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The urban mining potential of zinc in Switzerland

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ABSTRACT

The wide range of applications of zinc in modern society makes closing the zinc cycle a difficult task. Yet, studies on the zinc cycle have primarily focused on material flows, while policy-makers would clearly benefit from complementary information to put the material flow potentials into perspective. I conducted an urban mining potential analysis of zinc in Switzerland to inform the Canton of Zurich for upcoming strategic planning.

The urban mining potential analysis consists in identifying main elements of zinc management, the importance of secondary sources, and how these elements interact with the ecological, technological, economic, social, and governance domains. Based on this knowledge, experts evaluation the urban mining potential of zinc.

The main elements of zinc management are two steel works and municipal solid waste municipal solid waste incinerators (MSWIs), processing steel scrap and fly ash for zinc recovery abroad. More MSWIs are processing fly ash for recovery as a result of a new legal obligation. Because of high prices for recovery abroad, incinerators are cooperating to set up a centralized plant capable of recovering pure zinc metal from processed fly ash. Experts considered the increase of zinc recovery from bottom ash of MSW incinerators as a key next step for sustainable zinc management.

The study proved the usefulness of adding different perspectives to material cycles if policy-makers are to be informed. The urban mining potential analysis allowed identifying two key elements of zinc management in Switzerland, ways to support these elements, or priorities to improve zinc management in general.

KEYWORDS

Urban mining potential, policy, recycling, zinc

1 INTRODUCTION

1.1 BACKGROUND

Zinc is an essential element for all life forms and a key metal of industrial society [1,2]. It is present in a wide range of applications, from galvanized steel in construction to brass in vehicles to zinc oxides in paints, just to name a few. The largest zinc reserves are found in Australia, followed by China, Peru, Mexico, and the USA [3]. The demand in zinc has grown over the last two decades, mainly driven by China's development. Yet despite this, the economically recoverable ore grades barely changed in Australia and Canada during this time (Fig. 1). In line with this, zinc prices did not rise significantly. That said, zinc prices soared twice in the past; during the oil price shock of 1973 and right before the global economic crisis of 2008. Also, many applications are dissipative. In such applications, zinc is lost to the environment while in use [4]. The wide range of applications of zinc in modern society, its dissipative nature, and volatile prices make closing the zinc cycle a difficult task: Government and multiple economic sectors need to be involved in closing the zinc cycle and action taken only in waste management, at the end of the pipe, is unlikely to be sufficient.

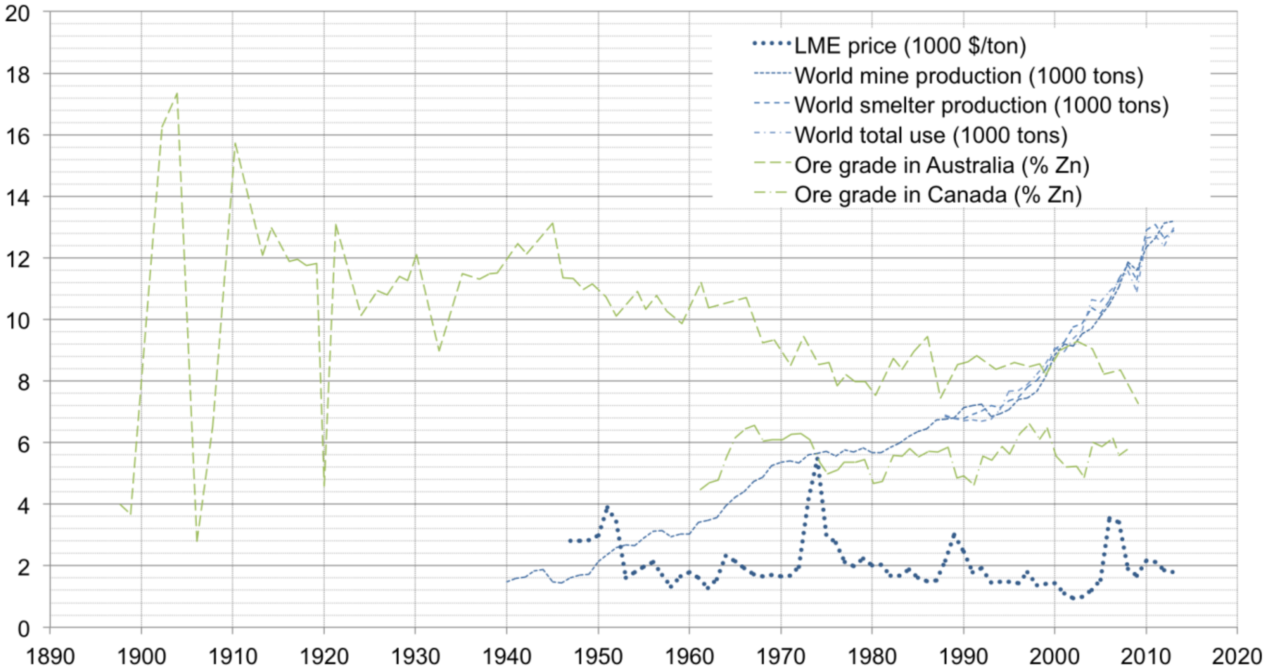

Fig. 1 LME (London Metal Exchange) price (1947-2013), inflation-adjusted (Source: Metals Week and Metal Statistics), mine production [5,6], smelter production [5] (1986-2013) and use (1988-2013) [5] of zinc, as well as zinc ore grade in Australia and Canada [7]

