polinares
EU Policy on Natural Resources

POLINARES is a project designed to help identify the main global challenges relating to competition for access to resources, and to propose new approaches to collaborative solutions

POLINARES working paper n. 39
March 2012

Fact Sheet: Indium

EUROPEAN COMMISSION
European Research Area
SEVENTH FRAMEWORK PROGRAMME
Funded under Socio-economic Sciences & Humanities

The project is funded under Socio-economic Sciences & Humanities grant agreement no. 224516 and is led by the Centre for Energy, Petroleum and Mineral Law and Policy (CEPMLP) at the University of Dundee and includes the following partners: University of Dundee, Clingendael International Energy Programme, Bundesanstalt fur Geowissenschaften und Rohstoffe, Centre National de la Recherche Scientifique, ENERDATA, Raw Materials Group, University of Westminster, Fondazione Eni Enrico Mattei, Gulf Research Centre Foundation, The Hague Centre for Strategic Studies, Fraunhofer Institute for Systems and Innovation Research, Osrodek Studiow Wschodnich.

Deposit

The geochemical properties of indium are similar to those of base metals. The result is a general common occurrence with copper (Cu), lead (Pb), tin (Sn), zinc (Zn) and with trace metals such as bismuth (Bi), cadmium (Cd) and silver (Ag). Indium can accumulate in a multitude of different deposits and is found primarily in zinc sulphide ores and in copper and tin ores. Because of its relatively low average level of occurrence indium is classified as a trace element and can only be economically extracted as a by-product under appropriate conditions. The most important deposits are base metal sulphide deposits, which are characterized by their metal abundance and a large tonnage.

The proportion of indium in these ores is 1-50 parts per million (ppm). Even in a zinc concentrate, the most common commercial source, the proportion of indium is relatively low at 70-200 ppm. Native indium and indium minerals, such as indit ($FeIn_2S_4$) and roquesit ($CuInS_2$), are rare.

Economic extraction is possible at certain points where indium accumulates as part of the production process. Almost the entire global production of indium comes from the processing and smelting residues of zinc extraction and the recycling of dusts and gases produced during the smelting of zinc. The remaining part, significantly less than 5%, is extracted from the residues of tin and copper treatment, and primarily copper sulphide concentrates (mainly chalcopyrite, $CuFeS_2$), which contain a very high indium content.

Large mines with indium bearing ore are in production on all continents. Large zinc or indium deposits are located in China, Peru, Canada, USA and Australia. Currently the most important deposits are in China and Canada. More than half of the world indium production comes from China, where indium is produced mainly from base metal sulphides, tin-rich deposits (Dachang district), and massive sulphide deposits (Yunnan) (Schwarz-Schampera & Herzig 2002).

Application

Flat display panels, thin-film coatings (indium tin oxide, ITO) (90%), solders, alloys (4%), electrical components and semiconductors (3%), intermetallic compounds (2%), research, other (1%).

Typical applications for indium are indium compounds of high purity low temperature alloys, solders and thin films. The most important application area for thin films of indium-tin oxide (ITO) are currently liquid crystal displays (LCD) and flat display panels used in consumer electronics (mobile phones, laptops, monitors, televisions, digital cameras, etc.). The use of indium in the production of flat screens occupies first place and is responsible for more than 80% of consumption. Furthermore, indium is increasingly used for solar cells (copper-indium-selenide or sulphide and cadmium telluride cells).

General Characteristics

Indium is a silvery-white, malleable, ductile metal. A special feature of indium is its high plastic properties even at freezing temperatures. It does not oxidize at ordinary temperatures. Indium is used to coat glass, forming a mirror surface with equally good reflective properties and more corrosion resistance than silver.

Indium is a relatively rare element compared with other metallic elements. The average continental crustal abundance of indium is estimated at 0.05 ppm (equivalent to 50 mg per tonne of rock). Indium is a chalcophile element, which means it occurs in many sulphide minerals.

Indium is a typical byproduct of smelting polymetallic ores of base metals such as lead, zinc, copper and tin. In such ore concentrates the average indium content is about 70 to 200 ppm. About 95% is produced as a by-product from zinc sulphide ore. The recovery yield of indium is currently only 35%. There is a high potential for the expansion of the indium extraction in mining and from metallurgical residual materials and, alternatively, from copper and tin ore.

Supply Status: Jan. 2011

estimated reserves: **12,400 t in zinc ore** (world total)

estimated resources: **95,000 t in zinc ore** (incl. reserves, world total)

Reserves World reserves by country. Status: Jan. 2011

There are no reliable estimates of global indium resources. Indium is recovered to about 95% as a by-product of zinc smelting. At best, indium resource assessments can be derived from the zinc deposits and their annual production. The average indium content of zinc deposits, from which indium is recovered, ranges from less than 1 to 100 ppm. Another small percentage comes from the smelting and processing of sulphide copper ore and tin ore.

In 2010 global zinc reserves were estimated at around 250 million t (Tolcin 2011a). Assuming there is an average indium content of only 50 g indium per tonne of zinc content in the ore, the calculated indium reserves in these zinc deposits are in the order of 12,400 t.

Zinc reserves (source: USGS, January 2011):

Country/Region	Million t Zn	Estimated indium content [t]	Share [%]
Australia	53	2,650	21
China	42	2,100	17
Peru	23	1,150	9
Kazakhstan	16	800	6
Mexico	15	750	6
USA	12	600	5
India	11	550	4
Canada	6	300	2
Bolivia	6	300	2
Ireland	2	100	1
Other	62	3,100	25

Country concentration and country risk for 75% of global Zn reserves.

HHI: 963 (low, non-critical) (for 75% of the Zn reserves);

Cr: +0.27 (moderate)

In January 2008 the USGS estimated the world's known reserves of indium at almost 11,000 t. China had sole access to about 75% of the reserves. Peru, Canada, the USA and Russia together possessed about 8% of the reserves (Tolcin 2008).

Indium reserves 2008 (source: USGS, January 2008):

Country/Region	Indium [t]	Share [%]
China	8,000	75.0
Peru	360	3.4
USA	280	2.6
Canada	150	1.4
Russia	80	0.7
other	1,800	16.9

Resources

World resources. Status: Jan. 2011

In 2010 global zinc resources were estimated at around 1.9 billion t of Zn content (USGS 2011). Assuming there is an average indium content of only 50 g indium per tonne of zinc content in the ore, the calculated indium resources in these zinc deposits are approx. 95,000 t.

