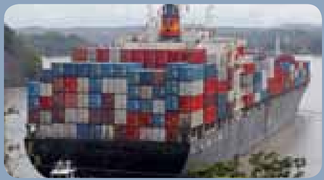
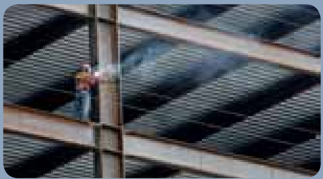
UNEP

International Resource Panel


Assessing Mineral Resources in Society:

METAL STOCKS & RECYCLING RATES

Acknowledgements

Acknowledgements

Editor: International Resource Panel, Working Group on the Global Metal Flows

Lead author of both reports is T. E. Graedel. This summary booklet was prepared by T. E. Graedel, M. Buchert, B. K. Reck, and G. Sonnemann.

Scientific advice: Öko-Institut e.V.

The first report on metal stocks in society is a rewritten and enhanced version based on M. D. Gerst and T. E. Graedel, Environmental Science & Technology, 42, 7038–7045, 2008. Parts of it were developed at a workshop held August 15–16, 2008, with the following participants: Thomas Graedel, Yale University, USA, coordinator; A. Dubreuil, Natural Resources Canada; Michael Gerst, Dartmouth College; Seiji Hashimoto, National Institute for Environmental Studies, Japan; Yuichi Moriguchi, National Institute for Environmental Studies, Japan; Daniel Müller, Norwegian University of Science and Technology; Claudia Pena, CIMM, Chile; Jason Rauch, Yale University, USA; Thompson Sinkala, School of Mines, Zambia; and Guido Sonnemann, UNEP, France.

Portions of the report on recycling rates of metals have appeared in the Journal of Industrial Ecology article by Graedel et al. (2011): "What Do We Know About Metal Recycling Rates? Authors of the second report report are T. E. Graedel, Yale University, USA, Julian Allwood, Cambridge University, UK, Jean-Pierre Birat, Arcelor-Mittal, France, Matthias Buchert, Öko-Institut, Germany, Christian Hagelüken, Umicore Precious Metals Refining, Germany/Belgium;, Barbara K. Reck, Yale University, USA, Scott F. Sibley, US Geological Survey (USGS), USA, and Guido Sonnemann, UNEP, France

Guido Sonnemann, UNEP, supervised the preparation of this report and provided valuable input and comments.

Thanks go to Ernst Ulrich von Weizsäcker and Ashok Khosla as co-chairs of the Resource Panel, the members of the Resource Panel and the Steering Committee for fruitful discussions. Additional comments of a technical nature were received from some governments participating in the Steering Committee.

Helpful comments were received from several anonymous reviewers in two peer review processes coordinated in an efficient and constructive way by respectively by Lea Kauppi and Yvan Hardy together with the Resource Panel Secretariat. The preparation of this report also benefitted from discussions with many colleagues at various meetings, although the main responsibility for errors will remain with the authors.

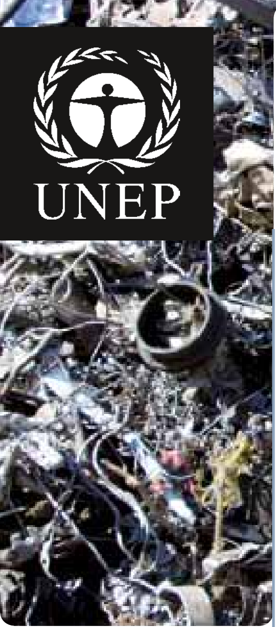
Photos: istockphoto.de: © James Whittaker (cover_1, p. 3), © Jonceclearvision (cover_2, p. 5), © Milos Peric (cover_3, p. 5), © JDNY59 (cover_4, p. 5), © Marco Hegener (cover_5, p. 5, p. 22_2); © Pete Saloutos (cover_6, p. 13_2), © Huchen Lu (p. 2, p. 10, p. 11, p. 13_9), © Joerg Reimann (p. 9), © HeleM (p. 12), © Sam Faltenbergs (p. 13_1, p. 16), © Dieter Spears (p. 13_3), © Ralph125 (p. 13_4), © Therry Wilson (p. 13_5), © Yonra Pechkin (p. 13_7, p. 20_3), © gerenme (p. 13_8, p. 20_1), © Prill Mediendesign & Fotografie (p. 14), © Mike Clarke (p. 17_1),© Peter van Vuuren (p. 17_2), © Sheldunov Andrey (p. 18), © Huguette Roe (p. 19, p. 20_2, p. 20_4, p. 28_1), © Christopher Pollack (p. 22_1), © Peter Zelei (p. 22_3), © Rob Belknap (p. 26_2), © Adam Kazmierski (p. 29_1), © Kyu Oh (p. 29_2), © Thadford (p. 31). Degussa (p. 24). Shutterstock © Tobias Machhaus (p. 26). Umicore (p. 27). Öko-Institut e.V. (p. 13_6, p. 28_2).

Design and creativ concept: www.3fdesign.de

ISBN number 978-92-807-3182-0

Job Number DTI/1382/PA

UNEP promotes environmentally sound practices globally and in its own activities. This publication is printed on FSC-certified paper with 80% recycled fibre, using eco-friendly practices. Our distribution policy aims to reduce UNEP's carbon footprint.



UNEP

International Resource Panel

The following is an excerpt of the first two reports of the Global Metals Flows Group

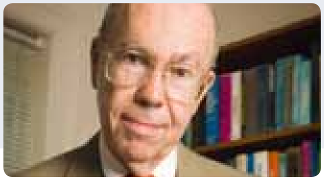
METAL STOCKS IN SOCIETY: SCIENTIFIC SYNTHETIS

RECYCLING RATES OF METALS: A STATUS REPORT

The full reports are available on CD-ROM (available inside the back page of this summary booklet).

Preface

Preface



The pace of industrialization around the world has brought with it an enormous increase in the use of materials, as well as increasing concern about long-term materials supply potential. A possible way to cope with supply challenges is to recover and reuse discarded materials in industrial and consumer products, thus "recycling our way to sustainability".

To see whether such a plan is feasible requires information: What quantities of the various materials are now in use and therefore potentially available for reuse at some time in the future? How well do we recycle discarded materials? How far could we improve our recycling performance? The Metal Flows Group of the International Resource Panel (IRP) has addressed the first two of these questions in the case of metals in its reports "In-Use Stocks of Metals" and "Recycling Rates of Metals". In late 2011 or early 2012 a third report will examine recycling technologies. Together with reports on geological stocks and on scenarios for future demand, the two reports summarized in this present document will help paint a picture of the planet's potential industrial future.

In-use stocks of metals invite for documentation at national levels of such stock and for industrial plans of later use. The report on recycling rates of metals, containing stupendous figures of low recycling rates of most of the high tech "spice" metals, calls for strategic action to increase the recovery of those metals. Industrial design should be improved with a view of easy recovery even of small quantities of them, and advanced techniques of separating metals should be developed. Fascinating tasks for a new generation of engineers!

