Study of By-Products of Copper, Lead, Zinc and Nickel

A report prepared by Oakdene Hollins for International Lead and Zinc Study Group
International Nickel Study Group
International Copper Study Group
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1 Executive Summary

The International Lead and Zinc Study Group (ILZSG), the International Copper Study Group (ICSG) and the International Nickel Study Group (INSG) decided in late 2011 to undertake a joint project to expand the information available on metal produced as by-products of copper, nickel, lead and zinc.

This project focuses on about a dozen metals which have relatively small volume of production but are increasingly seen as important or even critical because of the applications they are finding in emerging technologies, including renewable energy and telecommunications and information technology. The production of these hereto less important metals may have an impact on the cost of production of the principal metals. The following metals were included within the scope of the study:

- By-products of lead and zinc: bismuth, germanium, indium and tellurium
- By-products of nickel: cobalt, some platinum group metals (e.g. rhodium, palladium) and scandium
- By-products of copper: cobalt, molybdenum, rhenium, selenium, tellurium and rare earths.

The project methodology consisted of three main parts:
1. Review of the literature
2. Survey of producers, consumers and traders
3. Expert interviews.

Table 1 summarises estimates of the production of the by-product metals alongside the mine production estimates of the associated principal metals. Some of this data was well characterised before this study. However for other metals, notably scandium, selenium and tellurium, this is to the authors’ knowledge the first time that their production has been accurately quantified. As can be seen from Table 1, production volumes range from 250,000 tonnes in the case of molybdenum, to just 10 tonnes for scandium.

Availability and quality data tends to follow this continuum of production volumes (or value in the case of platinum group metals and rhenium). For some of the metals however there are considerable data gaps. It is recommended that member governments and metals stakeholders could consider promoting greater collection and dissemination of more reliable statistics. These data gaps include production, use and trade statistics; and greater government and industry collaboration could help to promote knowledge sharing.

Table 1: World production of the by-product metals and the principal metals (2011 estimates)

<table>
<thead>
<tr>
<th>Principal Metal</th>
<th>Mine Production (tonnes)</th>
<th>By-product Metal</th>
<th>Production (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>4,500,000</td>
<td>Bismuth</td>
<td>8,500</td>
</tr>
<tr>
<td>Zinc</td>
<td>12,400,000</td>
<td>Germanium*</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indium*</td>
<td>640</td>
</tr>
<tr>
<td>Nickel</td>
<td>1,800,000</td>
<td>Cobalt</td>
<td>98,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Platinum Group Metals</td>
<td>472</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scandium*</td>
<td>10^7</td>
</tr>
<tr>
<td>Copper</td>
<td>16,100,000</td>
<td>Cobalt</td>
<td>98,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Molybdenum</td>
<td>250,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rhenium</td>
<td>46^8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Selenium*</td>
<td>2,600^8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tellurium*</td>
<td>450^8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rare Earth Elements</td>
<td>130,000</td>
</tr>
</tbody>
</table>

*Main Source: USGS (2012), Mineral Commodity Summaries 2012; * Refinery Production; # Industry Estimates

^ Other by-product metals outside of the scope of this project include silver, tin, arsenic, antimony and cadmium (lead & zinc); copper and gold (nickel); silver tungsten, gold, lead and zinc (copper). Reference to some of these other metals is only made in passing in the report.
In terms of market dynamics the by-product metals can, in some senses, be divided into two groups:

1. Those with some current/potential primary production or co-production (molybdenum, cobalt, platinum group metals and rare earths)
2. Those that most realistically produced as by-product metals (bismuth, germanium, indium, scandium, rhenium, selenium and tellurium), although some poly-metallic deposits are being considered.

For the former group the recovery of these metals is often specifically considered within the economics of production of the principal metal, and can represent 15-25% of total revenues.

For the latter group, recovery relies on the strategic decisions of refiners of the principal metals as whether to engage in these markets, which may sometimes be considered to be ‘outside the core business’ (Figure 1). Recovery of these minor metals, which typically represent <5% of total revenue, is one factor amongst many. In some instances it means altering the refinery processes to recovery these metals (e.g. for the lead/zinc by-product metals, as well as scandium), although for the copper by-products is possible to sell on what would otherwise be the waste product at the refinery (copper anode slimes or flue dusts). Some opportunities exist for lead zinc and nickel, although freight costs can sometimes prohibit concentrates from reaching refineries and smelters capable of recovering the minor by-product metals.

