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European Commission

REPORT ON CRITICAL RAW MATERIALS FOR THE EU

NON-CRITICAL RAW MATERIALS PROFILES

Contents

See separate documents for main report and critical raw material profiles

Glossary

BGR	German Federal Institute for Geosciences and Natural Resources
BGS	British Geological Survey
BRGM	Le Bureau de Recherches Géologiques et Minières
CAGR	compound annual growth rate
CEPI	Confederation of European Paper Industries
CIGS	copper indium gallium (di)selenide
EEA	European Environment Agency
EOL-RR	end-of-life recycling rate
EUBA	European Bentonite Association
FAO	Food and Agriculture Organization of the United Nations
FGD	flue gas desulfurization
GCC	ground calcium carbonate
HSLA	High-strength Low-allow Steel
IC	integrated circuit
IFA	International Fertilizer Industry Association
ILZSG	International Lead and Zinc Study Group
IR	infrared radiation
ITRI	International Tin Research Institute
LED	light emitting diode
Li-ion	lithium-ion
MMTA	Minor Metals Trade Association
OECD	Organisation for Economic Co-operation and Development
PBNR	pebble bed nuclear reactor
PCB	printed circuit board
ppb	parts per billion
ppm	parts per million
PV	photovoltaic
PVC	polyvinyl chlorine
RFID	radio frequency identification
RoHS Directive	Restriction of Hazardous Substances Directive
SALB	South American leaf blight
SOFCs	solid oxide fuel cells
UNEP	United Nations Environmental Programme
USGS	US Geological Survey
VAT	value added tax
WMD	World Mining Data

Abiotic – Metals (or metallic ores) and industrial minerals. These are derived from static reserves.

Biotic – Materials which are derived from renewable biological resources that are of organic origin but not of fossil origin. Only non-energy and non-food biotic materials are under consideration in this report.

Deposit – A concentration of material of possible economic interest in or on the Earth's crust.

Reserves – The term is synonymously used for 'mineral reserve', 'probable mineral reserve' and 'proven mineral reserve'. In this case, confidence in the reserve is measured by the geological knowledge and data, while at the same time the extraction would be legally, economically and technically feasible and a licensing permit is certainly available.

Resources – The term is synonymously used for 'mineral resource', 'inferred mineral resource', 'indicated mineral resource' and 'measured mineral resource'. In this case, confidence in the existence of a resource is indicated by the geological knowledge and preliminary data, while at the same time the extraction would be legally, economically and technically feasible and a licensing permit is probable.

1 Non-Critical Abiotic Raw Materials

1.1 Aluminium

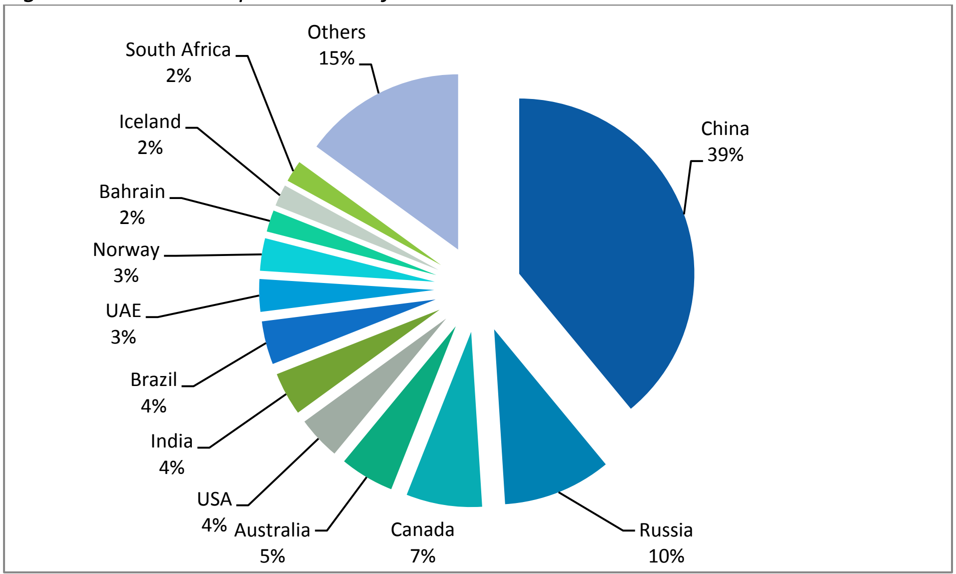
1.1.1 Introduction

Aluminium (Al, atomic number 13) is a silvery-white, lightweight metal, ranking third in abundance in the Earth's crust that has become the dominant non-ferrous metal in use today. Because aluminous minerals are very stable, large amounts of energy are required to extract aluminium from its ore. As a result, the industrial production of aluminium only became feasible in the middle of the 19th century, with strong growth in Europe and North America in the last decade of that century.[a] Current consumption in Europe amounts to almost 20 kg per capita in 2010.[b]

Today primary aluminium is produced in a two stage process. The first stage is the production of alumina (aluminium trioxide)from bauxite by means of the Bayer process, followed by the Hall-Héroult process, named after Charles Martin Hall and Paul L.T. Héroult, to extract aluminium from alumina.[a] The only source of aluminium oxide that is currently mined is bauxite (treated separately in this exercise). It is important to note that the production of alumina and aluminium can occur in geographically widely distinct places, the location of these industries being driven by energy and transport prices.

1.1.2 Supply and demand statistics

Figure 1: Worldwide production of aluminium metal in 2010



Source: World Mining Data 2012

Aluminium metal is produced in 43 countries worldwide (2010), including 15 EU Member States. In 2010, China was the largest producer with a share of 39%. The second largest was Russia (10%), followed by Canada (7%) and Australia (5%) (Figure 1).[c] EU-27 production was nearly 2.4 million tonnes.

Within the wider European area, production was about one tenth of world production. Norway (29.5% of EU35 Production) and Iceland (17.4%) were the largest producers of aluminium in this region, followed by

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a Ullmann's Encyclopedia of Industrial Chemistry: Aluminum, Wiley-VCH Verlag GmbH & Co. KGaA, 2009
b European Aluminium Association: http://www.alueurope.eu/pdf/Aluminium_use__in_Europe_by_country.pdf, accessed 26th August 2013
c World Mining Data 2012, C. Reichl et al., 2012

Germany (8.5%), France (7.5%) and Spain (7.1%).[a] The largest foreign provider of aluminium for the EU in 2010 was Mozambique (28.5%), followed by the Russian Federation (24.4%) (Table 1).

Table 1: World production and imports to EU of aluminium metal, 2010

	Production in t (2010)[bc]		Imports to EU in t (2010)[c]	
China	16,131,000	39.1%	1,717	0.1%
Russia	3,947,000	9.6%	633,980	24.4%
Canada	3,008,569	7.3%	181,106	7.0%
Australia	1,928,000	4.7%	3,169	0.1%
USA	1,727,200	4.2%	237	0.0%
India	1,609,900	3.9%	4,976	0.2%
Brazil	1,536,200	3.7%	126,319	4.9%
United Arab Emirates	1,400,000	3.4%	26,096	1.0%
Norway	1,093,000	2.6%	94,883	3.6%
Bahrain	860,000	2.1%	8,558	0.3%
Iceland	813,000	2.0%	468,363	18.0%
South Africa	807,000	2.0%	18,824	0.7%
Mozambique	557,000	1.3%	740,051	28.5%
New Zealand	344,000	0.8%	32,491	1.2%
Montenegro	82,000	0.2%	64,292	2.5%
Cameroon	76,000	0.2%	44,865	1.7%
Turkey	60,000	0.1%	44,201	1.7%
Other countries[d]	5,315,512	12.9%	105,552	4.1%
Total	**41,295,381**	**100.0%**	**2,599,679**	**100.0%**

Source: WMD 2012 and UN Comtrade

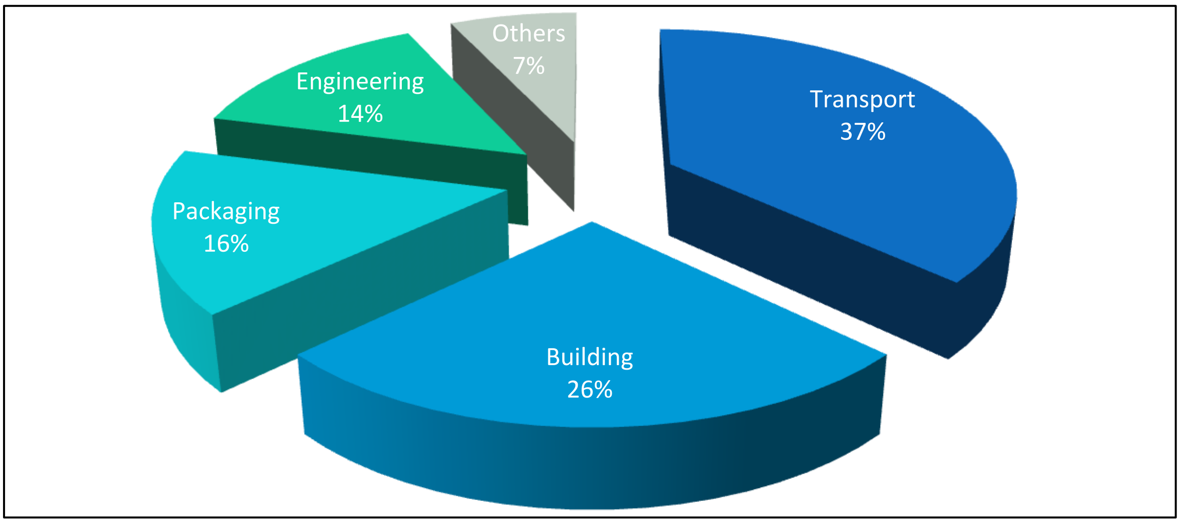
1.1.3 Economic importance

The main end-use markets for aluminium products in Europe as reported by the European Aluminium Association are shown in Figure 2. Building and transport are main end-use markets, each with around one third of the total. The remainder goes into applications such as electrical and mechanical engineering, office equipment, domestic appliances, lighting, chemistry and pharmaceuticals.[e] Through its versatile properties aluminium becomes a valuable material for different applications:[f]

- **Transport**: Because of its low density, important parts of cars, trains, ships, aircraft, bicycles, etc. consist of aluminium (low weight leads to lower fuel consumption). Aluminium also provides high ductility in combination with strength. Thus aluminium alloys can provide the strength of steel at only one third of the weight of steel.
- **Building**: Aluminium provides properties such as durability, fire resistance, low maintenance and design flexibility that are requested in the building sector for window frames and doors, cladding, roofing, etc.
- **Packaging**: Aluminium is used because of its low density and the fact that it constitutes a total protective barrier (air, bacteria, moisture, light) even when rolled to very thin layers.

a European Mineral Statistics 2007-11, British Geological Survey, 2013
b Aluminium refers to "content of recoverable valuable elements and compounds".
c UN Comtrade, http://comtrade.un.org/db/, Trade Code 7601 10, accessed 25th July 2013
d Please note that the term other countries is only used here to shorten the table, in the analysis each country enters separately out of the other countries mentioned.
e European Aluminium Association: http://www.alueurope.eu/consumption-end-use-markets-for-aluminium-products-2010/, accessed 26th August 2013
f European Aluminium Association: http://www.alueurope.eu/about-aluminium/properties/, accessed 26th August 2013

Figure 2: End-use of aluminium in Europe in 2011



Source: European Aluminium Association

1.1.4 Resource efficiency and recycling

Aluminium is recycled on a large scale. The recycling of aluminium is energetically favourable compared to primary aluminium production with energy savings of up to 95%. The recycling rate in Europe ranges from 63% (beverage cans) to more than 90% (building, automotive, transportation). Historically, more than 50% of the aluminium currently produced in the EU countries originates from recycled raw materials.[a]

For some applications aluminium can be replaced by other materials. Composites can substitute for aluminium in aircraft or automotive industries, where lightweight and high strength is needed. In the packaging sector glass, paper, plastics or steel can replace aluminium. As for its electrical conductivity, copper can replace aluminium in electrical applications. In the construction sector different composites, steel, vinyl or wood can substitute for aluminium.[b] Nevertheless, in practice it is not straightforward to substitute aluminium in all these applications, due to its unique properties (Table 2).

Table 2: Available substitutes for aluminium applications

Use	Substitutability score
Transport	0.7
Building	0.5
Packaging	0.7
Engineering	0.7

a European Aluminium Association: http://www.alueurope.eu/key-topics/recycling/, accessed 26th August 2013
b Mineral Commodity Summaries: Aluminum, US Geological Survey, 2013

1.1.5 Specific issues

Several countries have restrictions concerning trade with aluminium. According to the OECD´s inventory on export restrictions, Russia uses export taxes of 50% on aluminium waste and scrap and 3% on unwrought aluminium alloys. India, accounting for 4% of total world production, has an export tax of 25% on aluminium ores and concentrates. Besides, there are a wide range of other countries imposing trade restrictions on aluminium, but other main producers of primary aluminium are not affected.

Two aluminium containing products are present on the REACH SVHC list: zirconia aluminosilicate refractory ceramic fibres and aluminosilicate refractory ceramic.

1.2 Barytes

1.2.1 Introduction

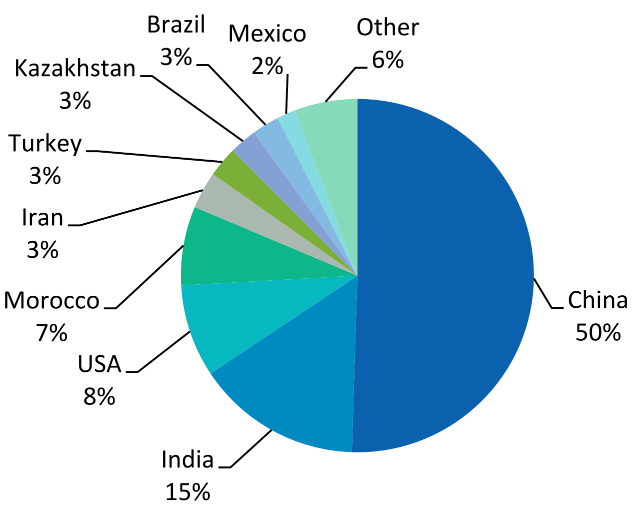
Baryte ($BaSO_4$) is the most important barium-containing mineral and is also known as barite, heavy spar or barium sulphate. It is inert, non-toxic and almost insoluble in water.[a] Baryte is used for its properties such as high mass density (between 4.3 and 4.7g/cm^3), chemical neutrality, softness and brightness.[b] It also significantly blocks x-ray and gamma-ray emissions and thus is used for radiation shielding (in nuclear plants, university research facilities or x-ray units in hospitals).[c]

1.2.2 Supply and demand statistics

Barytes deposits can be found all over the world. The most important sources in Europe are in Germany, France, Italy, the UK, Belgium, and Spain. Estimates indicate that there are 2 billion tonnes of barytes resources worldwide.[c]

Global production of barytes in 2010 amounted to around 8 million tonnes.[d] China was the largest producer of barytes in 2010, mining as much as 4 million tonnes, followed by India and the USA (Figure 3). Within the EU, barytes is produced in Germany (47% of EU production), the UK (28%), Slovakia (18%), Spain (4%), and Italy (3%) amounting to approximately 119.000 tonnes in 2010.[d] Imports to the EU are mainly from China (59%) and Morocco (34%) (Table 3).

Figure 3: Worldwide production of barytes in 2010.[d]



Source: World Mining Data 2012

Table 3: World production and imports to EU of baryte, 2010

	Production (tonnes)[e]		Imports to EU (tonnes)[f]	
China	4,000,000	50.5%	412,449	59.2%
India	1,200,000	15.2%	394	0.1%
USA	670,000	8.5%	3,101	0.4%
Morocco	572,400	7.2%	234,234	33.6%

[a] Ullmann's Encyclopedia of Industrial Chemistry: Barium and Barium Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2007
[b] European Mineral Statistics 2007-11, British Geological Survey, 2013
[c] Mineral Commodity Summaries: Barite, US Geological Survey, 2013
[d] World Mining Data 2012, C. Reichl et al., 2012
[e] World Mining Data 2012, C. Reichl et al., 2012
[f] UN Comtrade, http://comtrade.un.org/db/, accessed 25th July 2013, Trade Codes 251110 (Barytes (BaSO4) - Natural barium sulphate (barytes)) and 251120 (Barytes - Natural barium carbonate (witherite))

Iran	269,134	3.4%	-	-
Turkey	220,000	2.8%	30,617	4.4%
Kazakhstan	200,000	2.5%	-	-
Brazil	198,161	2.5%	-	-
Mexico	134,493	1.7%	0	0.0%
Russian Federation	60,000	0.8%	95	0.0%
Pakistan	55,000	0.7%	24	0.0%
Thailand	3,865	0.0%	140	0.0%
Norway	-	-	11,134	1.6%
Tunisia	-	-	1,821	0.3%
Other countries	337,682	4.3	2,831	0.4%
Total	**7,920,735**	**100.0%**	**696,841**	**100.0%**

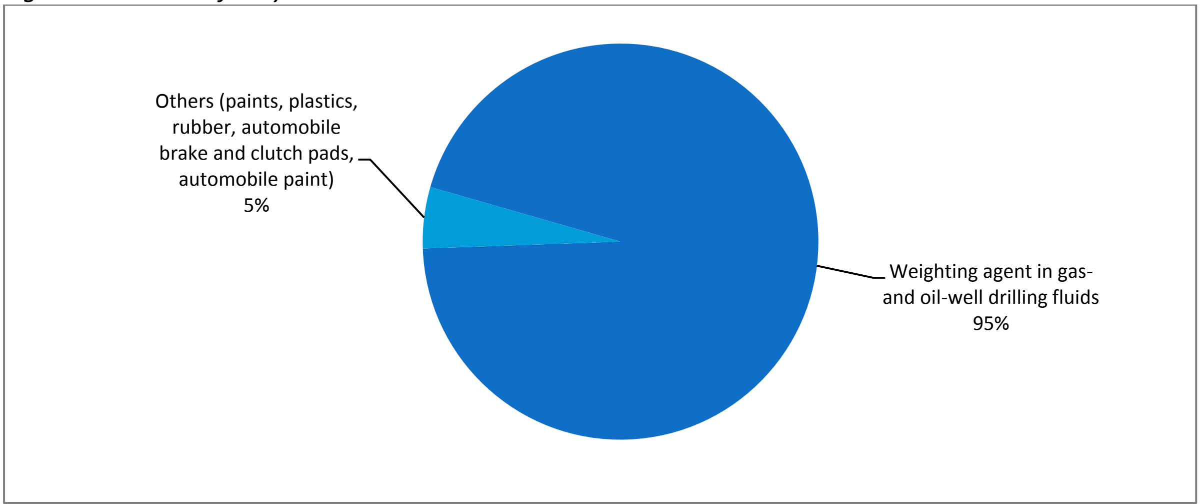
Sources: World Mining Data 2012, UN Comtrade

USGS states the demand for barytes to be strong with the worldwide oil and gas drilling market growing. China and India hold a very strong position in the barytes supply. While prices rose significantly in recent years there has been a major effort to develop new barytes exploration sites. Though China and India also in the future will dominate the market, new mining projects in different countries all over the world (Kazakhstan, Liberia, Mexico, and Zimbabwe) are in progress.[a]

1.2.3 Economic importance

End uses for the USA in 2012 are shown in Figure 4, (worldwide or EU data is not available for barytes end-uses).

Figure 4: End-use of barytes in the USA in 2012



Source: US Geological Survey MCS 2013

The main end-use markets for barytes (worldwide) are as follows:

- **Drilling muds:** The high mass density and inert nature is used in the oil and gas industry to increase the density of drilling muds. According to the Barytes Association, approximately 80% of barytes consumption worldwide is used for this purpose.[b]
- **Automotive:** Barytes are used as weighting agent in paints and in rubber and plastic products, and for sound-deadening applications in the automotive sector and other industries.
- **Medical applications:** High purity barytes can be used as a medium opaque for X-rays in medical examinations (barium meal).

[a] Mineral Commodity Summaries: Barite, US Geological Survey, 2013

[b] The Barytes Association (n.d.). http://www.barytes.org/uses.html [Accessed December 2013]

- **Ceramics, rubber, glass:** Barytes is used as filling material in many industry branches, for example in the manufacturing of ceramic glazes, rubbers and glass.

1.2.4 Resource efficiency and recycling

Barytes is not recycled at this time. In some filler applications cheaper alternatives such as ground calcium carbonate or clays can substitute for barytes (Table 4).[a]

Table 4: Substitutability scores for barytes

Use	Substitutability score
Weighting agent in gas- and oil-well drilling fluids	1
Others (paints, plastics, rubber, automobile brake and clutch pads, automobile paint)	0.5

1.2.5 Specific issues

One barytes derived compound is present on the REACH SVHC list for authorisation: silicic acid barium salt (lead-doped).

[a] The Barytes Association (n.d.) http://www.barytes.org/benefits.html, [Accessed August 2013]

1.3 Bauxite

1.3.1 Introduction

The term bauxite describes heterogenous sedimentary rocks containing economically recoverable quantities of one or more aluminium hydroxide minerals. The principal aluminium minerals are gibbsite (γ-$Al(OH)_3$), boehmite (γ-$AlO(OH)$) and diaspore (α-$AlO(OH)$). The other major components of bauxite are iron oxide, titanium dioxide and silicon dioxide. Bauxite is named after the village Les Baux in Southern France, where it was first recognised as containing aluminium and found by the French geologist Pierre Berthier in 1821.[a]

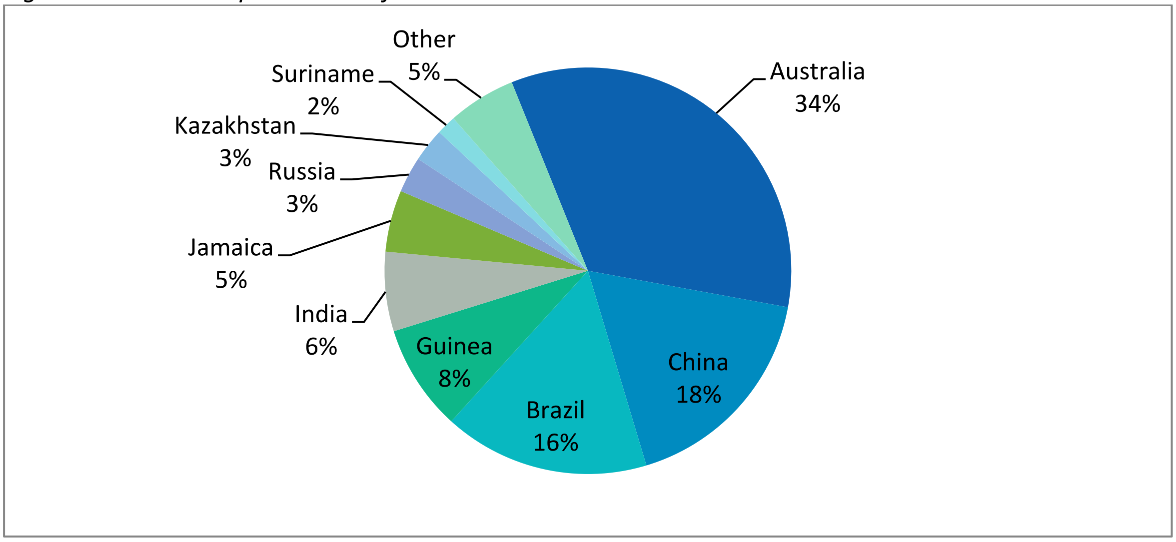
The bulk of world bauxite production is refined to alumina via the Bayer process. Again, most of the alumina produced with this refining process is smelted using the Hall-Héroult process to produce aluminium metal. For the digestion and extraction of aluminium from bauxite, gibbsite requires the mildest conditions in the Bayer process. This makes high-grade gibbsite bauxite economically favourable compared to bauxites containing more boehmite or diaspore.[b] Bauxite is the only source of aluminium that is currently mined.[c]

1.3.2 Supply and demand statistics

As Figure 5 shows, most bauxite is mined in Australia (34%) followed by China (17%) and Brazil (16%). Production in Guinea, India and Jamaica was constant or on the decline in recent years; however, in Brazil, China and Australia exploration has been increasing.[d] As shown in Table 5, total global production in 2011 amounted to nearly 206 million tonnes. EU-27 production amounted to 2,780,000 tonnes . In the EU, Greece is the main producer of bauxite, with a production of 2,320,000 tonnes in 2011, accounting for 83% of EU-27 production. Bauxite was also mined in Hungary (10% of EU-27 production) and France. Most of bauxite used in the EU is imported, however. Nearly 3.9 million tonnes were imported in 2011, mainly from Guinea (67%), followed by Brazil (14%) and Sierra Leone (10%).

According to USGS, bauxite reserves amount to approximately 28 billion tonnes, while resources are estimated to be around 55 to 75 billion tonnes. These resources are located in Africa (32%), Oceania (23%), South America and the Caribbean (21%), Asia (18%), and other regions (6%).[e]

Figure 5: Worldwide production of bauxite in 2011



Source: Raw Materials Data by Intierra

[a] Gesamtverband der Aluminiumindustrie e.V.: http://www.aluinfo.de/index.php/alu-lexikon.html?lid=20, accessed 26th August 2013
[b] Ullmann's Encyclopedia of Industrial Chemistry: Aluminum Oxide, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[c] European Mineral Statistics 2007-11, British Geological Survey, 2013
[d] World Mining Data 2013, C. Reichl et al., 2013
[e] Mineral Commodity Summaries: Bauxite, US Geological Survey, 2013

Table 5: World production and imports to EU of bauxite, 2011

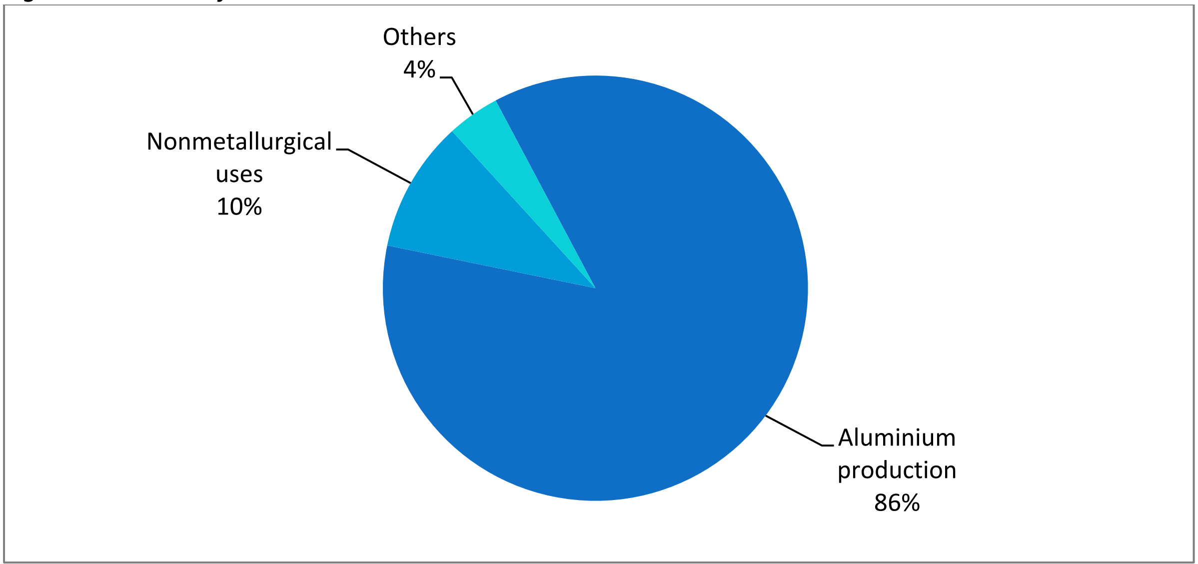
	Production (tonnes)[a]		Imports to EU (tonnes)[b]	
Australia	69,980,000	34.0%	9,458	0.2%
China	36,000,000	17.5%	84,214	2.2%
Brazil	33,700,000	16.4%	530,674	13.7%
Guinea	17,440,000	8.5%	2,586,344	66.9%
India	13,000,000	6.3%	2,998	0.1%
Jamaica	10,100,000	4.9%	2	0.0%
Russia	5,900,000	2.9%	23	0.0%
Kazakhstan	5,500,000	2.7%	1	0.0%
Suriname	3,200,000	1.6%	-	-
Venezuela	2,500,000	1.2%	-	-
Greece	2,320,000	1.1%	-	-
Guyana	1,820,000	0.9%	58,834	1.5%
Sierra Leone	1,320,000	0.6%	385,573	10.0%
Turkey	790,000	0.4%	23,434	0.6%
Bosnia and Herzegovina	560,000	0.3%	38,153	1.0%
Ghana	400,000	0.2%	83,314	2.2%
USA	60,000	0.0%	18,938	0.5%
Serbia	-	-	37,774	1.0%
Other Countries[c]	1,330,000	0.6%	5,053	0.1%
Total	**205,920,000**	**100.0%**	**3,864,786**	**100.0%**

[a] Raw Materials Data by Intierra
[b] UN Comtrade, http://comtrade.un.org/db/, accessed 25th July 2013, Trade Code 260600
[c] Please note that the term other countries is only used here to shorten the table, in the analysis each country enters separately out of the other countries mentioned.

1.3.3 Economic importance

Principal end uses of bauxite in the USA, and relative market shares, are shown in Figure 6. In Europe, the average bauxite consumption is usually 4.2 tonnes per tonne of aluminium.[a] A breakdown by application for the European bauxite market was not available at the time of writing.

Figure 6: End-use of bauxite in the USA in 2012



Source: US Geological Survey MCS 2013

The main end use markets for bauxite are:[b, c, d]

- **Aluminium production:** The main use of bauxite is the transformation of bauxite in aluminium oxide (alumina), most of which is, in turn, used for the production of aluminium metal.
- **Non-metallurgical alumina:** this is used after purification as alumina trihydrate (aluminium chemicals, flame retardants) and as calcined alumina.

Other uses are for Portland cements, calcium aluminate cements, steel production, abrasives, mineral fibres, proppants and refractories.

Specifications for the non-metallurgical grades of bauxite (such as abrasives, cement or refractory) are more stringent than those for bauxite used to produce alumina. This is because natural chemical impurities that exist within these ores are not chemically removed, as there is no metallurgical production, as the ores are used as direct feed for the production of their ultimate end products. European bauxite is very well positioned in this non-metallurgical bauxite market. European red bauxite, rich in iron, is the main component for the production of fused calcium aluminate cements.[b]

While metallurgical bauxite is used as feedstock for aluminium metal production and is characterised by high Fe_2O_3 and lower SiO_2 content, refractory grade bauxite requires higher SiO_2 content and only very low Fe_2O_3, and alkaline oxide (e.g. Na_2O, K_2O) contents.

[a] European Aluminium Association: http://www.alueurope.eu/about-aluminium/production-process/, accessed 26th August 2013
[b] Helenic Mining Enterprises S.A.: http://www.elmin.gr/Products/Solutions-Applications/Solutions-Applications.html, accessed 26th August 2013
[c] European Association of Mining Industries, Metal Ores & Industrial Minerals: http://www.euromines.org/mineral/Bauxite, accessed 26th August 2013
[d] Ullmann's Encyclopedia of Industrial Chemistry: Aluminum Oxide, Wiley-VCH Verlag GmbH & Co. KGaA, 2000

1.3.4 Resource efficiency and recycling

Up to 50% of refractory bauxite products are commonly recycled. Bauxite is the most important raw material used for aluminium production, although it is technically feasible to use other sources of alumina, and processes for recovering alumina from materials other than bauxite are being tested for their economic competitiveness.[a] Although more costly, there are also some other materials (silicon carbide or alumina-zirconia) that can substitute for bauxite-based abrasives. Refractory bauxite cannot be substituted, as the mineral composition creates specific properties which cannot be achieved with other raw materials (e.g. high flexibility under load at a wide range of temperature – as needed in steel ladles or cement rotary kilns). Substitutability scores for bauxite are shown in Table 6.

Table 6: Substitutability scores for bauxite

Application	Substitutability score
Aluminium production	1
Non-metallurgical uses	0.5
Others	0.5

[a] Mineral Commodity Summaries: Bauxite, US Geological Survey, 2013

1.4 Bentonite

1.4.1 Introduction

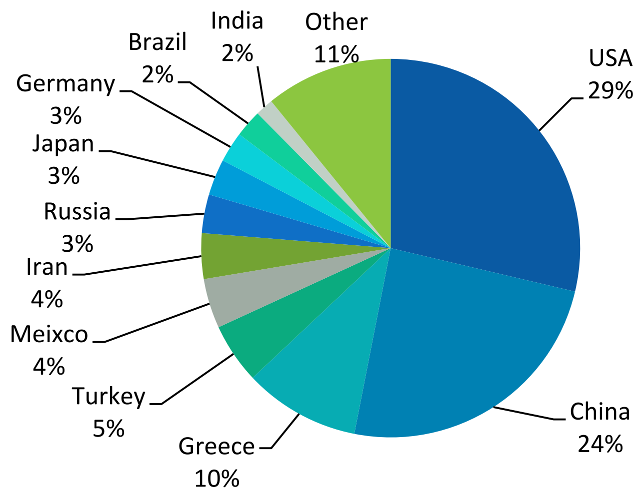
Bentonite is plastic clay generated by *in situ* devitrification of volcanic ash. It consists predominantly of smectite minerals, usually montmorillonite. Montmorillonite is ubiquitous at low concentrations in soil, in the sediment load of natural waters, and in airborne dust. Bentonite is found locally as substantial deposits which are exploited mainly by open pit mining.[a] Depending on the formation process and point of origin, bentonites may contain a variety of accessory minerals in addition to montmorillonite. These minerals may include quartz, feldspar, calcite and gypsum. The presence of these minerals can have an impact the industrial value of the deposit, reducing or increasing its value depending on the application being considered.

Bentonite and its minerals have special properties such as hydration, swelling, water absorption, viscosity, thixotropy, ability to act as a bonding agent and significant cation exchange capacity. This makes them valuable materials for a wide range of uses and applications.[b]

1.4.2 Supply and demand statistics

Reserves of bentonite are large so that the markets will continue to be served for the foreseeable future.[b] Bentonite reserves in major producing countries are large, but data on the reserves are not available. The USA is the largest producer of bentonite, with 29% share of the world production in 2010 (Figure 7). As bentonite is also being mined in many European countries, the EU sources most of its demand internally or from Turkey which accounts for 42% of the imports to EU (Table 7). EU-27 production in 2010 was 2,322,560 tonnes with Greece being the main producer (1,381,643 t, 10% of world production).

Figure 7: Global production of bentonite, 2010



Source: World mining Data 2012

Table 7: World production and imports to EU of bentonite, 2010

	Production[c]		Imports to EU[d]	
	Tonnes	**%**	**Tonnes**	**%**
USA	4,000,000	28.7%	40,301	8.0%
China	3,400,000	24.4%	26,814	5.3%
Greece	1,381,643	9.9%	-	-
Turkey	718,260	5.2%	211,982	42.2%

[a] Environmental Health Criteria 231: Bentonite, Kaolin and selected clay minerals, World Health Organization, 2005
[b] Ullmann's Encyclopedia of Industrial Chemistry: Clays, Wiley-VCH Verlag GmbH & Co. KGaA, 2006
c Reichl (2012), World Mining Data 2012
d UN Comtrade, http://comtrade.un.org/db/, [accessed July 2013], Trade code 250810

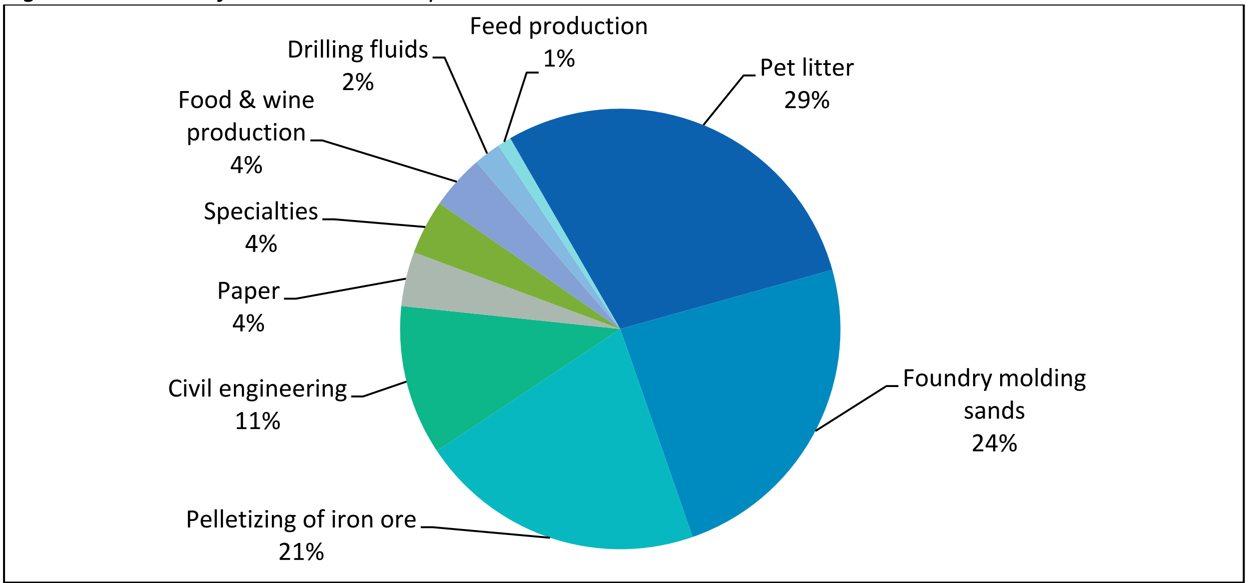
Mexico	591,000	4.2%	12,332	2.5%
Iran	542,935	3.9%	19	0.0%
Russia	460,000	3.3%	63	0.0%
Japan	432,000	3.1%	607	0.1%
Germany	362,023	2.6%	-	-
Brazil	326,428	2.3%	221	0.0%
India	214,000	1.5%	82,796	16.5%
Czech Republic	183,000	1.3%	-	-
Cyprus	162,969	1.2%	-	-
Spain	155,000	1.1%	-	-
Argentina	145,000	1.0%	126	0.0%
Morocco	110,700	0.8%	56,869	11.3%
Egypt	30,000	0.2%	9,379	1.9%
Canada			25,233	5.0%
Gibraltar			11,931	2.4%
Other countries	727,335	5.2%	24,223	4.8%
Total (rounded)	**14,000,000**	**100.0%**		**100.0%**

Sources: World Mining Data & UN Comtrade

1.4.3 Economic importance

There are many different uses for bentonite, as shown in Figure 8.

Figure 8: End-use of bentonite in Europe 2011



Source: EUBA-IMA-Europe

There are many different possible uses for bentonite. The most important are:[a,b]

- **Pet Litter:** Bentonite is used for pet litter due to its ability to absorb and bind waste by forming clumps. These clumps can easily be removed leaving the remaining product intact for further use.
- **Foundry moulding sands:** Green sand is an aggregate of different minerals and water to make moulds for metal casting. Bentonite is used as a bonding material in the preparation of this moulding sand for the production of iron, steel and non-ferrous casting.

[a] Industrial Minerals Association Europe: http://www.ima-europe.eu/sites/ima-europe.eu/files/minerals/Bentonite_An-WEB-2011.pdf, accessed 26th August 2013

[b] Ullmann's Encyclopedia of Industrial Chemistry: Clays, Wiley-VCH Verlag GmbH & Co. KGaA, 2006

- **Iron ore pelletising:** Bentonite is used as a binding agent in the production of iron ore pellets. Through this process, iron ore fines are converted into spherical pellets, suitable as feed material in furnaces for iron production.
- **Construction and civil engineering:** Bentonite in civil engineering applications is traditionally used as a thixotropic, support and lubricant agent in tunnelling, in horizontal and vertical directional drilling and pipe jacking. Due to its viscosity and plasticity, it is also used in Portland cement and mortars.
- **Paper:** Bentonite is crucial for paper making, where it is used in pitch control, i.e. absorption of wood resins that tend to obstruct the machines, and to improve the efficiency of the conversion of pulp into paper, as well as to improve the quality of the paper. It also offers useful de-inking properties for paper recycling.
- **Food and Feed:** Bentonite is used for the removal of impurities in oils where its adsorptive properties are crucial in the processing of edible oils and fats. In drinks as well as in products like sugar or honey, Bentonite is used as a clarification agent. Bentonite is also used as an additive in animal nutrition where it acts as a mycotoxins binder, a pelletising aid or an anti-caking agent.
- **Specialty applications:** Bentonite is used for specialty applications as rheological additives or emulsifiers for paints and coatings, used in polymers as a functional filler, adhesives, cosmetic, pharmaceuticals, or asphalts. It is also used as binder for animal feed or ceramics.
- **Drilling:** Another conventional use of bentonite is as a mud constituent for oil- and water- well drilling. Its role is mainly to seal the borehole walls, to remove drill cuttings and to lubricate the cutting head.

1.4.4 Resource efficiency and recycling

Direct recycling of bentonite is insignificant since, like other industrial minerals, bentonite *per se* is hard to directly recycle. However recycling could be considered to be done indirectly through the recycling or re-use of materials containing bentonite (e.g. in foundry moulding sands, pelletising of iron ore, civil engineering, paper,) which allows some of the mineral components to be recovered[a]. Foundry sands containing bentonite are invariably recycled after a metal has been cast and referred to as “system sand”. An increasing number of foundries re-use the spent sand in the production of sand for cores with organic binders: 80% of the foundry sand is currently re-used. Spent system sand from foundries can sometimes be used in construction applications. In such cases the amount of waste is minimized.

Bentonite used for iron ore pelletizing is recycled as a component of the slag generated in the blast furnace where iron pellets are used. With drilling fluids or civil engineering the materials can be recycled to some extent, but recovery of bentonite is not easy or possible because it is actually consumed (e.g. paper industry). In other applications recycling is possible but not cost effective. For example, the separation of sorbed impurities in the pet litter application is possible but such recovery is probably more costly than the virgin material. This condition might change in the future.

Some products in which bentonite participates are recyclable (e.g. paper). Hence the recycling of bentonite to be reused as bentonite is rare. In some uses, bentonite is transformed to another mineralogical phase. In this case the residual bentonite is only a component of a mixture, and such materials can sometimes be used in construction applications.

As for substitution, the characteristics and properties of bentonite cannot be matched by a single alternative mineral or material. For some applications alternative materials can replace bentonite (Table 8), for example calcium carbonate and talc for filler and extender applications, organic binders in iron ore pelletisation. However, the swelling behaviour, cation exchange capacity and low permeability achieved with bentonite cannot be matched by alternative minerals.

[a] Industrial Minerals Association: http://www.ima-europe.eu/sites/ima-europe.eu/files/publications/IMA%20Recycling%20Sheets%20FULL%20published%20on%2022.05.2013.pdf, accessed 26th August 2013

Table 8: Substitutability scores for bentonite

Use	Substitutability score
Iron ore pelletizing	0.7
Foundry sand bond	0.7
Drilling mud	0.7
Absorbents	0.3
Others	0.5

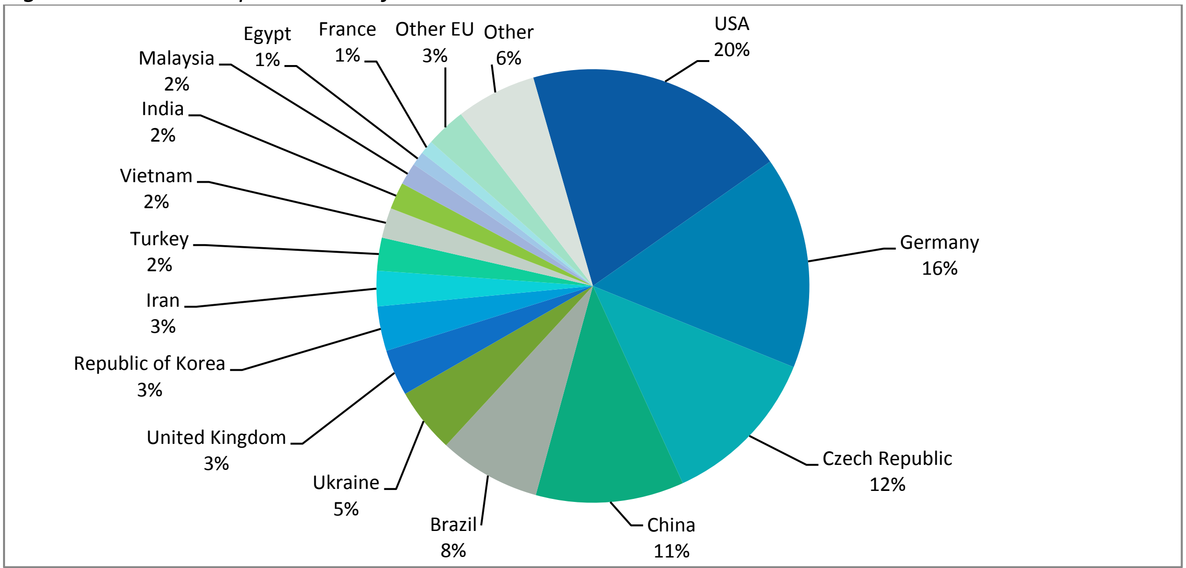
1.5 *Clay (Kaolin and kaolinitic clay)*

1.5.1 Introduction

Clays as discussed in this study, i.e. Kaolin and kaolinitic clay, are natural, earthy, fine grained raw materials mainly composed of hydrous aluminium silicates.[a] Kaolin and kaolinitic clay are the market names for the rocks containing the clay mineral kaolinite[b] which is used industrially, primarily as filler based on its optical, mechanical and chemical characteristics.[c] The main industrial applications of kaolin and kaolinitic clay are in the manufacture of paper, ceramics, rubber, plastics, paint and glass-fibres.[b] The name kaolin is derived from the Chinese word *kauling* meaning high ridge, the name of a hill near Jauchau Fu in China. In this region kaolin was mined for many centuries.[a]

1.5.2 Supply and demand statistics

Figure 9: Worldwide production of Kaolin in 2010



Source: World Mining Data 2012

Kaolin is one of the clays that can be found in nearly pure occurrence or at least be beneficiated to high purity. Major kaolin/kaolinitic clay reserves are located in the USA (Georgia), Australia, Brazil (Jari, Capim), Germany (Westerwald, Bavaria, Saxony), the UK (Cornwall, Devon), Czech Republic (Karlovy Vary and Pilszen area), France (Bretagne), Ukraine, Poland, China and India.[d] Minor kaolin deposits can be found all over the world.[a] Figure 9 shows that the USA was the largest producer of kaolin and kaolinitic clay in 2010 with an output of 5.7 million tonnes, followed by Germany (4.6 million tonnes), the Czech Republic (3.5 million tonnes) and China (3.2 million tonnes). Many countries' reserves are large, and resources of kaolin and all clays are considered to be extremely large.[e]

Table 9: World production and imports to EU of kaolin and kaolinitic clays, 2010

	Production of Kaolin (2010)[f]		Imports of kaolin and kaolinitic clay to EU (2010)[g]	
	tonnes	**%**	**tonnes**	**%**

[a] Ullmann's Encyclopedia of Industrial Chemistry: Clays, Wiley-VCH Verlag GmbH & Co. KGaA, 2006
[b] European Mineral Statistics 2007-11, British Geological Survey, 2013
[c] Kaolin Factsheet, Industrial Minerals Association, 2011
[d] The "chessboard" classification scheme of mineral deposits: Mineralogy and geology from aluminum to zirconium, Dill, H. G., Johannes-Gutenberg-University Mainz, 2009
[e] Mineral Commodity Summaries: Clays, US Geological Survey, 2013
[f] World Mining Data 2012, C. Reichl et al., 2012
[g] UN Comtrade, http://comtrade.un.org/db/, accessed 25th July 2013. Trade code 250700 (Clays (and kaolin) (IM) - Kaolin and other kaolinic clays, whether or not calcined)

USA	5,700,000	19.7%	807,905	29%
Germany	4,578,097	15.9%	-	-
Czech Republic	3,493,000	12.1%	-	-
China	3,200,000	11.1%	31,554	1%
Brazil	2,200,000	7.6%	1,270,853	45%
Ukraine	1,400,000	4.8%	645,826	23%
United Kingdom	1,000,000	3.5%	-	-
Korea, Republic of	962,275	3.3%	646	0%
Iran	761,530	2.6%	3	0%
Turkey	711,493	2.5%	20,496	1%
Viet Nam	650,000	2.3%	-	-
India	580,000	2.0%	4,799	0%
Malaysia	473,273	1.6%	5	0%
Egypt	304,200	1.1%	16,921	1%
France	300,000	1.0%	-	-
Serbia	156,672	0.5%	1,242	0%
Senegal			24	0%
Morocco			20,628	1%
Norway			1,798	-
New Zealand			1,394	-
Other Countries	2,410,268	8.3%	1,800	-
Total	**28,880,808**		**2,825,895**	

Source: World Mining Data 2012 and UN COMTRADE

EU-27 production in 2010 was over 10.5 million tonnes. 12 EU-27 States produced kaolin and kaolinitic clay in 2010 with Germany (4.6 million tonnes, 16% of world share), the Czech Republic (3.5 million tonnesand the UK (1 million tonnes) having the largest shares. 2.8 million tonnes were imported, according to trade data (Table 9).

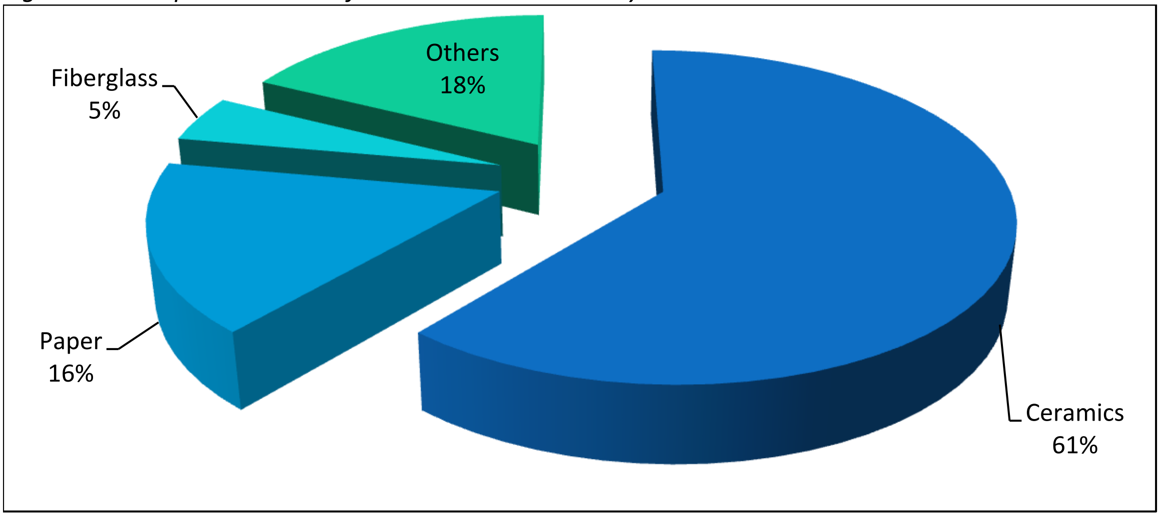
1.5.3 Economic importance

In Europe, the most important uses of kaolin and clays are as follows:[a]

- **Ceramics**: 61% of total kaolin and clay consumption is used by the ceramics industry for white wares, which consists of tableware, sanitary ware, and wall and floor tiles. It provides strength and plasticity in the shaping of these products and reduces the amount of pyroplastic deformation in the process of firing.
- **Paper**: The paper industry uses kaolin both as filler in the bulk of the paper and to coat its surface, and consumes another 16%.
- **Fibreglass**: For the production of fibre glasses 5% of total kaolin consumption is necessary.
- **Other**: Other uses are in paints, rubber, plastics, refractory industries and cosmetics/pharmaceuticals.