Prof. Ernst U. von Weizsäcker

Co-Chair of the International Panel
for Sustainable Resource Management

Prof. Thomas E. Graedel

Leader of the
Global Metal Flows Working Group

Preface

Preface

A transition to a green economy is already underway, a point underscored in UNEP's Green Economy report and a growing wealth of companion studies by international organizations, countries, corporations and civil society. But the challenge is clearly to build on this momentum. A green economy does not favour one political perspective over another. It is relevant to all economies, be they state or more market-led. Rio+20 offers a real opportunity to scale-up and embed these "green shoots".

Metals are a core, centre-piece of the global, economy: Whether it be in the manufacture of buildings or cars to the booming production of mobile phone, computers and other electronic goods, metals have become increasingly important to commerce. But metals are also part of the challenge society is facing in its transition to a low carbon, resource efficient 21st Green Economy. Metals are a finite resource, whose management, consumption and production echo to the need to adopt a recycling economy.

Understanding, quantifying and estimating the ways metals flow through economies is part of the solution to better managing their impacts and their benefits. Indeed the International Resource Panel, hosted by UNEP and established in 2007, identified metals as a key area in terms of the 21st century sustainability challenge. The Panel's Global Metal Flows Group has so far prepared two reports on Metal Stocks in Society and Recycling Rates of Metals. This booklet gives the key findings of both reports.

The first report provides from a global perspective, the best scientific information available on the quantity of metal stocks in the world and the second report makes available to governments and industry the relevant baseline information on metal recycling rates, also at a global scale, to foster recycling and make more intelligent and targeted decisions on metals management worldwide. This is the first time ever that this information has been brought together in such a comprehensive way.

I congratulate the Resource Panel for taking on this difficult task and providing us with the scientific insights we all need to help us move towards a Green Economy.

Achim Steiner

UN Under-Secretary General and
Executive Director UNEP

Concerns about metals and UNEP's activities

International Panel for Sustainable Resource Management

The Resource Panel was established to provide independent, coherent and authoritative scientific assessments of policy relevance on the sustainable use of natural resources and in particular their environmental impacts over the full life cycle. It aims to contribute to a better understanding of how to decouple economic growth from environmental degradation.

Global Metal Flows Group

The UNEP's Resource Panel launched the Global Metal Flows Group for a better understanding of global material flows of used metals. A key question hereby is whether society needs to be concerned about long-term supplies of certain metals. The Global Metal Flows Group has the order to promote the reuse and recycling activities of metals and the establishment of the international sound material-cycle society by providing scientific and authoritative assessment studies on the global flows of metals.
This summary booklet is based on the recently finished reports "Metal Stocks in Society: Scientific Synthesis" and "The Recycling Rates of Metals: A Status Report".

Relevance of metals for sustainable development

Economic development is deeply coupled with the use of metals. During the 20 th century the variety of metal applications grew rapidly.

Modes of applications range between bulk goods composed of base metals and electronic applications like mobile phones which contain lots of different metals with only minimal amounts. The usage of certain metal containing applications implicates positive environmental effects. Such sustainable technologies are, for example, photovoltaic modules, batteries, or catalysts. The reduction of negative environmental effects is hereby achieved because inefficient technologies are replaced.

Relevance of stocks in society and metals recycling

Global metals demand – a multiple challenge

Nearly all mineral resources show a significant growth in demand over the last few decades. Not only industrialized countries, but also emerging economies and developing countries utilize metals to enhance their economic and social prosperity. The growing demand implies a permanent pressure on natural resources. The fear of scarcity and dependence is growing, as are concerns about negative environmental effects and social and political tensions.

Increasing stocks in society

Metals are present everywhere around us as metals can be regarded as the foundation upon which our economies are built. This economic growth increases the amount of metals used in our societies. Metals remain as steel bars in our houses, as copper cables for communication, railway tracks, or as jewellery. If we take a closer look at ourselves, our share of computers, kitchen equipment, mobile phones, etc. forms an individual stock of metals. Stocks in society are increasing not only in industrialized and emerging economies, but also in developing countries. In many countries inadequate recycling infrastructures and illegal imports of discharged metal-containing used and end-of-life products accelerate this development.

Metals recycling as a sustainability strategy

Recycling is a way to mitigate negative impacts on increasing metals demand and to assure the potentials of economic growth. For instance, the largest municipal recycling park in China is capable of recovering one million tons of copper per year. The largest copper mine in China produces less than half of that. This ‘urban mining' is important in generating secondary raw materials. Hence, strengthening the recycling of metals is a key strategy for a sustainable future.

Metals under investigation

Metals under investigation

The following graphic of the periodic table of elements demonstrates the sixty metals which are under the focus of the Global Metals Flow Group. The different colors indicate the classification of the elements into four different groups: ferrous metals; non-ferrous meals; precious metals and specialty metals. The groupings are not to be understood as rigid, but refer to the fields of application.

1 H																	2 He
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg Magnesium											13 Al Aluminum	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br	36 Kr
37 Rb	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I	54 Xe
55 Cs	56 Ba Barium	57–71	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po	85 At	86 Rn
87 Fr	88 Ra	89–103	104 Rf	105 Db	106 Sg	107 Sg	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uug	115 Uup	116 Uuh	117 Uus	118 Uuo
		57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium	
		89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

Grouping of metals

Grouping of metals

For a better understanding, the following table relates the full name of the metals to their symbols under the classification of the four groups in the order of their atomic number.

Ferrous Metals

V – Vanadium
Cr – Chromium
Mn – Manganese
Fe – Iron
Ni – Nickel
Nb – Niobium
Mo – Molybdenum

Non-Ferrous Metals

Mg – Magnesium
Al – Aluminum
Ti – Titanium
Co – Cobalt
Cu – Copper
Zn – Zinc
Sn – Tin
Pb – Lead

Precious Metals

Ru – Ruthenium
Rh – Rhodium
Pd – Palladium
Ag – Silver
Os – Osmium
Ir – Iridium
Pt – Platinum
Au – Gold

Specialty Metals

Li – Lithium
Be – Beryllium
B – Boron
Sc – Scandium
Ga – Gallium
Ge – Germanium
As – Arsenic
Se – Selenium
Sr – Strontium
Y – Yttrium
Zr – Zirconium
Cd – Cadmium
In – Indium
Sb – Antimony
Te – Tellurium
Ba – Barium
La – Lanthanum
Ce – Cerium
Pr – Praseodymium
Nd – Neodymium
Sm – Samarium
Eu – Europium
Gd – Gadolinium
Tb – Terbium
Dy – Dysprosium
Ho – Holmium
Er – Erbium
Tm – Thulium
Yb – Ytterbium
Lu – Lutetium
Hf – Hafnium
Ta – Tantalum
W – Tungsten
Re – Rhenium
Hg – Mercury
Tl – Thallium
Bi – Bismut