Consumption 2009 (Estimated)

The total world consumption of indium is unknown. Roskill (2010) estimated primary indium consumption in 2008 at almost 1,000 t and 700 t in 2009. Total consumption including secondary indium was estimated at about 1,700 t in 2008 and at 1,300 t in 2009 (Roskill 2010).

Since the 1990s the global consumption of indium has risen steadily, particularly increasing towards the end of the decade. According to estimates made by Roskill (2010), the average annual growth rate was 6% between 1990-1995 rising to 11% between 1995 and 2000 and to 20% between 2000 and 2005. In 2009 and 2010 there was a sharp decline in consumption owing to the economic recession. During the first half of 2010 demand for ITO targets increased due to a rise in LCD panel production. However, during the second half of 2010, LCD panel inventories began to increase as a result of lower-than-expected LCD sales in the USA and global economic uncertainty (Tolcin 2011b).

Key Consumer

Estimated consumption by country in 2009

Japan: 240 t (primary), 362 t (secondary)

USA: 110 t

China: 40-50 t

The main customers are industrial countries with high-tech production locations. Japan is the largest consumer of primary indium accounting for about a third of global consumption. Japan's indium consumption is believed to have increased by 20% in 2010. The USA and China are also major consumers of indium, although the actual consumption figures for China are not known. Chinese indium consumption is expected to keep on growing significantly, having already risen to 75 t in 2010 due to increased demand for electronics containing LCD (Tolcin 2011b).

Production

Status: 2009

470 t mine production (estimated world total according to Roskill 2010),

546 t refinery production (estimated world total),

727 t refinery capacity (estimated world total, Roskill 2010)

Key Producer Mine Production

Production by country in 2009

Indium is produced solely as a minor by-product of conventional base metal mining, primarily of zinc ores and, to a lesser extent, tin and copper rich ores (Schwarz-Schampera & Herzig 2002).

In 2009 about 11.5 million t of zinc were mined and 11.1 million t of zinc were refined. The major mining countries were China (27.0%), Peru (13.2%), Australia (12.3%), USA (6.4%), Canada (6.1%), India (5.6%), Bolivia (3.8%) and Kazakhstan (3.7%). The major zinc refining countries were China (39.2%), Canada (6.2%), India (6.1%), South Korea (5.7%), Japan (4.9%), Spain (4.6%) and Australia (4.6%). Data for mine production or rather primary production of indium are not available. Roskill (2010) uses estimates based on the mine production of zinc ore according to USGS to calculate average indium content. According to Roskill (2010) an estimated 470 t of indium were co-produced through zinc mining in 2009. The average indium content in the world's zinc ore concentrate (sphalerite) is taken as being between 15 and 50 ppm, although this assumption is very conservative.

Country	Mine production zinc	Mine production ore concentrate	Estimated indium content in concentrate		Share
	million t Zn content	million t Sphalerit	[ppm]	[t]	[%]
China	2.8	4.2	50	210	45.0
Peru	1.5	2.2	20	44	9.4
Canada	0.7	1.1	37	40	8.6
Australia	1.3	1.9	15	29	6.2
USA	0.7	1.0	20	21	4.5
Mexico	0.5	0.8	20	16	3.4
other	3.6	5.4	20	107	23.0
total	**11.1**	**16.6**	**29**	**467**	

Estimated indium mine production from zinc deposits in 2009 (Roskill 2010).

Key Producer Refinery Production

Refinery production by country in 2009

Primary indium supply is limited to a few countries. Most primary indium producers are zinc smelters with an electrolytic process. However, not all of these smelters process their own residues for the production of indium and other trace metals. Rather, these metal-rich residues are sold to producers who have appropriate preparation line. Countries with major refinery production are China, South Korea, Japan, Canada, Belgium and Peru.

Country	Indium refinery production [t]	Share [%]
China	280	51
South Korea	70	13
Japan	67	12
Canada	40	7
Belgium	30	6
Peru	25	5
Brazil	5	1
United Kingdom	5	1
Italy	5	1
Netherlands	5	1
Russia	4	1
Germany	2	<1
total	**546**	

Estimated indium refinery production in 2009 (Tolcin 2011c).

Refinery Capacity — Refinery capacity by country 2009

The annual global refinery capacity for indium is estimated at 780 t (Roskill 2010, Tolcin 2011c) and is distributed as follows:

Country	Indium refinery capacity [t]	Share [%]
China	360	46.0
South Korea	100	12.8
Japan	70	11.1
Canada	87	3.8
Peru	45	5.8
USA	40	5.1
Russia, Ukraine, Kazakhstan	35	4.5
Belgium	30	9.0
Germany	15	1.9
total	**782**	

Estimated indium refinery capacity (Roskill 2010, Tolcin 2011c).

With an annual production of 540-600 t indium, the global refinery capacity is about 23 to 31% higher than the production.

Country Concentration (HHI) and Country Risk (Cr) Refinery Production — 2009

HHI: 3.145 (high, critical)

Cr: +0.19 (moderate)

Recycling — 2009

Secondary production: estimated 500 t,

Capacity secondary production: estimated 500-1,000 t

A significant proportion of global indium consumption now comes from the recycling of production residues or scrap, such as recovery of indium from ITO production waste during the sputtering process. The strong demand in recent years has led to investment in recycling capacity in major producing countries. Already up to 50% of global indium demand will be met by the recycling of production waste. Many countries, including China, South Korea, United Kingdom, Canada, Philippines, Taiwan and most of all Japan invest in the recycling of indium and the recovery of secondary indium. In 2007 Japan had an annual production capacity of about 350 t of indium from ITO production waste.

The recovery of indium from the sputtering process has currently reached almost 1,000 t per year and exceeds primary production significantly. Flat indium targets from tin-doped indium oxide (ITO) are usually sputtered onto glass plates (cathodic sputtering). In this inefficient process less than 30% of the target material is deposited on the glass. The remaining 70% is left on the shields of the sputtering chambers, in the process sludge and on the ITO target itself. It is estimated that up to 70% of the indium could be recovered by refining the ITO target process (Mikolajczak 2009).