[a] Kaolin Factsheet, Industrial Minerals Association, 2011

Figure 10: European end-use of kaolin and kaolinitic clays in 2010



Source: Critical Raw Materials for the EU 2010

1.5.4 Resource efficiency and recycling

Recycling rates of kaolin can be assumed to be insignificant.[a] However, recycling could be considered to be done indirectly through the recycling of paper or tiles and bricks which allows some of the mineral components to be recovered.[b] Recycling of kaolin and kaolinitic material used in ceramics is not possible as the ceramic manufacturing process (firing) destroys the mineralogy and plastic properties of these materials. Some recycling of ceramics (back into ceramics) is achieved by their use as ceramic chamottes, other uses usually downgrade the broken fired ceramics to filler applications.[c]

In the paper industry, ground calcium carbonate substitutes for kaolin and has become a strong competitor of kaolin in coating paper and as filler. However, as the plate-structure of kaolin is highly desired for many paper applications, substitution by calcium carbonate may not always be feasible.[b]

Table 10: Substitutability scores for kaolin

Application	Substitutability score
Paper	0.3
Ceramics	1.0
Fiberglass	0.7

[a] Mineral Commodity Summaries: Clays, US Geological Survey, 2013
[b] Mineral Planning Factsheet: Kaolin, British Geological Survey, 2009
[c] Recyclinggutachten NRW Substitution von Primärbaurohstoffen durch Recyclingbaustoffe in Nordrhein-Westfalen,Schwarzkopf, F., Breier, S., 2009

1.6 *Copper (Cuprum)*

1.6.1 Introduction

Copper (Cu from Latin *cuprum*) is a ductile, reddish metal, used since the early days of human history. In most applications it is used for its very high thermal and electrical conductivity in combination with ductility and corrosion resistance It is used as pure metal but often also in form of alloys: brass and bronze, being the most common one. CuBe alloy plays an important role inter alia in modern jetliners and hence might be seen as strategic. It is also a very important trace element for many living organisms, including humans.[a] There are over 150 identified copper minerals, with two of highest importance: chalcopyrite and bornite. About half of world's copper production is mined from chalcopyrite ($CuFeS_2$) with a maximum copper content of 34.6% Cu.[b]

Copper does not react with water, but reacts slowly with atmospheric oxygen. This oxidation forms a thin protective layer of brown-black copper oxide that prevents the bulk of the copper from being oxidised. In the absence of air copper is also resistant to many acids such as hydrochloric acid, sulphuric acid or acetic acid.[c]

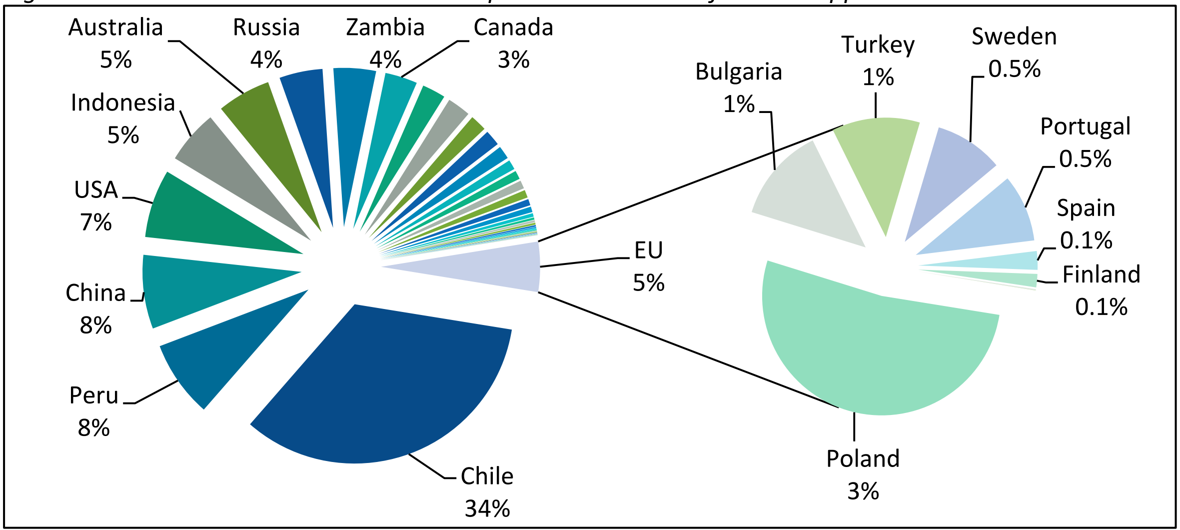
1.6.2 Supply and demand statistics

While the world's largest vast majority of copper reserves are found in the Americas (Chile, USA, Peru and Mexico), Europe has significant deposits in Poland.[d] There are three main techniques for mining copper: open pit mining, underground mining and in-situ leaching. Open pit mining is the most common form and appropriate for lower grade ores that are close to the surface (<100m). For example the open pit copper mine at Bingham Canyon in Utah, USA is one of the largest man-made excavations in the world. Underground mining is suitable for higher grade ores, e.g. those in the Lubin mine Poland. With in-situ leaching a weak sulphuric acid leach solution is pumped through lower grade ore bodies to dissolve copper. This technique is used in the Mopani mines in the Zambian Copper Belt.

Worldwide mine production of copper was 16 million tonnes in 2010, according to USGS.[e] Figures provided by World Mining Data are very similar, with total production at 16.1 million tonnes.[f] Figure 11 shows that Chile is the leader in world copper mining, with over 5.4 million tonnes in 2010 accounting for about one third of world production. With the addition of Peru (8%), China (8%) and the USA (7%), the four largest copper mining countries share more than half of the world production. In recent decades there has been strong growth in production in South America, mainly in Chile (from 16% in 1985 to 34% of world production today).[g] Asian production is of growing importance (e.g. China's production increased from less than 4% in 1994 to 8% in 2010).[d]

[a] Ullmann's Encyclopedia of Industrial Chemistry: Copper, Wiley-VCH Verlag GmbH & Co. KGaA, 2001
[b] Commodity Profiles: Copper, British Geological Survey, 2007
[c] Kupfer, Römpp Online, 2006
[d] Mineral Commodity Summaries: Copper, US Geological Survey, 2013
[e] USGS (2012) Mineral Yearbook 2010, Copper
[f] World Mining Data 2012
[g] Commodity Profiles: Copper, British Geological Survey, 2007

Figure 11: Worldwide production of copper in 2010 [a]



Source: USGS

EU-27 production of copper was 814,277 tonnes in 2010. This is dominated by Poland which accounts for over half of the copper being mined in Europe(425,400 tonnes). As European mined copper is not sufficient to meet demand, the European Union is highly dependent on refining and smelting imported concentrates as well as on recycling production scrap and end-of-life products.[g] Table 11 shows the data for copper imports to the EU in 2010. According to Comtrade data, by far the greatest amount of copper imported into the EU was from Peru and Chile; Chile being the leading producer for copper worldwide.

Table 11: World mine production and imports to EU of copper, 2010

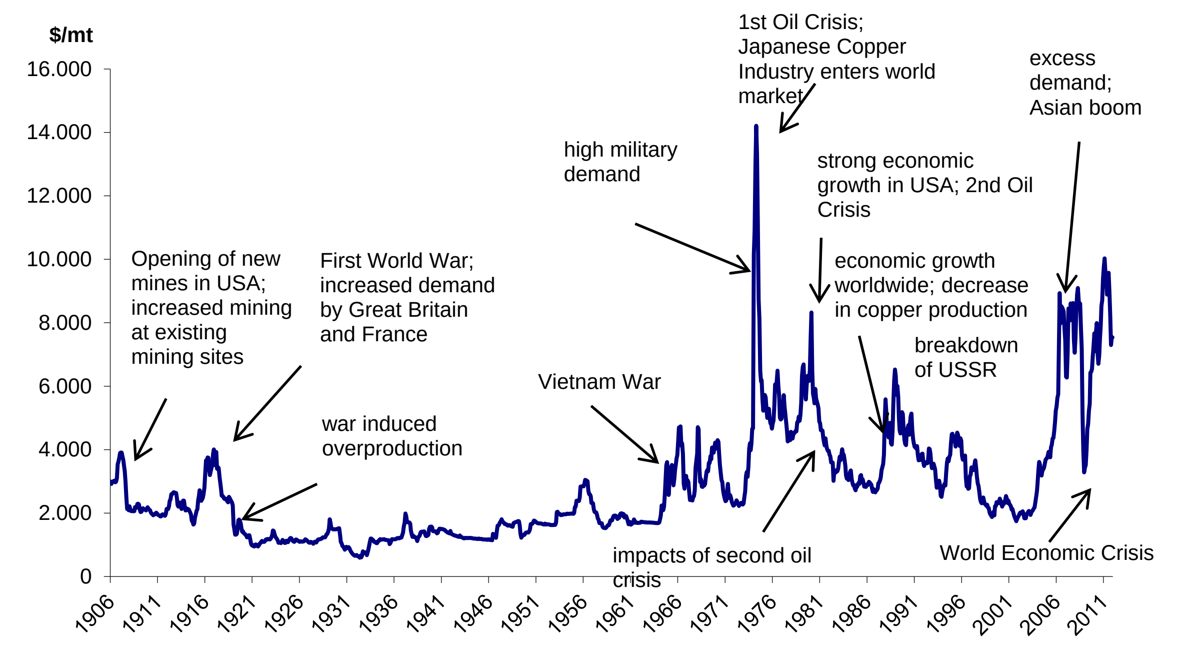
	Production, 2010		**Imports to EU, 2010**	
	Tonnes	%	Tonnes	%
Chile	5,418,900	33.9%	220,584	22.1%
Peru	1,247,184	7.8%	275,626	27.6%
China	1,200,000	7.5%	0	0.0%
USA	1,110,000	6.9%	166	0.0%
Indonesia	872,300	5.5%	109,200	10.9%
Australia	870,000	5.4%	19,572	2.0%
Russian Federation	703,000	4.4%	0	0.0%
Zambia	690,000	4.3%	1,405	0.1%
Canada	525,000	3.3%	52,549	5.3%
Poland	425,400	2.6%	-	-
Brazil	214,200	1.3%	95,175	9.5%
Argentina	140,318	0.9%	90,467	9.1%
Bulgaria	105,000	0.7%	-	-
Turkey	97,000	0.6%	44,165	4.4%
Sweden	75,977	0.5%	-	-
Portugal	74,300	0.5%	-	-
Georgia	6,100	0.0%	38,142	3.8%
Morocco	11,200	0.1%	15,412	1.5%
other countries	2,211,293	13.8%	36,640	3.7%
Total	**15,997,172**	**100%**	**999,102**	**100%**

Source USGS MYB 2010, UN Comtrade CN 260300

a Mineral Commodity Summaries: Copper, US Geological Survey, 2013

Figure 12 shows how the supply and demand situations worldwide influenced copper prices during the last century.[a] There have been several price peaks: the first one due to the First World War and the second due to the Vietnam War. However in the early 1970s, demand by military was still so high that prices went up dramatically, until first oil crisis induced a price decrease. Between 2003 and 2007, a boom in Asia, low production and low stocks led to an excess of demand over supply and a significant price increase. Since then the global recession has reduced demand and hence prices.

Figure 12: Development of real copper prices (Prices are deflated, 2011 = 100)



Source: DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen (Causes of price peaks, collapses and trends of mineral raw materials), Hamburg Institute of International Economics (HWWI) in contract for Deutsche Rohstoffagentur (DERA). April 2013, Dera, HWWI (2013), translated to English by Fraunhofer ISI

1.6.3 Economic importance

Due to its unique properties, copper is crucial for many applications (Figure 13).

Copper is the best electrical conductor after silver and is used in the production of energy-efficient power circuits. As it is also corrosion resistant, ductile and malleable, its main application is in all types of wiring; from electric energy supply from the power plant to the wall socket, through motor windings for electrical motors, to connectors in computers.

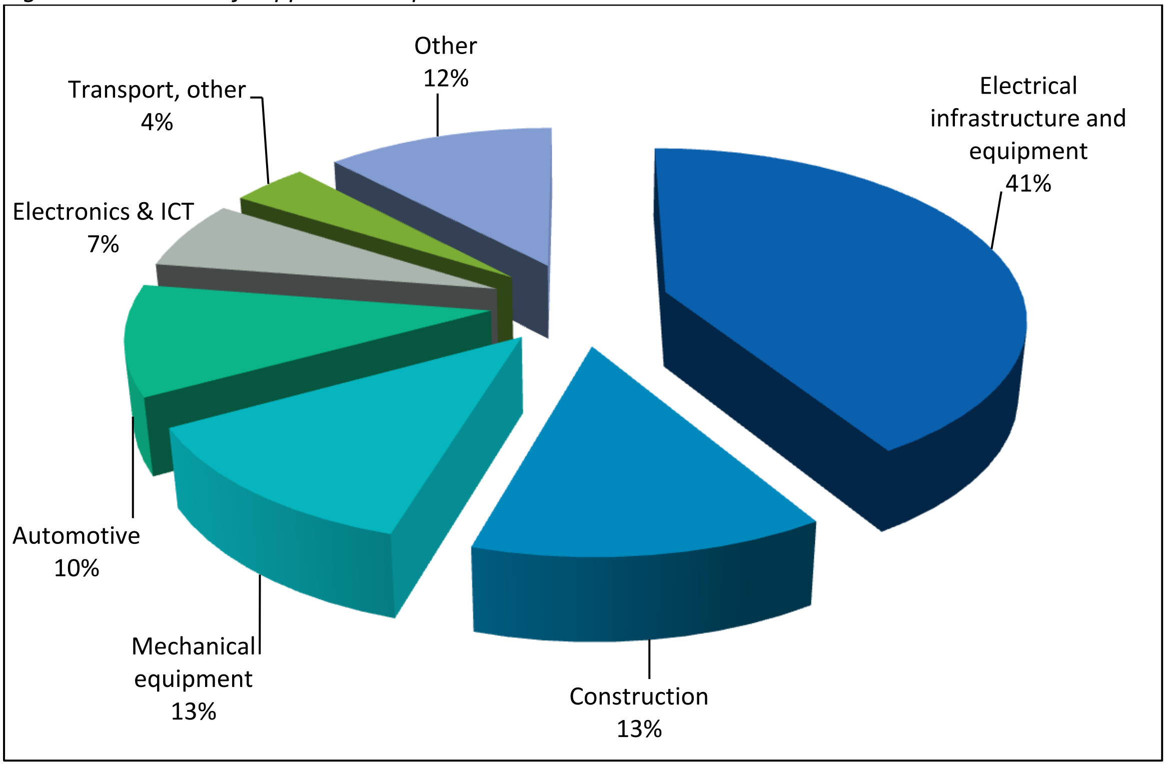
Copper is used in many forms in buildings including as wiring, pipes and fittings, electrical outlets, switches and locks. It is corrosion resistant, antibacterial and impermeable and thus has been used in the production of water pipes for at least 4,500 years.[b] Copper roofing is another common application where it is used for its functionality and architectural characteristics.[c]

Copper and its alloys, mainly brass and bronze, are important raw materials for many kinds of mechanical parts such as sleeve bearings and other forged parts.[d] In the automotive and transport sector, copper is an essential metal; there is an average 25kg copper in every car. Aside from its use in electrical parts, copper is used in heat exchangers and radiators due to its high thermal conductivity. The development of

[a] DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen. April 2013.
[b] European Copper Institute: http://eurocopper.org/kupfer/sanitar-und-heizung.html, accessed on 27th August 2013
[c] European Copper Institute: http://eurocopper.org/kupfer/kupfer-in-design-und-in-architektur.html, accessed on 27th August 2013
[d] Copper Development Association Inc.: http://www.copper.org/applications/rodbar/homepage.html, accessed on 27th August 2013

modern hybrid cars – in which an electrical motor supports the combustion engine - leads to an even higher copper consumption in cars.[a]

Figure 13: End-use of copper in Europe in 2011



Source: International Copper Association

According to Angerer *et al.* copper demand will grow in the coming decades.[b] The demand for electrical motors (in industrial applications and electrical vehicles) will lead to additional consumption of copper.

1.6.4 Resource efficiency and recycling

Most copper is used in its metallic form or in copper alloys. Nearly all copper products can be recycled over and over again without loss in product properties.[c] Most of the recycled copper originates from new or old scrap. Depending on its impurity content the scrap must be conditioned and is then used for smelting and casting new products.[d] The average global end-of-life recycling rate of copper from 2000 to 2010 is given at 45%.[e]

The unique properties of copper (especially regarding thermal and electrical conductivity) make it difficult to substitute, unless other materials show their ability to provide similar or improved functionality (e.g. substitution of copper by wireless transmission for voice or data). For the main applications possible substitutes are as follows:[f,g]

- in electrical applications, aluminium can replace copper wiring, though it is prone to conduction loss through corrosion
- in telecommunications, cables made from optical fibres or wireless technologies can substitute for copper wire

[a] European Copper Institute: http://eurocopper.org/kupfer/kupfer-im-verkehrswesen.html, accessed on 27th August 2013
[b] Rohstoffe für Zukunftstechnologien, Angerer, G. et al., Fraunhofer-IRB-Verlag, 2009
[c] Deutsches Kupferinstitut: http://www.kupferinstitut.de/front_frame/frameset.php3?client=1&parent=14&idcat=14&lang=1&sub=yes, accessed on 27th August 2013
[d] Ullmann's Encyclopedia of Industrial Chemistry: Copper, Wiley-VCH Verlag GmbH & Co. KGaA, 2001
[e] Dynamic Analysis of Global Copper Flows. Global Stocks, Postconsumer Material Flows, Recycling Indicators, and Uncertainty Evaluation, Glöser, S. et al., Fraunhofer Institute for Systems and Innovation Research ISI, 2013
[f] Commodity Profiles: Copper, British Geological Survey, 2007
[g] Mineral Commodity Summaries: Copper, US Geological Survey, 2013

- for pipes and plumbing fixtures, plastics can replace copper
- for heat exchangers, titanium, stainless steel, aluminium or plastics can substitute for copper, depending on the requirements of the application (temperature, aggressive fluids, etc.).

Table 12: Substitutability scores for copper

Application	Substitutability score
Mechanical equipment	0.7
Electronics & ICT	0.7
Electrical infrastructure and equipment	0.7
Construction	0.3

1.6.5 Specific issues

Several countries apply tariff and non-tariff barriers to the export of copper. According to the OECD´s inventory on export restrictions, China uses a value added tax (VAT) rebate reduction on copper wire and Indonesia has a licensing agreement on copper waste and scrap. Russia uses different export taxes of 10% (copper mattes, cement copper and copper base alloys) and 50% (copper waste and scrap). An export tax of 15% on copper ores and concentrates, mattes, cement copper, waste and scrap is due from Zambia. There is also a wide range of other countries imposing trade restrictions on copper.

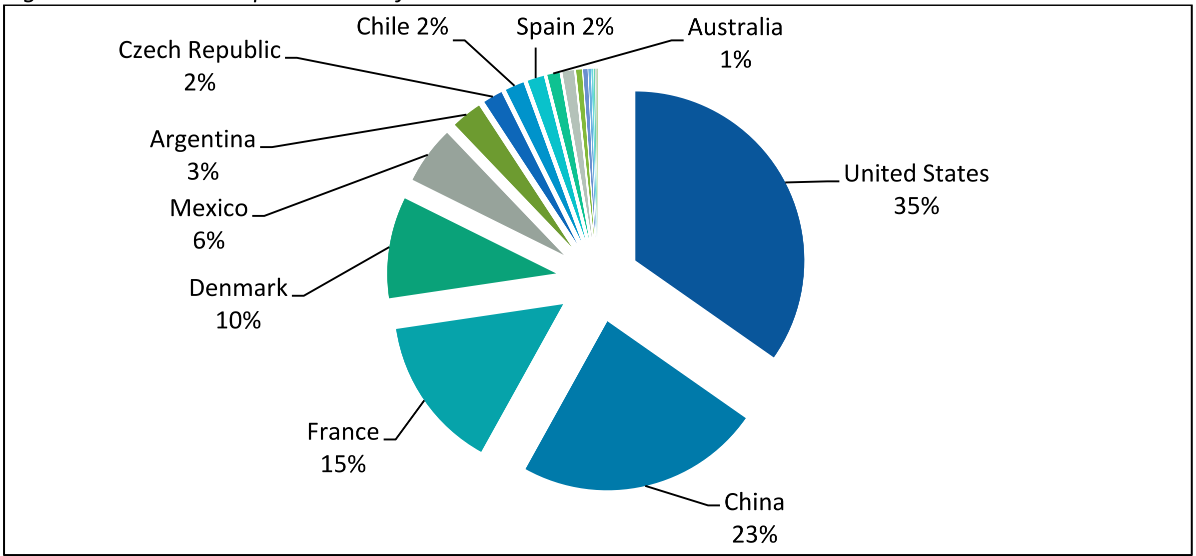
1.7 Diatomite

1.7.1 Introduction

Diatomite is a powdery, siliceous, sedimentary mineral. Its deposits are formed from the accumulated amorphous silica cell walls of dead diatoms in oceans or fresh water. It is of very low density, extremely porous and chemically inert.[a] The exact characteristics of these properties are determined by the diatom forms in the diatomite. There are at least 15,000-20,000 different forms of diatoms known. Further distinction in quality and possible applications derive from the impurities in the raw material such as clay minerals, iron content, or fine-grained carbonates. With its outstanding filtration properties, and low thermal and acoustic conductivity, it is a very versatile raw material.[b] Different applications of diatomite are: filter aids, absorbants for industrial spills, as functional additive in a variety of products from paints to dry chemicals, or as light additive in cement or other compounds.[c]

1.7.2 Supply and demand statistics

Figure 14: Worldwide production of diatomite in 2010



Source: World Mining Data 2012

EU-27 production of diatomite in 2010 was 475,175 tonnes with France being the main producer. Figure 14 shows that in 2010 the USA was the largest producer of diatomite with an output of almost 600,000 tonnes, followed by China (400,000 tonnes), France (250,000 tonnes), and Denmark (166,000 tonnes). Diatomite deposits are located worldwide. The largest deposits in the world however are found in the USA, followed by Romania, the Commonwealth of Independent State (CIS), and France.[b] Because every diatomite deposit has a different composition (different diatom species and different chemical fingerprints) which determines its potential market applications and potential economic value, broad summaries of reserves, production and shipments are not very illuminating. For example, the diatomite deposits from Denmark produce high quality absorbents but cannot be used for filter aids. Other diatomite deposits in the USA or China produce excellent filters but are not suitable for granular absorbents. It is generally true, however, that for every application world resources of crude diatomite are sufficient for the foreseeable future.

[a] Diatomite, Antonides L. E., US Geological Survey, 1997
[b] Ullmann's Encyclopedia of Industrial Chemistry: Silica, Wiley-VCH Verlag GmbH & Co. KGaA, 2008
[c] Diatomit, Römpp Online, 2007

Table 13: World production and imports to EU of diatomite, 2010

	Production (2010)[a]		Imports to EU (2010)[b]	
	Tonnes	**%**	**Tonnes**	**%**
USA	595,000	34%	23,953	56.0%
China	400,000	23%	751	1.8%
France	250,000	15%	-	-
Denmark	166,000	9.7%	-	-
Mexico	94,609	5.5%	13,645	31.9%
Argentina	50,000	2.9%	4	0.0%
Czech Republic	32,000	1.9%	-	-
Chile	30,925	1.8%	2	0.0%
Spain	27,175	1.6%	-	-
Australia	20,000	1.2%	27	0.1%
Turkey	NA	NA	1,373	3.2%
Armenia	130	0.0%	797	1.9%
India	NA	NA	560	1.3%
Peru	18,866	1.1%	509	1.2%
Cuba	NA	NA	340	0.8%
Switzerland	NA	NA	257	0.6%
Israel	NA	NA	61	0.1%
other countries	29,031	1.7%	461	1.1%
Total	**1,713,736**	**100%**	**42,739**	**100%**

Economic use of diatomite is determined by distance to market and the related transport costs.[c] Table 13 shows the data for diatomite imports to the EU in 2010. According to Comtrade data, by far the largest amount of diatomite imported into the EU was from the USA, and the USA, China and France are the leading producers for diatomite worldwide.

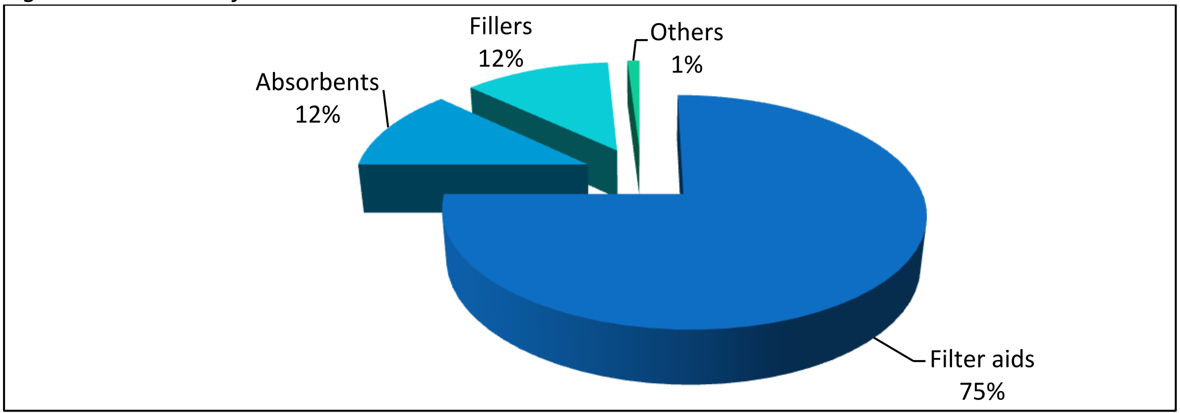
1.7.3 Economic importance

Diatomite has a wide range of applications; these are shown in Figure 15. Data for the USA are provided as EU and worldwide data was not available at the time of writing. The most important are:[d]

- **Filter aids**: With its high porosity in combination with low density and inertness, diatomite is an excellent filtration medium. Diatomite provides the ability to remove microscopically small suspended solids from liquids to process clear filtrates at high flow rates. It is commonly used in the filtration of beverages (beer, wine or juice), wastewater or paints.
- **Absorbants**: With their high capacity for liquids, diatomites are used in gas purification processes as well as in the production of pet litter. Calcined diatomite powder is also used in the production of explosives or seed coating.[e] Furthermore diatomite is used in the clean-up of spills in different industries.[f]
- **Fillers/carriers**: Diatomite is used as a filler in rubber or plastic. High quality dust white grade is also used as delustering agent in paints and to adjust their viscosity.
- Some minor amounts of diatomite are used as powder in polishes, toothpastes, and silver polishes. It is also used as packing material for hazardous liquids.

[a] World Mining Data 2012, C. Reichl et al., 2012
[b] UN Comtrade, http://comtrade.un.org/db/, accessed 25th July 2013
[c] Mineral Commodity Summaries: Diatomite, US Geological Survey, 2013
[d] Ullmann's Encyclopedia of Industrial Chemistry: Silica, Wiley-VCH Verlag GmbH & Co. KGaA, 2008
[e] Diatomite, Inglethorpe, S. D. J., British Geological Survey, 1993
[f] International Diatomite Producers Association: http://www.diatomite.org/Absorb, accessed 27 August 2013

Figure 15: End-use of diatomite in the USA in 2012



Source: US Geological Survey MCS 2013

1.7.4 Resource efficiency and recycling

Due to the complex morphology of the diatom skeletons it is very difficult to regenerate diatomite filter aids once they have been employed for filtration. Nevertheless, used filter aids are re-used for different purposes. Mainly it is used in agricultural industries, e.g. as fertiliser or animal feed. It can also be used in the construction industry (e.g. in the cement industry or the asphalt industry).[a]

Although diatomite has unique properties it can be substituted in nearly all applications. Possible substitutes for the main applications are:[b]

- **Filtration**: Expanded perlite and silica sands, as well as synthetic filters (ceramic, polymeric or carbon membrane) compete with diatomite as a filter aid. In the beverage industry, cellulose or potato starch can also replace diatomaceous earth; and there are other methods to filter beer such as mechanical centrifuging.[a]
- **Filler applications**: Clay, ground limestone, ground mica, perlite or talc can replace diatomite in some filler applications.

Table 14: Substitutability scores for diatomite

Application	Substitutability score
Absorbents (chemicals)	0.5
Fillers (construction)	0.3
Filter aids (beverages)	0.5

[a] Management Of Spent Diatomaceous Earth From The Brewing Industry: A Literature Review, Johnson, M., The University of Western Australia, 1997
[b] Mineral Commodity Summaries: Diatomite, US Geological Survey, 2013

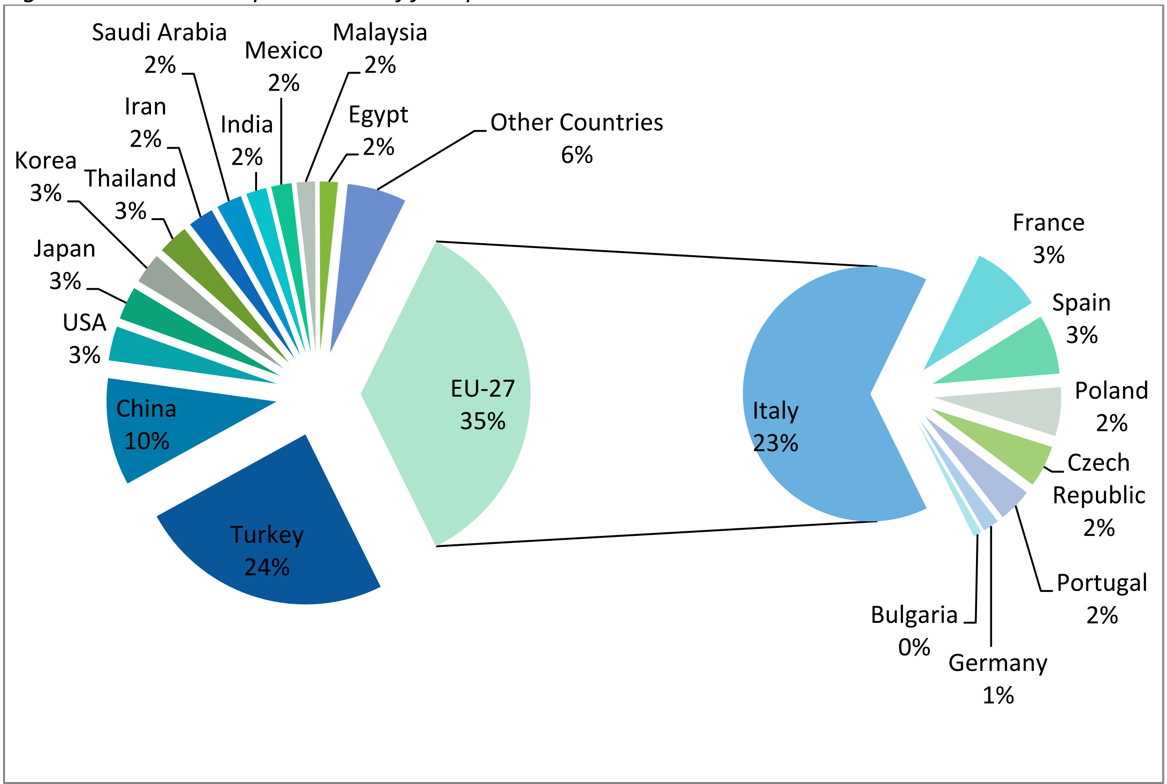
1.8 *Feldspar*

1.8.1 Introduction

The term feldspar traces back to 1785, when it was composed from the German words Feld *(field)* and Spath *(spar)* – a non-metallic mineral.[a] In this sense, feldspar describes a group of minerals which are by far the most common in the Earth's crust, forming about 60% of terrestrial rocks. However, not all available feldspar is suitable for industrial use. European resources include potassium feldspar as well as sodium feldspar and mixed feldspars. In industrial uses feldspar is primarily used for its high alumina and alkali content. Feldspar surrounds us in our daily life in the form of drinking glasses, glass for protection, glass wool for insulation, floor tiles, shower basins and tableware.[b] Feldspar is used as a fluxing agent because of its contributions to hardness, durability and resistance to corrosion.[c]

1.8.2 Supply and demand statistics

Figure 16: Worldwide production of feldspar in 2010.



Source: Mineral Commodity Summaries: Feldspar, US Geological Survey, 2012

Due to a high number of deposits and feldspar producing countries, Europe is relatively self-sufficient in the supply of feldspar. EU-27 production accounts for 35% of total world production with Italy being the main producer (Figure 16). Although worldwide production of feldspar increased significantly from 6.25 million tonnes in 1994 to 21.2 million tonnes in 2011[d], actual and potential resources of feldspar are likely to be more than adequate to meet anticipated world demand in the future.
Table 15 shows the data for feldspar imports to the EU in 2010 as reported by Comtrade data.

Table 15: World production and imports to EU of feldspar, 2010

	Production	Imports to EU

[a] Online Etymology Dictionary: Feldspar, http://www.etymonline.com, accessed on 22th August 2013
[b] Factsheet feldspar, IMA Europe, 2011
[c] European Mineral Statistics 2007-2011, British Geological Survey, 2013
[d] Mineral Commodity Summaries: Feldspar, US Geological Survey, 2013

	(2010)		(2010)
	Tonnes	**%**	**Tonnes**
Turkey	5,000,000[a]	24.3%	17[b]
Italy	4,700,000[c]	22.8%	-
China	2,100,000	10.2%	20,988
USA	670,000	3.3%	38.6
Japan	650,000	3.2%	-
France	650,000	3.2%	-
Rep. of Korea	600,000	2.9%	-
Thailand	600,000	2.9%	100
Spain	550,000	2.7%	-
Iran	500,000	2.4%	220
Saudi Arabia	500,000	2.4%	-
Poland	450,000	2.2%	-
Mexico	399,000	1.9%	195,997
Brazil	115,000	0.6%	179
South Africa	95,000	0.5%	67
Mongolia	NA	NA	13,725
Pakistan	NA	NA	1,259
Namibia	NA	NA	100
Australia	NA	NA	96
other countries	2,998,000	14.6%	154
Total	**20,577,000**	**100.0%**	[d]

Source: production data: USGS (2012), Mineral Commodity Summaries, feldspar; trade data: UN Comtrade CN 252910

1.8.3 Economic importance

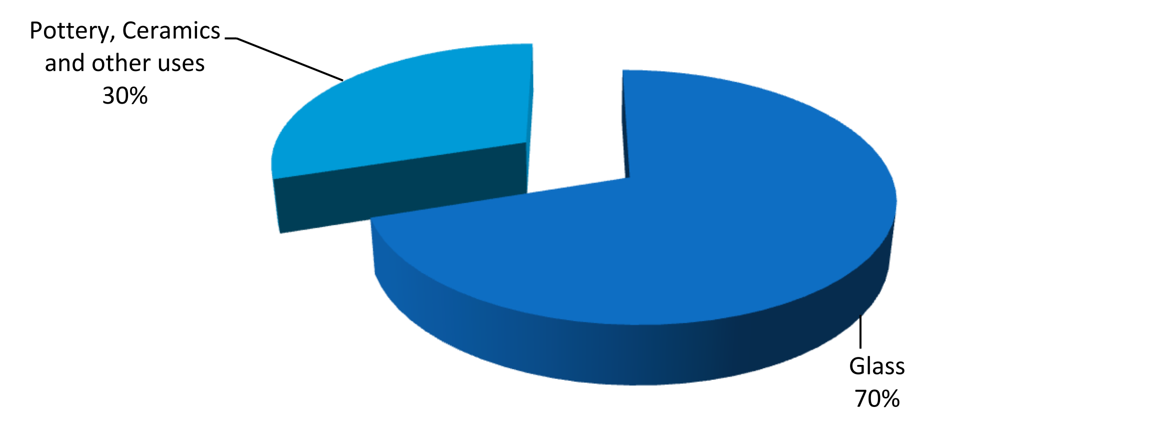
In Figure 17 the shares of different feldspar end-uses are shown; the data provided are for the USA as European and worldwide data was not available at the time of writing. The most important applications are:[e]

- **Glass**: Feldspar is an important ingredient and raw material in glass manufacture. While its alkali content acts as a fluxing agent, reducing the glass batch melting temperature and thus helping to save energy and reduce production costs, the alumina content of feldspar improves hardness, durability and resistance to chemical corrosion of the final product.
- **Ceramics & glaze**: Since feldspar melts gradually over a range of temperatures, adding feldspar to ceramics' main ingredient clay in a certain mix enables control of the important step of melting quartz and clay in the ceramic making process. Moreover feldspar supports formation of glazes as well as a glassy phase at low temperatures, and improves the strength, toughness, and durability of the ceramic body.
- Feldspar is also used as filler and extender in applications such as paints, plastics and rubber. Further end-uses are in mild abrasives, urethane, welding electrodes in the production of steel, latex foam and road aggregate.

The US Geological Survey states there is currently a gradual shift from ceramics towards glass markets, due to increasing demand for automotive glass, fibreglass for thermal insulation and solar glass, used in the production of solar cells.[a]

[a] BGS reports even a higher production for Turkey for 2010: 6,281,597 tonnes. See European Mineral Statistics 2007-11 published by British Geological Survey (BGS).
[b] This figure seems to be misleading. There are indications that Turkey exports around 3,000,000 tonnes of feldspar into the EU every year.
[c] There are indications that the feldspar production in Italy is much lower since reported official statistics include feldspathic sand. A production of 1,600,000 for Italy is estimated.
[d] No total is shown since data seems to be incomplete.
[e] Factsheet feldspar, IMA Europe, 2011

Figure 17: Estimated end-use of feldspar in the USA in 2012



Source: Mineral Commodity Summaries: Feldspar, US Geological Survey, 2013

1.8.4 Resource efficiency and recycling

Recycling rates of feldspar can be assumed to be insignificant. ; However, recycling could be considered to be done indirectly through the recycling of glass and ceramic which allows some of the mineral components to be recovered.[b] As an example, glass can be recycled by nearly 100% without any loss in purity and quality, reducing feldspar consumption up to 70% in glass manufacturing. Moreover, recycling of glass saves energy, reduces emissions and extends the life of plant and equipment. But to achieve optimal recycling, it is important to separate glass containers from other kinds of glass such as windows, ovenware, Pyrex or crystal and to separate different colours.[c] In 2008 the average glass recycling rate in the EU exceeded 60%, reaching over 70% in 2011 following efforts made in all EU Member States.[d]

The possible substitutes for feldspar depend on the specifications required for its end-uses (e.g. the low content in some accessory minerals such as Fe_2O_3 or TiO_2 is essential for the manufacturing of glass). The major alternative material in the USA is nepheline syenite. Feldspar can also be replaced by clays, electric furnace slag, feldspar-silica mixtures, pyrophyllite, spodumene or talc.[a]

Table 16: Substitutability scores for feldspar

Application	Substitutability score
Ceramics, pottery and other uses	0.3
Glass	0.7

[a] Mineral Commodity Summaries: Feldspar, US Geological Survey, 2013
[b] Recycling of industrial minerals (http://www.ima-europe.eu/sites/ima-europe.eu/files/publications/IMA%20Recycling%20Sheets%20FULL%20published%20on%2024.10.2013_0.pdf)
[c] Glass Packaging Institute, http://www.gpi.org/recycling/glass-recycling-facts, accessed on 23th August 2013
[d] Press Release: More than 70% of glass bottles and jars collected for recycling in the EU, The European Container Glass Federation (FEVE), 26th March 2013

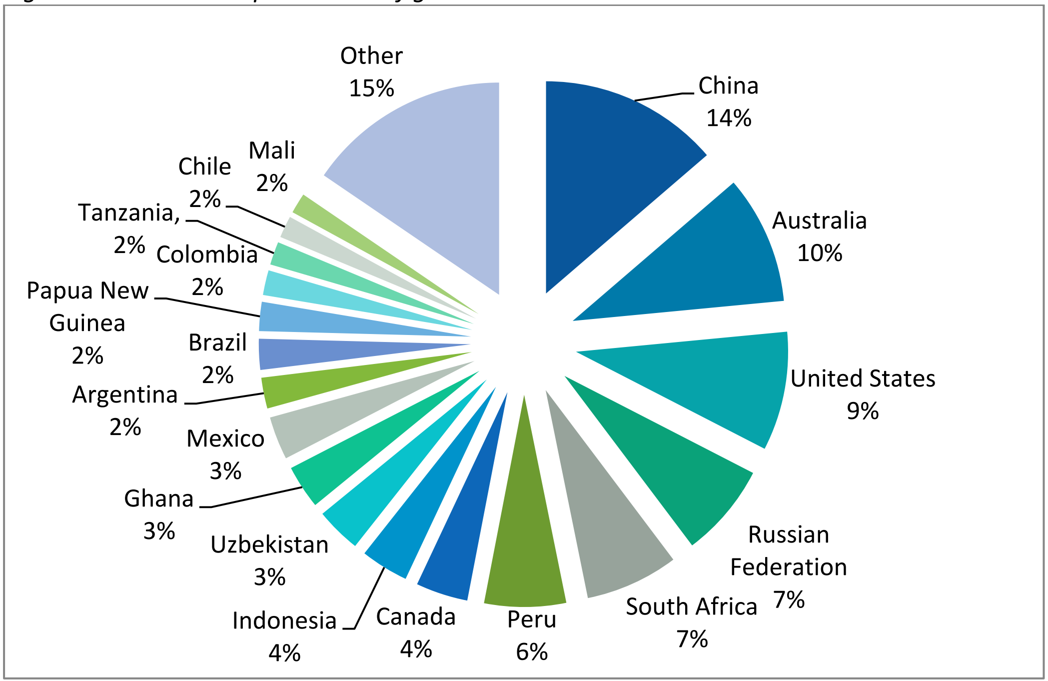
1.9 Gold (Aurum)

1.9.1 Introduction

Gold (Au, atomic number 79) was one of the first metals to be worked by man. As a noble metal, it is resistant to air, humidity and a variety of acids. ^{197}Au is the only naturally occurring isotope and it is found almost exclusively in its elementary state. With hardness on the Mohs scale of 2.5, pure gold is relatively soft compared with other metals, and it is also the most ductile of all metals. To increase hardness and other mechanical properties, gold is often alloyed with other metals; for example silver, copper, nickel and platinum among others. Due to its softness, gold can be highly polished which, together with its color and noble characteristics, makes it a treasured material for jewelry.[a] It melts at 1,064°C and has a very high density (19.32 g/cm^3).[b] Besides the naturally occurring stable isotope, gold's radioactive isotope ^{198}Au (half-life 2.7 days) plays an important role for medical radiology.[c]

1.9.2 Supply and demand statistics

Figure 18: Worldwide production of gold in 2011



Source: Raw Materials Data by Intierra 2013

Gold is one of the rarest metals in the Earth's crust. It is difficult to estimate quantities since the metal is distributed widely but very unevenly. Reported figures for the average gold concentration in the Earth's crust vary around 4-5 ppb.[d] Gold is produced in a large number of countries.

Table 17: World gold reserves (2012) and production (2011) and EU imports (2011)

	Reserves in t, 2012	Production in t, 2011	Imports to EU in t, 2011

[a] Ullmann's Encyclopedia of Industrial Chemistry: Gold, Gold Alloys and Gold Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[b] By comparison, the density of iron is 7.87 g/cm^3 (Ullmann's Encyclopedia of Industrial Chemistry: Iron, Wiley-VCH Verlag GmbH & Co. KGaA, 2011)
[c] Gold, Römpp Online, 2011
[d] Ullmann's Encyclopedia of Industrial Chemistry: Gold, Gold Alloys and Gold Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000

	(USGS 2013)		(RMD 2013)		(UN Comtrade)[a]	
	tonnes	%	tonnes	%	tonnes	%
Australia	7,400	14.2%	258	9.8%	2	1.0%
Brazil	2,600	5.0%	62	2.4%	0	0.1%
Canada	920	1.8%	105	4.0%	0	0.0%
Chile	3,900	7.5%	44	1.7%	14	6.0%
China	1,900	3.7%	361	13.7%	2	1.2%
Ghana	1,600	3.1%	88	3.3%	0	0.0%
Indonesia	3,000	5.8%	96	3.6%	0	0.0%
Mexico	1,400	2.7%	87	3.3%	1	0.5%
Papua New Guinea	1,200	2.3%	58	2.2%	3	1.3%
Peru	2,200	4.2%	164	6.2%	11	4.6%
Russia	5,000	9.6%	189	7.2%	6	2.4%
South Africa	6,000	11.5%	187	7.1%	19	8.0%
Uzbekistan	1,700	3.3%	91	3.5%	0	0.2%
Burkina Faso	NA	NA	32	1.2%	0	0.0%
Switzerland	NA	NA	0	0.0%	117	49.3%
Kazakhstan	NA	NA	37	1.4%	0	0.0%
Norway	NA	NA	0	0.0%	1	0.6%
USA	3,000	5.8%	239	9.1%	1	0.6%
Other countries	10,000	19.2%	526	20.0%	58	24.3%
Total	**52,000**	**100.0%**	**2,635**	**100.0%**	**238**	**100.0%**

Source: USGS, RMD & UN Comtrade

Gold occurs in several types of deposits, classified into primary deposits, secondary deposits (also called placers) and conglomerate deposits. The secondary deposits are deposits of gold particles where the gold was enriched by flowing water after weathering of primary source rocks. They occur all over the world, and have been the easiest available source of gold since ancient times. Recent studies imply that gold placers can be economic at a grade of 0.1 g/m3 or even lower, depending on size and recovery rates. In primary deposits the gold particles remained in the place where they originally formed (by magmatic and/or hydrothermal processes). Such deposits have a greatly varying gold content and are related to almost all types of orogenic and volcanic processes all over the world. Conglomerate deposits are deposits formed by lithification and/or hydrothermal overprint of former placer deposits, where gold is distributed as fine particles in very coarse sedimentary rocks. The largest conglomerate deposits are the Witwatersrand goldfields in South Africa, from which over 7% of current worldwide gold production is derived[a], and which have been an important source of gold for over one hundred years.

The gold reserves, i.e. the known and economically exploitable deposits (assuming current prices and technology) are estimated to be 52,000 tonnes, which is approximately 20 times the world production in 2011. The largest reserves are found in Australia (14%), South Africa (12%) and Russia (10%). However, China was the leading gold producer in 2011, with a share of 13.7% of the worldwide production, followed by Australia (9.8%), and the USA (9.1%).

There is a large number of import sources for the EU, and the source countries vary considerably from year to year. Between 2004 and 2009, the EU imported gold from more than 40 different countries. The most important source was South Africa, which supplied constantly high shares of the EU's gold imports (between 20% and 50%) in recent years. Smaller but relatively constant quantities came from Suriname (around 5%). Chile and Russia are examples of countries with extremely variable trading rates. Chile accounted for 14% of the imports to the EU in 2011. Russia, on the other hand, accounted for up to 18%

[a] UN Comtrade, http://comtrade.un.org/db/, accessed 25th July 2013 Trade codes 710812 (Gold - Gold in unwrought forms non-monetary) and 710811 (Gold - Gold powder non-monetary)

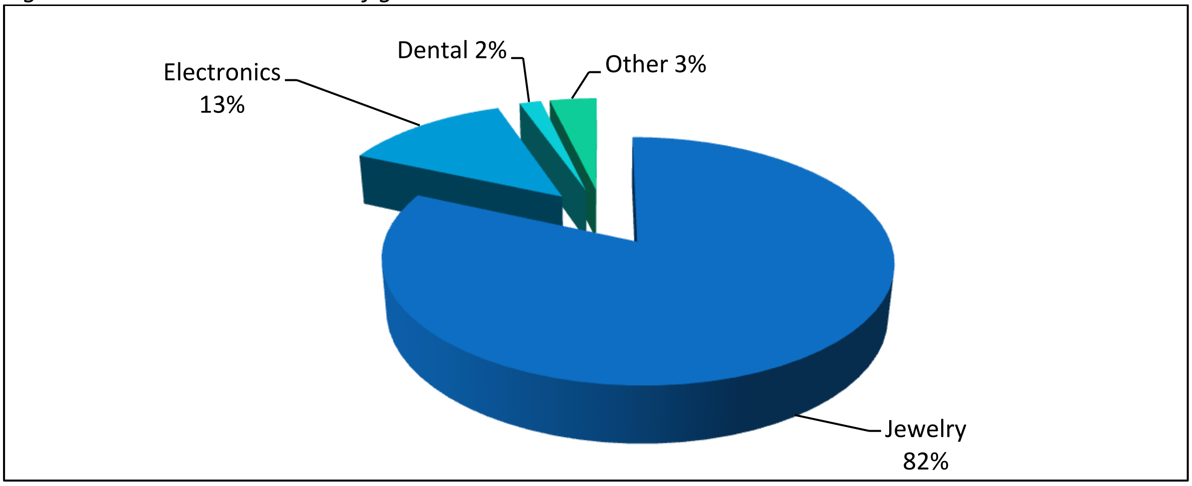
of imports in 2005, but did not export gold to the EU in 2009. Switzerland plays an important role as a reseller of gold. Although Switzerland has no primary gold production, the EU imports large quantities (e.g. 49% in 2011) from this country.

Smaller quantities are also produced within the EU. Most of the metal is produced in Finland, Sweden and Bulgaria (together accounting for more than 90% of EU production). The EU accounts for well under 1% of the world production and imports more than 90% of the gold it requires.[a]

1.9.3 Economic importance

Gold has both monetary and non-monetary uses. According to the World Gold Council, around 62% is for industrial use with the remainder being used for investment (excluding central banks).[a] The demand for gold as an investment tool increased with the rising price and the global economic instability that began in 2008.[b] In the context of this evaluation of criticality, only the industrial/manufacturing use is of interest. Thus, the relevant end-use structure of gold is as shown in Figure 19; worldwide data is shown as European data was not available at the time of writing.

Figure 19: Worldwide end-use of gold in 2012



Source: World Gold Council 2013

Relevant end-uses of gold are:[c,d,e,f]

- **Jewelry**: The majority of manufacturing gold consumption (82%) is used for jewelry. Because of its softness, gold is almost always alloyed with silver, copper or platinum group metals. Cheaper jewelry is often gilded using electrochemical processes. Gold consumption in this sector dropped in recent years due to rising prices.
- **Electronics**: this use represents 13% of gold consumption, together with electrical engineering. Its high resistance to oxidation and corrosion and its good conductivity are important properties for gold as a contact material in many electronic applications. Gold is used e.g. in diodes, transistors, integrated circuits and semi-conductor memories as well as in capacitors and resistors. Due to its high cost, gold is used in very thin layers in highly reliable components where other materials can cause problems by current-induced ion migration.
- **Electrical engineering**: High oxidation resistance, low ohmic resistance and low micro-migration of gold and gold alloys are important properties for low voltage contacts in communication and information transfer applications. Other alloys are used as resistor material in corrosive environments, in potentiometers or in thermometers.

[a] Gold Demand Trends (Second Quarter 2011), World Gold Council, 2011
[b] Mineral Commodity Summaries: Gold, US Geological Survey, 2013
[c] World Gold Council, 2013
[d] Ullmann's Encyclopedia of Industrial Chemistry: Gold, Gold Alloys and Gold Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[e] Mineral Commodity Summaries: Gold, US Geological Survey, 2013
[f] Gold, Römpp Online, 2011

- **Dental materials**: Gold alloys are used in dentistry where they are valued for their resistance to normal conditions in the mouth, their homogenous structure and their workability. Nevertheless, gold consumption in this sector is slowly declining due to the development of new ceramics and cheaper base metal alloys.
- **Coatings**: Gold coatings are used on a variety of substrates, such as base metals, glass, ceramics or plastic to prevent corrosion and gas diffusion or for decorative purposes. Moreover, gold coatings are used in sunglasses.
- **Gold leaf**: Because of its ductility, gold can be formed to extremely thin gold leaf of a thickness of 0.2 µm. Gold leaf is used for decorative purposes and for visual effects in beverages and food.

The use of gold in homogeneous and heterogeneous catalysis is currently under study but does not constitute a significant fraction of demand.

1.9.4 Resource efficiency and recycling

As gold is a valuable raw material, it is recycled from nearly all the above-mentioned products. Technically the easiest source of recycled gold is to remelt old jewelry and dental gold. Gold is also recycled from old and new electronic scrap as well as from metal coatings.[a] About one third of the current demand is covered by recycled gold (old and new scrap).[b] The largest fraction of recycled gold comes from jewelry and coins, which represent the largest use of gold and have a 90-100% end-of-life recycling rate. The end-of-life recycling rate is also high in industrial applications. All other uses have recycling rates below 20% and represent a small portion of gold use.[c]

Besides recycling, reducing the quantity used without loss of performance is an important factor for economic and sustainable use of the precious metal. In electrical and electronic applications, but also in jewelry, thinner coatings are used to reduce costs without losing the favorable properties of gold.[d]

Substituting gold in its main applications is rather difficult for different reasons. In jewelry, gold could be replaced by other precious metals or by cheaper alloys since it has no technical function. However, because it is a symbol of luxury, it is likely that a large scale replacement of gold in this sector would be difficult for consumers to accept. Substitution in electronic and electrical applications is often not possible or difficult because of its unique surface properties mentioned above. Palladium and platinum may be possible substitutes but were not considered economic in the past as the prices for these metals were higher than for gold. This has changed recently due to the large increase in gold price and may lead to substitution in the electronics sector. Silver is often not a good substitute because of ion migration leading to a reduced reliability of the device. In many smaller industrial applications gold is also indispensable. However, as a dental material, gold is increasingly being replaced by ceramics and cheaper base metal alloys.[e]

Table 18: Substitutability scores for gold

Use	Substitutability score
Electronics	1
Dental	0.3
Jewellery	0.7

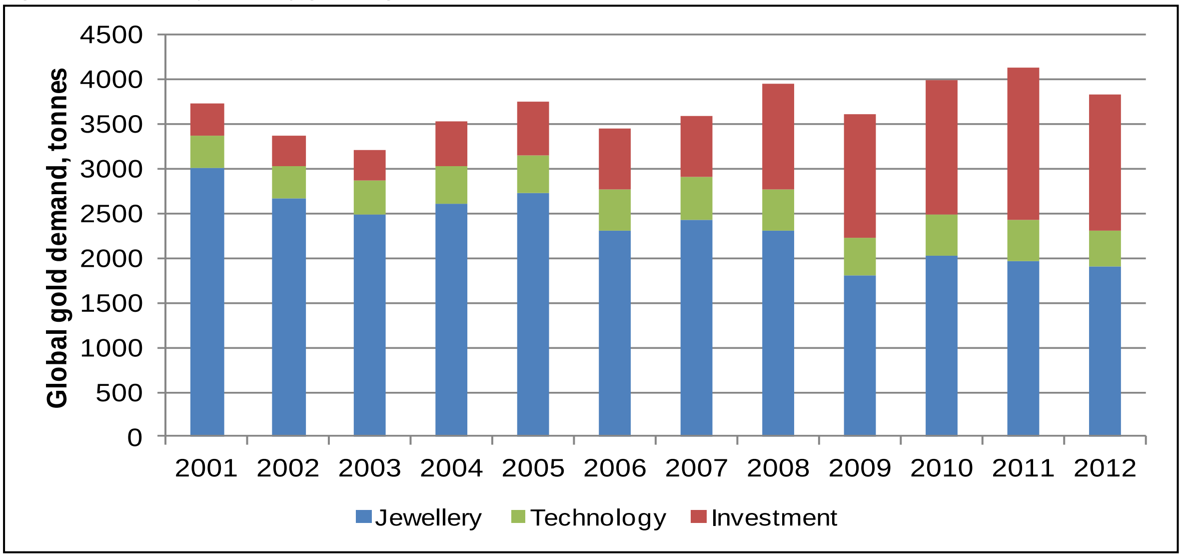
1.9.5 Specific issues

According to the OECD´s inventory on export restrictions Benin, Fiji, Indonesia, Mali, Senegal, Sierra Leone and South Africa have licensing agreements on gold trade. Export taxes are only reported for Benin and Fiji (both 3%). Further export restrictions in other countries are not reported.