Metal stocks in society

Life cycle of metals

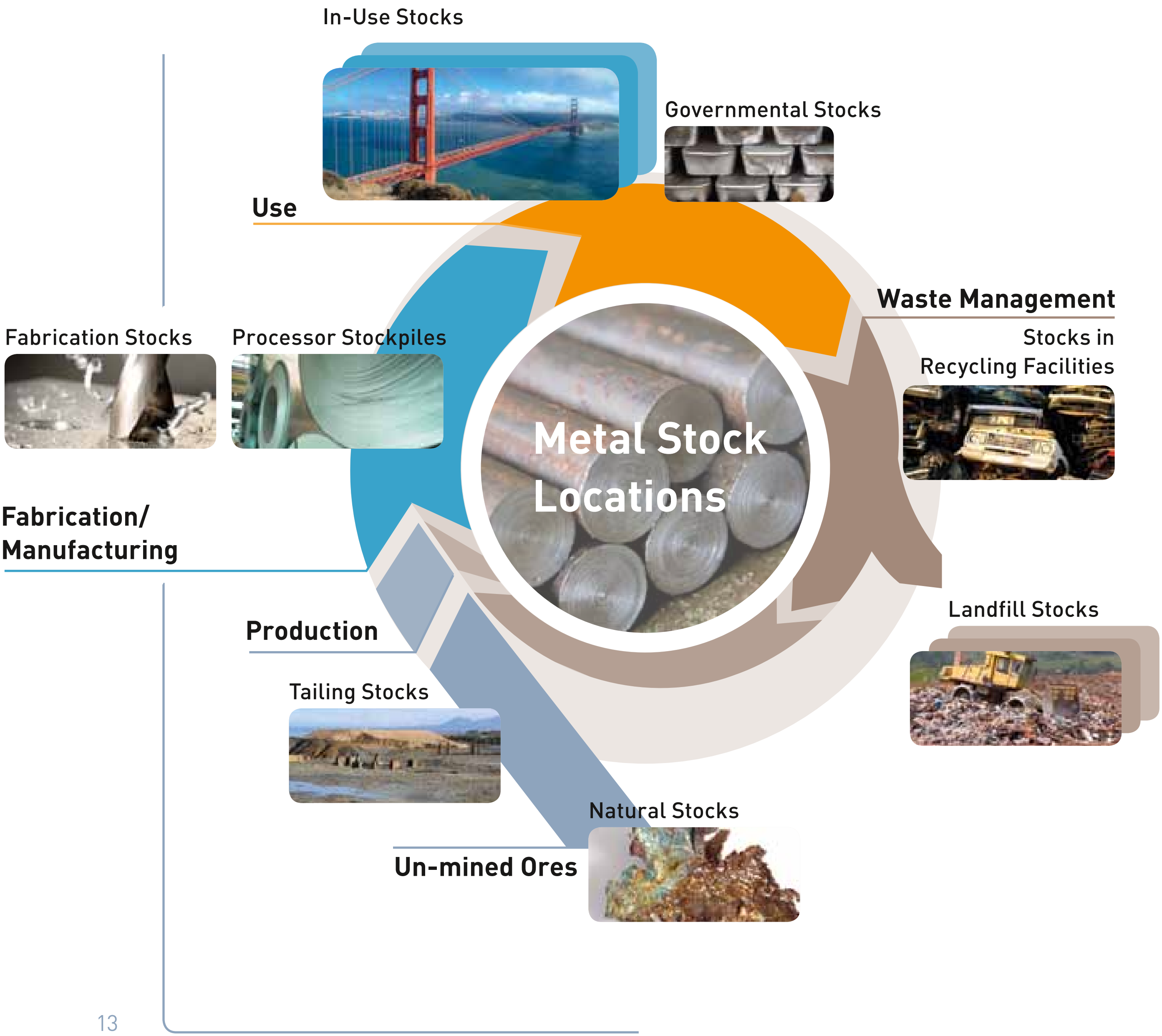
Before metals are embedded in certain products several process steps are required. Beginning from natural resources, the metal-containing ores are extracted and purified because natural stocks rarely exist in pure form. Subsequently, the concentrated ores are transformed into metals, either on-site or after transportation to a smelting facility. After further refining processes, metals or metal compounds are traded or further processed into specific components used in different applications. The lifetime of the different products and thus the embedded metals within them varies fundamentally – from weeks in the case of beverage cans, to decades or even centuries in the case of construction and infrastructure.

Development of stocks

Along the process steps and the use of the metals different kind of stocks may develop. On the mining site – beside unmined ores – by-products as tailings ponds still containing low concentrations of different metals are accumulated. During the various process and manufacturing steps processor stockpiles are possible, despite usually short retention times. The governments of some states like Japan, China and the United States additionally maintain stockpiles of strategic metals. Notwithstanding the above, the in-use stocks in the manifold applications and products are without question the most relevant metal stocks in society. Therefore, in-use metal stocks are a focus of the UNEP Resource Panel.

Landfills – urban mines of the future?

Even after the discharge of the metal containing products, further stockpiles can be identified: within recycling facilities and – to a much larger extent – in man-made landfills set up for the final fate of waste flows. In the case of copper a global stockpile of 225 million metric tones are estimated to reside in landfills. If a metal-containing product is taken out of service, it is not automatically recycled or landfilled. For example, in the case of obsolete undersea cables the containing metal is no longer in use, but has not yet been recovered and recycled. These “hibernating” stocks are potentially reusable, but their recovery may not be economically feasible.


In-Use Stocks
Governmental Stocks
Use
Waste Management
Stocks in
Recycling Facilities
Fabrication Stocks
Processor Stockpiles
Metal Stock
Locations
Fabrication/
Manufacturing
Landfill Stocks
Production
Tailing Stocks
Natural Stocks
Un-mined Ores

In-use stocks

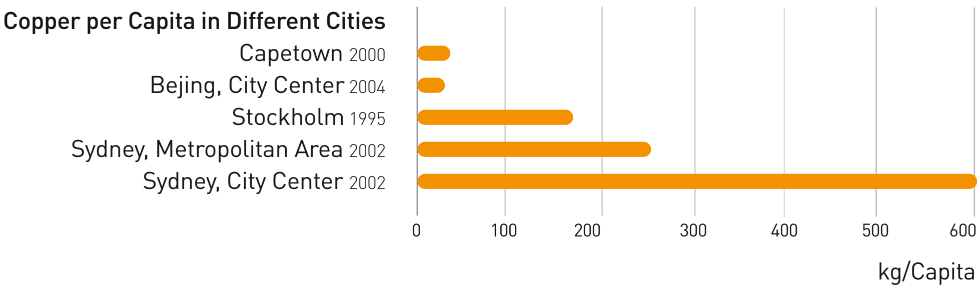
The global dimension

As already described, all metals put into use and currently providing service are regarded as in-use stocks. A broad variety of different metal-containing applications can be found in all societies. The private and public sector, as well as the industrial sector, all use metals for their purposes, and modern technologies tend to choose a whole bundle of different metals for the purpose of utilizing the specific properties of the individual metals. For example, a mobile phone contains over 60 different metals: indium in the LCD Display, tantalum in capacitors, and gold on the conductor boards. The amount of each metal in a mobile phone is small. It is the sum of globally used mobile phones that contribute to relevant total metal amounts.

Metal stock per capita

The continued increase in the use of metals over the 20th century has led to the phenomenon of a substantial shift in metal stocks from below the ground to above the ground in the form of applications in society. Such a shift raises social, economic, and environmental issues that cannot be addressed without quantifying the amount of "metal stock per capita" utilized by society, or within certain geographic borders.

