Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials

The *ad-hoc* Working Group is a sub-group of the Raw Materials Supply Group and is chaired by the European Commission

Note: The full report will be available on the Enterprise and Industry Directorate General website http://ec.europa.eu/enterprise/policies/raw-materials/documents/index_en.htm

European Commission
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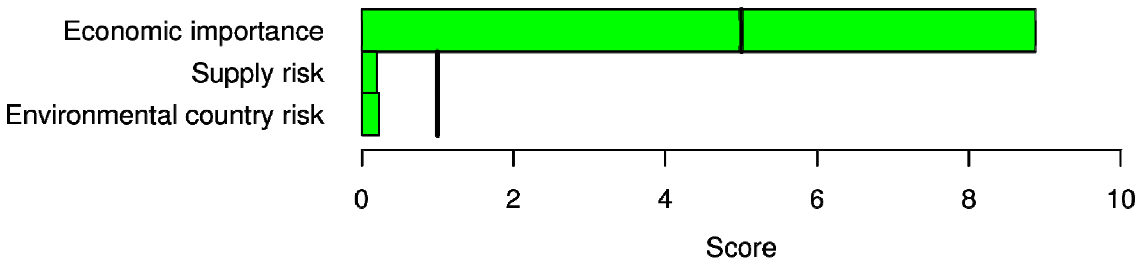


1 Aluminium

1.1 Introduction

Aluminium (Al, atomic number 13) is a strong, lightweight metal that has become the dominant non-ferrous metal in use today. Because aluminous minerals are very stable, large amounts of energy are required to reduce these compounds to metal. As a result, the industrial production of aluminum 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. Current consumption in Europe amounts to almost 22 kg per capita, up from 14 kg per capita in 1980. [1,2,3]

The only method used to produce aluminum today is the Hall-Herould process (electrolysis of alumina). The only source of aluminum that is currently mined is bauxite (treated separately in this exercise).[1,2]

1.2 Basic Supply and Demand Statistics

Aluminium metal is produced in 42 countries worldwide (2008), including 13 EU Member States. [2,4] Germany (13.4% of EU production) and France (9.5%) were the largest EU producers of aluminum in 2008, followed by Spain (9%), the United Kingdom (7%) and the Netherlands (7.1%).[2] The largest foreign provider of aluminum for the EU (2006) was the Russian Federation (27%), followed by Mozambique (20%). Brazil and Norway each contributed 11% to aluminum imports into the EU (see table on next page).

1 Ullmann's Encyclopedia of Chemical Technology: *Aluminum*. Wiley-VCH Verlag, Weinheim, 2009.

2 British Geological Survey: *European Mineral Statistics 2004-2008*.

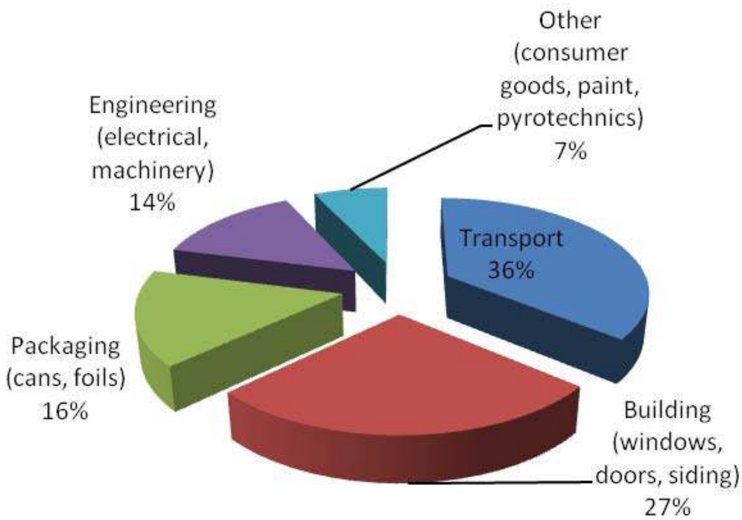
3 European Aluminium Association: *Aluminium: Key facts & figures*.

4 Bundesministerium für Wirtschaft, Familie und Jugend: *World Mining Data 2010*. L. Weber, G. Zsak, C. Reichl, M. Schatz. Vienna, 2010.

	Production (in 1000t; 2008)		EU imports (in 1000t; 2006)	
China	13,177	34%		
Russia	3,420	9%	722	27%
Canada	3,120	8%		
United States	2,658	7%		
Australia	1,974	5%		
Brazil	1,661	4%	281	11%
Norway	1,368	4%	302	11%
Germany	606	2%		
Mozambique	536	1%	530	20%
France	432	1%		
Spain	405	1%		
Russia	380	1%		
Netherlands	320	1%		
United Kingdom	316	1%		
Romania	290	1%		
Other	8,420	22%	819	31%
Total	**39,083**		**2,654**	

Source: World Mining Data 2010; trade data EUROSTAT ComExt (CN 7601 10 00).

1.3 Economic Importance



The main end-use markets for aluminium products in Europe (2004) as reported by the European Aluminium Association[3] are shown above.

- Transport: Because of its low density, important parts of cars, trains, ships, aircraft, bicycles, etc consist of aluminum (low weight, lower fuel consumption).
- 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.[5]
- Packaging: Aluminium is used because of its low density, the fact that it constitutes a total protective barrier (air, bacteria, moisture, light) even when rolled to very thin layers.

1.4 Recycling and Substitution

Aluminum is recycled on a large scale. The recycling of aluminum is energetically favorable compared to primary aluminum production with energy savings of up to 95%.[3,6] The recycling rate of aluminium in Europe is high, ranging from 62% in beverage cans to 95% in building and transportation. The 2008 EU27 aluminium recycling from old scrap amounted to about 35 % of the apparent consumption.[7]

Composites can substitute for aluminum in aircraft fuselages and wings. Glass, paper, plastics, and steel can substitute for aluminum in packaging. Magnesium, titanium, and steel can substitute for aluminum in ground transportation and structural uses. Composites, steel, vinyl, and wood can substitute for aluminum in construction. Copper can replace aluminum in electrical applications.[6] Nevertheless, it is not straightforward in practice to substitute aluminium in all these applications, due to its unique properties.[7]

1.5 Specific Issues

According to the European Commission's inventory on export restrictions, 8 countries apply export restrictions either on aluminum or bauxite. Most restrictions apply to aluminum waste and scrap and take the form of export taxes in countries such as Kazakhstan (15%), Russia (50%), Ukraine (27%) and Egypt (2000EGP/ton). Tanzania applies an export ban on waste and scrap. Algeria and South Africa resort to non-automatic export licensing. Regarding unwrought metal, Kazakhstan applies a 30% export tax.

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[5] European Aluminium Association: *Aluminium in Building and Construction*.

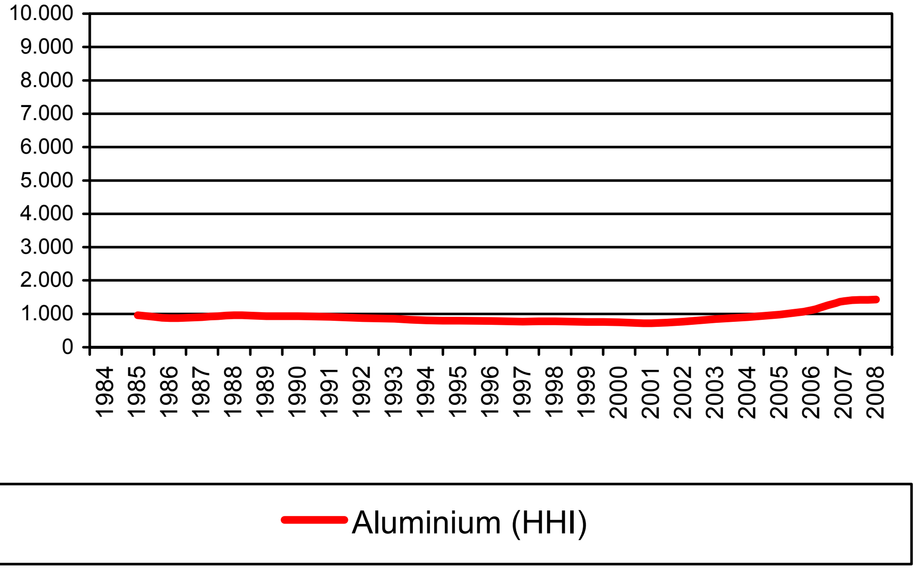
[6] U.S. Geological Survey: *Mineral Commodity Summaries: Aluminum*. 2009

[7] European Aluminium Association, 2010.

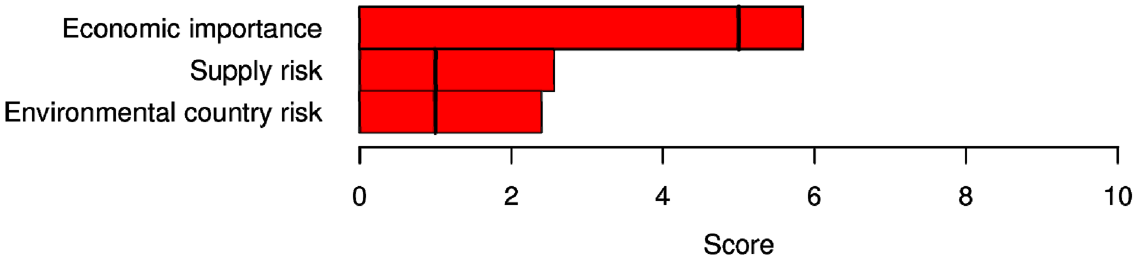
Use	Share	Megasector	Subst.
Transport	36%	Road Transport	0,7
Building (windows, doors, siding)	27%	Metals	0,5
Packaging (cans, foils)	16%	Metals	0,7
Engineering (electrical, machinery)	14%	Mechanical Equipment	0,7
Other (consumer goods, paint, pyrotechnics)	7%	Other Final Consumer Goods	0,5

Substitutability index	0,51
Recycling rate (recycled content from old scrap)	35%
Import Dependence	47%

Results	
Economic importance	8,9
Supply Risk	0,2
Environmental Country Risk	0,2



Source: World Mining Data 2010



2 Antimony

2.1 Introduction

Antimony (Sb, atomic number 51) is a silvery-white shining, very brittle and semiconducting element. Due to its poor mechanical properties, pure antimony is only used in very small quantities, larger amounts are used for alloys and in antimony compounds.[8] There are more than 100 known antimony-containing minerals, the most important of which is antimonite.[9]

2.2 Basic Supply & Demand Statistics

Antimony is midrange concerning its abundance in the earth's crust (0.0001%). It occurs in volcanic rocks and in sandstone with an average antimony content of approximately 1g/ton.[1] The most important antimony ore is antimonite (Sb_2S_3) which contains 71.7% antimony. Often antimony is a byproduct of gold, silver, lead, tungsten or zinc mines.[2]

World resources are primarily located in Bolivia, China, Mexico, Russia and South Africa. The EU is dependent entirely on imports, though total EU consumption in 2007 (792 tons) only accounted for 0.5% of the world production.

Less than 1 per cent of world production of antimony is produced in Europe (including Turkey excluding Russia) countries. Only Turkey shows a marginal production (see point 5). From 2008 to 2009 world production decreased by 5%.

	Reserves (in 1000t; 2010)		Production (in 1000t; 2009)		EU imports (in t; 2007)	
USA	-		-			
Bolivia	310	14,7%	4.5	2,4%	608	76,8%
China	790	37,4%	170	91,2%	122	15,4%
Russia (recoverable)	350	16,6%	3	1,6%		

[8] Römpp Online: *Antimon.* Georg Thieme Verlag, Stuttgart, 2004

[9] Ullmann's Encyclopedia of Chemical Technology: *Antimony and Antimony Compounds*. Wiley-VCH Verlag, Weinheim, 2006

South Africa	44	2,1%	3	1,6%		
Tajikistan	50	2,4%	2	1,1%		
Thailand	420	19,9%	-			
Japan					14	1,8%
Peru					48	6,1%
Others	150	7,1%	4	2,1%		
Total	**2,114**		**186.5**		**792**	

Source: USGS 2010; trade data provided by BGS based on EU comtrade (HS 261710)

Mine production of Antimony in Europe (including Turkey) [10]

Mine production of antimony tonnes (metal content)

Country	2003	2004	2005	2006	2007
Turkey	*400	*700	*1 200	*1 200	*1 500

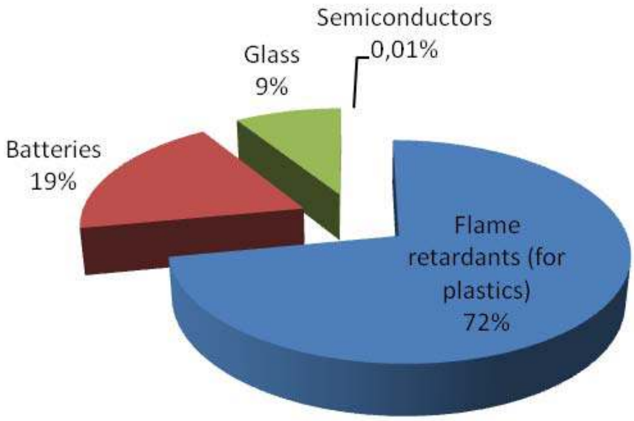
Note(s):-
(1) This table includes antimony content of antimonial lead alloys
(2) In addition, Hungary is believed to produce antimony

Principal identified world resources are located in Bolivia, China, Mexico, Russia, and South Africa,[11] but there is successful exploration for antimony in Italy and in Slovakia (Strieborna Silver/Copper/Antimony Deposit, at the conceptual stage).

[10] European Mineral Statistics 2003-2007, BGS

[11] U.S. Geological Survey: *Mineral Commodity Summaries: Antimony*. 2009

2.3 Economic Importance



The main end-use markets for antimony products (worldwide) in 2005 were:[12,2]

- Flame retardants: Most antimony is used in form of antimony trioxide, mainly for flame-retardants for plastics and other products. The use of antimony in flame retardants is not expected to decline since no substitutes are available. Increased use after 2004 was for example caused by the ban on some extreme toxic organic flame retardants.[13]
- Batteries: Antimony is also used for lead-acid batteries. Though, this sector loses importance, due to new battery technologies.
- Glass: Antimony trioxide is also used for the manufacture of glass and ceramics.
- Semiconductors: Small but increasing amounts are used as dopants in the manufacture of n-type semiconductors.
- Alloys: Antimony is used in zinc and lead alloys to increase hardness.

Below is a selection of future applications:

- Compound semiconductors
- Antimony-Tin-Oxide (same characteristics as Indium-Tin-Oxide, but cheaper; can find application in LCD-displays, OLEDs or photovoltaic cells)

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2 Ullmann's Encyclopedia of Chemical Technology: *Antimony and Antimony Compounds*. Wiley-VCH Verlag, Weinheim, 2006

12 Roskill Information Services: *The Economics of Antimony*, London, 2007

13 Stockholm Convention on Persistent Organic Pollutants (POP-convention); e.g. PCB

Antimony demand probably will decrease in the next decades, because of the declining importance for batteries and flame-retardants. In fact, the demand for antimony for micro capacitors will increase, but in this sector only small amounts are necessary.[14]

2.4 Resource Efficiency: Recycling & Substitution

Traditionally, antimony was recycled from old lead-acid batteries on a large scale, but new battery technologies lead to a declining amount of recycled antimony. Available information differs from 3%[15] to 20%[16] recycled antimony from old scrap.

Traditionally, the bulk of secondary antimony has been recovered as antimonial lead, most of which was generated by and then consumed by the battery industry. Changing trends in that industry in recent years, however, have generally reduced the amount of secondary antimony produced; the trend to low-maintenance batteries has tilted the balance of consumption away from antimony and toward calcium as an additive.[17]

Some uses of antimony are characterized as dissipative, which means that there is no recycling possible. The use of antimony in flame retardants is a dissipative application.

There are substitutes for antimony in its most important applications.

- Compounds of chromium, tin, titanium, zinc and zirconium substitute for antimony chemicals in paint, pigments, and enamels.
- Combinations of cadmium, calcium, copper, selenium, strontium, sulphur and tin can be used as substitutes for hardening lead.
- Selected organic compounds and hydrated aluminium oxide are widely accepted substitutes as flame retardants.[9]

2.5 Specific Issues

Several countries have restrictions concerning trade with antimony. According to the EU Commission's inventory on export restrictions, China, Russia and South Africa resort to export restrictions on antimony waste and scrap. China uses export quotas, while Russia imposes an export tax (6.5%), and South Africa a system of non-automatic export licensing. Tanzania applies an export ban on waste and scrap.