Largest Companies

In 2006 90 companies were engaged in the production of pure indium and indium bearing components worldwide. The vast majority were toll smelters and recyclers possessing the specific technical ability and capacity. There are only a few companies which operating along the entire value chain, i.e. mines and smelters with integrated indium processing. Examples are Xstrata and Teck Resources in Canada as well as Chinese consortia from mine operators and metallurgical plants (state combines).

Indium producers are often highly specialized companies that produce high purity indium (> 4N-quality). This applies primarily to companies in industrialised countries such as Japan, USA, South Korea and Germany. The number of primary producers has risen sharply, especially in China. In 2009 China's government launched a series of environmental regulations that restricted nonferrous metal production, including by-product metals such as indium. As a consequence, some Chinese plants that produced indium were shut down due to pollution. In 2010 there are believed to have been 21 indium producers in China (Tolcin 2011b). The Chinese industry has the technical ability for the extraction of rare trace metals and also currently dominates the market for other trace metals.

Important indium production companies are:

Companies	Plant location	Refinery capacity [t]	Secondary capacity [t]
Nanjaing Germanium Factory	China	150	
Huludao Zinc	China	50	
Zhuzhou Smelter Group	China	?	
Dowa Metals & Mining Co.	Japan	70	150
Asahi Pretec Corp.	Japan		200
Mitsubishi Mat. Group	Japan		96
Korea Zinc	South Korea	100	100
Umicore SA	Belgium	30	
Teck Resources Ltd	Canada	~75	
Xstrata Plc.	Canada	?	
Doe Run	Peru	45	

Company Concentration (HHI) 2009

No data

Production Method

The exclusive extraction of indium is uneconomical; therefore primary indium is obtained solely as a by-product in the smelting of polymetallic ores with base metals containing zinc, copper and tin. During their preparation, anode slimes, slag, fly ash and gases accumulate from which indium is recovered.

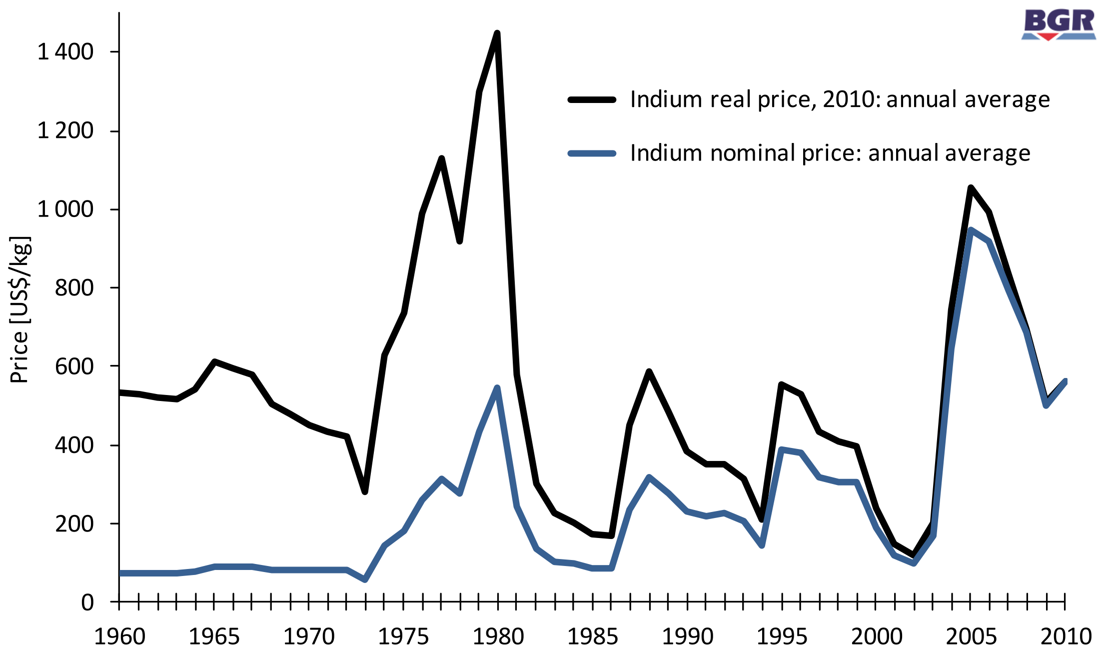
Anode slimes are a valuable waste product of metal production produced during electrolytic refining. During the electrolytic process the crude, impure metal undergoes dissolution and pure main metal precipitates at the cathode. All nobler, insoluble components (impurities) such as indium settle as solids at the bottom of the electrolysis cells forming anode slime out of which indium and other trace metals can be extracted. The pure metal is achieved by separation, purification and chemical concentration of the anode slime by different methods. The refining processes are very different from element to element. Indium can be dissolved from anode slime or its processed intermediates with hydrochloric acid (HCl) or sulfuric acid (H_2SO_4). It is concentrated and recovered at a purity of 99+%. This low-grade indium standard is further refined to 4N (99.99%) and higher levels of purity (5N-7N). For the manufacture of ultra pure metals the metal is further electrolytically refined. Zone refining is an important method used for obtaining ultra pure trace metals (e.g. indium-7N) or for the formation of single crystals.