[a] http://www.edelmetall-recycling.de/goldrecycling/, accessed on 23th August 2013
[b] World Gold Council, 2009
[c] Recycling Rates of Metals – A Status Report, Graedel, T. E. et al., 2001
[d] Mineral Commodity Summaries: Gold, US Geological Survey, 2013
[e] World Gold Council, 2009

The gold price has increased rapidly in recent years, from a level around 300 US$/oz at the turn of the century to an interim high of around 1,900 US$/oz in September 2011. After a price decline from October 2012 until the beginning of July 2013 the gold price stabilizes around 1300 US$/oz.[a] This price increase has reasons beyond the use of gold in manufacturing; i.e. there is a considerable influence from the use of gold as an investment tool. An increasing relative importance of gold use (on a tonnage basis) in investment is a particularly important aspect of global gold demand (Figure 20).

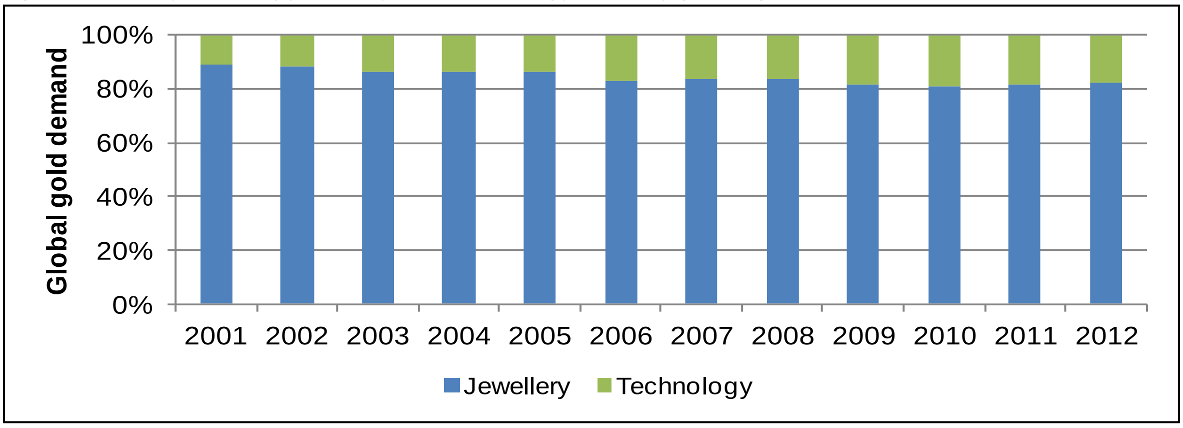
Figure 20: Development of global gold demand



Source: World Gold Council, Gold Demand Trends, Second Quarter 2013

This aspect of gold demand cannot be considered quantitatively within the criticality framework used, which measures the economic importance of a raw material based on its manufacturing use. Concerning the manufacturing use of gold, the declining demand for gold in jewelry and increasing demand for electronics have led to an overall increase of the importance of technology demand (Figure 21).

Figure 21: Comparison of jewellery and technology share of global gold demand



Source: World Gold Council, Gold Demand Trends, Second Quarter 2013

[a] The quoted price is the London PM fix. World Gold Council, http://www.gold.org/investment/statistics/prices/, accessed on 23th August 2013

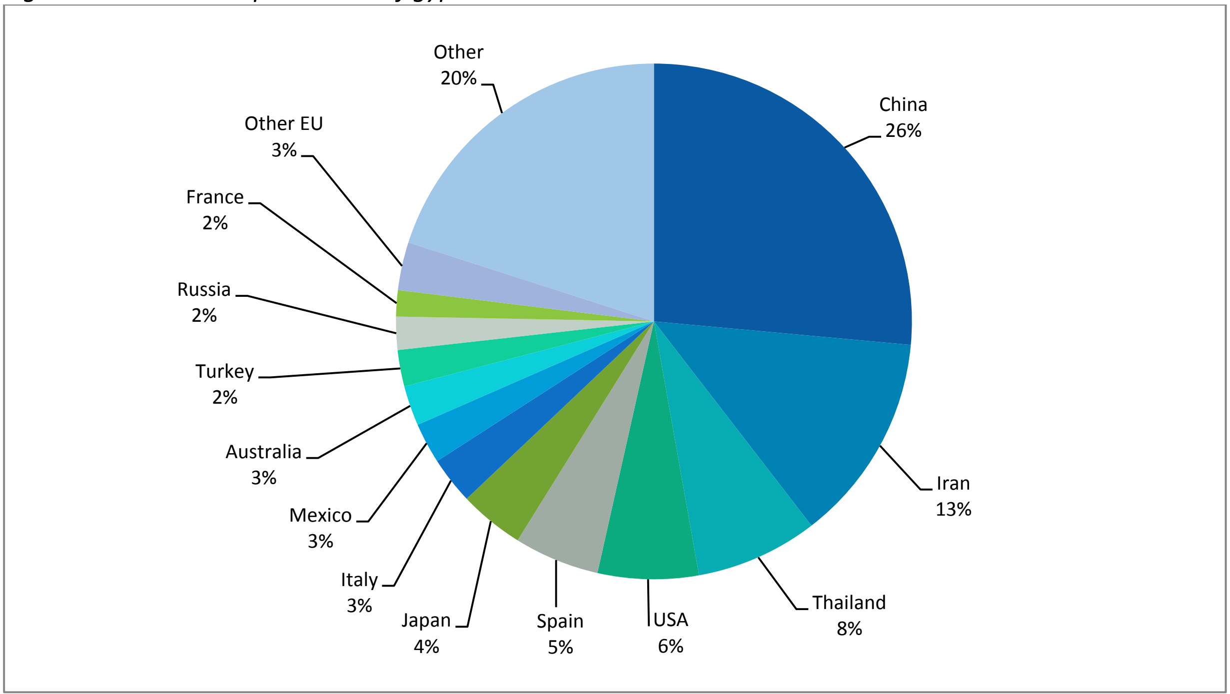
1.10 Gypsum

1.10.1 Introduction

Gypsum is a system of the mineral calcium sulphate and water molecules ($CaSO_4$-$2H_2O$) that can be transformed into semi-hydrate ($CaSO_4$-$1/2H_2O$) or anhydrite ($CaSO_4$) by dehydration (heat supply). It can be partly retransformed into gypsum by adding water (rehydration). These mechanisms are the basis for gypsum products.[a] Gypsum is a very soft mineral and defines the hardness of 2 on the Mohs scale of mineral hardness.[b] It is easy to work, and alabaster - a sort of very fine-grained white gypsum - has been used for sculpture throughout the centuries.[c] As construction material gypsum was already used by the ancient Egyptians as plaster for the Pyramid of Cheops.[d]

1.10.2 Supply and demand statistics

Figure 22: Worldwide production of gypsum in 2010



Source: US Geological Survey, MCS 2012

Deposits of mineable gypsum are found all over the world. Most of the deposits originate from Permian, Triassic and Tertiary formations. The best known deposits of primary gypsum can be found in the Paris Basin and in Mediterranean areas.[a] A total of 87 countries produced gypsum in 2010, with China having the largest share and an output of 37 million tonnes (Figure 22). Total world production of gypsum in 2010 was around 140 million tonnes, which was 15 million tonnes (ca.9%) less than in 2007. EU-27 production in 2010 was more than 24 million tonnes.[e]

Table 19 shows the data for gypsum imports to the EU in 2010. According to Comtrade data, by far the greatest amount of gypsum imported to the EU was exported by Morocco, followed by Norway and Ukraine; China and Iran are the leading producers for gypsum worldwide.

[a] Ullmann's Encyclopedia of Industrial Chemistry: Calcium Sulfate, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[b] Mohssche Härteskala, Römpp Online, 2007
[c] Alabaster, Römpp Online, 2004
[d] Gips, Römpp Online, 2009
[e] World Mining Data 2012, C. Reichl et al., 2012

Table 19: World production and imports to EU of gypsum, 2010

	Production (tonnes) in 2010[a,b]		Imports to EU (tonnes) in 2010[c]	
China	37,000,000	26.4%	664	0.3%
Iran	18,313,023	13.1%	-	-
Thailand	10,708,749	7.6%	17,802	8.5%
USA	8,840,000	6.3%	1,738	0.8%
Spain	7,480,000	5.3%	-	-
Japan	5,700,000	4.1%	20	0.0%
Italy	4,130,000	2.9%	-	-
Mexico	3,560,000	2.5%	0	0.0%
Australia	3,500,000	2.5%	0	0.0%
Turkey	3,200,000	2.3%	730	0.3%
Russian Federation	2,900,000	2.1%	51	0.0%
Canada	2,717,000	1.9%	45	0.0%
Morocco	NA	NA	93,040	44.2%
Norway	NA	NA	53,458	25.4%
Ukraine	NA	NA	33,626	16.0%
Venezuela	NA	NA	4,209	2.0%
Tunisia	NA	NA	2,153	1.0%
TFYR of Macedonia	NA	NA	1,210	0.6%
Bosnia Herzegovina	NA	NA	868	0.4%
Other countries	32,182,000	22.9%	718	0.3%
Total	**140,230,772**	**100.0%**	**210,332**	**100.0%**

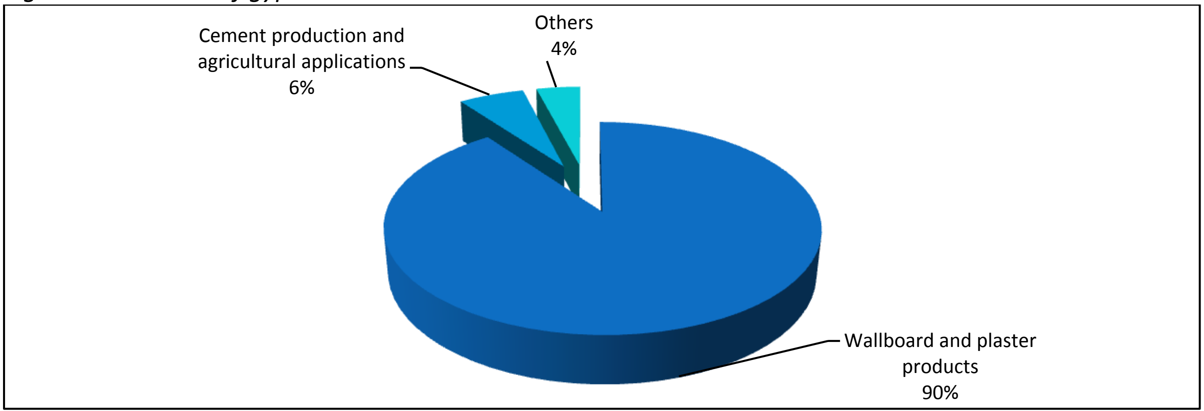
1.10.3 Economic importance

After refining the raw material, gypsum is used in different forms. Its end-use is mainly determined by the temperature in the dehydration process (burning process) but also by additives.[a] Figure 23 shows the main applications for gypsum in the USA; no EU or worldwide data were available at the time of writing. Although the shares of the end-uses may vary for other countries the most important applications are the same:

- **Wallboard and plaster products**: Gypsum is used for manufacturing wallboard and plaster products. Most quantities of gypsum are used in the building industry.[d]
- **Cement**: Gypsum is used as setting retardant in the production of cement.
- **Agriculture**: Also large quantities are used to improve properties of soils for agricultural reasons.[e]
- **Modelling forms**: Gypsum is a useful material to model forms for many substances, such as ceramics, metals, rubber and plastics. It is also used for dental applications. Although only small quantities are used in this sector, these applications are lucrative export products.[f]

[a] World Mining Data 2012, C. Reichl et al., 2012
[b] Mineral Commodity Summaries: Gypsum, US Geological Survey, 2013
[c] UN Comtrade, http://comtrade.un.org/db/, accessed 25th July 2013
[d] European Gypsum Industry: http://www.eurogypsum.org/applications, accessed 9th September 2013
[e] Gypsum Association: http://www.gypsumsustainability.org/other-uses.html, accessed 9th September 2013
[f] Gips, Römpp Online, 2009

Figure 23: End-use of gypsum in the United States in 2012



Source: US Geological Survey, MCS 2013

1.10.4 Resource efficiency and recycling

It is possible to reverse the hydration and dehydration process without property losses; closed loop recycling is therefore possible with pure gypsum, meaning that waste can be re-used in the same product again. This property is not very common for construction materials. However, only a small quantity from demolition waste is currently recycled due to contamination with other materials.[a] Recycled gypsum is primarily used for agricultural purposes but also as feedstock in the production of new wallboard.[b]

In some applications, such as stucco and plaster, cement and lime can be substitutes. Brick, glass, metal or plastics or even wood can be used for wallboard. Gypsum has no adequate substitute in cement production. Synthetic gypsum, a waste product of some industries (desulfurization of smokestack emissions), is an important substitute for mined gypsum and accounts for approximately 54% of the total domestic gypsum supply in 2012 in the USA.[b]

Table 20: Substitutability scores for gypsum

Use	Substitutability score
Cement production and agricultural applications	1
Wallboard and plaster products	0.7

[a] European Gypsum Industry, Factsheet on: What is Gypsum, 2007
[b] Mineral Commodity Summaries: Gypsum, US Geological Survey, 2013

1.11 Hafnium

1.11.1 Introduction

Hafnium (Hf, atomic number 72) is a hard, ductile metal similar to stainless steel in its appearance and chemically very similar to zirconium. In nature, it is always found with zirconium and its main commercial sources are zircon and baddeleyite; these are available as by-products from the extraction of titanium minerals from heavy-mineral sands.[a] Commercial production of hafnium is driven by demand in the nuclear industry for high purity zirconium metal alloys.[b] Major uses of hafnium are superalloys and nuclear reactor control rods.

The hafnium market is very niche, with low annual production (64 tonnes in 2012). This metal in not traded publicly and no official statistics are collected regarding its production. Data availability is therefore limited and consists mainly on industry estimates.

1.11.2 Supply and demand statistics

Hafnium is not present in nature in its elemental form. Hafnium ore minerals are rare, however two of these are known: hafnon and alvite. Hafnium is always found with zirconium and is retrieved as a by-product of its extraction. The two major sources of zirconium and hafnium are zircon and baddeleyite, in which it is normally present between 1.5-3.0% by weight, and is typically found in a zirconium to hafnium ratio of approximately 50:1. Hafnium and zirconium have similar chemical properties and for this reason are very difficult to separate. Ion-exchange, solvent-exchange and fractional crystallization are the preferred separation techniques.[c]

Zircon sand is obtained from the processing of heavy mineral sands to recover the titanium minerals rutile and ilmenite. Deposits of heavy metals sands which are commercially recoverable are found in China, Malaysia, Thailand, India, Sri Lanka, Australia, South Africa, Madagascar, and the USA. World reserves are not recorded, but can be estimated from those of zirconium. Table 21 shows the estimated world reserves. USGS estimates world resources of hafnium associated with those of zircon and baddeleyite as exceeding 1 million tonnes, which is consistent with the figures shown in Table 21.

Global production of zirconium mineral concentrates in 2011, excluding US production, was estimated to be 1.62 million tonnes; this has increased from the 2010 production of 1.25 tonnes. Major producers are Australia and South Africa.[d] Most of the production of hafnium worldwide is in France and the USA, where the production of high purity zirconium for nuclear applications is dominating (Table 22). It is believed that the Ukraine has currently stopped production and that raw material is exported to Russia for processing. Producers are known to exist in India and China however these are only for internal supply and are not exported.[e] Hafnium production is therefore highly concentrated, although within countries of low political risk.

[a] Nielsen & Wilfing (2010). Hafnium and Hafnium Compounds. Ullmann's Encyclopedia of Industrial Chemistry.
[b] European Commission (2011), Critical Metals in Strategic Energy Technologies.
[c] Munnoch (2008), Hafnium. http://www.mmta.co.uk/uploads/2013/01/09/135751_hafnium_avon_metals_2008_doc.pdf/ [Accessed February 2013]
[d] USGS (2013), Mineral Yearbooks 2011, Zirconium and Hafnium
[e] Lipmann Walton & Co (2012), Hafnium Supply-Demand – MMTA – Brief Metal Statistics.
http://www.lipmann.co.uk/articles/metal-matters/hafnium-supply-demand-mmta-brief-metal-statistics/ [Accessed February 2013]

Table 21: Estimated hafnium metal reserves, 2010

Country	Annual zircon production ('000s tonnes)[a]	zircon reserve* ('000s tonnes)	hafnium content of zircon reserves** ('000s tonnes)
Australia	480	32,000	390
USA	135	15,000	145
South Africa	135	15,000	145
Brazil	18	4,000	38
India	15	9,000	85
Sri Lanka	5	3,000	29
Malaysia	3	3,000	29
Total	**791**	**81,000**	**861**

Source: Nielsen & Wilfing (2010). Hafnium and Hafnium Compounds. Ullmann's Encyclopedia of Industrial Chemistry.
**Estimated*
***1.2% of zircon reserves*

Supply of hafnium is heavily dependent on the nuclear industry and its demand for pure zirconium. This is because production of zirconium requires separation of the two metals. Following the Fukushima accident many countries, such as Germany, Belgium and Switzerland, have reconsidered their nuclear energy policies. However, most countries remain committed to their energy programs.[a] Overall it is estimated that hafnium demand for nuclear applications will increase by 4% annually.[b] China plans to increase its nuclear power development, this is likely to result in an increase in demand for nuclear-grade zirconium and hafnium.[c] It must be noted that, given the interdependency of supply and demand of zirconium and hafnium from the nuclear industry, an expansion of the nuclear energy industry should also result in increased production.

Table 22: Global hafnium supply, 2012

Country	Production (tonnes)
France	30
USA	30
Russia	2
Ukraine	2
Total	**64**

Source: Lipmann Walton & Co (2012), Hafnium Supply-Demand – MMTA – Brief Metal Statistics.
http://www.lipmann.co.uk/articles/metal-matters/hafnium-supply-demand-mmta-brief-metal-statistics/ [Accessed February 2013]

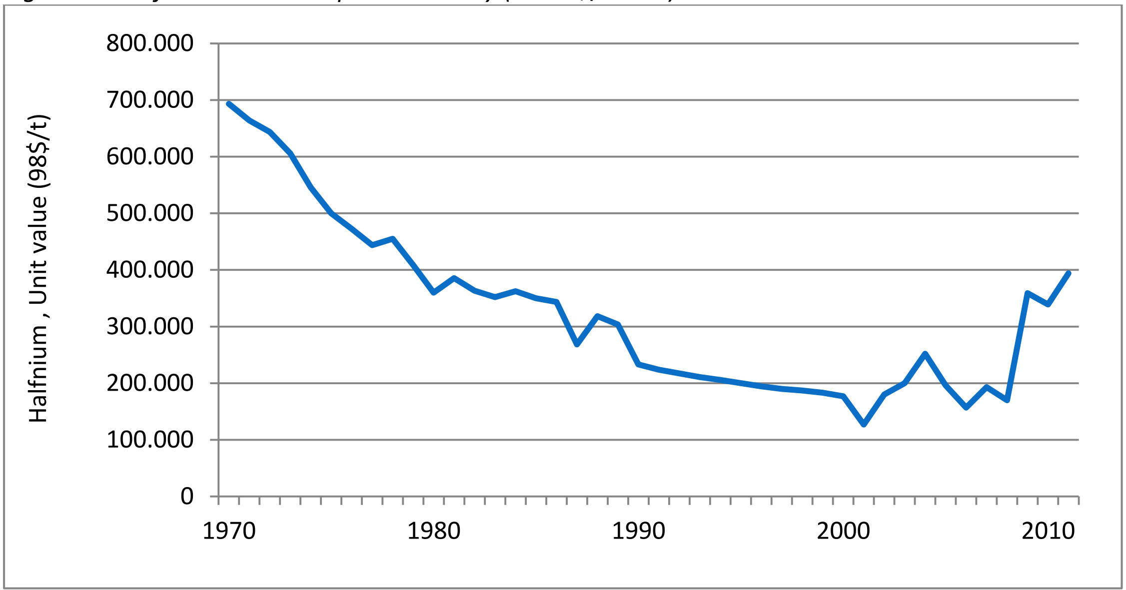
1.11.3 Economic importance

Hafnium metal is not traded publicly; hence data and price trends are not readily available. Figure 24 shows that there has been a significant increase in price since the early 2000s.

Figure 25 shows the uses of hafnium metal; superalloys used in the aerospace industry are the major output. It is thought that annual demand is approximately 70-80 tonnes.[d] Annual demand therefore is higher than annual supply by around 10 tonnes. Data regarding European end-uses were not available at the time of writing.

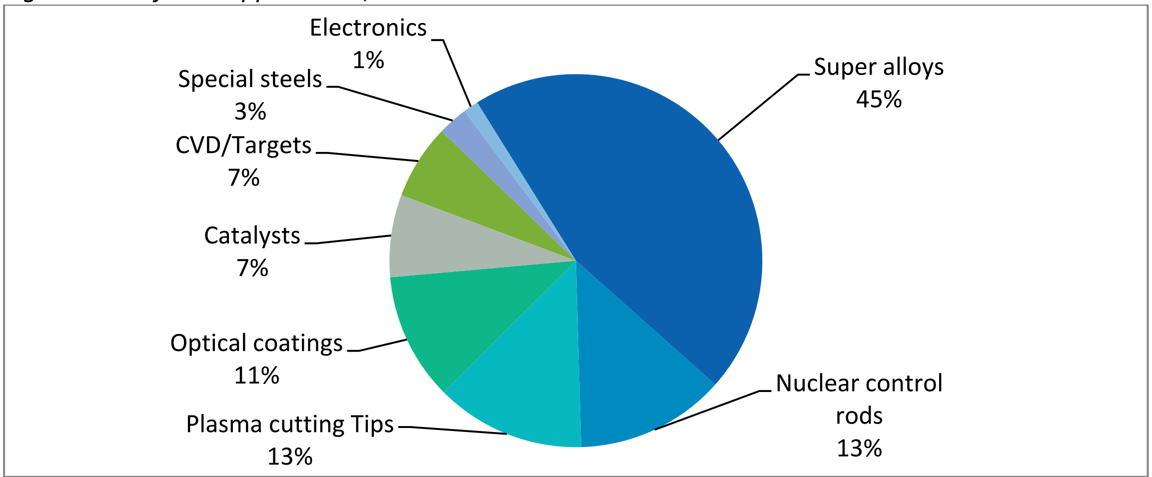
a World Nuclear Association (2012) Policy Responses to the Fukushima Accident.
b European Commission (2011), Critical Metals in Strategic Energy Technologies
c USGS (2013), Mineral Commodity Summaries 2013, Zirconium and hafnium
d Lipmann Walton & Co (2012), Hafnium Supply-Demand – MMTA – Brief Metal Statistics.
http://www.lipmann.co.uk/articles/metal-matters/hafnium-supply-demand-mmta-brief-metal-statistics/ [accessed February 2013]; Hambleton (2010), Assessing Rare Metals as the Critical Supply Chain Bottleneck in Priority Energy Technologies, NAMTEC Ltd.

Figure 24: Hafnium historical price volatility (98 US$/tonne)



Source: USGS (2012-), Historical Statistics for Mineral and Material Commodities in the United States [accessed February 2013]. Figures are indexed to 1998 values.

Figure 25: Hafnium applications, 2011



Source: *Lipmann Walton & Co (2012), Hafnium Supply-Demand – MMTA – Brief Metal Statistics.* *http://www.lipmann.co.uk/articles/metal-matters/hafnium-supply-demand-mmta-brief-metal-statistics/ [Accessed February 2013]*

As shown in Figure 25, the major applications for hafnium are:

- **Superalloys**: the major application for hafnium is as an alloy addition in polycrystalline nickel-based superalloys; for example, MAR-M 247 alloy contains 1.5% hafnium.[a] These alloys are used in the aerospace industry both in turbine blades and vanes but also in industrial gas turbines. The super-alloy industry requires the purest form of hafnium, crystal bars, with low zirconium content. Demand and supply for this form of hafnium approximately equal, making the sector volatile.[b]
- **Nuclear control rods**: hafnium and zirconium are both used in nuclear reactors. Both hafnium and zirconium must be in the pure form in order to work effectively, this leads to the production of hafnium-free zirconium and, as a result, hafnium as a by-product.[a] Hafnium is used in nuclear control rods due to its high thermal neutron absorption cross section.[c]

Other uses of hafnium are refractory ceramic materials, microchips and nozzles for plasma arc cutting.

a Munnoch (2008), Hafnium. http://www.mmta.co.uk/uploads/2013/01/09/135751_hafnium_avon_metals_2008_doc.pdf/ [Accessed February 2013]
b Lipmann Walton & Co (2012), Hafnium Supply-Demand – MMTA – Brief Metal Statistics. http://www.lipmann.co.uk/articles/metal-matters/hafnium-supply-demand-mmta-brief-metal-statistics/ [Accessed February 2013]
c USGS (2010), Minerals Yearbook 2010, Gallium

Demand is expected to increase by 3.6% for alloys in aerospace and by 5% for non-aerospace superalloys. For nuclear control rods, demand is expected to increase by 4%; a 3% increase is expected for all other applications.[a]

1.11.4 Resource efficiency and recycling

No information on hafnium recycling is currently available. According to USGS, hafnium metal recycling is insignificant in the USA. UNEP reports that the end-of-life recycling rate is lower than 1%.[b] It is likely that little to no post-use recycling is being carried out currently, given its contamination in the nuclear industry and the low percentage content in superalloys. It is likely that waste hafnium from production processes are reintroduced in the process.

Table 23: Available substitutes for hafnium applications

Use	Substitutability score
Superalloys	0.3
Nuclear reactor control rods	0.3
Others	0.5

1.11.5 Specific issues

Data on hafnium supply, demand and reserves are not recorded; the figures available are generally estimates. Hafnium metal is not traded publicly; hence data and price trends are not readily available. The lack of available data results in a difficulty in determining trends and making future predictions.

Russia operates an export tax of 6.5% on hafnium including waste, scrap, powder and unwrought material.[c]

a European Commission (2011), Critical Metals in Strategic Energy Technologies.
b UNEP (2011), Recycling Rates of Metals A Status Report
c OECD (n.d.), Inventory of Restrictions on Exports of Raw Materials. http://qdd.oecd.org/Subject.aspx?subject=1189A691-9375-461C-89BC-48362D375AD5. [Accessed February 2013]

1.12 Iron ore[a]

1.12.1 Introduction

Iron (Fe, atomic number 26) is the fourth most abundant element in the Earth's crust, with a concentration of 4.7%. Iron, globally the metal with the highest production volume, is found in ores requiring refinement to produce the metal. Consequently, iron production from ores occurs on a vast scale. In its pure form, iron is relatively soft and slightly magnetic but becomes much more magnetic when hardened. For technical purposes iron in most cases is alloyed with carbon. This alloy is called *steel* (up to 2.1% carbon) or *cast iron* (greater 2.1% carbon). The properties of steel are determined using a wide range of alloying metals, and consequently as many as 2,000 different iron and steel grades exist.[b] Iron ore is the only source for the iron used in steel production (aside from scrap iron or steel).

1.12.2 Supply and demand statistics

Despite being the most abundant metal on Earth, iron is rarely found in nature in a metallic form.[c] In general, iron and steel are the least expensive of the world's metals. Until the 1950s ironworks were mostly supplied from their own mines. Since then opposing cost trends in long distance transport costs versus labour and energy costs led to the effect that also countries with (nearly) no iron ore deposits have considerable steel production.[d]

In 2010, the world's production of iron ore was 1,300 million tonnes of usable ore, of which 27% was produced by China. EU-27 production in 2010 was 17 million tonnes. Sweden was the largest European producer, accounting for 16.2 million tonnes or iron ore production. Very small amounts are produced in Austria, the Slovak Republic and Germany. In addition to this, there is also production in Turkey and Norway. In 2011, world trade in iron ore reached a new record level, mainly driven by the higher demand in China. In 2011, China accounted for more than 60% of world iron ore imports (687 million tonnes). Europe is also a large importer and consumer with 133 million tonnes in 2011. As Europe nearly limited iron ore production the imports reflect the relatively large steel industries in Germany, France, Italy and Great Britain.[e]

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a The data provided are based on the World Mining Data and usually indicate 'metal content' (iron content) which take into account the different possible variations in ore/concentrate.

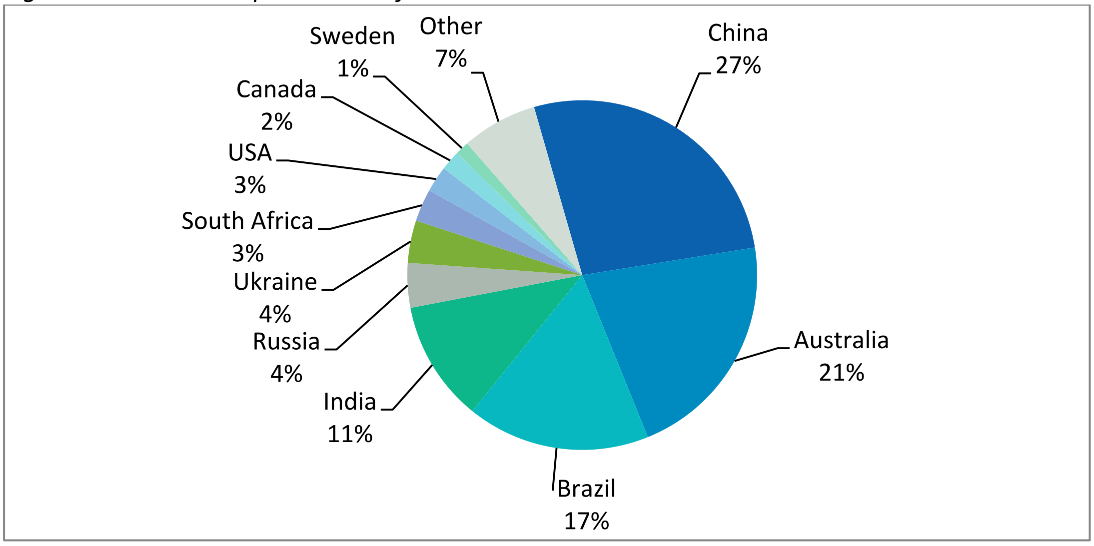
b Stahlinstitut VDEh: http://www.stahl-online.de/Deutsch/Linke_Navigation/Technik_Forschung/Werkstoff_und_Pr%C3%BCftechnik/Stahlsorten.php, accessed 10th September 2013

c On the island of Disko in Greenland natural metallic iron was found. See for instance: Klöck, W. et al (1986) Trace elements in natural metallic iron from Disko Island, Greenland, Contrib Mineral Petrol (1986) 93:273-282

d Ullmann's Encyclopedia of Industrial Chemistry: Iron, 1. Fundamentals and Principles of Reduction Processes, Wiley-VCH Verlag GmbH & Co. KGaA, 2011

e Steel Making Raw Materials: Market and Policy Developments, OECD Steel Committee, 2012

Figure 26: Worldwide production of iron ore in 2010



Source: World Mining Data 2012

Table 24 shows the imports to the EU in 2010. According to the data delivered by Comtrade, the largest amount of iron ore imported to the European Union came from Brazil (54.6%). The EU does not import from China, world's biggest producer, which is not surprising since China itself has such a high demand that it also needs to import iron ore.

Table 24: Production and imports to EU of iron ore, 2010

Country	Production (2010) ('000s tonnes)[a]		Imports to EU (2010) ('000s tonnes)[b]	
China	343,040	26.9%	0	0.0%
Australia	272,790	21.4%	942	1.7%
Brazil	215,829	17.0%	30,304	54.6%
India	142,442	11.2%	420	0.8%
Russian Federation	52,525	4.1%	1,988	3.6%
Ukraine	50,005	3.9%	6,459	11.6%
South Africa	38,161	3.0%	2,669	4.8%
United States	30,870	2.4%	0	0.0%
Canada	23,300	1.8%	4,119	7.4%
Sweden	16,187	1.3%	0	0.0%
Venezuela	15,200	1.2%	1,363	2.5%
Mauritania	7,218	0.6%	3,111	5.6%
Norway	1,987	0.2%	817	1.5%
other countries	63,747	5.0%	3,292	5.9%
Total	**1,273,301**	**100.0%**	**55,484**	**100.0%**

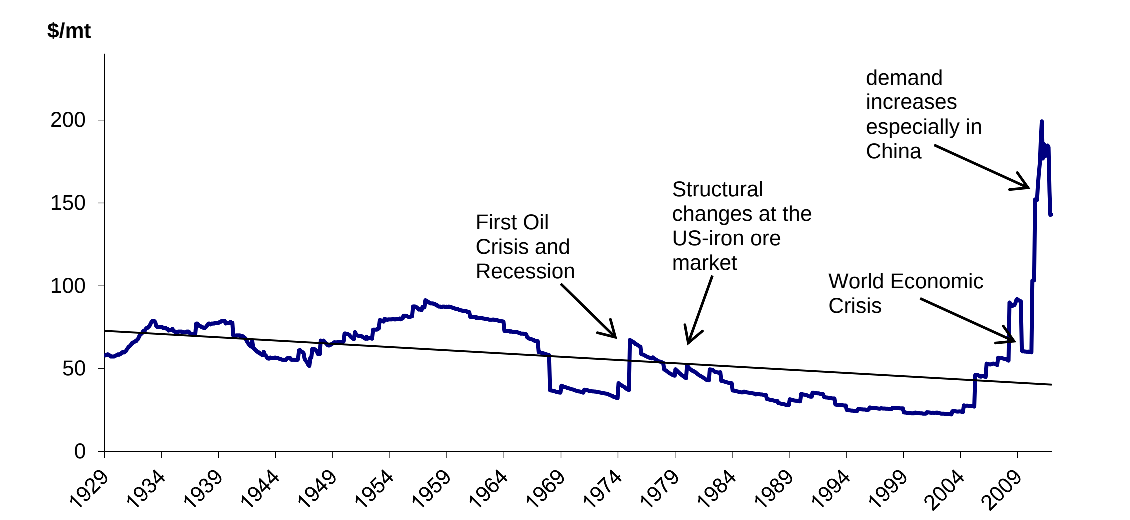
Source: World Mining Data 2012; UN Comtrade

[a] World Mining Data 2012
[b] UN Comtrade, Trade code 260111

1.12.3 Economic importance

Figure 27 shows how the different supply and demand situations worldwide influenced iron prices during the last century.[a] The recent price peak had been induced by increased Asian demand, especially from China.

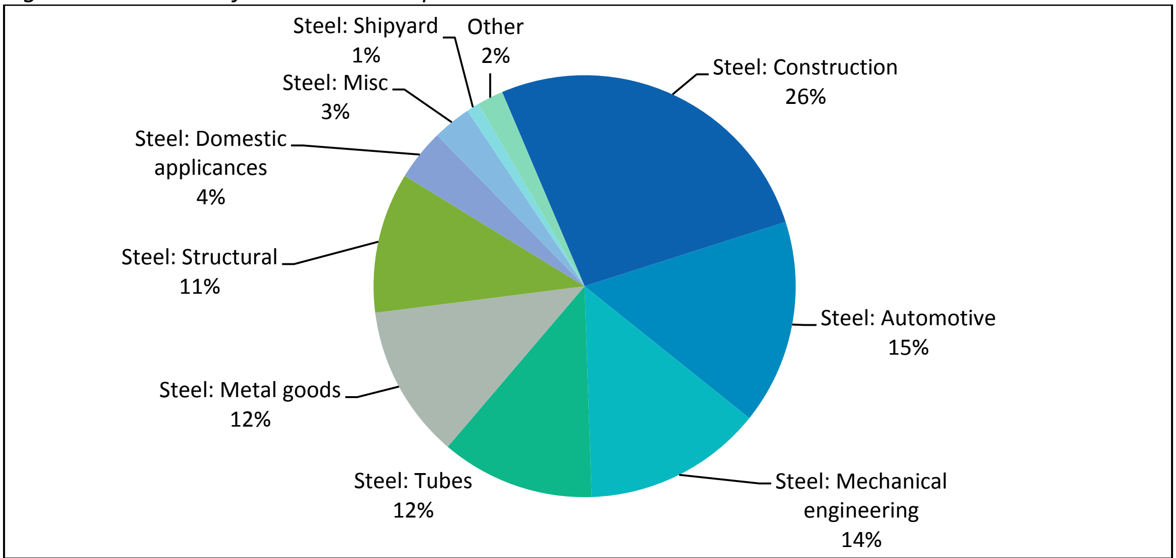
Figure 27: Development of real iron ore prices (Prices are deflated, 2011 = 100)



Source: DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen (Causes of price peaks, collapses and trends of mineral raw materials), Hamburg Institute of International Economics (HWWI) in contract for Deutsche Rohstoffagentur (DERA). April 2013, trend line and translation to English by Fraunhofer ISI

As shown in Figure 28, 98% of consumed iron ore is allocated to the steel production for different industries. The most important uses, which account for about two-thirds, are construction, automotive, mechanical engineering and the construction of tubes. The remaining 2% of the total iron ore consumption is used in a range of other applications such as the production of cement, manufacture of cattle feed, ferrites, heavy media, pigment, refractory applications, weighing materials and the use in lead smelting.[b]

Figure 28: End-use of iron ore in Europe in 2010



Source: Critical Raw Materials for the EU 2010

1.12.4 Resource efficiency and recycling

[a] DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen. April 2013.
b Minerals Yearbook 2011: Iron Ore, U.S. Geological Survey, 2012

Steel or iron can be recycled.[a] Data about the world wide recycling rate of iron and steel differ on a wide range. However, taking different collected data and expert opinion into consideration the Working Group on the Global Metal Flows to the International Resource Panel estimates an end-of-life recycling rate between 70% and 90% for iron and steel.[b] Recycling of iron and steel is very important as it results in significant reduction in resources, energy and cost.

According to USGS, iron ore is the only source of primary iron and is used directly as lump ore or converted to briquettes, concentrates, pellets, or sinter. It is reported that ferrous scrap can also be a significant raw material for some blast furnaces, amounting to as much as 7% of the feedstock. Scrap is also used extensively for the production of steel; however, availability of scrap can be an issue.[c]

Due to the interchangeable substitution possibilities of aluminium, steel and plastic, steel is in great competition with these two other material groups. They form a classic substitution triangle.[d] In recent years plastic components, aluminium parts or even ceramics have increasingly come to replace steel. For example, gas installations are increasingly adopting plastic pipes. Techniques such as tailored blanks on the other hand enable applications for steel, where steel can supply higher rigidity at lower weight than aluminium.[e]

Table 25: Substitutability scores for applications

Application	Substitutability score
Steel: Construction	1
Steel: Metal goods	1
Other	0.5
Steel: Automotive	0.7
Steel: Shipyard	1
Steel: Domestic appliances	0.7
Steel: Mechanical engineering	0.7
Steel: Structural	1
Steel: Tubes	0.7

1.12.5 Specific issues

Some important suppliers for iron ore applied export restrictions on iron ore in 2011. Not only India, one of the main exporters of iron ore, but also China, Vietnam, Argentina and Iran collect export duties on iron ore. India also applies export quotas for some provinces, mainly to ensure that domestic demand is met. Some smaller competitors (Vietnam, Philippines, Iran and Malaysia) have partial export bans on iron ore.[f]

a Mineral Commodity Summaries: Iron Ore, U.S. Geological Survey, 2013
b Recycling Rates of Metals, United Nations Environment Programme, 2011
c USGS (2013) Mineral Commodity Summaries 2013
d Sicherheit der Rohstoffversorgung – eine politische Herausforderung?, Matthes, F.C., Ziesing, H.-J., 2005
e For more information on tailored blanks: http://www.tailored-blanks.com/products.php, accessed 11th September 2013
f Steel Making Raw Materials: Market and Policy Developments, OECD Steel Committee, 2012

1.13 *Limestone (high grade)*

1.13.1 Introduction

Limestone, chalk and marble are pervasive, naturally occurring, crystalline minerals that contain calcium carbonate. Limestone mostly consists of the mineral calcite ($CaCO_3$) or aragonite ($CaCO_3$), but may also contain the mineral dolomite ($CaMg(CO_3)_2$) as a second main component. A variety of impurities, depending on the location of the deposit, have notable influence on the properties and thus the possible applications of the particular type of limestone.[a] Chalk is a more weakly consolidated sedimentary rock consisting mainly of calcite, which, in some deposits, has a much higher percentage of calcite. Hereafter, the term limestone will refer to these three geological calcium carbonate containing raw materials.

For many industrial applications high-grade limestone is used either as ground calcium carbonate (GCC) obtained after a benefication process or transformed into quicklime (CaO). Quicklime is produced by thermal decomposition of high-purity limestone in rotary or shaft kilns at 900-1200°C.[b] In a subsequent step, quicklime can be converted into slaked lime or hydrated lime ($Ca(OH)_2$) in a highly exothermal reaction by reacting quicklime with water.[c]

Most low grade limestone is used in road building, cement, the construction industry or as aggregates. Despite the fact that more than 4% of the Earth's crust comprises of calcium carbonate, few deposits provide sufficient quality for being processed for industrial and agricultural use.[d]

The subject of the present criticality study is high purity limestone that is used for the production of quicklime or ground calcium carbonate. Hence, ground calcium carbonate (GCC) is used as a practical definition.

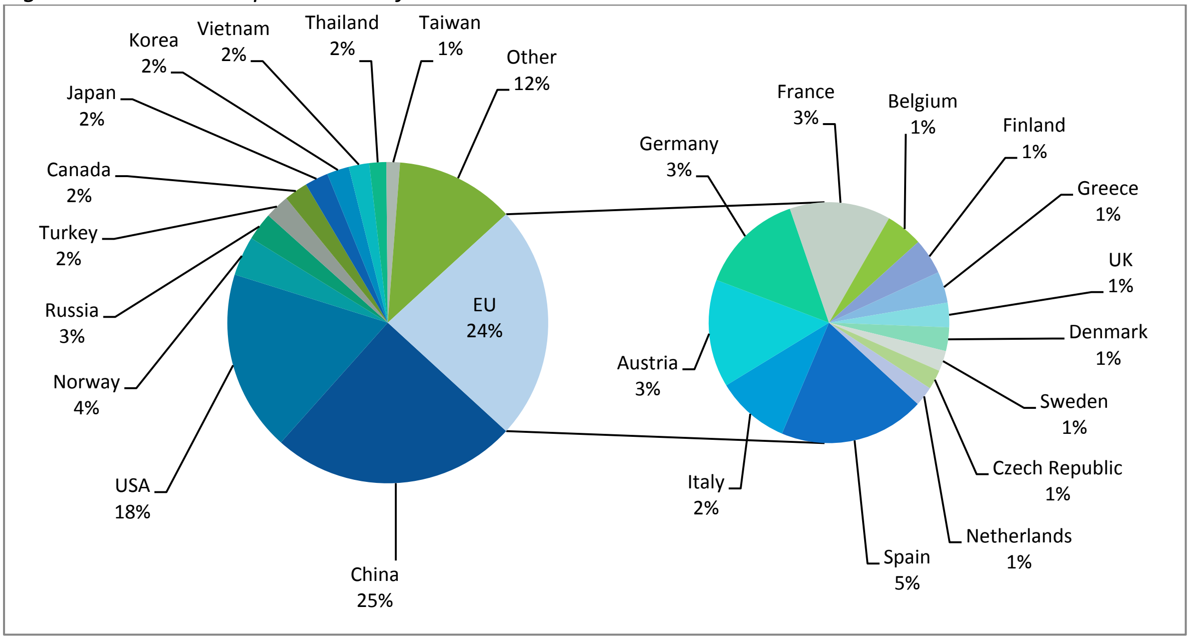
1.13.2 Supply and demand statistics

Limestone reserves are estimated to be adequate for projected worldwide demands. At present, international trading of GCC and lime seems to be rather small since imports are limited by transportation costs. However, this depends on the quality, the price level and the application. GCC for use in the paper industry is traded internationally. For lime, the current situation can be expected to change with significant impact of the Greenhouse Gas Emission Trading Scheme in Europe raising the prices for European produced lime compared to lime from areas like North Africa, Middle East and former Soviet Union.

Total world production of limestone (all grades) is around 4,500 million tonnes per year[a,] but only 80 million tonnes of ground calcium carbonate (GCC) is being produced. China is the largest producer of GCC with a share of 25% and an output of 20 million tonnes a year, followed by the United States (18% or 14.7 million tonnes) and Spain (5% or 3.7 million tonnes). Members of the European Union account for about one third of world production of GCC (Figure 29).

a Ullmann's Encyclopedia of Industrial Chemistry: Lime and Limestone, Wiley-VCH Verlag GmbH & Co. KGaA, 2006
b Calciumoxid, Römpp Online, 2006
c Calciumhydroxid, Römpp Online, 2004
d Calcium Carbonate Fact Sheet, http://www.cca-europe.eu/fileadmin/calcium/documents/Calcium_carbonate_fact_sheet.pdf, accessed 12th September 2013

Figure 29: Worldwide production of limestone in 2012



Source: Roskill Information Services 2013 (for 2013 CRM study)

Table 26: World production (2012) and imports to EU (2011) of ground calcium carbonate and equivalents

Country	Production of GCC, 2012		Imports to EU, 2011[a]	
	Tonnes	%	Tonnes	%
China	20,000,000	24.8%	4,430	0.1%
United States	14,710,000	18.3%	1,262	0.0%
Spain	3,730,000	4.6%	-	-
Norway	3,200,000	4.0%	1,618,807	41.4%
Austria	2,750,000	3.4%	-	-
Germany	2,655,000	3.3%	-	-
France	2,580,000	3.2%	-	-
Russia	2,267,000	2.8%	2,413	0.1%
Turkey	1,989,000	2.5%	421,426	10.8%
Canada	1,925,000	2.4%	124	0.0%
Japan	1,906,000	2.4%	9	0.0%
Italy	1,880,000	2.3%	-	-
Rep. of Korea	1,800,000	2.2%	575	0.0%
India	690,000	0.9%	3,647	0.1%
Serbia	290,000	0.4%	6,663	0.2%
South Africa	150,000	0.2%	3,321	0.1%
Croatia	50,000	0.1%	13,493	0.3%
Belarus	NA	NA	4,068	0.1%
Montenegro	NA	NA	3,021	0.1%
Other countries	17,925,000	22.3%	1,822,779	46.7%
Total	**80,497,000**	**100.0%**	**3,906,038**	**100.0%**

Sources: Roskill Analysis 2013 (for 2013 CRM study)*; UN Comtrade*

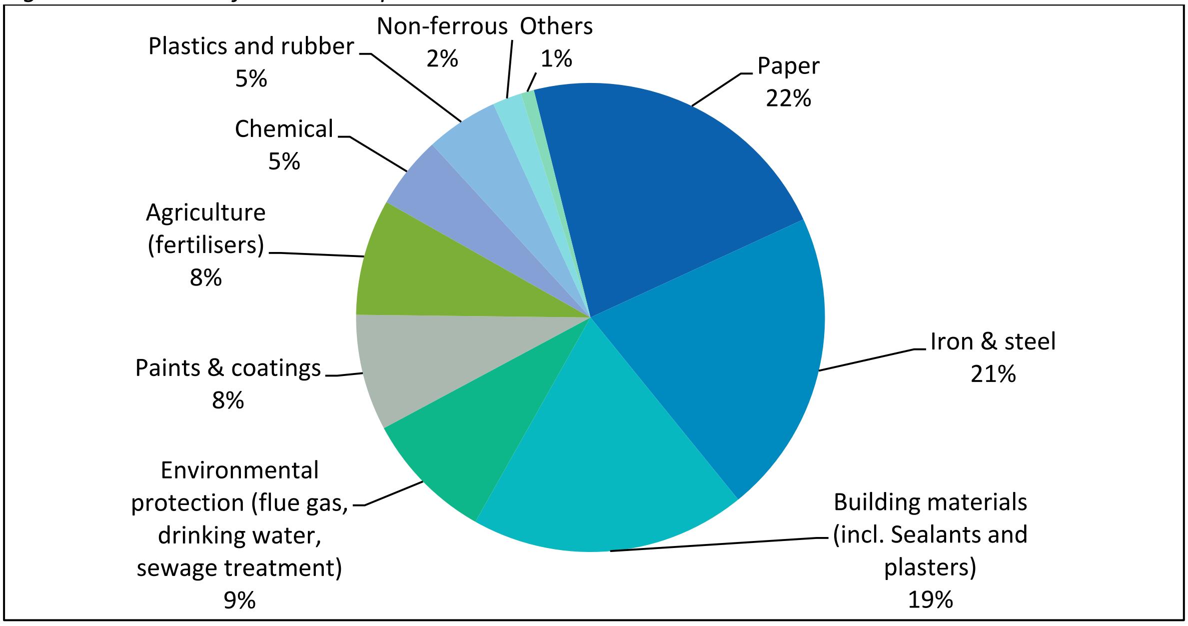
Table 26 shows the data for limestone imports to the EU in 2011. According to the data delivered by Comtrade, by far the biggest amount of limestone was exported by Norway to the European Union, whilst China and the United States were the leading producers worldwide. Due to a lack of data for 2012, import data from 2011 was used.

[a] UN Comtrade, Trade codes 252100 (Limestone (high grade) - Limestone materials for manufacture of lime or cement), 250900 (Limestone – Chalk) and 251741 (Limestone - Marble granules, chipping and powder).

1.13.3 Economic importance

Limestone and its products have many uses. Most quantities are used in the construction as aggregates and cement industry. However, these uses and the low-grade limestone used are not subject of this study.

Figure 30: End-use of GCC in Europe in 2007



Source: Critical Raw Materials for the EU 2010

For high quality limestone the main uses can be seen in Figure 30 and are as follows:[a,b]

- **Building materials:** As a high quality filler, ground calcium carbonate improves the density, pre stability and durability of modern concrete mixtures. Lime is widely used in construction materials such as concrete, asphalt, mortars.
- **Paper:** Ground calcium carbonate and to a smaller extent lime are used as filler and as coating pigment in the paper industry. Thus it helps to produce papers with high whiteness and good printing properties.
- **Plastic & Rubber:** Calcium carbonate is used in plasticised and rigid PVC, unsaturated polyesters, polypropylene and polyethylene. Other important areas of use include rubber, foamed latex carpet-backings, sealants and adhesives.
- **Paints & Coatings:** In paints and coatings, GCC is used as an extender that offers improvements in weather resistance, anti-corrosion and rheological properties, coupled with low abrasiveness, low electrolyte content, and a pH stabilising effect.
- **Chemical:** Quicklime and hydrated lime are cost effective alkaline chemicals that are readily available and play an important role in the chemical industry.
- **Agriculture:** Ground calcium carbonate and to a smaller extent hydrated lime are used as liming materials to stabilise the pH-value of the soil. High-grade limestone with high magnesium content also replaces calcium and magnesium which is removed with the crops. It is also used in animal feeds.
- **Iron & Steel:** GCC and quicklime are used as a flux in the production of metals, mainly for iron and steel, but also for zinc, lead, copper and antimony.

a Industrial Minerals Association Europe: http://www.ima-europe.eu/about-industrial-minerals/industrial-minerals-ima-europe/lime, accessed 12th September 2013

b Calcium Carbonate Fact Sheet, http://www.cca-europe.eu/fileadmin/calcium/documents/Calcium_carbonate_fact_sheet.pdf, accessed 12th September 2013

- **Environmental protection:** A growing amount of GCC and lime is used to remove sulphur dioxide from flue gases, for sewage treatment and for drinking water treatment.
- **Other:** GCC and lime are used in many other products, such as alumina, glass, wood pulp, ceramics, mineral wool, fillers, and other.

1.13.4 Resource efficiency and recycling

Lime and GCC themselves are not directly recycled but many products made with lime and GCC are recyclable or re-usable (steel, paper, plastics, etc.). By-products from processes where lime and GCC are used find further application, e.g. steel slags are used in agriculture as fertiliser or flue gas desulfurization (FGD), gypsum as building material. Aside from this, lime can be converted back to calcite and thus close the 'lime cycle'.[a] For example in the paper pulp industry high-grade limestone is converted to lime, which is used for the pulp purification and transformed back into calcite that is placed back in the lime kiln.

