (up to 2 times) | Similar |
| | 51% | Polymer coating | 5% | Similar or lower costs | Similar |
| | 51% | Steel | 5% | Similar or lower costs | Similar |
| Zinc die casting alloys | 17% | Aluminium | 10% | Similar or lower costs | Similar |
| | 17% | Magnesium | 10% | Similar or lower costs | Similar |
| | 17% | Brass | 10% | Very high costs (more than 2 times) | Similar |
| | 17% | Steel | 10% | Similar or lower costs | Similar |
| | 17% | Polymers : Polypropylene, Nylon (30% Glass) | 10% | Similar or lower costs | Similar |
| Brass and bronze | 16% | Tin brass & bronze (copper, zinc and tin) | 4% | Very high costs (more than 2 times) | Similar |
| | 16% | Nickel-silvers | 4% | Very high costs (more than 2 times) | Similar |
| | 16% | Silicon bronzes and brasses | 4% | Very high costs (more than 2 times) | Similar |
| | 16% | Manganese bronzes | 4% | Similar or lower costs | Similar |
| | 16% | Aluminium bronzes | 4% | Similar or lower costs | Similar |

**Other issues:** Zinc is an essential trace element for the normal growth and reproduction of all higher plants and animals, and of humans. In addition, it plays a key role during physiological growth and fulfils an immune function. Exposure to high doses has toxic effects but an acute zinc intoxication is a rare event (Prasat et al. 2020). In addition to acute intoxication, long-term, high-dose zinc supplementation interferes with the uptake of copper. Although zinc occurs naturally, most zinc finds its way into the environment because of human activities. Mining, smelting metals (like zinc, lead and cadmium) and steel production, as well as burning coal and certain wastes, can release zinc into the environment. Bolivia exports of zinc ores and concentrates represent 11% in value of the total trade exports of the country, followed by Tajikistan (8%).

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## MARKET ANALYSIS, TRADE AND PRICES

### GLOBAL MARKET

**Table 4: Zinc supply and demand (extraction) in metric tonnes, 2016-2020 average**

| Global production | Global Producers | EU consumption | EU Share | EU Suppliers | Import reliance |
|---|---|---|---|---|---|
| **12,140,004** | China 32%<br>Peru 12%<br>Australia 9%<br>India 6%<br>Mexico 6%<br>USA 6%<br>Bolivia 4%<br>Canada 3%<br>Kazakhstan 3%<br>Russia 2%<br>Sweden 2% | 1,720,091 | 14.1% | Peru 22%<br>USA 17%<br>Australia 13%<br>Mexico 10%<br>Bolivia 9%<br>Turkey 7%<br>Burkina Faso 5% | 56% |

**Table 5: Zinc supply and demand (processing) in metric tonnes, 2016-2020 average**

| Global production | Global Producers | EU consumption | EU Share | EU Suppliers | Import reliance |
|---|---|---|---|---|---|
| **13,592,760** | China 45%<br>South Korea 7%<br>Canada 5%<br>India 5%<br>Spain 4%<br>Japan 4%<br>Australia 3%<br>Mexico 3%<br>Belgium 2%<br>Brazil 2%<br>Finland 2%<br>Kazakhstan 2%<br>Netherlands 2%<br>Peru 2%<br>Russia 2% | 2,006,408 | 14.8% | Spain 22%<br>Finland 13%<br>Belgium 11%<br>Netherlands 11%<br>Germany 8%<br>France 7%<br>Poland 7%<br>Italy 6%<br>Norway 4%<br>Bulgaria 3%<br>Peru 4%<br>Namibia 2% | 0% |

Global zinc production is recovering after COVID-19 hit, the output causing a 5.9% decline in 2020 compared to 2019 (MT, 2022). The recovery of zinc production is expected to increase by 15% in 2025 compared to 2020 (MT, 2022). The growing need for galvanized steel is the major factor that will drive the zinc market growth. Zinc demand will stay reliably strong as urbanization continues to expand and new sources of final demand, such as offshore wind energy structures, solar panel frames, and electric vehicles. In 2021, the global demand for refined zinc decreased by 3% compared to 2020 due to the reductions in Brazil, China, France, Germany,

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Japan, Thailand and Ukraine that were partially balanced by rises in the Republic of Korea, Taiwan (China) and the United States (ILZSG, 2022).

Zinc is traded on the major exchanges around the world including the London Metals Exchange (LME) and the Shanghai Metal Exchange (SHME). The LME trades a contract on ingots of zinc that at least are 99.995% pure. Each contract represents 25 tonnes of zinc and is quoted in US dollars. Key players in the zinc market in 2016 were Glencore, followed by Vedanta Resources and Teck Resources (EC, 2020). Boliden was the main EU producer in 2016 (EC, 2020).

## EU TRADE

For this assessment, Zinc is evaluated at both extraction and processing stage.

**Table 6. Relevant Eurostat CN trade codes for Zinc**

| Mining | | Processing/refining | |
|---|---|---|---|
| **CN trade code** | **title** | **CN trade code** | **title** |
| **26080000** | Zinc ores and concentrates | 26201100<br>2817<br>79010000 | Zinc Spelter<br>Zinc Oxide and peroxide<br>Unwrought Zinc |

For extraction stage we evaluate the supply - demand and pricing of zinc ores and concentrates. At refining stage, alloys and mixtures such as zinc spelter, zinc chloride, oxide, unwrought and articles of zinc are evaluated for current and historic trends.

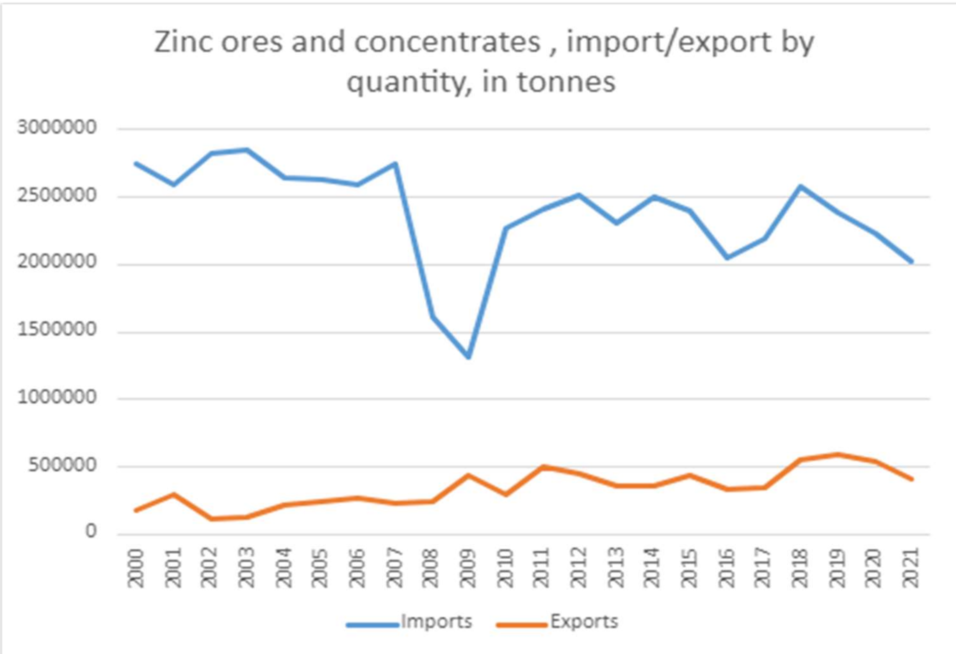


**Figure 5. EU trade flows of zinc ores and concentrates (CN 2608) from 2000 to 2021 (Eurostat, 2022)**

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EU is a net importer of zinc ore and concentrates. Since 2018, the import quantity has been observing a steady decline. The reason for decline could be twofold. Increasing EU export in the same period may indicate growing self-reliance on zinc ores and concentrates. Fall since 2019 could also be due to the impact of COVID.

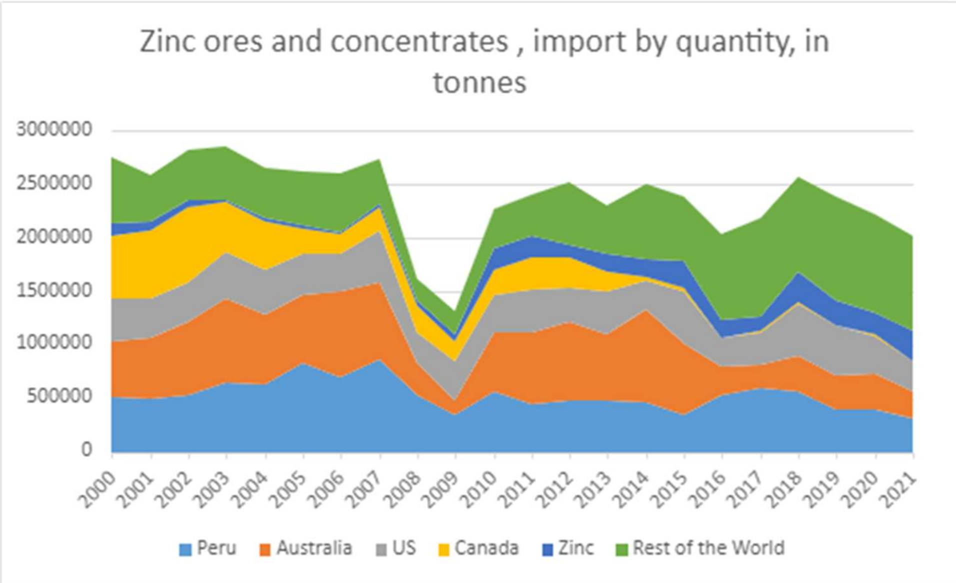


**Figure 6. EU imports of zinc ores and concentrates (CN 2608) by country from 2000 to 2021 (Eurostat, 2022)**

Top exporters of zinc ores and concentrates to EU include Peru, Australia and US. As discussed above, EU imports have been witnessing a steady decline since 2017.