Material flow analysis characterizes and quantifies flows of materials into, out of, and through a system of interest. The choice of scale can be spatial, quantitative, or temporal. Consequently, when talking about in-use stocks, beside the quantitative scale ("how much of a metal is in a certain stock?"), the temporal aspect has to be considered as well ("how long does a metal remain in a particular use?").



Global in-use stocks of Copper

Current situation

Differences in urban in-use stocks

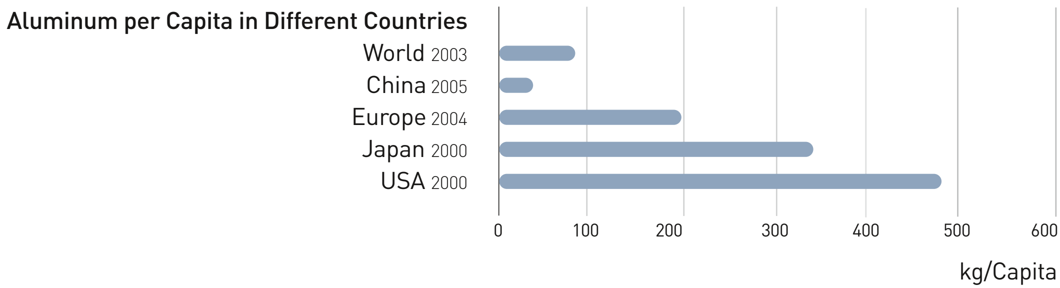
Using the example of copper, the bar chart below left shows in-use stocks per capita for different cities. The usage of copper relies to its capability to transfer electricity with only minimal losses. Therefore, copper is widely used for electrical infrastructure in buildings. It is obvious that stocks in cities of more-developed countries possess significantly higher amounts of in-use stocks per capita than in cities of less developed countries. Regarding the capital of Sweden, Stockholm, the amount of copper in-use stocks per capita is nearly four times higher than in Cape Town, South Africa. And Sydney shows even higher figures than Stockholm. This relation between urban in-use stocks of industrialized and less-developed countries is significant for all metals thus far examined.

Differences in national in-use stocks

As with the example of copper, differences in in-use stocks can be seen in the case of aluminum. The bar chart below right shows current in-use stocks of different countries, Europe, and worldwide. Japan and the United States possess the highest in-use stocks and exceed the value of China by 9 and 13 times. In fact, the average values of per capita in-use stocks of aluminum for Europe, Japan and the United States is more than four times higher than the world average value.

Both examples show that most in-use stocks currently reside in more developed countries. The average per capita stock in industrialized countries for copper is about 230 kg, for aluminum about 340 kg.

Global in-use stocks of Aluminum



Dynamics of in-use stocks in society

Demographic growth and economic development

Differences in current in-use stocks are the result of economic development. The temporal accumulation of in-use stocks shown below demonstrates that the copper stock per US citizen quadrupled over the last 70 years. This tendency suggests that if the populations in fast growing emerging economies are going to use a similar suite of technologies and lifestyles, global in-use metal stocks required would be 3–9 times those existing at present.

Mind the gap

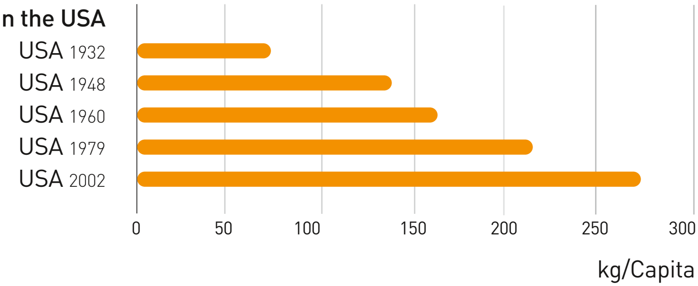
As has been shown, there is reasonably good understanding of the in-use stocks of two major engineering metals: aluminum and copper. There are, however, still too few studies with differing spatial or temporal references for a profound comparison with, for example, precious or specialty metals. The availability of worldwide data for a large variety of metals on equal spatial and temporal resolution is actually not available. A reasonably detailed picture of in-use stocks and in-use lifetimes exists for only more developed countries and the major metals aluminum, copper, iron, lead, and zinc. The data demonstrate that every citizen in the more developed countries can be credited with an in-use stock between ten and fifteen metric tons of these metals.

The limited data suggest that per capita in-use stocks in more-developed countries typically exceed those in less-developed countries by factors of five to ten.

Closing this data gap is a large challenge for the evaluation of stocks and therefore their use in making informed inferences about the future.

Development of copper stocks

Development of Copper Stocks in the USA



The mines of the future

Worldwide stock building

The already existing anthropogenic metal stockpile is gigantic. Continuously growing metal prices in the commodity markets indicate a dynamic demand for metals – in emerging countries due to economic growth, and in industrialized countries due to modern technologies with dissipative metal applications.

Urban mining as key strategy

Urban in-use stocks possess a high relevance for potential metal supply. The shift of mining activities from natural towards anthropogenic resources has to move into focus, not only in the interest of national metal supply but also on the global level. Total metal losses have to be reduced and recycling infrastructures and technologies have to be fostered in industrialized, emerging, and less developed countries. Taking advantage of "anthropogenic mines" has a great potential to reduce dependency on virgin metal resources and mitigate the environmental degradation often caused by mining activities. The enhanced exploitation of already known urban stocks and the detection of hibernating stocks (metal not in active use but not yet recovered, as in unused railroad bridges) is a key strategy in moving toward sustainable metal supply.