To control the pH-value of the soil magnesium-hydroxide can substitute for limestone and magnesium oxide can be used as a flux in steel production. In some construction uses fly ash, cement, or cement kiln dust replace lime.[b]

Table 27: Substitutability scores of lime and GCC

Application	Substitutability score
Building materials (incl. sealants and plasters)	1
Agriculture (fertilisers)	1
Chemical	1
Plastics and rubber	0.3
Paper (filler, coating)	0.3
Paints & coatings	0.3
Non-ferrous	0.5
Iron & steel	1
Environmental protection (flue gas, drinking water, sewage treatment)	1

1.13.5 Specific issues

According to the OECD´s inventory on export restrictions there is only a licensing agreement on limestone in Mauritius. For other countries no trade barriers are reported. Limestone/marble/chalk reserves are adequate for all listed countries and for projected worldwide demands as well.

a The Lime Cycle: http://johnspeweik.com/2011/10/27/the-lime-cycle/, accessed 12th September 2013
b Mineral Commodity Summaries: Lime, U.S. Geological Survey, 2013

1.14 Lithium

1.14.1 Introduction

The alkali metal lithium (Li, atomic number 3) has the lowest density (0.534 g/cm^3) of all known solids at room temperature. It is silvery, shining, tough, soft and can form strong alloys with other metals.[a] Lithium is a very reactive metal which also reacts with moist air at room temperature. To prevent it reacting chemically it is stored in petroleum ether. Currently the main use of lithium compounds is as fluxes in the ceramics and glass industries, but an increasing use of lithium is in rechargeable batteries.[b]

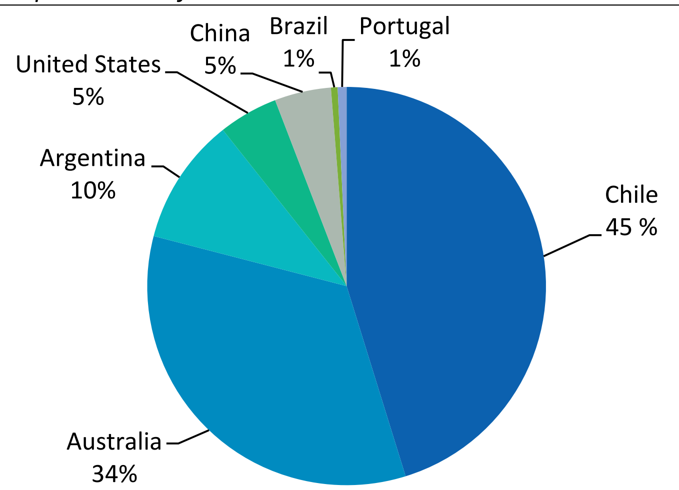
In the EU, only Portugal produced a significant amount of lithium in 2011, from the mineral lepidolite. Austria, Belgium, the Czech Republic, Denmark, France, Germany, Italy, the Netherlands, Poland, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom are importers and exporters of lithium carbonate and lithium oxide.[b] Several European industries use various applications of lithium e.g. automotive industry uses lithium in rechargeable batteries for electric or hybrid vehicle. Recycling plants for lithium batteries were under development in Belgium and Germany (amongst others) in 2012.[c]

1.14.2 Supply and demand statistics

Occurring at 60 ppm in the Earth's crust, lithium is the 27th most abundant element. There are more than 150 known lithium-containing minerals, the most important of which are amblygonite, lepidolite, petalite and spodumene.[d] These minerals contain up to 8% of lithium oxide; in most cases, however, the content ranges between 3.5% and 7.5%.[e] In recent years lithium-containing brines have become the most important source of raw material for lithium chemicals.

Over half of world reserves are located in Chile, and other South American countries have considerable reserves of lithium. Portugal is the only country in the EU with significant lithium reserves. According to USGS, worldwide resources amount to nearly 40 million tonnes.[f] Total mine production of lithium in 2011 amounted to 62,231 tonnes, Chile and Australia being the most important producers.

Figure 31: Worldwide production of lithium in 2011



Source: World Mining Data 2013, Lithium specified as "content of recoverable valuable elements and compounds"

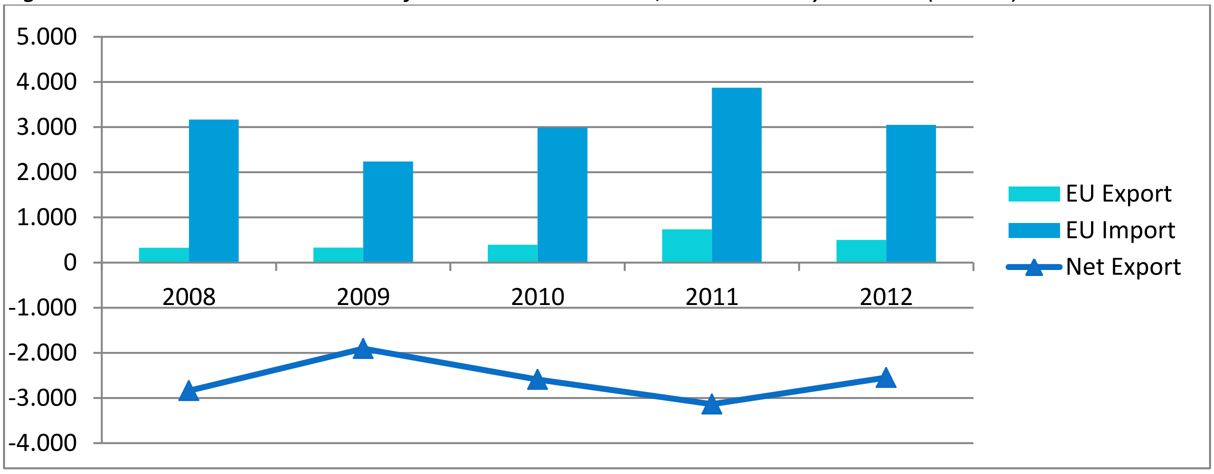
[a] Ullmann's Encyclopedia of Industrial Chemistry: Lithium and Lithium Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[b] European Mineral Statistics 2007-11, British Geological Survey, 2013
[c] Minerals Yearbook 2012: Lithium, US Geological Survey, 2013
[d] Lithium, Römpp Online, 2006
[e] Ullmann's Encyclopedia of Industrial Chemistry: Lithium and Lithium Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[f] USGS (2013), Mineral Commodity Summaries 2013, Lithium

Within the EU, the only production of lithium is in Portugal. USGS reports two mining projects for lithium minerals in Europe. A spodumene mine is under development in Finland and a jadarite mining operation in Serbia, an EU candidate country.[a] Jadarite is a quite new mineral species which was discovered recently in Serbia and approved by the International Minerals Association in 2006.[b] It contains high amounts of lithium oxide. Although different lithium-containing mineral deposits have been discovered in different countries all over the world, digging is not economically favourable.[e]

EU trade flows and consumption

Overall, the EU is a net importer of lithium industrial chemicals, importing around 13,000 tonnes per year of lithium carbonates, oxides and hydroxides. Import and exports for lithium carbonates are around four times larger than those of lithium oxide and hydroxide. These figures do not take into account trade of other lithium substances and products, therefore do not give a complete picture of trade flows.

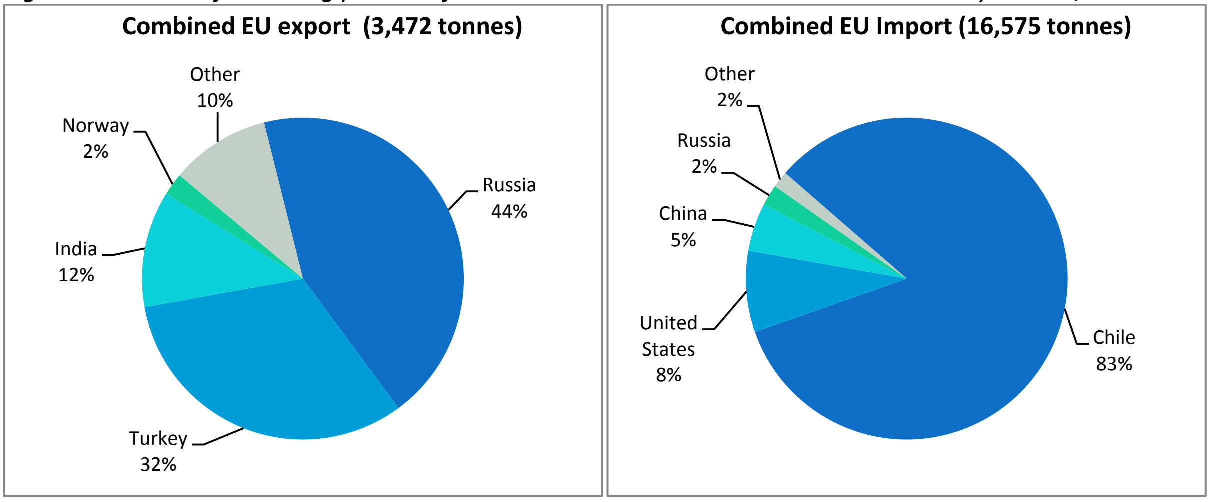
Figure 32: Trends in extra-EU trade for lithium carbonates, oxides and hydroxides (tonnes)



Source: Eurostat-Comext Database, CN 2825 2000 and 2836 9100 [accessed August 2013]

Most of the lithium is imported from Chile (Figure 33); this is consistent with Chile being the major worldwide producer. Other major importers to the EU are the USA and China. Exports from the EU are low compared to imports and involve a number of countries, but major recipients are Russia and Turkey.

Figure 33: EU's major trading partners for Lithium Carbonate and Lithium Oxide and Hydroxide, 2012



Source: Eurostat-Comext Database, CN 2825 2000 and 2836 9100 [accessed August 2013]

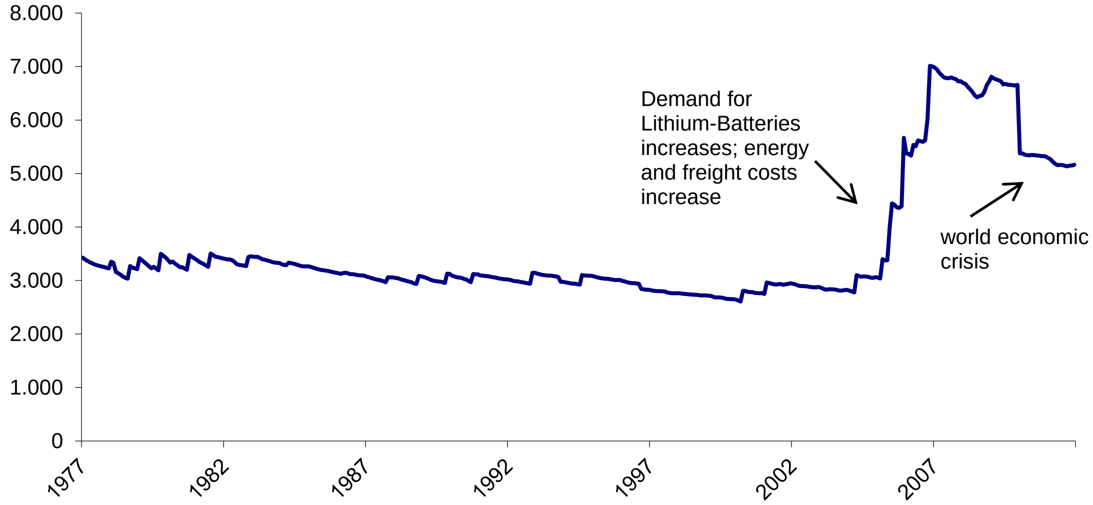
[a] Minerals Yearbook 2012: Lithium, US Geological Survey, 2013
[b] Jadarite: http://www.mindat.org/min-31570.html, accessed 10th September 2013

With estimated 34,000 tonnes, of lithium carbonate equivalent (LCE) or 24% of total worldwide lithium consumption (150,000 tonnes of LCE for 2012), the EU is second consumer after East Asia (60% of consumption) .North America comes third with 9% of consumption.

1.14.3 Demand and Supply

After a long period of relative stability, worldwide demand has soard in 2005, and, after the crisis years 2008-09, seems to stabilise again, albeit on a higher level than before.[a]

Figure 34: Development of real Lithium prices in $/mt (Prices are deflated, 2011 = 100).

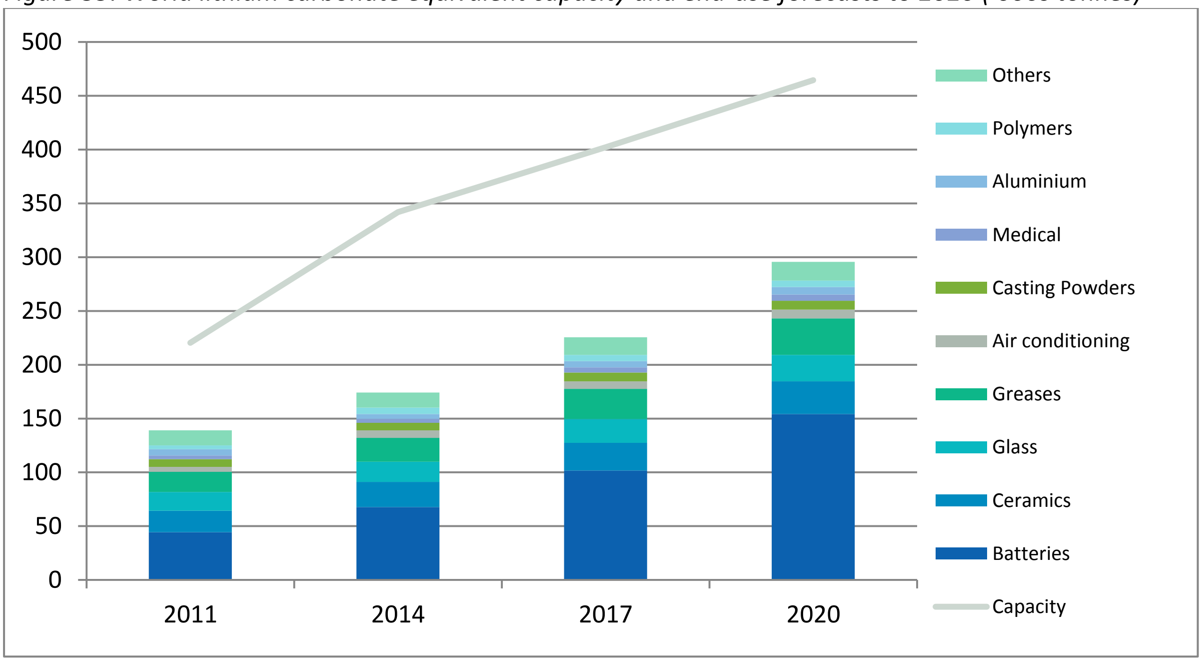


Source: DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen (Causes of price peaks, collapses and trends of mineral raw materials), Hamburg Institute of International Economics (HWWI) in contract for Deutsche Rohstoffagentur (DERA). April 2013., translated to English by Fraunhofer ISI

Future trends

The market outlook forecast for world lithium capacity and demand is shown in Figure 35.

Figure 35: World lithium carbonate equivalent capacity and end-use forecasts to 2020 ('000s tonnes)



Sources: Li3Energy & Roskill Presentations (2013), International Lithium Alliance & Chemetall Presentations (2012)

[a] DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen. April 2013.

Demand is forecast to increase by more than 8% a year, the main driver being the market for lithium batteries between 2011 and 2020, due to the anticipated uptake in hybrid and electric vehicles which contain Li-ion batteries. Annual growth rates for this market could hit nearly 15% per year, but also less, depending on the uptake scenarios anticipated for hybrid and electric vehicles. More modest growth is expected in most of lithium's other end-markets.

In terms of the supply-side, all of the major lithium-producing companies have already announced significant expansions to their capacity for the coming years. In addition, there are numerous other projects on-going by various companies, although not all of these will be successful. Nonetheless, significant excess capacity is forecast for the lithium market, meaning that capacity utilisation rates will be around 50-60% for the coming decade.

1.14.4 Resource efficiency and recycling

Recycling for the lithium content (e.g. in different alloys or lubricating grease) has long been insignificant.[a] With more lithium being used in batteries, recycled content has been growing steadily in the last years. The EU has set a mandatory target that 45% of batteries in portable electronics in EU Member States shall be recycled by 2016.[b] Nevertheless, in many cases the batteries are not recycled for the lithium content but for cobalt or ferromanganese, and the lithium is part of the slag e.g. used in road construction.[c]

Substitution for lithium is not possible in its most important applications, such as ceramics and glass, batteries, and lubricating grease. Battery anodes can be produced from calcium, magnesium, mercury or zinc. Calcium and aluminium soaps can substitute for stearates in greases, as well as sodium and potassium based fluxes can replace lithium in glass and ceramic production.[d] Light aluminium alloys containing lithium can be replaced by fibre composites.

Table 28: Substitutability scores for lithium applications

Use	Substitutability Index
Ceramics and glass	1
Batteries	1
Lubricating grease	0.7
Gas and air treatment	0.3
Continuous casting	0.7
Synthetic rubbers and plastic	0.7
Pharmaceuticals	0.3
Aluminium smelting	0.3

1.14.5 Specific Issues

Lithium exceeds the threshold for economic importance; however the supply risk is non-critical using the poor governance indicator, but critical using the EPI indicator. Due to inconsistencies between the environmental performance in the mining sector of relevant producing countries and the EPI indicator values, the Ad hoc Working Group on Critical raw materials decided to use the WGI indicator for assessing the supply risk of all raw materials assessed including lithium. This is the only difference to the previous report.

[a] Mineral Commodity Summaries: Lithium, US Geological Survey, 2013
[b] Directive 2006/66/EC on batteries and accumulators, European Parliament and Council, 2006
[c] Lithium – ein Spannungsmacher auf Kreislaufkurs: http://www.ingenieur.de/Themen/Rohstoffe/Lithium-Spannungsmacher-Kreislaufkurs, accessed 10th September 2013
[d] Mineral Commodity Summaries: Lithium, US Geological Survey, 2013

1.15 *Manganese (Manganum)*

1.15.1 Introduction

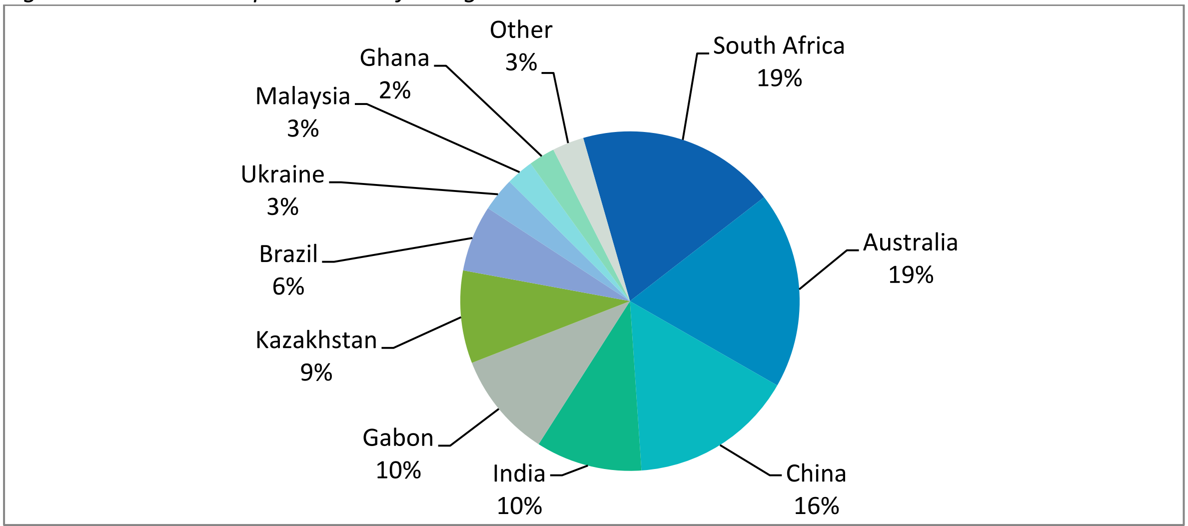
Manganese (Mn, atomic number 25) is one of the most important heavy metals due to its indispensability in steel production.[a] The principal use of manganese is in the steel industry as a desulphurization and alloying agent to provide hardness and wear resistance.[b] If the content of manganese in steel exceeds a certain value, non-magnetic steel can be produced. This finds application in retainer rings for turbo alternators and collars on oil rigs. Manganese is also an additive of many aluminium alloys which contain up to 9% manganese. Manganese compounds are used in dry-cell batteries and other fields of the chemical industry.

1.15.2 Supply and demand statistics

Manganese is the second most common heavy metal. When all chemical elements are considered, it ranks in twelfth place with 950 ppm in the Earth's crust. As a base metal, manganese occurs naturally only in compounds. Almost all soil types contain manganese compounds in low concentration, but to be economically viable a manganese content in excess of 35% is required. Around 250 minerals containing manganese are known, but only a dozen are of mining significance: pyrolusite (manganese dioxide, MnO_2), braunite, manganite, psilomelane, hausmannite, jacobsite, bixbyite, rhodonite, rhodochrosite and bementite. Manganese deposits with economic importance are all of sedimentary origin, having been dissolved from crystalline rocks and deposited as oxides, hydroxides or carbonates.[cd]

Worldwide manganese reserves, including low grade ores, are currently estimated to reach several billion tonnes.[e] If only ores of metallurgical grade are considered, reserves are in the range of 630 million tonnes, primarily located in the southern hemisphere, with South Africa, Australia, Gabon, and Brazil supplying over 50% of the international market. Land-based manganese resources are large, but irregularly distributed to few areas. Three-quarters of identified resources are located in South Africa; the second largest occurrence is found in the Ukraine (10%).[f] Figure 36 shows the shares of worldwide manganese production by country. EU-27 production of manganese in 2010 was roughly 50,000 tonnes, accounting for just 0.3% of worldwide production. Countries in which manganese is mined are Bulgaria, Hungary, Romania and Italy.

Figure 36: Worldwide production of manganese in 2010



a SBB insight, issue 113, 2010
b European Mineral Statistics 2007-2011, British Geological Survey, 2013
c Mangan, Römpp Online, 2006
d Ullmann's Encyclopedia of Industrial Chemistry: Manganese, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
e International Manganese Institute, http://www.manganese.org/about_mn/reserves, accessed on 17th September 2013
f Mineral Commodity Summaries: Manganese, U.S. Geological Survey, 2012

Source: World Mining Data 2012

Table 29 shows the data for manganese imports to the EU in 2010. According to the data from Comtrade, by far the biggest amount of manganese was exported by Brazil to the European Union, whilst South Africa, Australia, and China being the leading producers for manganese worldwide.

Table 29: World production and imports to EU of manganese, 2010

Country	Production[a] (2010)		Imports to EU (2010)[b]	
	Tonnes	%	Tonnes	%
South Africa	3,155,680	18.9%	183,418	28.1%
Australia	3,120,000	18.7%	1,143	0.2%
China	2,600,000	15.6%	64	0.0%
India	1,682,000	10.1%	235	0.0%
Gabon	1,664,000	10.0%	128,805	19.8%
Kazakhstan	1,460,064	8.8%	0	0.0%
Brazil	1,048,000	6.3%	286,437	43.9%
Ukraine	536,500	3.2%	38,108	5.8%
Malaysia	429,769	2.6%	0	0.0%
Ghana	417,926	2.5%	4,800	0.7%
Norway	NA	NA	4,125	0.6%
Burkina Faso	NA	NA	1,826	0.3%
Morocco	37,800	0.2%	1,531	0.2%
Singapore	NA	NA	724	0.1%
Other countries	502,397	3.0%	807	0.1%
Total		**100.0%**	**652,023**	**100.0%**

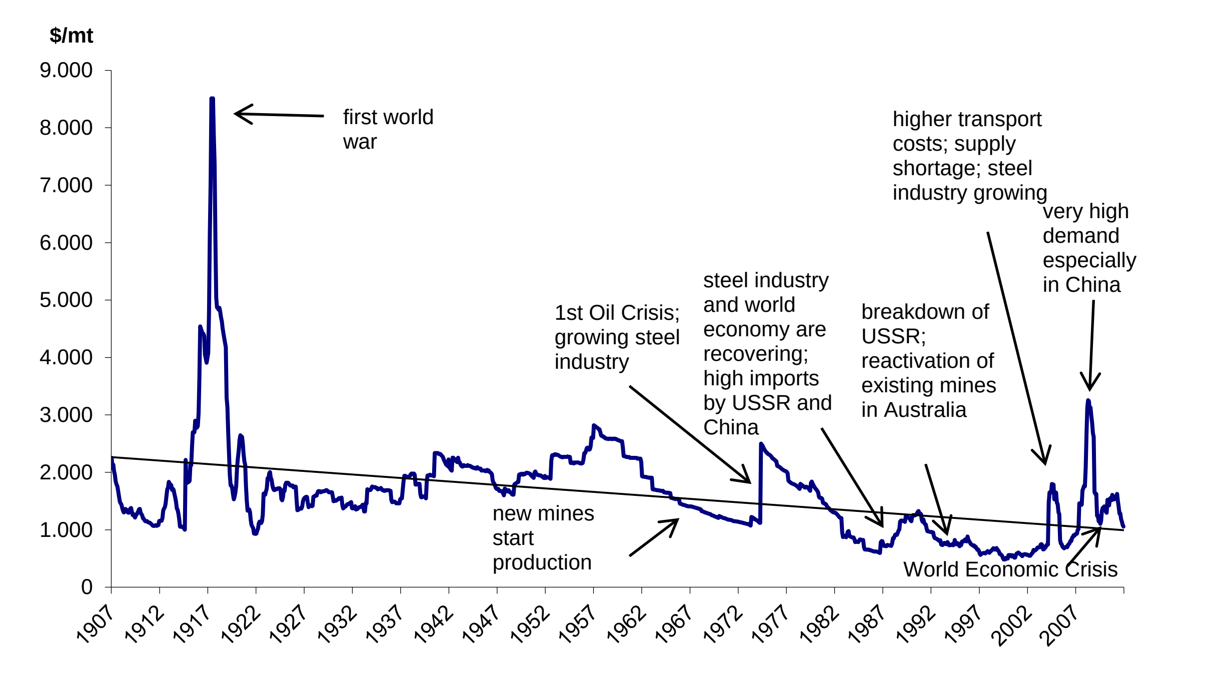
Source: World Mining Data 2012; UN Comtrade [Accessed July 2013]

a "content of recoverable valuable elements and compounds"
b Trade code 260200 (Manganese ores, concentrates, iron ores >20% Manganese)

1.15.3 Economic importance

Figure 37 shows how the different supply and demand situations worldwide that influenced manganese prices during the last century.[a] As can be seen at a first glance, there had been several significant price peaks: the first and highest one due to the First World War. The last years had been dominated by a high Asian demand, especially from China and India.

Figure 37: Development of real manganese prices (Prices are deflated, 2011 = 100).



Source: DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen (Causes of price peaks, collapses and trends of mineral raw materials), Hamburg Institute of International Economics (HWWI) in contract for Deutsche Rohstoffagentur (DERA). April 2013, trend line and translation to English by Fraunhofer ISI

By far the largest use of manganese (over 90%) is in steel metallurgy, where it is used as reduction and desulphurization agent. This steel has end uses across many sectors, primarily the construction, automotive and mechanical engineering sectors. Other metallurgy uses are in copper and nickel smelting for the same purpose and in aluminium alloys to improve the corrosion resistance. Moreover there are several multifunctional non-metallurgy applications such as in the production of dry cell batteries or as additive in animal feedstuffs and fertilisers.[b]

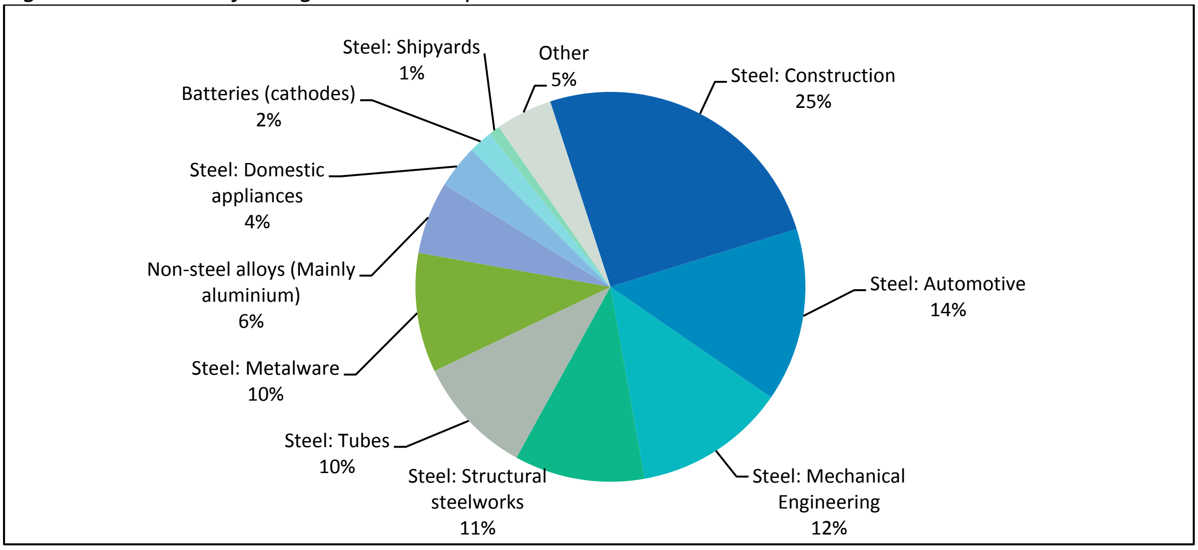
To specify the structure of usage, some innovative applications shall be mentioned in the following, each containing a more or less important amount of manganese:[c]

- tailored blanks (reducing weight in car bodies)
- airframe light weight construction (reducing weight in aviation)
- micro-electronic capacitors
- Li-ion batteries using manganese as cathode (lithium-manganese batteries)
- corrosion-resistant material for desalination of seawater
- superalloys.

The end uses for manganese (including separate uses in steel) are shown in Figure 38.

a DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen. April 2013.
b Mangan, Römpp Online, 2006
c Rohstoffe für Zukunftstechnologien, Angerer et al., Fraunhofer-Institut für System- und Innovationsforschung ISI, 2009

Figure 38: End-use of manganese in Europe in 2012



Source: Euroalliages

1.15.4 Resource efficiency and recycling

Manganese can be recycled as constituent of ferrous and nonferrous scrap; however, the amount of recovered manganese in particular is negligible.[a] Recycled manganese content from old scrap is estimated to 12%[b].

In its major applications manganese has no satisfactory substitute.[c] In contrast, manganese itself is used as a substitute for other commodities such as vanadium.

Table30: Substitutability for manganese

Application	Substitutability score
Construction	1
Machinery	1
Other iron and steel applications	0.5
Transportation	1

1.15.5 Specific issues

Several countries have restrictions concerning trade with manganese. According to the OECD´s inventory on export restrictions, whereas South Africa has a licensing agreement on manganese and articles thereof including waste and scrap, India uses export taxes of 20% on manganese ores and concentrates, ferruginous manganese ores and concentrates and concentrates with a manganese content of 20% or more. Export taxes in Gabon amount to 3.5%. In addition, there is a wide range of other countries imposing trade restrictions on manganese.

a Mineral Commodity Summaries: Manganese, U.S. Geological Survey, 2012
b Estimation by Working Group
c Mineral Commodity Summaries: Manganese, U.S. Geological Survey, 2012

1.16 Molybdenum

1.16.1 Introduction

Molybdenum (Mo, atomic number 42) occurs in the Earth's crust most commonly as the mineral molybdenite (MoS_2). Small quantities are also found in other metals such as wulfenite ($PbMoO_4$), powellite ($CaMoO_4$) and ferrimolybdite ($Fe_2Mo_3O_{12}$). Molybdenite is the primary source of molybdenum.[a]

Molybdenum is a lustrous silver-white solid, but appears dull grey when produced as a powder. The typically metallic properties of molybdenum depend to a large degree on the production method used and on its subsequent treatment.[a]

The first major use of molybdenum was during World War I as additive in steel production to improve toughness and strength at high temperatures for use as tank armour and in aircraft engines. Today, molybdenum is used as alloying element in steel, cast iron and super-alloys in a wide range of applications. Besides toughness and strength, corrosion resistance is also increased.[a]

1.16.2 Supply and demand statistics

At present there are basically three generic types of molybdenum deposits with economic importance. Firstly, porphyry deposits in which metallic sulphides are disseminated throughout large volumes of altered and fractured rock. Secondly, contact-metamorphic zones and bodies in which silicated limestone is adjacent to intrusive granites; and thirdly, quartz veins. However, average molybdenum concentration are very low. In primary porphyry deposits it ranges from 0.05% to 0.25%; the value of secondary copper ranges from 0.01% to 0.05%.[a] However, world resources are adequate to satisfy projected demands in the foreseeable future.[b]

Molybdenite, which is the only source of molybdenum with economic importance, is either mined and concentrated as primary product or recovered as a concentrate during the processing of ore from a copper mine. In the latter case, the molybdenite can be either a by- or a co-product, depending on its economic importance to the output of the mine. Molybdenum supply in the Western world can be broken down into four segments:

1. Primary mine production (ca.40%)
2. By- or co-production output from copper and scheelite mines (ca.55%)
3. Imports from the People's Republic of China (3%)
4. Molybdenum recovered from the processing of spent petroleum catalyst (2%).[a]

Molybdenum occurs widely in all continents but usually in small quantities. The large-scale mining, milling, and processing facilities now required for economic production of molybdenum compounds are only justified where large reserves of ore exist.[a] The largest deposit of molybdenum in Europe is located in Norway[c], but it is not in production. According to USGS[d] and the statistics of the Austrian World Mining Data, there is no molybdenum production in Europe (Figure 39). As a consequence European molybdenum consumption is entirely covered by imports.[e]

[a] Ullmann's Encyclopedia of Industrial Chemistry: Molybdenum and Molybdenum Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[b] Mineral Commodity Summaries: Molybdenum, US Geological Survey, 2013
[c] Molybdän, Römpp Online, 2006
[d] Mineral Commodity Summaries: Molybdenum, US Geological Survey, 2013
[e] USGS Mineral Commodity Summaries 2013: Molybdenum

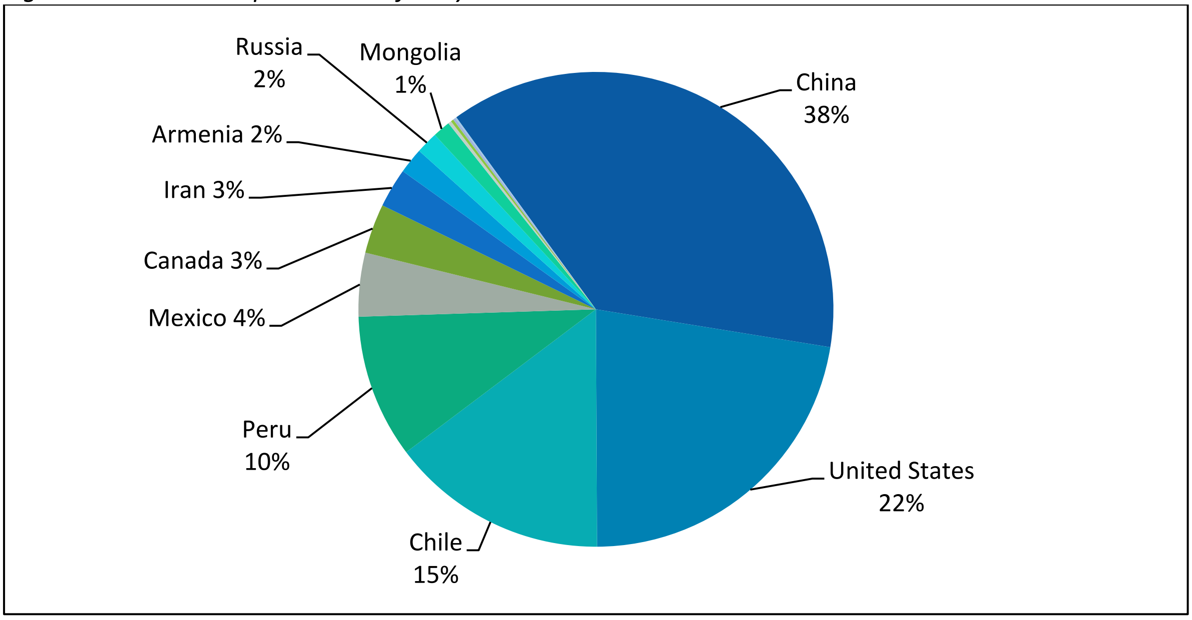
Table 31: Global reserves of molybdenum

Country	Reserves ('000s tonnes)
Armenia	150
Canada	220
Chile	2,300
China	4,300
Iran	50
Kazakhstan	130
Kyrgyzstan	100
Mexico	130
Mongolia	160
Peru	450
Russia	250
USA	2,700
Uzbekistan	60
Total (rounded)	11,000

Sources: USGS (2013), Mineral Commodity Summaries 2013, Molybdenum

Total global mine production for 2010 amounted to 250,000 tonnes. China is by far the largest producer followed by the USA. There is no EU production.

Figure 39: Worldwide production of molybdenum in 2010



Source: World Mining Data 2012

Table 32 shows the data for molybdenum imports to the EU in 2010. According to Comtrade data, by far the largest amount of molybdenum imported to the EU was exported by the USA, the second largest producer for molybdenum worldwide, followed by Chile.

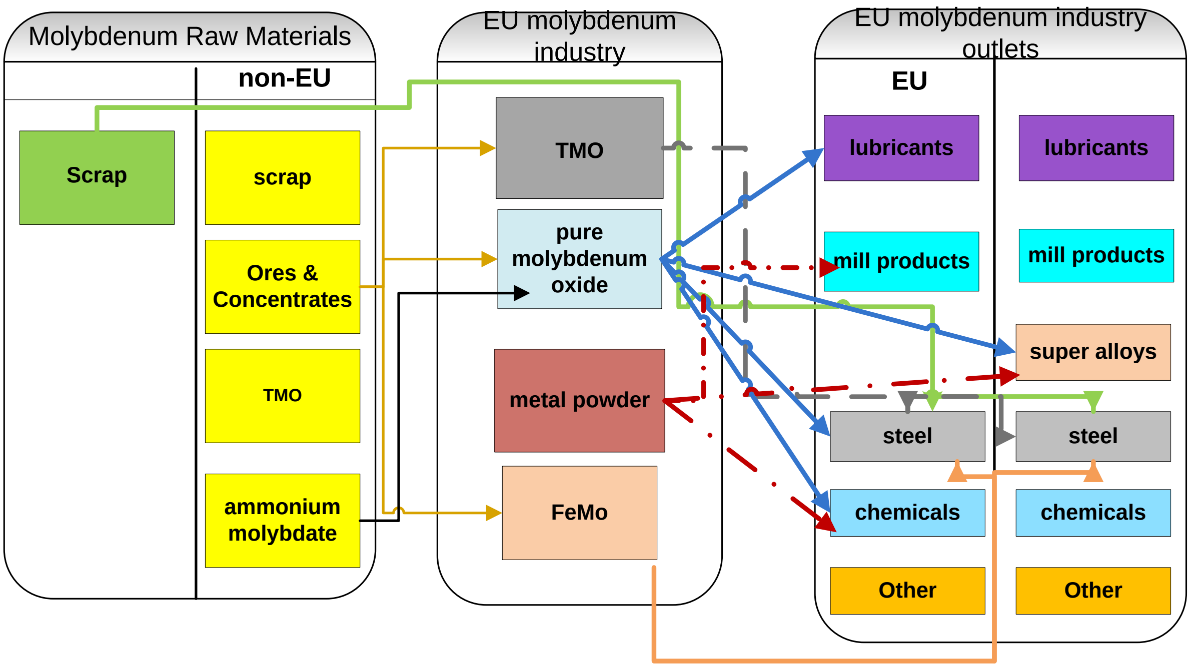
Table 32: World Production and imports to EU of molybdenum, 2010

Country	Production (2010)[a]		Imports to EU (2010)[b]	
	Tonnes	%	Tonnes	%
China	94,000	37.6%	3,589	9.3%
USA	56,000	22.4%	19,678	51.2%
Chile	37,044	14.8%	10,519	27.4%
Peru	24,482	9.8%	94	0.2%
Mexico	10,853	4.3%	2,044	5.3%
Canada	8,447	3.4%	1,028	2.7%
Iran	6,683	2.7%	411	1.1%
Armenia	4,377	1.7%	16	0.0%
Russian Federation	3,760	1.5%	106	0.3%
Mongolia	3,000	1.2%	0	0.0%
Brazil	NA	NA	378	1.0%
Rep. of Korea	NA	NA	185	0.5%
Thailand	NA	NA	125	0.3%
Other countries	1,668	0.7%	285	0.7%
Total	**250,314**	**100.0%**	**38,456**	**100.0%**

Sources: World Mining Data 2012; UN Comtrade

The diagram in Figure 40 illustrates the structure of the EU molybdenum industry.

Figure 40: Summary of the EU molybdenum industry

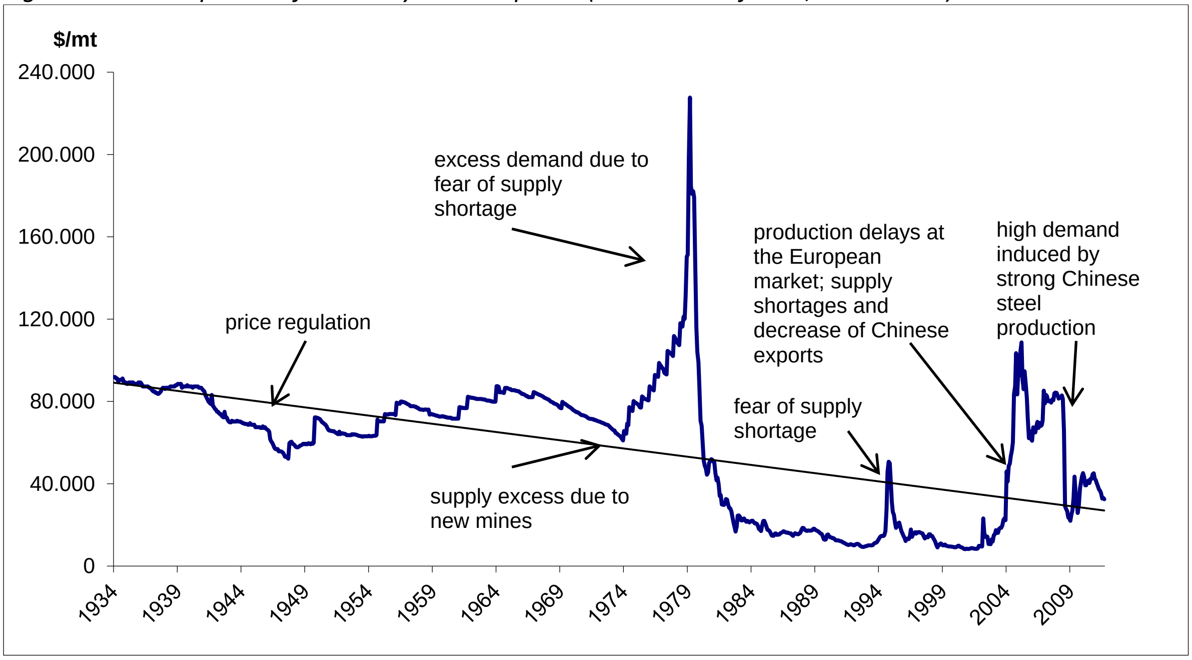


[a] World Mining Data 2012, C. Reichl et al., 2012
[b] UN Comtrade, http://comtrade.un.org/db/, accessed 25th July 2013, Trade codes 261310 (Molybdenum - Molybdenum concentrates, roasted) and 261390 (Molybdenum - Molybdenum ores and concentrates except roasted) – adjusting for factor content.

1.16.3 Economic importance

Figure 41 shows how the different supply and demand situations worldwide influenced molybdenum prices during the last century.[a] There have been several significant price peaks, the highest one in the late 1970s induced by the fear of a supply shortage – which did not eventually happen – and the latest price peak due to high demand for Chinese steel production.

Figure 41: Development of real molybdenum prices (Prices are deflated, 2011 = 100)



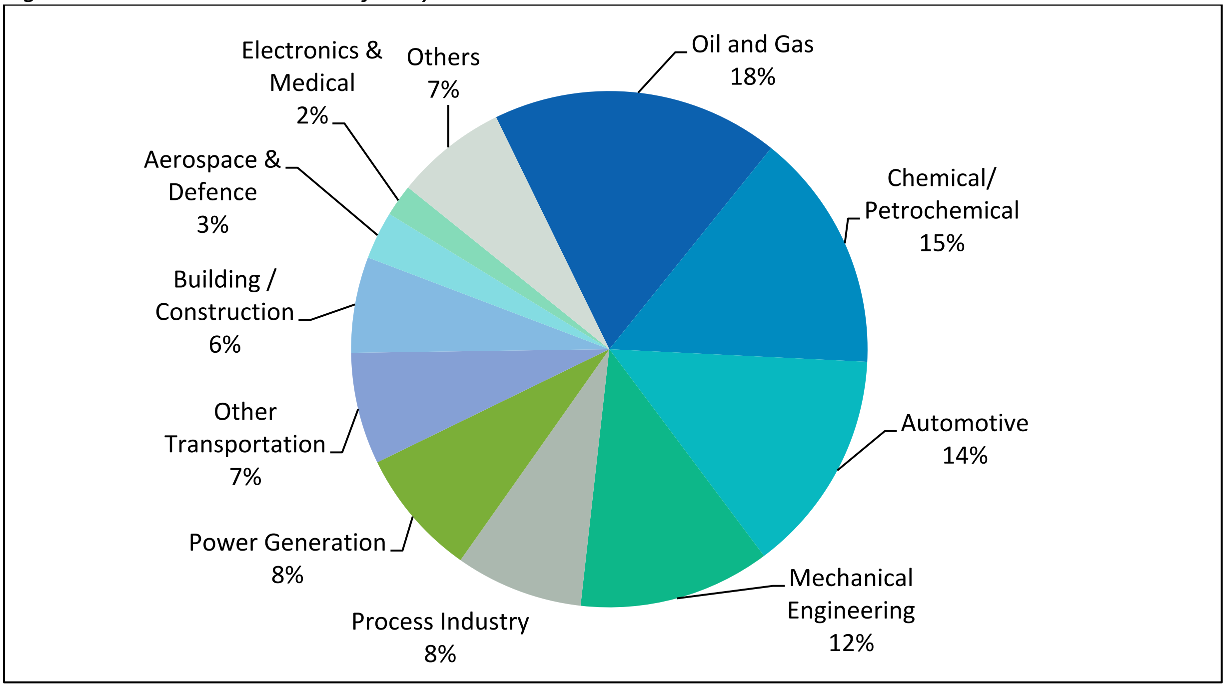
DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen (Causes of price peaks, collapses and trends of mineral raw materials), Hamburg Institute of International Economics (HWWI) in contract for Deutsche Rohstoffagentur (DERA) April 2013,, trend line and translation to English by Fraunhofer ISI

Molybdenum is an increasingly important material in a wide range of applications. Figure 42 shows in which sectors molybdenum is in 2010, these include:[b]

- **Lamp and lighting industries:** support wires, sealing ribbons, dimming caps.
- **Electronics and semiconductor industries:** semiconductor base plates, heat sinks, contact pins, sputtering targets, control grids, klystron and travelling-wave tube components.
- **High-temperature and vacuum furnace construction**: heating elements, thermal radiation shields, furnace ware.
- **Glass and ceramics industries:** glass-melting electrodes, installations in glass production tanks, drawing dies, crucibles for producing sapphire single crystals.
- **Casting technology and metalworking**: forging dies for isothermal forging, extrusion dies, die-casting moulds, hot-galvanizing equipment.
- **Coating**: spray wire, spray powder, evaporation boats, sputtering targets, components of chemical vapour deposition equipment.
- **Nuclear technology:** furnace parts and charging equipment fusion reactors.
- **Medicine:** rotating X-ray anodes, collimators.

[a] DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen. April 2013.
[b] Ullmann's Encyclopedia of Industrial Chemistry: Molybdenum and Molybdenum Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000

Figure 42: Worldwide end-use of molybdenum in 2010



Source: SMR GmbH, Steel & Metals Market Research 2011

1.16.4 Resource efficiency and recycling

Molybdenum is not recovered from scrap steel, but because of the significant recycling of steel alloys, some molybdenum content is reutilized. The amount of molybdenum recycled as part of new and old steel and other scrap is estimated up to 30% of the apparent supply of molybdenum.[a]

In high-temperature applications, molybdenum can be substituted by iron-, nickel- and cobalt-based super-alloys, ceramics, and other high-melting point metals (tungsten, tantalum, and niobium). But, while alternative super-alloys can be used up to 1,200°C, some molybdenum materials show adequate heat resistance and creep properties up to 1,800°C. In addition molybdenum materials have a higher failure tolerance and ductility than ceramics and are less expensive than tantalum and niobium.[b]

1.16.5 Specific issues

China - the world’s largest supplier of molybdenum ores, concentrates and intermediates - has placed restrictions on exports of these materials. A trade dispute is currently underway at the World Trade Organisation on the legality of China's export quota system.

According to the OECD’s inventory on export restrictions, molybdenum waste and scrap is subject to export taxes in Russia (6.5%), to a system of non-automatic export licensing in Algeria and South Africa. There is also a wide range of other countries imposing trade restrictions on molybdenum.

One molybdenum product is present on the REACH SVHC list: lead chromate molybdate sulphate red (C.I. Pigment Red 104).

[a] Mineral Commodity Summaries: Molybdenum, US Geological Survey, 2013
[b] Ullmann’s Encyclopedia of Industrial Chemistry: Molybdenum and Molybdenum Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000

1.17 *Nickel (Niccolum)*

1.17.1 Introduction

Nickel (Ni, atomic number 28) is a silver white metal with typical metallic properties. In nature, it occurs mainly as isotopes of mass number 58 (68%) and 60 (26%). Further stable isotopes are of mass number 61, 62 and 64. Nickel alloys are characterised by strength, toughness and corrosion resistance over a wide temperature range. For instance, nickel-containing alloys played a key role in the development of materials for the aerospace industry and are essential to the iron and steel industry.[a]

1.17.2 Supply and demand statistics

Nickel deposits of economic importance occur in magmatic sulphides and laterites. Nickel concentrations of sulphide ores, which are the main source of mined nickel at present, range from 0.15% to around 8% nickel, but 93% of known deposits are in the range 0.2-2% nickel. The most important nickel sulphide mineral is pentlandite, which occurs mainly in iron- and magnesium-rich igneous rocks in Russia, South Africa, Canada and Australia. Lateritic ores, with an average nickel content of 1-1.6%, are formed by (sub-)tropical surface weathering. Their main nickel-bearing minerals are garnierite and nickeliferous limonite, occurring in New Caledonia, Australia, the Philippines, Indonesia, Colombia and Greece.[b]

According to USGS data, the vast majority of nickel reserves are found outside the EU, most notably in Oceania (Australia and New Caledonia), the Americas (mainly Brazil, Cuba and Canada) and Russia (table 33). The reserves in New Caledonia, representing a quarter of the world total, are part of French territory.[c] The known world reserves of nickel are adequate to maintain this level of production for approximately 40 years.

Table 33: Global reserves of nickel

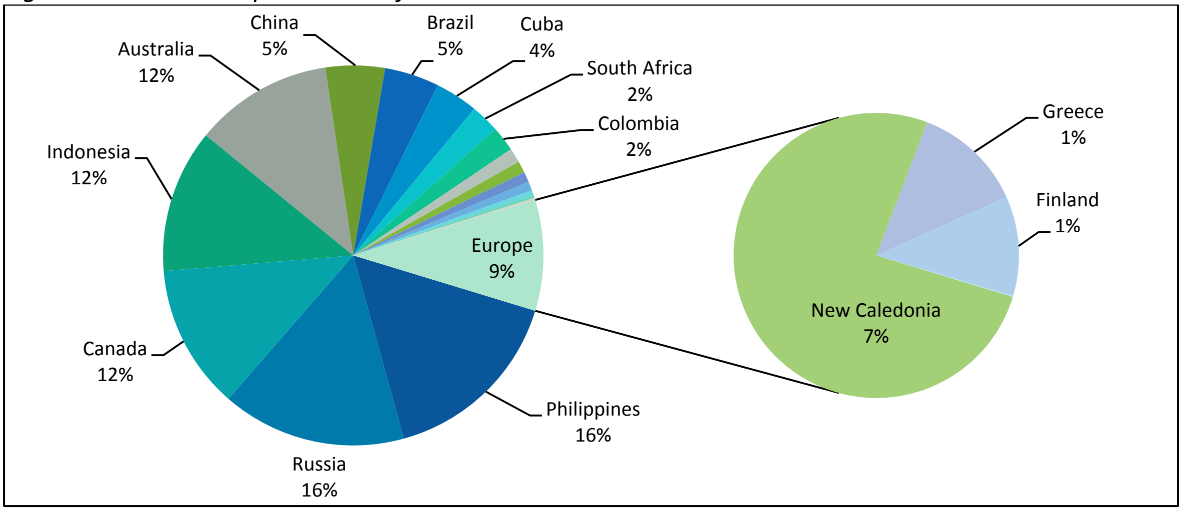
Country	Reserves (tonnes)	Country	Reserves (tonnes)
Australia	20,000,000	Madagascar	1,600,000
Botswana	490,000	New Caledonia	12,000,000
Brazil	7,500,000	Philippines	1,100,000
Canada	3,300,000	Russia	6,100,000
China	3,000,000	South Africa	3,700,000
Colombia	1,100,000	USA	7,100
Cuba	5,500,000	Other	4,600,000
Dominican Republic	970,000	**Total**	**75,000,000**
Indonesia	3,900,000		

Source: USGS (2013), Mineral Commodity Summaries 2013, Nickel

Between 1994 and 2011, world production doubled from 0.9[d] million tonnes to almost 1.8[e] million tonnes. The Philippines along with Russia are the largest world producers, followed by Canada, Indonesia and Australia. EU mine production including New Caledonia[f] accounts for 9.4% of the total worldwide nickel production, shown in Figure 43.