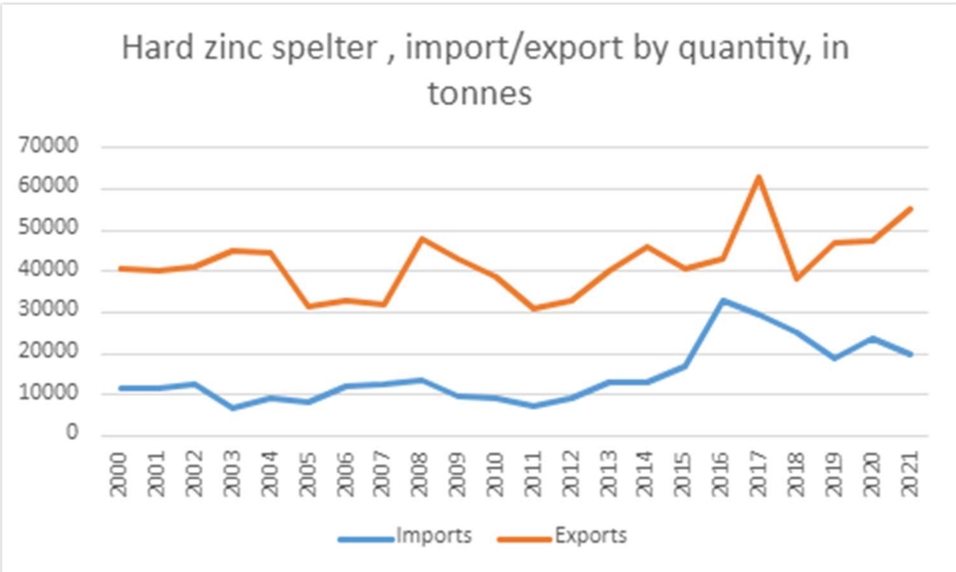


**Figure 7. EU trade flows of zinc spelter (CN 262011) from 2000 to 2021 (Eurostat, 2022)**

EU is self-reliant in zinc spelter as annual exports are much higher than imports. In the past few years, exports have seen a growing trend, compared to imports which have been falling. This is indicative of strengthening domestic production for zinc spelter

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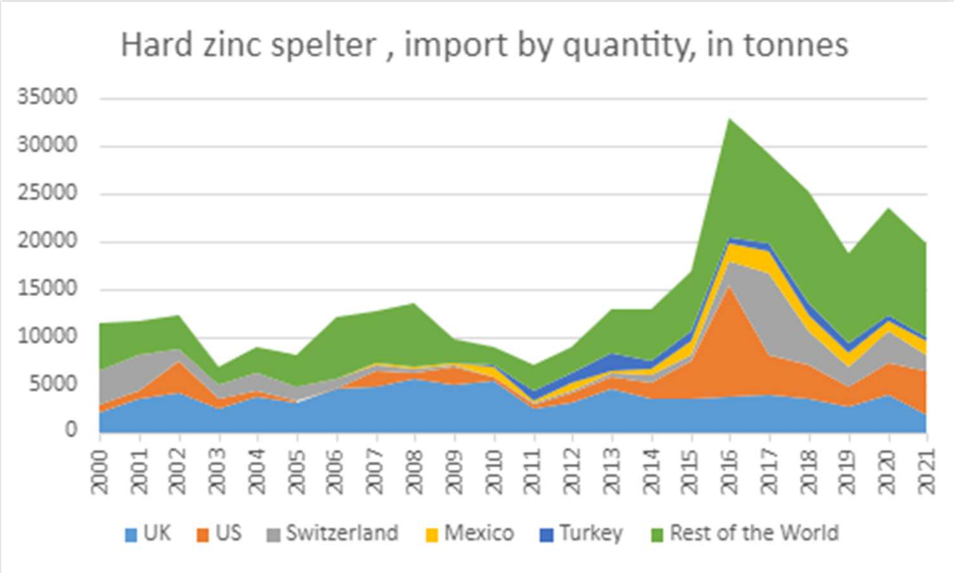


**Figure 8. EU imports of zinc spelter (CN 262011) by country from 2000 to 2021 (Eurostat, 2022)**

The top exporters of zinc spelter to the EU are the UK, US, and Switzerland. The overall import trend has been showing a decline since 2016. Although 2019 to 2020 saw a growth in imports only to be slowed down due to a lack in demand.

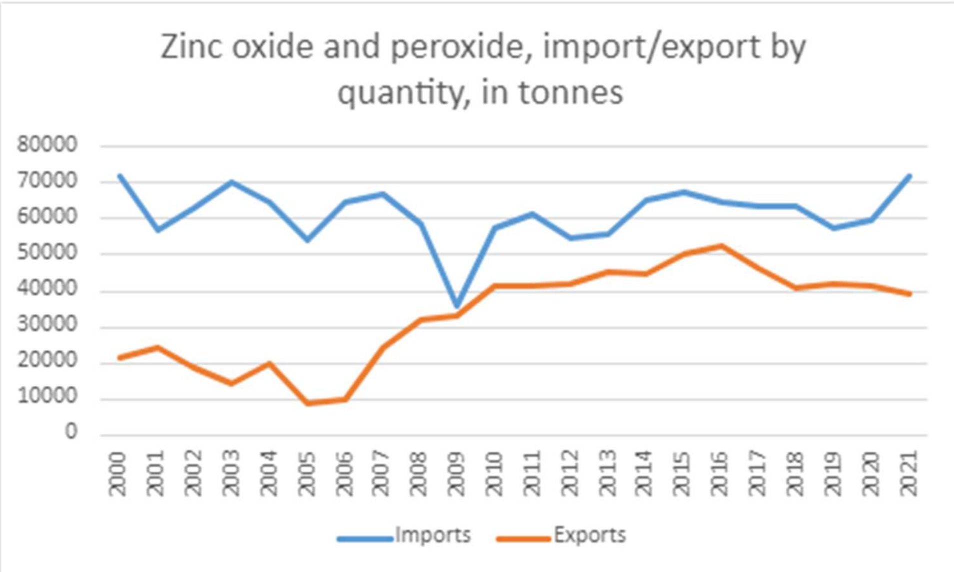


**Figure 9. EU trade flows of Zinc oxide and peroxide (CN 2817) from 2000 to 2021 (Eurostat, 2022)**

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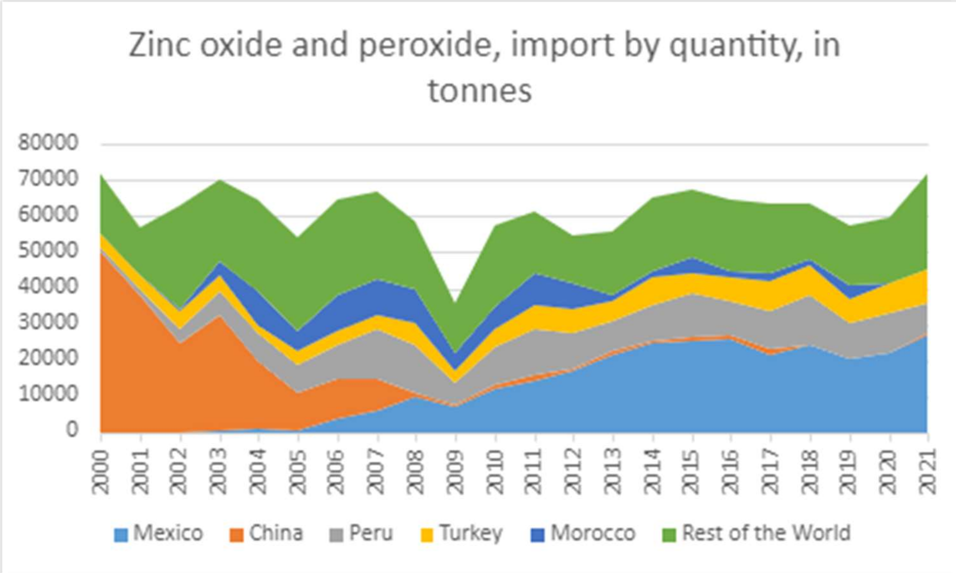


**Figure 10. EU imports of Zinc oxide and peroxide (CN 2817) by country from 2000 to 2021 (Eurostat, 2022)**

Unlike zinc spelter, the EU is not self-reliant on zinc oxide and peroxide. Imports are much higher than exports and have been showing a growing trend lately. Top exporters of zinc oxide to EU include Mexico, Peru, and Turkey. China remained an important source of import till 2007 but Mexico replaced its dominance post that period.