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[14] Fraunhofer Institut für System und Innovationsforschung and Institut für Zukunftsstudien und Technologiebewertung: *Rohstoffe für Zukunftstechnologien*, 2009, Fraunhofer IRB Verlag, Stuttgart

[15] UNEP Draft Report

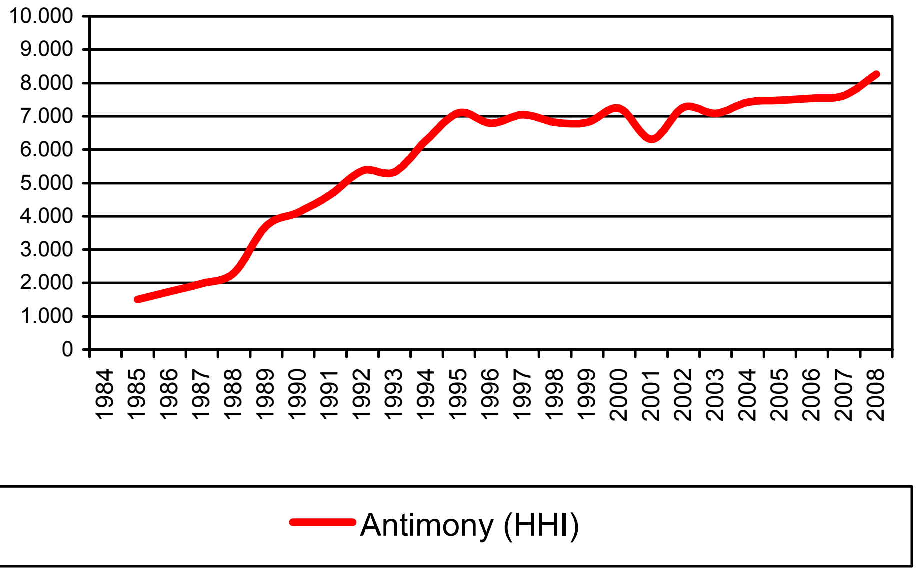
[16] Carlin (2006)

[17] U.S. Geological Survey: *Mineral Commodity Summaries: Antimony*. 2010

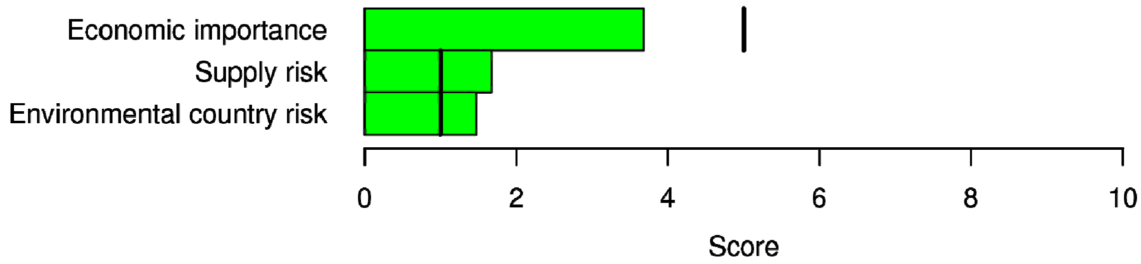
Use	Share	Megasector	Subst.
Flame retardants (for plastics)	71%	Rubber, plastic & glass	1,0
Glass	5%	Rubber, plastic & glass	0,3
Catalysts	4%	Chemicals	0,7
Pigments & others	4%	Chemicals	0,3

Substitutability index	0,64
Recycling Rate (recycled content from old scrap)	11%
Import Dependence	100%

Results	
Economic Importance	5,8
Supply Risk	2,6
Environmental Country Risk	2,4



Source: World Mining Data 2010



3 Barytes

3.1 Introduction

Barytes ($BaSO_4$) is the most important barium-containing mineral and is also known as barite, heavy spar or barium sulfate. It is inert and non-toxic. One of its most interesting properties is the high mass density between 4.3 and 4.7 g/cm^3. [18]

3.2 Basic Supply & Demand Statistics

Barytes deposits can be found all over the world.[19] Estimations indicate that there are 2 billion tons of barytes resources worldwide. The largest identified deposits are situated in China and India.[20]

	Reserves (in 1000 t; 2010)		Production (in 1000 t; 2009)		EU imports (in 1000 t, 2007)	
USA	15,000	8.9%	380	7.0%	0.069	~0.0%
Algeria	9,000	5.3%	40	0.7%		
Bulgaria	NA		30	0.6%		
China	62,000	36.7%	3,000	55.4%	346	62.6%
Germany	1,000	0.6%	0.075	0.0%		
India	34,000	20.1%	800	14.8%	0.1	>0.1%
Iran	NA		180	3.3%		
Kazakhstan	NA		70	1.3%		
Mexico	7,000	4.1%	160	3.0%		
Morocco	10,000	5.9%	350	6.5%	171	30.8%
Pakistan	1,000	0.6%	35	0.6%		
Russia	2,000	1.2%	50	0.9%		
Turkey	4,000	2.4%	110	2.0%	30	5.4%
UK	1000	0.1%	40	0.7%		
Vietnam	NA		60	1.1%		
Norway					6.4	1.1%
Others	24,000	14.2%	110	2.0%		
Total	**169,100**		**5,415**		**553**	

18 Römpp Online: *Baryt.* Georg Thieme Verlag, Stuttgart, 2005

19 Ullmann's Encyclopedia of Chemical Technology: *Barium and Barium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

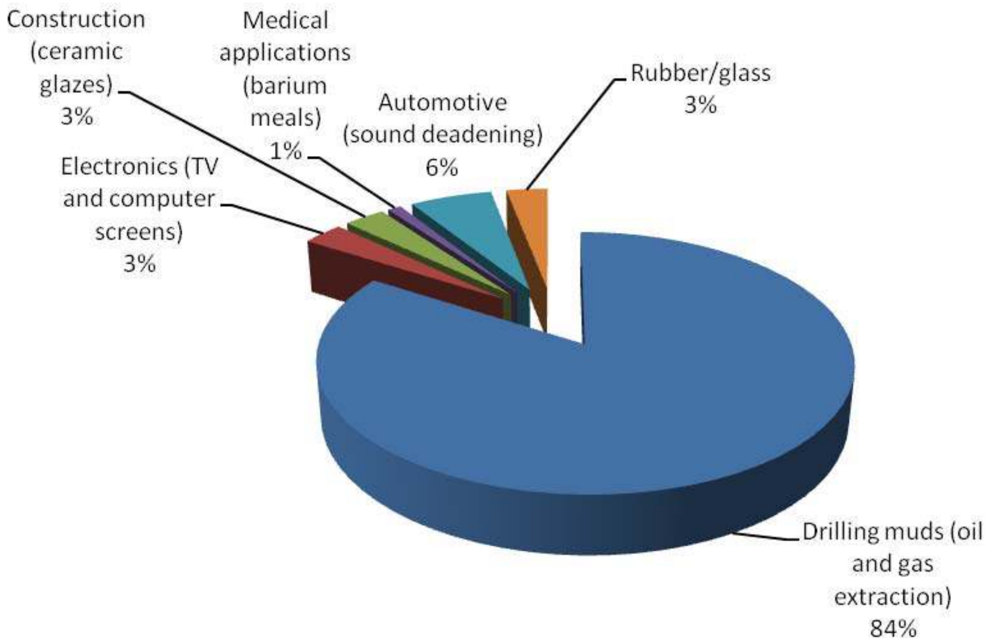
20 USGS Mineral Commodity Summaries 2010: *Barite*

Source: USGS 2010; trade data provided by BGS based on EU comtrade (HS 2511)

Within the European Union, barytes are produced in Germany (44% of EU production), the United Kingdom (26%), Bulgaria (24%), Slovakia (5%), Italy (2%) and Poland (1%), amounting to approximately 214,000 tons in 2008[21]. Additionally, 554,000 tons (74% of EU consumption) were imported from non-EU countries in the same year, which is equal to one tenth of the world's production. A further 127,000 t were imported to neighboring Norway (2007) to service the North Sea oil industry.

There appears to be no export restrictions applied on barytes in the countries included in the export restrictions database.

3.3 Economic Importance



The main end-uses markets for barytes (worldwide) are as follows[3,4]:

- Drilling muds: The high mass density and inert nature is used in the oil and gas industry to increase the density of drilling muds. Approximately 84% of the world-wide barytes consumption is used in this sector

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3 USGS Mineral Commodity Summaries 2010: *Barite*

21 The Barytes Association, 2010

- Automotive: Barytes are used as weighting agent in paints and in rubber and plastic products, and for sound-deadening applications in the automotive sector, but also in other industries.
- Electronics: Barium compounds are used in screens for TVs and computers.
- Medical Applications: enables medical x-ray examinations (barium meal).
- Ceramics, rubber, glass: Barytes are used as filling material in many industry branches, for example in the manufacturing of ceramic glazes, rubbers and glass.

3.4 Resource Efficiency: Recycling & Substitution

Barytes is not being recycled at this time. In the oil industry some minor substitutions have been very occasionally used (e.g. ilmenite, iron ore), but none of these are suitable replacements or available in sufficient quantity. Thus, they have had no impact on the barytes market. [3,22]

Use	Share	Megasector	Subst.
Drilling muds (oil and gas extraction)	84%	Oil & Gas Extraction	1
Electronics (TV and computer screens)	3%	Electronics and ICT	0,3
Construction (ceramic glazes)	3%	Construction material	0,7
Medical applications (barium meals)	1%	Pharmaceuticals	1
Automotive (sound deadening)	6%	Road transport	0,7
Rubber/glass	3%	Rubber, Plastic & Glass	0,7

Substitutability	0,94
Recycling rate	0%
Import Dependence	57%

Results	
Economic importance	3,7
Supply Risk	1,7
Environmental Country Risk	1,5

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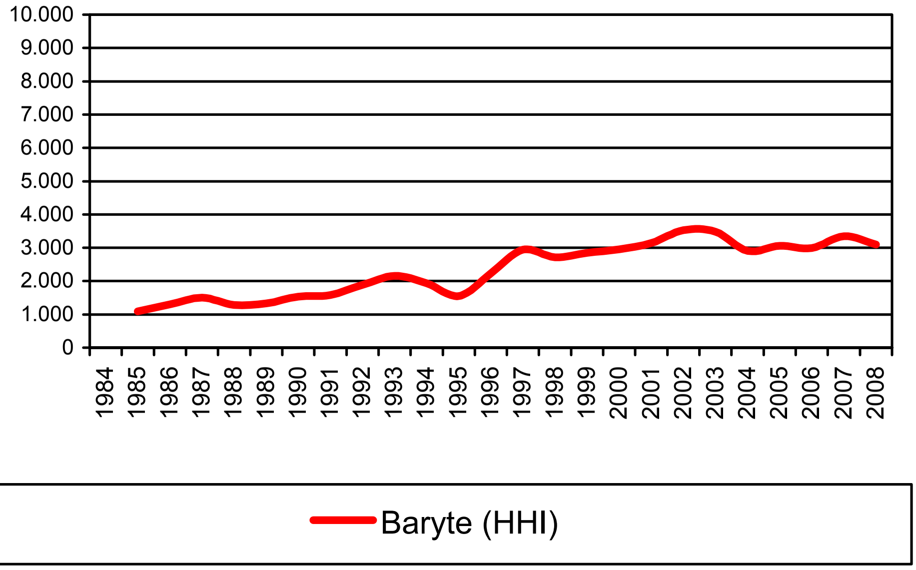
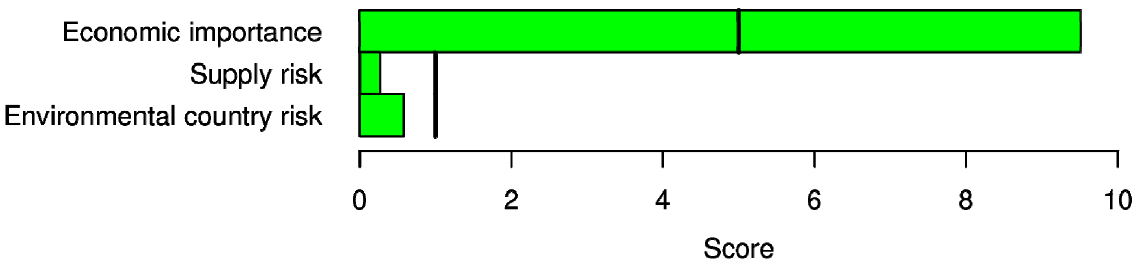
3 USGS Mineral Commodity Summaries 2010: *Barite*

5 The Barytes Association, 2010



Source: World Mining Data, 2010



4 Bauxite

4.1 Introduction

The term bauxite describes sedimentary rocks containing economically recoverable quantities of the aluminum minerals gibbsite (γ-$Al(OH)_3$), boehmite (γ-AlOOH) and diaspore (α-AlOOH). The major components of all bauxites are aluminium oxide, iron oxide and titanium and silicon dioxides.[23]

4.2 Basic supply and demand statistics

Bauxite reserves amount to approximately 27 billion tons, while resources are estimated to lie around 55 to 75 billion tons.[24] These resources are located mainly in Africa (32%) and Oceania (23%), followed by South America and the Caribbean (21%) and Asia (18%).

	Reserves (in 1000t, 2009)		Production (in 1000t, 2008)		EU imports (in 1000t, 2006)	
Guinea	7,400,000	27%	18,500	9%	8,413	55%
Australia	6,200,000	23%	61,400	30%	2,863	19%
Vietnam	2,100,000	8%	30	0%		
Jamaica	2,000,000	7%	14,000	7%		
Brazil	1,900,000	7%	22,000	11%	1,455	10%
India	770,000	3%	21,200	10%	786	5%
China	750,000	3%	35,000	17%	497	3%
Greece	600,000	2%	2,220	1%		
Hungary			550	0%		
Other	5,380,000	20%	30,000	15%	1,160	8%
	27,100,000		**204,900**		**15,174**	

Source: USGS 2008, 2010; trade data provided by BGS based on UN comtrade (HS 2606)

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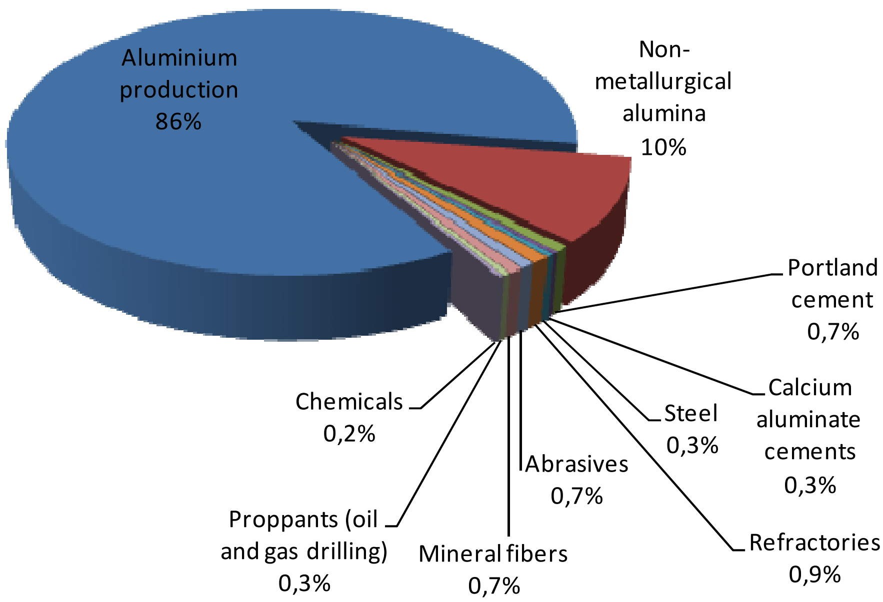
[23] Ullmann's Encyclopedia of Chemical Technology: *Aluminum oxide*. Wiley-VCH Verlag, Weinheim, 2005.

[24] U.S. Geological Survey: *Mineral Commodity Summaries: Bauxite and alumina*. January 2010.

Greece is the main producer of bauxite in the EU, accounting for close to 73% of the total European production (2007) of approximately 3 million tons.[25,26] Most bauxite, however, is imported into the EU (approximately 15 million tons). The main sources for the EU in 2006 were Guinea (≈55%), Australia (≈19%) and Brazil (≈10%), with other countries contributing 5% or less.

4.3 Economic importance



The main end-use markets for bauxite are[4,27]:

- Aluminum production: The main use of bauxite is in the production of aluminum oxide, most of which is used for the production of aluminum metal.
- Non-metallurgical alumina: this is used after purification as alumina trihydrate (aluminium chemicals, flame retardants) and as calcined alumina.
- Portland cements: Bauxite is used as an additive to limestone / clay to help match alumina required level if needed.
- Calcium aluminate cements: Bauxite is mixed with limestone and / or clay to increase / fasten resistance and heat properties.

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25 U.S. Geological Survey: *2008 Minerals Yearbook: Bauxite and alumina*. January 2010.

26 Hellenic Mining Enterprises, 2010.

27 British Geological Survey: *European Mineral Statistics 2003-2007*.

- Steel: Bauxite is added to molten steel to purify it and improve the slag cement quality properties.
- Abrasives: Bauxite is mainly used for fused alumina.
- Mineral fibers: Bauxite is used as an additive for the manufacture of mineral or stone wool.
- Proppants: Small hard bauxite based balls are used in oil and gas wells to prevent obstruction.
- Refractories: Bauxite is melted to produce refractory bricks used in furnace (steel, glass, etc.).

Metallurgical & Non-Metallurgical Uses

Bauxite is typically classified according to its intended commercial application, such as abrasive, cement, chemical, metallurgical, and refractory. Of all bauxite mined, approximately 85% is converted to alumina (Al_2O_3) for the production of aluminum metal, and an additional 10% is converted to various forms of specialty alumina for nonmetal uses. The remaining 5% is used directly for nonmetallurgical bauxite applications.

The bulk of world bauxite production is used, therefore, as feed for the manufacture of alumina via a wet chemical caustic leach process known as the Bayer process. Most of the alumina produced from this refining process is smelted using the Hall-Héroult process to produce aluminum metal by electrolytic reduction in a molten bath of natural or synthetic cryolite (Na_3AlF_6).

Specifications for the nonmetallurgical grades of bauxite are more stringent than those for bauxite used to produce alumina and are based on the processing requirements and special properties required of their final commercial products. The natural chemical impurities that exist within these specialty grade ores are not chemically removed by refining because the ores are used as direct feed for the production of their ultimate end products. Although global figures on nonmetallurgical bauxite production and consumption are not commonly available, the principal industrial end uses are considered to be in refractories and abrasives, followed by cement applications. In addition, the aluminum chemicals and steel industries also consume significant quantities of bauxite.[28]

[28] U.S. Geological Survey: *2005 Minerals Yearbook: Bauxite and alumina*. January 2007.

Although there are substantial bauxite resources in the world, premium-grade bauxite ores suitable for use in these special niche markets have, over time, been limited to a few principal sources, such as China and Guyana. [29].

European bauxite is very well positioned in this non-metallurgical bauxite market[4]. European Red Bauxite, rich in iron, is the main key component for the production of fused calcium aluminates cement. It is estimated that more than 90% of European iron containing calcium aluminates cements are manufactured with a specific process using reverbatory furnace which requires the use of large blocks of raw materials. Monohydrate bauxites (diaspore), like Mediterranean or Chinese bauxites, meet this requirement whereas tropical tri-hydrate bauxites (gibbsite) are too soft and brittle to allow direct use in reverbatory furnaces.

The use of tri-hydrate bauxites (gibbsite) should be theoretically possible but requires burning and agglomerating the ore. It would be less efficient in terms of energy consumption and CO_2 generation. The additional cost of agglomeration should make it more costly under current conditions. As gibbsite main producing countries are Australia, Brazil and Guinea, sea transportation would also be less economically and less environmentally efficient. Moreover the iron content of red bauxite is not considered as an impurity in calcium aluminates technology, and is completely used for production without waste, compared to alternative use of bauxite like Bayer alumina production.

Block bauxites offer tend to be squeezed by a limitation of bauxite mining permits all over the world and the stronger export quota policy of Chinese authorities toward their own bauxite blocks mining producers. European calcium aluminate cement production is dependent on European bauxite production. Therefore European bauxite availability is critical for the sustainability of European calcium aluminate cement producers. It is of great importance not only for European downward industries but also because about 50% of calcium aluminate cement production is exported and sold out of the European Union and generate significant revenues[30].