**Figure 1: Why does the company not produce particular by-product metals?**

<table>
<thead>
<tr>
<th></th>
<th>Not present in ore/ concentrate</th>
<th>Outside core business</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>47%</td>
<td>41%</td>
<td>12%</td>
</tr>
</tbody>
</table>

Source: Oakdene Hollins Industry Survey

For many of the metals, the long term market outlook is expected to be strong, although in the short term the market may be volatile, as outlined by a number of industry experts. Tellurium, rare earth elements, indium, rhenium and scandium are among the metals which appear to have the strongest growth in their usage, or particularly tight market balances. Cobalt on the hand appears to be moving towards significant surplus. To some extent there is price elasticity that will encourage new production or greater efficiency of recovery, however these price signals may exist with a delay or be indirect.

For many of the metals mentioned above with attractive market outlooks there are significant opportunities to increase or diversify existing production:

- For tellurium, indium and germanium there are considerable volumes of these metals that are currently being mined, but not refined. For these opportunities there may be a need to stimulate interest with the refiners of the principal metals, as and when market demand requires it. The diversification in world supply would also be welcome.
- For rhenium the market is very tight and there is limited prospect of additional production in the pipeline. Efficiency in recovery and recycling, may improve further but there is genuine concern about rhenium having to be rationed in its main application of aerospace super-alloys.
- For scandium the current very small market size is said to be limiting the potential application of the metal. Two significant junior mining projects are in the pipeline, although market development work may be necessary alongside the progression of these projects.
- For rare earths there are numerous projects in the pipeline, motivated by the recent high prices. It should be stated however that the by-product link for rare earth with copper production is weaker, with arguably many more economic opportunities elsewhere.
2 Introduction

2.1 Context

In recent years use of minor metals has expanded rapidly. Many of these metals are produced as by-products or co-products of zinc, lead, copper and nickel (see Figure 2). However, information is lacking on the outlook of supply and long term sustainability of these metals in the economy. Concerns have been raised in some countries that metals which previously had little or no economic value may become quite valuable or even critical in some new industrial processes. The production of these heretofore less important metals may have an impact on the cost of production of the principal metals.

Figure 2: By-product and co-product metals

2.2 Aims and Scope

The objective of this project, commissioned by the International Study Groups for Nickel, Lead & Zinc and Copper is to produce in depth information on the production, use and trade of metals produced as by-products of the four principal metals (lead, zinc, copper and nickel).

The information generated from this project is intended to inform member countries of changes in the market that may have potential economic and environmental consequences. The project will also provide the basis for a database that may be used for future work.
The study focuses on metals that meet the following criteria:

- Linked to the production of the four study group metals
- Have no or limited own-production infrastructure, i.e. are not mined as a primary metal
- Typically have high value
- Finding increasing uses in new technologies such as electronics and renewable energy.

Using these criteria, the metals included in the study are:

- by-products of lead and zinc: bismuth, germanium, indium and tellurium
- by-products of nickel: cobalt, some platinum group metals (e.g. rhodium, palladium) and scandium
- by-products of copper: cobalt, molybdenum, rhenium, selenium, tellurium and rare earths.

It should also be realised that there are a number of other metals commonly produced as by-products of one of the principal metals, but which are outside of the scope of this project. Passing reference to some of these metals is made in in the report. These other by-product metals include:

- silver, tin, arsenic, antimony and cadmium (lead & zinc)
- copper and gold (nickel)
- silver tungsten, gold, lead and zinc (copper).

2.3 Background to By-product Metals

In comparison to the principal metals, many of these metals have relatively small markets. Collectively world production of the principal metals accounts for 30% of non-ferrous metal production (Figure 3), whereas the by-product metals are included within ‘Other Metals’ with less than 2% of total non-ferrous metal production.

Many of these metals are highly reliant on a single application, for example indium in flat panel displays, rhodium in auto catalysts and tellurium in photovoltaic solar. This therefore can make these metals vulnerable to technological change, which can induce substitution, particularly if their prices become expensive relative to potential alternative materials. Alternatively the growth of just a single new application can add significantly to demand or indeed. In general the by-product status of some of these metals are produced as by-products of much larger principal metals mean that they may have only a negligible impact on the profits of diversified miners. Consequently many producers of the principal metals

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An example of this might be cadmium, which has to be recovered from zinc refining due to its toxicity. However, according to industry sources, cadmium is now being stored in bunkers, rather than being sold to the market due to a lack of market demand following a shift of battery chemistries away from NiCd.