Switzerland, a highly industrialized country, is also dependent on zinc for its wellbeing. The material flow analysis [8] depicted on Fig. 2 reveals the stocks and flows of zinc in Switzerland in 2010. The Swiss zinc demand is entirely covered by imports and recycling. Zinc is imported to Switzerland as zinc slab, semi-finished products and goods. The in-use zinc stock amounted to some 93 kg/capita in 2010 (global average of 24 kg/capita [9]). 5.3 kg/capita were imported in 2010. Every Swiss person needed ca. 4.5 kg of zinc back then, more than twice as much as the global average (1.9 kg). Meanwhile, every Swiss person generated 3.7 kg of zinc waste, of which 1.5 kg returned to production processes and 2.2 kg were landfilled in Switzerland or abroad. 0.23 kg were downcycled in cement plants among others. 1.3 kg were rerouted to the zinc cycle. Both the Swiss steel works and the municipal solid waste incinerators (MSWIs) play an important role in recycling. Steel works presently recover 1 kg Zn/capita as zinc-bearing filter dust [10]. In 2010, a third of fly ashes (2016: ca. 60%) from MSWIs was further processed for zinc recovery, corresponding to the recycling of 0.09 kg Zn/capita. Zinc recovery in MSWIs is made possible by acid washing of fly ash (FLUWA) [11-13]. FLUWA produces zinc-bearing hydroxide sludge processed to zinc metal by means of foreign Waelz kilns just as filter dust from steel scrap. Thirty four percent of the waste zinc collected in Switzerland in 2010 was rerouted to the zinc cycle.

The rising costs of processing hydroxide sludge abroad make domestic recovery ever more attractive. Efforts focus on bringing about a central solution to the more complex part of metal recovery from fly ash in order to keep the costs of such recovery as low as possible. The plant planned for this purpose could process from 2021 on all Swiss hydroxide sludge to zinc metal by means of a novel metal recycling technology [14,15]. MSWIs could then recycle up to 0.26 kg Zn/capita from their fly ash. Fifty percent of zinc entering MSWIs ends up in bottom ash as metal and mineral components [16]. MSWIs already partially recover brass (i.e., copper-zinc alloys), steel and zinc alloys. Low zinc concentrations among other factors hamper the recovery of zinc from non-metal fractions.

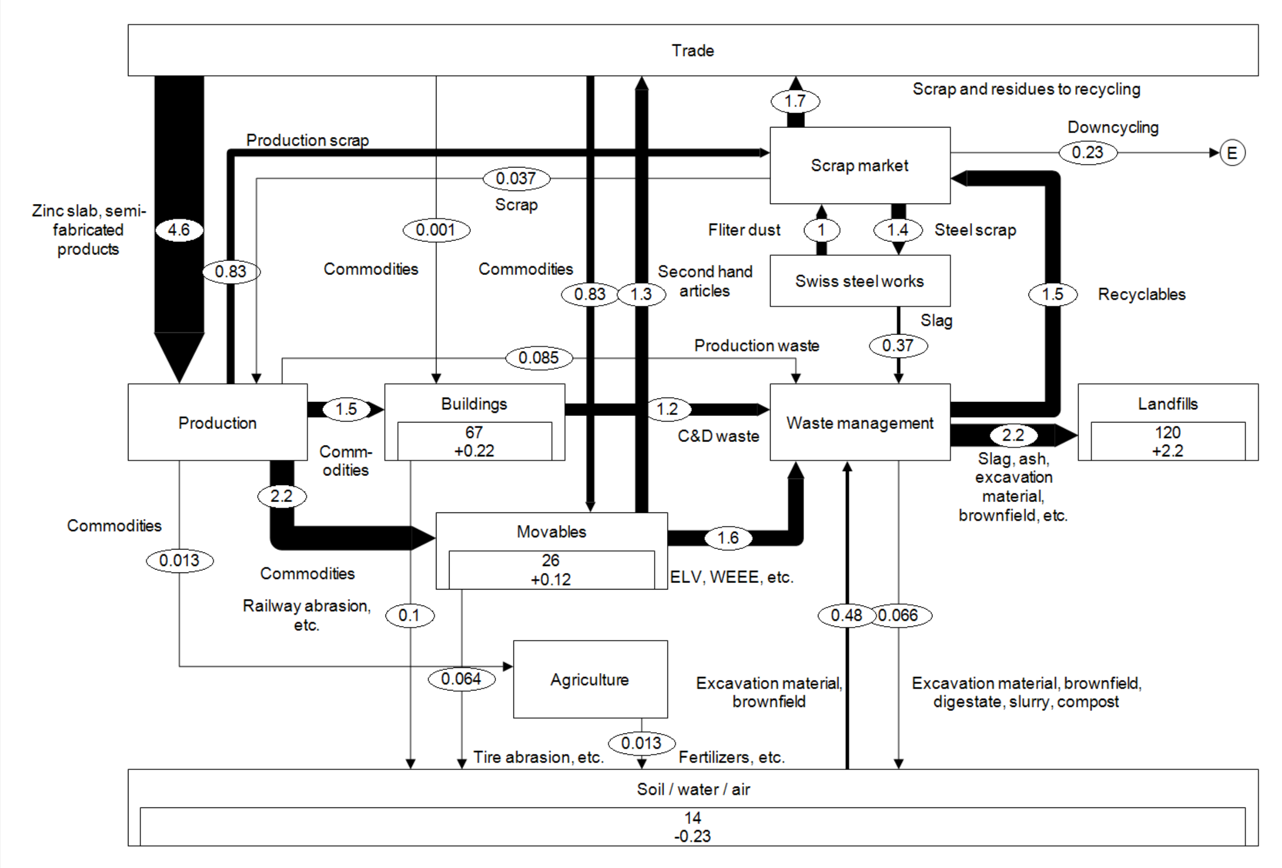

Fig. 2 Zinc flows 2010 (kg/capita/a), stocks 2010 (kg/capita) and stock changes 2010 (kg/capita/a) (based on Hügi et al. [17], Kral et al. [18], Meylan, Reck [9], Schlumberger [11]). The process Waste Management includes municipal solid waste incineration, the acid washing of fly ash, composting and anaerobic digestion, the sorting and treatment of construction & demolition waste and recyclables, etc. (C&D: construction and demolition, ELV: end-of-life vehicles, WEEE: waste electrical and electronic equipment)