29 Industrial Minerals and Rocks, Commodities, Markets and Uses, Society for Mining Metallurgy and Exploration, Inc. (SME)

30 KERNEOS ALUMINATE TECHNOLOGIES, 2010

Refractory Bauxite

	Typical metallurgical bauxite (wt. %)	Typical refractory bauxite (wt. %)
Al_2O_3	50 - 60	> 80
SiO_2	0 - 5	4 - 10
Fe_2O_3	10 -30	< 3
TiO_2	2 - 6	3 - 4
alkaline oxides	n. d.	0 – 0.5

While metallurgical bauxite is used as feed stock material for Al-metal production and characterised by high Fe_2O_3 and low SiO_2 content, refractory grade Bauxite is characterised by low Fe_2O_3, low TiO_2 and somewhat higher SiO_2 content. Of great importance is that alkaline oxides (e.g. Na_2O, K_2O) are at very low level.

Before refractory grade bauxite is used for refractory purposes normally it is calcined and sintered to get a bulk density of > 3.1 g/ccm

The major production of refractory bauxite takes place in China with a large number of producers. There is also production of refractory bauxite in India but this material cannot be used in the western world due to the high Fe_2O_3 content. The only commercial producer outside of China is located in Guyana/South America. This production is controlled by the Chinese bauxite producer Bosai. Therefore, all production of high quality refractory bauxite is controlled by China at this time. There is also a resource of refractory grade bauxite located in Brazil which is currently not used.

Furthermore bauxite is the basic material for other essential refractory raw materials, such as calcined and sintered alumina, white and brown fused alumina, calcined and sintered mulite.

4.4 Recycling and substitution

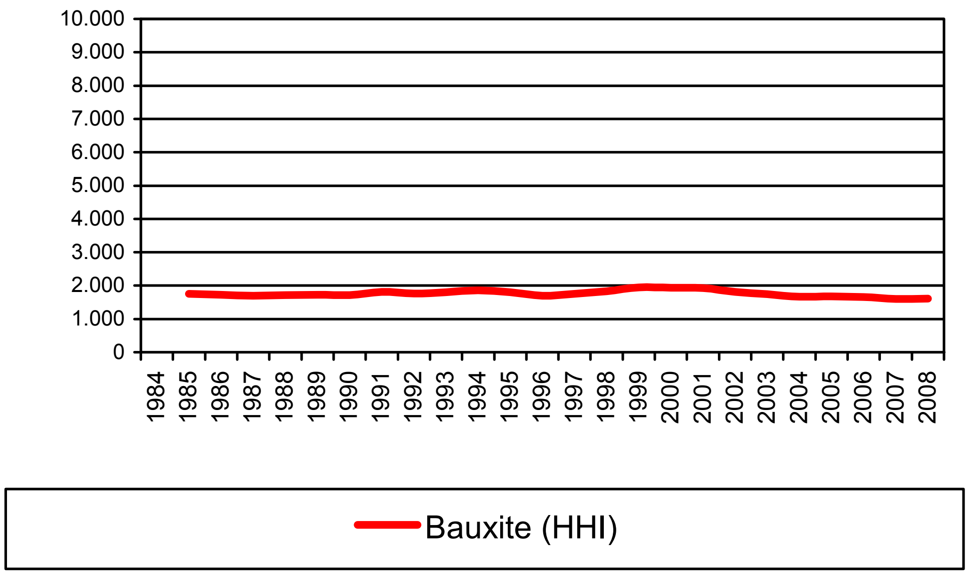
Bauxite is not recycled[2]. However, refractory bauxite products will be recycled commonly up to 50%.

Bauxite is the most important starting material for aluminum production, though other sources of alumina are technically feasible.[2,4] Refractory Bauxite can not be substituted, as the mineral composition creates specific properties which cannot be reached 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).

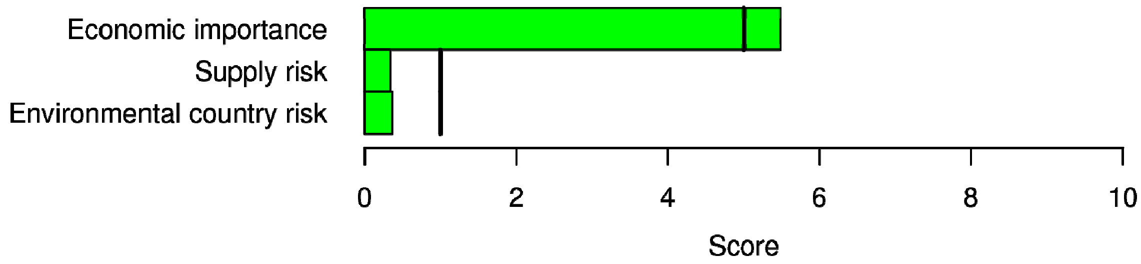
Use	Share	Megasector	Subst.
Aluminium production	86%	Metals	1
Non-metallurgical alumina	10%	Chemicals	0,5
Portland cement	0,7%	Construction Material	0,7
Calcium aluminate cements	0,3%	Construction Material	1
Steel	0,3%	Metals	1
Refractories	0,9%	Metals	0,7
Abrasives	0,7%	Mechanical Equipment	0,7
Mineral fibers	0,7%	Other Final Consumer Goods	0,7
Proppants (oil and gas drilling)	0,3%	Oil & Gas Extraction	0,7
Chemicals	0,2%	Chemicals	0,7

Substitutability index	0,94
Recycling rate	0%
Import Dependence	95%

Results	
Economic importance	9,5
Supply Risk	0,3
Environmental Country Risk	0,6



Source: World Mining Data 2010



5 Bentonite

5.1 Introduction

Bentonite is a plastic clay frequently generated from the alteration of volcanic ash and consists predominantly of smectite minerals, usually montmorillonite. Note that "montmorillonite is ubiquitous at low concentrations in soil in the sediment load of natural water and airborne dust" –WHO Environmental Health Criteria 231 Bentonite, Kaolin and selected clay minerals 2005 - but bentonite is found as localised substantial deposits which, when extracted, is mainly by open pit mining.

Depending on the nature of their genesis, bentonites contain a variety of accessory minerals in addition to montmorillonite. These minerals may include quartz, feldspar, calcite and gypsum. The presence of these minerals could impact the industrial value of the deposit, reducing or increasing its value depending on the application.

Bentonite presents strong colloidal properties and its volume increases several times when coming into contact with water, creating a gelatinous and viscous fluid. The special properties of bentonite (hydration, swelling, water absorption, viscosity, thixotropy and significant cation exchange capacity) make it a valuable material for a wide range of uses and applications.

5.2 Basic Supply & Demand Statistics

Bentonite reserves are large in major producing countries, but data are not available. The US is the largest producer of Bentonite, with approximately 42% of the world's production[31]. However, much of the EU's needs are sourced internally or from Turkey.

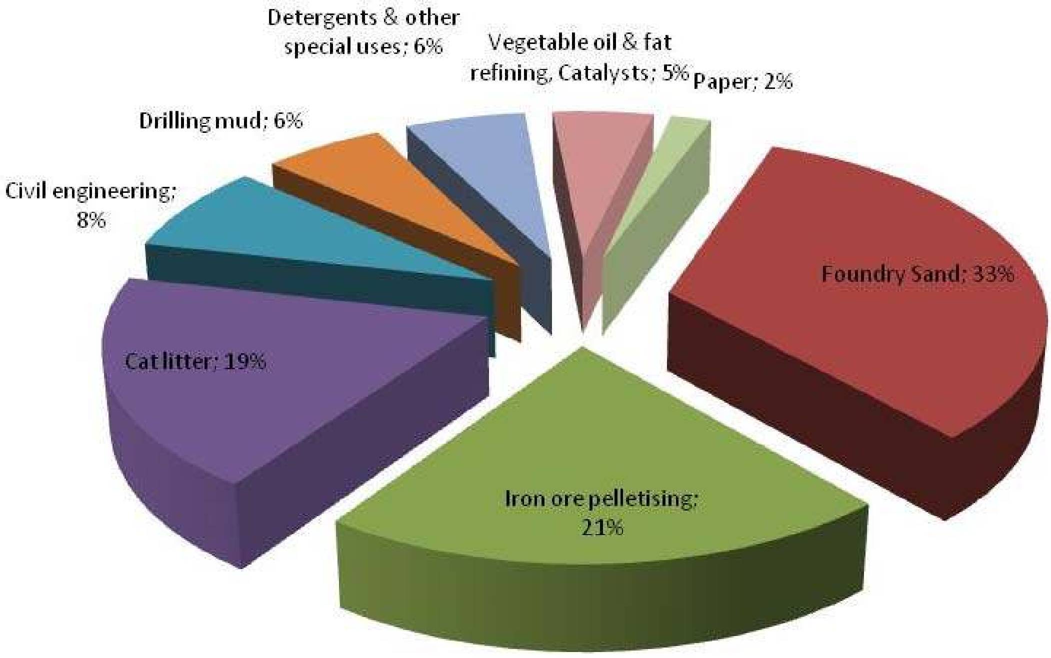
	Production (in 1000t, 2008)		Imports to EU (in 1000 t, 2006)	
United States	4,900	41.9%	141	26.9%
Brazil	32	0.3%		
Czech Republic	174	1.5%		
Germany	414	3.5%		
Greece	950	8.1%		
India	NA	NA	120	20.2%

[31] USGS

Italy	599	5.1%		
Korea, Republic of	N/A	N/A		
Mexico	375	3.2%	21	4.1%
Spain	150	1.3%		
Turkey	900	7.7%	146	27.9%
Ukraine	300	2.6%		
United Kingdom	N/A	N/A		
Uzbekistan	N/A	N/A		
Other countries	2,900	24,80%	130	21%
World total	11,694		520	

Source: USGS; Comtrade HS 250810 & HS 250820

5.3 Economic Importance



Bentonite has the following uses (IMA Europe, 2010):

- Foundry moulding sands: Green sand is an aggregate of sand, bentonite clay, pulverised coal and water, whose principal use is in making moulds for metal casting. The largest portion of the aggregate is sand, which can either be silica or olivine. There are many recipes for the proportion of clay which vary according to mouldability, surface finish, and ability of the hot molten metal to degas.
- 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,

i.e. the spherical form is suitable as feed material in blast furnaces for pig iron production, or in the production of direct reduction iron (DRI).

- Cat litter: Bentonite is used for cat litter due to its advantage of absorbing and binding refuse and forming clumps (which can be easily removed) leaving the remaining product intact for further use .i.e. minimizing the usage of litter.
- Civil engineering: Bentonite in civil engineering applications is traditionally used as a thixotropic, support and lubricant agent in foundations, in tunnelling, in horizontal directional drilling (HDD) and pipe jacking. Bentonite, due to its viscosity and plasticity, is also used in Portland cement and mortars. Bentonite creates a low permeability barrier so is used in diaphragm walls and containment situations – lining landfill sites - preventing leachate escape or rainwater ingress, ponds and canals and nuclear repositories where the ability to bind radionuclide's is an additional advantage to the sealant system.
- Drilling fluid: 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. The drilling fluids themselves are recycled during use.
- Vegetable oil & fat refining- Catalysts: Bentonite is modified through chemical processing to give an acidic nature to the mineral and alter its structure to give a greater surface area. This acid activated bentonite is mainly used for bleaching fats and oils particularly vegetable oils – in the EU mainly palm, rapeseed and sunflower oils..This form of bentonite also is used as a solid state acid catalyst and also as a component in carbonless copy paper.
- Specialty applications: Bentonite is used for specialty applications as rheological additives or emulsifiers for paints and coatings, polymers and nanocomposite polymer materials, adhesives, cosmetic, pharmaceuticals, or asphalts, as well as other applications as binder for animal feed or ceramics. 1% of bentonite is used in detergent applications.
- Paper: Bentonite is crucial to 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.. Bentonite also offers useful de-inking properties for paper recycling. In addition, as mentioned above acid activated bentonite is used as the active component in the manufacture of carbonless copy paper.

5.4 Resource Efficiency: Recycling & Substitution

The recycling rate of Bentonite is 0%, thus no bentonite is recycled nowadays.

Nevertheless:

- Foundry sands containing bentonite after a metal has been cast are invariably recycled and referred to as “system sand”. Most of the components are reused with relatively small arbitrary portion of the system sand removed (not specifically that which is spent) and replaced by fresh sand, clay, coal and water. Alternative binders do not offer this opportunity. There are some recycling initiatives as the use of spent foundry sands in construction applications or even the use of spent sand containing bentonite at landfill sites to replace fresh bentonite. Furthermore an increasing number of foundries are recycling and reuse the spend sand in the production of sand for cores with organic binders; in such cases the amount of waste is minimized.
- With drilling fluids or civil engineering the materials can be recycled to some extent but recovery of bentonite in most applications is not easy or possible, due to the fact that in the major bentonite applications, i.e. foundry, pelletizing and paper, bentonite is actually consumed. In the other applications little recycling is possible as the separation of bentonite from other components in the mixture makes recovery difficult e.g. separation of sorbed impurities in the cat litter application is probably more costly than the virgin material and does not justify the need for recycling. This condition might change in the future.

So the recycling of bentonite (to be used again as Bentonite) is rare. In some uses the bentonite is transformed to another mineralogical phase, so recycling involves considering a material whose properties are no longer dominated by montmorillonite clay and where the residual bentonite is only a component of a mixture e.g. spent system sand from foundries – such materials can sometimes be used in construction applications.

Concerning substitution, the characteristics of bentonite cannot be matched by a single alternative mineral or material. Therefore use of alternative materials is dependent on the particular application. Alternatives such as calcium carbonate and talc are available for filler and extender applications, while other special clays (hectorite, sepiolite, attapulgite) or organic thickeners can replace bentonite as a rheology modifier. Absorbent minerals such as attapulgite, sepiolite, diatomite or calcium silicate can substitute bentonite as cat litter. Organic binders can replace bentonite in iron ore pelletisation for green strength enhancement. Zeolites can be used in applications where the cation exchange capacity is important. However the swelling behaviour, cation exchange capacity and low permeability achieved with bentonite cannot be matched by alternative minerals.

5.5 Specific Issues

Bentonite has been used for multiple industrial applications for many decades. These products play an important role in the formulation of dozens of applications. This role is based upon the performance of such products, which depends upon the physical-chemical characteristics of the mineral. Assuring a competitive access to valid raw material is a key issue to guarantee the validity of such formulation for the European industry. The cost for the Industry to eventually reformulate for adapting to new inferior specifications of the mineral would entail a significant cost and risk.

Environmental issues and their legal implications will require a special effort by the industry of bentonite, in order to comply with the more and more tightening legal framework. On the other hand, given the efforts to be deployed for this purpose, the Industry of bentonite should take as much of advantage as possible to build a friendly image to European citizens. For this purpose, significant communication skills and investments would have to be implemented in a coordinated way.

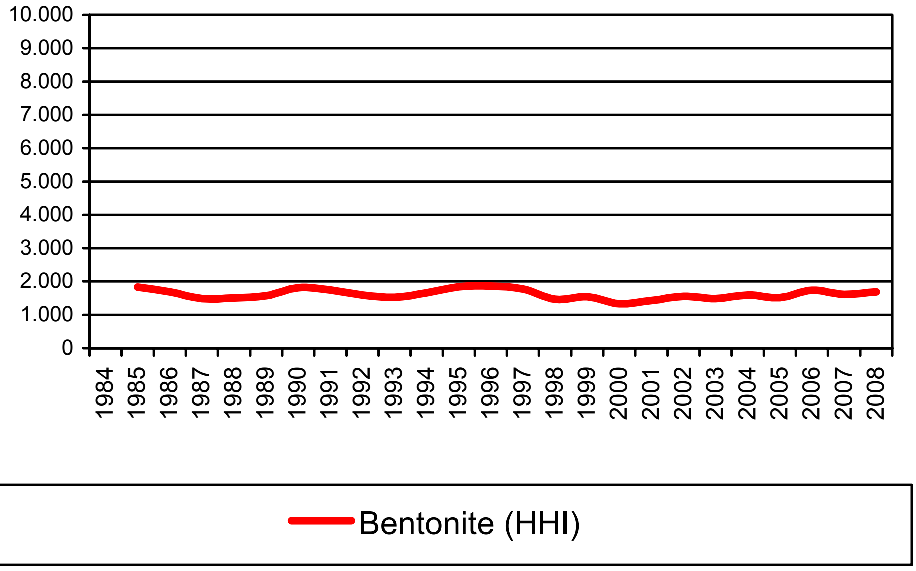
Many bentonite applications have already been commercially exploited for many years and some of these applications have suffered from limited technological development. A strong and determined action of investment in research and development is necessary to overcome many of the challenges that this Industry will face in future. In many cases, adaptation of the production facilities will be required. Access to financial resources to support those investments will determine the capacity of the Industry to get ready for the future.

Academic investigations into novel uses for Bentonite are relatively rare. The use of Bentonite as a major component of nuclear waste repositories has been (and continues to be) extensively investigated. However, interest in this mineral in the academic world has waned significantly since work looking at its behaviour in modifying polymer's properties peaked some years ago. As this mineral shows many unusual absorptive properties, binding properties amenable to surface modification and manipulation, the natural and relatively abundant substrate should be promoted as the basis for new research. This lack of research is particularly evident in the biological area e.g. as selective sorption and pacifying agent for deleterious

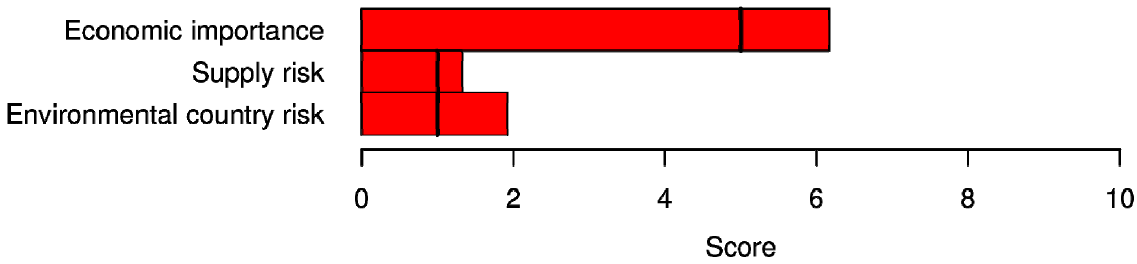
Use	Share	Megasector	Subst.
Drilling fluids	6%	Oil & Gas Extraction	0,7
Foundry molding sands	33%	Metals	0,7
Pelletizing of iron ore	21%	Mining of Metal Ores	0,7
Cat litter	19%	Other Final Consumer	0,3
Bleaching earth	5%	Food	0,7
Civil engineering	8%	Construction Material	0,5
Paper	2%	Paper	0,5
Detergents	1%	Chemicals	0,5
Specialties	5%	Chemicals	0,7

Substitutability index	0,53	
Recycling rate	0%	no information available
Import Dependence	15%	

Results	
Economic importance	5,5
Supply Risk	0,3
Environmental Country Risk	0,4



Source: Wolrd Mining Data, 2010



6 Beryllium

6.1 Introduction

Beryllium (Be, atomic number 4) is a silvery-white shining, hard and brittle light metal, which is highly toxic[32]. Its mechanical and thermal properties relative to its low density is superior to those of all other materials. Formerly, the metal was also called glucinium.[33]

Beryllium is a relatively rare element of the earths crust, as it is inferior to 6 ppm, which means it is number 32 in the abundance order[34]. It is a sub-product from feldspar deposits, and Brazil has the largest beryl mineral reserves in the world. Beryllium is mostly extracted from beryl[34].