Stages of Production

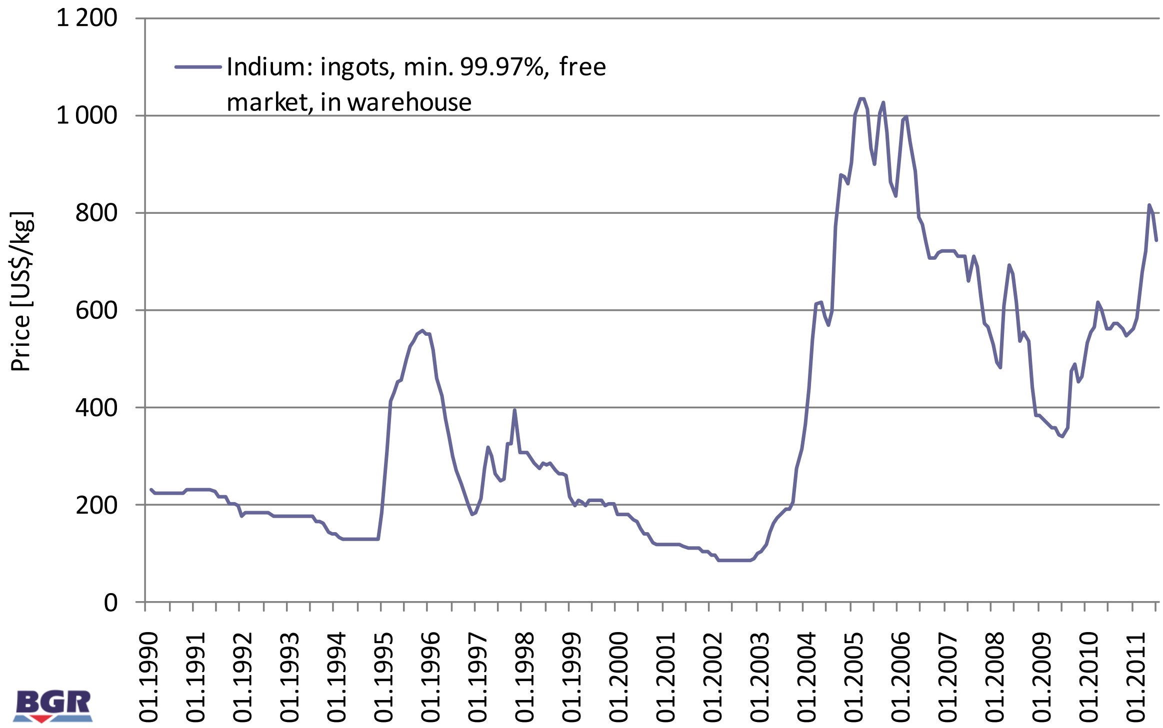
1. Zinc mining,
2. Preparation of anode slime by electrolytic refining sulphidic ores (primary zinc production),
3. Installations for the production of by-products: further processing of anode slimes,
4. Refinery

Price Development

Annual average price



Monthly average price



The price of indium has followed a cyclical trend since 1970. In the years 1975, 1980, 1988, 1995 and 2003 there was a sharp rise in the world indium price followed each time by a slower, more gradual, decrease. The indium price reached a low point in 2002. The tightening of the global economy, the rapid growth of economies in emerging countries, the increased demand for flat panel displays, technical innovations with the establishment of thin film solar cells, closure of deposits, problems in the zinc production and the general expectation of a worldwide shortage led the price increase to an all-time high in 2005. As a result indium production was stepped up considerably and recycling was intensified. Due to increased exploration in zinc-rich and base metal-rich deposits together with weaker than expected demand from Asia there was a gradual decrease in the indium price up to 2009, intensified by the recession in the global economy. The ITO demand accelerated in mid-2009 and the first half of 2010 with the price rising again since 2010.

Trade — Import/Export

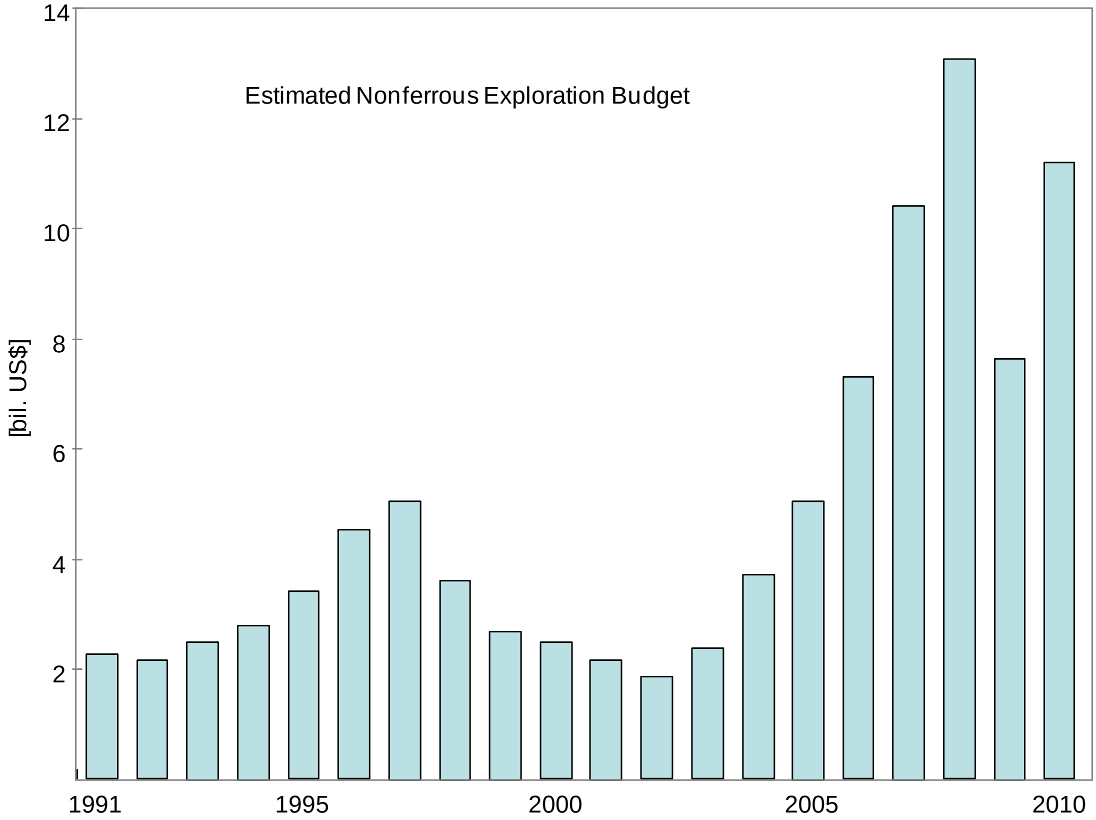
Most indium is produced at electrolytic zinc refineries but some zinc refineries ship the anode slime to other indium producing refineries. Countries with limited domestic mine sources, such as Belgium, Japan, Netherlands, UK, Italy and Republic of Korea refine indium from imported anode slime, lead/zinc residues, flue dust and drosses. The majority of indium consumption takes place in industrialised countries.

Indium is traded in purchase contracts between buyer and seller. Japanese end-users mainly purchase indium via long-term contracts. Indium metal is sold in diverse forms (foil, ingot, powder, ribbon, wire and others) and grades. Universal product standards range from 3N (99.9%) to 7N (99.99999%), but there are also commercially available standards up to 9N. Indium is a versatile metal, a large proportion is further processed into a series of compounds. Many companies produce compounds, indium tin oxide (ITO) coatings, high-purity indium alloys, solders and other products.