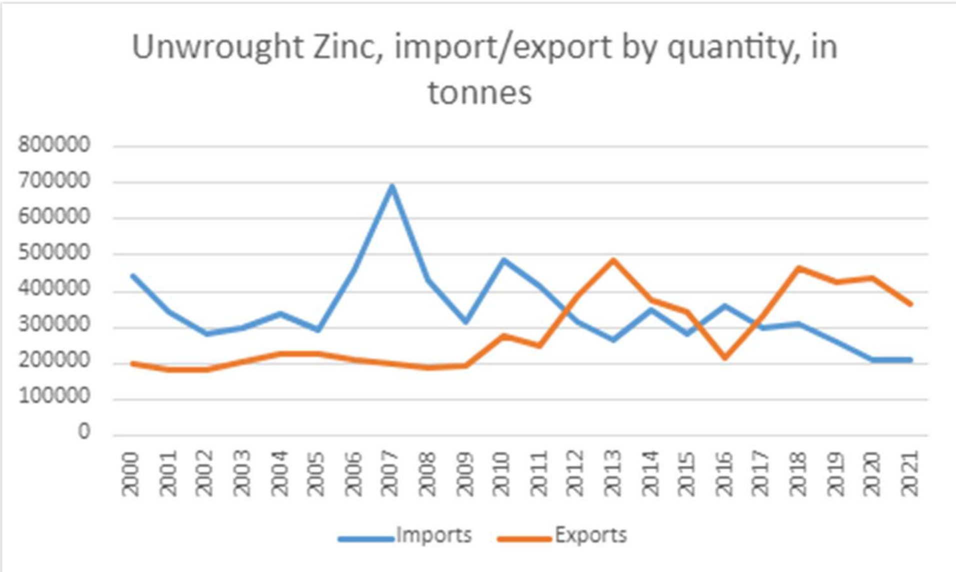


**Figure 11. EU trade flows of unwrought zinc (CN 7901) from 2000 to 2021 (Eurostat, 2022)**

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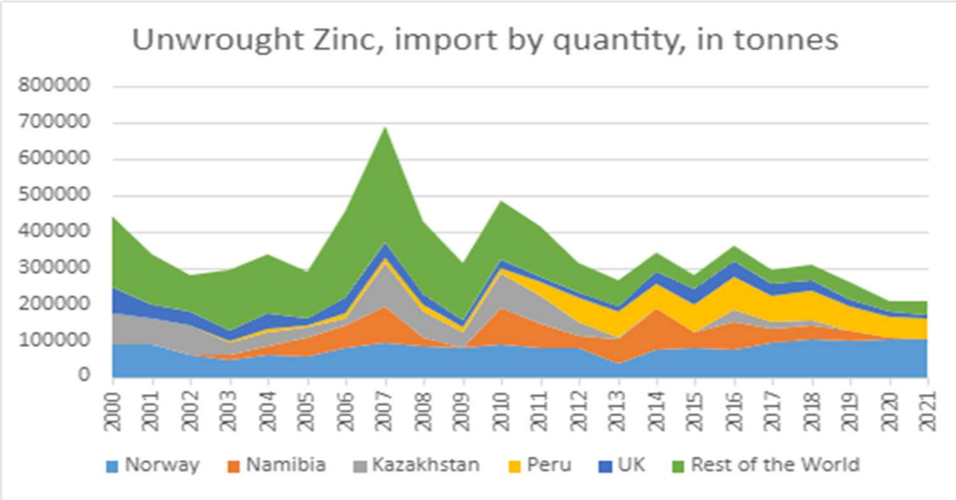


**Figure 12. EU imports of unwrought zinc (CN 7901) by country from 2000 to 2021 (Eurostat, 2022)**

For unwrought zinc, the EU has evolved from a net importer to a net exporter with time. Around 2011, exports exceeded imports for the first time and the current annual export quantity is almost double the imports. This is indicative of the strengthening of domestic production with time in the EU.

## 3.3. PRICE AND PRICE VOLATILITY

Current Zinc price is much lower than the high price in 2018 as the market prices in Chinese demand show weakness and the there is a rising prospect of European recession. It is expected that the falling demand might continue to create a falling price trend in the short term.

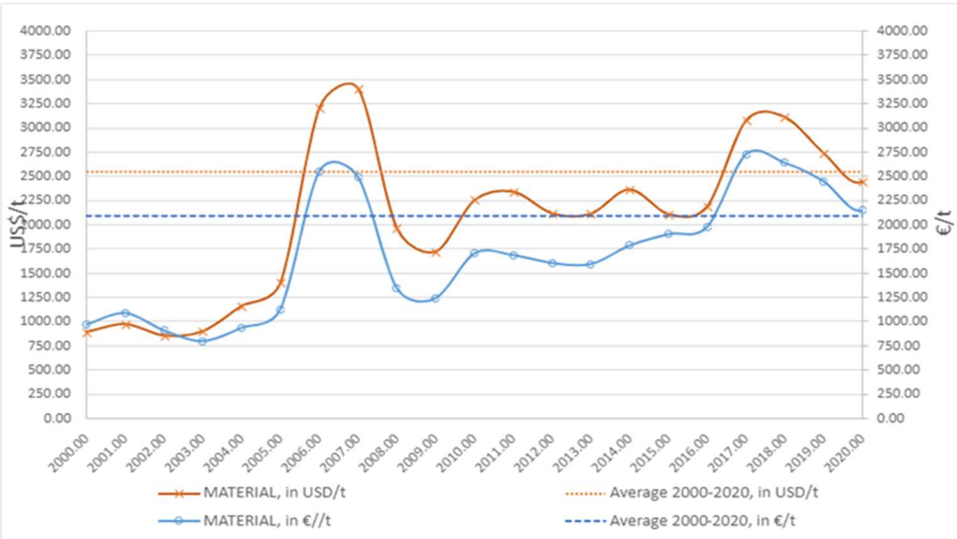


**Figure 13. Annual average price of Zinc between 2000 and 2020, in US$/t and €/t[3]. Dash lines indicates average price for 2000-2020 (USGS, 2021)**

[3] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

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## OUTLOOK FOR SUPPLY AND DEMAND

Zinc's weakening demand so far this year has come largely from China, where a troubled property sector has depressed demand for steel, including zinc-coated galvanized steel. Attempts to revitalise the flagging commercial construction sector are being stymied by a combination of continued rolling COVID-19 lockdowns and power rationing in drought-affected parts of the country.

Demand fears have now spread to Europe, which seems to be facing imminent recession due to soaring power prices.

## DEMAND

## EU DEMAND AND CONSUMPTION

Annual average worldwide consumption of refined zinc is about 13.8 Mtonnes for 2017-2021 (ILZSG, 2022).

Zinc extraction stage EU consumption is presented by HS code CN 26080000 - Zinc ores and concentrates. Import and export data is extracted from Eurostat Comext (2022). Production data is extracted from BGS (2022).

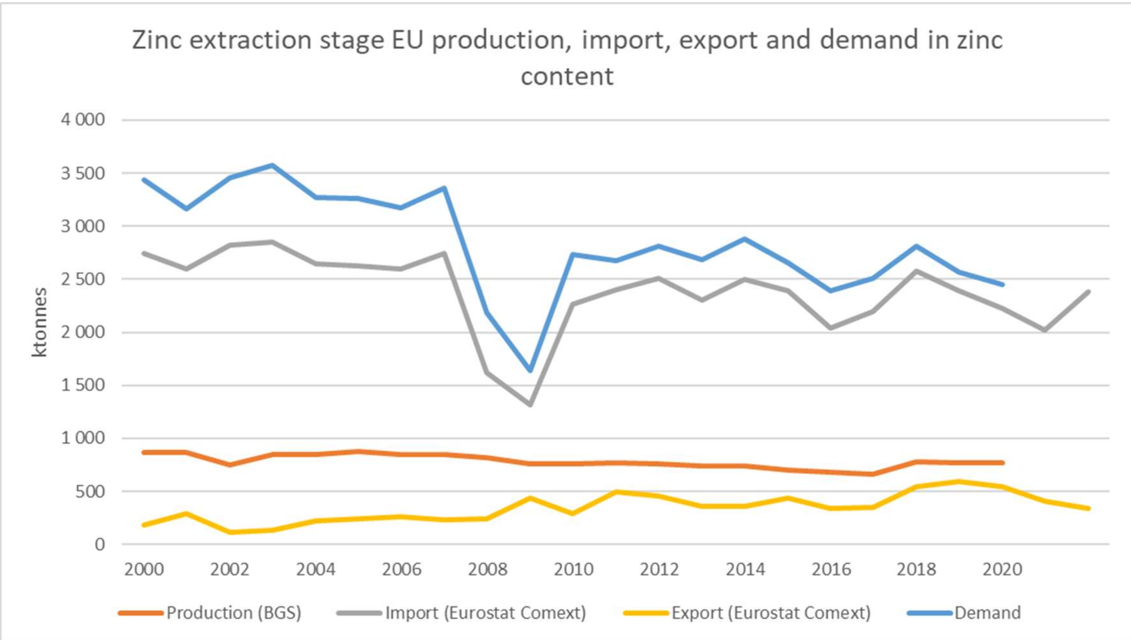


**Figure 14. Zinc (CN 26080000) extraction stage apparent EU consumption. Production data is available from BGS (2022). Consumption is calculated in zinc content (EU production+import-export).**

Zinc processing stage EU consumption is presented by HS code CN 7901 - Unwrought zinc: Import and export data is extracted from Eurostat Comext (2022). Production data is extracted from BGS (2022).