Recycling of metals

Recycling of metals

Metals recycling today

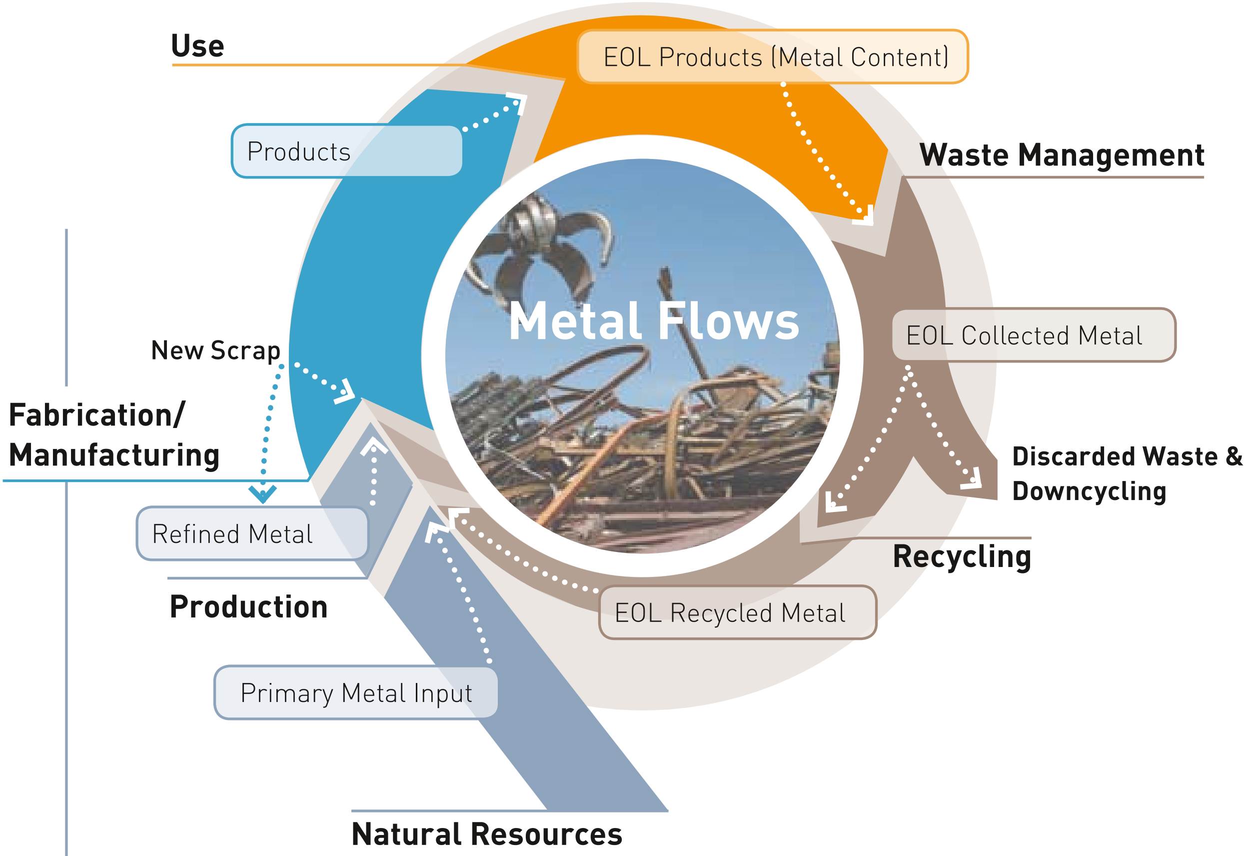
Metals are regarded as having excellent properties for recycling. For metals such as iron/steel, aluminum, and copper recycling has a long tradition. In these cases appropriate recycling infrastructure and recycling technologies exist in many countries, involving scrap dealers, dismantlers, operators of shredder plants, etc.. However, the report "Recycling rates of metals: a status report" has discovered tremendous weak points in global metals recycling.

The reasons are manifold. The lack of basic recycling infrastructure and modern recycling technologies in many developing countries and emerging economies causes dissipative losses even of base metals like steel. A second main reason is the phenomenon of new and complex applications of metals at mass production scales in the last three decades. Mobile phones, solar panels, new light weight materials, catalysts, batteries, and many more have created a new era of metal use. The modern applications often employ low concentrations of "specialty metals" like gallium, indium, and rare earth elements for which currently almost no recycling infrastructure exists.

New scrap and old scrap

To understand the key challenges of metals recycling in the 21st century it is necessary to distinguish between the main types of scrap – the so-called new scrap and old scrap. New scrap is generated in manufacturing processes and has lives of weeks to months until its return to the production process. It has a known composition and origin. When it is a non-contaminated pure metal or alloy it can often be recycled within the processing facility. If contaminated, it might be sent to an external facility. This recycling of new scrap is generally economically beneficial and easy to accomplish. It may not be identified in recycling statistics, but can sometimes be estimated from process efficiency data.

The second major category is end-of-life (EOL) scrap, or "old scrap", which may be returned to the EOL phase within weeks (a beverage can) to decades (turbines or cars). This is material recovered from products, and often constitutes mixtures of elements, alloys, plastics, and other constituents which need detailed processing to obtain recyclates for raw materials production. Functional recycling is the decisive EOL recycling approach in contrast to non-functional recycling (sometimes termed "downcycling"), which means that the metal or alloy is "lost" in another dominant material flow (often that of common steel scrap).



End-of-life (EOL) recycling rates

The most important parameter to measure the efficiency of an overall recycling system is the functional EOL recycling rate. The functional EOL recycling rate excludes non-functional recycling flows of discarded products, and depends on the efficiency of all single steps in the recycling chain: collection, separating, sorting, and final metal recovery. An important thing to note is that a functional EOL recycling rate of (for example) 40 % means that there are 60 % losses of a valuable metal.

Recycled content

The metric recycled content (also termed the recycling input rate) describes the fraction of recycled metal (from new scrap and old scrap) in relation to total metal input. This measure is of limited relevance for metals, however, for two reasons. First, the long lifetimes of many metal products in combination with high growth rates makes achieving a high recycled content difficult because of the limited availability of secondary metals. Second, because metals can be recycled more than once, it is unclear how the ratio should be computed.