6.2 Basic Supply & Demand Statistics

As noted above, with an abundance of 6ppm in the earth's crust, beryllium is a rare element. Though, it occurs concentrated in some minerals, predominantly in the minerals beryl and bertrandite.[2] World resources are estimated at 80,000 tons, of which 65% are located in the United States[35]. Because of the military relevance of beryllium, information on reserves and applications is limited.

	Reserves (in tonnes; 2010)	Production (in tonnes; 2009)	
USA	NA	120	85.1%
China	NA	20	14.2%
Mozambique	NA	1	0.7%
Others	NA	small	>0.5%
Total	**0**	**141**	

32 Römpp Online: *Beryllium.* Georg Thieme Verlag, Stuttgart, 2002

33 Ullmann's Encyclopedia of Chemical Technology: *Beryllium and Beryllium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

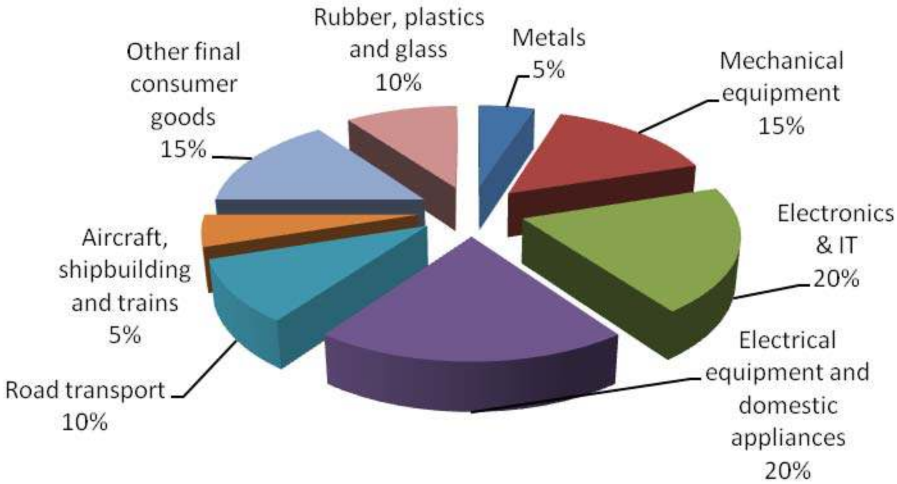
34 Pereira C. A., Renata (2004), Desenvolvimento de processo para obtenção de cloreto de berílio a partir do berilo mineral; Belo Horizonte

35 USGS Mineral Commodity Summaries 2010: *Beryllium*

Source: USGS 2010; ComExt (CN 8112 12 00)

Demand is limited by cost. Beryllium is not mined within the EEA. However, given estimated global reserve levels and annual usage, it appears that there is a abundant supply in the USA of the ores from which all Beryllium based materials are produced, reserves which could satisfy EU and world demand for over 100 years at current usage rates.

6.3 Economic Importance



Beryllium metal is used in discrete components within certain specialised, high technology equipment where low weight and high rigidity are important qualities (e.g. in aerospace equipment). As such, most beryllium is used for military purposes. Due to its high price and its toxicity, beryllium is only used in small quantities in the civilian sector:

- Approximately 40% of beryllium is used for <u>Electronic equipment and domestic appliances</u> and Electronics and IT - due to their favorable electric conductivity[36].
- <u>Construction</u>: Beryllium alloys are used for structural parts that have to be light and that are exposed to great forces (for example in the aircraft industry)[37], where lightweight structures, combined with rigid and good thermal properties are vital.

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[36] USGS Mineral Commodity Summaries 2010: *Beryllium*

[37] Römpp Online: *Beryllium.* Georg Thieme Verlag, Stuttgart, 2002

- Other applications where beryllium is used are[38,39]:
  - CT scanners and X-ray machines: Beryllium metal is used for x-ray transparent windows.
  - Ceramics: Beryllium oxide (BeO) is used for special ceramics.
  - Physical instruments: Beryllium has properties that make it interesting for a variety of physical instruments (e.g. neutron monochromators).
  - Joint European Torus Reactor and International Thermonuclear reactor: Important role in European efforts to develop controlled nuclear fusion energysystems, as a possible future alternative to the burning of fossil fuel.

6.4 Resource Efficiency: Recycling & Substitution

Recycling

About 19% of beryllium consumption[40] is recycled content from old scrap.

Approximately 50% of the “First Processing” materials are recovered as scrap that is recycled through an active “Secondary Processing” industry within the EU, or re-exported to the original smelting companies outside the EU. Within the 50% scrap recovered, approximately 90% of the Beryllium contained is recovered, and returned in First Processed alloys. The beryllium contained in post consumer scrap is not recovered specifically, but is contained in the slag produced by copper recycling processes[41].

Substitution

Due to its high costs beryllium is only used in applications where its properties are crucial. Therefore it is hard to substitute. Nevertheless certain metal matrix or organic composites, high-strength grades of aluminum, pyrolytic graphite, silicon carbide, steel, or titanium may be substituted for beryllium metal or beryllium composites. There are some more possible substitutes in specific alloys, but often combined with a loss in performance[42].

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38 Römpp Online: *Beryllium.* Georg Thieme Verlag, Stuttgart, 2002

39 Ullmann’s Encyclopedia of Chemical Technology: *Beryllium and Beryllium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

40 Civic, 2009

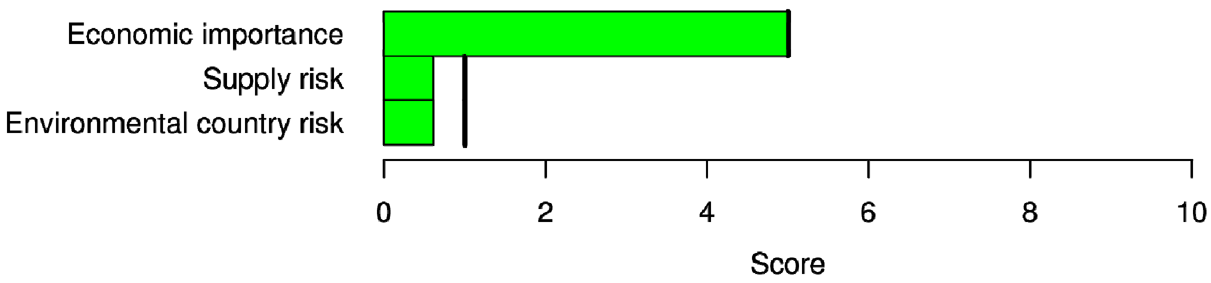
41 USGS Mineral Commodity Summaries 2010: *Beryllium*

42 USGS Mineral Commodity Summaries 2010: *Beryllium*

6.5 Specific issues

The most significant threats originate from perceived risks associated with the use of beryllium in electronic products. EU regulatory fears and NGO propagated “banning” of the use of materials containing beryllium lead to unwarranted attempts to find substitutes that do not offer the same qualities with respect to performance, sustainability and environmental protection. The data that authorities rely on is not current and does not reflect the most recent scientific studies. In general, authorities are reluctant to break from the past and are not open to new scientific studies even if they are conducted in accord with OECD guidelines or originate from proven workplace strategies.

Algeria and South Africa resort to non-automatic export licensing to limit the quantities of waste and scrap exported. Russia applies a 6.5% export tax on waste and scrap.



7 Borates

7.1 Introduction

Borates are naturally-occurring minerals containing boron, the fifth element on the Periodic Table. Trace amounts exist in rock, soil and water. The element boron does not exist by itself in nature. Boron products are used in a wide range of industrial products that improve our standard of living, are a micronutrient required by plants to grow and are an essential part of a healthy diet.

Despite the millions of tons of industrial borates mined, processed and distributed around the world every year, far larger quantities of boron are transferred around the planet by way of natural forces. Rain, volcanic activity, condensation and other atmospheric activities, redistribute at least twice as much boron as all commercial practices combined.[43]

7.2 Basic Supply & Demand Statistics

According to the USGS, Borates reserves are quite large in all major producing countries. The production of Borates in the United States is confidential, thus the total world production number excludes the USA production. Turkey is one of the largest producers, with approximately 46% of the world production[44].

	Reserves(in 1000t)		**Production (in 1000t; 2008)**		**Imports to EU (in 1000t; 2006)**	
United States	40,000	23.26%	W		9.7	17.76%
Argentina	2,000	1.16%	785	18.06%	0.9	1.70%
Bolivia	NA		56	1.29%	0.9	1.70%
Chile	NA		583	13.41%	2.4	4.29%
China	25,000	14.53%	140	3.22%		

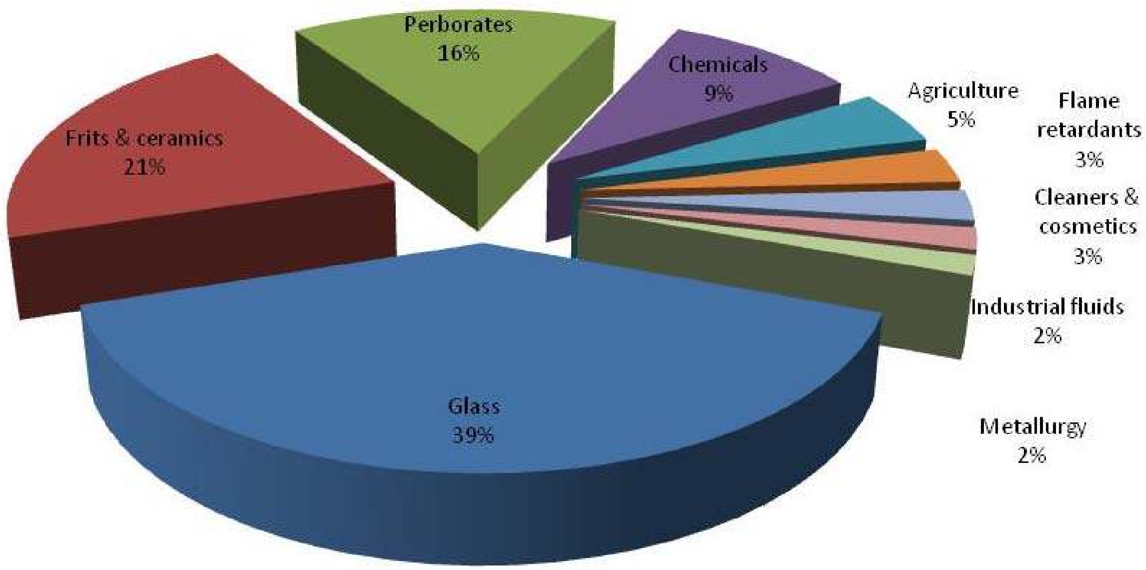
43 http://www.ima-na.org/Borates

44 http://www.boren.gov.tr/en/expin3.htm#1._WORLD_BORON_PRODUCERS_AND_CAPACITIES

Iran	1,000	0.58%	2	0.05%		
Kazakhstan	NA		30	0.69%		
Peru	4,000	2.33%	350	8.05%	1.3	2.43%
Russia	40,000	23.26%	400	9.20%	0.7	1.37%
Turkey	60,000	34.88%	2,000	46.02%	38.8	70.75%
World total (rounded)	**172,000**		**4,346**		**54.8**	

Sources: USGS; ComExt CN 2528 10 00 (Natural sodium borates and concentrates thereof; Natural borates (excl. Na-Borates)) & CN 2528 90 00(Refined borax Borates); W = Withheld

7.3 Economic Importance



- Glass and Fibreglass: Borates are an important ingredient in both insulation fibreglass – which represents the largest single use of borates worldwide – and textile fibreglass, used in everything from circuit boards to surfboards. In both products, borates act as a powerful flux and lower glass batch melting temperatures. They also control the relationship between temperature, viscosity and surface tension to create optimal glass fiberisation.

  Borosilicate glass is the foundation for all heat resistant glass applications and the myriad products they make possible – from cathode ray tubes to Pyrex cookware. Borates increase the mechanical strength of glass, as well as their resistance to thermal shock, chemicals and water. The use of borates to manufacture large, thin pieces of glass have progressed the growth of flat panel screens for televisions.

- Ceramics: Borates have been an essential ingredient in ceramic and enamel glazes for centuries, integral to affixing glazes or enamels, and enhancing their durability and lustre. Borates are now gaining acceptance as an essential ingredient in ceramic tile bodies, allowing manufacturers to use a wider range of clays, heightening productivity and decreasing energy usage.
- Wood Treatments and Agriculture:
  - Agriculture: Boron is an essential micronutrient for plants, vital to their growth and development. Without sufficient boron, plant fertilisation, seeding and fruiting are not possible. On every continent of the world, crop yields and food quality are diminished due to insufficient boron concentrations in the soil. These deficiencies can be corrected with borate fertilisers. In areas of acute deficiency, borates can increase crop yields by 30 to 40 percent.
  - Wood Treatments: Borate treated wood is on the rise as a safe and long-lasting method to protect homes and other structures from wood-destroying organisms. Borate-based preservatives can be used to treat solid wood, engineered wood composites and other building materials like studs, plywood, joists and rafters. Borates prevent fungal decay and are deadly to termites, carpenter ants and roaches – but are safe for people, pets and the environment.
- Cleaners & Cosmetics**:** Borates enhance stain removal and bleaching, stabilise enzymes, provide alkaline buffering, soften water and boost surfactant performance in detergents and cleaners. Their biostatic properties control bacteria and fungi in personal care products. New trials demonstrate that adding borates to laundry soap bars significantly improves their cleaning action and reduce levels of dirt redeposition.
- Flame retardants: Zinc borates are used primarily as a fire retardant synergist in plastics and rubber applications. They can also function as smoke and afterglow suppressants, anti-tracking agents, and can be used in polymers requiring high processing temperatures. Zinc borates can be found in polymers ranging from electrical parts and automobile interiors to wall coverings and carpeting (IMA Europe, 2010).

7.4 Resource Efficiency: Recycling & Substitution

Recycling

According to USGS and the Fraunhofer-Institute, the recycling rate of Borates is insignificant. This condition might change in the future. The use of borates in applications such as glass and ceramics do not prevent these products from being recycled. In addition the use of borates reduces energy demand during manufacturing of vitreous products and, in the case of insulation products, provide a long term energy saving benefit.

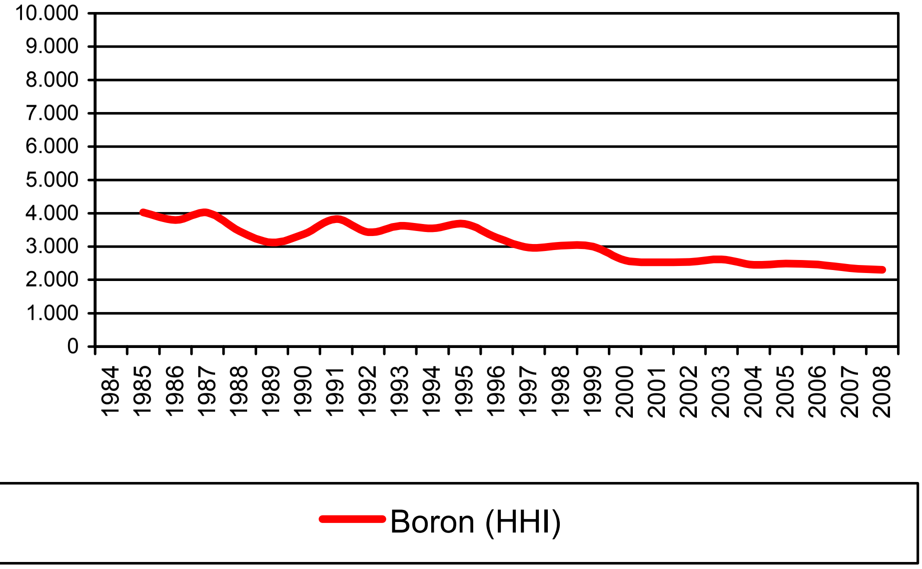
Substitutes

Substitution for boron materials may be possible in such applications as detergents, enamel, insulation, and soaps. Sodium percarbonate can replace borates in detergents and requires lower temperatures to undergo hydrolysis, which is an environmental consideration. Some enamel can use other glass-producing substances, such as phosphates, depending on the requirement of the final properties. Insulation substitutes include cellulose, foams, and mineral wools. In soaps, sodium and potassium salts of fatty acids can act as cleaning and emulsifying agents.

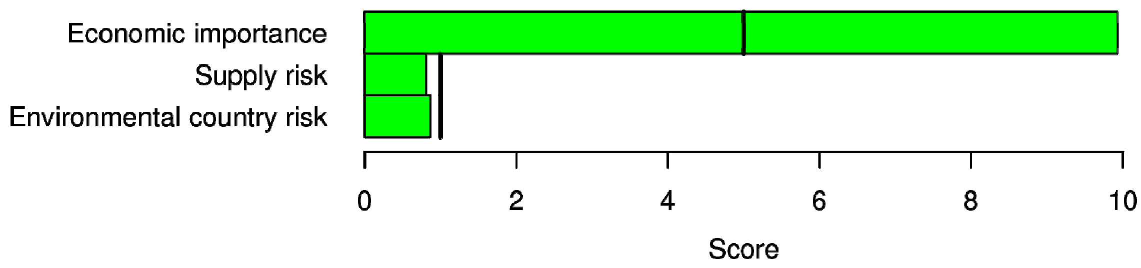
Use	Share	Megasector	Subst.
Glass	37%	Rubber, Plastic & Glass	1,0
Frits & ceramics	19%	Construction material	0,7
Cleaning	26%	Chemicals	0,7
Chemicals	3%	Chemicals	0,5
Agriculture	2%		1,0
Flame retardants	3%	Chemicals	0,3
Industrial fluids	3%	Chemicals	0,5
Metallurgy	1%	Metals	1,0
Wood preservation	1%	Other Final Consumer Goods	0,5
Other	5%	Other Final Consumer Goods	0,5

Substitutability index	0,72
Recycling rate (recycled content)	0%
Import Dependence	100%

Results	
Economic importance	5,0
Supply Risk	0,6
Environmental Country Risk	0,6



Source: World Mining Data, 2010



8 Chromium

8.1 Introduction

Chromium is a hard metallic element that is an essential component of stainless steel and other alloy steels, where it is used in the form of the alloy ferro-chromium. It is also used extensively on superalloys and metal plating. Its compounds have been extensively utilised as pigments, but their use has decreased due to environmental concerns. The mineral chromite is used in refractories[45].