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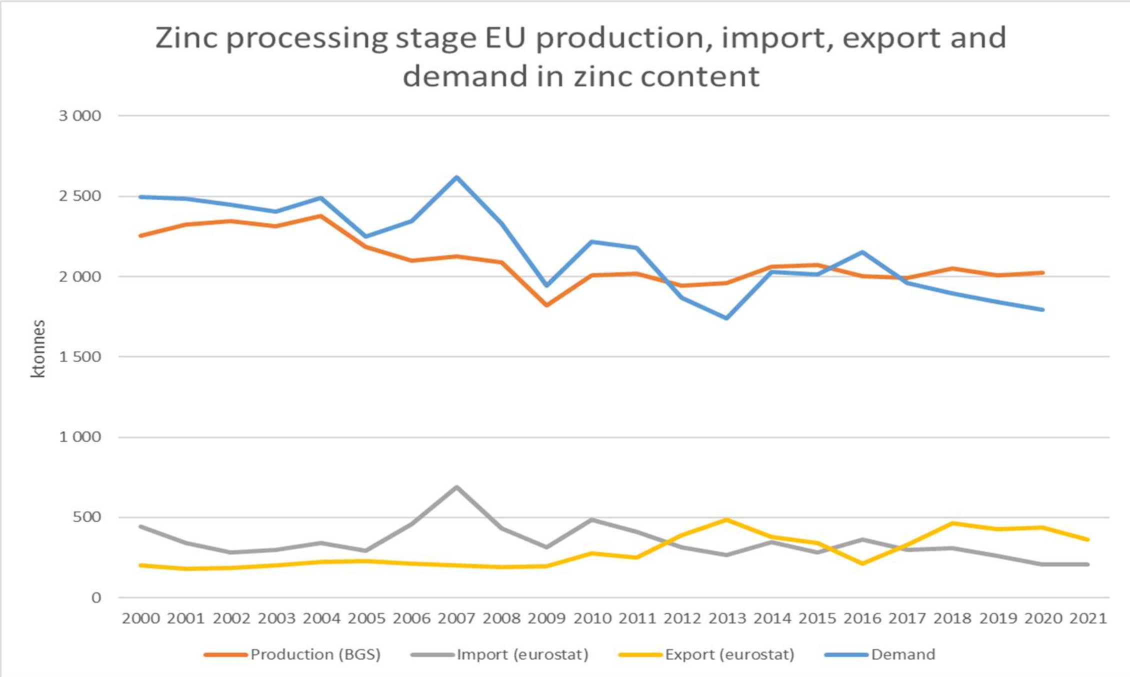


**Figure 15. Zinc (CN 79010000) processing stage apparent EU consumption. Production data is available from BGS (2022). Consumption is calculated in zinc content (EU production+import-export).**

Average import reliance of zinc is 71.5 % at extraction stage and 0 % at processing stage for 2016-2020.

## GLOBAL AND EU USES AND END-USES

Zinc is used to galvanize steel products, to produce zinc base alloys, brass and bronze, chemical compounds as well as semi manufactures like zinc sheet and wire.

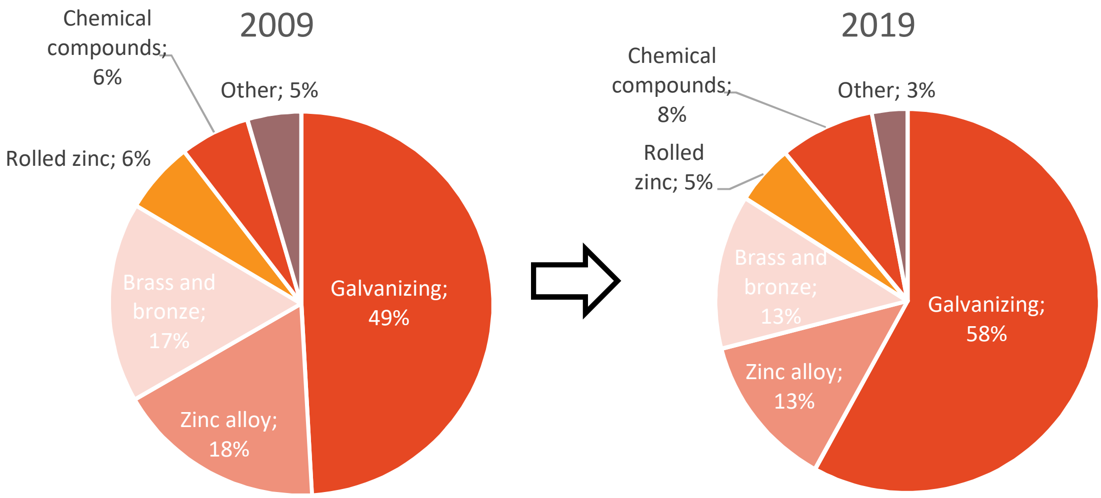


**Figure 16: Global first uses of zinc in 2009 (left) and 2019 (right) (Rostek et al., 2022)**

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Figure 16 presents the main global first uses of zinc for 2019 and 2009. Galvanizing is the most important application for zinc and even increased in market share from 49 % in 2009 to 58 % in 2019 (Rostek et al., 2022).

The first use goods are used to manufacture products of the sectors shown in Figure 17.

In terms of end products, 40 % of the zinc is used by the construction sectors, which includes both buildings and infrastructure. 22 % is used by the transportation sector including automotive applications, ships and trains. The industrial sector and consumer products account for 12 % each. 3 % of the demand belong to the health and nutrition sector, where applications like medicine, fertilizers and feed are included. Within the observed timeframe, the sectors of construction, consumer goods as well as health and nutrition increased in marked share, while the other sectors show a decreasing market share (Rostek et al., 2022).

To the best of our knowledge, there is no up-to-date data available for the European uses and end use shares of zinc since 2015. At this time, the EU uses were aligned with the global uses

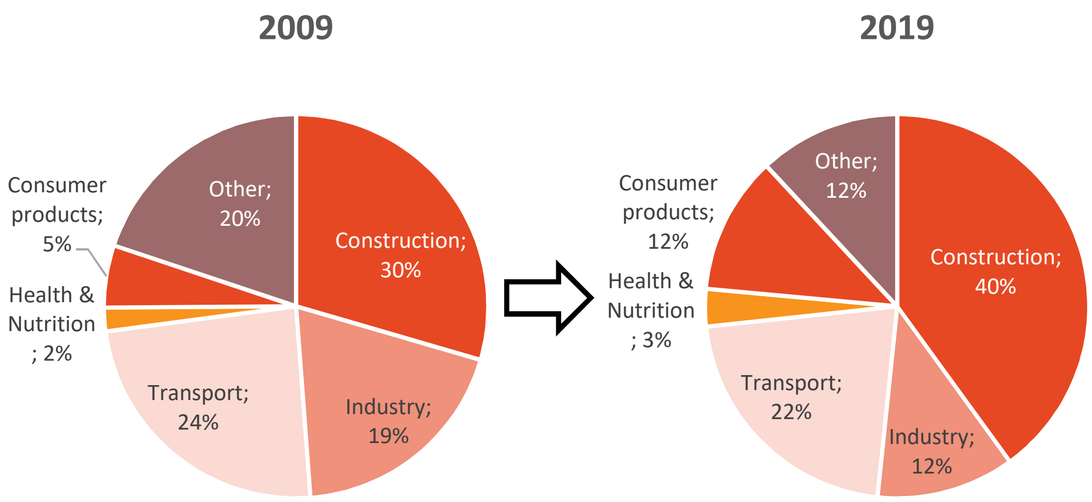


**Figure 17: Global end uses of zinc in 2009 (left) and 2019 (right) (Rostek et al., 2022)**

Relevant industry sectors are described using the NACE sector codes as listed in Table 7 and illustrated in Figure 18 (Eurostat, 2021).

**Table 7: Zinc applications, 2-digit and examples of associated 4-digit NACE sectors, and value-added per sector for 2018 (* for 2014) (Eurostat, 2021).**

| Applications | 2-digit NACE sector | Value added of NACE 2 sector (M€) | 4-digit CPA |
|---|---|---|---|
| Galvanizing | C25 - Manufacture of fabricated metal products, except machinery and equipment | 183,016 | 25.61 - Treatment and coating services of metals |

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| | | | |
|---|---|---|---|
| Zinc alloys | C24 - Manufacture of basic metals | 71,391 | 24.43 - Semi-finished products of lead, zinc and tin or their alloys<br>24.54 - Casting services of other non-ferrous metals |
| Brass and bronze | C24 - Manufacture of basic metals | 71,391 | 24.44 - Semi-finished products of copper or copper alloys |
| Chemical compounds | C20 - Manufacture of chemicals and chemical products | 117,093* | 20.30 - Paints, varnishes and similar coatings, printing ink and mastics.<br>20.15 - Fertilisers and nitrogen compounds |
| Zinc semi-manufactured | C25 - Manufacture of fabricated metal products, except machinery and equipment | 183,016 | 24.43 - Zinc bars, rods, profiles and wire; zinc plates, sheets, strip and foil |

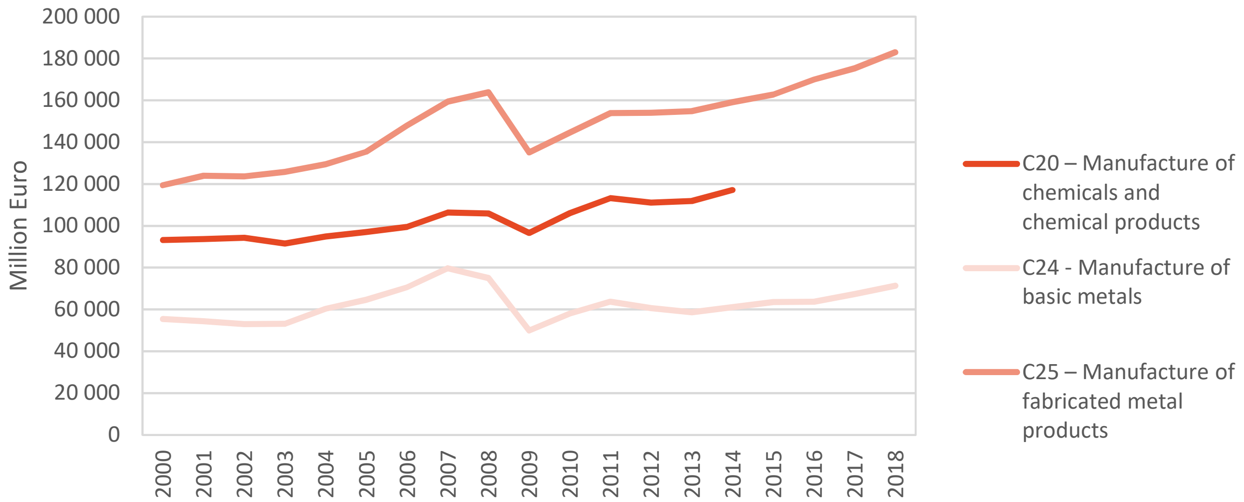


**Figure 18: Value added per 2-digit NACE sector over time (Eurostat, 2021).**

## APPLICATIONS OF ZINC

### GALVANIZATION

Galvanization is a process for coating steel structures to protect the component from corrosion. The thin layer of zinc functions as a barrier and sacrificial protection for the steel (ILZSG 2020). The galvanizing process is either continuous for producing galvanized steel sheets, strips or wire, or it is discontinuous to galvanize components with more complex shapes by batch or general galvanizing. Galvanized steel is used in a wide variety of products. Sheets are used to produce car bodies, corrugated sheet for construction, street furniture, household appliances and many more. Batch galvanized components are for example structural parts for buildings and infrastructure as well as smaller components like bolts, nuts and nails (ILZSG 2020).