China restricts indium exports by export quotas. In the second half of 2010, China's indium producers were allowed to export a combined total of 93 t of indium. In the first half of 2010 140 t was permitted. Most of this material was exported to Japan (Tolcin 2011b).

Trends in Exploration Activity

In recent years mine production of base metals has risen significantly. The resurgence of global exploration for base metal deposits will contribute to the development of new indium reserves in the future. Between 2002 and 2008 spending on nonferrous exploration rose to estimated 13.2 billion US$ in 2008. In 2009 many companies cut their exploration budgets as a result of the global economic crisis (a decrease of about 5.5 billion US$ on 2008). In response to rising prices and more stable market conditions most companies increased their exploration budgets. In 2010 the estimated exploration budget rose 45% (3.5 billion US$ excluding uranium) on 2009 (Metals Economics Group 2010).



Estimated total worldwide nonferrous exploration budgets, 1991-2010 (Data source: Metals Economics Group 2010).

The high demand for indium has also led to greater interest and a more active search for indium containing base metal ores. In addition to the Canadian deposits at Mount Pleasant and New Brunswick, other projects in Bolivia and Brazil promise to deliver high indium content. The Australian Crusader Holdings has acquired exploration licenses in the prospective Goiás tin-district in Brazil, which is well-known for its high indium content.

Other

A “technical scarcity” has been postulated for indium as by-product element, because its availability depends on the extraction, smelting and refining rates of base metals, particularly zinc, as carrier metal. A smelter is unlikely to increase the production of the main metal in order to produce more of a by-product (Wellmer 2008). Indium and other trace metals production require large investment in production technologies that are only profitable at high prices. As a consequence, the worldwide smelter capacity for indium production is limited. Only about 35% of the indium content in base metal concentrates is extracted for indium metal production. However, there is a high potential for the expansion of indium extraction in mining, from metallurgical waste materials and, alternatively, from copper and tin ore.

The Republic of Korea stockpiles indium. Japan also plans to include indium in its rare-metal inventory.

Trends

It is expected that the demand of indium will increase significantly. More than 80% of indium is used in thin-film technologies. Thin-film ITO coatings will continue to be important drivers of future indium demand. Indium based solar panels are also an important future technology with strong growth potential.

Based on predicted and geologically secured indium and zinc reserves, the availability of indium in the coming decades looks assured. Supply is further relieved by secondary sources (recycling, stockpiling).

China intends to increase its domestic production of high-end LCD electronics rather than selling the raw materials to other countries and buying back the electronic products at high prices. Consequently, Chinese indium export quotas were cut by 30% on first half of 2010 in second half 2010 (from 140 t to 93 t) (Tolcin 2011b).

Conflict / Supply Risk

Uncertainty over future availability exists in the political and economic development of important indium producers. Some countries set up export restrictions, for instance, China applies a combination of export quotas and export tax. Trade restrictions and economic protectionism affect the global availability, as well as the formation of producer cartels and a growing environmental problem.

The global mining capacities of by-products are limited, and the potentials of extracting the by-product elements as main elements by current methods are not fully utilized. Increasing the production of the by-products would be achieved by increasing the production of the carrier elements or by extending the extraction capacities within an established production process. Moreover, the supply could be enhanced with the refining from alternative concentrates as well as with residues from mining and processing.

Sources

Metals Economics Group (2010): Trends in worldwide exploration budgets.- Metals Economics Group - Strategic Report, November/December 2010, p. 1-10.

Mikolajczak, C. (2009): Availability of Indium and Gallium: 4 S.: www.indium.com/_dynamo/download.php?docid=552.

Roskill Information Services Ltd. (2010): Indium: Global industry markets and outlook (9^{th} ed.): London, United Kingdom, Roskill Information Services Ltd., p. 142.

Schwarz-Schampera, U. & Herzig, P. (2002): Indium, Geology, Mineralogy, and Economics: p. 257; Springer, Berlin.

Tolcin, A. C. (2008): Indium.- U. S. Geological Survey, Mineral Commodity Summaries January 2008, pp 80-81.

Tolcin, A. C. (2011a): Zinc.- U. S. Geological Survey, Mineral Commodity Summaries January 2011, pp 188-189.

Tolcin, A. C. (2011b): Indium.- U. S. Geological Survey, Mineral Commodity Summaries January 2011, pp 74-75.

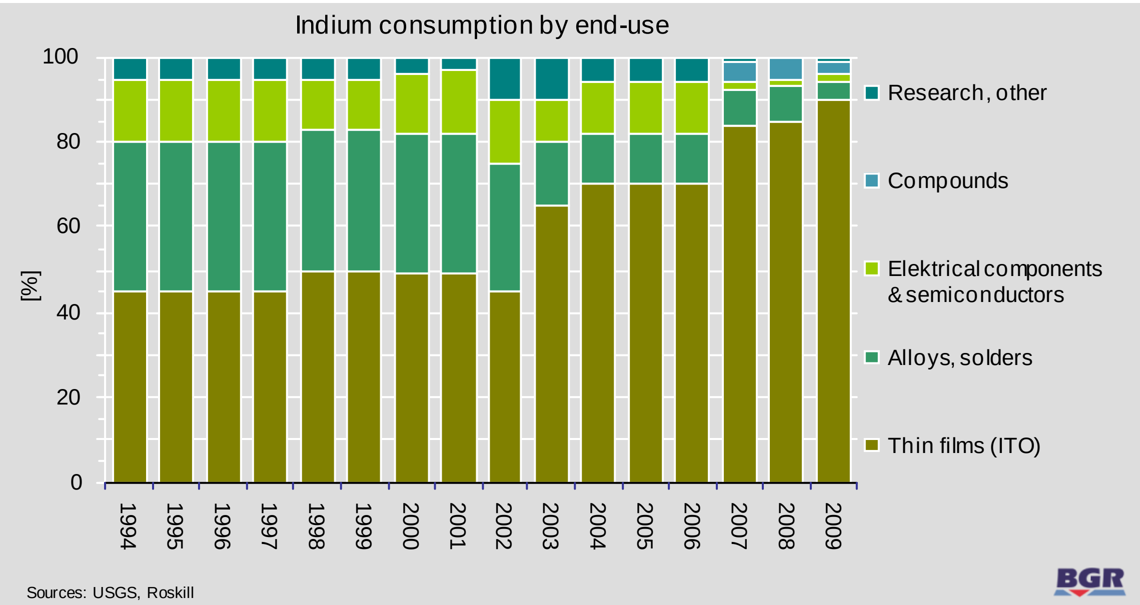
Tolcin, A. C. (2011c): Indium [Advance Release].- U. S. Geological Survey, Minerals Yearbook 2009, pp 35.1-35.5; Reston, VA.