Recycling rates of ferrous metals

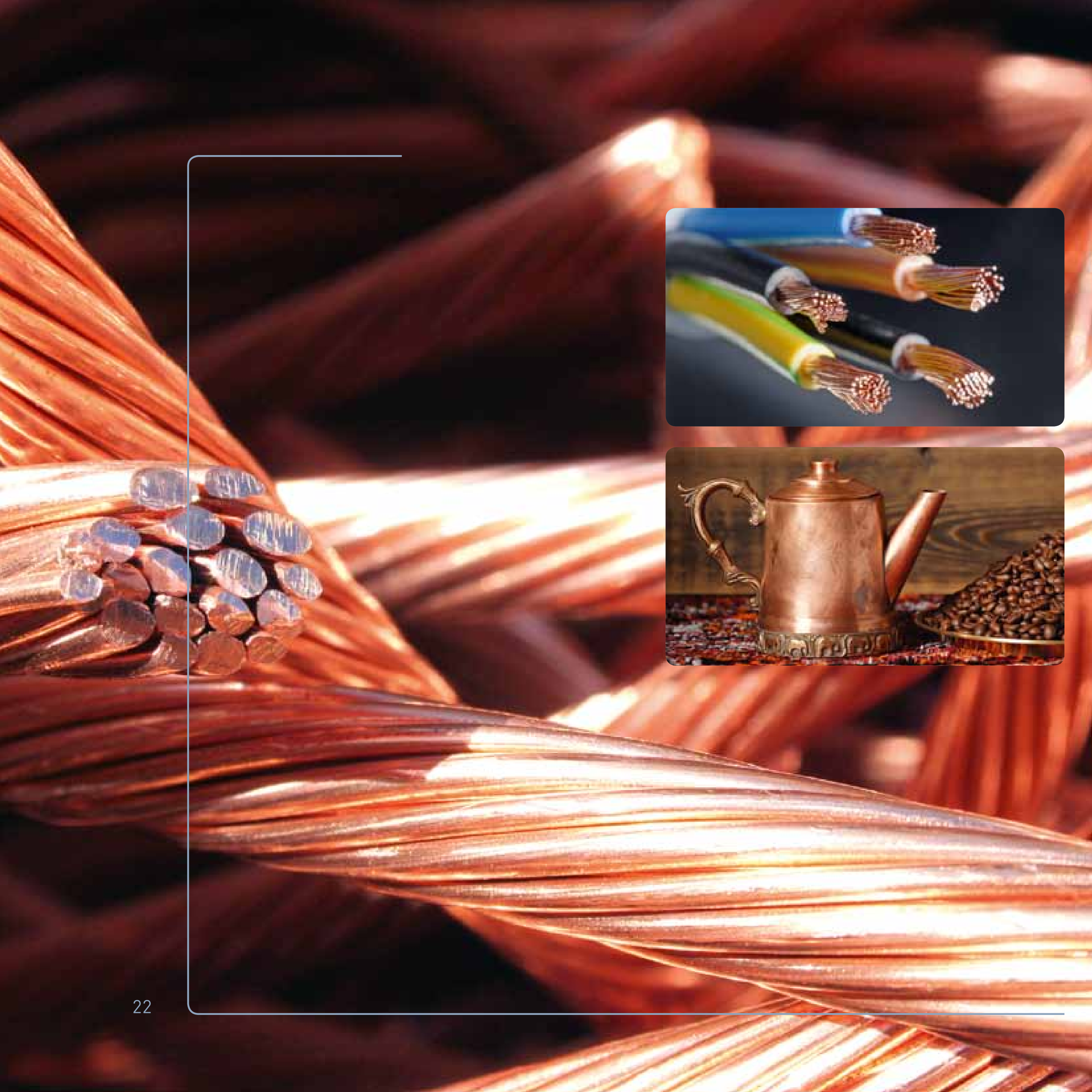
Overview of ferrous metals

The ferrous metals are predominantly iron-based, and mostly magnetic. Iron is the principal constituent of steel, and steel is by far the most widely-used metal. In 2009 more than 1.2 billion tonnes of steel were produced worldwide, and the demand for steel – especially in emerging economies – is growing further. The other ferrous metals (vanadium, chromium, nickel, etc.) are components in steel, stainless steels, and superalloys. It is important to mention that for stainless steel and other special alloys separated recycling flows exist in practice, because the properties of those materials are lost if they are mixed with common steel scrap.

End-of-life recycling rates of steel and the ferrous metals

Functional end-of-life recycling rate estimates for steel and its major alloying metals are listed in the report. The range of the figures, often obtained by different methods, is wide and a high level of uncertainty in the data is present. However, with these existing data an end-of-life recycling rate of 70–90 % can be estimated for iron and steel. This value is one of the highest end-of-life recycling rates among all the industrially-used metals. The reasons are a very long tradition of steel in different applications with mature recycling systems, the often large quantities of new and old scrap (e. g., from demolition waste), and the well-established recycling infrastructure for steel in many countries.

More than 50 % end-of-life recycling rates could be found for manganese (present at 0.3–1.0 % in nearly all steels) niobium (used in high strength-low alloy steels and superalloys) nickel (often a constituent of stainless steels and superalloys) and the stainless steel constituent chromium. Molybdenum follows with rates between 25–50 %, while vanadium is below 1 %.



Recycling rates of non-ferrous metals

Overview of non-ferrous metals

The non-ferrous metals contain no iron, and are used in quantities second only to the ferrous metals. Aluminum is used principally in construction and transportation and has the second largest production figures of all metals (more than 30 million tonnes per year). Copper is third among the metals (about 24 million tonnes in 2007) and sees wide use in conducting electricity and heat. Cobalt's major uses focus on superalloys, catalysts, and batteries. Lead's use centers on batteries. Magnesium is used in construction and transportation. Tin's major uses are in cans and solders. Titanium's main applications are paint and transportation while zinc's major use is in coating steel (galvanizing).

The recycling structures for the non-ferrous metals are quite different and depend on the specific applications and the amount of material flows. Separate recycling infrastructures exist for copper, aluminum, and lead, respectively. In the case of aluminum the different compositions of aluminum alloys play a major role. On the other hand cobalt and tin are often embedded in mixed old scrap which effort special sorting and pretreatment procedures. The recycling of zinc is significantly interlinked with steel recycling procedures because steel is often coated with zinc for corrosion protection.

Recycling rates of the non-ferrous metals

Most of the non-ferrous metals are widely enough used, and often sufficiently valuable, that their recycling and reuse rates are reasonably high. This is especially true for lead (EOL recycling rate > 50 %), which is mostly used in large vehicle and industrial batteries that are returned and subsequently recycled in commercially and industrially linked recycling chains. For aluminum and copper a wide range of EOL recycling rates are reported. Nevertheless, for both these important metals an EOL recycling rates > 50 % is estimated. High EOL recycling rates are also reported for cobalt, tin, titanium, and zinc. For magnesium, EOL recycling rates in the range > 25–50 % are estimated. The wide range of rates reported reflects the significant data uncertainties for the non-ferrous metals.