Most geogenic zinc deposits of Switzerland are situated in the eastern and western Swiss Alps and in Tessin [19]. At present, extraction is not profitable. In contrast, Switzerland can today rely on large secondary zinc reserves: approx. 1’00’000 tons of zinc are stocked in Swiss landfills, which is the equivalent of around 120 kg per capita in 2015 or 130% of the zinc in-use stock. The in-use zinc is contained mainly in construction, vehicles, and smaller products ending up in MSWIs. Waste electric and electronic equipment (WEEE) and end-of-life vehicles (ELVs) contain some 5-10 g Zn/kg. Construction and demolition (C&D) waste contains 0.9 g Zn/kg, while fly ash from MSWIs have some 40 g Zn/kg. The highest zinc concentrations are found in filter dust from steel works with 150-450 g Zn/kg and zinc oxides from Waelz kilns with 550-700 g Zn/kg [18,20,21,9,22-25]. The evolution of the in-use zinc stock per capita shows a decline as of 2000 and a flattening as of 2010. The amounts landfilled in 2050 depend on the deployment of acid washing of fly ash and the subsequent metal recovery. Should all fly ash be treated with these two technologies, the landfill stock would amount to 144 kg of zinc per capita by 2050. The landfill stock would rise to 153 kg/capita if neither technology were taken up and the decision was made to landfill fly ash. The full deployment of fly ash treatment could thus reduce the future landfill stock by a quarter in comparison to the total absence of these technologies [18,26,9,11,27].

1.2 RESEARCH GAP

So far, studies on the zinc cycle have primarily focused on material flows, providing a complete cycle picture for different countries, world regions, and the world [9,1,28] or on specific issues of material flows, such as zinc used in galvanized steel [29] or dissipation [4]. These studies inform policy-makers on potentials for resource management, highlighting for instance the amount of zinc coming out of use and sent back to the zinc cycle or indicating the share of zinc from secondary sources in the total amount of zinc consumed. While the usefulness of such studies is undisputed, policy-makers would clearly benefit from complementary, concise information to put the material flow potentials into perspective [30]. For instance, economic barriers or environmental issues can limit material potentials in a specific, regional context. Governance can then be leveraged to counteract these economic barriers and start moving towards fulfilling the material potentials.

1.3 RESEARCH GOAL

I conducted an urban mining potential analysis [31] of zinc in Switzerland in order to inform the Canton of Zurich, a major political entity of Switzerland, for upcoming strategic planning in resource and waste management. The objective of the analysis was to systematically investigate how the main elements of zinc management in Switzerland and the most important secondary sources interact with the five domains of technology, environment, economy, society, and government. The results of the urban mining potential analysis will soon be published as factsheet available to the broader public on the website of the Waste Management Section of the Canton of Zurich. The present contribution relies extensively on this factsheet.

2 METHODS

Simoni et al. [31] derived the method of urban mining potential analysis from the Sustainable Livelihoods (SL) framework and the associated Five Capitals model [32,33]. The Five Capitals model [33] is an adaptation of the SL framework to mining and sustainability to link mineral cycles and social, ecological, technological, economic, and governance domains. Within an urban mining potential analysis, the systematic review of relative advantages of impacts of secondary over primary production enables a grounded, context-specific formulation of policy measures. The facts and figures presented in the five domains come from published information produced by different types of societal actors and consortia thereof: academia, government, industry, non-governmental organizations. In the governance domain, in order to provide an outlook with respect to priorities for future governance, experts rate the current state in each domain and the fields of action and state briefly the rationale for their ratings.

Fig. 3 synthesizes the different stages of the urban mining potential analysis. The first stage presents relevant global information such as long-term time-series of prices and ore grades as well as the best available material flow analysis of the region of interest. The stage closes with region-specific information on primary resources of this region as well as extensive information on secondary resources in the form of in-use stocks or tonnages of waste streams. Here, so-called tonnage-ore diagrams help identify the most important waste streams in terms of mass of a specific element, e.g., zinc. In the second stage, each of the five domains is scrutinized by focusing on the contrast between primary and secondary production. While the two fist stages rely mostly on literature review with expert inputs, the third and final stage is the expert evaluation of the urban mining potential of the element. Simoni et al. [31] chose a three-point scale. In addition, experts are asked to indicate and justify the field of action as well as its importance. An advisory group, in this case members of the Waste Management Section of the Canton of Zurich, supported and guided the urban mining potential analyst on topics of interest in each domain, relevant literature, as well as evaluated the urban mining potential.