Around 94% of global chromite production is destined for use in the metallurgical industry, for the production of ferro-chrome, with the remainder produced for use in the foundry, chemical and refractory sectors. World mine production of chromite therefore follows the pattern of world ferro-chrome production. Around 70% of global chromite production is consumed domestically in ferro-chrome production in the country of origin. Supply situation of ferro-chrome is of strategic importance for steel production.[46]

Chromite ore is a byproduct of PGM mining (platinum group metals). Increased future PGM mining may also increase output of chromite ore.

8.2 Basic Supply & Demand Statistics

Chromium is found in many different minerals, but only chromite ($FeO \cdot Cr_2O_3$) is used as commercial source for chromium. Chromite rarely contains more than 50% of Cr_2O_3. [47] Chromium is a rather common element (0.002% of the earths crust).[48] World resources of chromite are estimated to be larger than 12 billion tons, which is considered enough to cover the world's chromium demand for centuries. 95% of these resources are located in Kazakhstan and southern Africa[49].

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[45] European Mineral Statistics 2003-2007, BGS

[46] Roskill Information Services: *The Economics of Chromium*, London, 2009

[47] Ullmann's Encyclopedia of Chemical Technology: *Chromium and Chromium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

[48] Römpp Online: *Chrom.* Georg Thieme Verlag, Stuttgart, 2007

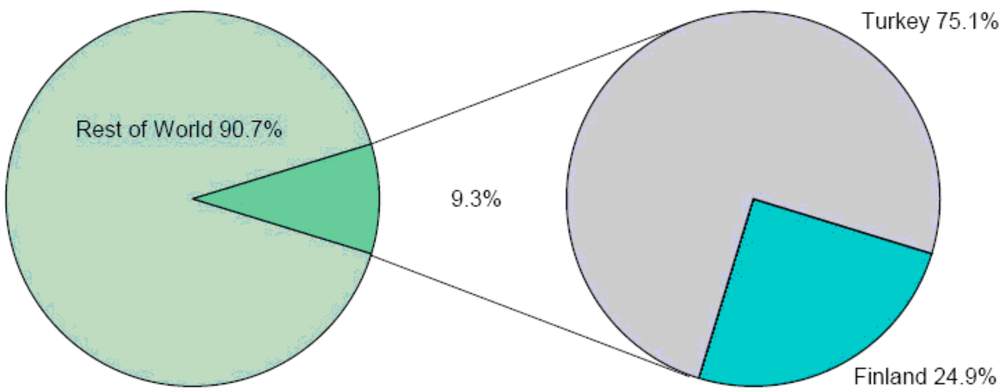
[49] USGS Mineral Commodity Summaries 2010: *Chromium*

	Reserves (in 1000t; 2010)	Production (in 1000t; 2009)		Imports to EU (1000t-ores; 2006)	
USA	620	-			
India	44,000	3,900	16.7%	0.02	< 0.1%
South Africa	130,000	9,600	41.0%	293	79.1%
Kazakhstan	180,000	3,600	15.4%		
Albania	NA	NA		6.6	1.8%
Brazil	NA	NA			
Madagascar	NA	NA		5.1	1.4%
Oman	NA	NA		0.4	0.1%
Pakistan	NA	NA		6	1.6%
Turkey	NA	NA		59.2	16.0%
Others	NA	6,300	26.9%		
Total	**>350,000**	**23,400**		**370**	

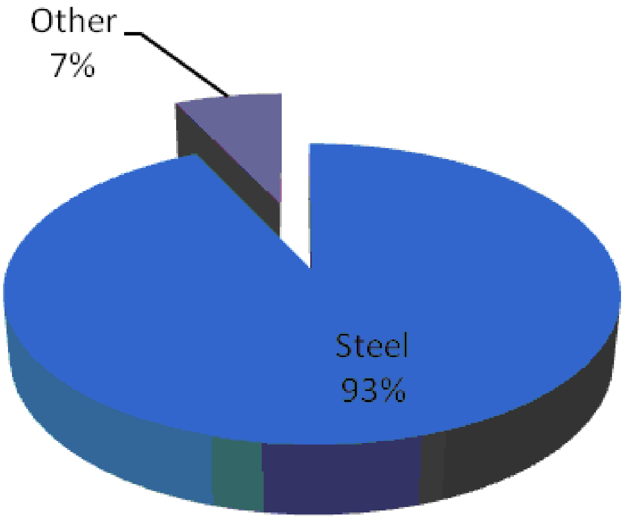
Source: USGS 2010; trade data provided by BGS based on EU comtrade (HS 2610)

The main sources for EU imports in 2006 were South Africa (approximately 80%).

Approximately half of the Europe's needs are met by European production (including Turkey). Within the EU, Finland was the main producer of chromium in 2006, producing over 99% of the total EU chromium production (219,500 tonnes) and exploration in Finland may lead to the discovery of new deposits. Greece produced approximately 700 tons. The diagram below presents European ore production (9.3%) as a percentage of world output.



8.3 Economic Importance



Main end-use markets for chromium products (worldwide), 2005[2,50]:

- Steel: Chromium increases an alloy's hardenability, creep and impact strength and its resistance to wear, oxidation and corrosion. Most quantities of chromium are used for stainless steel.
- Refractories: Chromite is used for manufacturing bricks and other devices in the refractory industry.
- Pigments: Chromium compounds are used for pigments
- Other: Chromium containing chemicals are used for leather tanning, metal corrosion inhibition, drilling muds, cosmetics, for textile dyes, catalysts and for wood and water treatment.

Emerging technologies requiring chromium (seawater desalination, orthopedic implants) are not expected to significantly increase total demand up to 2030.

8.4 Resource Efficiency: Recycling & Substitution

The recycling rate in the US is approximately 30% (calculated as the ratio between recycled metal and apparent supply). There is no information available on recycling in Europe.

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2 Ullmann's Encyclopedia of Chemical Technology: *Chromium and Chromium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

50 Fraunhofer Institut für System und Innovationsforschung and Institut für Zukunftsstudien und Technologiebewertung: *Rohstoffe für Zukunftstechnologien*, 2009, Fraunhofer IRB Verlag, Stuttgart

In its major applications in the metallurgical sector, for example for stainless steel production, chromium has no substitute.[51] Due to their carcinogenic potential, inorganic chromium compounds used in dyes and pigments are more and more substituted.[52]

8.5 Specific issues

Import Dependence

Finland and Turkey are the only countries in Europe with significant chromium production, which amounted to 9 per cent of world production[53]. Relating to the fact that 70% of worldwide chromite production is used in the country of origin to produce ferro-chrome, Europe is considered to be import dependent on chromite ore as well as on ferro-chrome.

Company control

Largest South-African chromite mining is done at Bushveld Igneous Complex; this area is estimated to contain nearly 70% of world reserves of chromite. Samancor company seems to be the largest producer, mining about 3Mt per annum. 76 per cent (2.3 million metric tonnes) of the production is used within the company, only 23 per cent are exported.[54]

The top 3 of worldwide producers of ferro-chrome are English-Kazakh ENRC (Eurasian Natural Resources Corporation), English-Russian Kermas Group and Swiss Xstrata, together holding 45% of world production.[55]

Environmental Issues

Chromite is covered by Commission Regulation (EC) N° 552/2009 amending Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards Annex XVII.[56]

Trade Issues

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51 USGS Mineral Commodity Summaries 2010: *Chromium*

52 Römpp Online: *Chrom.* Georg Thieme Verlag, Stuttgart, 2007

53 European Mineral Statistics 2003-2007, BGS

54 Source: Samancor

55 BGR

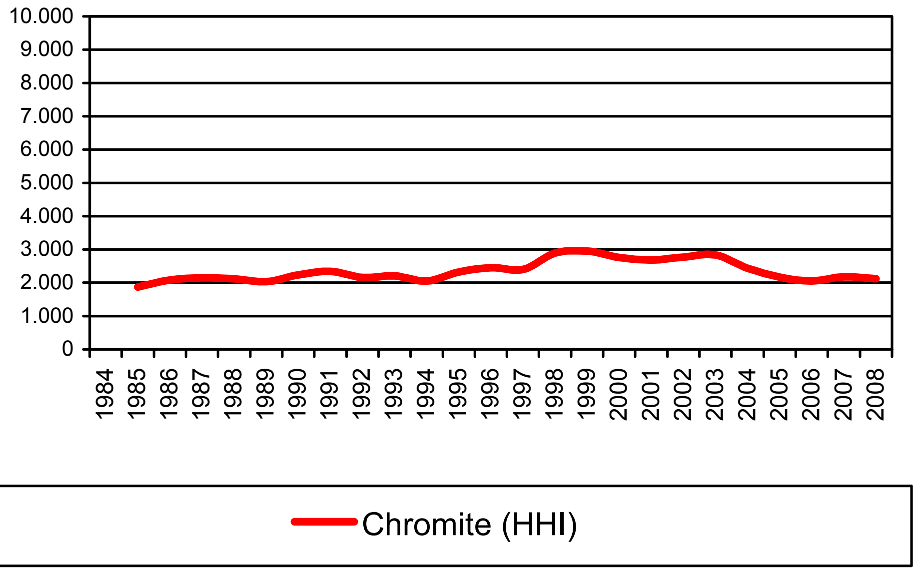
56 More info at: http://ecb.jrc.ec.europa.eu/classification-labelling/search-classlab/

According to the EU Commission's inventory on export restrictions, Algeria and South Africa resort to non-automatic export licensing to limit the quantities of waste and scrap exported. Tanzania applies an export ban.

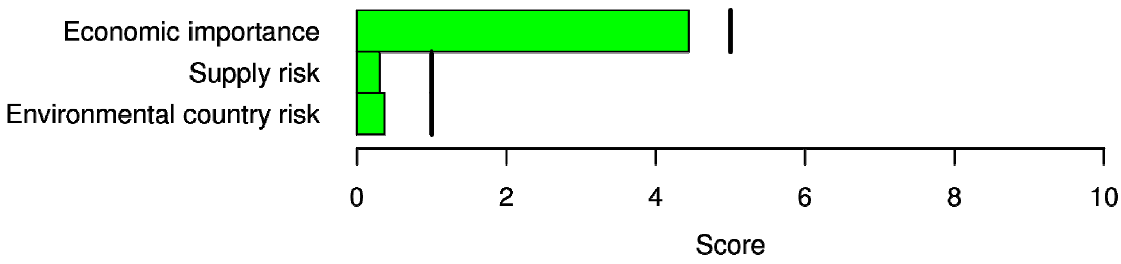
Use	Share	Megasector	Subst.
Ferrochromium alloys	95%	Metals	1
Pigments	2%	Chemicals	0,7
Refractories	3%	Metals	0,7

Substitutability index	0,97
Recycling rate (recycled content from old scrap)	13%
Import Dependence	46%

Results	
Economic importance	9,9
Supply Risk	0,8
Environmental Country Risk	0,9



Source: World Mining Data, 2010



9 Clays

9.1 Introduction

Clays are comprised of certain groups of hydrous aluminum, magnesium and iron silicates that may contain sodium, calcium, potassium and other ions[57]. The specific clay mineral discussed here is kaolin and plastic clay. Kaolin is used industrially, primarily as a filler based on its optical, mechanical and chemical characteristics.[58] Plastic clay is primarily use in ceramics. It is a soft, white plastic clay consisting mainly of the mineral kaolinite which is a hydrated aluminum silicate.[59]

9.2 Basic Supply & Demand Statistics

Major Kaolin reserves are located in the USA (Georgia), Australia, Brazil (Jari, Capim), Germany (Bavaria, Saxony), UK (Cornwall,Devon), Czech Republic (Karlovy Vary and Pilszen area)[60], France (Bretagne), Ukraine, Poland, China and India. Minor kaolin deposits can be found all over the world[61]. Reserves of major producing countries are large, resources are considered to be extremely large[62].

Major plastic clay deposits can be found in Germany (Westerwald (Rhineland-Palatinate and Hesse), in Saxony and in Bavaria[63]), UK (Devon), USA (Tennessee, Kentucky) and in the Ukraine (Donbas region) .

In the following table the three most important clays (kaolin, bentonite and fuller's earth) are pooled.

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57 Murray 1985-1996

58 IMA Europe, 2010

59 Murray 2002

60 Dill, H.G., 2010: The "chessboard" classification scheme of mineral deposits: Mineralogy and geology from aluminum to zirconium. Earth Science Reviews, doi:10.1016/j.earscirev.2009.10.011

61 Murray 2002

62 USGS, MCS 2010, Clays

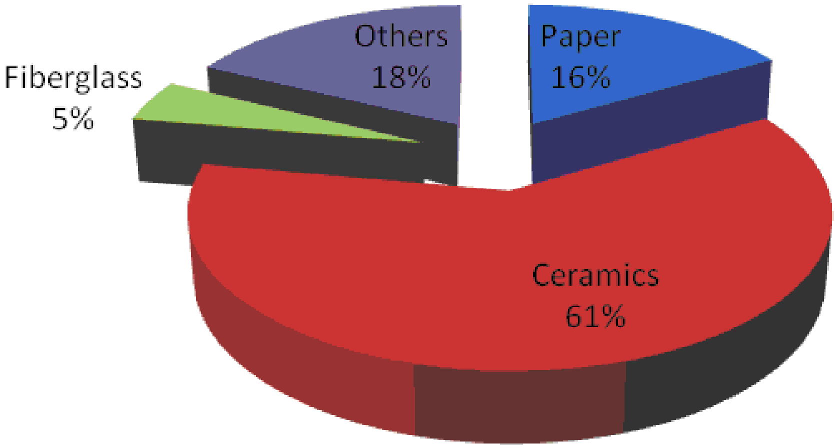
63 BKRI, Geschäftsbericht 2009/ 2010; www.bkri.org

	Production (in 1000t; 2009)		EU imports (in 1000t; 2007)	
USA	11,660	26,5%	906	29,7%
Brazil	2,158	4,9%	1.042	34,2%
Czech Republic	3,550	8,1%		
Germany	3,620	8,2%		
Greece	900	2,0%		
Italy	1,043	2,4%		
Korea	900	2,0%		
Mexico	475	1,1%		
Spain	1,350	3,1%		
Turkey	1,210	2,7%		
Ukraine	2,240	5,1%	1.073	35,2%
UK	1,550	3,5%		
Uzbekistan	4,600	10,4%		
China	NA		28	0,9%
others	8,827	20,0%		
Total	**44,083**		**3,049**	

Source: USGS 2010; trade data provided by BGS based on EU Comtrade (HS 2507)

In 2007, clays were produced within the European Union by 13 member states, of which Germany (48%), the United Kingdom (21%) and the Czech Republic (8%) produced the largest shares. In the same year, EU production totalled little more than 8 million tonnes, 3 million tons were imported, mainly from the Ukraine, Brazil and from the United States.

9.3 Economic Importance



In Europe, the most important users of Kaolin and Clays are as follows[64]:

- 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%.
- Fiberglass: For the production of fiber glasses 5% of total kaolin consumption is necessary.
- Other: Other uses are in paints, rubber, plastics, refractories and cosmetics/pharmaceuticals.

64 IMA Europe, 2010

9.4 Resource Efficiency: Recycling & Substitution

Recycling rates of kaolin and plastic clay can be assumed to be insignificant. However, one way of recycling could be done indirectly through the recycling of paper or tiles and bricks which allows some of the mineral components to be recovered.[65] The recycling of kaolin and clay used in Ceramics is not possible for quality reasons.[66]

Substitution of kaolin and plastic clay in the ceramics sector is assumed to be very difficult, because it fires white, is plastic, and has good shrinkage and strength properties. For the paper industry substitution of kaolin is feasible, e.g. by calcium carbonate which is a strong competitor[67]. In fact, for the paper industry, substitution of kaolin by calcium carbonates has largely taken place over the past 10 years, but had a reduced pace recently.

9.5 Specific Issues

According to industry, the following issues (actions) should be addressed (taken) to improve the supply of clays:

- Secure the access to mineral deposits within the EU while experiencing long lasting permitting procedures and complex land-use planning policies in some Member States.
- Actions against the "not in my back yard" effect (see the IMA Europe position paper for the WG Best Practice)
- Regulatory burdens (e.g. REACH, GHS, Natura 2000, ETS
- Substitution of kaolin by calcium carbonates in paper and specialty (polymers & coatings) markets
- Develop new products and new markets through innovations (= research and development)

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[65] BGS 2009

[66] Recyclinggutachten NRW Substitution von Primärbaurohstoffen durch Recyclingbaustoffe in Nordrhein-Westfalen http://www.wirtschaft.nrw.de/400/400/500/MWME_NRW_Recyclinggutachten.pdf

[67] Murray 2002

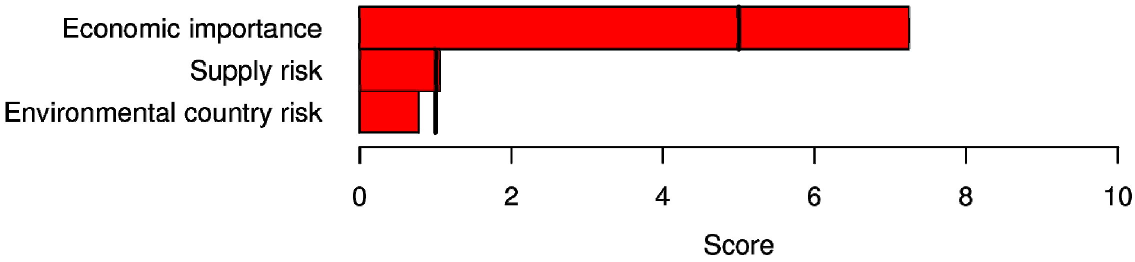
- High energy prices, especially for companies which process minerals (e.g. calcination of clays, wet mining of kaolin)
- Improve the sectors image.
- Coping the consequences of the financial and economic crises (decline of the market).