### ZINC ALLOYS

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Zinc alloys are widely used in the production of die-casting components in automobile manufacturing, in the mechanical industry, for electrical and electronic goods, for household appliances, toys, furniture, and buildings. Zinc is alloyed to copper, aluminium, magnesium, chromium and titanium for die casting process (ILZSG 2020).

### BRASS AND BRONZE

Brass is an alloy of copper and zinc, which contains between 5% and 45% of zinc. It is applied for aesthetic products such as artworks, fittings, and trophies. Beside these, brass is used in technical applications like pipes, fasteners, machine parts, ammunition, and corrosion resistant mechanical products like bearings (ILZSG 2020).

Bronze is an alloy of copper and tin, which only contains a maximum of 1% zinc. It is used for sculptures and metals. Both brass and bronze are used for music instruments (ILZSG 2020).

### CHEMICAL COMPOUNDS

Zinc compounds or zinc chemicals such as zinc oxide are found in many common commercial products, including fertilisers, paints, plastics, rubber products, food supplements and additives for animals and humans, medicines, cosmetics, etc. Zinc sulphate is used in electrolytes for zinc plating. Metallic zinc powder is used as an anode material in zinc air button batteries (ILZSG 2020).

### ROLLED ZINC

Rolled semi manufactures include zinc sheet, strip, plate, rod and wire. These are mainly used when corrosion resistance is required. Main applications are in the construction sector and include roofing, cladding, facades, drain pipes and gutters (ILZSG 2020).

## SUBSTITUTION

**Table 8: Substitution options for zinc by application.**

| Application | Share | Substitutes | SubShare | Cost | Performance |
|---|---|---|---|---|---|
| Galvanising | 51% | Aluminium | 10% | Similar or lower costs | Similar |
| | 51% | Zn/Al/Mg/Si alloys | 10% | Slightly higher costs (up to 2 times) | Similar |
| | 51% | Polymer coating | 5% | Similar or lower costs | Similar |
| | 51% | Steel | 5% | Similar or lower costs | Similar |
| Zinc die casting alloys | 17% | Aluminium | 10% | Similar or lower costs | Similar |
| | 17% | Magnesium | 10% | Similar or lower costs | Similar |
| | 17% | Brass | 10% | Very high costs (more than 2 times) | Similar |
| | 17% | Steel | 10% | Similar or lower costs | Similar |
| | 17% | Polymers : Polypropylene, Nylon (30% Glass) | 10% | Similar or lower costs | Similar |

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| | | | | | |
|---|---|---|---|---|---|
| Brass and bronze | 16% | Tin brass & bronze (copper, zinc and tin) | 4% | Very high costs (more than 2 times) | Similar |
| | 16% | Nickel-silvers | 4% | Very high costs (more than 2 times) | Similar |
| | 16% | Silicon bronzes and brasses | 4% | Very high costs (more than 2 times) | Similar |
| | 16% | Manganese bronzes | 4% | Similar or lower costs | Similar |
| | 16% | Aluminium bronzes | 4% | Similar or lower costs | Similar |

### GALVANIZING

For corrosion protection, zinc coating is substituted by aluminium alloys (less effective), cadmium, paint and plastic coatings (less durable). Galvanised plates, e.g., in automobiles, can be replaced by aluminium, steel or plastics.

### DIE CASTING ALLOYS

Aluminium, magnesium as well as their alloys, and plastics are major competitors for parts of zinc-based die-casting alloys (USGS, 2022). Aluminium is commonly employed in die-casting but is prone to cracking or shrinking at high temperatures. Magnesium has a high strength-to-weight ratio despite being a relatively light alloy, and it is useful for die-casting operations that require thin-structured walls and close precision (FisherCast, 2008; IZA, 2019).

### BRASS AND BRONZE

Plastics and stainless steel can serve as a substitute of brass used e.g., in plumbing applications such as fittings, pipes and fasteners. Silver and gold can be used for music instruments but have much higher price compared to brass. Brass in friction applications can be replaced by steel or plastics but comes with a reduction of performance (Kalman-Schueler 2021).

### CHEMICAL COMPOUNDS

Many elements are substitutes for zinc in chemical, electronic, and pigment uses (USGS, 2022). The particular substitute depends on the specific application. Zinc is indispensable for plants, animals and human, so that an exhaustive substitution in fertilizers and feed is not feasible.

### ROLLED ZINC

Zinc sheets in buildings are mainly applied in Europe due to historical and aesthetic reasons. It can be replaced by other building materials, e.g., by tiles in roofing or by plaster, concrete, wood, and stone for facades. Zinc sheet can be substituted by galvanized steel sheet, which still contains zinc but in lower quantity.

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# SUPPLY

## EU SUPPLY CHAIN

Zinc ore is extracted and processed in the EU. About 733 kt of refined zinc were produced in EU by primary European resources during the period 2016-20120. Sweden, Portugal and Spain are the largest producers of zinc by primary resources. At the same time, 2 million tonnes of zinc were produced at the processing stage mainly in Spain, Netherlands, Finland and Belgium. The average annual imported amount of zinc products (zinc concentrates with an average content of 55 wt.% and metallic zinc) by EU during 2016-2020 was around 2.4 million tonnes. Zinc concentrates are mainly imported by Mexico, Peru and United States. During the same period, around 1 million tonnes of refined zinc is exported to third countries. China, Turkey and Norway are the main partners in respect of exports. An additional average of about 700 ktonnes per year of zinc are produced from recycling materials (scrap, residues, by-products and specific products (e.g. brass) going directly to zinc use sectors without passing through the smelters. The recycling rate in EU is estimated at 31% (Eurostat, 2021).

## SUPPLY FROM PRIMARY MATERIALS

### GEOLOGY, RESOURCES AND RESERVES OF ZINC

#### GEOLOGICAL OCCURRENCE

The average zinc concentration in the Earth continental upper crust is estimated to be 67 ppm (Rudnick & Gao, 2014). The main zinc mineral is sphalerite (ZnS). Zinc mineralisations and deposits are common and occur at various sizes and volumes all over the globe.

Zinc is extracted from two main types of deposits hosted in sedimentary rocks: sedimentary-exhalative (SEDEX) and carbonate hosted deposits, which include Mississippi-valley type (MVT) and Irish type carbonate lead zinc deposits. Carbonate replacement deposits (CRD), Zn-Pb skarn deposits and volcanogenic massive sulphide deposits (VMS) are also important sources of zinc.

- *SEDEX deposits* are hosted in fine grained clastic sediments, mainly shales. They form from warm brines (~100-200 °C) discharged on or just below the seafloor, in sedimentary basins in continental rift settings. They include some of the largest Pb-Zn deposits in the world, such as McArthur River in Australia and Red Dog in the USA.
- *MVT deposits* are epigenetic stratabound deposits hosted mainly by dolomites and limestones. They form from warm brines with temperatures in the range of 75-200 °C (the Irish style tend to have higher temperatures with some data indicating up to 240°C) in carbonate platforms adjacent to cratonic sedimentary basins (e.g. Viburnum trend, USA; Upper Silesia, Poland). The mineralization occurs as replacement of the carbonate rocks and as open-space fill (Paradis *et al.*, 2007; Leach *et al.*, 2010).
- *Carbonate-replacement deposits (CRD) and Zn-Pb skarn* deposits (e.g. Groundhog, USA; Bismark, Mexico) are hosted by carbonate rocks (limestones, dolomites, calcareous clastic sediments). They form by

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reaction of high temperature hydrothermal fluids (»250 °C) with the carbonate rocks, in the vicinity of igneous intrusions. CRD deposits occur as massive lenses, pods, and pipes (mantos or chimneys) (Hammarstrom, 2002).

- *Volcanogenic Massive Sulphide Deposits (VMS)* are hosted either in volcanic or in sedimentary rocks and occur as lenses of polymetallic massive sulphide. VMS deposits form on, and immediately below the seafloor, by the discharge of a high temperature, hydrothermal fluids in submarine volcanic environments. They also are significant sources for cobalt, tin, selenium, manganese, cadmium, indium, bismuth, tellurium, gallium, and germanium.

## GLOBAL RESOURCES AND RESERVES:

The USGS estimated the world identified zinc resources at about 1,900 million tonnes (USGS, 2019). A recent study assessing the world zinc mineral resources (Mudd *et al.*, 2017) indicates that at least 610 Mtonnes are present within 851 individual mineral deposits and mine waste projects from 67 countries, at an average zinc grade of 1.2%.

The most recent global reserves of zinc estimated by USGS (USGS; 2000) are230 Mtonnes with Australia and China accounting for almost half of the global total (46%) (Table 9).