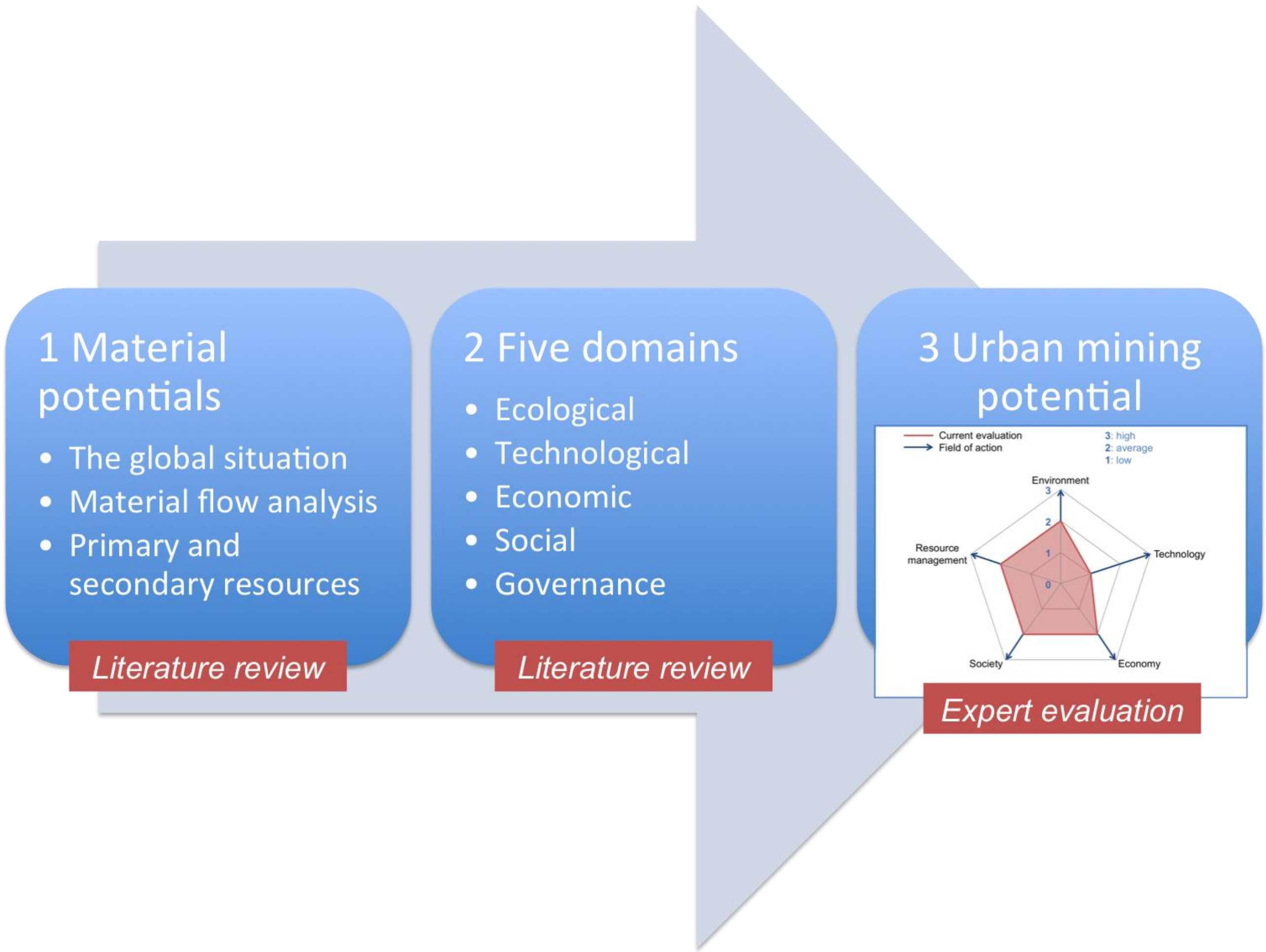

Fig. 3 Methodological stages of an urban mining potential analysis

3 RESULTS

3.1 MATERIAL POTENTIALS

The zinc flow analysis in 2010 highlights the main elements of zinc management in Switzerland (see Fig. 2): the two steel works and MSWIs. The two steel works use electric-arc furnaces to produce steel from steel scrap and recover ca. 1 kg Zn per year per capita as filter dust. Waelz kilns abroad process the filter dust into zinc oxides that can be fed to zinc smelters. Thirty MSWIs process half of all Swiss MSW and zinc-rich wastes such as automobile shredder residues [23]. In 2010, a third of incinerators was equipped with a wet chemical process to recover ca. 0.09 kg Zn per year per capita as zinc-rich sludge from fly ash [34]. Like EAF dust, Waelz kilns abroad process this zinc-rich sludge into zinc oxides. The main secondary sources of zinc in Switzerland are C&D waste (9 Gg Zn/a), ELVs (3 Gg Zn/a), and residual waste (4 Gg Zn/a).

3.2 THE FIVE DOMAINS

3.2.1 ECOLOGICAL DOMAIN

Zinc is an essential element for all life forms, plants and animals can either lack zinc or feel the toxic effects at high levels of exposure. Some plants lack zinc at concentrations in tissues below 20 ppm [21]. It is toxic above 400 ppm [21]. The use of zinc in coating and as mineral fertilizer and waste management are responsible for its emission into the soil and water bodies [4]. Some 126 g of zinc per capita were lost to the environment in 2013 in the Canton of Zurich [18]. Waste management is responsible for 52% of these emissions. Twenty eight percent come from buildings and infrastructure, 11% come from agriculture, 9% come from waste water treatment [18]. Zinc mines and mills release substances more toxic than zinc, for instance lead, copper, and cadmium [21]. The smelting and refining of zinc are most problematic when it comes to occupational heath. Standards for occupational exposure were therefore established to prevent metal fume fever [21].