- Increase of all costs related to transportation & logistics (road taxes, fuel taxes, truck bans etc.) as product price includes a significant part of logistic costs.

Use	Share	Megasector	Subst.
Paper	17%	Paper	0,3
Ceramics	61%	Construction Material	1,0
Fiberglass	5%	Rubber, Plastic & Glass	0,7
Others	18%	Other Final Consumer Goods	0,5

Substitutability	0,78
Recycling rate	0%
Import Dependence	23%

Results	
Economic importance	4,4
Supply Risk	0,3
Environmental Country Risk	0,4



10 Cobalt

10.1 Introduction

Cobalt (Co), a transition metal appearing in the periodic table between iron and nickel, is very hard, retains its strength at high temperatures and has fairly low thermal and electrical conductivity. Cobalt is also ferromagnetic and can therefore be magnetised. Other properties that are important in industrial applications are its ability to form alloys with many other metals, imparting strength at high temperatures, and its ability to keep its magnetic properties at high temperatures.

The CDI (Cobalt Development Institute) is the authoritative source of information regarding the global cobalt market and cobalt applications[68].

10.2 Basic supply and demand statistics

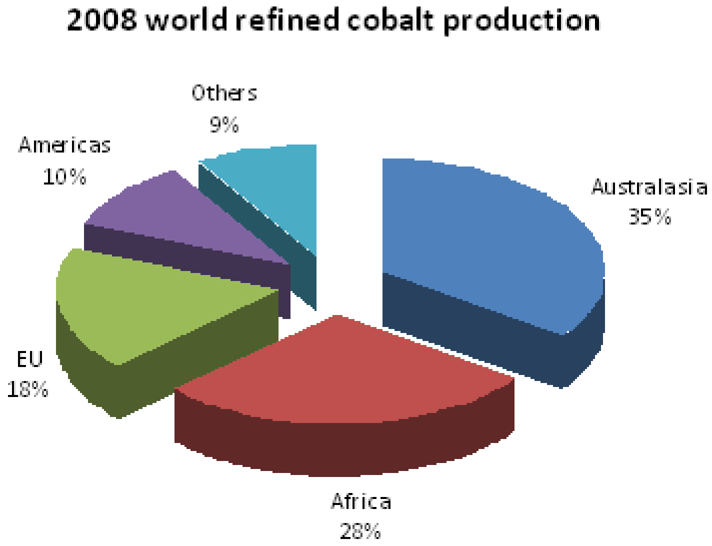
Cobalt is generally associated with copper or nickel in minerals meaning that about 85% of current cobalt production worldwide arises from nickel (~50%) and copper (~35%) production and ~15% only arise from genuine cobalt operations. Africa is the predominant source of mining product supply, followed by the Americas and Australasia. There is no mine production of cobalt in Europe. The CDI estimates cobalt reserves worldwide to be of the order of 7.1 million tonnes cobalt content.

Source: USGS, 2010; UN ComTrade HS 2605 in gw - gross weight

	Reserves (in 1000t)		Production (in 1000t; 2008)		Imports to EU (in 1000t gw; 2007)	
DRC	3,400	51.5%	31	40.8%	18.6	70.3%
Australia	1,500	22.7%	6.1	8.0%		
Cuba	500	7.6%	3.2	4.2%		
Zambia	270	4.1%	6.9	9.1%		
Russia	250	3.8%	6.2	8.2%	5.0	19.1%
New Caledonia	230	3.5%	1.6	2.1%		
Canada	120	1.8%	8.6	11.3%		
China	72	1.1%	6.0	7.9%	.05	0.2%
United States	33	0.5%	0	0.0%		
Brazil	29	0.4%	1.2	1.6%	0.5	2.0%
Morocco	20	0.3%	1.7	2.2%		
Others	180	2.7%	3.4	4.5%	2.2	8.4%
Total	**6,604**		**75.9**		**26.5**	

68 http://www.thecdi.com

World production of cobalt has almost quadrupled since 1995. Assessed by reference to the production of cobalt metal or cobalt chemicals from cobalt containing materials requiring further refining, was estimated by the CDI at 56 400 tonnes in 2008. EU production accounted for 18 % of this total amount, based on feed originating mostly from Africa and Russia.

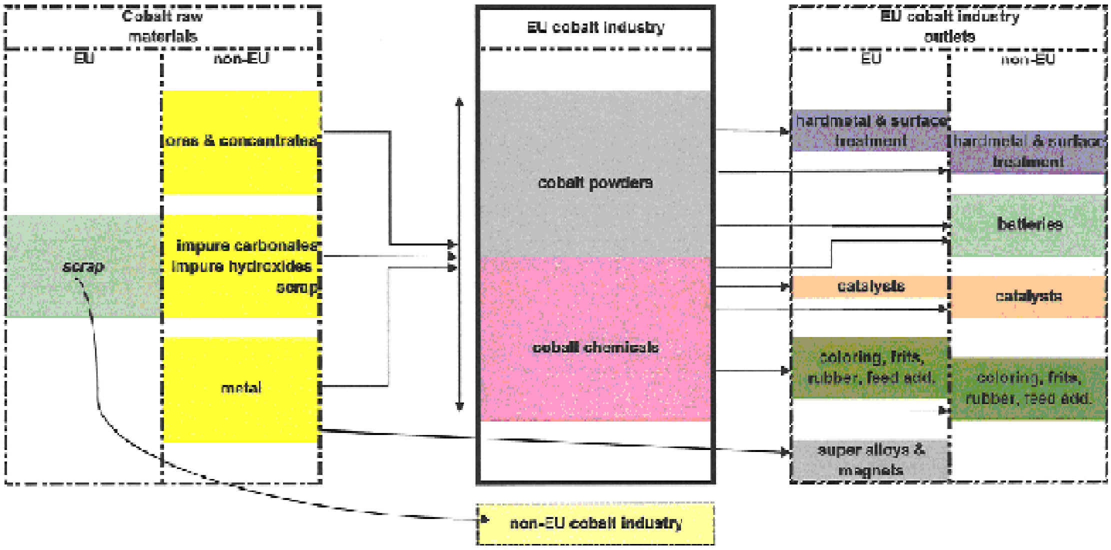


10.3 EU cobalt industry structure

The EU cobalt industry consists of only a few companies whose product range features cobalt powders and chemicals. Their combined output is hovering between 10,000 and 15,000 tonnes Co per year.

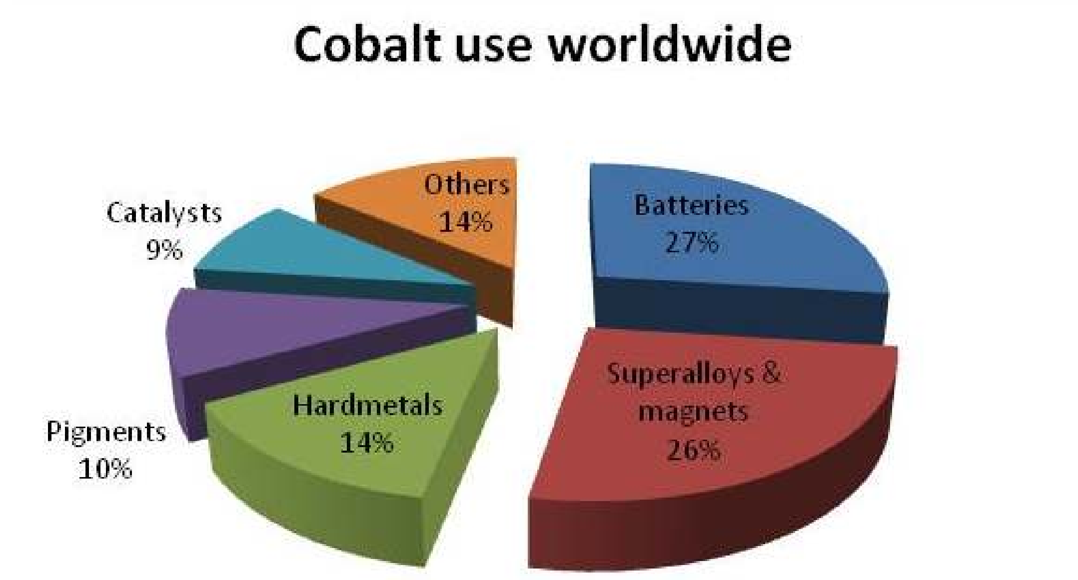
Most of their feed supplies (ores and concentrates, impure chemicals, scrap or metal) are imported meaning that they are highly dependent on access to raw materials on the international market.

In addition, their activity is very much geared towards exports considering that EU demand for powders and chemicals represents only a fraction of their output.



The EU Cobalt Value Chain[69] (Source: Eurometaux)

10.4 Economic importance

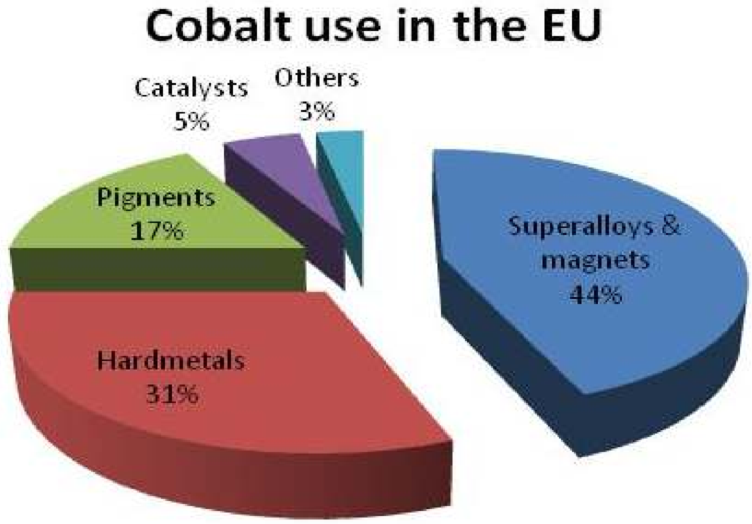


69 Eurometaux

- Rechargeable batteries: today's main cobalt end-use sector, including nickel-cadmium batteries, nickel-metal hydride batteries and lithium-ion batteries, with the highest proportion of cobalt found in high-performance models (the cathode of lithium-ion batteries may contain up to 60 per cent of lithium-cobalt oxide).
- Superalloys/wear resistant alloys: historically the major end-use of cobalt which is alloyed with other metals (mostly nickel, but also iron) to provide superior thermal, corrosion and wear resistance to a wide range of alloys developed for applications in e.g. jet engines, all types of turbines, space vehicles, certain parts of motors, chemical equipment, etc.
- Hardmetals: cobalt is a powerful binder for the manufacture of carbide and diamond tools by the hardmetal industry.
- Catalysts: Co-based catalysts are widely used in the petro-chemical and plastics industries.
- Magnetic alloys**:** cobalt unique feature in magnet applications is to ensure permanent and stable magnetism at high temperature, which makes Co containing magnetic alloys still the preferred material for high-demanding magnet applications even though substitutes have been developed and implemented for less demanding applications as a result of price volatility in particular.
- Others: cobalt has many other applications where it is used in the form of oxides or salts, such as pigment in ceramic and glazing, as a decolouriser in glass, as a drier in paints, as an adhesive in rubber applications, as an oligo-element in agriculture and medicine, etc.

World distribution of cobalt consumption per end-use is estimated by the CDI as follows:

In view of the EU industry fabric however, the distribution of cobalt consumption in the EU significantly differs from worldwide distribution. In particular, there is no production of rechargeable batteries and only a small production of Co catalyst in the EU. However, the EU cobalt industry is a major world supplier of cobalt chemicals for both latter applications.



Source: Eurometaux

Future consumption will be affected by two major developments:

- the growth of use sectors in Asia will shift market demand for cobalt products towards these regions (e.g. rechargeable batteries production is already concentrated in Asia) and will therefore require high export competitiveness from the EU cobalt industry,
- the growth of chemical applications will result in an increased demand for Co chemicals, in particular for Co-based catalysts (e.g. for gas-to-liquid technology for the processing of natural gas into synthetic diesel fuel for instance), and for rechargeable batteries whose fast growth of production is likely to offset some substitution of cobalt by other metals (manganese and nickel).

Both trends will require from the EU cobalt industry a continued and improved competitiveness on export as export outlets will become even more important for the EU cobalt enterprises than it is at the present time.

Competitiveness and level playing-field in access to raw materials will in this respect remain a key factor to secure such competitiveness on export.

10.5 Recycling and substitution

Recycling of cobalt has developed naturally for economic reasons (price volatility, cost benefits) and because of the geopolitical structure of supply (historical predominance of Central African countries). Recycling of alloy and hardmetal scrap is generally operated by and within the superalloy and metal carbide sectors and cobalt is recovered, in fact, in alloyed or mixed form. Some recovered hardmetal materials are recycled, however, through the cobalt industry route. Recycling of catalysts and batteries is also done via the cobalt industry. These end-of-life products are an increasingly important source of cobalt supply for the EU cobalt industry in particular. Cobalt recycling from applications in pigments, glass, paints, etc is not possible as these usages are dissipative.

The End of Life Recycling Rate (EOL-RR) of cobalt is estimated at 68% by UNEP (higher than for most other metals), and the Recycled Content (RC) rate is estimated at 32% (lower than most other metals).

Substitutes for cobalt are constantly being sought mainly because of the metal price volatility. However, due to the unique properties of cobalt, there are limited options for substitution and almost all substitutes result in reduced product performance. So far, substitution has mostly affected the magnet applications but substitution in battery applications is gearing up.

10.6 Specific issues

On the supply side, the EU cobalt industry is sourcing all of its *primary cobalt feed* from outside the Community, with a strong reliance on African producers as regards ores and metal. It meets increasing competition from Chinese cobalt producers which are also out on the market for feed supplies, focusing on African sources. These producers derive a purchasing edge (they can overprice the raw materials they need) from their operating conditions in China (low financial costs linked to State support, low compliance with EHS legislation, etc) and generally take advantage of lower ethics in securing supply from “grey” channels. Terms of competition are therefore not “equal” and this is a serious cause for concern in view of the size of the Chinese cobalt industry and its rate of development under State incentive policies.

Cobalt containing materials for recycling (from industrial processes or end-of-life products) are complementing EU cobalt industry's primary feed supplies in increasing proportions and are purchased from both EU and international market. There is, however, a growing concern about the deterioration of terms of competition for these materials as well, due to the behaviour of Chinese producers encouraged by above mentioned policies.

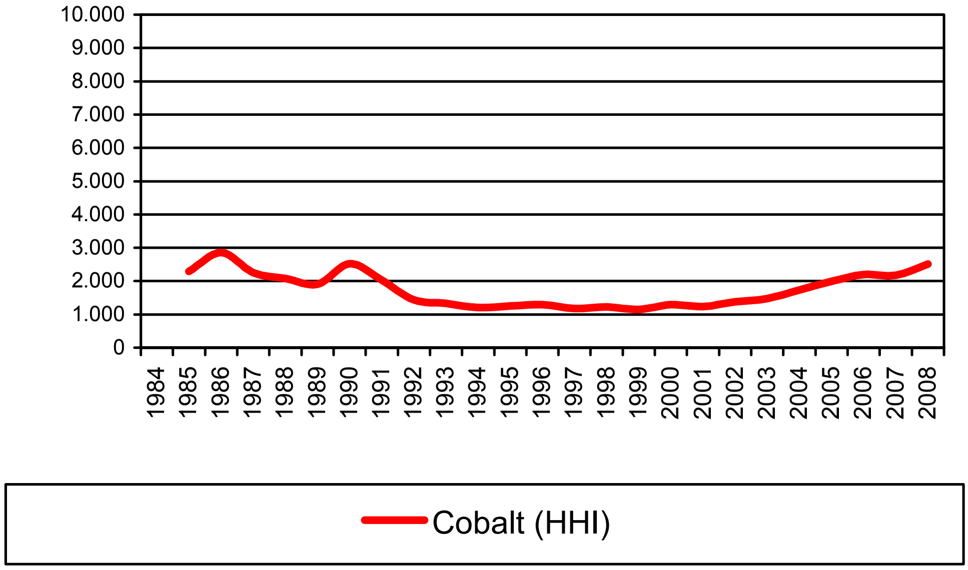
On the demand side, the EU cobalt industry has historically developed a world leadership as top ranking supplier of cobalt powders and chemicals, meeting more than 65% of global requirements in most end-use sectors for powders and chemicals. The EU market is the industry's natural outlet but is significantly less important in size and product scope than the international market, in particular regarding certain applications such as catalysts and rechargeable batteries. Demand growth occurs outside the EU and competitiveness on the export market is essential to the development of the EU cobalt industry. It is increasingly confronted on this export market with Chinese competition whose pricing policy is erratic and destructive of the normal price structure (prices for added value products are quoted below metal price).

Under these circumstances, securing a level playing-field in access to cobalt raw materials is increasingly seen as a vital conditions for ensuring the future viability of the EU cobalt industry.

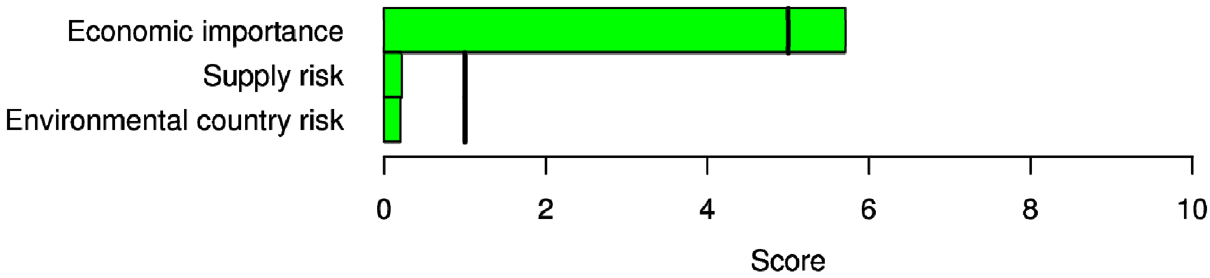
Use	Share	Megasector	Subst.
Batteries	49%	Chemicals	1,0
Superalloys and magnets	16%	Metals	0,7
Hard metal and surface treatment	12%	Metals	1,0
Pigments	9%	Chemicals	0,7
Catalysts	6%	Chemicals	0,7
Other	8%	Chemicals	0,7

Substitutability	0,9
Recycling rate (recycled content from old scrap)	16%
Import Dependence	100%

Results	
Economic importance	7,2
Supply Risk	1,1
Environmental Country Risk	0,8



Source: World Mining Data, 2010



11 Copper

11.1 Introduction

Because of its properties, singularly or in combination, of high ductility, malleability, and thermal and electrical conductivity, and its resistance to corrosion, copper has become a major industrial metal, ranking third after iron and aluminum in terms of quantities consumed.