Source: Adapted from Resnick Institute (2011), Critical Materials for Sustainable Energy Applications; based on USGS data
may consider these metals are being ‘non-core’. For these reasons price volatility is therefore often much greater for these metals than for the base metals and there is often a lack of market transparency and limited statistics available.

2.4 **Methodology**

The project methodology consisted of three main parts:

1. Review of the literature relating to these by-product metals e.g. data from geological surveys, policy reports, consultancy reports, trade press, company presentations etc.
2. Survey of producers, consumers and traders. This was conducted using a web-based format and allowed participation of all relevant stakeholders. Participants were able to provide production data and provide comments on the production barriers for the by-product metals.
3. Expert interviews. A number of interviews were conducted with various industry experts with coverage across all elements of the supply chain, including miners, refiners/smelters, recyclers, traders and consumers, and for each of the metals of interest.

The acknowledgements list provides a full list of participants in the study, some of whom reviewed particular chapters of the report in addition to providing data, information and insights.

2.5 **Structure of this Report**

The structure of the report is as follows:

- **Chapter 3** provides an overview of the policy context of this study from the major countries with specific policies, which affect the markets of the by-product metals
- **Chapter 4** provides the results of the online industry survey
- **Chapters 5, 6 and 7** provide detailed sections on each of the by-product metals, grouped according to the main principal metal with which they are associated: lead & zinc, nickel and copper respectively.
- **Chapter 8** concludes the report
- **Appendices** are provided on definitions of recycling and contain detailed trade statistics for 2010 from COMTRADE for the by-product for which this data is available.

Although there will inevitably be some differences in both the nature of the material that is relevant and available for such a large range of by-product metals, this report has attempted to provide a consistent format and structure for each of the chapters. For example USGS data has been quoted on production statistics, for each metal with the purpose of providing consistent data throughout. Other data sources do exist such as the British Geological Survey and World Mining Data, although it is observed that for some of the smaller by-product metals, these sources are often considerably more conservative. However where additional data is available, such as from industry sources or is considered relevant or more accurate, that has been reported as well. Similarly the UNEP report on the recycling of metals has been quoted as the reference document on recycling rates, although additional details have also been provided.

Each of the by-product metals chapters has four key sections covering the following topics:

- **Overview**: a summary table on production, use and trade highlighting key data limitations
- **Supply**: common sources, refinery processes, by-production, recycling, outlook
- **Demand**: markets, contracts, pricing mechanisms, use, prices, outlook
- **Governmental regulations**: REACH status, government stockpiles, trade restrictions.

**NOTE:** In addition to this report, the study has also compiled a list of the key companies involved in the mining and refining of the by-product metals, including contact information and estimates of production where that is available. This Directory is also available for purchase.

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About the authors:

Peter Willis BSc MSc
Peter is a resource economist and has been involved in various studies regarding metals and material security for clients such as the European Commission, UK government and private companies. His research has covered all stages of the supply chain including exploration, mining, refining, use and recycling. He was a lead author of Oakdene Hollins’ recent report to the European Commission JRC Institute for Energy and Transport: Critical Metals in Strategic Energy Technologies. Peter joined Oakdene Hollins with a first class degree in economics from the London School of Economics and an MSc with distinction from University College London.

Adrian Chapman MSci PhD MRSC
Adrian heads up Oakdene Hollins’ team on metals and mining, providing project management and technical expertise. He has been led in major studies on recycling critical raw materials, lithium ion battery innovation and reviewing methodologies for assessing materials criticality. His work includes clients such as the European Commission, UK government and private companies. He has presented at various international conferences on metals and recycling. Adrian joined us from Nottingham University where he gained a PhD in Green Chemistry and experience in technology transfer.

Anna Fryer MA PGCBM
Anna recently joined Oakdene Hollins as a Research Consultant and has already contributed to a range of projects for both the public and private sectors. In this study Anna has worked tirelessly to compile and check the metals directory. Anna has an MA in Modern and Medieval Languages from Cambridge University, and subsequently completed a Postgraduate Certificate in Business Management at Cheltenham Business School.

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