**Table 9: Global reserves of zinc in 2022 (USGS, since 2000)**

| Country | Estimated zinc reserves (Mtonnes) |
|---|---|
| Australia | 66.0 |
| China | 31.0 |
| Peru | 17.0 |
| Mexico | 12.0 |
| Kazakhstan | 7.4 |
| United States | 7.3 |
| India | 9.6 |
| Bolivia | NA |
| Canada | 1.8 |
| Sweden | 4. |
| Other countries | 30.0 |
| World total (rounded) | 210.0 |

## EU RESOURCES AND RESERVES

Resource data for some countries in Europe are available in the Minerals4EU website (Table 10) (Minerals4EU, 2019) but cannot be summed up as they are partial and do not use the same reporting code.

**Table 10: Reserve data for the EU compiled in the European Minerals Yearbook (Minerals4EU, 2019) (rounded values).**

| Country | Reporting code | Quantity | Unit | Grade | Code Reserve Type |
|---|---|---|---|---|---|
| Portugal | NI43-101 | 16.5 | Mt | 5.83% | Proven |
| Ireland | JORC | 14.8 | Mt | 7.39% | Proven & Probable |

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| | | | | | |
|---|---|---|---|---|---|
| Finland | NI43-101 | 7.4 | Mt | 1.8% | Proven |
| | JORC | 2.4 | Mt | 0.68% | Proved |
| Sweden | NI43-101 | 12.3 | Mt | 6.69% | Proven |
| | FRB-standard | 17.2 | Mt | 5.2% | Proven |
| Italy | None | 3.4 | Mt | 24.6% | Estimated |
| Poland | Nat. rep. code | 8.2 | Mt | – | total |
| Ukraine | Russian Classification | 723.746 | kt | – | C1 |
| Slovakia | None | 0.049 | Mt | 2.78% | Probable (Z2) |
| Kosovo | Nat. rep. code | 13,247 | kt | 3.17% | (RUS)A |
| Turkey | NI43-101 | 4.49 | Mt | 3.19% | Proven |

## GLOBAL AND EU MINE PRODUCTION

The primary global zinc production since 1984 and since 2000 according to WMD and USGS data, respectively can be seen in Figure 19 and Figure 20. Global zinc production seems to have a slightly reducing trend after 2014, while the after 2016 it has been stabilized at around 12 Mtonnes. China is the larger producer representing over the 32% of world production in 2020 (WMD, since 1984). Peru, Australia, Unites States, Mexico, Bolivia and India consist also major zinc producers representing together about the 40% of the world production. EU represents about the 4% of the global zinc production by primary resources.

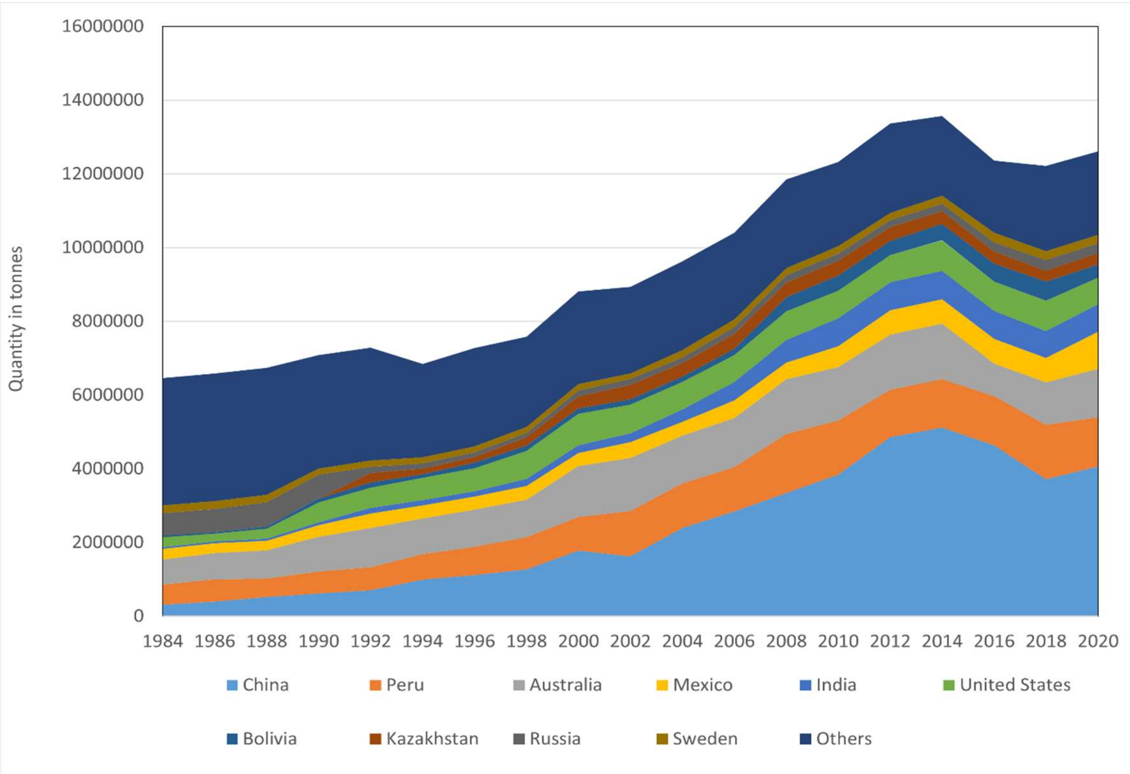


**Figure 19. Global production of refined zinc by primary resources in tonnes since 1984 according to WMD data (WMD, since 1984).**

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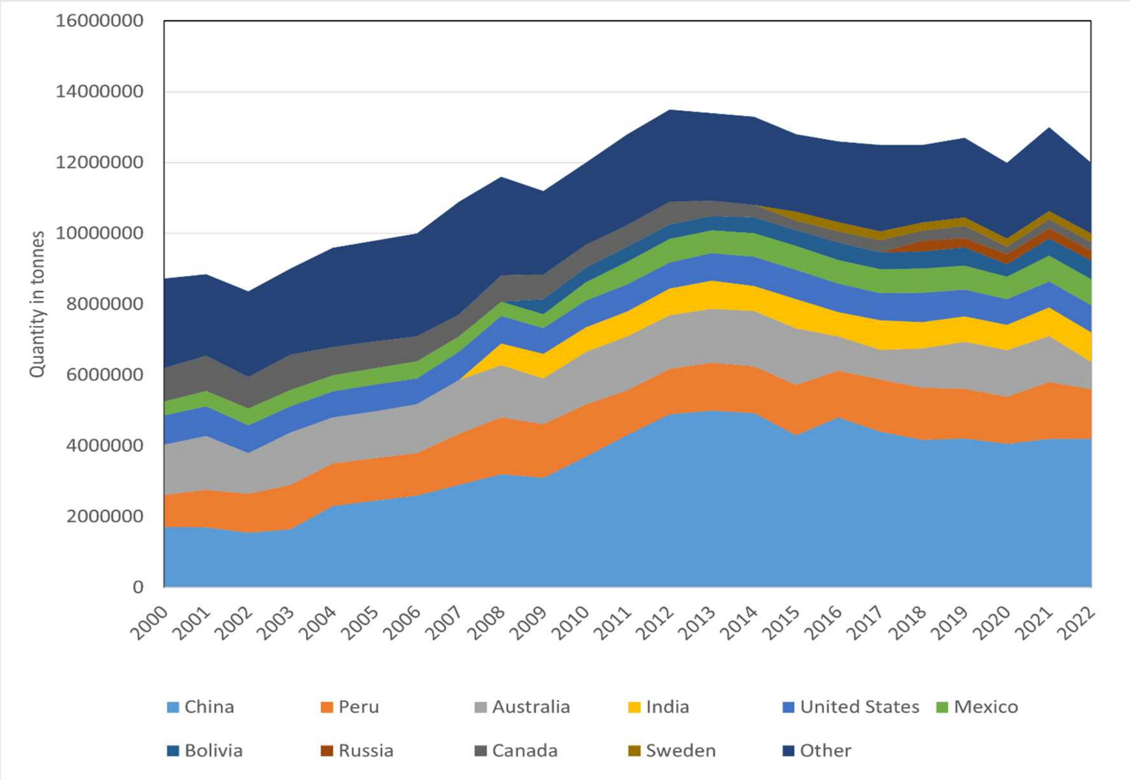


**Figure 20. Global production of refined zInc in tonnes since 2000 according to USGS data (USGS, since 2000).**

## OUTLOOK FOR SUPPLY

Following the decline in 2022, refined zinc production is forecasted to increase by 2.6% to 13.84 million tonnes in 2023. Zinc production in China is expected to grow by 3.8%. Rising output is also forecast in Australia, India, Kazakhstan, Mexico and Turkey, where a new smelter has recently been commissioned (capital.com, 2022). Europe accounts for around 12% of global refined zinc output, but zinc availability on the European continent has been hammered recently due to the energy crisis triggered by the Russia-Ukraine war as well as a supply disruption. Furthermore, worry about labour disputes has hampered copper output in Peru (the world's second-largest zinc producer), which may spill over to zinc mines. Ultimately deepening the fear of a future supply shortage. Fitch Solutions also predicts China's annual refined zinc production balance to average a 196,000-tonne surplus from 2026 to 2031 compared with a deficit of 292,000 tonnes from 2016 to 2022, which will make the country a significant supplier of zinc. Most market analysts also predict new zinc supply is expected to come from regions including Central and South America, Eastern Europe, and Africa (theassay.com, 2022).