[a] Ullmann's Encyclopedia of Industrial Chemistry: Nickel, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[b] Commodity Profiles: Nickel, British Geological Survey, September 2008
[c] Mineral Commodity Summaries: Nickel, US Geological Survey, 2013
[d] Mineral Commodity Summaries: Nickel, US Geological Survey, 1996
[e] Raw Materials Data, Intierra Resource Sector Intelligence, 2013
f New Caledonia is a French overseas territory, see http://ec.europa.eu/europeaid/where/octs_and_greenland/

Figure 43: Worldwide production of nickel in 2011



Source: Raw Materials Data by Intierra

Table 34: World production and imports to EU of nickel, 2011

Country	Production[a]		Imports to EU [b]	
	tonnes	%	tonnes	%
Philippines	286,000	16.0%	0	0.0%
Russia	280,000	15.7%	0	0.0%
Canada	219,600	12.3%	30,221	27.1%
Indonesia	218,000	12.2%	165	0.1%
Australia	210,000	11.8%	0	0.0%
China	90,000	5.0%	0	0.0%
Brazil	83,000	4.6%	13,535	12.1%
Cuba	65,000	3.6%	-	-
South Africa	44,000	2.5%	51,904	46.5%
Colombia	37,900	2.1%	-	-
Mozambique	NA	NA	13,088	11.7%
Norway	200	0.0%	2,195	2.0%
USA	NA	NA	254	0.2%
Saudi Arabia	NA	NA	223	0.2%
Malaysia	NA	NA	40	0.0%
Mexico	NA	NA	21	0.0%
Other countries	252,600	14.1%	53	0.0%
Total	**1,786,300**		**111,699**	

Sources: Intierra (2013), Raw Materials Data 2013; UN Comtrade

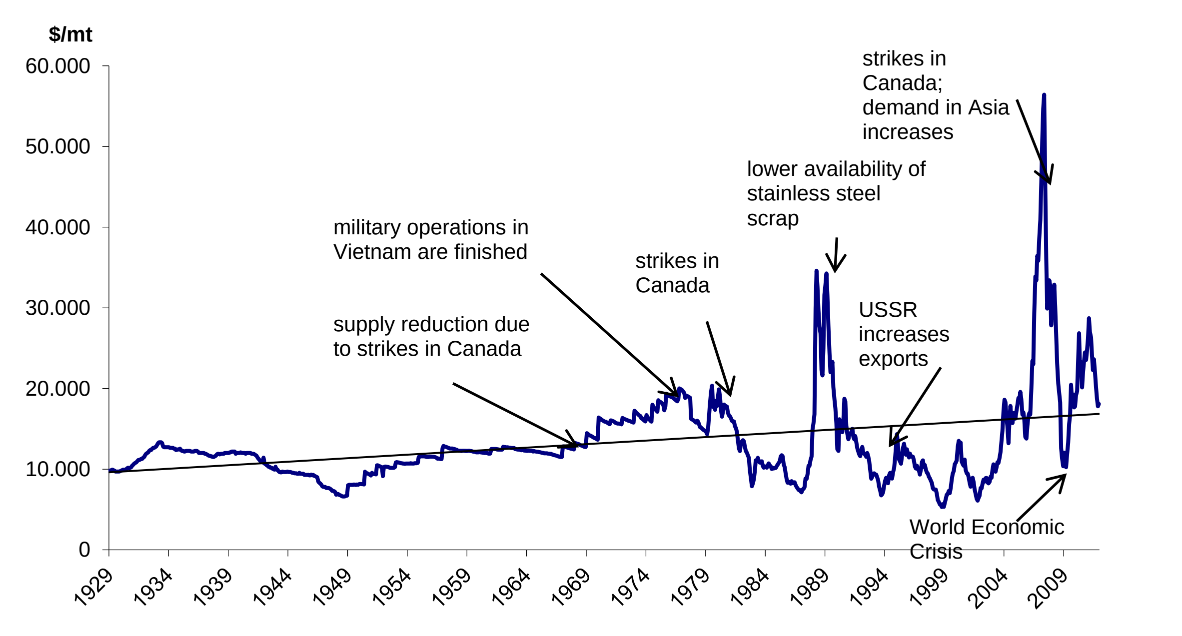
Table 34 shows the data for nickel imports to the EU in 2011. According to Comtrade data, by far the largest quantity of nickel imported by the EU was exported by South Africa; the Philippines, the Russian Federation, Canada, Indonesia, and Australia are the leading producers of nickel worldwide.

[a] Raw Materials Data 2013
[b] UN Comtrade, http://comtrade.un.org/db/, accessed 25th July 2013, Trade code 260400

1.17.3 Economic importance

Figure 44 shows how the different supply and demand situations worldwide influenced nickel prices during the last century.[a] Prices had been overall rising during that period, but price peaks had been induced or increased several times by strikes in Canada – with the last strong price peak induced by both strikes in Canada and a high demand in Asia.

Figure 44: Development of real Nickel prices (Prices are deflated, 2011 = 100)



Source: DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen (Causes of price peaks, collapses and trends of mineral raw materials), Hamburg Institute of International Economics (HWWI) in contract for Deutsche Rohstoffagentur (DERA). April 2013, trend line and translation to English by Fraunhofer ISI

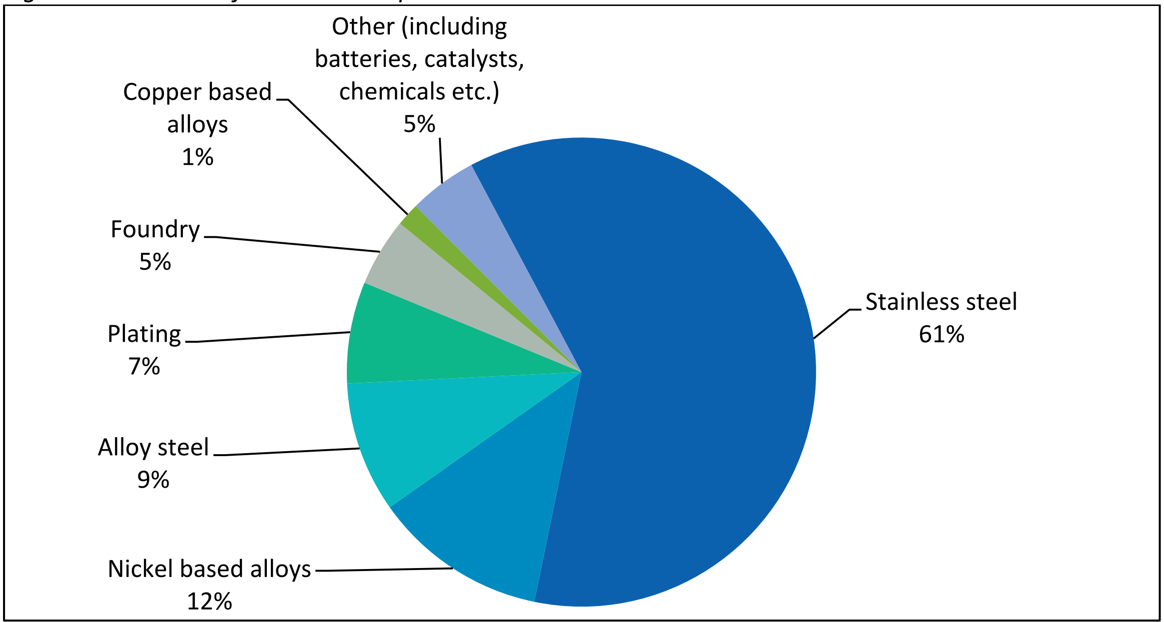
Short explanations of selected end-uses are given below[b], with relative market shares for these applications shown in Figure 45:

- **Stainless steel**: Nickel increases stainless steel's strength, toughness and ability to be hardened. The addition of nickel (8-10%) prevents the conventional cooling behaviour of carbon steel, changing from austenitic to a mixture of ferrite and cementite and results in the most important class of corrosion- and heat-resistant steels.
- **Other steel alloys:** About 10% of nickel is used in other steel alloys to improve the hardness, malleability and closeness of grain. Nickel-iron alloys also have very useful low expansion characteristics which make them well suited for applications where extreme temperatures are required.
- **Non-ferrous alloys:** Around 12% of nickel is used in non-ferrous alloys. The most common, cupronickel, is used extensively in coins to improve corrosion resistance. Its adjustable electrode potential enables seawater resistance, most important in the marine industry and for desalination plants. Other non-ferrous alloys are nickel-titanium memory alloys which can revert back to their original shape without undergoing plastic deformation under stress and super-alloys for power generation, aerospace and military applications.
- **Plating:** Thin layers of nickel are used in plating to increase corrosion resistance, especially in medical equipment, construction materials and cosmetic applications such as cutlery and domestic fittings. Nickel plating is also used in the manufacture of computer hard discs and optical storage media.
- **Foundry:** Foundry products include nickel castings for pumps, valves and fittings.

[a] DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen. April 2013.
[b] Commodity Profiles: Nickel, British Geological Survey, September 2008

- Beside its application in batteries, nickel is used in a wide range of chemical processes, including hydrogenation of vegetable oils, reforming hydrocarbons and production of fertilisers, pesticides and fungicides.

Figure 45: End-use of nickel in Europe in 2010



Source: Nickel Institute, 2012

A socio-economic study of nickel in the EU[a] finds that nickel is an "enabling technology", not simply an important primary material. In the past its particular properties pushed developers to new products, industries and new user benefits, with enhanced performance in a wide range of advanced manufacturing sectors. Using the widest definition of the impact of nickel on the EU economy, the total value added by the nickel industry and its value chain is estimated to be in excess of 80-100 billion Euro, of which around 50 billion Euro is estimated to be generated by industries and applications that are critically dependent on nickel. The nickel value chain also supports a large number of mostly high-skill manufacturing jobs, estimated to be in the order of 1.25-1.50 million. Of this, an estimated 690,000 jobs in the EU are critically dependent on nickel. Nickel and nickel-based platform technologies also contribute additional benefits to the EU and its citizens that are often not apparent to policy-makers and the general public. Nickel compounds, for instance, play an important role in underpinning the competitiveness of major industrial and service sectors such as aerospace, automotive, oil refining, and optical media. Economic efficiency and innovation across large parts of the EU's economy, and the achievement of European environmental goals are based on a noncritical nickel supply.

1.17.4 Resource efficiency and recycling

The corrosion resistance of nickel makes it suitable for recycling and its high price provides a significant incentive for these activities. Refining processes of stainless steel take into account the use of recycled material, including steels, high-nickel alloys, mixed turnings, waste from primary nickel producers and re-melted ingot from processing nickel-containing slags, dusts, batteries etc. Although special alloys are recycled as mono-material wherever possible, in practice different alloys and products may get mixed and blending processes are used to maintain quality.[b] For the USA a share of 43% in the total nickel consumption is reported for recovered nickel.[c]

[a] The socio-economic impact of the nickel industry: A baseline analysis, Final Report, The Weinberg Group LLC, 2004

[b] Commodity Profiles: Nickel, British Geological Survey, September 2008

[c] Mineral Commodity Summaries: Nickel, US Geological Survey, 2013

The options for substitution of nickel are very limited. Even if stainless steels and other nickel alloys can be substituted with plastics, and nickel content may be reduced using nickel-coated steel rather than stainless steel, any substitution ultimately results in a reduction in performance. The replacement of some super-alloys with ceramics in certain applications is still under research. The significant increase in nickel price in 2007 forced many steel producers to lower their nickel use by converting low-grade laterite ore to nickel pig iron (a low grade alternative to nickel metal). Also steels with higher chromium and manganese contents enable to production of low-nickel alternatives.[a]

Table 35: Substitutability scores for nickel

Use	Substitutability score
Electroplating	1
Nonferrous alloys and superalloys	0.7
Stainless and alloy steel production	1.

1.17.5 Specific issues

Several countries have restrictions concerning trade with nickel. According to the OECD´s inventory on export restrictions, Russia uses export taxes on unwrought nickel and nickel alloys as well as on nickel waste and scrap. The Philippines has a licensing agreement on trade with nickel ores and concentrates. There is also a wide range of other countries imposing trade restrictions on nickel.

[a] Commodity Profiles: Nickel, British Geological Survey, September 2008

1.18 Perlite

1.18.1 Introduction

Perlite is a generic term for naturally occurring siliceous rock. A volcanic glass, it has a relatively high water content, generally formed by the hydration of obsidian, a black volcanic glass. Its distinguishing feature is that when heated to a certain point in its softening range, it expands by four to twenty times its original volume. This is due to the high water content- typically between 2% and 6% in crude perlite. When heated quickly to above 1,600°F (871°C), the water vaporizes and creates countless tiny bubbles, which causes the crude rock to 'pop' in a similar manner to popcorn. These bubbles are what account for expanded perlite's light weight and exceptional physical properties (it is fireproof, has a low density, non-toxic, and is an excellent insulator).

Perlite usage is typically focused on the construction industry, with its usage being highly dependent on the level of activity in this area. Perlite consumption (and also production) has reduced slightly in recent years; however, the USGS notes that this has started to recover, and expects the upward trend to continue as the global economy recovers.[a]

1.18.2 Supply and demand statistics

According to the USGS, Greece and the USA are the two largest producers of perlite globally, with a combined production of 920,000 tonnes in 2011- over 50% of known world supply (Table 36).

Table36: World production of perlite, 2011

Country	2011 Production (tonnes)	Percentage
Armenia	35,000	2.0%
Georgia	45,000	2.5%
Greece	500,000	28%
Hungary	65,000	3.7%
Iran	30,000	1.7%
Italy	60,000	3.4%
Japan	300,000	17%
Mexico	30,000	1.7%
Slovakia	25,000	1.4%
Turkey	250,000	14%
USA	420,000	24%
Other	14,200	0.8%
Total	**1,770,000**	

USGS; Minerals Yearbook 2011

Because of unreliable data, reserve statistics are not included, although the USGS estimates US and Greece reserves to be approximately 50,000,000 tonnes each. These statistics do not include all major producing countries; the USGS notes that China (excluded due to a lack of reliable information) was probably the leading or second ranked producer in the world in 2011.

For EU imports, the most recent statistics- 2006- show the EU as importing 18,500 tonnes of Perlite, mostly from Turkey. Beyond this, it is in a relatively stable position in terms of perlite, with Greece,

[a] www.perlite.net, http://www.perlite.org/library-perlite-info/industrial-perlite/Perlite-for-Formed-Products.pdf

Hungary, Italy and Slovakia all being major producers of Perlite. Additionally, Turkey, USA and Japan are all major EU trade partners and key producers of Perlite.

1.18.3 Economic importance

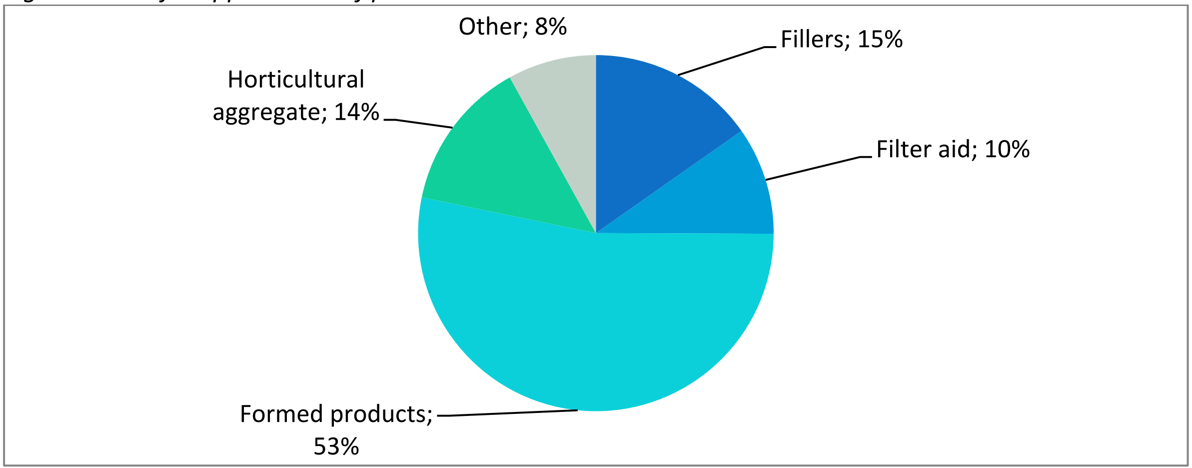
Usage statistics for perlite are difficult to come by, and distinguishing between expanded and non-expanded perlite is an issue. The USGS provides use statistics for perlite in the USA and by application (Table 37).

Table37: Applications of perlite for the USA, 2012

Use	Sub-use[a]	Quantity (tonnes)[a]	Percentage[a]
Construction	Concrete aggregate	3,550	1%
	High-temperature insulation	5,690	1%
	Low-temperature insulation	1,930	0%
	Masonry- and cavity-fill insulation	1,530	0%
	Plaster aggregate	3,290	1%
Formed products	Formed products	251,000	53%
Horticulture	Horticultural aggregate	64,800	14%
Industry	Filter aid	46,200	10%
	Fillers	72,100	15%
Other	Other	1,740	0%
	Unspecified	23,800	5%
Total		475,000	

Source: USGS

Figure 46: Major applications of perlite[a]



Source: USGS

- **Formed products**: Perlite's biggest use is formed products, accounting for over half of all perlite usage in the USA. These include ceiling tiles, pipe insulation, fire doors and roofing boards.
- **Construction**: Perlite is used as loose-fill insulation in construction. It is useful in providing thermal and sound insulation, improving fire safety and reducing rot. Other uses of perlite in construction include as an aggregate in concrete.
- **Horticultural**: Perlite is used worldwide as a component of soilless growing mixes, as it provides aeration and excellent moisture retention.

[a] USGS, Minerals Yearbook 2011

- **Industry**: Perlite has a wide range of industrial applications, from high performance fillers for plastics to cements for petroleum, water and geothermal wells. Among further uses, it is also used as a filter media for pharmaceuticals, and an abrasive in soaps. [a]

1.18.4 Resource efficiency and recycling

The government of New South Wales, Australia, states several established substitutes for various uses of perlite (Table 38).

Table 38: Summary of alternatives to perlite

Use	Substitute	Substitutability score
Animal feed Supplement	Bentonite, sepiolite, vermiculite, zeolite	0.3
Filler	Barite, calcite, feldspar, kaolin,mica, nepheline syenite, pyrophyllite, silica, talc, wollastonite	0.5
Fire retardant	Antimony oxide, asbestos, borates, bromine, chromite, diatomite, magnesite, magnesia, phosphates, pumice, vermiculite	0.5
Filter media	Activated carbon/anthracite, asbestos, cellulose, diatomite, garnet, ilmenite, magnetite, pumice, silica sand	0.3
Foundry	Bauxite and alumina, chromite, kaolin, olivine, pyrophyllite, silica sand, vermiculite, zircon	0.3
Lightweight aggregate	Expanded clay, pumice, vermiculite, zeolite	0.3
Soil additive/amendment	Bentonite/kaolin, diatomite, gypsum, peat, vermiculite, zeolite	0.3
Thermal or sound insulator	Asbestos, brick calys, diatomite, foamed glass, cement, mineral wool, pumice, vermiculite, wollastonite, zeolite	0.3

Source: Perlite, NSW Department of Primary Industries

Pumice, diatomite, expanded clay and shale are perhaps the key substitutes, which can be used in place of perlite in a number of applications without losing any benefits. [b]

1.18.5 Specific issues

There are no known trade restrictions or taxes on perlite.

a www.perlite.net, http://www.perlite.org/library-perlite-info/industrial-perlite/Perlite-for-Formed-Products.pdf, accessed May 2013
b http://www.mineralseducationcoalition.org/minerals/perlite, accessed May 2013

1.19 *Potash*

1.19.1 Introduction

The term potash includes a variety of salts which contain potassium in a water-soluble form; it includes both mined and manufactured salts. Potassium is one of the three primary plant nutrients essential for plant growth and maturation with fixed nitrogen and soluble phosphorus. Potash is mainly used as a fertiliser. Its demand is strictly correlated to population growth and food demand, therefore production and consumption of potash will continue to rise.

1.19.2 Supply and demand statistics

Potassium is one of the most abundant elements, constituting around 2.4% by weight of the Earth's crust. Production of potassium compounds derives principally from the extraction from underground ores. Exceptions are operations in the Dead Sea and in the Great Salt Lake. The four principal commercial sources are sylvite, carnalite, kainite and langbeinite. Sodium chloride is the principal source of contamination.[a]

Three potassium salts are mainly recovered from the ores: potassium chloride (or sylvite) which accounts for 98% of production, potassium sulphate (SOP) and potassium-magnesium sulphate (SOPM). Muriate of potash (MOP) is a mixture of potassium chloride (95%) and sodium chloride that is used as a fertiliser; this also contains trace amounts of other minerals from the mined ore.[b].

Most potassium chloride is extracted from underground ores occurring between 300-1700m below ground. The ore is extracted using conventional mining methods similar to those employed for coal. Deposits exceeding 1100m depth are extracted by solution mining. In countries with favourable climatic conditions potassium chloride is produced by solar evaporation. The brines are pumped to evaporation ponds where solar energy is used to dry the substance under controlled conditions.[a]

The world's major producer of potash is Canada (Table 39), followed by Belarus and Russia. Europe produces approximately 11% of worldwide supply. China and the USA are also major producers. In 2011, the European Union cut import duties on import of potash from Russia and Belarus after almost 20 years since implantation; these duties were as high as 27.5%.[c] They were introduced in 1993 as anti-dumping measures. As can be seen from Table 39world reserves are plentiful. The USGS estimated world resources total about 250 billion tonnes.[d]

a Freilich et al. (2005), Potassium Compounds. Kirk-Othmer Encyclopedia of Chemical Technology.
b USGS (2012), Minerals Yearbook 2010, Potash
c Reuters (2011), EU cuts import duties on potash from Russia, Belarus. http://www.reuters.com/article/2011/07/13/eu-trade-potash-idUSLDE76C10Z20110713 [Accessed February 2013]
d Source: USGS (2013), Mineral Commodity Summaries 2013, Potash

Table 39: World production of marketable potash (thousand tonnes of potassium oxide equivalent), 2011 & 2012(estimate)[a]

Country	Mine Production		Reserves
	2011	2012[1]	
Belarus	5,500	5,650	750,000
Brazil	454	460	300,000
Canada	11,000	9,000	4,400,000
Chile	980	900	150,000
China	3,700	3,900	210,000
Germany	3,010	3,000	140,000
Israel	1,960	1,900	40,000[2]
Jordan	1,380	1,400	40,000[2]
Russia	6,500	6,500	3,300,000
Spain	420	425	20,000
United Kingdom	427	430	22,000
USA	1,000	900	130,000
Other	-	-	50,000
Total	**36,331**	**34,465**	**9,552,000**

Source: USGS
[1] Estimated
[2]Total reserves in the Dead Sea are arbitrarily divided equally between Israel and Jordan for inclusion in this tabulation.

World production of potash experienced a strong reduction in 2009 during the financial crisis. It saw recovery in 2010; in 2011 it was reported that production was back to pre-crisis levels. In 2012 however, demand was reduced once again. The Food and Agriculture Organization (FAO) and the International Fertilizer Industry Association (IFA) forecasted 2012 supply at 40 million tonnes earlier in 2012; however USGS estimated that approximately 34 million tonnes (see Table 39) were produced at the end of the year.[b] This was lower than forecasted because of weak demand for potash from India and China, the Euro zone crisis and US droughts. China and India postponed 2012 purchases of fertilisers and consumption in these countries was lower than expected, strongly affecting demand. [c]

Many companies had to reduce their production as expected demand did not materialise. For example, at the end of 2011, the world's potash leading producer, PotashCorp, temporarily closed two mines in Canada due to poor potash demand. Further production cuts were announced later in the year; these included a scheduled closure between December 2012 and February 2013 at their potash mine in the UK.[d]

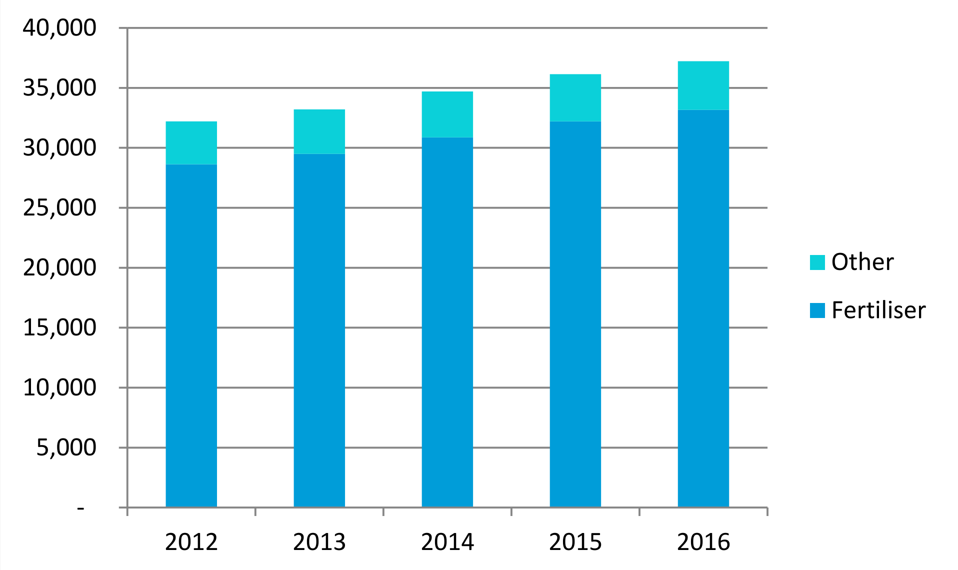
In order to cope with future demand increase, several new mining projects are currently being undertaken. IFA reported that capacity is estimated to increase from 43.3 million tonnes in 2011 to 61.4 million tonnes in 2016; this would constitute a 40% increase.[e] According to USGS, in 2011, 170 new projects were under development worldwide. These are expected to be completed between 2017 and 2020. Out of these 45 were from leading producers, 75 from smaller companies, and 50 still in the exploration phase.[f] Around half of the capacity increment is likely to be in North America and 32% from

[a] USGS (2013), Mineral Commodity Summaries 2013, Potash
b FAO (2012), Current world fertilizer trends and outlook to 2016; IFA (2012), Fertilizer Outlook 2012-2016. 80th IFA Annual Conference, Doha
c Industrial Minerals (2013), Year in Review 2012: Potash
d Industrial Minerals (2012), PotashCorp announces further mine closures in Canada
e IFA (2012), Fertilizer Outlook 2012-2016. 80th IFA Annual Conference, Doha
f USGS (2012), Minerals Yearbook 2010, Potash

32% in East Europe & Central Asia.[a] The majority of the projects were located in Argentina, Belarus, Brazil, Canada, Chile, China, Congo (Brazzaville), Eritrea, Ethiopia, Laos, Mexico, Peru, Kazakhstan, Russia, Turkmenistan, UK, and Uzbekistan. The majority of this new capacity will be in the form of MOP.[b]

World demand for potash demand was estimated at 32 million tonnes. As can be seen in Table , this is below the expected total supply. Demand is forecasted to grow in the future as world population increases and living standards improve. Even though demand from China was poor in 2012, potash purchases are expected to increase.[c] A forecast of demand growth can be seen in Figure 47; a compound annual growth rate (CAGR) of 3.75% is expected. Major increase in demand is expected in Asia, with a CAGR of 5.79% compared to 2.03% in Europe.[d]

Figure 47: Estimated future potash demand (million tonnes of potassium oxide equivalent)



Source: FAO (2012), Current world fertilizer trends and outlook to 2016

It is thought that the new projects described above will result in the risk of over-supply of potash. Supply/demand balance estimates from IFA are shown in; Table 40 the industry could face a potential of 7.4 million tonnes over supply between 2013 and 2016. Large companies such as PotashCorp are confident that there is no risk and expect that demand could dramatically increase to 56-60 million tonnes in 2013. However, following recent events, such as PotashCorp mine closures and reductions on potash production, show that over-supply is a distinct possibility.

Table 40: World potash supply/demand balance (million tonnes of potassium oxide equivalent)

		2013	**2014**	**2015**	**2016**
Supply	**Capacity**	49.8	52.7	58.4	61.4
	Total supply	43.5	45.7	48.6	54.8
Total demand		33.8	34.8	35.7	36.6
Potential balance		**6.3**	**7**	**9.8**	**6.6**

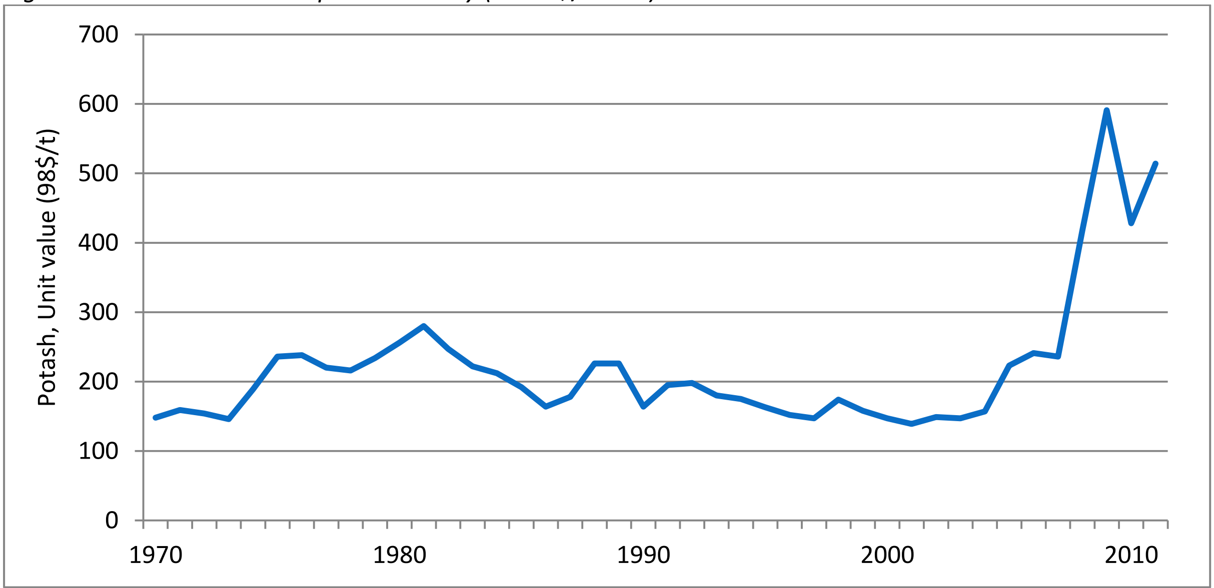
Sources: IFA (2012), Fertilizer Outlook 2012-2016. 80th IFA Annual Conference, Doha

a IFA (2012), Fertilizer Outlook 2012-2016. 80th IFA Annual Conference, Doha
b USGS (2013), Mineral Commodity Summaries 2013, Potash
c Industrial Minerals (2013), IM 2012 Round-ups: Potash
d FAO (2012), Current world fertilizer trends and outlook to 2016

1.19.3 Economic importance

Potash prices have experienced a steep increment in price since 2008. High potash prices combined with the global economic crisis led to a collapse in the market. These conditions followed throughout 2009. Lower consumption led to an increase in producers' stocks, and many buyers waited for prices to fall before re-entering the market.[a] This has also resulted in producers reducing their annual production. In 2012 prices remained high and major markets such as India delayed purchases and putting downwards pressure on prices.[b]

Figure 48: Potash historical price volatility (98 US$/tonne).



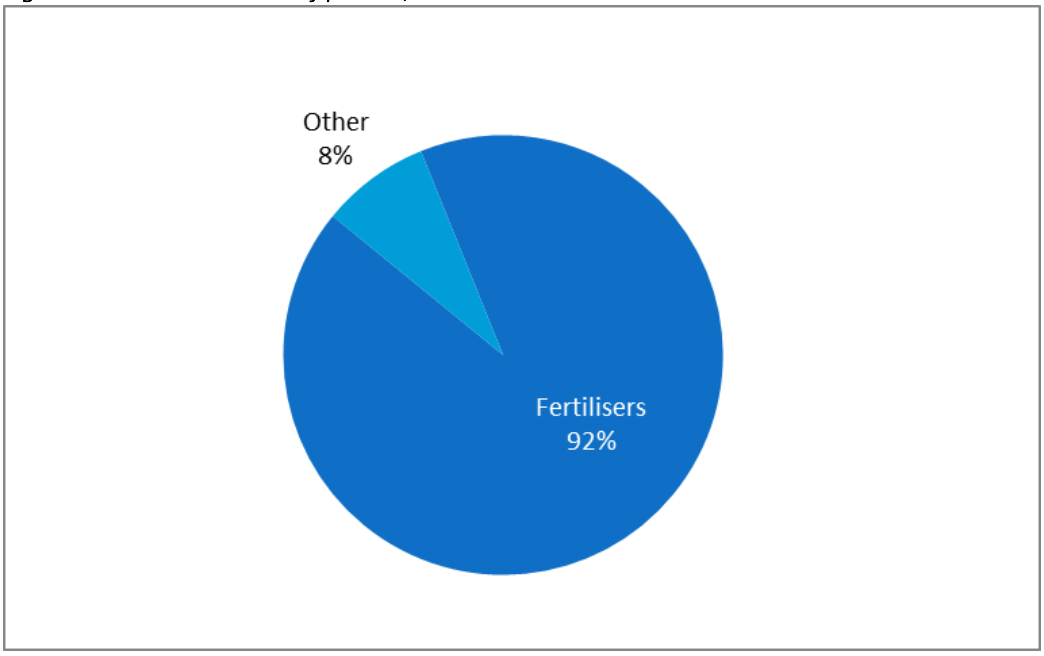
Source: USGS (2012-), Historical Statistics for Mineral and Material Commodities in the United States [accessed February 2013]. Figures are indexed to 1998 values.

The principal use of potash is as a source of potassium in fertilisers. As shown in Figure 49, 92% of potash is used for this application according to the USGS. Potassium is one of three essential nutrients for plant growth; potash provides a soluble source which is easily applicable and cheap. It is essential in determining the osmotic pressure of plant fluids; plants with low potassium have inefficient water use. Specifically potassium nutrition has been associated with increased yields, fruit size, improved fruit colour, increased shelf life and shipping quality.[c] Potash can be applied as a solid single-nutrient fertiliser or as a multi-nutrient fertiliser.[d]

Other uses of potash are in the form of potassium chloride or potassium hydroxide. The former is used in aluminium recycling to produce potassium hydroxide, in metal electroplating, oil-well drilling mud and in snow and ice melting. Potassium hydroxide is used as a precursor for other potassium chemicals and for soap manufacturing. Potassium carbonate is used to produce animal feed supplements, cement, fire extinguishers, food products, textiles, and as a catalyst for synthetic rubber manufacturing.[e]

a USGS (2011), Minerals Yearbook 2009, Potash
b Industrial Minerals (2013), IM 2012 Round-ups: Potash
c Lester et al (2010), Impact of Potassium Nutrition on Food Quality of Fruits and Vegetables: A Condensed and Concise Review of the Literature. Better Crops, Vol.94.
d Scherer et al. (2009), Fertilizers, 1. General. Ullmann's Encyclopedia of Industrial Chemistry
e USGS (2013), Minerals Yearbook 2011, Potash

Figure 49: Worldwide use of potash, 2011



Source: USGS (2013), Minerals Yearbook 2011, Potash

1.19.4 Resource efficiency and recycling

There is no evidence of potash recycling; this is unlikely given fertilisers are dispersed during use.

Potash is one of the three major plant nutrients and has no cost-effective substitutes (Table 41). Some alternatives such as animal manure, bone meal, compost and glauconite are available however these have lower nutrient content. These have high cost of transportation per tonne of nutrient beyond relatively short distances.[a]

Table 41: Available substitutes for potash

Use	Substitutability score
Fertilisers	0.3
Others	0.5

[a] USGS (2013), Minerals Yearbook 2011, Potash

1.20 Rhenium

1.20.1 Introduction

The greyish white metal rhenium (Re, atomic number 75) was the last naturally occurring element to be discovered, in Germany in 1925. It is one of the rarest elements in the Earth's crust, with an average concentration estimated at 0.001 parts per milliona. It has been in demand primarily since the 1950s, when tungsten-rhenium and molybdenum-rhenium alloys were prepared, and found important applications in industry, primarily due to its exceptional high temperature properties. The main current uses of rhenium are in platinum-rhenium catalysts, used for producing lead-free, high octane gasoline, and in high-temperature super-alloys in jet engines.

1.20.2 Supply and demand statistics

Rhenium is produced primarily as a by-product of copper-molybdenum deposits, and thus its market dynamics are driven by this by-product status. The world's largest producer of copper, Chile, is also the world's largest producer of rhenium, responsible for over 50% of world production (this does, however, include the processing of concentrates from elsewhere). Mine production has been relatively static, remaining around 50 tonnes for the last five years (Table 42).

Table42: World production and reserves of rhenium, 2011 and 2012 (estimated)[b]

Country	Mine production (Kg)*		2011 Production as%	Reserves (tonnes)	Reserves %
	2011	2012e			
Armenia	600	600	1%	95	3.8
Canada	-	-	-	32	1.3
Chile[#]	27,000	27,000	53%	1,300	52
Kazakhstan	3,000	3,000	6%	190	7.6
Republic of Korea	500	500	1%	NA	-
Peru	-	-	-	45	1.8
Poland	6,000	6,200	12%	NA	-
Russia	500	500	1%	310	12.4
USA	8,610	9,400	17%	390	15.6
Uzbekistan	3,000	3,000	6%	NA	-
Other countries	1,500	1,500	3%	91	3.6
World total	**50,700**	**52,000**		**2,500**	

Source: USGS
**Estimated amount of rhenium recovered in association with copper and molybdenum production.*
#Estimated rhenium recovered from roaster residues from Belgium, Chile, and Mexico

There are two main processes that produce rhenium. The first (and dominant) process is through roasting the molybdenum concentrates from porphyry-copper ores. Some of the by-product molybdenite concentrates from copper mines contain small quantities- <0.1% - of rhenium. The second is the roasting of molybdenum sulphide. This produces molybdenum trioxide, and can lead to the recovery of rhenium through treatment of flue gases. However, the minimum average rhenium concentration in the MoS_2 for this to be viable is around 250g/t.

The main producer within the EU is Poland, responsible for just under 10% of global production. Approximately 3.5 tonnes of this comes from KGHM Ecoren, which claims to be the sole European

[a] http://www.rsc.org/periodic-table/element/75/rhenium
[b] USGS (2013), Mineral Commodity Summaries 2013

producer of ammonium perrhenate from its own resources, using a new rhenium facility near Legnica, Poland. This claim can also be seen as implying that the remaining 1.2 tonnes produced in Poland (and any other EU production) is reliant on external sources of rhenium.[a]

The world's largest rhenium producing company is thought to be the Chilean company Molymet, which is, according to Polish company KGHM Ecoren, responsible for over 50% of global output (approximately 27 tonnes). Other known major producers of rhenium are KGHM Ecoren and copper company Codelco. There are two notable Rhenium projects thought to be on the near horizon:

- Rio Tinto is also developing a Molybdenum Autoclave Process facility near Bingham Canyon. This uses pressure oxidation in an autoclave, purification and crystallization to produce molybdenum products from lower-grade concentrate. This is scheduled for 2014[b]) and reportedly could potentially increase US Rhenium production by over 50% (4 million tonnes). Rio Tinto expects Phase 1 (2012) to produce 30mlbs of molybdenum, and Phase 2 (2015) to have a capacity of 60m lbs.[c]
- Ivanhoe Australia claims to have reserves of 160 million tonnes rhenium at their Merlin site, contained in a molybdenum-rhenium mineralized zone. The rhenium has an average grade of 23 g/t (meaning it can, as Ivanhoe claims, be mined solely for rhenium, rather than as a by-product). They expect to produce 7.5 million tonnes each year, although it is not clear when Merlin will start production[d].

1.20.3 Economic importance

Within the USA, consumption of rhenium in 2011 was approximately 42 tonnes, an increase of just over 2 tonnes from 2010.[e] There is no government stockpile, and over 80% of this is imported (mostly from Chile). Use of rhenium is linked to high value applications, where alternatives are not available (Table 43).

Table43: Major applications of rhenium

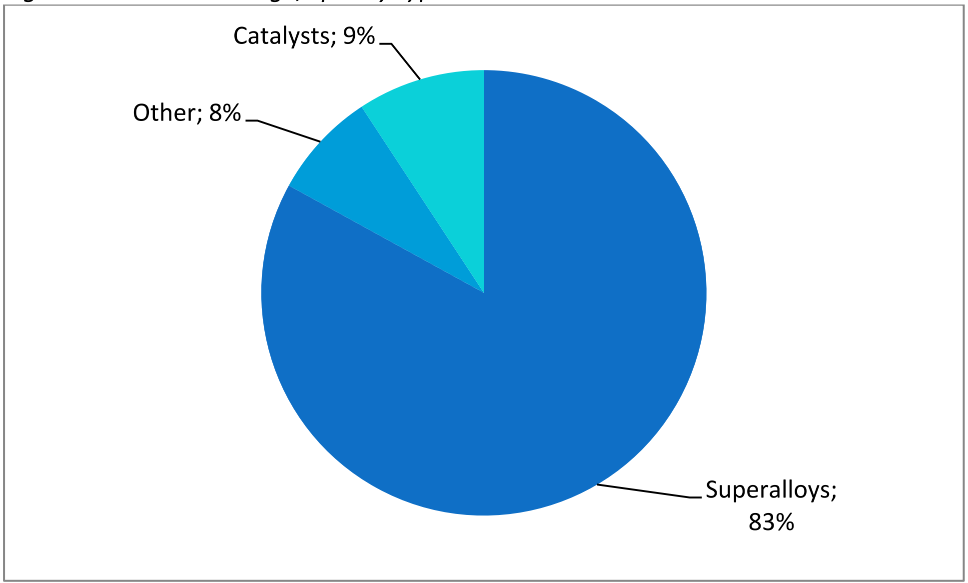
Use, 2011 (%)	
Aerospace	63%
Gas Turbines	13%
Catalysts	9%
Auto	5%
Tools	2%
Oil/gas	2%
Other	7%

Sources: Lipmann A (2011), MMTA Metal Statistics – Rhenium, Roskill (2007), Economics of Rhenium; 7th Edition

Broadly, the aerospace, gas turbines, auto, tools and oil/gas usage can be attributed to superalloys. The 9% and 7% that are attributed to catalysts and other are within the same usages (Figure 50).

a KGHM Ecoren; http://en.ecoren.pl/rhenium.xml
b Lipmann & Walton Co; http://www.lipmann.co.uk/articles/metal-matters/rhenium-one-metal-two-guvnors/
c Lipmann & Walton Co; http://www.lipmann.co.uk/articles/metal-matters/rhenium-one-metal-two-guvnors/, and Rio Tinto; http://www.kennecott.com/library/media/MAP%20Information%20Brief%20August%202010.PDF)
dIvanhoe Australia; http://www.ivanhoeaustralia.com/s/Merlin.asp
e USGS (2012) , Mineral Commodity Summary 2012

Figure 50: Rhenium usage, split by type



Source: Lipmann Rhenium Statistics

- **Superalloys:** The majority of rhenium is used in superalloys, where, due to its exceptional properties under high temperatures, it is particularly suitable for use in the turbine blades towards the rear of jet engines that are subjected to particularly extreme temperatures and forces. The outlook for these markets appear strong, based upon engine orders.
- **Catalysts**: Rhenium is alloyed with platinum to form petroleum-reforming catalysts. This is used in the production of high-octane hydrocarbons, which are used in petrol blends, particularly those with high-octane ratings. The demand in this sector is, however, largely just top-up inventories.
- **Other:** These uses include rhenium tungsten alloys (in X-ray tubes and rotating X-ray anodes) and rhenium-molybdenum alloys, which are superconductors at 10 K. Occasionally, rhenium has been used in plating jewellery.

1.20.4 Resource efficiency and recycling

The aerospace industry is continuing to look into reducing reliance on rhenium. This includes testing superalloys with lower rhenium content for engine blades, rhenium-free allows for other engine components. Pratt & Whitney and Rolls-Royce plc have been involved with each other in various joint ventures since 2011 to develop new engines, which are thought to be looking at lower operating temperatures, which would in turn reduce the need for rhenium. It should, however, be noted that whilst rhenium can be reduced, it is difficult to eliminate.

Materials that can substitute for rhenium in some of its other end uses are as follows, however it is irreplaceable for many applications.

- cobalt and tungsten for coatings on copper x-ray targets
- rhodium and rhodium-iridium for high-temperature thermocouples
- tungsten and platinum-ruthenium for coatings on electrical contacts
- tungsten and tantalum for electron emitters.

Table 44: Substitutability for rhenium

Use	Substitutability score
Super-alloys (gas turbines)	1
Catalysts	0.7
Tools	1
Automotive Parts	1
Petroleum Production	1
Super-alloys (aerospace)	1
Others	0.5

Interest in rhenium recycling has increased following the price spike in 2008. Approximately 15 tonnes of rhenium are recycled each year from spent reforming catalysts (this is not generally shown in production statistics, as it does not affect the supply and demand balance). According to the USGS, the majority of Rhenium recycling in 2012 was in Germany and the USA. However, significant amounts were also recovered in Russia and Estonia[a].

1.20.5 Specific issues

There are no known government stockpiles or significant trade restrictions for rhenium, since the Kazakhstan national stockpile was sold. Within the EU, there is a supply from Poland of an estimated 3.5 million tonnes annually. Corporate stockpiles, however, are likely to exist. Rhenium is a supply constrained market, and represents a relatively small proportion of manufacturer's revenue; therefore it is fairly unresponsive to market demand and price changes.

The USGS expects consumption of both catalyst grade ammonium perrhenate by petroleum industry, and rhenium usage within the aerospace industry, to remain strong, although views the latter as being more unpredictable[b]. Boeing estimates that 29,000 new planes will be needed by 2029, which Ivanhoe Australia take as implying a demand of 1,450 tonnes of rhenium.[c]

a USGS (2012), Mineral Commodity Summary 2012
b USGS (2012), Mineral Commodity Summary 2012
c Ivanhoe Australia Ltd,2011, Corporate Presentation

1.21 *Scandium*

1.21.1 Introduction

Scandium (Sc, atomic number 21) is a soft, silvery-white metallic element, which oxidises easily and tarnishes to pink or yellow. Scandium has some characteristics that are similar to the rare earth elements and is often so classified.

The small size of its ion allows it to react chemically like aluminium, magnesium and zirconium; its light weight and high melting point, lends itself to potential aerospace applications as an alloying element of aluminium. Published data on scandium is scarce.

1.21.2 Supply and demand statistics

Scandium is said to occur in trace amounts in over 800 minerals, but scandium is rarely concentrated in nature.[a] The USGS reports that major resources of scandium are known in Australia, China, Kazakhstan, Madagascar, Norway, Russia, and Ukraine. Australia's scandium resources are estimated at 6,190 tonnes, most of which are associated with two exploration projects, in Queensland and New South Wales respectively.[b] Quantitative estimates of world reserves are not available.

Scandium has been produced as a by-product material from tailings or residues in China, Kazakhstan, Russia, and Ukraine such as from uranium; tungsten, tin and titanium; rare earths and phosphates. Scandium has been produced almost exclusively as a by-product from these sources, although other deposit types are currently under exploration.[c] Extraction from red mud residues left over from the Bayer aluminium process has been considered, but has been shown to be uneconomic.[d]

The widely quoted historic supply estimates for scandium are of the order 1-2 tonnes per year.[a] More recent statistics compiled by the International Nickel Study Group estimated world scandium production at 10 tonnes for 2011, 70% of which originates in China, and 30% from Russia and the Ukraine (Table 45).

Table 45: World mine production of scandium, 2011

Country	World Supply (in tonnes, 2011)	
China	7	70.0%
Russia/Ukraine	3	30.0%
Total	**10**	

Source: International Nickel Study Group et al (2012), Study of the By-Products of Copper, Lead, Zinc and Nickel

a Munnoch & Worstall (2007), Scandium; Mining Journal
b International Nickel Study Group et al (2012), Study of the By-Products of Copper, Lead, Zinc and Nickel
c USGS (2011), Mineral Commodity Summaries 2011, Scandium
d Avon Metals, personal communication (January 2012)

Two major primary scandium projects are in the pipeline in Australia, which are worth a mention:

- In New South Wales, Nyngan, which is due to complete a feasibility study in early 2012 with the aim of commencing construction later in the year and begin its first scandium oxide production in 2013. The average ore grade is 261ppm of scandium and targeted production is 28 tonnes per year.[a]
- In Queensland, Nornico, a multi-metal project by Metallica Minerals has inferred scandium resources of around 2,000 tonnes of scandium at an average grade of 133ppm, together with nickel and cobalt minerals.[b] The project targets production of 40 tonnes of scandium for 2015. The feasibility study and the progression of drafting off take agreements are its aims for 2012.[c]

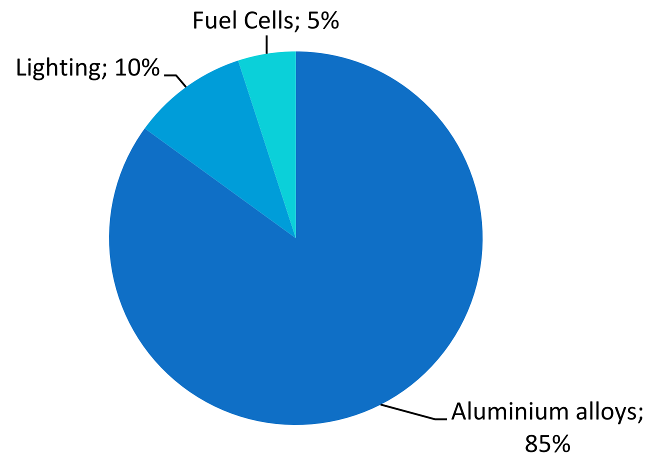
There is currently no European production of scandium, although possible production in Germany is being investigated. The project is currently awaiting planning permission, but aims to produce approximately 1 tonne per year from 2013 onwards.[d] No specific trade data for scandium exists, as it is included within rare earth trade categories.

1.21.3 Economic importance

The major application for scandium is in aluminium alloys, but it also finds usage in solid oxide fuel cells and lighting applications to a smaller extent (Figure 51). The uses of scandium in these applications are as follows:[e]

- **Aluminium alloys:** Sports equipment (bicycle frame, golf clubs, baseball bats etc.) and aerospace parts, at typical concentrations of 0.3-0.5%. The main advantages of using scandium is improving strength to weight ratios (by up to 15%) and improving welding with the effect of reducing heat cracking in aerospace applications.
- **Lighting:** High-intensity applications, such as mercury vapour lamps for TV cameras, due to its ability to resemble sunlight and allows good colour reproduction.
- **Solid oxide fuel cells (SOFCs)**: An efficiency enhancer when used as a dopant or substitute in yttrium stabilised zirconia fuel cells. Scandium can also increase the lifespan and ionic conductivity of SOFCs and reduce the operating temperature.

Figure 51: Uses of scandium, 2011 (tonnes)



Source: International Nickel Study Group et al (2012), Study of the By-Products of Copper, Lead, Zinc and Nickel

a EMC Metals Company Presentation (January 2012)
b Metallica Minerals (2012), Quarterly report to 31 Dec 2011
c Metallica Minerals, personal communication (February 2012)
d Tim Worstall, personal communication (November 2012)
e International Nickel Study Group et al (2012), Study of the By-Products of Copper, Lead, Zinc, Nickel; Munnoch & Worstall (2007), Scandium; Mining Journal

1.21.4 Resource efficiency and recycling

End-of-life recycling rates for scandium are below 1%, according to the recent report by UNEP.[a] Given its low volume usage and low concentration within aluminium alloys, its largest market, scandium appears unlikely to be successfully targeted for recycling.

In applications such as lighting and lasers, scandium is generally not subject to substitution. For high-strength aluminium alloys, carbon fibre and carbon nanotube material may substitute its usage over the medium and long term.[b]

For fuel cells, there are a variety of other technologies and dopants that exist, although it could become a large market for scandium.[c] However there are two major doubts regarding scandium's usage in this market, on whether fuel cells generally and scandium based SOFCs in particular, will be successfully commercialised.

Table46: Substitutability scores for scandium

Use	Substitutability score
Aluminium alloys	0.3
Lighting	0.7
Fuel cells	0.3

1.21.5 Specific issues

For scandium there are three specific issues warranting particular mention:[d]

- In many instances scandium is considered a rare earth, so much of the government stockpiles and trade restrictions invoked for rare earths generally, such as the Chinese export quotas and taxes, will also apply to scandium.
- Government stockpiles significantly influence the supply of scandium. Sale from a former Soviet Union military stockpile currently adds approximately 2-3 tonnes to world scandium supply; although industry estimates think this is close to exhaustion, with less than 15 tonnes still remaining. It is reported that a 13 tonne Kazakh national stockpile was sold a few years ago for use in fuels cells.
- Demand for scandium is currently limited by its cost and availability. For example Airbus has reportedly been looking at using scandium within its aerospace alloys, but has significant serious reservations in using it.

a UNEP International Resource Panel (2011), Recycling Rates of Metals: A Status Report
b USGS (2013), Mineral Commodity Summaries
c Fraunhofer & IZT (2009), Raw materials for emerging technologies
d International Nickel Study Group et al (2012), Study of the By-Products of Copper, Lead, Zinc and Nickel

1.22 Selenium

1.22.1 Introduction

Selenium (Se, atomic number 34) is a semi-conducting metalloid, and therefore shares properties associated with both metals and non-metals.