Copper is one of the materials which contribute strongly to economic growth in Europe. This material is very significant to the economy because it has many different application in a wide range of key economical sectors. The three areas of this analysis emphasise: (1) sector identification by employment importance, (2) consumption of copper by industry sector, (3) emerging use (expected increase in demand due to fitire technologies).

(1) Copper importance for employment in Europe and for community development

From data collected in on the size of the workforce exposed to copper during production and processing is it estimated that the total number of workers employed in the EU in the copper producing sector is around 5,000.

(2) Consumption of copper by industry sectors (in %)

See chapter "2. Use" below.

(3) Emerging use = expected increase in demand due to future technologies

New areas are growing for copper use, such as in more sophisticated cars, and in the medical industry due to copper's anti-bacterial properties. Major opportunities exist to expand the use of copper in higher-efficiency motors and wiring, hybrid vehicles and other applications to reduce pollution. In long-range projections — even to 2020, the highest growth rate of copper consumption is expected in electronics, despite of miniaturization, and the largest share will have the automotive industry (improving cars standard by growing use of electronics).

11.2 Basic Supply & Demand Statistics

While the vast majority of Nickel reserves are found in Latin America (Peru, Chile, Mexico), Europe does have significant deposits in Poland and smaller ones in Bulgaria, Portugal and Sweden.

	Reserves (Ores, in 1000t)		**Production (ores, in 1000t; 2008)**		**Imports to EU (metal content in 1000t; 2007)**	
Chile	160,000	30.2%	5,330,000	34.5%	333	36.2%
Peru	63,000	11.9%	1,270,000	8.2%	126	13.8%
Mexico	38,000	7.2%	247,000	1.6%		
United States	35,000	6.6%	1,310,000	8.5%		
China	30,000	5.7%	950	6.2%		
Poland	26,000	4.9%	430	2.8%		
Australia	24,000	4.5%	886	5.7%	13.8	1.5%
Russia	20,000	3.8%	750	4.9%		
Zambia	19,000	3.6%	546	3.5%		
Kazakhstan	18,000	3.4%	420	2.7%		
Indonesia	18,000	3.4%	651	4.2%	171	18.6%
Canada	8,000	1.5%	607	3.9%	17	1.9%
Others	70,000	13.2%	2,030	13.2%	257	28%
Total	**529,000**		**15,427**		**919**	

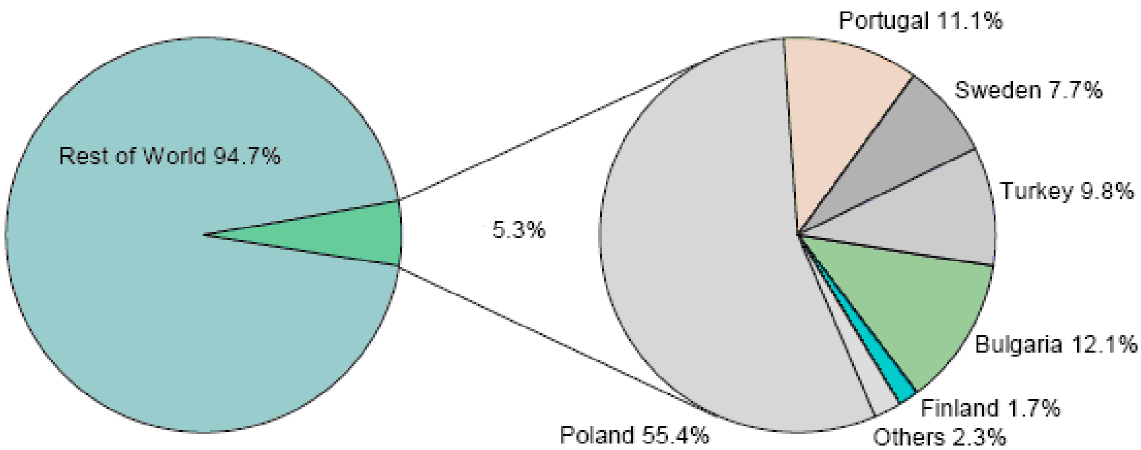
Source: USGS, 2010; UN Comtrade HS 2603

The European Union net imports equate to 20% of total world production. Import dependence is 47%. Between 1995 and 2008 world production of copper has increased 50% from 9.8 billion tonnes to 15.5 1.6 billion tonnes. The major change seen in the industry over the last 25 years concerns the proportion of copper mined in South America, increasing from one quarter to one half of total world production. This is largely due to an increase in production from Chile, from 16% of world production in 1985, up to 35% in 2005.

During the last decade there has been a major relocation of global manufacturing capacity towards the emerging economies of central Asia, in particular, China. The impact of these changes is obvious in the natural resources markets where direct copper usage is shifting from developed countries to newly industrialising nations. This has had a significant influence on copper trade flows worldwide (British Geological Survey, 2008).

Since copper consumption in Europe substantially exceeds their production, there is a threat of not meeting the demand in the event of constrains or restrictions on the part of large metal producers, i.e. companies operating in South American, Asian and African countries.

This means that the 3 largest producers hold more than 50 % of world production.



European (32 countries) copper mine production 2007[70]

[70] European Mineral Statistics, 2003-2007

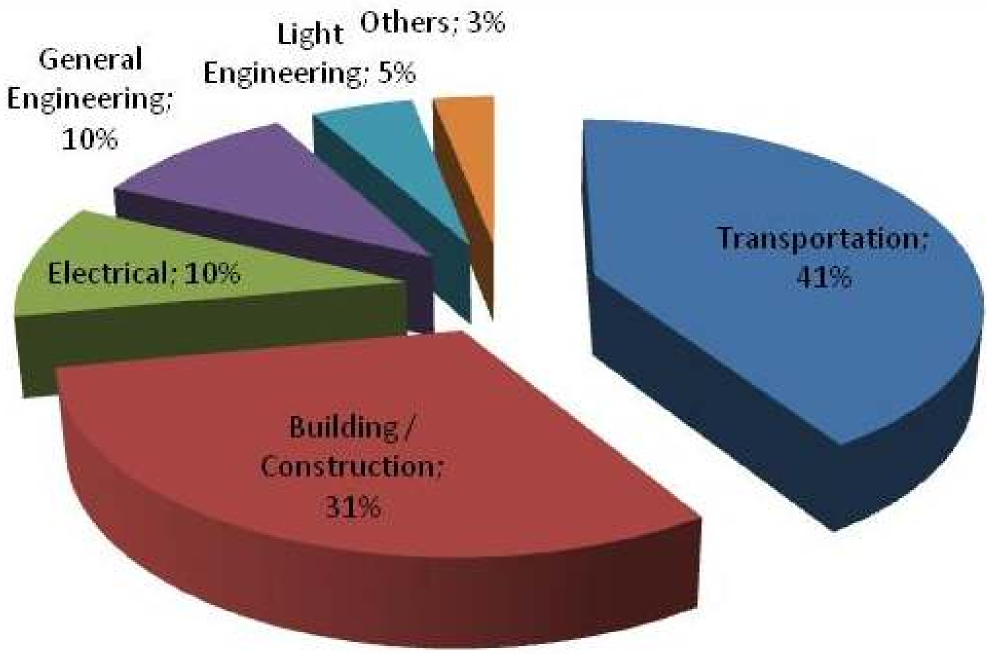
tonnes (metal content)

Country	2003	2004	2005	2006	2007
Bulgaria	91 600	79 600	82 700	99 000	99 000
Cyprus	2 500	—	—	800	2 900
Finland	14 900	15 500	15 000	13 000	13 600
Macedonia	619	—	4 799	7 054	7 029
Poland	503 544	530 768	511 799	497 200	451 900
Portugal	77 581	95 700	89 541	78 576	90 182
Romania	23 389	20 380	16 286	12 535	2 213
Spain	635	1 308	7 358	8 700	6 281
Sweden	83 143	82 415	87 088	86 748	82 905
Turkey	43 245	38 876	30 087	*30 000	*60 000
Total	841 000	865 000	845 000	834 000	816 000

European mine production of copper (source: European Mineral Statistics, 2003-2007)

Currently, there are in total 5 EU mining projects, 4 of them take place in Sweden and 1 in Romania. Out of the total, 3 projects are in conceptual phase, 1 is in pre-feasibility and 1 in feasibility phase[71]. Furthermore, there are 3 known copper deposits in Germany. Only one of them, the deposit *Spremberg-Graustein,* located in Saxony and Brandenburg, was estimated to be economically mineable in 2008[72].

11.3 Economic Importance



71 Raw Materials Data. Copyright: Raw Materials Group, Stockholm, 2009

72 BGR Commodity Top News No. 29

- Transportation: Copper is commonly used for radiators, brakes and wiring in motor vehicles, with a modern car containing up to 28 kg of copper. Improvements in electronics and addition of powered accessories have led to increased use of copper in modern cars.
- Construction: Copper is used in many forms in buildings including wire, plumbing pipes and fittings, electrical outlets, switches and locks. Construction of an average modern house requires at least 200 kg of copper metal. Copper roofing is highly rated for its corrosion resistance and architectural characteristics.
- Electrical: Copper is the best electrical conductor after silver and is widely used in the production of energy-efficient power circuits. Electron tubes used in televisions and computer monitors, audio and video amplification and in microwave ovens depend on copper for their internal components. Copper is extensively used in computers where cables, connectors and circuit boards all rely on copper. Copper is increasingly being used in computer chips in place of aluminium, resulting in faster operating speeds. Copper wire is extensively used in telecommunications and is essential for high-speed communication between computers.
- Consumer and general products: Copper is extensively used in household products. Most silver-plated cutlery has a copper-zinc-nickel alloy base. Copper is used in many other domestic applications including cooking pans, lighting, clocks and for decorative purposes.

In terms of future demand possibilities:

- Copper is used in large quantities in all electrical equipment, construction and or vehicle.
- Given the expanded emphasis on renewable electricity and the resulting need for more cables, generators etc, copper demand will go up with renewable targets.
- Electric vehicles also require significantly more copper than existing vehicles.

11.4 Resource Efficiency: Recycling & Substitution

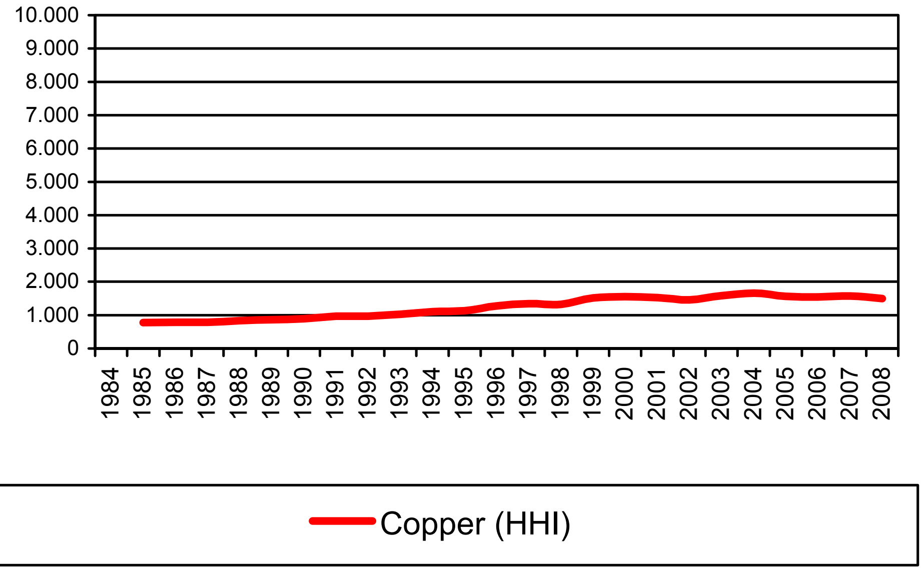
Although copper is relatively easy to recycle, the recycling rate has been static for some time. All-in-all, while the EOL-RR is circa 47%, higher than for most other metals, the RC rate is a lower at ~34%.

The unique qualities of copper make it difficult to substitute. That said, copper use in a number of non-electrical construction applications can be replaced by aluminium or non-metal materials. This is a sizable proportion of existing use.

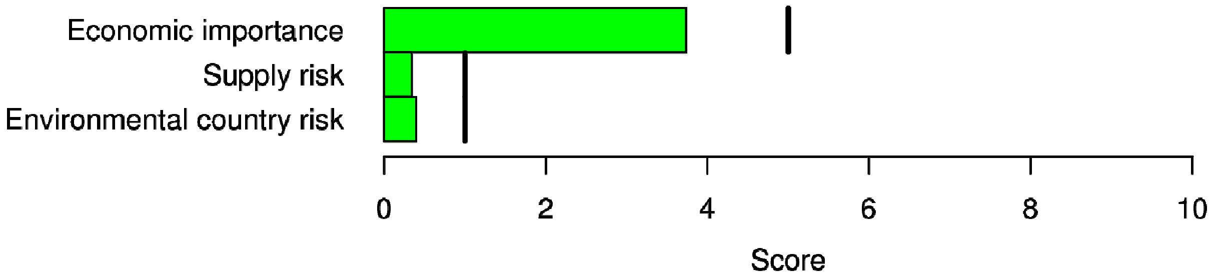
Use	Share	Megasector	Subst
Construction	23%	Construction Material	0,3
Equipment Manufacturing	12%	Mechanical Equipment	0,5
Road Transport	10%	Road Transport	0,7
Transport, other	4%	Aircraft, Shipbuilding, Trains	0,7
Electronic	13%	Electronics & ICT	0,7
Electrical equip	28%	Electrical Equipment + Domestic Appliances	0,7
Other	10%	Other Final Consumer Goods	0,5

Substitutability	0,56
Recycling rate (recycled content from old scrap)	20%
Import Dependence	54%

Results	
Economic importance	5,7
Supply Risk	0,2
Environmental Country Risk	0,2



Source: World Mining Data, 2010



12 Diatomite

12.1 Introduction

Diatomite is a powdery, non-metallic mineral composed of the silicon-based skeletons of microscopic plankton. It is extremely porous, very low in density and chemically inert, which allows it to be used not only as a filter aid, but also, amongst others, as an absorbent for industrial spills, a functional additive in a variety of products from paints to dry chemicals, an insulation material as sawn and moulded shapes as well as loose granular, a mild abrasive in polishes and a silica additive in cement and various other compounds.

12.2 Basic Supply & Demand Statistics

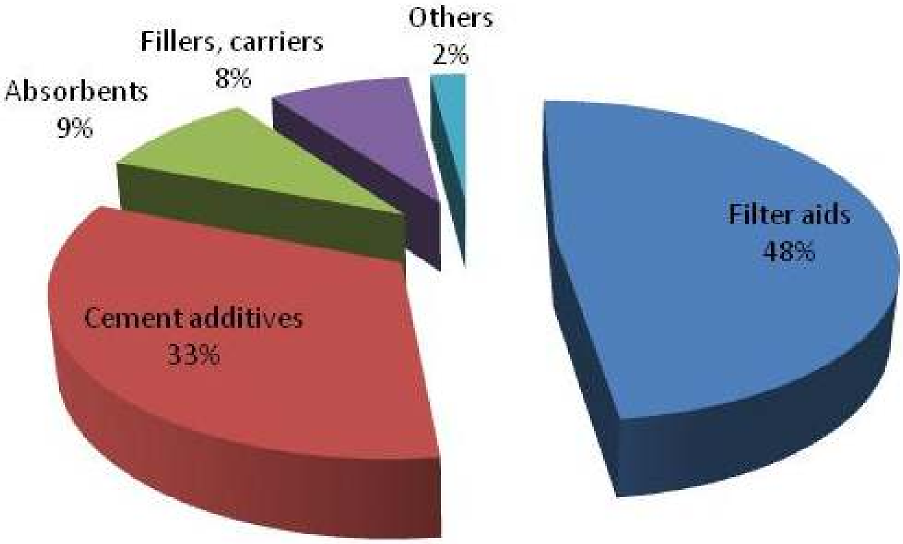
Because every diatomite deposit has a different composition (different diatom species and different chemical fingerprints) which determines its potential market applications and potential economic value, broad summaries of reserves, production and shipments are not very illuminating. For example, the diatomite deposits in Denmark (and some in the US) produce excellent absorbents, but cannot be used to produce filter aids. Other diatomite deposits in the US, Mexico and China produce excellent filter aids, but cannot produce granular absorbents. It is generally true, however, that for every application diatomite reserves vastly outweigh annual production.

	Reserves (in 1000t)	Production (in 1000t; 2008)		Imports to EU (1000t; 2007)	
United States	250,000	764	34.7%	27.2	38.9%
China	110,000	440	20.0%	0.6	0.9%
Denmark		240	10.9%		
Italy		120	5.5%		
Other Countries		636	28.9%	42	60.2%
Total		**2,200**		**70**	

Source: USGS, 2010; UN Comtrade HS 2512

Overall, while the EU produces considerable quantities of diatomite, considerable amounts are also imported from the US. Import dependence is in the order of 17%. In terms of production evolution, world production of diatomite amounted to 2,200,000t in 2008, up from circa 1,500,000t in 1995.

12.3 Economic Importance



- Filter Aids: Because of its high degree of porosity combined with its low density and inertness, diatomite makes an excellent filtration medium, providing the ability to economically remove microscopically small suspended solids from large volumes of liquid. It is routinely used in the filtration of beer, wine, sugar, edible oils, lube oils, chemicals, drinking water and wastewater. It is also used in the removal of microbial contaminants, in the filtration of human blood plasma and in pharmaceutical processing.
- Absorbents: Diatomite's absorbent qualities make it useful for toxic and non-toxic spills. It also can be used to improve the water holding characteristics of soils to reduce watering requirements and improve drought resistance.
- Fillers/Carriers: Diatomite can also serve as a functional additive in paints, plastics, paper and dental mouldings. Its shape allows it to act as a carrier for active ingredients and diluents e.g. in catalysts and in pesticides.