Degussa
PLATINUM
999.5

Recycling rates of precious metals

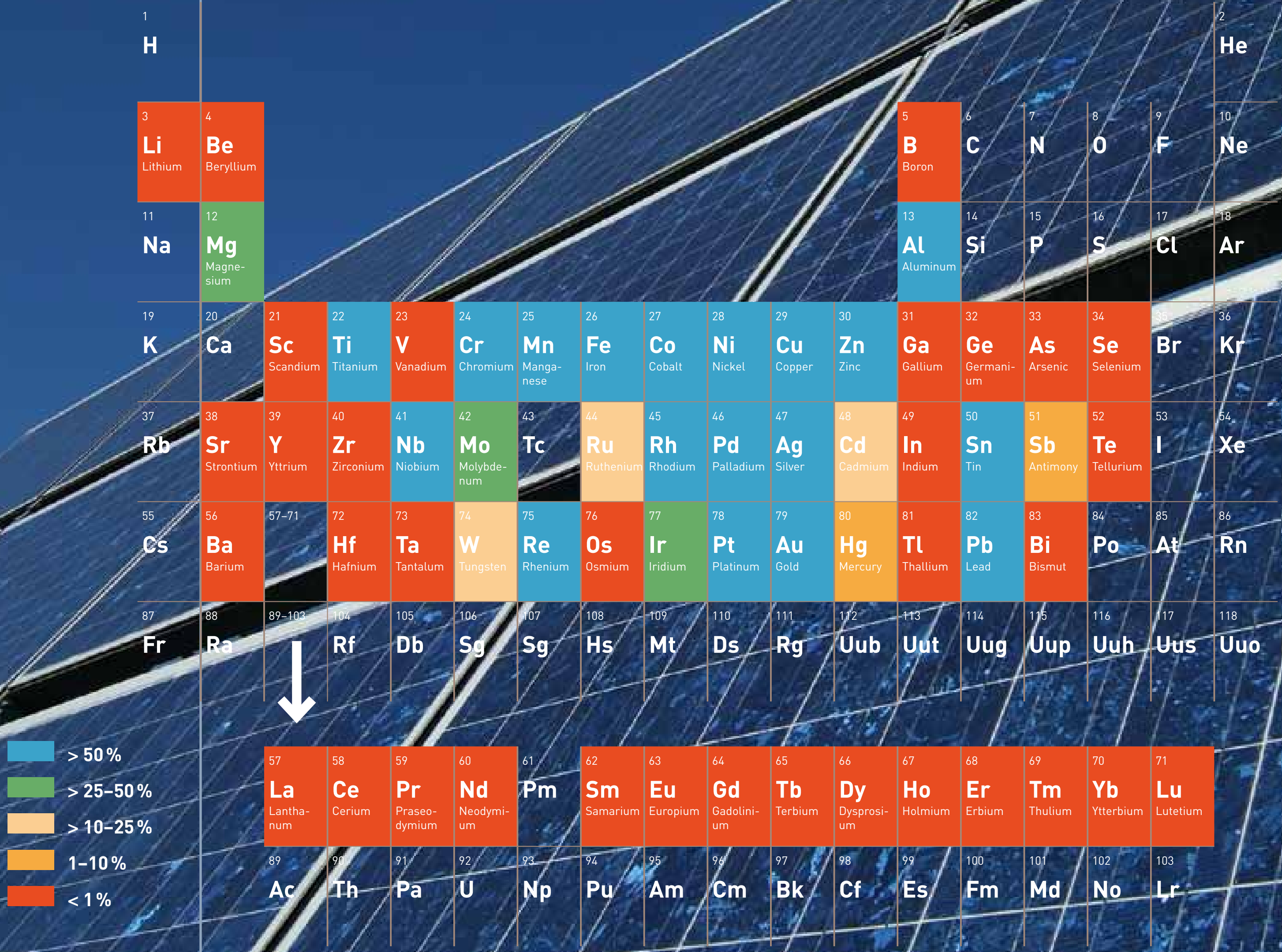
Overview of precious metals

Precious metals like gold, silver, and platinum are sufficiently valuable that they are efficiently recycled except in some applications and/or when used in very small amounts (e. g., silver in mirrors or car glass; platinum/ruthenium in computer hard disks) or when end-of-life products do not enter into an appropriate recycling chain. The end-of-life recycling rates for the platinum group metals palladium (60–70 %), platinum (60–70 %) and rhodium (50–60 %) seem to be the highest among the precious metals. Silver and gold follow with EOL recycling rates > 50 % when coins and jewellery are taken into account in addition to the technical applications (electronics, dental etc.). Iridium which is used mainly for industrial catalysts is ranked in the > 25–50 % range for the EOL rate, and ruthenium used for electronics as well as for industrial applications is estimated in the > 10–25 % category. Osmium is rarely used and no significant recycling data are available.

The platinum example

Taking the relative price levels of precious metals into account, it seems surprising that those metals do not have the highest end-of-life recycling rates among all metals. A gram of platinum for instance represents a price of about 50 $ (or more) – so there should be enough incentive for recycling. Furthermore, experienced actors and state of the art facilities already exist to refine precious metals from many applications. But assessing the recycling rates of the different platinum applications provides a deeper insight. For industrial applications the recycling rate of platinum is 80–90 %. However, the rate for platinum from automotive catalysts (50–55 %) and electronics (0–5 %) is much lower. Obviously, consumer applications are more difficult to address by recycling than industrial applications. This is a well-known phenomenon among recycling experts, and platinum is merely an example for many other metals and applications. Therefore, enhancing recycling rates for consumer applications is a key strategy for platinum and many other metals.

End of life recycling rates



Recycling rates of specialty metals

Overview of specialty metals

The 37 specialty metals are the largest group of the 60 metals that were investigated. Most of these metals can be thought of as "new-comers" regarding their technological applications. Many of them show therefore a rapidly increasing relevance in the last 3 decades or even in the last few years, driven by innovative technologies with high potentials for a sustainable future. Lithium is very important for modern batteries (hybrid and electric vehicles), gallium, germanium, indium, and tellurium show growing relevance for solar cells, and the rare earth metals are essential for many applications such as catalysts, battery constituents, and permanent magnets (electric power drives, wind turbines, etc.). It can be expected that the demand for many specialty metals will grow rapidly in the next few years due to the increasing market potentials of new and innovative technologies.

The figure presents information for the metals in whatever form (pure, alloy, etc.) recycling occurs. To reflect the reliability of the data or the estimates, data are divided into five bins: > 50 %, > 25–50 %, > 10–25 %, 1–10 % and < 1 %. It is noteworthy that for only twelve of the sixty metals the experts estimate the end-of-life recycling rate to be above 50 %. Another eight metals are in the 25–50 % group, and four more in the 10–25 % group.For a very large number, little or no end-of-life recycling is occurring today.

The indium example

The report shows that for most (32) of the 37 specialty metals the current end-of-life recycling rates are very close to zero (< 1 %). The indium example exemplifies the story for many specialty metals. Indium demand has grown rapidly in the last 20 years due to several modern and innovative applications: liquid crystal displays (TVs, notebooks, etc.), semiconducters, solders, and solar cells. These widespread consumer applications of indium constitute a major challenge regarding recycling logistics and the development of a suitable legal framework. The concentration of indium in old scrap is quite low, and suitable sorting and pre-treatment infrastructure is rare. As a consequence, the end-of-life recycling of indium and many other specialty metals is still in its infancy.

Indium bullion (photo by courtesy of Umicore Precious Metals Refining)

Lessons

The global dimension of metal stocks

On a global scale, in-use stocks of metals in society are growing every year. More people need more houses and ask for more cars, electrical devices, and other consumer goods. More people ask for energy in their houses and for pharmaceutical products. The more industrialized countries show much higher per capita stocks of metals than do the less developed countries. But the emerging economies play the game too, and therefore further growth of metal stocks in human society can be foreseen. Despite the obvious data gaps for many metals, it is obvious that the increasing in-use stocks are the mines of the future.

The circular economy is a key answer for the future

The results of the investigations concerning end-of-life recycling rates are disappointing at first glance – currently a large share of the secondary metal resources are lost. For only eighteen metals (aluminum, cobalt, chromium, copper, gold, iron, lead, manganese, niobium, nickel, palladium, platinum, rhenium, rhodium, silver, tin, titanium, and zinc) is the very important EOL-RR above 50 % at present. But the better results for some traditional and important metals like steel, aluminum, copper, and lead prove that there is a learning curve for recycling. In the 21st century this learning curve needs acceleration, because the variety and complexity of applications which embed metals (in a mobile phone at least 60 elements) is increasing. Furthermore, more and more countries in the world face rapidly growing waste flows for which they have no appropriate recycling infrastructure. Therefore, enhanced technology transfer and international cooperation should be decisively accelerated by international recycling conferences, technological implementation programs in emerging economies and developing countries, and specific scientific exchange programs.

Urgent issues

Research & development

Understanding the potential of urban mines is severely limited as a result of the sparse information currently available on in-use stocks and on recycling rates. Limitations in recycling technology also are strong contributors to low recycling rates. Enhanced government support for data acquisition and analysis, recycling technologies research, and other research and development efforts is thus a priority. Such efforts could focus on issues such as recycling demonstration plants, closed-loop recycling of rare earths from batteries, and tantalum from electronic scraps.

Stopping illegal waste transport

Despite existing regulations like the Basel Convention the shipment of waste to countries without basic waste treatment and recycling infrastructure is an increasing global problem. The export is often incorrectly declared as export of second-hand goods. Therefore international organizations like UNEP and OECD have to multiply their engagement in the monitoring and controlling of illegal scrap exports, which often contain metals with long-term supply concerns.