Selenium is well known for its conflicting attributes: it adds and removes colour, oxidizes and deoxidizes and it can conduct electricity, but it is also nonconductive.

1.22.2 Supply and demand statistics

Selenium is widely distributed within the Earth's crust, with an estimated overall abundance of 0.03-0.08 ppm. Selenium is not found in pure form naturally, and is mostly produced as a by-product from refining copper sulphide ores and to a lesser extent from lead ores. The USGS estimates world reserves within copper deposits to be 98,000 tonnes. This includes countries such as Chile, Russia, Peru, the USA and Canada.[a] European reserves of selenium are estimated at approximately 7,000 tonnes, and are mostly located in Poland.[b]

A range of estimates exist for total world production of selenium although there are significant differences between them. The basic problem is set out by Naumov, who states that of the 80 operating plants in the world only 20 provide data on whether and how much selenium they produce.[c]

The most widely quoted source organisation for world metals production statistics is the US Geological Survey (USGS), which estimates world selenium production at 3,000-3,500 tonnes per year. However, the USGS Mineral Commodity Summary for selenium actually quotes a considerably lower figure of 2,000 tonnes, due to output of refined selenium for a number of countries not being reported or information is inadequate for formulation of reliable production estimates.[d]

A more conservative figure is quoted by the International Copper Study Group (ICSG) at 2,600-2,700, based upon industry estimates. However, the ICSG estimates do provide a full country-by-country breakdown of world selenium refinery production, based upon output at copper and lead refineries. Based upon the ICSG data, the location of production is relatively diverse: the world's leading producers, China and Japan, are each attributed to approximately 20% of world production. The EU's share of world selenium production is also approximately 20%.

a USGS (2013), Mineral Commodity Summaries – Selenium
b EC JRC (2011), Critical Metals in Strategic Energy Technologies
c Naumov A.V. (2010), Selenium and tellurium: state of the markets, the crisis, and its consequences; Metallurgist Vol. 54 Nos. 3-4
d USGS (2013), Mineral Commodity Summaries – Selenium

Table 47: World selenium refinery production, 2011[a]

Country	Refinery production (in tonnes, 2011)	
Belgium	150	5.6%
Canada	120	4.5%
Chile	70	2.6%
China	500	18.8%
Germany	250	9.4%
India	140	5.3%
Japan	480	18%
Kazakhstan	80	3.0%
Mexico	60	2.3%
Norway	100	3.8%
Peru	45	1.7%
Philippines	80	3.0%
Russia	160	6.0%
South Korea	100	3.8%
Sweden/Finland	60	2.3%
USA	170	6.4%
Others	100	3.8%
Total	**2,600-2,700**	

Source: International Copper Study Group

In terms of the EU, significant producers are Belgium, Germany, Norway (as a member of the EEA), and Sweden/Finland. The major producing companies in each country provide some indication of whether these countries actually mine the selenium-containing minerals:

- Umicore (Belgium) primarily produces selenium from anode slimes and other copper and lead mining and refining residues sourced elsewhere.
- Aurubis (Germany) have production centres in Europe. However, they use copper concentrates from elsewhere.[b] In addition, Retorte, a sub-division of Aurubis, acts as a high purity refiner for crude selenium produced at other refineries.
- Xstrata (Norway) has mines in Norway, but it actually refines the selenium in Canada.[c]
- Boliden (Sweden/Finland) produces 20% of its copper concentrate for smelters (ultimately a source of selenium) from its own mines.[d]

1.22.3 Economic importance

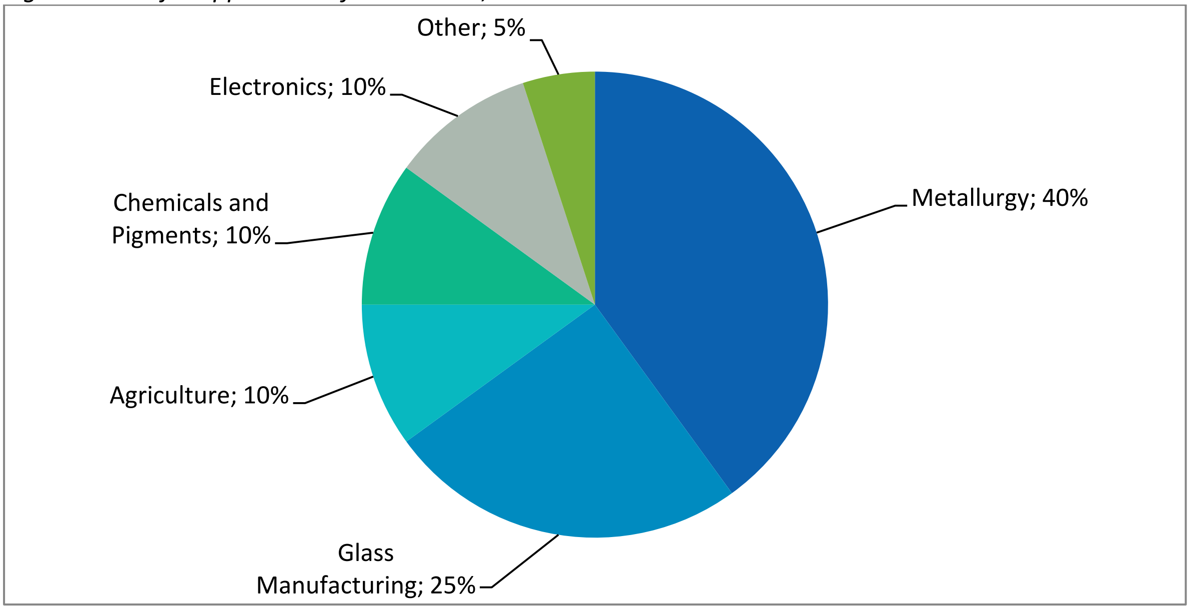
The major uses of selenium are as follows (Figure 52):

- **Metallurgy**: The main use of selenium is in the electrolytic production of manganese, where it increases yields. Selenium also improves machinability of carbon steel, copper, and stainless steel.
- **Glass manufacturing**: Selenium is used as both a colorant and decolorant in glass. It is also crucial in reducing solar heat transmission in plate glass.
- **Agriculture**: The leading agricultural uses are as a dietary supplement for livestock and as a fertilizer additive to enrich selenium-poor soils. Selenium as a trace element is essential for the health of many animals, influencing disease resistance and growth.

a International Copper Study Group (2012), Study of By-Products of Copper, Lead, Zinc and Nickel
b http://www.aurubis.com/en/our-business/raw-materials/copper-concentrates/ [accessed April 2013)
c http://www.xstrata.com/assets/pdf/xcu_brochure_200804.en.pdf [accessed April 2013)
d http://www.boliden.com/Products/Copper/ [accessed April 2013)

- **Chemicals and pigments**: Cadmium sulfo-selenide pigments are used in plastics, ceramics and also glass to produce a ruby-red colour.
- **Electronics**: Historically, the main electronic use of selenium was as a photoreceptor in photocopier drums; however, this has now been replaced by newer processes. Selenium is used in thin-film photovoltaic copper indium gallium diselenide (CIGS) solar cells, which is projected to become an increasingly major use.
- **Other**: Selenium is also used as a human dietary supplement (it is also an important trace element for humans) and in anti-dandruff shampoo.

Figure 52: Major applications for selenium, 2011[a]



Source: USGS

The use of selenium has changed considerably over time. For example the growth of the Chinese electrolytic manganese industry has meant that metallurgy has displaced the glass industry as the largest end-user for selenium worldwide. China is now responsible for the largest proportion of global selenium consumption; trade statistics indicate imports of 1,564 tonnes in 2011 (in addition to Chinese production), which is more than half of the global selenium production.[b]

Broadly, the consensus is that the selenium market is in balance, and the diversity of applications for selenium has helped to provide stability to prices. In the major markets (manganese production, glass and feed) no major demand increases are expected and, in the short term, industry observers hope that demand will remain level.[c] However, there is some discussion in the industry regarding the long-term substitutability or reduction of selenium in its main market, electrolytic manganese in China

1.22.4 Resource efficiency and recycling

With regards to recycling, the USGS notes that recovery of selenium has declined in recent years, due to the reduction in available scrap selenium based copier drums. Overall, selenium has an end of life recycling rate of less than 5%, with dissipative uses making recycling difficult.[d] They now estimate US production of secondary selenium to be very small.[e] However, post-industrial recycling of copper indium gallium selenide (CIGS) scrap is thought to be possible.

a USGS (2012), Minerals Yearbook 2011 – Selenium and Tellurium
b Metal Pages (February 2012), China 2011 imports down marginally on year
c International Copper Study Group (2012), Study of By-Products of Copper, Lead, Zinc and Nickel
d UNEP International Resource Panel (2011), Recycling Rates of Metals: A Status Report
e USGS (2013), Mineral Commodity Summaries – Selenium

Selenium can, in its main use (in the production of electrolytic manganese) be substituted by sulphur dioxide. However, it is not clear at what price this might occur, although a reduction of selenium usage already appears to have taken place.

A number of substitutes have been developed for various end uses of selenium: [a]

- Sulphur dioxide can be used as a replacement for selenium dioxide in the production of electrolytic manganese metal.
- Silicon and sulphur are major substitutes for selenium in low, medium and high voltage rectifiers, and solar photovoltaic cells.
- Organic pigments have been developed to substitute for cadmium sulfo-selenide pigments.
- Cerium oxide can replace selenium as a colorant or decolorant in glass.
- Tellurium can be used instead in pigments and rubber.
- Bismuth and lead can be used in both free-machining alloys and lead-free brasses in the place of selenium.

Table48: Substitutability of selenium

Use	Substitutability score
Metallurgy	0.3
Glass manufacturing	0.7
Electronics	0.3
Chemicals and pigments	0.3
Agriculture	1
Others	0.5

1.22.5 Specific issues

There are no known trade restrictions for selenium. There are also no known taxes, regulations, or stockpiles of any significance.

Because selenium is produced largely as a by-product metal from copper, its production is dependent on refiners' willingness to engage in its recovery. However, its overall impact on revenues is very modest. Data on recovery rates suggest that, at most, only 50% of recoverable selenium is actually refined as market supply.[b]

There is some concern regarding the shift towards SX-EW copper refining, which may affect selenium recovery in the future. However, this may have relatively little impact for selenium, because the deposit types for which SX-EW is likely to be used contained limited quantities of selenium.

a USGS (2013), Mineral Commodity Summaries – Selenium
b International Copper Study Group (2012), Study of By-Products of Copper, Lead, Zinc and Nickel

1.23 Silica sand

1.23.1 Introduction

Silica sand used for industrial applications is characterised by the high content of quartz (SiO_2) which can be up to 99.9%. The major applications for silica sand are in the construction industry and for glass production. Other uses include foundry castings, ceramics. Extremely high-purity quartz is used to produce metallurgical grade silicon (see the factsheet on silicon metal[a]) and products tailored for the optical and electronics industries.

1.23.2 Supply and demand statistics

Quartz makes up approximately 12% by weight of the lithosphere, making it the second most common mineral in the Earth's crust. Quartz is found in all three types of rock (igneous, metamorphic and sedimentary) but particularly in sedimentary rock given its resistance to physical and chemical weathering. Quartz crystals are almost pure silicon dioxide, containing low quantities of impurities. For industrial purposes, silica sand with a purity of at least 95% is required.[b] High-technology applications for quartz require extreme qualities, with specific low-ppm or sub-ppm requirements for maximum concentrations of certain trace metals.[c]

Silica sand is commonly produced from loosely consolidated sedimentary deposits or by crushing weakly cemented sandstones or processing quartzite and quartz containing rocks such as granite. High grade quartz is normally found in granites and in veins up to several metres thick within other rocks, commonly granite. Extremely high-grade quartz can also be produced by processing naturally pure vein quartz. Quartz for metallurgical purposes can be produced from high-quality resources of quartzite.

Quartz is valued for both its chemical and physical properties; each application must have a specific set of these properties and consistency in quality is of critical importance. These include high silica content and low content of impurities such as iron and aluminium oxide, heavy metals and other metals such as chromium. Specific size distribution of the grains is also an essential requirement for certain applications; this is generally in the range of 0.5 to 0.1 mm. Given the specificity of the properties for each application, the use of different types of silica sand is not interchangeable.[d]

Purification is achieved by washing and scrubbing on the grains to remove impurities. The sand grains are screened to obtain the required particle size distribution. For uses which require extremely pure silica such as electronic applications, the sand grains are exposed to more aggressive treatment with strong acids combined with thermal shock.[e]

[a] See separate document for critical material profile for silicon metal
b Flörke et al (2008), Silica. Ullmann's Encyclopedia of Industrial Chemistry.
[c] For example, see http://www.iotaquartz.com/product-range.cfm
d BGS (2009), Silica Sand, Mineral Planning Fact Sheet.
e Eurosil (n.d.), What is Silica. http://www.eurosil.eu [Accessed April 2013]

Table49: Worldwide production of industrial sand and gravel, 2010-2012

Country	**Production, '000s tonnes**		
	2010[a]	**2011**[b]	**2012**[b]
Australia	5,300	5,600	5,600
Belgium	1,800	1,800	1,800
Canada	1,171	1,430	1,300
Chile	1,400	1,240	1,300
Czech Republic	1,400	1,350	1,400
Egypt	1,757	1,800	1,800
Finland	2,250	2,250	2,250
France	5,000	5,000	5,000
French Guyana	1,500	1,500	1,500
Germany	7,000	7,770	7,500
India	1,800	1,800	1,800
Iran	1,500	1,500	1,500
Italy	19,800	19,800	19,800
Japan	3,078	2,900	3,000
Latvia	1,359	1,360	1,360
Mexico	2,480	2,570	2,600
Norway	1,500	1,200	1,200
Poland	2,730	2,460	2,600
South Africa	2,910	2,900	2,900
Spain	5,000	5,000	5,000
Turkey	4,000	5,000	4,000
United Kingdom	3,760	3,760	3,800
USA	29,900	43,700	49,500
Other Countries	13,000	14,000	14,000
World total (rounded)	**121,000**	**138,000**	**140,000**

Source: USGS

Data for production of quartz sand is not readily available. Table 49 shows USGS data for worldwide sand and gravel production; however, this data is not reliable due to the variation of reporting standards in each country. For example, this data may also include production of aggregates or even building stones such as marble.[b]

Another factor that must be taken into account is regional occurrence. Silica sand is usually not transported over long distances due to the cost of transport; therefore the industry of use must be located close to the sand source. Hence if a specific type of sand is absent in a specific region then there may still be a regional scarcity even though other types of silica are plentiful. It may be economically viable to transport silica sand for niche applications over a long distance. Due to this reason, supply and demand issues can only be studied when defining the quality niche.
According to this data, approximately 58,000,000 tonnes of industrial sand and gravel were produced in Europe in 2012. As previously stated this data includes both sand and gravel and may also include other

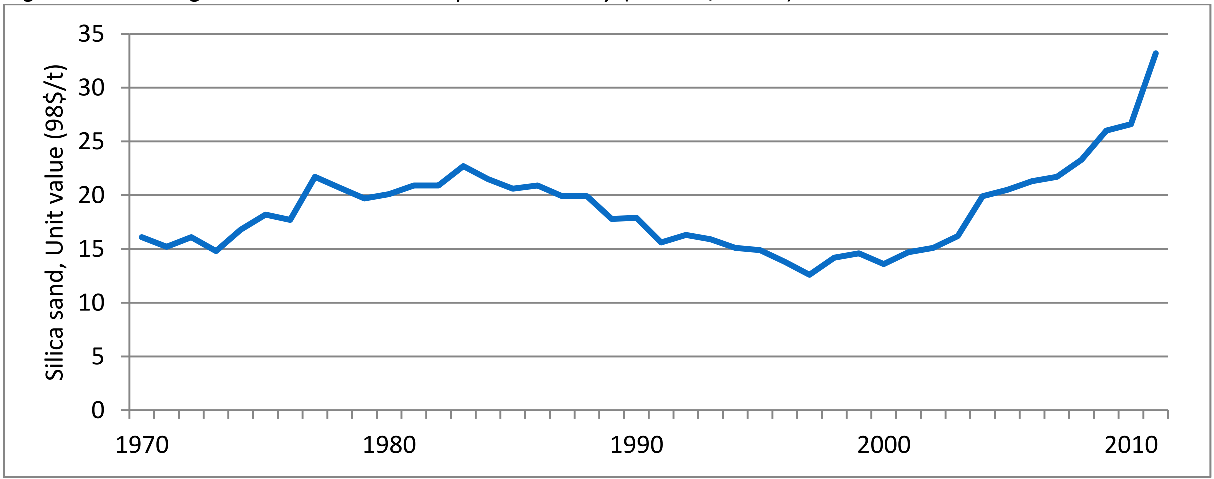
a USGS (2012), Mineral Commodity Summaries 2012, Sand and Gravel (Industrial)
b USGS (2013), Mineral Commodity Summaries 2013, Sand and Gravel (Industrial)

aggregates depending on how each country categorises these materials. According to IMA-Europe, annual consumption in the EU-28 is 66 million tonnes.[a] The increase in total amount of sand and gravel production shown in the table can be attributed to an increase in silica sand production due to an increase in frac sand (used in hydraulic fracturing) production in the USA.[b]

1.23.3 Economic importance

Average historical prices for silica sand are shown in Figure 53. Values have increased for some end uses but have decreased for others; as shown in the figure there has be a steep overall increase in the average unit value. According to USGS, prices for different applications range from several dollars per tonne to hundreds of dollars per tonne.

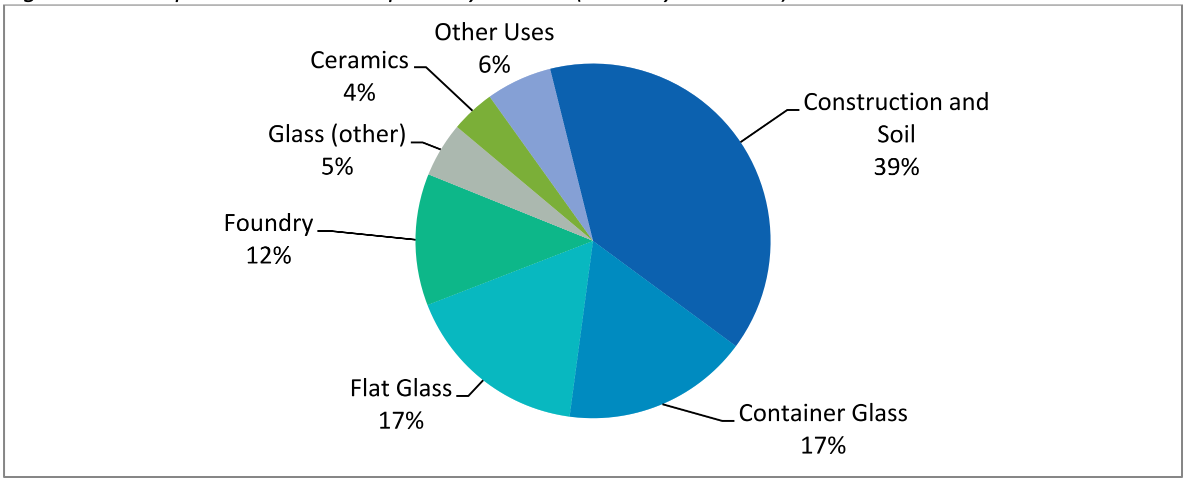
Figure 53: Average silica sand historical price volatility (98 US$/tonne).



Source: USGS (2012-), Historical Statistics for Mineral and Material Commodities in the United States [accessed February 2013]. Figures are indexed to 1998 values.

European silica consumption by market is shown in Figure 54. As can be seen, the major uses are in construction and soil applications and in the production of glass. Consumption in the EU varies significantly compared to the USA where hydraulic fracturing is being practised extensively.

Figure 54: European silica consumption by market (industry estimate)



Source: IMA-Europe (2013), Recycling Industrial Minerals.

The major uses of silica sand are:

a IMA-Europe (2013), Recycling Industrial Minerals.
b USGS (2013), Minerals Yearbook 2011, Silica (Includes Industrial Sand and Gravel, Quartz Crystal, and Tripoli and Special Silica)

- **Construction and soil:** Both high-quality sand and low-end by-products of silica are used for this purpose. These uses include high-end concrete, composite kitchen tops, equestrian surfaces, sports soils, asphalt and road construction.[a]
- **Glass (flat and container):** Silica is the principal ingredient in all types of glass. Jars and containers are the main glass products followed by flat glass (windows, mirrors), tableware, glass fibre (composite reinforcing and insulation material) and special uses such as plasma screens and optical glass. Sand is fused with sodium carbonate to reduce fusion temperature. Calcium oxide, magnesium oxide and alumina are also added to increase stability and durability of the product.[b] The size of the sand grains used in glass industry should be between 100-600 microns and the purity content should be of a minimum of 98.5% of silicon dioxide. The presence of these impurities gives colour effect in the glass.[c]
- **Foundry Casting:** Crystalline silica together with a binder is used to make moulds used on the production of metal castings. Silica has a higher melting point than iron, copper and aluminium therefore can be used at the temperatures required to melt the metals. These casts form an essential part of the engineering and manufacturing industries. Quartz and cristobalite are used for precision casting for products such as jewellery and aviation turbines.[d]

Other uses of silica sand are in ceramics, filtration, paints and plastics, polymer compounds, rubber, sealants and adhesives, sports and leisure applications, agriculture and in the chemical industry.

1.23.4 Resource efficiency and recycling

Materials containing silica sand are widely recycled across Europe; this includes silica used in construction and soil applications, and in flat and container glass. According to IMA-Europe, 73% of silica entering the market is recycled. Recycling rates and silica recycling rates for the major applications of silica sand are shown in Table 50.

Table50: Silica sand recycling rates[a]

Application	Application recycling rate (%)	Silica recycling rate (%)
Construction and soil	85	33
Container glass	75	13
Flat glass	80	14
Glass (other)	25	1
Foundry	80	10
Ceramics	60	2
Total		**73**

Source: IMA-Europe

Construction materials containing silica sand are highly valued due to the benefits provided by this industrial mineral; it is estimated that 85% of these material are recycled annually in secondary raw materials. These products are re-used in concrete, asphalt or landfill ground levelling.[a]

Increased efforts to recycle packaging glass are likely to lower the demand for mined glass sand as the recycled glass cullets can replace the virgin material. Average recycling rates for container glass in the EU in 2011 were around 70%,[e] 80% of this glass being recycled closed loop. It is reported that every tonne of recycled glass saves up to 1.2 tonnes of raw material, including silica sand. In addition, glass cullet has a lower melting point by 20-25% compared to a conventional batch, providing further energy savings.[f]

a IMA-Europe (2013), Recycling Industrial Minerals.
b Silica and Moulding Glass Association (n.d.), Glass. http://www.samsa.org.uk/use_glass01.htm [Accessed March 2013]
c BGS (2012), Role of National Geological Surveys in evaluation of high-purity silica resources; Clive Mitchell. http://nora.nerc.ac.uk/18281/1/Evaluation_of_silica_Clive_Mitchell_BGS.pdf [Accessed March 2013]
d IMA-Europe (2011), Silica. http://www.ima-europe.eu/sites/ima-europe.eu/files/minerals/Silica_An-WEB-2011.pdf [Accessed March 2013]
e FEVE, Statistics. http://www.feve.org/index.php?option=com_content&view=article&id=10&Itemid=11
f Industrial Minerals (2013), Glass: a fragile industry?

Including other container glass, such as construction related products, the total recycling rate is estimated to be 75%. Flat glass requires high quality cullet and therefore it is generally down-cycled for use in container glass. [a]

Foundry sand can also be recycled and recycling levels are thought to be increasing. According to IMA-Europe, the recycling rate in Western Europe is over 90%; the sand is regenerated four times on average. Once this material can no longer be re-used, it is recycled into construction materials.[b]

Substitution scores for silica sand in its end-uses can be seen in Table 51.

Table51: Substitutability of silica sand by application

Use	Substitutability score
Glass (flat and container glass)	1
Foundry Castings	1
Building Materials	1
Others	0.5

1.23.5 Specific issues

The general quality of data for production is highlighted as an issue in this analysis, for example characterisation of applications for which this mineral is used beyond that of glassmaking, or better separation of the grade of material assessed. More specific data, avoiding collation with other aggregates and taking into account the non-transferability of one type of quartz from one application to another would provide a more specific view for this material.

On the supply side, one of the major issues is that the silica sand market is regional and market dependant. Given the high cost of transport, specific grades of silica cannot be transported over long distance but different grades of silica cannot be interchanged for different purposes. The combination of these two factors results in the regional market being fairly restricted.

From the point of view of occupational health, working with silica sand poses a risk to human health if not handled carefully. Inhalation of crystalline silica dust can cause silicosis, a form of *pneumoconiosis.* The contraction of this incurable fibrogenic lung disease can be prevented by limiting exposure; all member states have set limits for the exposure to these particles in the work place.[c]

Furthermore, in order to prevent the risk of contracting such an illness, the employers and employees of 14 industrial sectors in Europe that make use of or produce silica sand have gathered within the European Network of Silica (NEPSI). In 2006 they negotiated, signed and agreed on applying an "Agreement on workers' health protection through the good handling and use of crystalline silica and products containing it" (OJ 2006/C279/02). This aims at minimising exposure by applying Good Practices and increasing the knowledge about potential health effects of respirable crystalline silica dust.[d]

a IMA-Europe (2013), Recycling Industrial Minerals.
b IMA-Europe (2013), Recycling Industrial Minerals.
c Eurosil (2007), Occupational Exposure Limits in mg/m3 – Respirable dust In EU 27 + Norway & Switzerland. http://www.eurosil.eu/sites/eurosil.eu/files/files/OEL-FULL-TABLE-Oct07-Europe.pdf [Accessed April 2013]
d NEPSI (2010), Application of the European Multi-Sectoral Social Dialogue Agreement on Workers' Health Protection through the Good Handling and Use of Crystalline Silica and Products Containing It. http://www.nepsi.eu/media/2411/nepsi%202010%20executive%20summary%20_19.08.2010.pdf [Accessed April 2013]

1.24 *Silver (Argentum)*

1.24.1 Introduction

Silver (Ag, atomic number 47) is one of eight precious, or noble metals which are resistant to corrosion. Silver is soft, very malleable and ductile and has the highest electrical and thermal conductivity of all metals. It has high photosensitivity to visible, x-ray, and gamma-ray wavelengths in the electromagnetic spectrum, and is chemical inert to oxygen. Its use, however, is restricted by its relatively high cost.

1.24.2 Supply and demand statistics

Silver metal occurs naturally as an alloy with gold and other metals, and in minerals such as argentite and chlorargyrite, contained within both sulphide ore minerals and non-sulphide minerals. World silver reserves contained within both primary silver deposits, as well as polymetallic base metals ores are estimated at over half a million tonnes.The largest of these are located within Peru, Poland, Chile and Australia, which between them account for approximately two thirds of world reserves.

Mine production for silver is distributed between at least 50 different countries worldwide, and from a diverse range of sources. The three largest silver producing countries are Mexico, China and Peru, which between them account for 11,500. This represents nearly one half of world silver mine production, which stood at 24,000 tonnes in 2012 (Table 52).

Table52: World mine production and reserves of silver, 2011 and 2012(estimated)[a]

Country	Mine production				Reserves (tonnes)	
	2011 (tonnes)		2012[1] (tonnes)			
Mexico	4,150	17.8%	4,250	17.7%	37,000	6.9%
China	3,700	15.9%	3,800	15.8%	43,000	8.0%
Peru	3,410	14.6%	3,450	14.4%	120,000	22.4%
Australia	1,730	7.4%	1,900	7.9%	69,000	12.9%
Russia	1,350	5.8%	1,500	6.3%	NA	—
Bolivia	1,210	5.2%	1,300	5.4%	22,000	4.1%
Poland	1,170	5.0%	1,170	4.9%	85,000	15.9%
Chile	1,290	5.5%	1,130	4.7%	77,000	14.4%
USA	1,120	4.8%	1,050	4.4%	25,000	4.7%
Canada	570	2.5%	530	2.2%	7,000	1.3%
Other countries	3,600	15.5%	3,900	16.3%	50,000	9.3%
World total	**23,300**		**24,000**		**540,000**	

Source: USGS
[1] *Estimated values*

[a] US Geological Survey (2013), Mineral Commodity Summaries

However, only approximately 30% of mine production comes from so-called primary silver mines, where silver is the main source of revenue. The majority of the metal is therefore obtained as a by-product of refining other ores, notably lead and zinc (37%), copper (21%) and gold (13%).[a] World mine production for silver is therefore correlated with the production of these other metals.

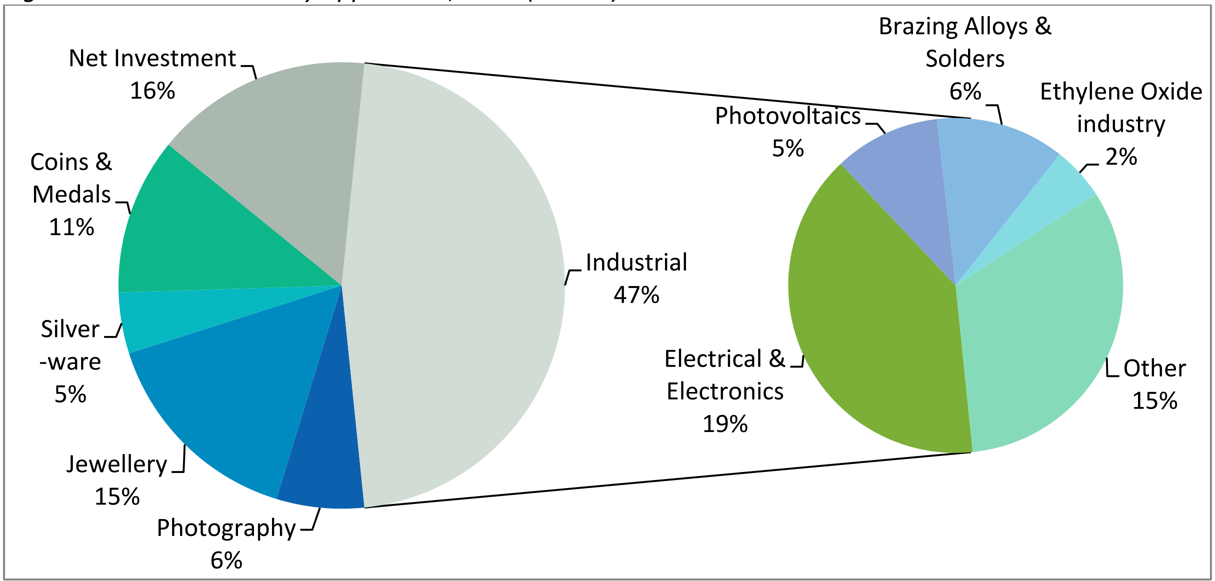
The EU represents a significant source of world silver mine production, at approximately 7% of the world total. Poland is the largest producer, accounting for approximately 5% of world silver mine production. There are a further eight silver producing countries within Europe, most notably including Sweden, Finland and Bulgaria.[b]

1.24.3 Economic importance

Silver is used for a variety of industrial and aesthetic applications such as electronics and jewellery. Figure 55 provides a breakdown of silver demand by application for 2011. Approximately half of world silver demand is in industrial applications, with around one fifth used for silverware or jewellery.

However, as a precious metal, it is worth noting that silver is also used for investment purposes, whether that is for silver coins or as bullion. This has a significant impact upon the year-to-year market balance for silver and market prices. For 2011, just over one quarter of world silver demand was related to investment.

Figure 55: Silver demand by application, 2011 (tonnes) [a]



Source: Silver Institute

Descriptions of the major fabrication applications are as follows:[a]

- **Coins, silverware and jewellery:** silver's aesthetic properties, as well as its store of value make it an attractive material for these markets. These include use both as solid silver and silver plate.
- **Electrical and electronics:** silver's usage in electrical and electronics industry is widespread due to its high electrical and thermal conductivity. For example it is used for electrical contacts, switches and passive electronic components such as multi-layer ceramic capacitors. The end-markets for these components include cell phones, PCs and computers and automotive applications.
- **Photovoltaic:** silver's use in PV solar cells is mainly as a conductive paste for thick film crystalline silicon cells. The use of silver in thin film solar PV or Concentrating Solar Power (CSP) is more limited.

a Silver Institute (2012), World Silver Survey 2012
b USGS (Jan 2013), 2011 Minerals Yearbook: Silver

- **Brazing alloys and solders:** silver is used as one element in these alloys, which are used to join together two different metals of different (higher) melting points.
- **Ethylene oxide industry:** silver oxide is used as a catalyst in this petro-chemical industry for the production of polyester intermediates.
- **Photography:** silver's high optical reflectivity has given it historical usage for film photography within light sensitive silver halide crystals; however this market has been in decline with the advent of digital photography since the late 1990s.
- **Other industrial applications:** these include coating materials for compact disks and digital video disks, mirrors, glass coatings and cellophane and batteries. Silver has also a number of emerging applications such as solid state lighting, RFID-tags, water purification and hygiene. New markets for nano-silver are frequently being discovered.

1.24.4 Resource efficiency

A significant proportion of silver is recycled. For 2011, an estimated 256.7 million troy ounces of old silver scrap were recycled each year.[a] This is approximately 8,000 tonnes, meaning that recycling contributes around quarter of total world silver of each year, additional to mine production.

As for the end-of-life recycling rate (EOL-RR) for silver, this is greater than 50% worldwide.[b] Jewellery, silverware and coins have very high recycling rates, typically greater than 90% due to the ease of collecting and recycling of these applications. Once these applications are excluded from the calculation; the EOL-RR for silver falls in the range 30%-50%.

However, the EOL-RR varies considerably by application:[b]

- vehicles: 0%-5%
- electronics: 10%-15%
- industrial applications: 40%-60%
- others: 40%-60%

For applications where silver use is more dissipative, such as vehicles and electronics, losses occur in collection, shredding and metallurgical recovery operations. For electronics specifically, recovery rates at state-of-the-art metallurgical plants can be close to 100% of the silver contained, if the printed circuit boards are appropriately collected and pre-treated. In comparison to electronics, industrial applications such as photography and catalysts have a relatively recycling rate.

In terms of substitutability the following commentary is relevant:

- **Coins, silverware and jewellery**: these applications are all in principle substitutable by other precious metals such as gold, although silver is much less expensive, and used in much larger quantities.
- **Electrical and electronics**: copper, aluminium and other precious metals can replace silver completely or partially in many electrical and electronic uses. However, this is based upon both cost and performance, where silver offers the highest electrical conductivity at a relatively lower.
- **Brazing alloys and solders**: substitution of silver from these applications with other metals such as tin is possible, and has been occurring over the past decade due to the cost of silver.
- **Photography**: this market has been in decline with the introduction of digital photography.

a Silver Institute (2012), World Silver Survey 2012
b UNEP (2011), Recycling Rates of Metals: A Status Report

The overall substitutability of silver is summarised in Table 53 , below.

Table53: Substitutability of silver by application

Application	Substitutability score
Electrical & electronics	1.0
Net investment	0.7
Jewellery	0.7
Coins & medals	0.7
Photography	0.3
Brazing alloys & solders	0.3
Photovoltaics	0.7
Silverware	0.7
Ethylene oxide industry	1.0
Other	0.5

1.24.5 Specific issues

Significant investor stocks of silver exist which influences the market.

1.25 *Talc*

1.25.1 Introduction

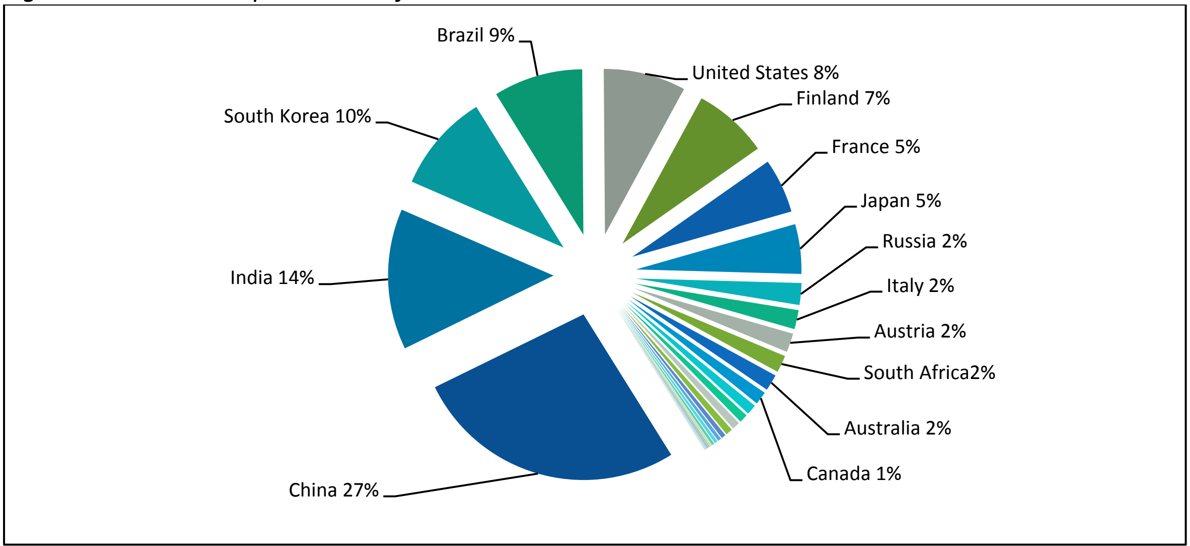
Talc ($Mg_3Si_4O_{10}(OH)_2$) is a hydrous magnesium silicate mineral[a] and belongs to the group of phyllosilicates. In its massive and impure form the mineral is also known as steatite[b] and soapstone[c]. The mineral has a greasy feel because of its very low hardness. On the Mohs scale of hardness talc is ranked at "1", thus it is the softest mineral on this scale, and its density varies from 2.7 to 2.8 g/cm^3.[b]

Applications of talc are amongst others the production of paper, ceramics, plastics, paints, roofings, sealants, cosmetics, pharmaceuticals, and agricultural chemicals.[b] Talc is a smooth, opaque, porous mineral with high sheet retention, low abrasion, and low yellow index score. These properties allow its extensive use as a filler.[b]

1.25.2 Supply and demand statistics

Talc deposits are widespread and are mined worldwide.[b] In 2011, China was the largest talc producer with 27% of the total output Figure 56.

Figure 56: Worldwide production of talc in 2010



Source: World Mining Data 2012

Talc production from the EU35 countries amounted to 1.1 million tonnes in 2011 which represented 14.4% of global talc production. These 14.4% are split up by Finland (38.3%), France (35.7%), Austria (11.8%), Italy (9.8%), and other EU-countries (4.5%)[d].

a European Mineral Statistics 2007-2011, British Geological Survey, 2013
b Ullmann's Encyclopedia of Industrial Chemistry: Talc, Wiley-VCH Verlag GmbH & Co KGaA, 2000
c www.mineralseducation.org/minerals/talc, retrieved online September 14, 2013
d European Mineral Statistics 2007-2011, British Geological Survey, 2013

Table54: World mine production and reserves (2011) of talc and pyrophyllite.[a]

	Mine production, 2011 ('000s tonnes)	Reserves ('000s tonnes)
Brazil	656	230,000
China	2,200	large
Finland	500	large
France	420	large
India	650	75,000
Japan	374	100,000
South Korea	706	14,000
USA [1]	616	140,000
Other countries	1,570	large
World total (rounded)	7,690	large

Source: USGS

1) Without pyrophyllite

Table 55shows the data for talc imports to the EU in 2010. More than 80% of the talc is supplied within the EU. According to the data delivered by Comtrade, by far the biggest amount of talc was exported by China and Pakistan to the European Union, whilst the China and India being the leading producers for talc worldwide.

Table 55: Production and imports to EU of talc

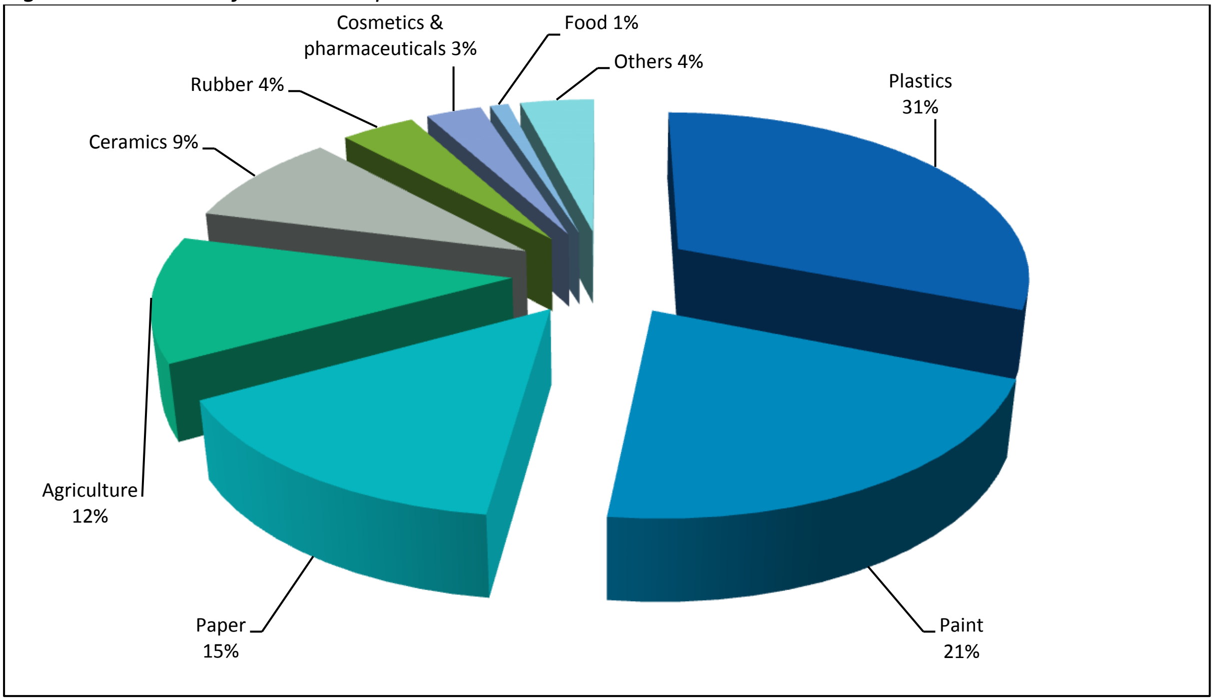
	Production in tonnes in 2010[b]		Imports to EU in tonnes in 2010[c]	
China	2,000,000	26.6%	105,708	42.2%
India	1,033,000	13.8%	15,367	6.1%
Rep. of Korea	723,936	9.6%	1,641	0.7%
Brazil	655,000	8.7%	3,009	1.2%
USA	604,000	8.0%	9,039	3.6%
Finland	550,000	7.3%	-	-
France	400,000	5.3%	-	-
Japan	364,000	4.8%	564	0.2%
Russian Federation	160,000	2.1%	73	0.0%
Italy	140,000	1.9%	-	-
Austria	138,367	1.8%	-	-
South Africa	125,661	1.7%	23	0.0%
Australia	120,000	1.6%	21,190	8.5%
Canada	96,000	1.3%	40	0.0%
Pakistan	NA	NA	82,736	33.0%
Egypt	75,000	1.0%	6,131	2.4%
Norway	6,000	0.1%	3,689	1.5%
other countries	315,914	4.2%	1,163	0.5%
Total	7,506,878	100.0%	250,372	100.0%

[a] Mineral Commodity Summaries: Talc and pyrophyllite, US Geological Survey, 2013
b World Mining Data 2012, C. Reichl et al., 2012
c UN Comtrade, http://comtrade.un.org/db/, Trade codes 252620 (Talc (IM) - Natural steatite, crushed or powdered) and 252610 (Talc (IM) - Natural steatite, not crushed or powdered)

1.25.3 Economic importance

For Europe, the largest applications of talc are plastics and paints consuming respectively 31% and 21% of the total talc consumption. Further end-uses are represented by paper, agricultural applications, and the manufacturing of ceramics, rubber, food, cosmetics and pharmaceuticals (Figure 57).

Figure 57: End-use of talc in Europe



Source: IMA-Europe

Talc is used as a component in plastics, ceramics, paper, rubber, paints, coatings, roofings, cosmetics, textiles, and a variety of other uses. Talc, which is a very soft mineral, is often used in milled form as powder.

The most important uses of talc are[a]:

- **Plastics**: Thermoplastics strengthened by the addition of talc are extensively used as construction materials e.g. for the automobile production for dashboards and bumpers and to produce thermoplastic resins. Moreover talc is used as an anti-blocking agent for plastic films, e.g. to make the opening of plastic bags easier.
- **Paint**: As a bulking agent in pigment industry, where up to 30 wt% of paint can consist of talc. The mineral leads to a better pseudo-plasticity and corrosion resistance, to an ease of re-dispersion of sediments, to an improvement of the adhesion to substrates, to a reduced diffusion through coating films, and to good dielectric properties.
- **Paper**: As bulking agent, for deposit control, and for coating.
- **Agriculture**: Talc is used as a dry carrier for pesticides, fertilizers, herbicides, fungicides, and insecticides.
- **Ceramics**: Talc is utilised in traditional and technical ceramics to enhance pressing and permeability properties. Steatite ceramics are used for electrical isolating applications. Furthermore talc is used as a filler and glazing agent.
- **Roofing**: Talc stabilizes the asphalt of tar paper and shingles. By improving its fire resistance and weatherability.
- **Rubber**: As filler, talc is used in carpet backings, valves, and cable insulation. As coating, talc serves to lubricate dies and to avoid sticking together of surfaces.

a Ullmann's Encyclopedia of Industrial Chemistry: Talc, Wiley-VCH Verlag GmbH & Co KGaA, 2000

- **Cosmetics**: Talc is used for face powder and body talc, as an additive for soaps, and as filler in solid antiperspirant sticks. In cosmetics, talc grants stability, texture, skin adhesion, and water resistance.
- **Pharmaceuticals**: The quantity of high-purity talc consumed by the pharmaceutical industry is rather small. Moreover, it needs complicated processes to remove all contamination (for example accompanying minerals, carbon, iron oxide, and base metal traces)
- **Food**: For processing foods, mostly polishing of foodstuffs (e.g. rice) or coating of chewing gum to prevent sheets sticking together.
- **Animal feed**: As an anti-caking agent and to improve processability.

Some minor applications are the sealant industry, sculpturing, and polishing (e.g. shoe, floor, and car polishing).

1.25.4 Resource efficiency and recycling

Thus, talc recycling is rather negligible[a]. However, recycling could be considered to be done indirectly through the recycling of paper, ceramics, paints and plastics which allows some of the mineral components to be recovered[b].

According to the various end-uses of talc, different properties of the minerals are required for the given application. Depending on these properties there are potential substitutes for talc.

In plastics, talc can be replaced by bentonite, kaolin, mica, and wollastonite. Substitutes for talc in paints are chlorite, kaolin, and mica. Calcium carbonate and kaolin can replace talc in paper, while bentonite, chlorite, kaolin, and pyrophyllite can replace it in ceramics. In rubber, it can be substituted by kaolin and mica.[c] For agrochemical applications talc is sometimes substituted by fuller's earth, kaolin, diatomite, perlite, gypsum, and sepiolite[c].

Application	Substitutability score
Paper	0.3
Plastics	0.3
Roofing	0.5
Rubber	0.5
Ceramics	0.3
Paint	0.3
Others	0.5
Cosmetics	0.5

a Mineral Commodity Summaries: Talc and pyrophyllite, US Geological Survey, 2013
b Recycling of industrial minerals (http://www.ima-europe.eu/sites/ima-europe.eu/files/publications/IMA%20Recycling%20Sheets%20FULL%20published%20on%2024.10.2013_0.pdf)
c Ullmann's Encyclopedia of Industrial Chemistry: Talc, Wiley-VCH Verlag GmbH & Co KGaA, 2000

1.26 Tantalum

1.26.1 Introduction

Tantalum (Ta, atomic number 73) is a metallic element. It is a silvery-grey, hard, very tough but flexible and ductile metal. Its density is 16.6 g/cm^3. The melting point of tantalum is 3,020°C, and its boiling point is 5,534°C.[a] Tantalum is a base metal, although in air it evolves a thin film of tantalum oxide, coating the metal and protecting it against many acids. Only fluoric acid, hot oleum, hot chlorine, fluorine, and sulphur can attack it.[a]

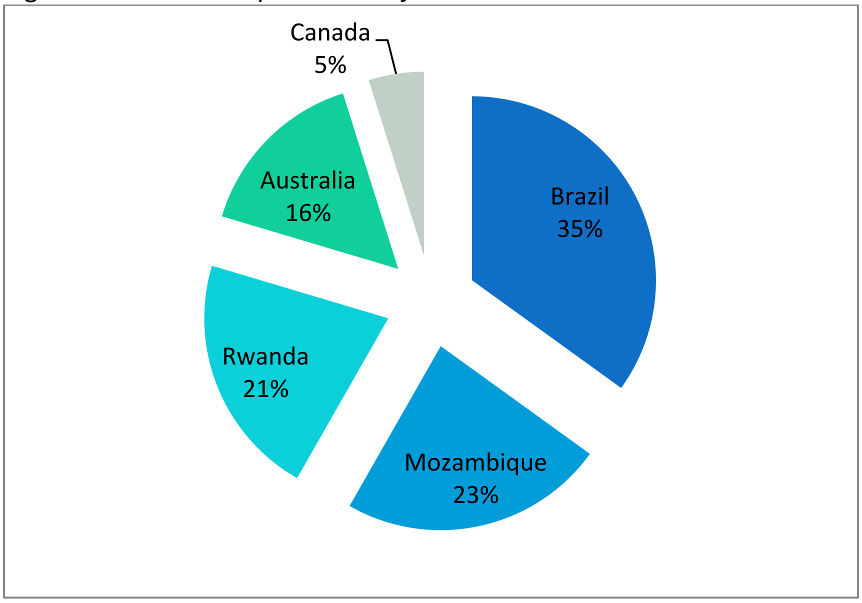
Tantalum is a relatively rare metal in the Earth's crust. Its estimated share is only 2.1 ppm (0.00021%), thus being the 52nd element in order of abundance in the Earth's crust[b], but tantalum ore deposits are widely distributed throughout the world.[a] The metal occurs mainly accompanied by niobium (also known as columbium).[a]

Although tantalum was included in the list of critical raw materials in 2010, it is not part of the updated list. This is on account of a reduced supply risk indicator, in turn resulting from changes in the concentration of tantalum primary production. Australia (with excellent governance rating) and D.R. Congo (with poor governance rating) have historically been major tantalum producers and their respective shares in world supply are known to vary strongly from year to year, depending on the price of tantalum (see Figure 7 of the main report). At the time of the previous exercise, Australian mines had closed down due to low tantalum prices such that D.R. Congo had a very large role in world supply. In the meantime, Brazil has emerged as an important tantalum supplier and production in Australia has been restarted. Nevertheless, it is worth pointing out that reliable tantalum production figures for conflict regions are very difficult to obtain.

1.26.2 Supply and demand statistics

Economically important tantalum-containing minerals are tantalite, wodginite, microlite, and columbite.[b] Tantalum is also produced as by-product during tin smelting from tin refinery slags.[c] The largest identified tantalum resources are located in Australia and Brazil.[d] These resources are considered to be sufficient to cover projected demands[d] (Table 56). USGS does not provide reserves data for Rwanda, which is currently one of the largest producers of tantalum (Figure 58).

Figure 58: *Worldwide production of Tantalum in 2011*



[a] Tantal, Römpp Online, 2007
[b] Ullmann's Encyclopedia of Industrial Chemistry: Tantalum and Tantalum Compounds. Wiley-VCH Verlag GmbH & Co KGaA,, 2011
[c] European Mineral Statistics 2007-2011, British Geological Survey, 2013
[d] Mineral Commodity Summaries: Tantalum, US Geological Survey, 2013

Source: Raw Material Data by Intierra

Tantalum is not mined in Europe. Table 57shows the data for tantalum imports to the EU in 2010. According to Comtrade data, the largest quantity of tantalum imported to the EU was exported by China and the USA; Brazil, Mozambique and Rwanda were the leading producers for tantalum worldwide in 2010 (Table 57) and 2011 (Figure 58). In the analysis, production data for 2011 has been used. For sake of comparison data for 2010 for production and trade is shown as well.