U.S. Geological Survey (USGS) (2010): Commodity Statistics and Information. Minerals Information Statistics, United States Geological Survey, http://minerals.usgs.gov/minerals.

Wellmer F.-W. (2008): Reserves and resources of the geosphere, terms so often misunderstood. Is the life index of reserves of natural resources a guide to the future?- Z. dt. Ges. Geowiss., 159/4, p. 575-590; Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

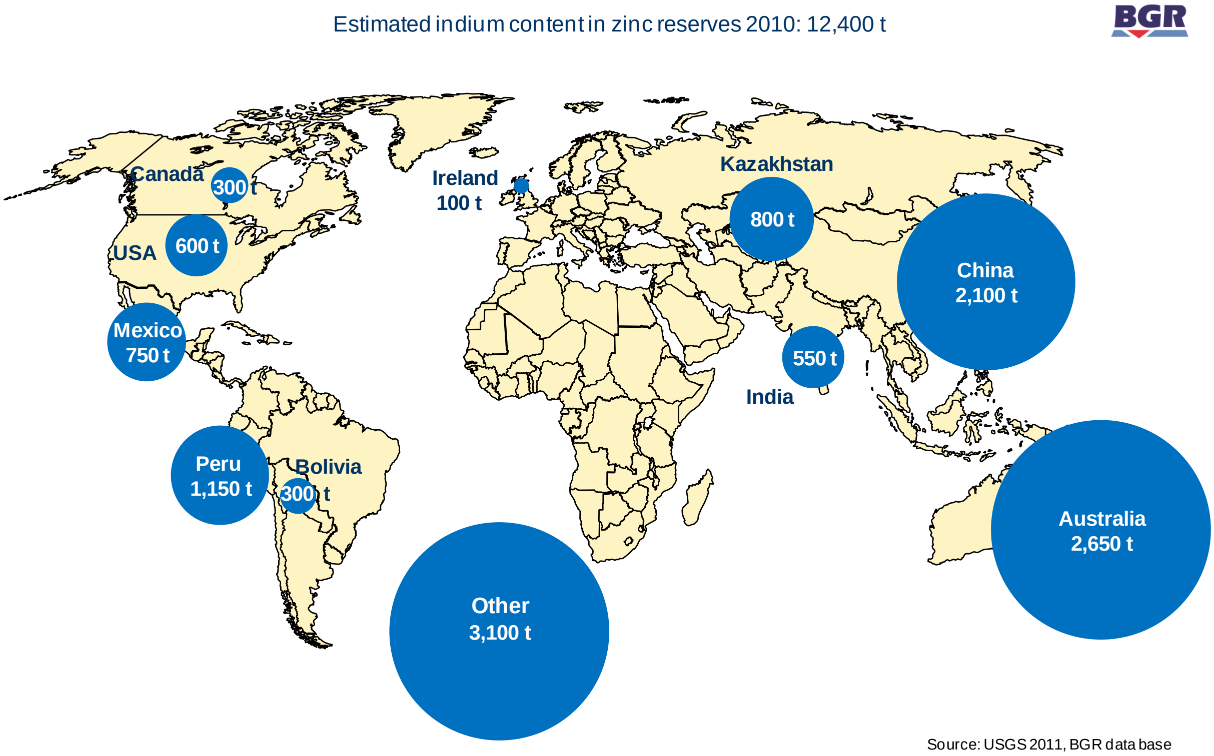
World Bank Group (2010): Worldwide Governance Indicators (WGI). Accessed November, 2010, http://info.worldbank.org/governance/wgi/index.asp.

Consumption by Application



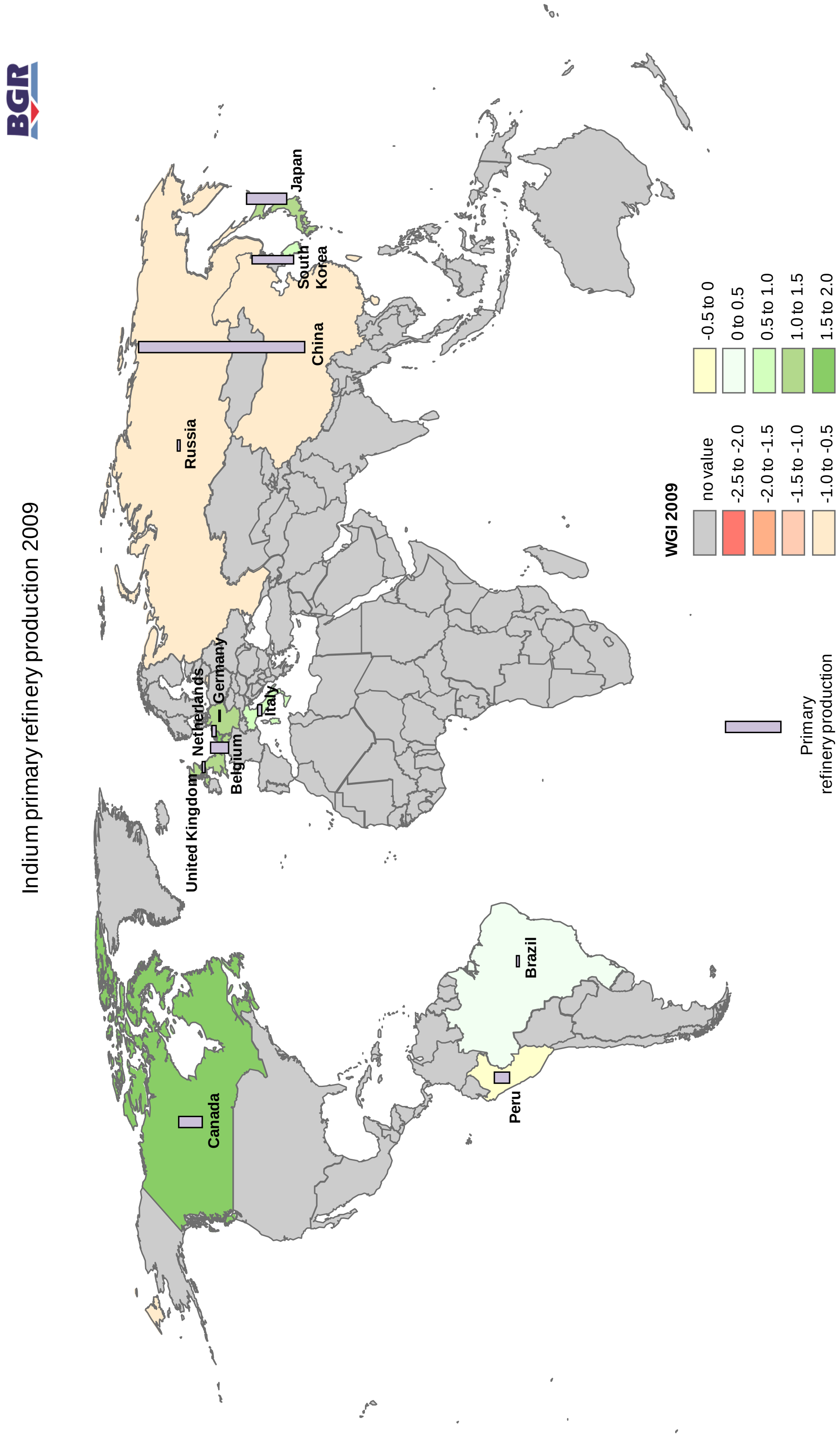
Indium for photovoltaic application particularly in CIS (copper-indium-selenide) thin-film solar cells is a relatively new application with strong growth potential.