A life cycle assessment of all life cycle stages from mining to refining showed that purification and refining have the highest environmental impacts [35] (Fig. 4 a); the impacts on human health (DALY/kg) and ecosystem quality (Species.a/kg) are assessed with the impact assessment method ReCiPe Endpoint (H, World) v1.08 [36] and correspond to potential damages prior to normalization and weighting. This observation holds for zinc-lead mines, which make up some 93% of primary production [35]. Zinc (with a global production of 11'700 kt in 2008 [37]) is ranked among the 10 metals with the highest CO_2 footprint (40 Mt CO_2 equivalents/year) and highest impacts on human health and ecosystems. The cumulative energy demand of global zinc production amounted to 619 PJ in 2008, which corresponds to 1.3% of total metal production and the fifth rank among all metals [35]. This makes zinc one of the ecologically most relevant metals. A comparative life cycle assessment shows on Fig. 4 b how the SwissZinc process outperforms Waelz kilns as alternative to treat hydroxide sludge [22]. The investigated environmental indicators are the CO_2 footprint and the total Environmental Impact Points (UBPs). The relative values (%) refer to the Waelz kiln impacts. The UBPs 2013 and the CO_2 Footprint are calculated with the Method of Ecological Scarcity [38] and the CO_2 Footprint method [39], respectively. The SwissZinc process produces zinc metal. Waelz kilns recover zinc oxides as Waelz oxides, which substitute zinc ore. The better environmental performance of the SwissZinc process stems on the one hand from its higher product quality, as smelting of Waelz oxides is necessary. On the other hand, the SwissZinc process has a lower CO_2 footprint, as it does not require coke as reducing agent and the SwissZinc site at the MSW incinerator in Zuchwil does not rely on fossil fuels.

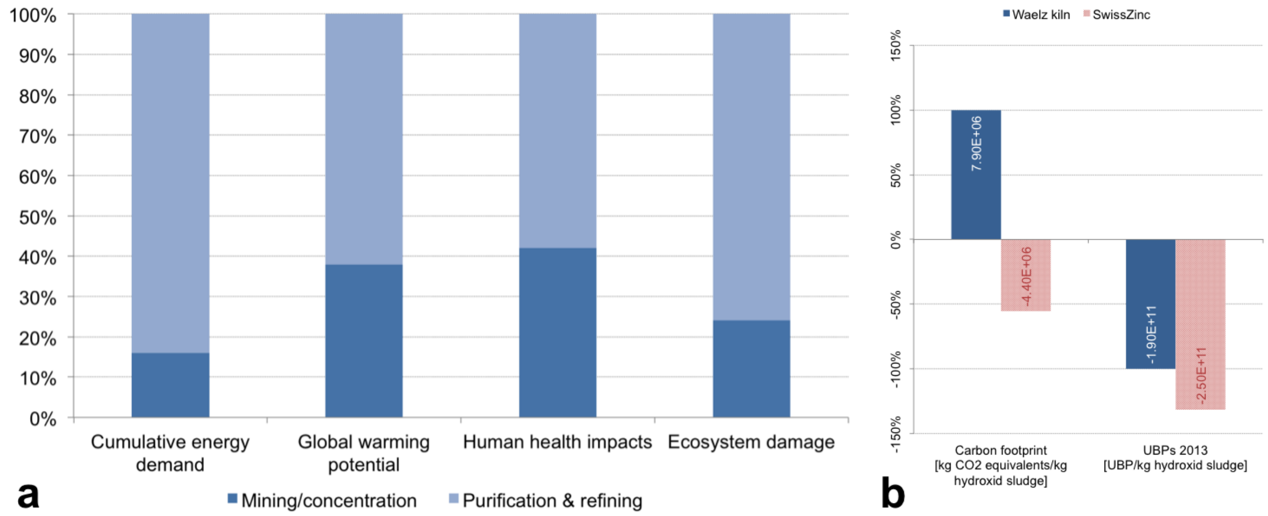

Fig. 4 Relative environmental impacts of life cycle stages of primary production [35] (a) and life cycle assessment of hydroxide sludge disposal in Waelz kilns (blue, no pattern) and with the SwissZinc process (red, pattern) (b)

3.2.2 TECHNOLOGICAL DOMAIN

Zinc is extracted from primary and secondary materials (Fig. 5). Different pathways exist in both primary and secondary production to yield zinc metal. In pyrometallurgy and hydrometallurgy, zinc passes from the oxidized form to the reduced one. The stages required to treat waste and residues from industry and waste treatment are highlighted in purple. For instance, waste incineration allows accumulating zinc in fly ash. Not shown on the figure are the production of other zinc products (e.g., zinc chemicals) and the possibility of remelting scrap from zinc alloys and brass.

In zinc mines around the world, zinc ore is extracted underground and in open pits [21]. The extracted ore is first concentrated at the mining site and fed to subsequent smelting as concentrate. Smelting is performed in pyrometallurgical and hydrometallurgical processes. Today, hydrometallurgical processes account for 95% of global zinc production [40]; zinc concentrates are roasted and converted to zinc oxides, which then undergo sulphuric acid leaching, purification, and zinc electrolysis. The product is special high-grade zinc (purity >99.995%).

Because its environmental footprint is significantly smaller than that of primary production, zinc recycling is becoming ever more important in the framework of a sustainable circular economy. For instance, zinc-bearing filter dust from steel production is further processed for zinc recovery mainly in Europe, Japan, and the USA [9]. The second recovery pathway, so far applied only in Switzerland, starts at MSW incinerators, where zinc accumulates in fly ash at an average of 40 g Zn/kg [22]. In the downstream FLUWA process, acid wastewater, a by-product of flue gas treatment, enables the dissolution of heavy metals contained in fly ash – above all zinc [11,13]. The subsequent precipitation of dissolved metals yields hydroxide sludge. Foreign Waelz processes treat the resulting hydroxide sludge together with filter dust from steel works. Waelz oxides can be processed by smelters, in which they replace zinc concentrates proportionally. The introduction of the FLUREC process in Switzerland demonstrated the feasibility of recovering zinc metal from MSW incinerators fly ash (purity >99.995%). The technology builds on the FLUWA process, as it consists of purifying the FLUWA filtrate, increasing its zinc content by means of solvent extraction, and precipitating zinc metal through electrolysis. Extending the FLUREC process to all FLUWA-MSW incinerators is foreseen in the framework of the SwissZinc project. Such industry solution enables the fulfillment of the legal requirement on metal recovery [41].