Table56: World reserves of tantalum, tonnes of tantalum content

Country	Reserves
Australia	53,000
Brazil	88,000
Canada	4,000
Ethiopia	4,000
World total (rounded)	**> 150,000**

Source: Mineral Commodity Summaries: Tantalum, US Geological Survey, 2013

Table57: World production and imports to EU of tantalum, 2010

Country	Production, 2010		Imports to EU, 2010	
	Tonnes	%	Tonnes	%
Brazil	180	26.4	1	0.2
Mozambique	120	17.6	-	-
Rwanda	110	16.2	-	-
China	NA	NA	173	28.6
USA	NA	NA	170	28.1
Japan	NA	NA	111	18.4
Kazakhstan	NA	NA	89	14.8
Mexico	NA	NA	46	7.6
Rep. of Korea	NA	NA	4	0.7
Russia	NA	NA	3	0.5
Thailand	NA	NA	3	0.5
Singapore	NA	NA	2	0.3
other countries	271	39.8	3	0.4
Total	**681**	**100.0%**	**604**	**100.0%**

Source: Mineral Commodity Summaries: Tantalum, US Geological Survey, 2012; Eurostat Comext

1.26.3 Economic importance

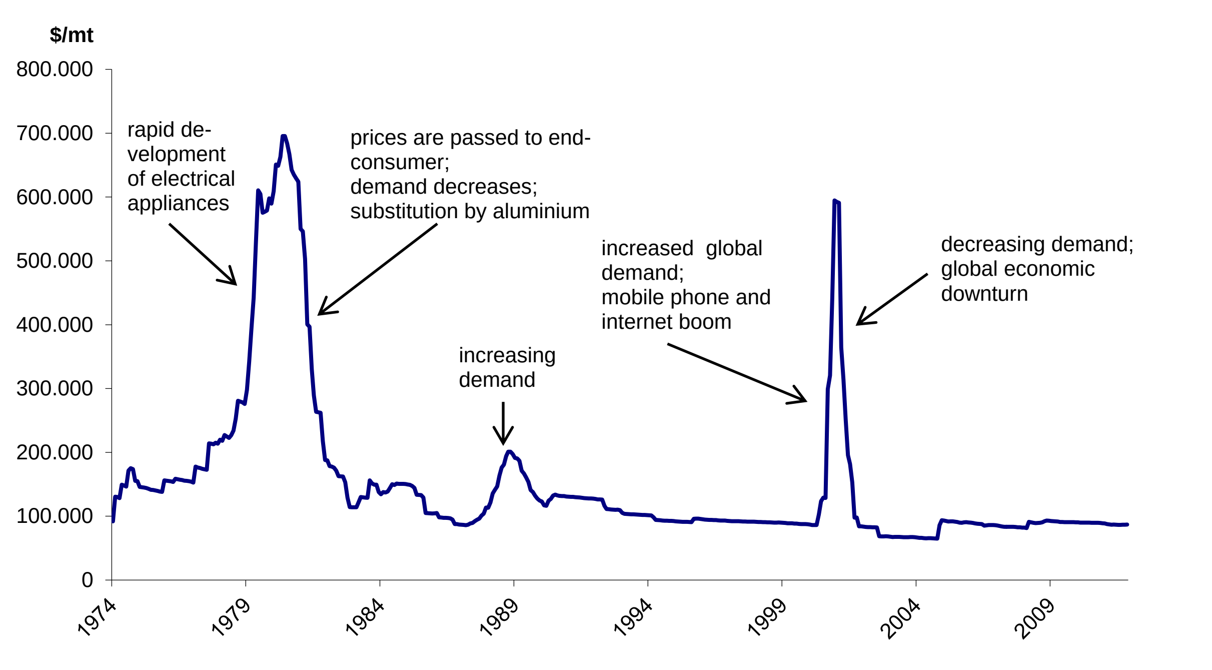
Figure 59 shows the development of tantalum prices during the last 40 years, characterized by two huge and one smaller price peak.

The first peak at the beginning of the 1980s resulted from a rapid development of new electronic devices that created an increased demand for tantalum. In the following years, the high producer prices were passed to consumers resulting in a decrease in demand. The search for substitutes and recycling made tantalum prices decrease until the end of 1982.[a] The second huge price peak in 2000 was caused by an increased global demand and a sudden decrease in supply, after which stocks were built up and the worldwide economic downturn led to decreasing prices.[a]

[a] DERA Rohstoffinformationen, HWWI, 2013

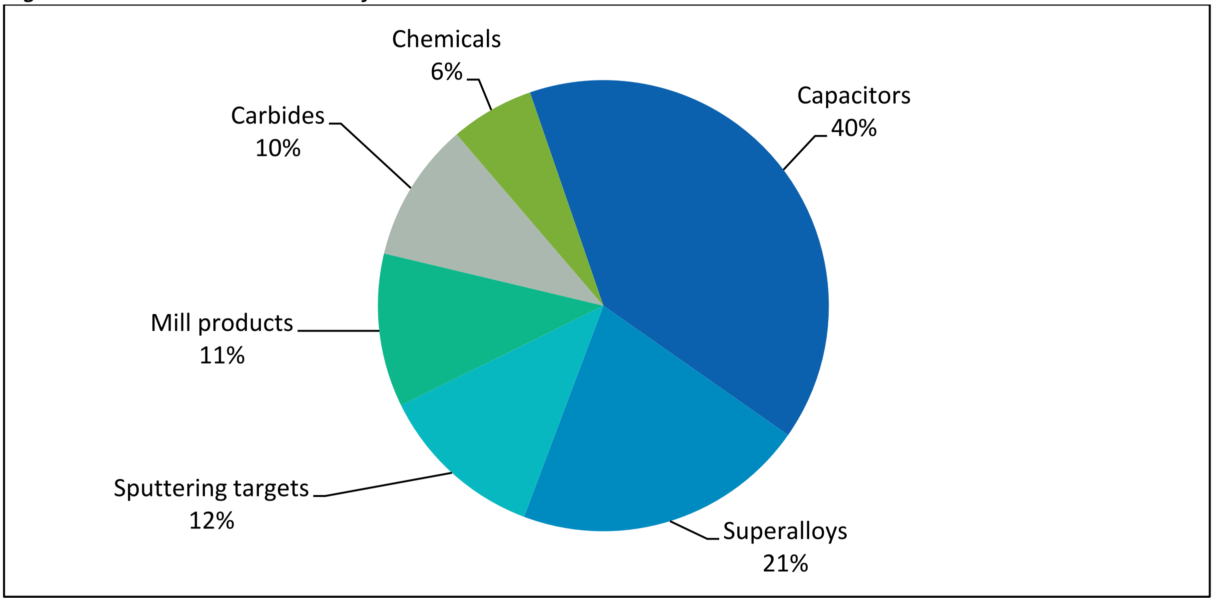
Tantalum is used for chemical apparatus engineering, for manufacturing of tantalum-capacitors, spinnerets, laboratory equipment, and for several surgery purposes (Figure 60).[a] It is used for high-temperature applications, e.g. aircraft engines, in the form of super-alloys based on nickel and cobalt. Tantalum carbide is used for the fabrication of cemented carbides. Tantalum oxide is used for manufacturing special glasses. But two characteristics of tantalum have led to its economic importance: Its corrosion-resistance and its applicability as capacitor.[b]

Figure 59: Development of real tantalum prices (Prices are deflated, 2011 = 100)



Source: DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen (Causes of price peaks, collapses and trends of mineral raw materials), Hamburg Institute of International Economics (HWWI) in contract for Deutsche Rohstoffagentur (DERA). April 2013, translated to English by Fraunhofer ISI

Figure 60: Worldwide end-use of tantalum in 2011



Source: Roskill 2013 in Minor Metals Conference

[a] Tantal, Römpp Online, 2007
[b] Encyclopedia of the elements: Tantalum, Enghag, Wiley-VCH Verlag GmbH & Co KGaA, 2004

- **Capacitors[b]:** The main application of tantalum (ca.60% of its total consumption), is in electronic devices. Tantalum, in the form of metal powder, is chiefly used to manufacture capacitors which are components of mobile phones and other communication systems, and of instruments to control ships or aircrafts.
- **Corrosion-resistant equipment[b]:** Due to the thin oxide film which coats tantalum in air, the metal has outstanding corrosion-resistance. This passive layer enables the use of tantalum in the chemical industry. It is used for manufacturing corrosion- and heat-resistant equipment. Tantalum has similar properties to as platinum with several corrosive agents.
- **Medicine[a]:** Tantalum is used in several medical applications because of its non-toxicity in human tissue. Due to its passive oxide layer, the metal is completely bio-inert in the body.
- **Optical industry**[b]: Tantalum compounds, mainly tantalum pentoxide, are used for special glasses (heat-reflecting, high refractive index, low optical scattering).

1.26.4 Resource efficiency and recycling

The worldwide tantalum supply is composed of 60% primary and 10% secondary concentrates, as well as 10% tin slags and 20% from scrap recycling and artificial concentrates.[a]
Although most substitutes have higher costs or adverse properties, tantalum can be replaced by other materials. There are efforts to substitute tantalum in capacitors by aluminium and ceramics. Niobium might be used in carbides. Glass, niobium, platinum, titanium, and zirconium could replace tantalum in corrosion-resistant equipment. Hafnium, iridium, molybdenum, niobium, rhenium, and tungsten can be used for high-temperature applications.[c] Substitutability scores for tantalum are shown inTable 58.

Table58: Substitutability scores for applications of tantalum

Uses	Substitutability score
Cemented carbides (tools)	0.3
Capacitors	0.3
Superalloys	0.7
Other	0.5

1.26.5 Specific issues

Several countries have restrictions concerning trade with tantalum. According to the OECD´s inventory on export restrictions, Rwanda is the only country among primary tantalum producers controlling trade with tantalum. Rwanda has a licensing agreement on tantalum ores and concentrates and an export prohibition on tantalum waste and scrap. China has a VAT rebate reduction on tantalum and articles thereof, and Russia uses an export tax of 6.5% on tantalum waste and scrap. Many other countries impose trade restrictions on tantalum.

[a] Ullmann's Encyclopedia of Industrial Chemistry: Tantalum and Tantalum Compounds. Wiley-VCH Verlag GmbH & Co KGaA,, 2011
[b] Roskill Information Services: The Economics of Tantalum, London, 2005
[c] Mineral Commodity Summaries: Tantalum, US Geological Survey, 2013

1.27 Tellurium

1.27.1 Introduction

Tellurium (Te, atomic number 52) is a brittle, metallic, silvery-white element. As a metalloid, it shares properties associated with both metals and non-metals. Reliable information on the world tellurium market is often difficult to obtain.

1.27.2 Supply and demand statistics

Tellurium is found in combination with gold, silver, copper, lead or nickel in various minerals. It is mostly produced as a by-product from the refining of copper sulphide ores, with some also produced from lead ores. Over 90% of known tellurium supply is produced from copper anode slimes, which are collected from electrolytic refineries. The remainder is mostly recovered from processing waste in lead refineries and from the treatment of dust and gases captured during smelting. There is increasing interest for direct mining of tellurium from bismuth or gold telluride deposits.[a]

Information on reserves is difficult to come by and largely incomplete. However, the USGS estimates global reserves of tellurium in copper deposits to total 24,000 tonnes, of which approximately 7,000 tonnes is held by the USA and Peru.[b] European reserves of tellurium are estimated at approximately 2,000 tonnes, and are mostly located in Poland.[c] The Kankberg Mine in Sweden has a reserve of 2.88 million tonnes grading 4.1 g/t gold and 186 g/t tellurium, which would give a reserve of 536 tonnes tellurium: it was opened by Boliden in 2012.[d]

A range of estimates exist for world production of tellurium. The longstanding estimate of the USGS for global tellurium production is that it has been between 450 and 500 tonnes per year.[e] However in a recent publication the USGS has revised its view upwards, estimating world tellurium production at 630 tonnes in 2010.[f] Due to secrecy, official data on the tellurium production are only available for few states, although production of tellurium containing products is known to exist in many countries. For 2011 the USGS estimated world production in Canada, Japan and Russia stands at 80 tonnes.

A more conservative figure is quoted by the International Copper Study Group (ICSG) at 450 tonnes, based upon industry estimates (Table 59). However, the ICSG estimates do provide a full country-by-country breakdown of world selenium refinery production, based upon output at copper and lead refineries. Based upon the ICSG data, the location of production is relatively diverse: the world’s leading producers, China and Japan, are each attributed to just less than 20% of world production. The EU’s share of world selenium production is also approximately 30%. Further high-purity refining, however, is often much more concentrated than that for crude or copper telluride production.

Table59: World tellurium refinery production, 2011[g]

Country	Refinery production (in tonnes, 2011)	
Belgium	60	13%
Canada	25	6%
China	80	18%
Germany	35	8%

a International Copper Study Group (2012), Study of By-Products of Copper, Lead, Zinc and Nickel
b USGS (2013), Mineral Commodity Summaries – Tellurium
c EC JRC (2011), Critical Metals in Strategic Energy Technologies
d Boliden Presentation (2011), Kankberg – a new Boliden gold mine, http://www.boliden.com/Documents/Press/Presentations/Kankberg.pdf
e USGS (2011), Selenium and Tellurium Minerals Yearbook 2010
f US Department of Energy (2011), Critical Materials Strategy
g International Copper Study Group (2012), Study of By-Products of Copper, Lead, Zinc and Nickel

India	12	3%
Indonesia	15	3%
Japan	65	14%
Kazakhstan	20	4%
Philippines	20	4%
Russia	25	6%
South Korea	20	4%
Sweden/Finland	20	4%
Others	53	12%
Total	**450**	

Source: International Copper Study Group

In common with selenium, Europe has a strong position in terms of tellurium refining, with Belgium, Germany and Sweden/Finland all major producers. Some further EU production is located in Poland and Spain. However, many of the major producers of Tellurium obtain their tellurium-containing source (often anode slimes or copper concentrates) from outside the EU:

- Umicore (Belgium) primarily produces selenium from anode slimes and other copper and lead mining and refining residues sourced elsewhere.
- Aurubis (Germany) have production centres in Europe. However, they use copper concentrates from elsewhere.[a]
- Boliden (Sweden/Finland) produces 20% of its copper concentrate for smelters (ultimately a source of tellurium) from its own mines.[b]

1.27.3 Economic importance

The major uses of tellurium are as follows (Figure 61):[c]

- **Solar cells**: Tellurium's major use is as Cadmium Telluride thin-film photovoltaics, where it helps improve efficiencies. This is an area that has grown significantly since 2008. Although the short term outlook is relatively weak, it is likely to grow further, potentially displacing other markets.
- **Thermo-electrics**: Mercury-cadmium-telluride has applications in devices such as infrared sensors, heat-seeking missiles and other thermal imaging devices. Semiconducting bismuth telluride is also used in thermoelectric cooling devices in electronics and consumer products.
- **Metallurgy**: Tellurium has many uses as an alloying additive. It can be added to stainless steel and copper to improve machinability without affecting conductivity. Among other uses, tellurium can be used in steel as a free-machining additive, in copper to improve machinability without affecting conductivity, and in lead to improve resistance to vibration.
- **Rubber formulation**: Tellurium is used as a vulcanizing agent and accelerator in the processing of rubber. It improves heat resistance in particular.
- **Other**: Further uses for tellurium include in blasting caps, and as a pigment to produce blue and brown colours in ceramics and glass.

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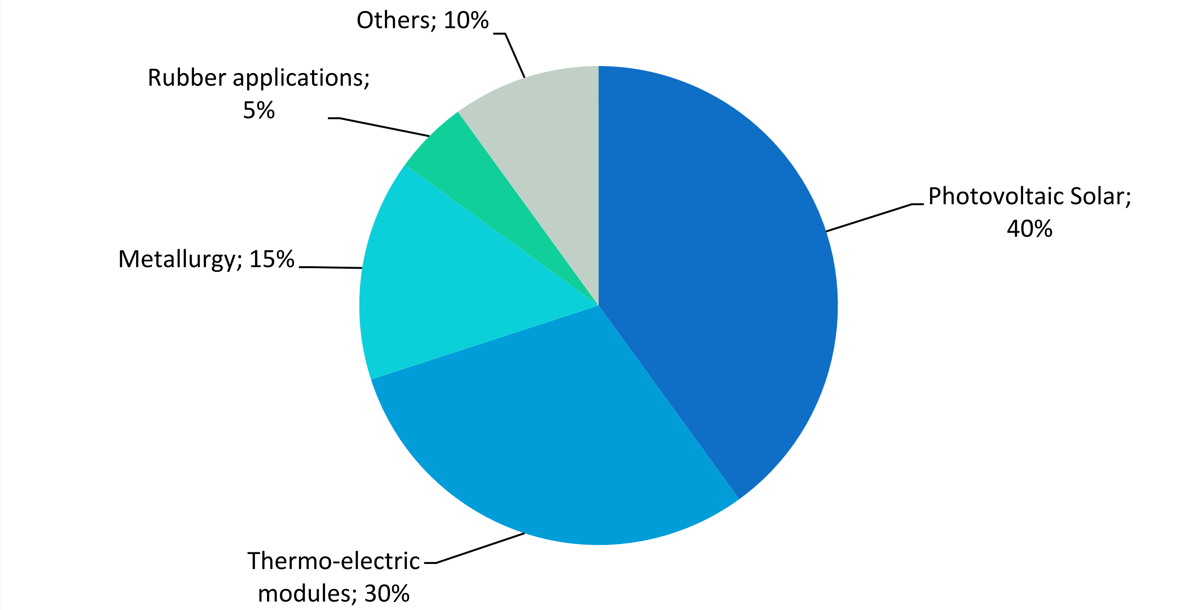
a http://www.aurubis.com/en/our-business/raw-materials/copper-concentrates/ [accessed April 2013]
b http://www.boliden.com/Products/Copper/ [accessed April 2013]
c USGS (2012), Minerals Yearbook 2011 – Selenium and Tellurium

Figure 61: Major applications for tellurium, 2011.[a]



Source International Copper Study Group

Although tellurium demand increased slightly in 2011, during 2012 there was a significant drop in demand. Traders reported that the photovoltaic solar industry was currently taking a ‘holiday’ in purchasing new material, instead of using up existing inventories. This could last several years, to improve their cash-flow situation amidst highly competitive market conditions for panels.[a]

1.27.4 Resource efficiency and recycling

Recycling has typically been low, due to low amounts of scrap from which secondary tellurium could be extracted. Many of the major uses of tellurium are also dissipative, thus there is very little processing of secondary material. Indeed UNEP report an end of life recycling rate of less than 1%.[b] Some tellurium has been recovered from selenium-tellurium photoreceptors in old copiers.

The USGS also note a plant in the USA that can recycle tellurium from cadmium-tellurium based solar cells (post-consumer photovoltaic solar collection is already relatively established). Data released by First Solar, the world’s largest producer of CdTe solar cells, indicates that the recycling of post-industrial CdTe production scrap contributes approximately 65 tonnes of supply to the market. The process is highly efficient and recovers 95% of the semi-conductor materials contained on the panel.[c]

Tellurium is substitutable in most of its uses; however, this will generally lead to a loss in efficiency or properties. Indeed, tellurium’s use in rubber applications and thermo-electric modules is actually quite price sensitive, indicating that acceptable substitutes already exist.

A number of substitutes have been developed for various end uses of tellurium :[d]

- Bismuth, calcium, lead, phosphorus, selenium and sulphur can be used instead of tellurium is many free-machining steels.
- Tellurium can often be replaced as a catalyst, by either another catalyst or by a non-catalysed process.
- Sulphur or selenium can replace tellurium as vulcanization agents in rubber compounding.

a International Copper Study Group (2012), Study of By-Products of Copper, Lead, Zinc and Nickel
b UNEP International Resource Panel (2011), Recycling Rates of Metals: A Status Report
c First Solar (April 2012), The long-term supply of tellurium and the anatomy of the immediate market decline; MMTA Conference
d USGS (2013), Mineral Commodity Summaries – Selenium

- Tellurides can be replaced by selenides and sulphides of refractory metals in high-temperature, high-vacuum lubricants.
- Amorphous silicon and copper indium diselenide are the two main competitors to cadmium telluride in photovoltaic power cells.
- Selenium-tellurium photoreceptors used in copiers and printers are being replaced by organic photoreceptors in newer machines.

Substitutability scores are show in Table60.

Table60: Substitutability scores for tellurium

Application	Substitutability score
Metallurgy	0.3
Thermo-electronics	0.7
Rubber Formulation	0.3
Photovoltaics	0.5
Other	0.3

1.27.5 Specific issues

There are no known trade restrictions for tellurium. There are also no known taxes, regulations, or stockpiles of any significance.

Because tellurium is produced largely as a by-product metal from copper, its production is dependent on refiners' willingness to engage in its recovery. However, its overall impact on revenues is very modest. Data on recovery rates suggest that, at most, only 50% of recoverable tellurium is actually refined as market supply.[a]

There is some concern regarding the shift towards SX-EW copper refining, which may affect tellurium recovery in the future. However, this may have relatively little impact for tellurium, because the deposit types for which SX-EW is likely to be used contained limited quantities of tellurium.

[a] International Copper Study Group (2012), Study of By-Products of Copper, Lead, Zinc and Nickel

1.28 *Tin (Stannum)*

1.28.1 Introduction

Tin (Sn, atomic number 50) is a silvery-white post-transition metal, which is malleable and has a highly crystalline structure. There are two allotropic forms of tin: α and β. When grey α-tin is warmed to 13.2°C it changes into white β-tin, the ordinary form of the metal. On cooling, β-tin turns back into α-tin. The two allotropes of tin have contrasting properties, owing to their different crystal structures. In order to inhibit the transformation of β-tin to α-tin in commercial grades, small amounts of other metals such as silver and antimony are added.

Tin is resistant to corrosion from water and can be highly polished; because of these properties tin is commonly used as a coating for other metals and to form useful alloys. Tin alloys with lead are used as a solder for electronic appliances, this is the by far the largest end-use of tin. Owning to its non-toxicity, tin is used to coat steel to produce tin cans which are used for food packaging.

In nature tin occurs in granite rocks, the main commercial ore of tin is cassiterite. However, small amounts of tin are recovered from sulphide minerals such as stannite. Tin is mined from both primary and secondary deposits. Primary deposits are usually associated with granite intrusive rocks. Weathering and erosion of primary deposits forms secondary deposits of cassiterite; these are recovered from river beds, other fluvial deposits, and beach sand.

As well as mining, secondary sources of tin are an important component of tin supply and contribute to around 20% of global supply.[a]

1.28.2 Supply and demand statistics

Tin has a relatively large market with global mine production of 230,000 tonnes in 2012.[b] Mining in five countries accounts for almost 90% of the total world tin production.[c] Of these five, China is the world's leading tin producer, with 43% of world production; Indonesia and Peru represent important tin producing countries. The geographical concentration of production is viewed as moderate when compared to overall metal production.[a]

In addition to production, in 2011, China accounts for around 43% of global tin use, and in fact used around five times as much tin as Europe.[d] Following rapid growth from the mid-1990s to 2007, tin consumption has stagnated over the past five years. There has been a slight decline in demand in the tin solder market, likely due to poor performance in the electronics industry and technological advances which allow for the use of less solder.

Tin reserves are large relative to current production and are estimated to be around 15 times that of global primary tin consumption. The greatest part of tin reserves are held in South America and Asia.

a Critical Metals in Low-Carbon Energy Technologies, Oakdene Hollins and Fraunhofer ISI, JRC-IET, January 2013
b Tin Mineral commodity summary, USGS, 2013
c Tin 2010 Minerals Yearbook, James F. Carlin Jr, USGS, May 2012
d ITRI Tin use and recycling survey 2011, ITRI, 2011

Table61: World tin production and reserves, 2012

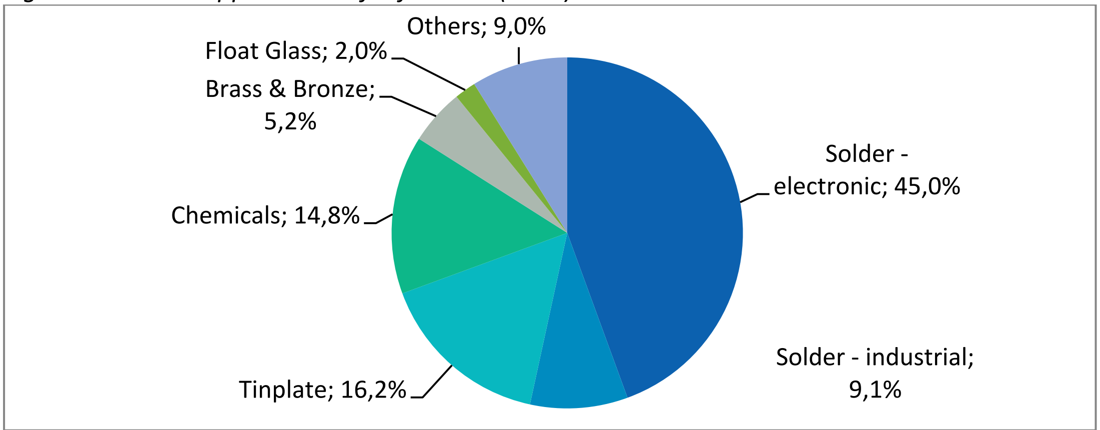
Country	Production, 2012[a]		Reserves (tonnes) [b]
	Tonnes	%	
China	115,900	39%	1,500,000
Indonesia	94,300	32%	800,000
Peru	26,105	9%	310,000
Bolivia	19,700	7%	400,000
Brazil	10,800	4%	710,000
Australia	6,000	2%	240,000
DRC	2,500	1%	NA
Vietnam	5,400	2%	NA
Malaysia	3,600	1%	250,000
Rwanda	3,500	1%	NA
Russia	1,500	1%	350,000
Thailand	200	0%	170,00
Nigeria	2,400	1%	NA
Myanmar	700	0.2%	NA
Portugal	43	0.0%	NA
Other countries	800	0.3%	180,000
World total	**293,448**		**4,900,000**

Source: Production data: BGR using World Bureau of Metal Statistics, ITRI and Direccao Geral de Energia e Geologia (Portugal). Reserves: USGS

1.28.3 Economic importance

Tin demand is dominated by use in solders. The rapid move from leaded to lead-free high tin content solder lead to an increase of world tin use in 2006 and 2007. However, since 2007 there has been little change in the lead free solder market. The effects of technological advances allowing for miniaturisation and used of smaller quantities of solder may also contribute to this. Therefore, the likelihood of rapid demand growth over the coming decade is viewed as low, though it is predicted to keep growing at a slow but steady pace driven mainly by applications in the electronics industry. Other important applications of tin include; tin plate, chemicals, alloys such as brass and bronze, and in the production of float glass (Figure 62). The historic price for tin dropped through the 1980s and 1990s (Figure 63) however in recent years the price has increased despite recent economic conditions.

Figure 62: Global applications of refined tin (2010)



Source: ITRI 2011

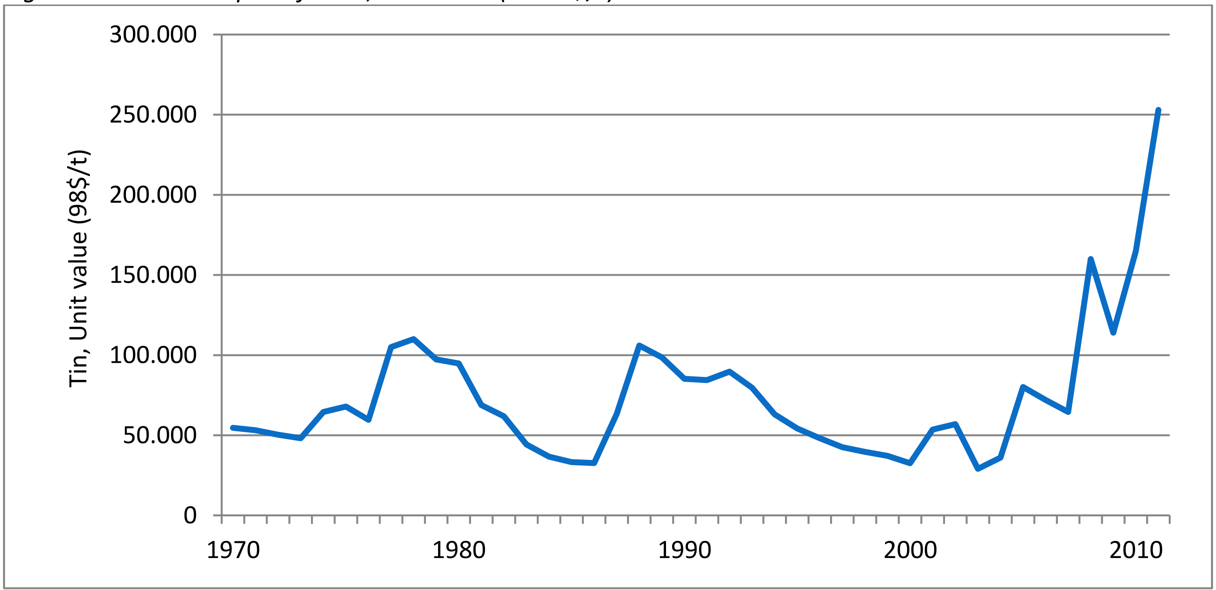
Descriptions of the main used of tin are as follows:

[a] Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) - Aggregated from World Bureau of Metal Statistics, ITRI and Direccao Geral de Energia e Geologia data

[b] Tin Mineral commodity summary, USGS, 2013

- **Solder - electronic:** Alloys of tin and lead are used as solders for electric circuits found in the majority of electronic appliances. Lead free solders contain metal additives such as copper, silver, bismuth, indium, zinc or antimony. Additives are commonly used to overcome the problem of tin whiskers.
- **Solder - industrial:** Tin-lead alloys are also widely used as industrial solders, mostly due to their low melting range. Applications for industrial solders include automotive radiators, joining lead pipes and sheet metal.
- **Tinplate:** By far the largest application of tinplate is for packaging; tinplate is produced by coating steel in a thin layer of tin. Because of its non-toxicity, light weight and resistance to corrosion, tinplated steel containers are commonly used as food containers.
- **Chemicals:** The tin chemicals sector has seen the strongest growth in the tin market over the last 2 years. There are a number of new and interesting tin chemical applications which are likely to support further growth of this sector in the coming years. A major commercial use of organo-tin chemicals is for PVC stabilisers. In the absence of stabilisers PVC degrades to give a brittle plastic in the presence of light, heat or atmospheric oxygen.
- **Brass & bronze:** Many useful alloys feature tin; alloys such as brass and bronze have many different applications, including industrial applications such as springs and valves. Brass is an alloy of copper, zinc and tin and bronze is an alloy of copper and tin. For both brass and bronze, varying the amount of copper in the composition will change the properties of the alloy.
- **Float glass:** Tin is used in the Pilkington process for making window glass, whereby molten glass is floated on top of molten tin at 1100°C. This process produces glass sheets with perfectly smooth surfaces and a uniform thickness.
- Other applications of tin include pewter items, tin powders and batteries.

Figure 63: Historical price for tin, unit value (98 US$/t)



Source: *Source: USGS (2012-), Historical Statistics for Mineral and Material Commodities in the United States [accessed February 2013]. Figures are indexed to 1998 values.*

1.28.4 Resource efficiency and recycling

The infrastructure for reclaiming tin is well developed and recycling rates for the metal are high. Tin which has been re-refined from secondary scrap is indistinguishable to primary mined tin and consequently a significant proportion of tin consumed in Europe is recycled metal. In 2010 the recycling input rate for tin was estimated to be 31.6%. Of all end-users of tin, copper alloys use the highest proportion of secondary tin to refined tin with approximately 50% usage from secondary sources. In volume terms the most significant use of secondary tin is for solder; the recycling input rate is estimated to be around 20%.

Table62: Mined, refined and secondary production tonnages for tin in 2010

Metal	Mined Production	Refined metal Production	Secondary Production	Recycled Sources (%)
Tin	265,000	362,000	74,000	20%

Source: ITRI

There are viable substitutes for tin for some applications. For tinplate there are several viable alternatives including aluminium, glass, plastics and composite materials for food packaging. For PVC stabilisers organo-tins can be substituted by several different chemicals such as zinc and calcium compounds but at a loss of performance.

Table63: Substitutability scores for tin

Use	Substitutability score
Solder - electronic	0.7
Solder – industrial	0.7
Tinplate	0.3
Chemicals	0.7
Brass & Bronze	0.3
Float glass	0.3
Other	0.5

As well as substitution, tin use may also be reduced through technological advances allowing for thinner coatings of tin plates and the usage of less solder. On such technological advance is selective soldering, in comparison to wave soldering the amount of tin lost in solder dross is significantly reduced.[a]

1.28.5 Specific issues

In Europe the RoHS directive has restricted the use of lead in solder in certain electronic products. Lead solders have been substituted for high tin content solders in consumer electronics products. From July 2014 medical devices as well as monitoring and control instruments will no longer be exempt from RoHS.[b] Furthermore, two tin products are present on the REACH SVHC list: dibutyl-tin dichloride (DBTC) and bis(tributyl-tin)oxide (TBTO).

Tin production in China declined in 2012 and the amount of tin imported to China increased significantly due to a range of factors. Drought conditions combined with the closure of small tin mines for pollution control led to a significant decline in tin production in China.

a ITRI Tin use and recycling survey 2011, ITRI, 2011
b http://ec.europa.eu/environment/waste/rohs_eee/ accessed 26.02.13

1.29 Titanium

1.29.1 Introduction

Titanium (Ti, atomic number 22) is a lustrous-white metal of low density (4.51 g/cm^3) with high mechanical strength.[a,b] The light metal has a high melting point (1,668°C). Its boiling point is 3,500°C.[c] Titanium is affected by hydrofluoric acid and hot acids, but it is resistant to diluted, cold hydrochloric acid and sulphuric acid, and to nitric acid up to 100°C in every concentration. At room temperature it is resistant even to aqua regia. Pulverized titanium, formed by various cutting processes, is pyrophorus.

Its remarkable properties, like its low weight, high mechanical strength, high melting point, and small thermal expansion, make titanium and titanium alloys important for many applications, e.g. for aircraft industries or medical use. Despite its high melting point, titanium is not suitable for high temperature applications, since its mechanical strength drops sharply when the temperature exceeds 426°C.[a]

The economically important sources for titanium metal and dioxide are ilmenite, titanite, leucoxene, rutile, slag, and synthetic rutile.[d,b] By far the largest quantities of titanium mineral concentrates are used by titanium dioxide producers, for example for pigments.[d] Rutile is the most useful mineral for the extraction of titanium dioxide.[c]

1.29.2 Supply and demand statistics

Titanium is a widely distributed and fairly abundant element. Its mean content in the Earth's crust is 5,650 ppm. Thus, at 0.565%, titanium is the ninth most abundant element.[b] Since the ionic radius of titanium is similar to some other common elements, titanium is present in most minerals, rocks, and soils. However, there are few titanium minerals with more than 1% titanium content. Titanium ores are mostly obtained by open pit mining. Another relevant source of titanium is titaniferous slag, which can contain up to 95% titanium dioxide. It is extracted by pyrometallurgical processing of ilmenite-containing iron ores, titano-magnetites and titano-haematites.[b]

The world's largest reserves are found in China, Australia, India, and South Africa. Estimated world resources of ilmenite, rutile, and anatase are more than 2 billion tonnes. Ninety two percent of the world's consumption of titanium minerals is ilmenite

The leading titanium producing countries are Australia, South Africa, Canada, and China (Figure 64). Together they produce more than 50% of global titanium production, which amounted to 6 million tonnes.[d] There is no titanium production in the EU-27. In Europe only Norway produces titanium with a share of 6% of global titanium mineral production (Figure 64 and).

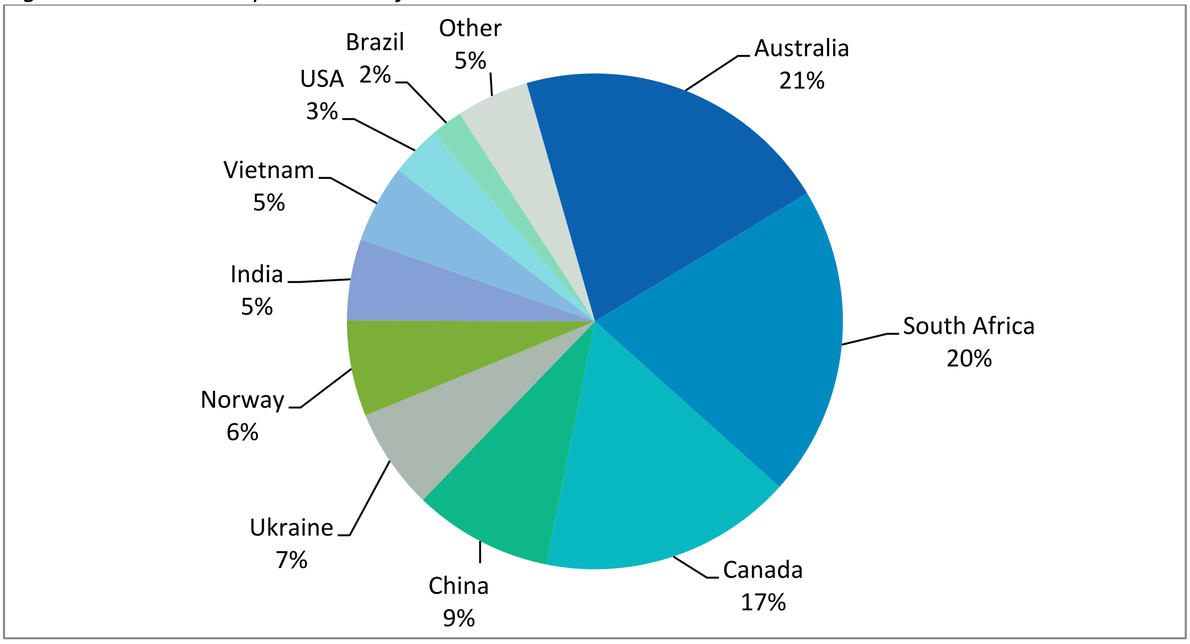
[a] Titan, Römpp Online, 2007
[b] Encyclopedia of the elements: Titanium, Enghag, Viley-VCH Verlag GmbH & Co. KGaA, 2004
[c] Ullmann's Encyclopedia of Industrial Chemistry: Titanium, Titanium Alloys, and Titanium Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[d] Mineral Commodity Summaries: Titanium and titanium dioxide, US Geological Survey, 2013

Table64: World reserves of ilmenite and rutile (2011), weight of contained titanium dioxide

Country	Reserves ('000s tonnes)
Australia	118,000
Brazil	44,200
Canada	31,000
China	200,000
India	92,400
Madagascar	40,000
Mozambique	16,480
Norway	37,000
Sierra Leone	3,800
South Africa	71,300
Sri Lanka	N/A
Ukraine	8,400
USA	2,000
Vietnam	1,600
Other countries	26,400
World total (rounded)	**700,000**

Source: Mineral Commodity Summaries: Titanium mineral concentrates, US Geological Survey, 2013

Figure 64: Worldwide production of titanium in 2010



Source: World Mining Data 2012

Since neither reserves or mine production of titanium in the EU-27 have been reported; the EU is totally dependent on imports. According to Comtrade data, the largest quantity of titanium imported by the EU was exported by Canada and Norway; Australia, South Africa, and Canada were the leading producers for titanium worldwide.

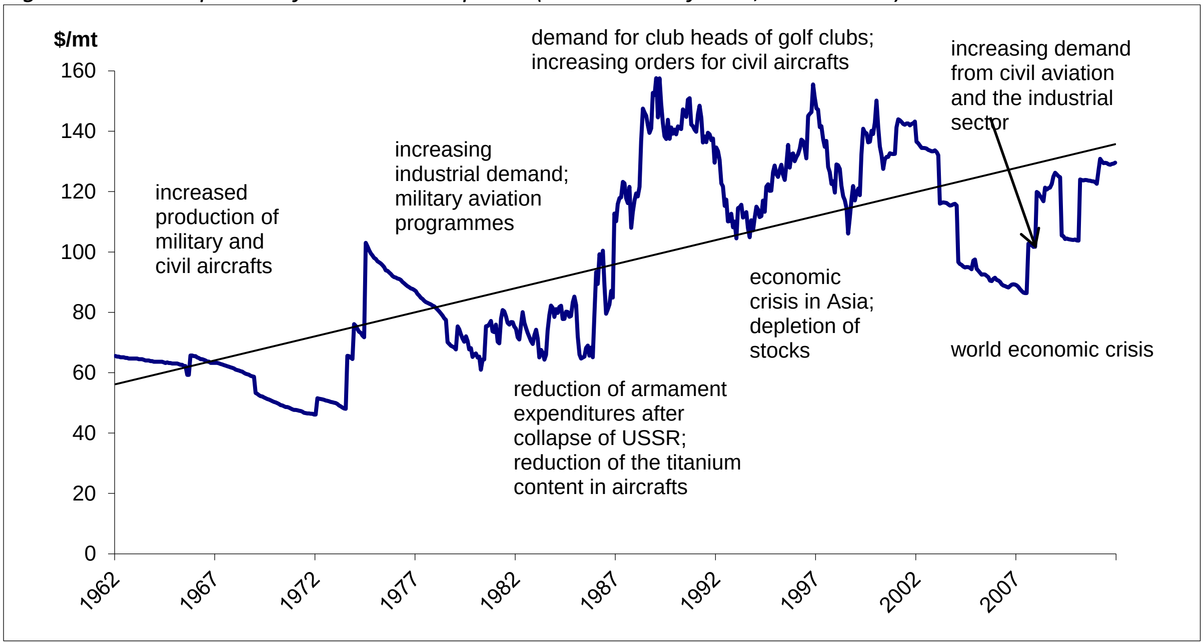
Table65: World production and imports to EU of titanium, 2010

Country	Production, 2010		Imports to EU, 2010)[a]	
	Tonnes	%	Tonnes	%
Australia	1,260,800	20.8%	57,765	6.9%
South Africa	1,230,000	20.3%	121,321	14.5%
Canada	1,000,000	16.5%	217,391	26.0%
China	550,000	9.1%	10	0.0%
Ukraine	400,000	6.6%	42,204	5.0%
Norway	380,160	6.3%	197,656	23.6%
India	321,000	5.3%	103,944	12.4%
Vietnam	308,048	5.1%	0	0.0%
USA	200,000	3.3%	-	-
Brazil	125,900	2.1%	16,332	2.0%
Mozambique	NA	NA	77,782	9.3%
Sierra Leone	77,301	1.3%	2,662	0.3%
other countries	209,838	3.5%	30	0.0%
Total	**6,063,047**	**100.0%**	**837,097**	**100.0%**

Source: World mining Data 2012; Eurostat Comext

1.29.3 Economic importance

Figure 65: Development of real titanium prices (Prices are deflated, 2011 = 100)



Source: DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen (Causes of price peaks, collapses and trends of mineral raw materials), Hamburg Institute of International Economics (HWWI) in contract for Deutsche Rohstoffagentur (DERA), trend line and translation to English by Fraunhofer ISI

Figure 65 shows that real titanium prices rose steadily between the late 1970s and the late 1980s. From 1971 to 1981, titanium price rose by 80% due to a growing demand from military and civil aviation

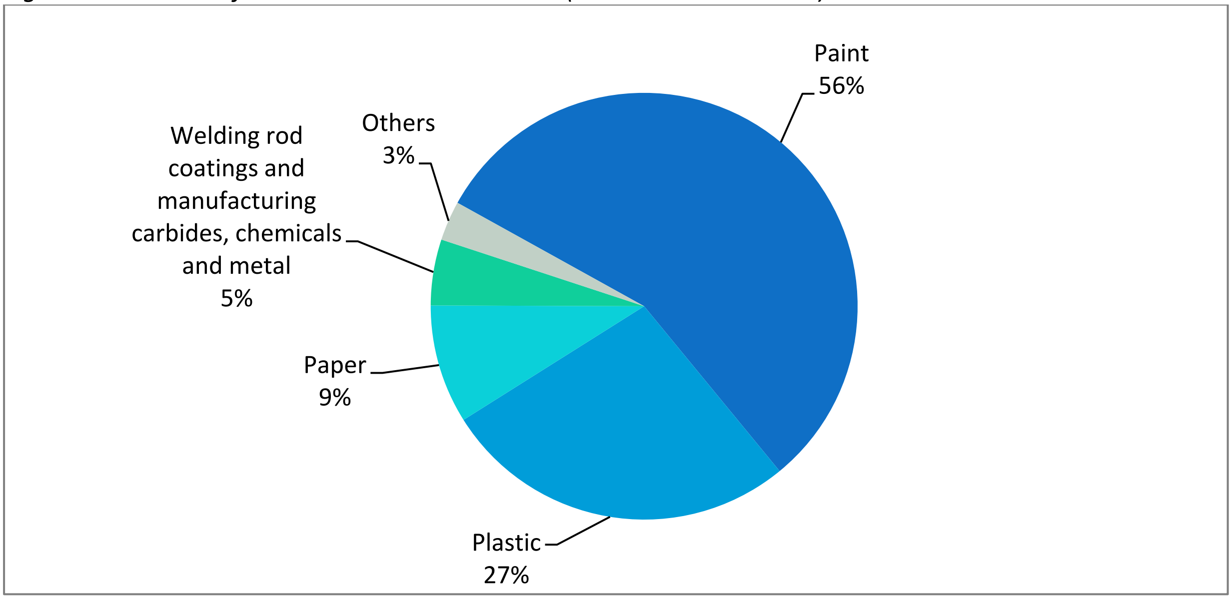
[a] Eurostat Comext [Accessed July 2013], Trade code 261400 (Titanium ores and concentrates)

industries. Titanium prices stayed at a high level with minor fluctuations until early 2000s, before decreasing with the global economic crisis[a].

The main end-uses of titanium are paints, plastics, paper, metal and chemical applications (Figure 66), this data is for the US market and no EU data was available. The major markets for titanium dioxide are inorganic pigments, so-called 'titanium white'. These non-toxic pigments are used for paints, plastics and papers, and also for opaquely white porcelain glazes. Approximately 95% of all titanium is used as TiO_2 pigment. Since the TiO_2 demand exceeds the available amount, an artificial substitute had to be found. Synthetic TiO_2 is produced from titanium slag, which is extracted by a metallurgical process in which iron is extracted from ilmenite or titano-magnetites. Titanium oxide is also used for rutile welding electrodes.[b]

Titanium metal has a distinct tendency to build a passive film of TiO_2, which leads to a high corrosion resistance for the metal. Hence titanium and its alloys are used in chemical plants and in seawater.[b] This passive layer also leads to a good toleration of titanium by human tissue[c], and titanium is used for implants, pins for fixing broken bones and heart pacemaker capsules.[b]

Figure 66: End-use of titanium in the USA in 2012 (EU data not available)



Source: Mineral Commodity Summaries: Titanium, US Geological Survey, 2013

Some titanium alloys can be used at working temperatures up to 600°C. Titanium is lighter than steel, and titanium alloys are stronger than aluminium alloys at elevated temperatures. This specific combination of low weight and high-temperature strength makes titanium valued for the aerospace applications. A civil aircraft can contain up to 1,100 kg titanium[b], and the aircraft industry is the largest consumer (72%) of titanium alloys.[d] Cemented carbides are usually manufactured from tungsten and a binding element (e.g. cobalt). Modern hard metals have significant contents of titanium carbide or titanium nitride.[b]

Some important technologies that are expected to increase the demand for titanium metal are micro-capacitors, sea water desalination, orthopaedic implants and dye-sensitised solar cells.[e]

[a] DERA Rohstoffinformationen, HWWI, 2013
[b] Encyclopedia of the elements: Titanium, Enghag, Viley-VCH Verlag GmbH & Co. KGaA, 2004
[c] Ullmann's Encyclopedia of Industrial Chemistry: Titanium, Titanium Alloys, and Titanium Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[d] Mineral Commodity Summaries: Titanium and titanium dioxide, US Geological Survey, 2013
[e] Rohstoffe für Zukunftstechnologien, Fraunhofer ISI and IZT, 2009

1.29.4 Resource efficiency and recycling

In 2012, about 35,000 tonnes of new scrap and 1,000 tonnes of old scrap were recycled. Whereas the steel industry used about 10,000 tonnes of recycled titanium and ferrotitanium, 1,000 tonnes were used by the super-alloy industry and further 1,000 tonnes by other industries.[a] Recycled content from old scrap currently accounts for 6% of the entire use.[b] In the future, recycled titanium will only cover a small share of the demand, due to rapidly rising consumption.[c]

Due to its outstanding properties, there are few materials which can compete with titanium in relation to strength-to-weight ratio and corrosion resistance. Where good corrosion resistance is necessary, titanium can be substituted by aluminium, nickel, specialty steels or zirconium alloys. For applications where high strength is required, titanium competes with superalloys, steel, composites, and aluminium. As a white pigment, titanium dioxide can in some cases be replaced by calcium carbonate, kaolin or talc.[a] Substitutability scores for titanium are shown in Table 66.

Table66: Substitutability scores for titanium applications

Uses	Substitutability score
Plastic	0.3
Paint	0.3
Welding rod coatings and manufacturing carbides, chemicals and metal	0.7
Paper	0.3

1.29.5 Specific issues

Several countries have restrictions concerning trade with titanium. According to the OECD´s inventory on export restrictions, Ukraine and Vietnam use export taxes on titanium waste, scrap, ores, concentrates and articles thereof ranging between 5% and 45%. There is a wide range of other countries imposing trade restrictions on titanium.

Two titanium products are present on the REACH SVHC list: lead titanium zirconium oxide and lead titanium trioxide.

[a] Mineral Commodity Summaries: Titanium and titanium dioxide, US Geological Survey, 2013
[b] The Recycling of Metals: A Status Report, UNEP, 2011
[c] Rohstoffe für Zukunftstechnologien, Fraunhofer ISI and IZT, 2009

1.30 Vanadium

1.30.1 Introduction

Vanadium (V, atomic number 23) is a steel-grey, bluish, shimmering and ductile metallic element[a] with a density of 6.11 g/cm^3.[b] Its melting point is 1,910°C and its boiling point is 3,407°C.[c] Its main application is in ferrovanadium as an additive in alloy steels to improve their strength and resistance to corrosion.[d] Vanadium occurs in many minerals and is basically obtained as a by-product during the production of steel.[c] With a mean content of 120 ppm in Earth's crust, vanadium is a rather common element. The metal is a significant alloying element in steel and titanium alloys, as well as a catalyst for chemicals.[b] Vanadium's earliest use was in 1903, where vanadium-alloyed steel was produced.[b]

1.30.2 Supply and demand statistics

Vanadium is primarily produced as a by-product, mainly from steel slags, although other sources are available. The most important sources account for around 75% of production (67). The remaining 25% arises from primary sources.

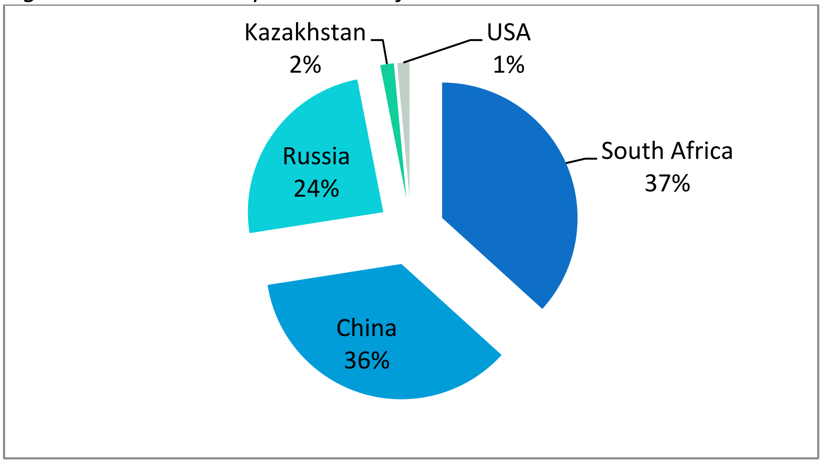
Table67: Vanadium production as a by-product

Raw material	Coupled product	Vanadium by-product
Titano-magnetites	iron / steel	vanadium slag
Mineral oils	energy / petrochemicals	fly ashes boiler residues
Uranium-vanadium ores	uranium	petrochemical residue
Bauxite	aluminium	vanadium salt
Phosphates	phosphorus	vanadium containing Fe-P salamander
Lead vanadates	lead, zinc	vanadium slag

Source: Ullmann's Encyclopedia of Industrial Chemistry: Vanadium and Vanadium Compounds, 2000

Global production of vanadium in 2010 amounted to 61,500 tonnes. The largest producers of vanadium are South Africa, China and Russia (Figure 67). Together they produce around 97% of the world's production.[e] Table 68 shows world reserves for vanadium; China, Russia and South Africa have the largest global reserves. This is consistent with production data. Vanadium is not produced in the EU.

Figure 67: Worldwide production of vanadium in 2010



Source: World Mining Data 2012

[a] Vanadium, Römpp Online, 2003
[b] Ullmann's Encyclopedia of Industrial Chemistry: Vanadium and Vanadium Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[c] Encyclopedia of the elements: Vanadium, Enghag, Wiley-VCH Verlag GmbH & Co. KGaA, 2004
[d] European Mineral Statistics 2007-2011, British Geological Survey, 2013
[e] World Mining Data 2012

Table68: Worldwide reserves of vanadium

Country	Reserves ('000s tonnes)
China	5,100
Russian Federation	5,000
South Africa	3,500
USA	45
Other countries	NA
World total rounded)	**14,000**

Source: Mineral Commodity Summaries: Vanadium, US Geological Survey, 2013

According to the data delivered by Eurostat, Mexico and the Netherlands were the leading importers for vanadium to the EU. South Africa, China, and the Russian Federation are in contrast the leading vanadium producers worldwide.