Reserves (tonnes) Status Jan. 2011

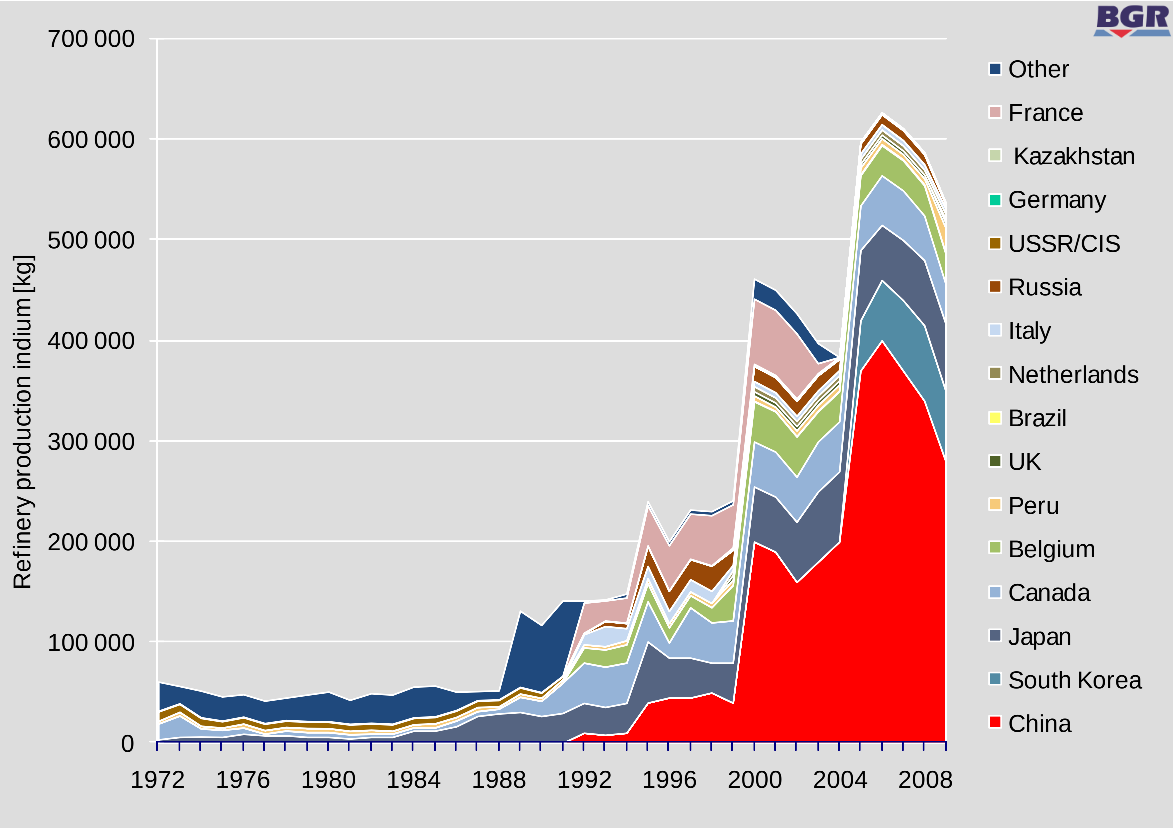


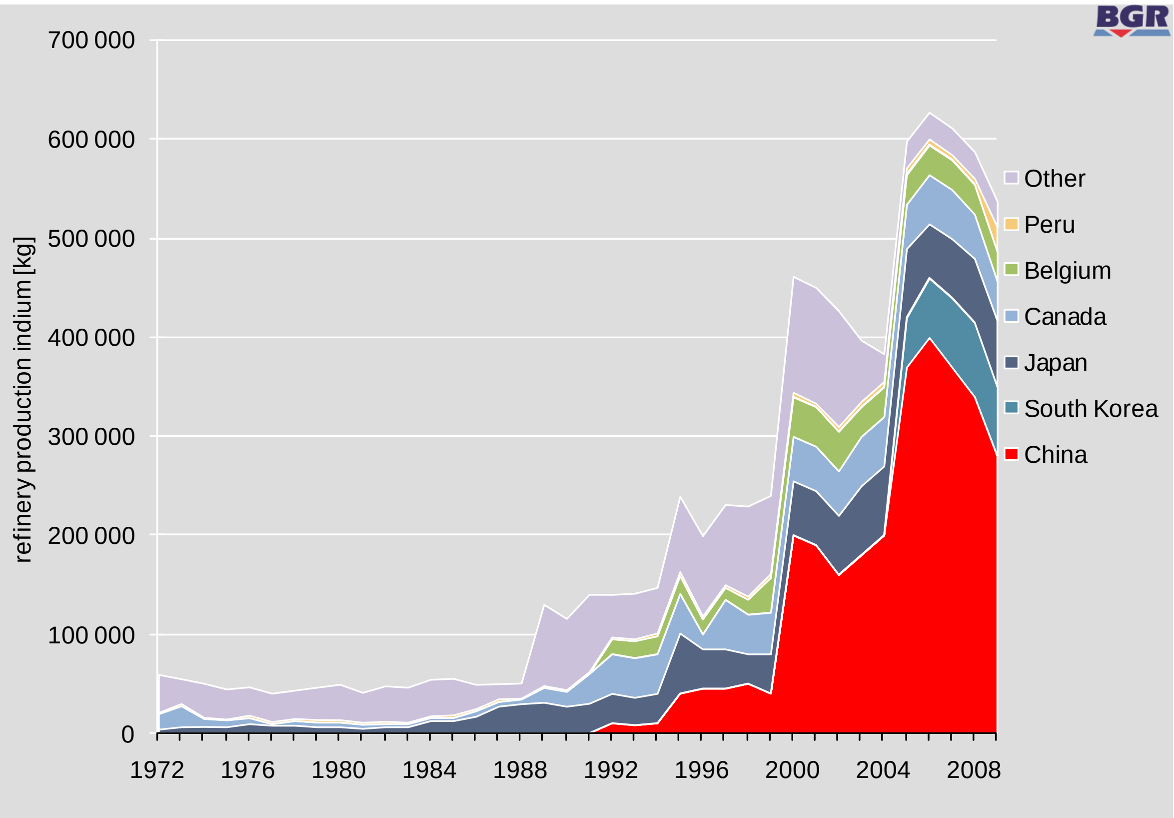
Definitive data on the economic reserves for indium are not available. Data are revised, based on an estimated average indium content of zinc ores.

Production by Country and World Governance Indicator 2009



Historical Primary Production 1972 - 2009





Indium production has increased from 40-50 to 600 t per year since 1972.

Resources — World resources

A concentration of naturally occurring solid, liquid, or gaseous material in or on the earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible (USGS 2011). Resources are known (to various levels of certainty), but their economic viability has not been established. The potential resources are as yet not known but by geological reasoning they can be expected to be discovered by means of modern exploration technologies (Wellmer 2008).

Resources include reserves.

Energy resources: the energy resources which are either proved but are at present not economically recoverable, or which are not demonstrated, but can be expected for geological reasons. In the case of oil, natural gas and uranium, only recoverable amounts are considered reserves. For coal this term is used for all in-place resources.

Resources do not include reserves.

Resources are not distributed evenly across the world. Regions and countries with rich occurrences or high production of mineral or energy raw materials do not necessarily coincide with regions and countries with high demand.

Reserves — World reserves

The share of the total resources that can be economically extracted or produced with available technology at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials (USGS 2011, Wellmer 2008).

Energy reserves: the portion of energy resources which is known in detail and can be recovered economically using current technologies. Accordingly, the amount of reserves depends on the current prices as well as on technological progress.

Country Concentration (HHI)

HHI: sum of squared values of raw materials production (in %) in each country.

The country concentration can be measured by the Herfindahl-Hirschman Index (HHI). The Herfindahl–Hirschman Index is the sum of squared values of raw materials production (in %) in each country (Rosenau-Tornow et al. 2009). Scores between 1,000 and 1,800 have been defined as benchmarks for moderate supply risk (US Department of Justice and Federal Trade Commission 1997) scores above 1,800 are problematic, and scores below 1,000 are relaxed.

Country Risk (Cr)

Cr: Sum of global raw materials production (P, in % for each country) weighted with the Governance Index (WGI) of the World Bank for each country.