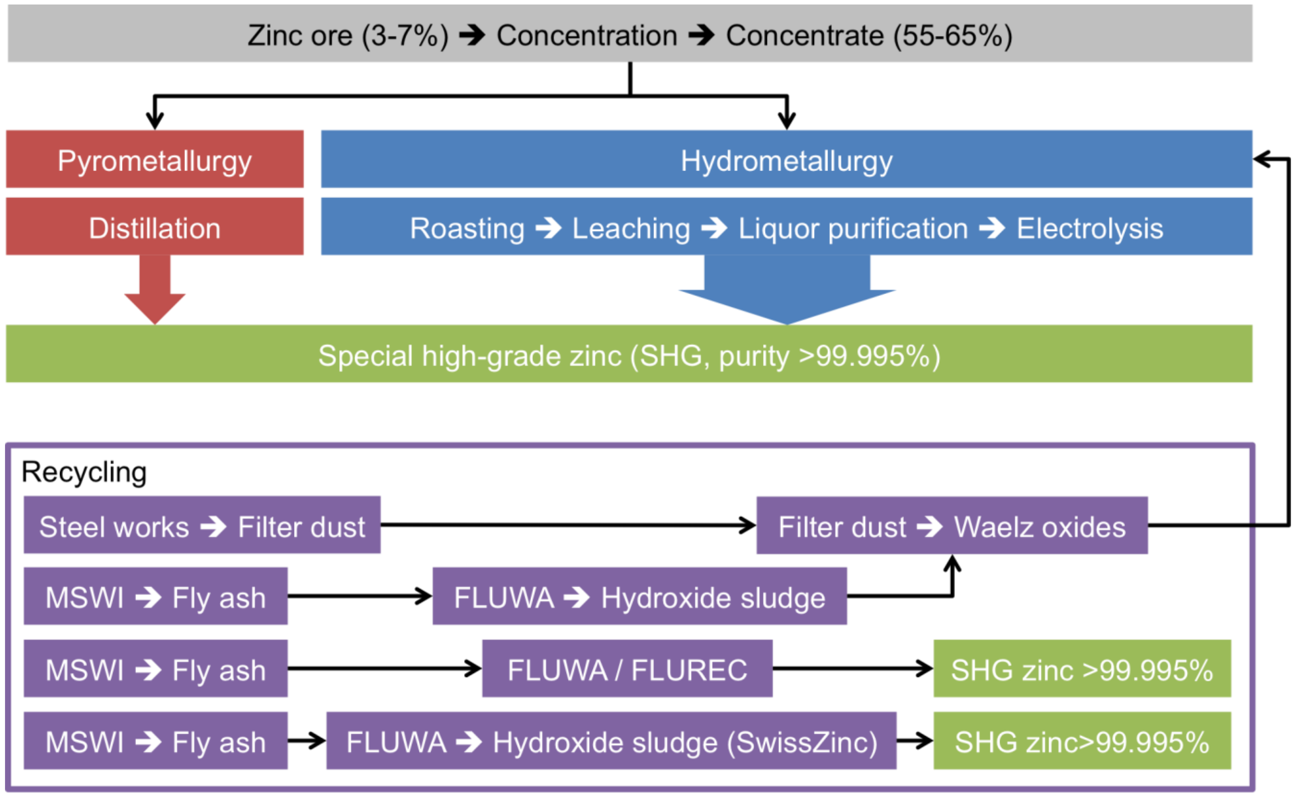

Fig. 5 Primary and secondary zinc production [21,14,15,25].

3.2.3 ECONOMIC DOMAIN

2015 saw Switzerland import 21’000 tons of zinc products (i.e., products with zinc as main component) worth 63 million CHF; 16’000 tons worth 24 milion CHF were exported [42] (Fig. 6). Raw materials make up the largest share of imports, while exports consist predominantly of goods. Unwrought zinc (i.e., zinc metal and zinc alloys) and semi-finished products represent together more than 90% of imports. 12’000 tons alone were imported as zinc metal showing a purity of more than 99.99% and worth 25 million CHF. This import category corresponds to the product substituted by the FLUWA and SwissZinc processes. Semi-finished products made up much of the exports, while scrap made up 15% of exports. The different nature of imports and exports affected the zinc price: while the import of a ton of zinc cost an average of 3’000 CHF in 2015, the exported ton was worth an average of 1’500 CHF.

The international zinc prices rose by some 40% between 2005 and 2016 (Fig. 1). After the peak in 2006 and the economic crisis of 2008, the prices rose quickly again – presumably mainly thanks to speculative investments made because of the improving economic climate [37]. After that, the important price factors were the Chinese demand and the closure of large mines [43,44]. The danger arising from the emergence of oligopolies on markets is relatively small because the supply of zinc is possible in many countries on different continents [9]. The zinc import prices in Switzerland range from 1’900 to 2'800 CHF/t [42]. The USD-CHF exchange rate plays a role here as well. The price of landfilling MSWI fly ash in foreign underground deposits tended to decrease in the last years and amounted to 250 CHF/t. FLUWA can be considered as cost-neutral. The reduced landfill costs of output streams compensate the expenses entailed in FLUWA. Treating fly ash with the SwissZinc process will allow saving costs of underground landfilling, while securing the entire value chain in Switzerland. Switzerland can generate some 30 million CHF with this industrial solution. The net costs of zinc recovery from hydroxide sludge certainly depend to a large extent on the plant size and the actual zinc prices.