## SUPPLY FROM SECONDARY MATERIALS/RECYCLING

Over the past decade (2010–2019), zinc recycling doubled while zinc mining remained at a constant level. This has improved the indicators such as the Recycling Input Rate (RIR) or the End-of-Life Recycling Rate (EoL RR) that is currently 39%. Zinc production, use, and recycling are closely interconnected with the material cycles

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of steel, brass, and lead, which adds to the complexity (IZA, 2022). Depending on the recycling scenarios presented above, zinc supply from mining would be required to grow from 12 Mt in 2020 to between 17 and 22 Mt by 2050, depending on what comes back from recycling (Figure 21) .Despite previous suggestions in the literature, zinc resources available via mining (crustal content, known and extractable resources, etc.) exceed those necessary to ensure long-term availability of zinc from mined sources. Taken together with the anticipated improvements in waste management and increased recycling of industrial by-products, the End-of-Life Recycling Rate (EoL RR) for zinc could rise from 34% in 2019 to over 50% by 2050 (zinc.org, 2022).

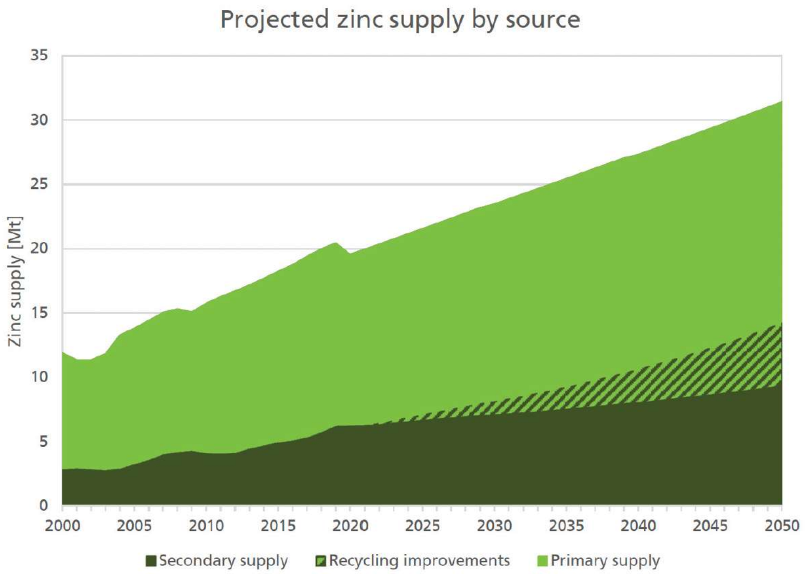


**Figure 21: Forecast of zinc supply by primary and secondary resources until 2050 (zinc.org, 2022).**

**Post-consumer recycling (old scrap)**

In addition to ore concentrate, zinc smelters feed an average of 10-15% secondary raw materials into their processes. These are predominantly crude oxides (waelz oxides), which are enriched zinc containing flue dusts from production of galvanized steel. In some cases, the recycled zinc content in the smelter feed can be higher – in specific cases up to 100%. These recycled tonnages are included in the primary zinc production data in the previous chapter.

An additional (global) tonnage of 4,000-5,000 ktonnes of zinc was recycled annually in re-melt processes, in the copper or the zinc compound industry, without passing through the zinc smelters (about 700 ktonnes in the EU). Different from many other metals, there is not a single technology for recycling, but instead tailor made recycling technologies for the most important zinc uses are well established:

Zinc sheet and zinc die casted parts are re-melted. Over 95% of zinc sheet scrap is recycled in Europe. Re-melting zinc requires only 5% of the energy that is needed to produce primary zinc from ores.

Galvanized steel is re-melted in the steel industry e.g. electric arc furnace. Zinc ends up in the flue dust (EAF dust) and is further concentrated in the Waelz process. The Waelz/crude oxide is a welcome raw material for primary zinc production at less costs than concentrates supply, its use often being limited by the available

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tonnage. Other potential technologies for zinc recycling from galvanized steel are being tested at pilot plant or conceptual phase. 11% of steel scrap from building and construction is reused e.g. in Germany, while 88% are recycled in the steel industry. All EAF dusts that are produced in Europe are recycled. With the emerging markets for galvanized steel a significant growth at global scale is expected.

Zinc as an alloying element in brass is recycled by the copper industry. There it is used for brass production or alternatively returned to the zinc industry.

Various technologies are applied to recycle zinc from residues, wastes and by-products. Often zinc in these recycling loops is directly used to produce zinc compounds without passing through zinc smelters, thus saving costs, energy and raw materials (Grund *et al.*, 2019).

## PROCESSING OF ZINC

Zinc is extracted by primary resources either through a hydrometallurgical-electrochemical process or through pyrometallurgy. The first route involves as first step the oxidative roasting of the concentrate at 900 °C to convert the zinc sulfide to calcine (zinc oxide). Subsequently zinc oxide is leached with sulfuric acid to produce aqueous zinc sulfate solution. The iron impurities are dissolved as well and they are precipitated out as jarosite or goethite in the presence of calcium carbonate or ammonia. Jarosite and goethite are usually disposed of in tailing ponds. The addition of zinc dust to the zinc sulfate solution improves the purification process. The purification of leachate leads to precipitation of cadmium, copper, and cobalt as well. The final step comprises the electrolysis of the pure solution using lead alloy anodes and aluminum cathodes. The high-purity zinc deposited on aluminum cathodes is stripped off, dried, melted, and cast into zinc ingots (with 99.99 % purity) (Figure 22).

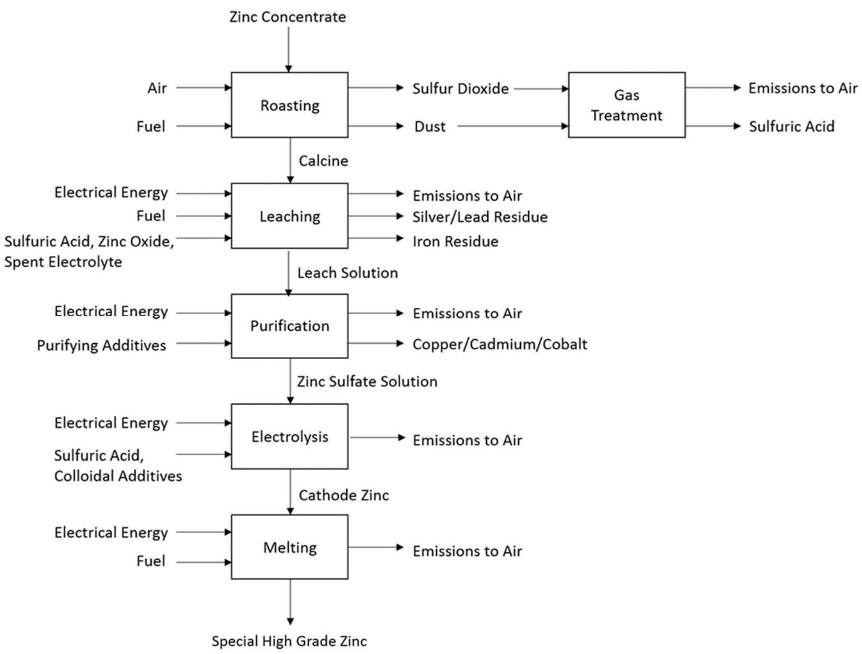


**Figure 22: Zinc extraction by primary ores through hydrometallurgical processing (Van Genderen et al. 2016).**

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Pyrometallurgical processing for zinc extraction is applied at a limited extent worldwide. The primary ore is reduced with coke in imperial smelting furnace operating at temperatures up to 1500 °C. The reduction is enhanced by the conversion of carbon to carbon monoxide, and zinc and lead oxides are reduced to metallic zinc and lead. The liquid lead bullion is collected at the bottom of the furnace along with other metal impurities (copper, silver, and gold). Zinc in vapor form is collected from the top of the furnace along with other gases. Zinc vapor is then condensed. The process is energy-intensive and produces zinc of lower purity (around 98%) than the hydro/electro-metallurgical process (Van Genderen et al. 2016).

## OTHER CONSIDERATIONS

### HEALTH AND SAFETY ISSUES RELATED TO THE ZINC OR SPECIFIC/RELEVANT COMPOUDS AT ANY STAGE OF THE LIFE CYCLE

Zinc is an essential trace element for the normal growth and reproduction of all higher plants and animals, and of humans. In addition, it plays a key role during physiological growth and fulfils an immune function. It is vital for the functionality of more than 300 enzymes, for the stabilization of DNA, and for gene expression (Nriagu, 2007; Frassinetti et al., 2006). The Recommended Dietary Allowance (RDA) for adults 19+ years is 11 mg a day for men and 8 mg for women (US NIH, 2022).

Exposure to high doses has toxic effects but an acute zinc intoxication is a rare event (Prasat et al. 2020). In addition to acute intoxication, long-term, high-dose zinc supplementation interferes with the uptake of copper. Hence, many of its toxic effects are in fact due to copper deficiency (Plum, 2010; Prasat, 2020). Whereas intoxication by excessive exposure is rare, zinc deficiency is widespread and has a detrimental impact on growth, neuronal development, and immunity, and in severe cases its consequences are lethal (Prasat, 2020).

An excess of zinc in drinking water – at concentrations greater than 3mg/l can be detrimental to the appearance of the water, with a greasy surface film developing and an unpleasant metallic taste. The (WHO, 2006), taking into consideration the most recent studies on humans, established that it was not needed to define a guideline value for zinc content in drinking water. Nonetheless, it is assessed that a value above 3 mg/L may not be acceptable for drinking water. and (US EPA, 2023) fixes a secondary maximum contaminant level (SMCL) for zinc of 5.0 mg/l. The EU Drinking Water Directive does not set a standard for zinc.

The (OSHA, 2016) established the legal airborne permissible exposure limit (PEL) at 1 mg/m$^3$ (for zinc chloride), 5 mg/m$^3$ (for zinc oxide fume), 15 mg/m3 (for zinc oxide total dust), and 5 mg/m$^3$ (for zinc oxide respirable dust) averaged over an 8-hour work shift. Germany set a limit value of 2 mg/m$^3$ of inhalable zinc and inorganic zinc compounds at the working place. (GESTIS 2023).