The World Bank's 'Worldwide Governance Indicators' (WGI) are used to classify the countries' stability (World Bank Group 2010). Six governance indicators (Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law and the Control of Corruption) are measured in units ranging from about -2.5 to 2.5, with higher values corresponding to better governance outcomes. The country risk (Cr) is the sum of global raw materials production for each country weighted with the Governance Indicator of the World Bank for each country.

In relation to the World Bank scale for country risks, countries with a country risk minus 0.5 are classified as problematic, whereas values above 0.5 as non-critical.

Company Concentration (HHI)

HHI: sum of squared values of raw materials production (in %) of each company.

The company concentration (market power) can be measured by the Herfindahl-Hirschman Index (HHI). The Herfindahl-Hirschman Index is the sum of squared values of raw materials production (in %) in each country (Rosenau-Tornow et al. 2009). Scores between 1,000 and 1,800 have been defined as benchmarks for moderate supply risk (US Department of Justice and Federal Trade Commission 1997) scores above 1,800 are problematic, and scores below 1,000 are relaxed.

Prices

fob: free on board; term of sale signifying that freight from the producer to the consumer is paid for by the purchaser.

cif: cost, insurance, freight; term of sale signifying that the price invoiced or quoted by a seller includes insurance and all other charges up to the named port of destination.

real price: A price that has been adjusted to remove the effect of changes in the purchasing power of the dollar. Real prices, which are expressed in constant dollars, usually reflect buying power relative to a base year.

Abbreviation

Mt: million tonnes

ppm: parts per million

t: (metric) tonnes

oz tr: troy ounce

Sources

Rosenau-Tornow, D., Buchholz, P., Riemann, A., Wagner, M. (2009): Assessing long-term supply risks for mineral raw materials – a combined evalutation of past and future trends. Resources Policy 34, pp. 161-175.

U. S. Geological Survey (USGS) (2011): Mineral Commodity Summaries: http://minerals.usgs.gov/minerals/pubs/mcs/2011/mcsapp2011.pdf.

U.S. Department of Justice and Federal Trade Commission (1997): Horizontal merger guidelines, <http://www.usdoj.gov/atr/public/guidelines/horiz_book/ toc.html>.

Wellmer, F.-W. (2008): Reserves and resources of the geosphere, terms so often misunderstood. Is the life index of reserves of natural resources a guide to the future? – Z. dt. Ges. Geowiss., 159/4, p. 575-590. Stuttgart, Schweizerbart'sche Verlagsbuchhandlung.

World Bank Group (2010): Worldwide Governance Indicators (WGI). Accessed November, 2010, http://info.worldbank.org/governance/wgi/index.asp.