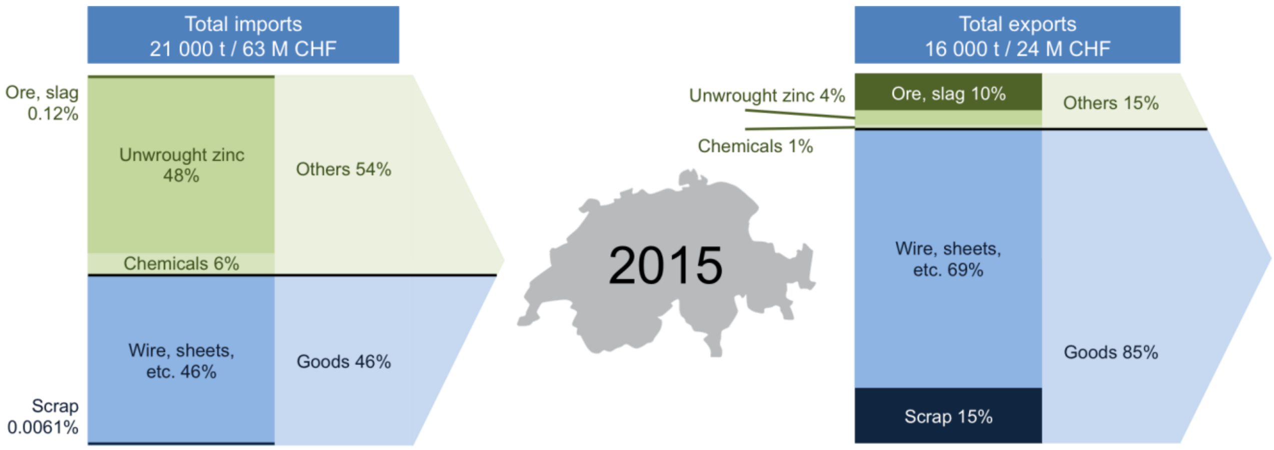

Fig. 6 2015 imports and exports of raw materials (green, upper part of block arrow) and goods (blue, lower part of block arrow) with zinc as main component [42]. Filter dust from steel scrap, FLUWA hydroxide sludge, MSWI fly ash, and galvanized steel are not included

3.2.4 SOCIAL DOMAIN

Some 1'000 businesses are active in the Swiss industrial and metal working machinery and generate about 10% of the gross domestic product [45]. In this sector, zinc is used in batteries and sensors together with critical raw materials, i.e., lithium, nickel, and platinum. Approximately 6'500 persons are employed in metal recycling, including zinc [46]. The steel scrap processors and the two steel works in Gerlafingen and Emmenbrücke also play a role. The 12 Swiss municipal solid waste incinerators recycling zinc by means of the FLUWA and FLUREC processes must be added as well. As of today, FLUWA/FLUREC generates some 27 full time jobs. The industrial solution relying on the FLUWA and SwissZinc processes would mean some 40-50 persons would take care of zinc recycling from fly ash.

The social and cultural aspects of zinc ore mining are increasingly being scrutinized and are analyzed in so called social or socio-economic impact assessments at the opening or closing of mines. Different indicators of social and socio-economic impacts are used (Tab. 1). There is still no standardized method for social impact assessment, although the use of such standards has been acknowledged long ago [47]. A standardized method would indeed help compare not only mines on different continents but also primary and secondary production with respect to social and cultural aspects. The comparability between primary and secondary production provides the knowledge base to develop market instruments, such as labels.

The main zinc recycling potential lies in C&D waste, ELVs, and refuse. Sorting on the construction or demolition site makes possible the extensive recovery of metals and hence zinc. Besides refuse, more than half of zinc found in end-of-life vehicles ends up in MSWIs as residues from shredders (RESH) after triage and shredding [18]. Some 50% of zinc present in the MSWI input lands in MSWI bottom ash [16]. The possibility of increasing the recycling rate of zinc from MSWI bottom ash should be the object of continuous scrutiny in order to close raw material cycles and create new jobs.

In the midterm, the accumulation of knowledge and technology on acid washing and the treatment of hydroxide sludge or metal recovery by means of hydrometallurgical processes can be exported. The new „Circular Economy Package" conceived by the European Commission and the corresponding adaptation of the Waste Directive [48] should reinforce this trend. The export shares of some Swiss suppliers of waste technologies are already reaching 30 to 40% [49]. To help these providers tap into export markets, the Swiss Association for Environmental Technology (SVUT) is planning to set up an expert platform, which aims to support the implementation of environmental legislation and the commercialization of Swiss environmental technologies in other countries [49].

Tab. 1 The social impacts considered in two zinc ore mines [50,51]

Social impacts of a mine opening (South Africa)	**Social impacts of a mine closure (Australia)**
Macroeconomics (incl. jobs)	Economic progress (incl. jobs)
Social aspects and health	Preservation of indigenous culture and traditions
Visual landscapes	Conservation of landscape and environment
Traffic	Social progress and stronger communities
Cultural heritage, archeology, and paleontology	Fulfillment of agreement between indigenous population and other stakeholders

3.2.5 GOVERNANCE DOMAIN

Most uses of zinc are dissipative (c.f. tire wear, for instance), so that measures should be taken in product design.