Table69: Production vanadium[a]

Country	Production, 2010	
	Tonnes	%
South Africa	22,600	36.7%
China	22,000	35.8%
Russian Federation	15,000	24.4%
Kazakhstan	1,000	1.6%
USA	900	1.5%
Austria	NA	NA
Germany	NA	NA
Italy	NA	NA
Japan	NA	NA
Mexico	NA	NA
Netherlands	NA	NA
United Kingdom	NA	NA
Total	**61,500**	**100.0%**

Sources: World mining data 2012; Eurostat Comext

1.30.3 Economic importance

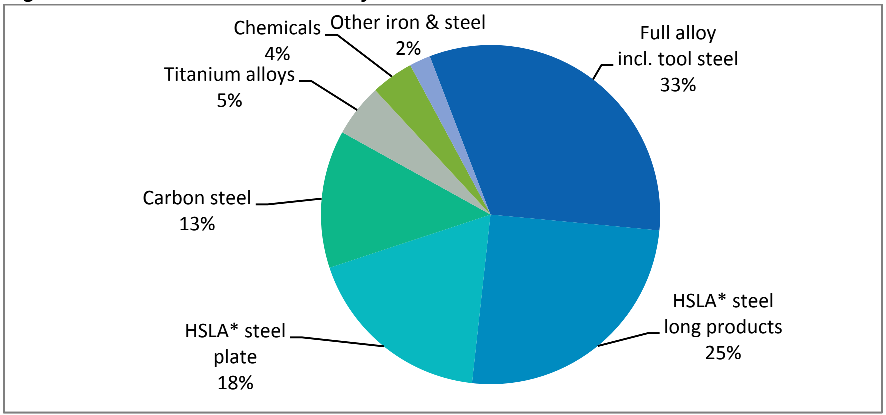
Principally, vanadium is used as an alloying component in the steel industry[b] (Figure 68). Other uses of vanadium are in non-ferrous alloys for the aerospace technology, vanadium-bearing alloys for batteries, and vanadium compounds for catalysts.[a] The steel industry represents about 90% of the worldwide end-uses of vanadium. Only 4% of the globally-used vanadium is used for the production of chemicals, and 5% is used for titanium alloys.

- **Steel (HSLA):** Vanadium itself is soft in its pure form, but when it is alloyed with other metals such as iron, it hardens and strengthens them significantly. Consequently, vanadium is used extensively to make alloys (mostly steel alloys) for tools and construction purposes. Most of the vanadium consumed is used for these applications.
- **Steel (Carbon):** Vanadium is alloyed with iron to make carbon steel, HSLA steel, full alloy steel, and tool steel. These hard, strong ferro-vanadium alloys are used for military vehicles and other protective vehicles. It is also used to make car engine parts that must be very strong, such as piston rods and crank shafts.
- **Chemical applications:** Some vanadium is used in other industrial applications. For example, vanadium pentoxide (V_2O_5) is used production of glass and ceramics and as a chemical catalyst.

[a] The imports to the EU of vanadium oxides was about 10.000 tonnes in 2012. For the ores and concentrates no precise statement can be made.

[b] Ullmann's Encyclopedia of Industrial Chemistry: Vanadium and Vanadium Compounds, Wiley-VCH Verlag GmbH & Co. KGaA, 2000

Figure 68: Worldwide end-use of vanadium in 2012



Source: Roskill 2013, Titanium Europe Conference
** HSLA steel = High-strength low-alloy steel*

1.30.4 Resource efficiency

The US Geological Service considered two kinds of vanadium scrap: tool steel scrap, which was mainly recycled for it vanadium content; and spent chemical process catalysts, which constitute 40% of the entire supply.[a]

Vanadium as an alloying component in steel can be replaced by manganese, molybdenum, niobium, titanium, and tungsten to some extent. Vanadium compounds as catalysts are interchangeable with platinum and nickel in several chemical processes.[b] Substitutability scores for vanadium applications are shown in Table 70.

Table70: Substitutability scores for vanadium

Use	Substitutability score
Metallurgical use	0.5
Non-metallurgical use (catalysts for the production of maleic anhydride and sulphuric acid)	0.3
Other	0.5

[a] Mineral Commodity Summaries: Vanadium, US Geological Survey, 2013

1.31 Zinc (Zincum)

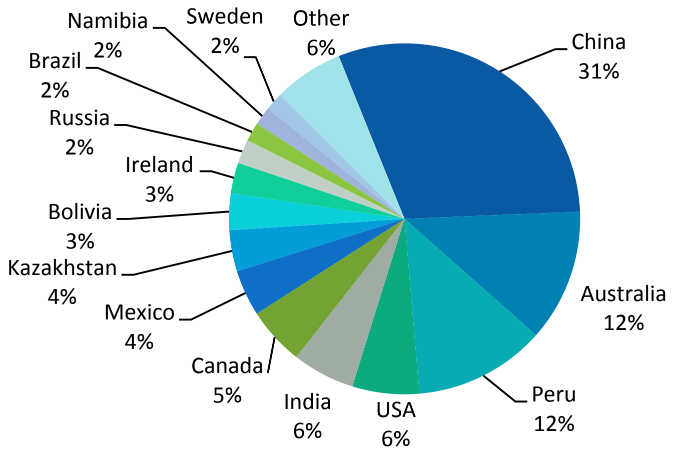
1.31.1 Introduction

Zinc (Zn, atomic number 30) is a shimmering, bluish metal.[a] It has a low melting point of 419.5°C, a boiling point of 906°C and a density of 7.14 g/cm^3 at 20°C.[b] At room temperature zinc is brittle, between 100°C and 150°C it becomes malleable, above 200°C it is brittle again and can be ground into a powder.[c] Above 900°C zinc burns with a bluish-green flame to zinc oxide (ZnO) or 'philosopher's wool'.[c] Zinc is a relatively abundant element: at a mean content in the Earth's crust of 70 ppm, zinc is the 24th most abundant element.[a] Worldwide, sphalerite - also known as zinc blende (Zn,Fe)S - is the most common ore for zinc mining and production.[a]

1.31.2 Supply and demand statistics

Zinc is fairly abundant, and global resources are estimated at 1.9 billion tonnes.[d] According to its traded weight, zinc is 4th among the metals worldwide. Only iron, aluminium and copper are traded in greater amounts. Zinc ore deposits are widely distributed and are mined in several countries worldwide (Figure 69).

Figure 69: Worldwide production of zinc in 2010



Source: US Geological Survey MY 2011

In 2010, China was the world's largest producer of zinc, followed by Australia and Peru. About 954,000 tonnes or 7.5% of the world's zinc production was mined in the EU35, with Ireland and Sweden as the most important.[e]

Table 71 shows the data for zinc imports to the EU in 2010. According to Comtrade data, by far the largest quantity of zinc imported was imported from Australia and Peru; China was the leading producer for zinc worldwide.

Table71: World Production and imports to EU of zinc, 2010

Country	Production, 2010[a]	Imports to EU, 2010[b]

[a] Encyclopedia of the elements: Zinc, Enghag, Wiley-VCH Verlag GmbH & Co. KGaA, 2004
[b] Ullmann's Encyclopedia of Industrial Chemistry: Zinc, Wiley-VCH Verlag GmbH & Co. KGaA, 2000
[c] Zinc, Römpp Online, 2006
[d] Mineral Commodity Summaries: Zinc, US Geological Survey, 2013
[e] European Mineral Statistics 2007-2011, British Geological Survey, 2013

	Tonnes	%	Tonnes	%
China	3,700,000	30.5%	1	0.0%
Australia	1,479,000	12.2%	297,111	24.0%
Peru	1,470,450	12.1%	294,197	23.8%
USA	748,000	6.2%	199,709	16.2%
India	700,000	5.8%	5,498	0.4%
Canada	648,905	5.3%	121,654	9.8%
Mexico	518,429	4.3%	15,969	1.3%
Kazakhstan	459,000	3.8%	0	0.0%
Bolivia	411,409	3.4%	138,069	11.2%
Ireland	342,434	2.8%	-	-
Russian Federation	269,000	2.2%	0	0.0%
Brazil	211,203	1.7%	-	-
Namibia	205,324	1.7%	0	0.0%
Sweden	198,686	1.6%	-	-
Turkey	88,000	0.7%	66,910	5.4%
Macedonia	35,000	0.3%	31,915	2.6%
Morocco	61,900	0.5%	27,702	2.2%
Serbia	1,000	0.0%	14,793	1.2%
other countries	602,709	5.0%	22,034	1,8%
Total	**12,150,449**	**100.0%**	**1,235,562**	**100.0%**

Sources: USGS, UN Comtrade

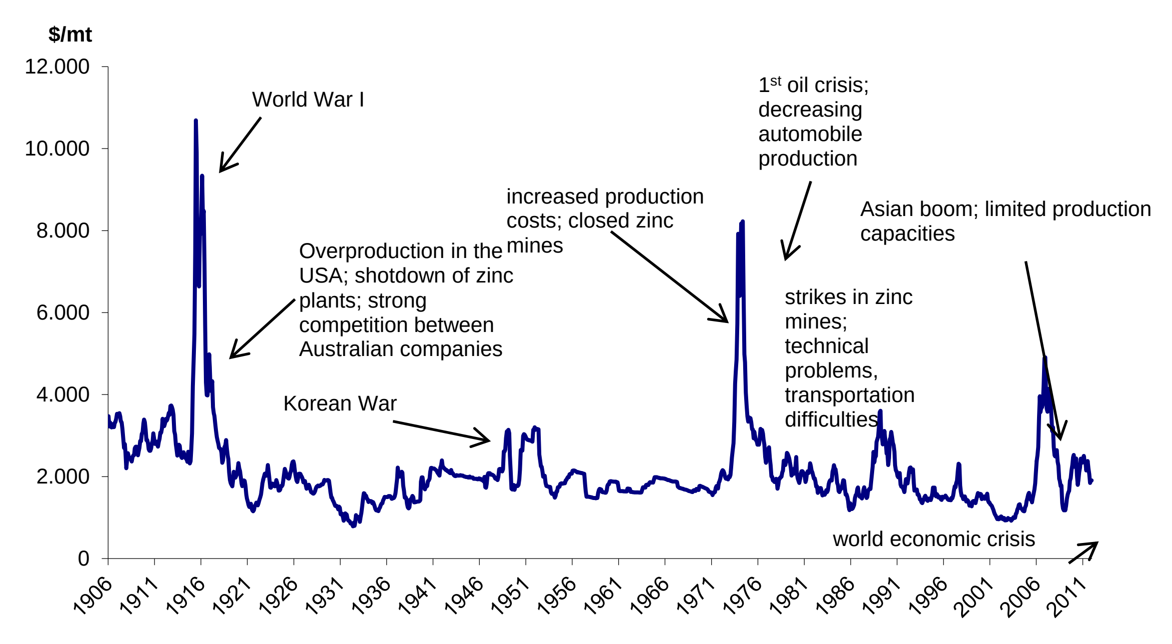
1.31.3 Economic importance

Figure 70 shows how the different supply and demand situations worldwide influenced zinc prices during the last century.[c] Due to the elevated demand for ammunition during World War I, more zinc was required in this period and, with supply difficulties at sea, zinc prices dramatically increased. The next price spike followed in 1973/1974 due to increased production costs and closed zinc mines. The most recent price peak in 2007 was induced by the fast growing Asian economy, when limited production capacities were unable to meet the demand. World recession has resulted in decreased demand for zinc. In 2009, decreased production and closing of mines in the USA resulted in an excess of demand over supply that was dampened by increased Chinese production.[a]

Zinc has many different industrial applications. 50% of zinc is used for galvanizing to protect steel from corrosion[d]; 17% each go into the production of zinc base alloys to supply e.g. the die casting industry and the production of brass and bronze. Low-alloy zinc grades, which have a better creep resistance than zinc itself, are used for roof drainage parts (e.g. gutters, down-pipes) and for covering buildings. Another field of application of zinc are pressure die castings, which primarily supplies the automotive industry. Zinc chemicals account for only 6% of the global zinc consumption (see Figure 71).

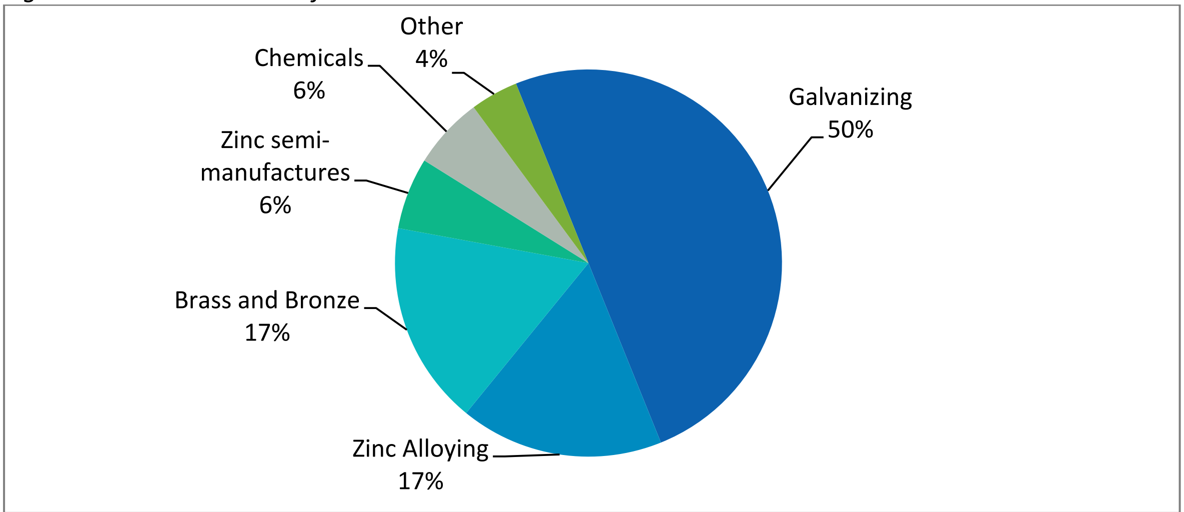
[a] Minerals Yearbook: Zinc, US Geological Survey, 2011
[b] UN Comtrade, accessed 25th July 2013, Trade code 260800
[c] DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen. April 2013.
[d] Ullmann's Encyclopedia of Industrial Chemistry: Zinc, Wiley-VCH Verlag GmbH & Co. KGaA, 2000

Figure 70: Development of real zinc prices (Prices are deflated, 2011 = 100)



Source: DERA, HWWI (2013) Ursachen von Preispeaks, -einbrüchen und –trends bei mineralischen Rohstoffen (Causes of price peaks, collapses and trends of mineral raw materials), Hamburg Institute of International Economics (HWWI) in contract for Deutsche Rohstoffagentur (DERA), translated to English by Fraunhofer ISI

Figure 71: Worldwide use of zinc



Source: ILZSG

1.31.4 Resource efficiency and recycling

Zinc scrap is used increasingly: in 2000, the USA produced 371,000 tonnes of zinc metal, of which 143,000 tonnes (38.5%) were secondary production.[a]

Substitutability scores for zinc are shown in Table 72. For the purpose of corrosion protection zinc is substituted by aluminium alloy, cadmium, and plastic coatings. Galvanized plates can be replaced by aluminium, plastics or steel. Diecast zinc parts principally are replaced by aluminium, magnesium, and plastics.[b]

[a] Ullmann's Encyclopedia of the elements: Zinc, Enghag, Wiley-VCH Verlag GmbH & Co. KGaA, 2004
[b] Mineral Commodity Summaries: Zinc, US Geological Survey, 2013

Table72: Substitutability scores for zinc

Use	Substitutability score
Galvanizing	0.7
Brass and bronze	0.5
Zinc-based alloys	0.7

1.31.5 Specific issues

Several countries have trade restrictions concerning zinc. According to the OECD´s inventory on export restrictions, China uses a VAT rebate reduction on zinc bars, rods, profiles, wire, plates, sheets, strip and foil. Russia uses export taxes of 30% on zinc waste and scrap. There is a wide range of other countries imposing trade restrictions on antimony.

Zinc is an essential trace element for humans, animals, plants and microorganisms.[a] A lack of zinc can lead to e.g. deferred wound healing and loss of hair. Particularly for newborn infants and children, zinc deficiency can inhibit growth and slow down mental development. For a grown-up person, a daily intake of 0.15 mg zinc per kg body weight is suggested, while the recommendation for newborns is ten times higher than for adults (i.e. 1.5 mg zinc per kg body weight).

[a] Zinc, Römpp Online, 2006

2 Non-Critical Biotic Raw Materials

2.1 Natural rubber

2.1.1 Introduction

Natural rubber is primarily harvested from the rubber tree *Hevea brasiliensis,* although native to the Amazon region over 90% of natural rubber is now produced in Southeast Asia. The tyre industry is the largest consumer of natural rubber, accounting for around 70% of annual demand. There are many uncertainties in natural rubber production for both end-user and producer. It takes five to eight years for a rubber tree to grow to a stage where it can be tapped; from this point onwards it has an economic life of 20 to 30 years. Returns can be severely affected by weather conditions such as floods and droughts. Approximately 85% of world production comes from smallholders. Producers may choose to plant alternative crops if returns on rubber are low; thus resulting in a boom and bust cycle.[a]

2.1.2 Supply and demand statistics

Natural rubber is a biotic material which is harvested from rubber trees, mainly growing in tropical forests close to the equator. These trees are harvested by making a slight cut in through the bark into the lactiferous vessels of the trees which produce a milky white latex fluid. Care must be taken not to cut too deeply into the cambium layer as this will injure the tree. The product is collected on the same day in the form of liquid latex or can be collected at the time of the next tapping as a dried cuplump. For optimum yields, trees should be tapped twice weekly.[b]

The climatic conditions required to grow rubber trees mean that these can be cultivated only in specific areas of the world. The vast majority of these cultivations are found in South East Asia. Thailand, Indonesia and Malaysia are the biggest producers and operate a Tri-partite Consortium of natural rubber: International Rubber Consortium (IRCO).[c] Between them they account for over 60% of natural rubber produced globally each year. Major producing countries are shown in Table 73.

Table73: Worldwide natural rubber production, '000s tonnes

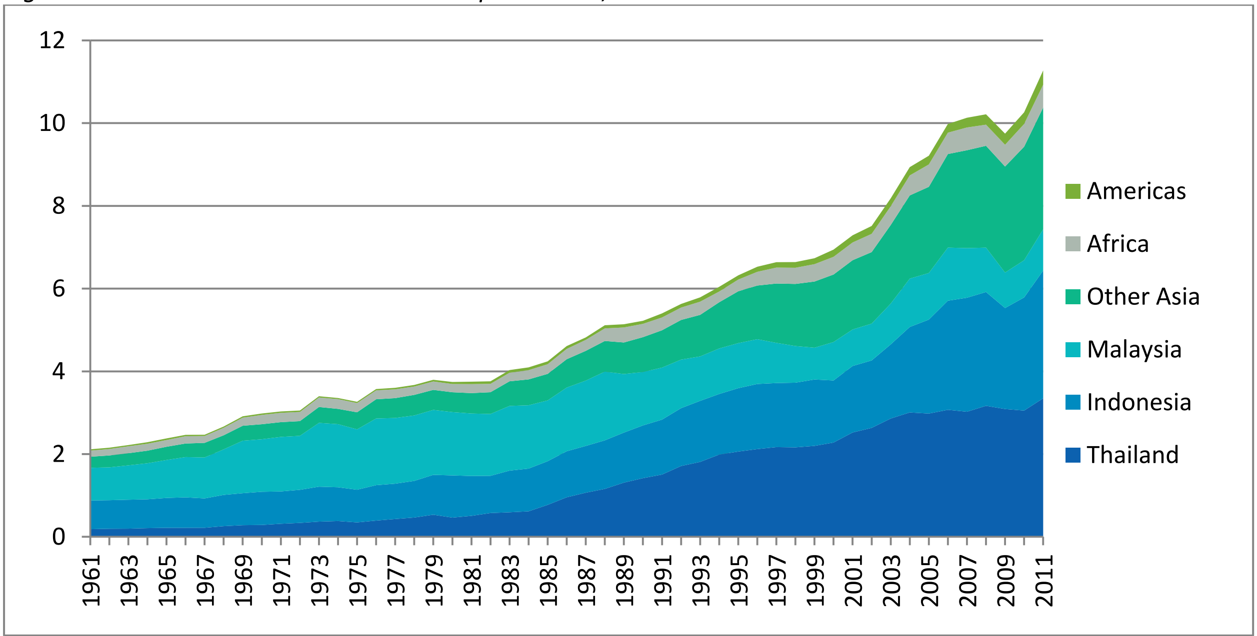
Country	2011	2012	%
Thailand	3,394	3,512	31
Indonesia	2,982	3,015	27
Vietnam	812	955	8
Malaysia	996	923	8
India	893	915	8
China	727	795	7
Côte d'Ivoire	234	255	2
Brazil	166	171	2
Sri Lanka	158	150	1
Myanmar	128	136	1
Philippines	106	111	1
Other Africa	222	223	2
Other Latin America	137	141	1
Other Asia/Pacific	78	87	1
Total	**11,031**	**11,383**	**-**

Source: ETRMA

a All figures from ETRMA presentation, Transparency on Natural Rubber Fundamentals, Role of IRSG, European Parliament – INTA Committee, December 2011.
b Luckett (2012), Natural Rubber: A primer on the commodity
c International Rubber Consortium Limited, http://www.irco.biz/ accessed August 2013

Global production has increased rapidly over the past 50 years (Figure 72). This increase has been mostly due to increased production in Thailand, Indonesia and generally Asian countries, with the exception of Malaysia where production has been reduced since 2006.[a] In 2011 76% of all natural rubber produced was grown in South East Asia.

Figure 72: Historical world natural rubber production, million tonnes



Source: FAO Stat

The major producers of natural rubber are also net exporters. Europe and North America are net importers and were historically the major consumers of rubber. In recent years China has become the major consumer and a net importer; consumption is expected to grow to 6.5 million tonnes by 2020 as shown in Table 74.

Table74: Consumption of natural rubber, '000s tonnes

Area	2011		2012		2020	
	'000s Tonnes	%	'000s Tonnes	%	'000s Tonnes	%
China	3,603	33	3,765	34	6,552	41
North America	1,173	11	1,092	10	1,215	8
EU-27	1,222	11	1,058	10	1,344	8
India	957	9	1,001	9	1,645	10
Japan	753	7	740	7	853	5
Other Asia Pacific	514	5	516	5	626	4
Thailand	480	4	502	5	630	4
Indonesia	441	4	492	4	679	4
Malaysia	402	4	439	4	683	4
Korea	402	4	406	4	448	3
Brazil	354	3	318	3	445	3
Other Latin America	231	2	251	2	284	2
Other Europe	176	2	157	1	237	1
Africa/Middle East	164	1	143	1	217	1

[a] Malaysian Rubber Board (n.d.), Natural Rubber Statistics 2012

Russia	57	1	61	1	96	1
Total	**10,944**	**-**	**10,947**	-	**15,970**	**-**

Source: ETRMA

2.1.3 Economic importance

It is reported that the tyre industry uses up to 75% of natural rubber consumed in the EU.[a] An average car tyre will contain 15% natural rubber by weight and a truck tyre will contain 30%.[b] The remaining content of tyres consists of synthetic rubber, carbon black and silica as tyre fillers, steel cord and wires to provide strength and other chemicals such as oils and zinc oxide.[c]

As mentioned above, the EU-27 is completely reliant on rubber imports as this material is not produced in Europe. The European tyre industry accounts for 21% of global tyre production and in 2011 4.6 million tonnes of tyres were produced.[a] The majority of European tyre plants are located in Germany, France and Italy, however, tyre production occurs throughout Europe.

Other uses can be divided into three categories: industrial products, such as moulded and extruded products, belting, hose and tube; consumer products, such as footwear, toys, sports and leisure goods; and latex products, such as dipped goods, thread, adhesives, carpet underlay, gloves and condoms. Production of general rubber goods also occurs in Europe, with many tyre companies also active in this area.[a]

2.1.4 Resource efficiency and recycling

Once used for the compounding of tyres, it is not possible to selectively separate and recycle natural rubber present in end-of-life tyres. On the other hand, recovery data for end-of-life tyres is readily available. However, there is no data for other uses of rubber; it is thought that natural rubber used in these applications is not widely collected for recovery or recycling.

As part of the EU Landfill Directive, the landfilling of whole tyres was banned in July 2003 and the landfilling of shredded tyres in July 2006. Since 1999, recovery has increased significantly in the EU with rates rising from 50% to 95% in 2011. Once these tyres are collected they are divided into part-worn tyres or end-of-life tyres (ELTs). The former can be re-used directly (or exported for re-use) or retreaded before being re-used. ELTs can either be recovered by recovering the material or can be used to recover energy; closed-loop recycling of tyres is not technically feasible at present. A small percentage of these tyres are still entering landfill or unknown disposal routes. Figure 73 shows how recovery, recycling and disposal percentages have changed between 1996 and 2011.

Retreading of tyres consists of the replacement of the worn-out tread in order to increase the lifetime of the tyre. Casing integrity, performance and security must be guaranteed. In order to ensure that retreaded tyres fulfil similar quality requirements as for new tyres, provisions of UN/ECE Regulations 108 and 109 must be fulfilled for retreaded tyres entering the EU market as set out in Council Decision 2006/443/EC. Retreading can be done more than once, for example, truck tyres can be retreaded up to 5 times and aircraft tyres up to 10 times. Retreading is environmentally beneficial as it requires 5 times less energy and raw material compared to new tyres and reduces the amount of tyre waste generated. According to ETRMA, 40-45% of truck tyres in the EU have been retreaded.[d]

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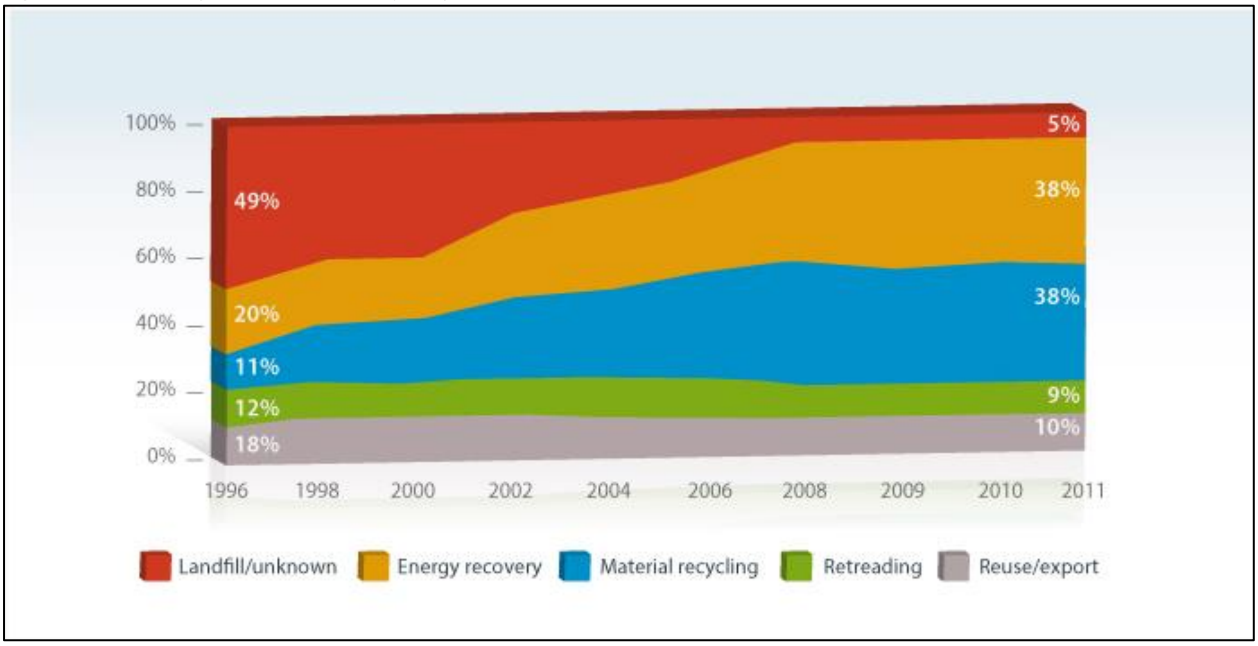
a ETRMA (2012), European Tyre & Rubber Industry Statistics.
b ETRMA (2013), Guidance on the use of vulcanized-rubber pseudo substances in IMDS declaration of tyres.
c World Business Council for Sustainable Development (2008), Managing End-of-Life Tires.
d ETRMA (n.d.), Retreading. http://www.etrma.org/tyres/retreading [Accessed April 2013]

Figure 73: Fates of collected used tyres from 1996 to 2011



Source: ETRMA (n.d.), Recovery routes. http://www.etrma.org/tyres/ELTs/recovery-routes-and-trends/recovery-routes [Accessed April 2013]

ELTs can be re-used in civil engineering applications. These can be used as whole tyres, in applications such as coastal protection or erosion barriers, or can be shredded and used as tyre derived aggregates (TDA). Some uses of TDA are foundations for roads and railways, draining material replacement for sand and gravels and in landfill construction.[a]

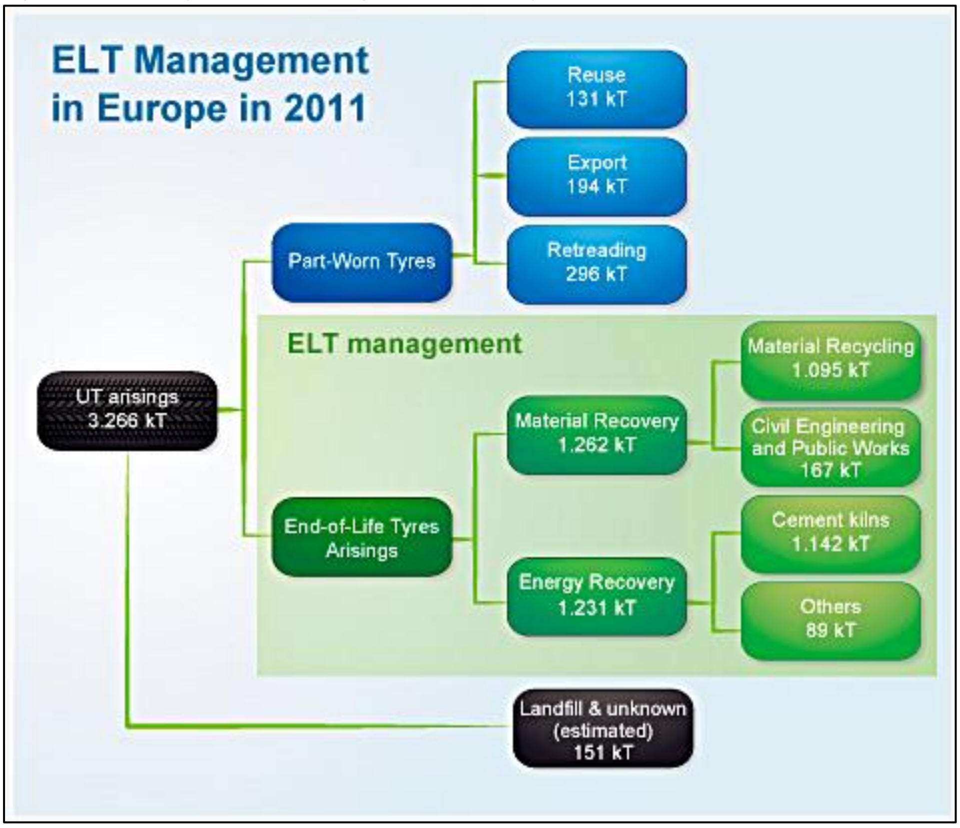
Rubber from tyres can be recycled in the form of rubber granulate and powder; this can then be used as moulded rubber in products such as wheels for caddies and dustbins and garden furniture. This product is also used for rubber flooring in playgrounds and athletics tracks. Granulates are also used in artificial turf used in football pitches.

Alternatively, ELTs can be used for recover energy as these have the same calorific value as coal. In Europe this is done mainly in cement kilns equipped for the recovery of tyres. Iron oxides from the steel content of the tyres will be used in the end product, thereby reducing the amount of additional material that needs to be added in the cement kilns. In the USA, ELTs are also recovered in thermal power stations and pulp and paper mills.[b]

In 2011, nearly 3.3 million tonnes of used tyres arose in Europe, Switzerland and Norway; 95% of these were collected and treated. The vast majority of these tyres were ELTs and resulted in material or energy recovery. The figure shows a material flow for these tyres. Germany, Italy and France are the countries with the greatest quantity of used tyres arising. Most countries have achieved a 100% used tyres treatment rate. In terms of recovery, material recovery is on a par with energy recovery at EU level.

a http://www.etrma.org/tyres/ELTs/recovery-routes-and-trends/material-recovery [Accessed April 2013]
b http://www.etrma.org/tyres/ELTs/recovery-routes-and-trends/energy-recovery [Accessed April 2013]

Figure70: Used tyres (UT) management in Europe, 2011



Source: ETRMA (n.d.), ELT Management. http://www.etrma.org/tyres/ELTs/ELT-management [Accessed April 2013]

Synthetic rubber (styrene butadiene rubber (SBR)) has long been used as an alternative or supplement to natural rubber. However, synthetic rubber cannot match the price and performance of natural rubber.[a] Furthermore, synthetic rubber at present has not achieved the same performance as natural rubber in tyre applications. For example, synthetic rubber does not have an equally high molecular mass which defines the quality of the rubber and does not contain the non-rubber components which are found in the latex produced by rubber plants.[b] Natural rubber also exhibits greater resistance to tearing at high temperatures and builds up less heat from flexing. For this reason, truck tyres require a higher percentage of natural rubber that those for passenger cars.[c]

A last important point to be made about synthetic rubbers is that these are produced from oil. Given the current oil prices and the fact that this is not a renewable source this should not be considered as a sustainable alternative to natural rubber.

Research for rubber substitutes is concentrated on finding alternative plant sources of latex. More specifically scientists are looking at using *Parthenium argentatum* (guayule) and *Taraxacum koksaghyz* (Russian dandelion) as alternative rubber and latex sources; these are the only other species known to produce large amounts of rubber with high molecular weight. In this respect the EU has launched the EU-PEARLS (Production and Exploitation of Alternative Rubber and Latex Sources) project. This project is formed of consortium which links stakeholders from the EU and other countries working on developing these two alternatives to natural rubber from *Hevea brasiliensis*.[d]

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a Van Beilen and Poirer (2007), Establishment of new crops for the production of natural rubber
b Gronover et al. (2011),. Natural Rubber Biosynthesis and Physic-Chemical Studies on Plant Derived Latex, Biotechnology of Biopolymers, Prof. Magdy Elnashar (Ed.).
c Polymers & Tyre Asia (2010), Future of Natural Rubber.
d About EU-PEARLS: http://www.wageningenur.nl/en/Research-Results/Projects-and-programmes/eu-pearls-projects/About-us-1.htm [Accessed April 2013]

Table75: Substitutability scores for rubber

Use	Substitutability score
Tyres (land vehicles) & other automotive	0.9
General (non-automotive)	0.3
Tyres (aircraft)	1.0

2.1.5 Specific issues

The yields of natural rubber production can be severely affected by climatic and natural conditions such as heavy rains or droughts. Rubber trees go through a winter period which lasts between 4 to 8 weeks during which yield is greatly decreased. Extreme climatic conditions can prolong this period and can affect leaf formation resulting in increased production drop. Heavy rains can also disrupt the tappers' ability to collect latex on a regular basis.[a]

South American Leaf Blight (SALB) is also of strategic concern; this is a fungal disease which causes defoliation or even death of the tree. Natural rubber plantations are particularly susceptible given their uniform genetic background. The disease is still restricted to its continent of origin and outbreaks in South East Asia have been rare thanks to strict pest controls standards however increased trading and travel may increase the risk of exporting the disease. If the disease were to spread in Asia this could have devastating consequences on natural rubber plantations.[b]

Price volatility has been identified as an element of risk in the supply of natural rubber. There has been a sharp increase in natural rubber price since 2009. Prices evolved from $1.2/kg in February 2009 to $6.4/kg in February 2011. This volatility undermines long term planning and thus the industry.[c] Competition for land use is also an issue. Given the price volatility of natural rubber, many growers cut down their rubber trees to move to more profitable crops such as palm oil. An example of this is Malaysia, where production peaked in 2006 but saw a reduction until 2010 when production increased slightly.[d]

Some companies have integrated themselves both upstream and downstream in the natural rubber supply chain. For example, the Chinese group Sincochem acquired 51% of the rubber plantation company GMG Global Ltd.[e] Integrating production and processing thus ensures on-going supply of the raw material. Such developments should be monitored, in order to mitigate and future risks which may arise from increased company concentration.

a Luckett (2012), Natural Rubber: A primer on the commodity
b Gronover et al. (2011),. Natural Rubber Biosynthesis and Physic-Chemical Studies on Plant Derived Latex, Biotechnology of Biopolymers, Prof. Magdy Elnashar (Ed.).
c ETRMA presentation, Transparency on Natural Rubber Fundamentals, Role of IRSG, European Parliament – INTA Committee, December 2011.
d FAO statistics
e GMG, http://www.gmg.sg/about.html

2.2 Pulpwood

2.2.1 Introduction

The term pulpwood refers to trees which are grown with the intention of harvesting the timber for use of making wood pulp for the production of paper products. Pulpwood is used along with pulp from recycled paper and non-fibrous material in order to produce paper and board. The pulpwood industry is resource efficient and makes use of timber which is not suitable for other applications as well using recycled input. Pulpwood is of significant importance to the European paper industries. In 2012 CEPI countries consumed 1,429,000m^3 of wood in the production of paper of board of which less than 20% was imported.[a] There is increasing demand for pulpwood as a source of biomass for energy; this has the potential to put strain on the supply of pulpwood for paper production.

2.2.2 Supply and demand statistics

Timber for pulpwood comes from hardwood tree species such as aspen, birch, maple and eucalyptus and softwood trees such as spruce, pine, fir, larch and hemlock. As such a wide variety of tree species can be used there are no geographic constrains to where pulpwood can be cultivated. The world production tonnages for pulpwood for paper in 2012 are shown in Table 76. By far the largest producing region is North America, accounting for almost 40% of global production. Within Europe, the Nordic region produces the largest tonnages of pulpwood; most of Europe's paper mills are also located within this region.

Table76: World pulpwood production, tonnes, 2012

Country	Production (tonnes)	% share
USA	50,859,744	27%
China	19,212,200	10%
Canada	17,190,000	9%
Brazil	14,060,000	8%
Sweden	12,019,151	6%
Finland	10,350,000	6%
Japan	8,641,000	5%
Russian Federation	8,181,394	4%
Indonesia	6,560,000	4%
Chile	5,080,000	3%
India	4,047,900	2%
Spain	2,847,130	2%
Germany	2,636,000	1%
Country	**Production (tonnes)**	**% share**
Portugal	2,436,300	1%
Austria	1,726,855	1%
France	1,724,692	<1%
South Africa	1,615,000	<1%
New Zealand	1,554,971	<1%

[a] Key Statistics – European pulp and paper industry 2012, Confederation of European Paper Industries (CEPI), 2013.

Australia	1,431,000	<1%
Argentina	1,243,000	<1%
Norway	1,239,000	<1%
Poland	1,186,000	<1%
Thailand	1,132,000	<1%
Uruguay	1,095,000	<1%
Rest	7,071,218	4%
Total (rounded)	**185,139,555**	**-**

Source: FAO stat

Pulpwood can come from either mixed logging operations or from forest stands cultivated solely for pulpwood. From mixed logging operations pulpwood usually derives from trees which make poor sawlogs, dead or diseased trees, small trees or the tops cut from trees harvested for sawlogs.

Imports of pulpwood for paper to the EU

Despite producing over 20% of the world supply of pulpwood, in 2012 Europe imported almost 8 million tonnes of pulp. The largest exporter of pulpwood to Europe is China, followed by the USA. Data on imports of pulpwood are readily available from Eurostat and FAO Stat. In 2012 the EU imported 18,135,494 tonnes of pulpwood, however, in the same year exported 13,662,215 tonnes.

2.2.3 Economic importance

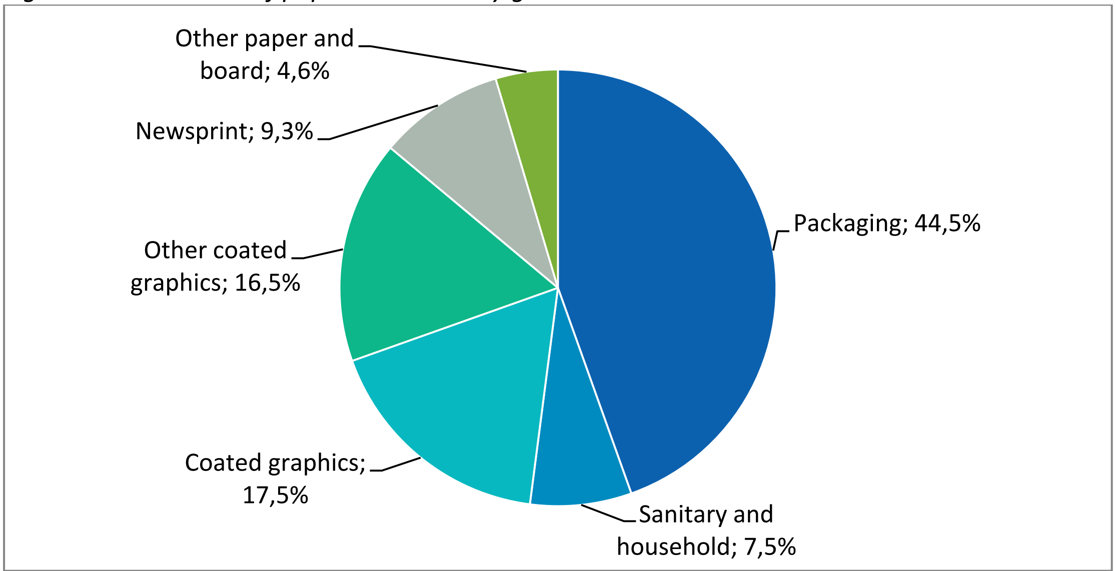
Only pulpwood for use in the paper industry is under consideration, consequently the only megasector using this raw material is paper. Cellulosic fibres and other by-products of pulp production may be used by other end-sectors, for instance textiles. In the context of this report, these are out of scope. Additionally, statistics and data are not readily on the use of pulp for these applications.

According to the Confederation of European Paper Industries (CEPI), about 72 million m^3 of soft roundwood was used in 2012 for the production of paper by CEPI countries.[a] This accounts for half of the wood used overall in the paper industry, the other half being non-coniferous wood; 80.5% of this was domestically sourced and a further 9% was sourced by other European countries.

Pulpwood is used alongside pulp from recycled paper and non-fibrous materials to produce paper and board such as news print, tissues and packaging paper. Figure 74 shows the market share for the different grades of paper and board produced.

a CEPI represents the paper industry in the following countries: Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, The Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and United Kingdom.

Figure 74: Production of paper and board by grade in CEPI countries in 2012



Source: CEPI

Paper and paperboard mill closures in 2011 and 2012 resulted in a loss of production capacity of over 7.4 million tonnes in North America and Europe. This was a consequence of the continuing decline in demand for paper as electronic media, including the Internet, continue their rise. Major investment in large paper machines in China is another factor, enabling China to become a world powerhouse in the paper industry. Paper and paperboard production in 2011 decreased by 0.6% in Europe during 2010, whereas in North America the decline was 1.0%. Apparent consumption in Europe was lower by 1.2%.[a]

2.2.4 Resource efficiency and recycling

Paper recycling plays an important role in the resource efficiency of wood. The recycling rate for paper reached almost 72% in 2012. This represents an 18 million tonne increase since 1998 and is the highest paper recycling rate in the world. A third of the paper collected was imported from outside Europe for recycling.[b] Of the different paper types, packaging papers has the highest recycling input rate. According to CEPI, 51% of the paper collected in the country it represents is used in the production of paper within those countries, resulting in closed loop recycling. They also report that 18% of the paper collected is exported to non-CEPI countries.[c] Paper produced in CEPI countries is composed of 44% recycled paper (Table 77).

Table 77: CEPI raw materials consumption in paper making

Material	2010	2011
Wood pulp	45,014	43,850
Non-wood pulp	507	681
Paper for recycling	48,969	48,404
Non-fibrous material	16,578	15,891
Total	**111,068**	**108,826**

Source: CEPI (2011), Key Statistics 2011

Substitution of pulpwood is less viable due to its applications, though some reduction in usage is possible through development of electronic alternatives.

a Forest products: annual market review 2011-2012, Geneva timber and forest study paper 30 United Nations Economic Commission for Europe and Food and Agriculture Organisation of the United Nations, 2012.
b http://www.paperforrecycling.eu/uploads/Modules/Publications/Monitoring%20report%202011%20final%20WEB.pdf
c CEPI Statistics 2012 (only CEPI countries: Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Sweden, The Netherlands, United Kingdom

Table78: Substitutability scores for pulpwood

Application	Substitutability score
Graphic paper	0.7
Packaging papers	0.7
Household & sanitary	0.7
Other papers	0.7

2.3 Sawn softwood

2.3.1 Introduction

The coniferous industrial roundwood category is an aggregation of three commodities which determine the final use: these are sawlogs and veneer logs, pulpwood, round and split and other industrial. These commodities are then further processed by different wood industry sectors before becoming final use products. As it is simpler to consider the raw material at the commodity level, in this instance soft sawnwood has been chosen. Sawnwood is a processed wood product which is produced from sawlogs by the forest processing industry and used as a raw material by other industries outside of the forestry sector. Soft sawnwood has been chosen for its importance to both the construction and furniture industries in Europe.

Softwood is the term used to categorise wood from trees classified botanically as Gymnospermae; these may also be referred to as coniferous. Softwood tree species include: spruce, cedar, pine, linden and cypress.

2.3.2 Supply and demand statistics

Europe covers a significant share of industrial roundwood production and accounts for half of the major producers (including the Russian Federation). European wood covers for around 43% of worldwide production. Coniferous wood is more prominent in northern European countries and this is reflected in the production statistics.

2.3.3 Global production of soft sawnwood

Soft sawnwood is produced by sawmilling industry from coniferous sawlogs. The process of converting logs into sawnwood involves breaking the logs down to boards of varying thickness, re-sawing, ripping and crosscutting. Table 79 shows the global production data for soft sawnwood in 2012 in cubic metres. Production of soft sawnwood is not limited by geographic region and occurs throughout the world. By far the largest producing regions are North America, Asia and Europe.

Imports of soft sawnwood to the EU
High levels of domestic production mean that EU soft sawnwood imports only contribute a small proportion to overall supply. As such supply should be considered from within Europe. Data on imports of soft sawnwood are readily available from Eurostat and FAO Stat. In 2012 the EU imported 29,619,033 m^3 of soft sawnwood, however, in the same year exported 43,127,478 m^3. In summary, the EU is not import dependent on soft sawnwood.

Table79: World coniferous sawnwood production, m^3, 2012

Country	Production (m^3)	% share
USA	48,745,800	17%
Canada	39,416,977	14%
Russian Federation	30,040,000	10%
China	22,318,000	8%
Germany	20,032,253	7%
Sweden	15,800,000	5%
Japan	9,656,000	3%
Finland	9,300,000	3%
Brazil	9,100,000	3%
Austria	8,793,000	3%
France	6,852,459	2%
Chile	6,507,000	2%
Turkey	4,307,000	1%
New Zealand	4,230,000	1%
Czech Republic	4,153,000	1%
Poland	4,100,000	1%
Australia	3,826,000	1%
Republic of Korea	3,654,000	1%
Romania	3,390,030	1%
United Kingdom	3,356,832	1%
Other	17,731,995	11%
Total (rounded)	**290,062,000**	

Source: FAO stat

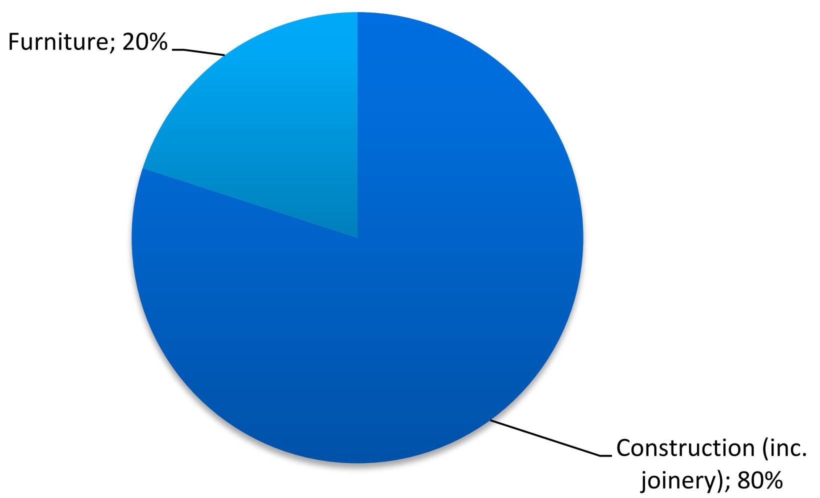
2.3.4 Economic importance

The EU has a large and diverse wood processing and furniture industry, compromising of over 300,000 enterprises and also accounts for a significant proportion of manufacturing employment.[a]

The demand for wood is expected to increase in the future, however it is thought that geographic importance and products markets will change.[b] Sawnwood has a variety of different end-uses, however, the construction sector is a primary driver for the demand for soft sawnwood.[c] The recent years have seen record lows for new construction in Europe and the USA as a result of the economic crisis. Despite this, the consumption of many wood products increased slightly in 2011. This was driven by increased consumption in Russia. Sawnwood and wood-based panels experienced increased consumption unlike paper and paperboard industries which suffered from lower demand and overcapacity. Data for end-sector usage of wood is not collected at the European level and as a consequence estimates have been used in this study.

a Timber Trade Federation
b Poyry Management Consulting (2012), Forest Sector Trends.
http://www.fefpebcongress2012.es/archivos/pdf/ponencias/FEFPEB_2012_3_Cormac_O_Carroll_Poyry_051012_v2.pdf
c Forecasting the demand for sawnwood in western Europe from an end-use perspective, EC Timber Committee and FAO European Forestry Commission, seminar Strategies for the sound use of wood, Romania 2003.

Figure 75: European applications of soft sawnwood



Source: Estimates by European Organisation of the Sawmill Industry EOS OES, 2013.

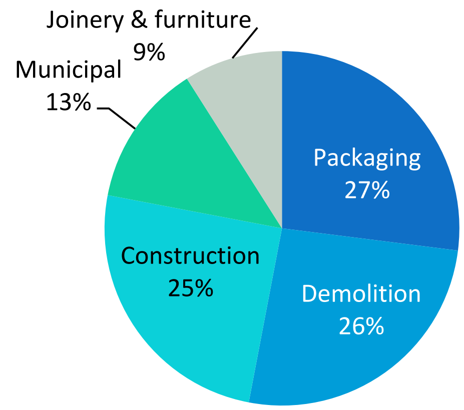
- **Construction** – In Europe by far the most significant end-user of soft sawnwood is the construction industry. Applications for sawnwood in this sector include both residential and commercial buildings as well as flooring, doors, window and door frames, joists and other joinery. There is low demand for sawn wood because of low construction activity due to the economic crisis, but the market share of FSC wood increasing. Imports are decreasing.
- **Furniture** - the valuable and appearance grade sawnwood is used for the manufacture of furniture. However, following the global economic downturn the consumption of soft sawnwood for furniture decreased significantly. The use of sawnwood for furniture also faces competition from particleboard and non-wood alternatives.
- **Packaging** – the major use of sawnwood in packaging is pallets. This end-use often requires lower grades of sawnwood than furniture and construction. It is also used in the manufacture of crates and boxes. However, no data or estimates were available on the relative share for this end-sector; it has therefore been assumed to be negligible.

2.3.5 Resource efficiency

Wood waste arises from many sectors, principally from construction and demolition waste. It is estimated that 70.5 million tonnes of this waste was generated in 2004 in the EU-27; of this, 31% was recycled directly and 34% was recovered in energy recovery processes. No official data is available for waste wood, at the commodity level; instead it is reported by end-use. The type of wood waste varies from sawdust to old furniture to construction wood. The re-use or recycle potential of these will depend on the quality of the wood and on the level of contamination.[a] This data excludes paper waste. Figure 76 shows the wood waste arising by source in the UK in 2010.

a JRC (2010), Study on the selection of waste streams for end-of-waste assessment

Figure 76: Wood waste arising by sector in the UK, 2010



Source: WRAP (2011), Realising the value of recovered wood

The major fates for recovered wood are recycling into pane board or use as biomass to recover energy. Other uses are in animal bedding; equine surfaces and bedding; mulches, soil conditioners and composting; pathways and coverings.[a]

Large quantities of wood are unavailable for recycling as they form part of in-use stocks and are thus stored over a significant length of time. In 2010 36.1 million cubic metres of post-consumer wood was recovered; based on the total market volume of wood the recovery rate is 22.3% of which 9.2% is material and 12.1% is for energy.[b]

The other major use of waste wood is as a source of energy; this is not considered as recycling in the current study. Wastes, including recovered wood and municipal solid waste are the second source for biomass in the EU.[c] Care must be taken because of wood contamination; WID compliance of these combustion facilities is key to burning waste wood.[d] Non-combustible contaminants such as nails may cause additional waste to the biomass combustion plants hence recovered wood should be processed to avoid blockages or mechanical faults.[e] Use of recovered wood for the recovery of energy is expected to increase as policy drives the energy sector towards more sustainable energy sources.

Substitution of this wood type is possible to a certain extent, either through more expensive wood types, or through other structural materials such as metals. However, neither of these options can completely replace it due to costs and performance.

Table80: Substitutability scores for soft sawnwood

Application	Substitutability score
Construction	0.7
Furniture	0.7

2.3.6 Specific issues

According to the OECD both Russia and Canada have implemented export restrictions on timber/.

a Realising the value of recovered wood, WRAP, 2011.
b Wood flows in Europe, U. Mantau, commissioned by Confederation of European Paper Industries CEPI and European Confederation of Woodworking Industries CEI-Bois, 2012.
c http://www.europeanclimate.org/documents/Biomass_report_-_Final.pdf
d http://archive.defra.gov.uk/environment/waste/topics/documents/wastewood-biomass.pdf
e http://www.wrap.org.uk/sites/files/wrap/Wood%20Market%20Situation%20Report_0.pdf