The Guidelines for Canadian drinking water quality defines the levels of zin recommended in drinkable water – in fact, water containing zinc at concentrations below 5.0 mg/l is generally considered to be non-toxic (Government of Canada, 2022).

The use of zinc was also included in the Covid-19 treatment guidelines developed in the USA – however as most of the cohort studies and clinical trials on this topic have many limitations, there is still insufficient evidence to recommend the use of zinc in the treatment of Covid-19 (NIH 2022).

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## ENVIRONMENTAL ISSUES

Although zinc occurs naturally, most zinc finds its way into the environment because of human activities. Mining, smelting metals (like zinc, lead and cadmium) and steel production, as well as burning coal and certain wastes, can release zinc into the environment (Noulas et al., 2018). High levels of zinc in soil may result from the improper disposal of zinc-containing wastes from metal manufacturing industries and electric utilities. In soil, most of the zinc stays bound to the solid particles. When high levels of zinc are present in soils, such as at a hazardous waste site, the metal can seep into the groundwater (Hussain et al., 2022). Industries also can release dust containing higher levels of zinc into the air we breathe. Eventually, the zinc dust will settle out onto the soil and surface waters. Rain and snow also can remove zinc dust from the air. Most of the zinc in lakes, rivers and streams does not dissolve but settles to the bottom. Some fish in these waters may contain high levels of zinc. High levels of zinc in the soil, water and air are often found along with high levels of other metals like lead and cadmium (Hussain, et al., 2022; Barman and Roy, 2018).

At high concentrations in the soil, zinc is phytotoxic, and plants that accumulate it through root absorption or deposition, pose health risks to consumers (Guarino et al., 2020).

The Canadian Council of the Ministers of the Environment issued the “Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health. They describe effects of zinc on plants and microorganisms in soil and set up quality and check thresholds for zinc concentrations for agricultural, residential, commercial and industrial lands. (CCME 2018)

## NORMATIVE REQUIREMENTS RELATED TO MINING/ZINC PRODUCTION, USE AND PROCESSING OF THE MATERIAL

No specific aspects could be identified.

## SOCIO-ECONOMIC AND ETHICAL ISSUES

### ECONOMIC IMPORTANCE OF ZINC FOR THE MAIN PRODUCING/EXPORTING COUNTRIES

Table 11**Erreur ! Source du renvoi introuvable.** lists the countries for which the economic value of exports of zinc represents more than 0.1 % of the total value of their exports.

**Table 11: Countries with the highest economic shares of zinc exports in relation to their total exports.**

| Country | Export value (USD) | Share in total exports (%) |
|---|---|---|
| Bolivia | 820,435,724 | 11.7 |
| Tajikistan | 57,755,024 | 8.0 |
| Peru | 1,576,817,513 | 4.1 |
| Montenegro | 12,083,847 | 2.9 |
| Burkina Faso | 106,736,354 | 2.4 |
| Mongolia | 167,680,497 | 2.2 |
| Namibia | 116,802,648 | 2.1 |

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| | | |
|---|---|---|
| Kazakhstan | 799,490,083 | 1.7 |
| Uzbekistan | 152,388,514 | 1.2 |
| Finland | 706,059,355 | 1.1 |

*Source: (COMTRADE 2022), based on data for 2020.*

Bolivia exports of zinc ores and concentrates represent 11% in value of the total trade exports of the country, followed by Tajikistan (8%). Peru has a more diversified export portfolio, including, in addition to zinc ores, unwrought (not alloyed) and alloyed zinc.

### SOCIAL AND ETHICAL ASPECTS

From the 1970s to 2003 the Topilnica zinc and lead smelting factory was operating in the city of Veles, Northern Macedonia. The smelting plant emitted pollutants such as sulphur compounds, which caused acute respiratory problems and cardiovascular diseases (Steger, T., 2007). The shutdown of the plant came after years of protests by the city population, which was strongly affected by air and water pollution. Three years after the cease, in 2006, the company Metrudhem DOOEL Skopje bought the plant with the intention of reactivating the smelting activity. This triggered a long period of legal battles and street protests between the Veles city population and the company, ending up with the permanent closure of the smelter. Nonetheless, the entire area is still heavily polluted, and decades of actions of ecosystem remediation will be needed to restore the environmental quality of the city and the surroundings (Environmental Justice Atlas, 2016; Shashevski, B., 2015; Pančevski, Z., 2014).

## RESEARCH AND DEVELOPMENT TRENDS

### RESEARCH AND DEVELOPMENT TRENDS FOR LOW-CARBON AND GREEN TECHNOLOGIES

- Zinc-air battery for energy storage

Even though zinc-air batteries (ZAB) are considered a promising technology for energy storage, they have some drawbacks, namely a short life due to the high corrosion of the metal in an alkaline medium (Li et al., 2019). (Mainar et al., 2018) showed that a combined approach including surface treatment of the zinc electrolyte and the use of additives in the alkaline electrolyser allows for an increase in battery performance. In fact, with this method, the life cycle of ZAB was increased by 50 % and the roundtrip efficiency grew by 55 % after 270 h operation.

- ZAS[4] project: Zinc Air Secondary Innovative Nanotech Based Batteries for Efficient Energy Storage - (EU, 2015-2018)

The goal of the project was to improve the ZAB lifetime and performance - namely, increase energy density - and to reduce production costs. This required the manufacturing of the materials for the electrolyte and the electrode for producing a full-cell model. Later, the cell was studied and data about the technology was

[4] https://cordis.europa.eu/project/id/646186

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provided. Long-term tests have shown that the ZAB developed during the ZAS project can be operated for at least 2,000 hours/200 cycles and produced at 300 €/kWh.

## OTHER RESEARCH AND DEVELOPMENT TRENDS

- STAR[5] project: Safe, Transparent, Active and Reliable mineral sunscreen technology (2018 – 2019, EU)

MicNo®, is a patented Zinc Oxide UV filter for use in cosmetic formulations. MicNo® are designed platelet-shaped micron particles composed of nano primary particles - developed to exploit benefits of the nano-size particles while removing adverse effects of them. The aim of this project is to mature, in-vivo test and commercialise MicNo® onto the global markets. MicNo® has gone through in-vitro testing, toxicity tests as well as efficacy tests – they all showed superior broad-spectrum protection, improved transparency at application by 15-20 %, mitigation of safety and health concerns related to nano zinc particles, as well as high area coverage/unit mass – a 40 % reduction in raw materials usage for same UV protection.

- Zinc Complexes Derived from 5-Bromo-2-(((2-isopropylamino)ethyl)imino)methyl)phenol: Microwave-Assisted Synthesis, Characterization, Crystal Structures and Antibacterial Activities (Zhang et al. 2021)

Three new zinc complexes [Zn3L2(μ2-η1:η1-CH3COO)2(μ2-η2:η0-CH3COO)2] (1), [ZnCl2(HL)] (2) and [ZnBr2(HL)] (3), where L = 5-bromo-2-(((2-isopropylamino)ethyl)imino)methyl)phenolate, HL = 5-bromo-2-(((2-isopropylammonio) ethyl)imino)methyl)phenolate, have been synthesized under microwave irradiation. The complexes were characterized by elemental analyses, IR, UV-Vis spectra, molar conductivity, and single crystal X-ray diffraction. X-ray analysis revealed that the Zn atoms in complex 1 are in square pyramidal and octahedral coordination, and those in complexes 2 and 3 are in tetrahedral coordination. The molecules of the complexes are linked through hydrogen bonds and π···π interactions. In order to evaluate the biological activity of the complexes, in vitro antibacterial against Staphylococcus aureus, Bacillus subtilis, Escherichia coli and Pseudomonas aeruginosa was assayed.

- Efficiency of exogenous zinc sulfate application reduced fruit drop and improved antioxidant activity of 'Kinnow' mandarin fruit (Liaquat et al. 2022)

Kinnow' mandarin (Citrus nobilis L.× Citrus deliciosa T.) is an important marketable fruit of the world. It is mainstay of citrus industry in Pakistan, having great export potential. But out of total production of the country only 10 % of the produce meets the international quality standard for export. Pre-harvest fruit drop and poor fruit quality could be associated with various issues including the plant nutrition.

Zinc (Zn) is amongst those micronutrients which affect the quality and postharvest life of the fruit and its deficiency in Pakistani soils is already reported by many researchers. Therefore, this study was carried out to evaluate the influence of pre-harvest applications of zinc sulphate (ZnSO4; 0, 0. 4%, 0.6 % or 0.8 %) on pre-harvest fruit drop, yield and fruit quality of 'Kinnow' mandarin at harvest. The treatments were applied during the month of October, i.e. 4 months prior to harvest. The applied Zn sprays had significant effect on yield and

[5] Cordis EU research results, 10.3030/741192

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quality of the "Kinnow" fruit. Amongst different foliar applications of ZnSO4applied four months before harvest, 0.6 % ZnSO4 significantly reduced pre-harvest fruit drop (10.08 %) as compared to untreated control trees (46.45 %). Similarly, the maximum number of fruits harvested per tree (627), fruit weight (192.9 g), juice percentage (42.2 %), total soluble solids (9.5 °Brix), ascorbic acid content (35.5 mg 100 g-1) and sugar contents (17.4) were also found significantly higher with 0.6 % ZnSO4 treatment as compared to rest of treatments and control. Foliar application of 0.6 % ZnSO4 also significantly improved total antioxidants (TAO) and total phenolic contents (TPC) in fruit. In conclusion, foliar spray of ZnSO4 (0.6 %) four months prior to harvest reduced pre-harvest fruit drop, increase yield with improved quality of 'Kinnow' mandarin fruit.

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