The private sector promotes recycled steel through its campaign „Öko-Stahl“ initiated by „Stahlpromotion“, the umbrella organization of the Swiss steel and metal construction industry. „Öko-Stahl“ strives for the acceptance of recycled steel in the construction industry. Significant achievements are the public recognition of the real share of recycled steel in steel profiles and the use of ecoinvent data in the Swiss Component Catalogue. The Component Catalogue enables the environmental impact assessment of building constructions. The ecoinvent data do not include avoided environmental burdens through zinc recycling taking place in steel works and improving the overall environmental performance of steel recycling. Including these avoided burdens would make steel recycling even more attractive.

As to the Government, the new Ordinance on Waste Prevention and Disposal (VVEA) [41] prescribes the recovery of metals from MSW incineration fly ashes. In addition to currently available recovery pathways (Waelz process among others), further technical possibilities and processes (SwissZinc) are developed to contribute to the ecological improvement of the entire system. Around half of zinc contained in the MSW incineration input ends up in bottom ash. Today, zinc is partially recovered as steel, brass, and zinc alloys from MSW incineration bottom ash. So far, the FLUWA process cannot treat bottom ash for economic reasons linked to FLUWA’s high alkalinity on the one hand, and because of lower zinc concentrations (dilution effect), on the other hand.

3.3 URBAN MINING POTENTIAL

Fig. 7 shows the evaluation of zinc’s urban mining potential by means of qualitative expert assessment. The rationale for the evaluation is given in the following lines. *Environment*: High environmental savings through secondary production, low recycling rates. *Technology*: Improve product design, zinc recovery from mechanically treated MSW incineration bottom ash. *Economy*: Zinc recovery from hydroxide sludge in development competes with relatively high treatment costs and unstable zinc prices. *Society*: Standardized methods for the comparison of socio-economic impacts of primary and secondary production are inexistent. Labels would raise awareness on environmental performance. *Resource management*: Need for further development of the technical recyclability of zinc and of the economic framework as well as need for the improvement of product design.

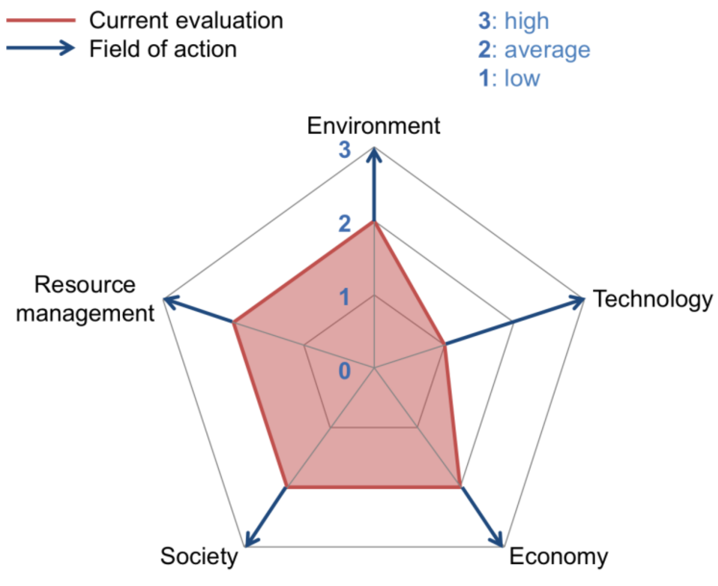

Fig. 7 Evaluation of zinc’s urban mining potential (all uses) by means of qualitative expert assessment

4 CONCLUSIONS AND OUTLOOK

4.1 CONCLUSIONS

Looking at the technological and ecological domains gives a whole new perspective to current zinc management in Switzerland. More MSW incinerators are getting equipped to recover zinc-rich sludge from fly ash as a result of a legal obligation. The incinerators are also cooperating to set up by 2021 a centralized recycling plant capable of processing zinc-ridge sludge of all incinerators into 0.26 kg of pure zinc metal per year per capita, in effect by-passing Waelz kilns and zinc smelters. The main driver behind this cooperation is the high price for treatment of the zinc-rich sludge in Waelz kilns. Moreover, a life cycle assessment highlighted the environmental benefits of the centralized recycling plant in comparison to Waelz kilns. That said, the centralized plant will have to cope with fluctuating world zinc prices. Since 2010, the import prices of pure zinc slab in Switzerland ranged between 1’900 and 2’800 Swiss francs (CHF) per ton. Import prices are also influenced by the currency rate between CHF and USD. Labels acknowledging the environmental benefits of the centralized plant can provide support against fluctuating zinc prices until the ecological value added of the centralized plant is economically effective (e.g., via an international CO_2 emissions trading system). Also, a clear, standardized methodology for comparing socio-economic impacts of primary and secondary production is still needed. Such a methodology would then provide the basis for developing the socio-economic aspects of the aforementioned labels. With respect to the evaluation of the urban mining potential, experts considered the increase of zinc recovery from bottom ash of MSW incinerators – not economically viable for the time being – as a key next step for sustainable zinc management.

4.2 OUTLOOK

To conclude, the study proved the usefulness of adding different perspectives to a material cycle if policy-makers are to be informed. The urban mining potential analysis allowed identifying two key elements of zinc management in Switzerland, ways to support these elements, or priorities to improve zinc management in general. The analysis, because available to the broader public, is not only useful for relevant policy-makers, but also serves to raise awareness on zinc recycling among the Swiss population. One intriguing question is to what extent such an approach is applicable in other countries. The answer largely depends on the data available to produce the material flow analysis and assessment of primary and secondary resources. While every country has more or less reliable import and export statistics, data describing waste management is often scarce and coarse in many countries. Yet, findings on the five domains might be just as interesting: shedding light on the role of the informal waste management sector, highlighting innovation activities and solutions in the field of sensor sorting technology, identifying trade asymmetries for a specific metal. All these aspects could help design and ground priorities of agencies responsible for waste management.

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