Continuous improvements of legislative systems

The growth of global metal demand is currently faster than the adaption of legislation concerning recycling. Continuous improvements of the legislative systems in the industrialized countries are urgently needed in order to enable better recycling rates for many metals and post-consumer goods. The more developed countries should reinforce their attempts to help the less developed countries install appropriate legislative systems and ensure their enforcement in order to take advantage of metal stocks in society.

Glossary

Ferrous Metals

V – Vanadium
Cr – Chromium
Mn – Manganese
Fe – Iron
Ni – Nickel
Nb – Niobium
Mo – Molybdenum

Non-Ferrous Metals

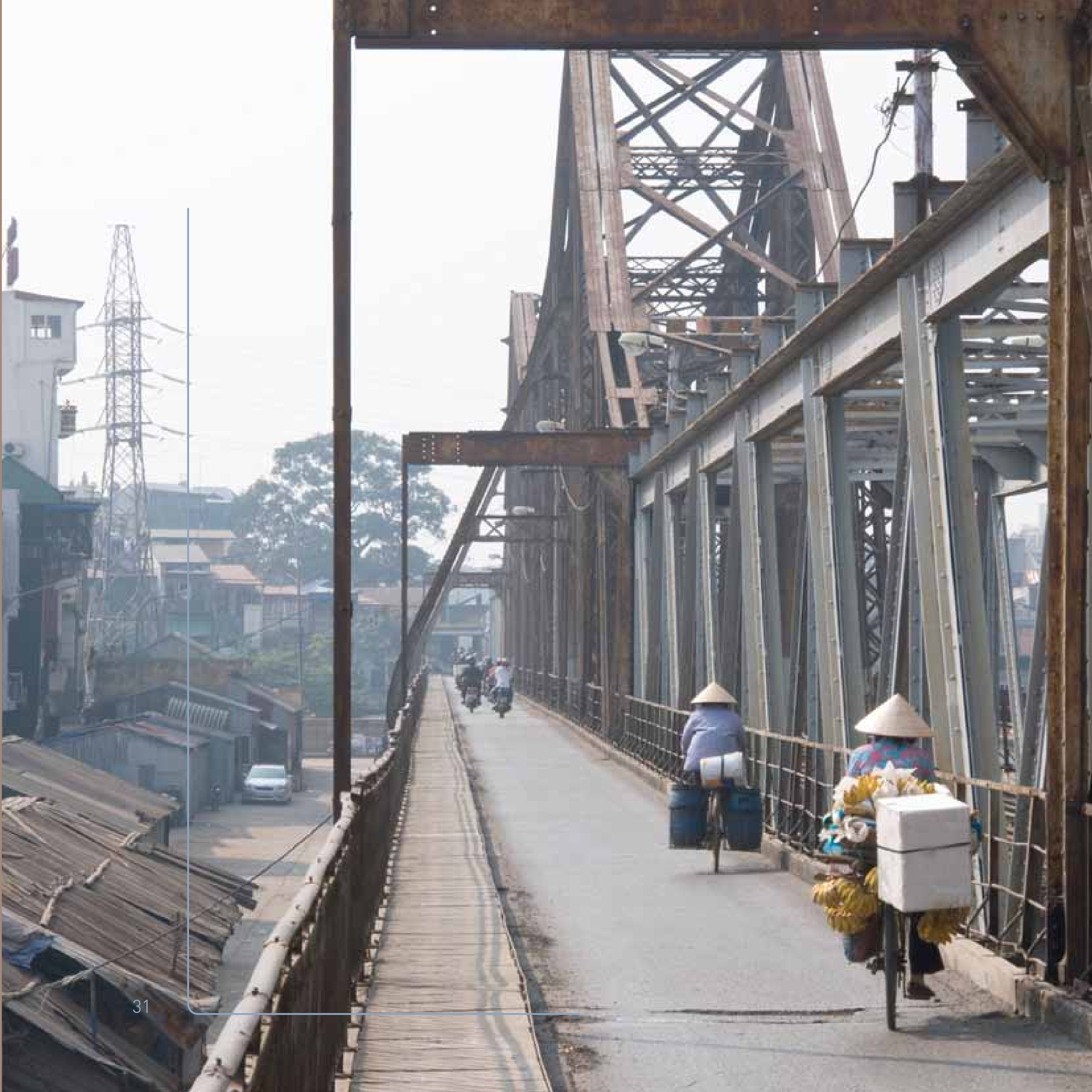
Mg – Magnesium
Al – Aluminum
Ti – Titanium
Co – Cobalt
Cu – Copper
Zn – Zinc
Sn – Tin
Pb – Lead

Precious Metals

Ru – Ruthenium
Rh – Rhodium
Pd – Palladium
Ag – Silver
Os – Osmium
Ir – Iridium
Pt – Platinum
Au – Gold

Specialty Metals

Li – Lithium
Be – Beryllium
B – Boron
Sc – Scandium
Ga – Gallium
Ge – Germanium
As – Arsenic
Se – Selenium
Sr – Strontium
Y – Yttrium
Zr – Zirconium
Cd – Cadmium
In – Indium
Sb – Antimony
Te – Tellurium
Ba – Barium
La – Lanthanum
Ce – Cerium
Pr – Praseodymium
Nd – Neodymium
Sm – Samarium
Eu – Europium
Gd – Gadolinium
Tb – Terbium
Dy – Dysprosium
Ho – Holmium
Er – Erbium
Tm – Thulium
Yb – Ytterbium
Lu – Lutetium
Hf – Hafnium
Ta – Tantalum
W – Tungsten
Re – Rhenium
Hg – Mercury
Tl – Thallium
Bi – Bismut



www.unep.org
United Nations Environment Programme
P.O. Box 30552 Nairobi, Kenya
Tel.: ++254-(0)20-762 1234
Fax: ++254-(0)20-762 3927
E-mail: uneppub@unep.org

UNEP

THIS BOOKLET SUMMARIZES the first two reports of the Global Metals Flows Group – the full reports are available on CD-Rom (see page 27 of this summary booklet). In its first two metal reports, "Metal Stocks in Society: Scientific Synthesis" and "The Recycling Rates of Metals: A Status Report", UNEP's International Panel for Sustainable Resource Management addresses the issue of mines above ground.

Economic development is deeply coupled with the use of metals, but the growing demand implies a permanent pressure on the natural resource. In contrast, the growing metal stocks in our society can serve as mines above ground. However, there are considerable data gaps regarding the size of these metal stocks and their recycling potential. These gaps have to be filled. The recycling rates of many metals are low. Open material cycles are typical for consumer goods like appliances and electronics. Therefore, these product groups need special attention. Recycling rates are very low for specialty metals like indium, for which an appropriate recycling infrastructure still has to be developed. This development needs to be supported by policy instruments such as research and development, economic incentives, and capacity building activities. Tapping the full potential of mining above ground and closing of material cycles with appropriate global infrastructure are essential if we are to establish a green economy and to secure sustainable development.