In terms of future demand possibilities, it is likely that the use of diatomite will be correlated with the growth rate in relative gross domestic product (GDP). In addition, there is expected future demand in connection with, among other things, bio-fuel filtration (e.g. improving cold stability of biodiesel and for filtration during the processing of cellulosic ethanol), the pretreatment of salt water prior to reverse osmosis in desalination processes, the elimination of parasitic organisms from recreational water sources and as a soil amendment for reducing watering requirements.

12.4 Resource Efficiency: Recycling & Substitution

Due to their uniquely intricate morphology, is it extremely difficult to regenerate diatomite filter aids once they have been employed for filtration, but they are extensively recycled. The most common forms of recycling are as a carrier of nutrients and moisture in soil (soil amendments), as an animal feed additive, as cement additives and as silica sources for a variety of building materials (e.g. glass, ceramics and concrete). Diatomite spent filter cake from high btu-content sources (e.g. biofuels, food oils, lube oils and sugar-refining processes) can also be used as a feedstock for green energy processes such as biogas and syngas generators.

A number of alternate materials can be used in substitution of diatomite; however, the unique properties of diatomite has assured its continuing use for many applications.

- In filtration, expanded perlite, milled cellulose fibers and asbestos compete for filtration purposes, although, in most instances, diatomite is a superior material.
- In filler/functional additive applications, substitution in some cases is possible using nepheline synenite talc or precipitated silica.
- For absorbent applications, substitution from granular absorbent clay materials, such as bentonite or sepiolite is possible, but these materials typically have much lower absorption capacity.

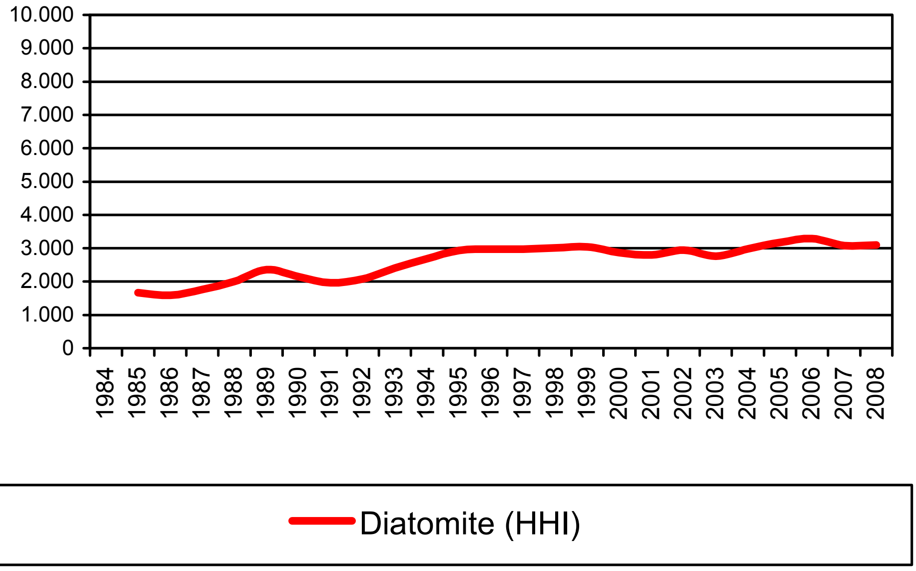
12.5 Specific issues

Diatomite filtering is a simple and proven technology that does not require power, as does membrane filtration. Consumption in the EU is around 300 kt of products per year. Replacing diatomite by other technique in filtration is difficult without changing some characteristics of very traditional products like beer and wine. Nevertheless, very stringent regulations are being considered which may have an adverse impact in the final product. Furthermore, the spent filtration cakes are generally used in fields as fertilizers thereby resulting in a natural reuse of the diatomite that provides a natural slow release for the fertiliser and an environmental friendly fertiliser. This use too is being hindered by some regulation specifically regarding the spent cake itself. It should be noted that the spent cake itself does not present any hazard for the environment, nor for human health.

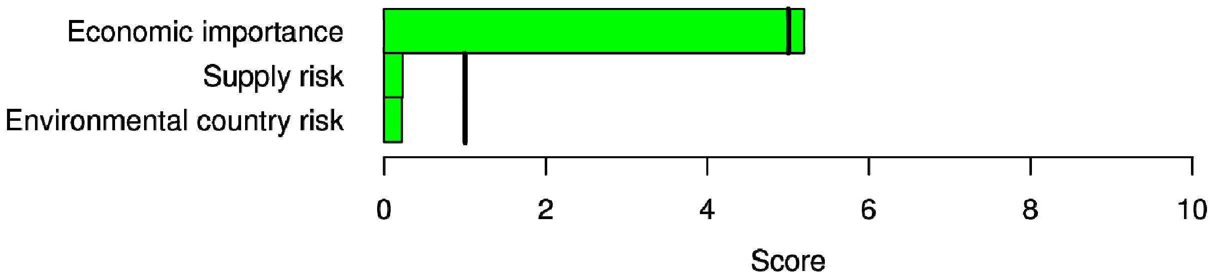
Use	Share	Megasector	Subst.
Filter aids (beer, wine, sugar, oils)	48%	Beverages	0,3
Absorbents	9%	Chemicals	0,5
Fillers, carriers	8%	Chemicals	0,3
Cement additives	33%	Construction Material	0,3
Insulation	2%	Construction Material	0,3
Others (art supplies, cosmetics, biomedical)	< 1%	Other Final Consumer	0,5

Substitutability	0,3
Recycling rate	0%
Import Dependence	25%

Results	
EI (GVA/Megasector)	3,7
Supply Risk (HHI mod. WBI)	0,3
Environmental Risk (HHI mod. EPI)	0,4



Source: World Mining Data, 2010



13 Feldspar

13.1 Introduction

Feldspar is by far the most abundant group of minerals in the earth's crust, forming about 60% of terrestrial rocks. However, not all the feldspars available are suitable for industrial use. Most European Feldspar group of minerals’deposits offer potassium feldspar as well as sodium feldspar, mixed feldspars and Nepheline Syenite.

Feldspars are primarily used in industrial applications for their high alumina and alkali as well as low iron content. The term feldspar encompasses a whole range of materials. Most of the products used on a daily basis are made with feldspar – glass at 60% (house and car windows, container glass, glass wool) and pottery/ceramics at 35% (floor, tiles and other household ceramics as well as tableware).

13.2 Basic Supply & Demand Statistics

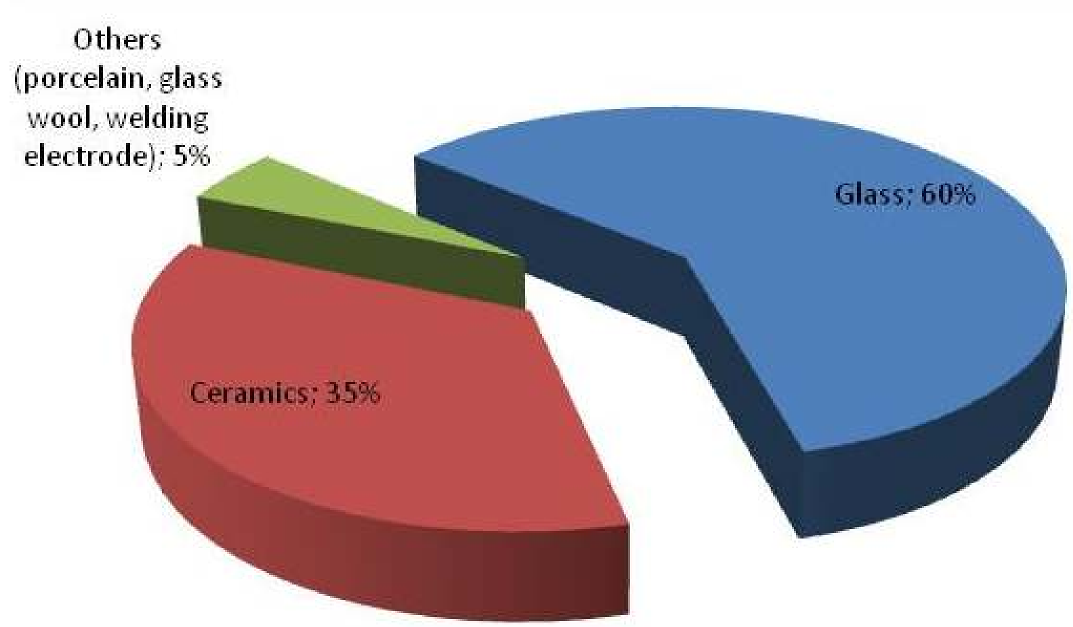
Due to a high number of deposits and high transport costs, Europe (and indeed other regions of the world) is relatively self-sufficient in Feldspar. The most important import markets lie on Europe's borders – Turkey, Ukraine and Norway.

	Production (in 1000t; 2008)		Imports to EU (in 1000t; 2007)	
Turkey	6,500	29.7%	3,840	97.3%
Italy	4,700	21.5%		
China	2,000	9.1%		
Other	8,700	39.7%	106	2.7%
Total	21,900		3,947	

Source: USGS, 2010; UN Comtrade HS 252910

Overall, the EU produces two-thirds of what its uses. As noted above transport costs – representing between 25% to 50% of the delivered feldspar price and 50% to 75% for the imported products are a key determinant in trade. In terms of production evolution, world production of feldspar amounted to 21,900,000t in 2008, up significantly from circa 7,000,000t in 1995.

13.3 Economic Importance



- Ceramics: In the manufacture of ceramics, feldspar is the second most important ingredient after clay. They improve the strength, toughness, and durability of the ceramic body

- Glass: here, feldspars are used for their alumina content and their content of alkali. The alkali act as flux ingredients, lowering the batch melting temperature and therefore contributing to the reduction of production costs. Alumina acts as a matrix former, reducing the tendency for glass to devitrify. It also acts as a stabiliser which improves the chemical durability of glass, as well as its physical resistance. The addition of feldspar to glass also improves the workability of the material produced, making it more suitable e.g. for pressing.

- Other: Feldspars are also used as fillers and extenders in applications such as paints, plastics and rubber.

In terms of future demand possibilities:

- Future demands much dependent to the building sector's improvement.

- High quality feldspars show huge potential of growth especially in the strongly developing market of high-tech solar glasses.

13.4 Resource Efficiency: Recycling & Substitution

While there is no direct recycling of feldspar, glass container producers may recycled glass, thereby reducing feldspar consumption. This glass recycling rate rose to more than 65% in the EU in 2008 (FEVE) with Belgium and Sweden reaching 100% and Germany more than 90%. This applies essentially to container glass which is a lower glass quality. The substitution with PET-packaging is however to be feared. Products containing high grade potassic feldspars (glass for medical application, perfume bottles etc.) do not show a high rate of recycling.

Concerning substitutes, alternatives for feldspar in glass can be soda ash, potash and aluminium hydroxide, but this is only a theoretical and cost intensive possibility which is rarely used nowadays. Substitutes for ceramic industry could be possible with local high alkali content raw materials. This is also not a very economic solution.

13.5 Specific Issues

Abundance of Feldspar is offset by the fact that not all feldspars available are of interest for industrial use. Most do not have the purity level required for glass and ceramics application, or would require too high a level of processing in order to become suitable.

Typically, Feldspar, being a low cost material does not travel well. That is the reason why it is necessary to have quarries located within a reasonable supply chain costs from the usage area.

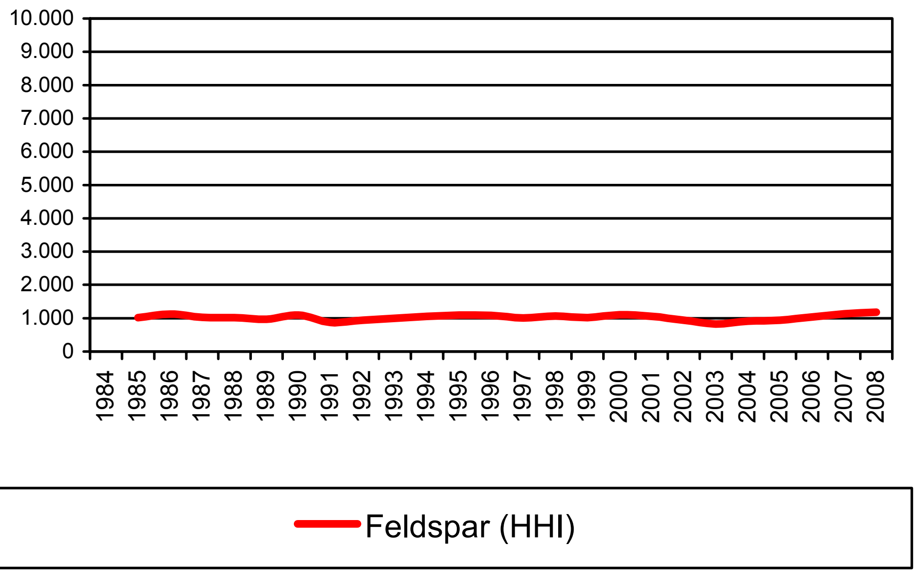
As shown in the statistics above, EU is heavily depending on the availability of Turkish feldspar, that offers an excellent fitness for use and supply chain scheme to the big ceramic tiles area of Sassuelo in Italy and Castillon in Spain, and also in Poland and Bulgaria. This source of feldspar is very competitive and nowadays discourages almost any new project of feldspar mining in the EU. Would the availability of this source decrease for any reason (including purely logistical reasons), then EU producers would be confronted with regular issues regarding industrial minerals extraction such as,

- Access to resources : - We will need to secure the access to mineral deposits within the EU because of EU regulation constraints (e.g. Nature 2000,) and Member States regulation and administration (e.g. Land Planning);
- Long lasting permitting procedures.

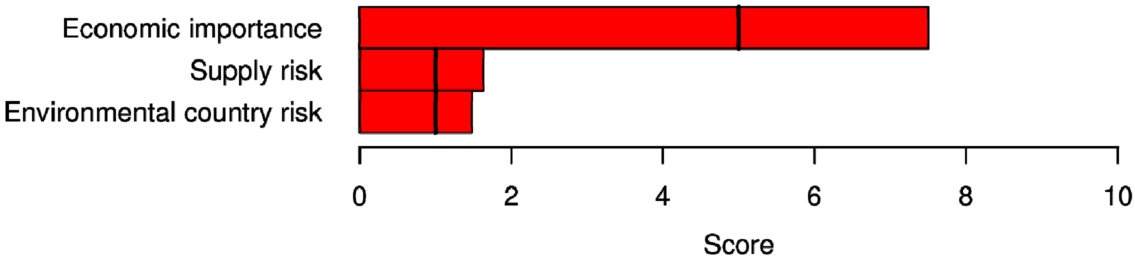
Use	Share	Megasector	Subst.
Glass	60%	Rubber, Plastic & Glass	0,7
Ceramics	35%	Construction Material	0,3
Others (porcelain, glass wool, welding electrode)	5%	Other Final Consumer Goods	0,5

Substitutability	0,55
Recycling rate	0%
Import Dependence	47%

Results	
Economic importance	5,2
Supply Risk	0,2
Environmental Country Risk	0,2



Source: World Mining Data, 2010



14 Fluorspar

14.1 Introduction

Fluorspar (CaF_2) is the most important fluoric containing mineral[73]. About 52% of fluorspar consumption worldwide is used as starting material for the production of hydrofluoric acid; another 18% is used for aluminum fluoride, the fluxing agent in the aluminium industry; and 25 % for the steel industry as a flux[74].

Fluorspar is the commercial name for the mineral fluorite (calcium fluorite) and it is an important raw material source of fluorine. Most fluorspar production is used in the manufacture of the hydrofluoric acid (HF) which is used primarily in the refrigerant and air conditioning, electronic, chemical, pharmaceutical and agrichemical industries. Fluorspar is also used in steel and aluminium manufacture[75].

Acid grade fluorspar is used in the production of hydrofluoric acid (HF), mostly within the US, Japan, China and Europe. HF production is the largest market for acid-grade fluorspar, accounting for over half of world consumption.

14.2 Basic Supply & Demand Statistics

World reserves of fluorspar are distributed over all five continents.[76] The identified worldwide fluorspar resources are estimated to 500 million tons of contained fluorspar. A reserve of 18 billion tons of phosphate is equivalent to 1.29 billion tons of fluorspar, but according to experts the deposits have only small and decreasing economic importance in the aluminum fluoride manufacture[1]. In spite of the wide distribution of reserves, China is the leading global producer.

	Reserves (in 1000t; 2010)		Production (in 1000t; 2009)		Imports to EU (in 1000t; 2007)	
USA	NA		NA			
China	21,000	9,3%	3,000	58,8%	192	26,9%

[73] USGS Mineral Commodity Summaries 2010: *Fluorspar*

[74] Roskill Market Report: The Economics of Fluorspar, 10th Edition 2009 – www.roskill.com

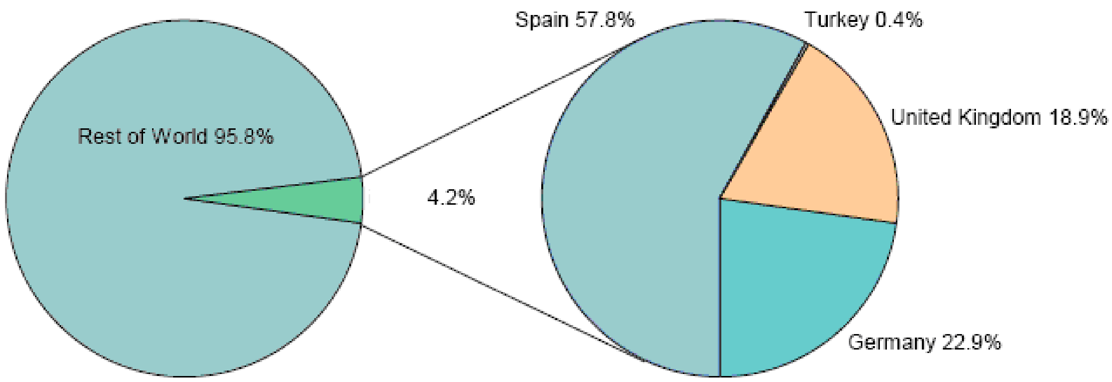
[75] European Mineral Statistics 2003-2007, BGS

[76] Ullmann's Encyclopedia of Chemical Technology: *Fluorine Compounds, inorganic*. Wiley-VCH Verlag, Weinheim, 2006

Kenya	2,000	0,9%	45	0,9%	44	6,1%
Mexico	32,000	14,1%	925	18,1%	170	23,8%
Mongolia	12,000	5,3%	280	5,5%	1.6	0,2%
Morocco	NA		40	0,8%	13.9	2,0%
Namibia	3,000	1,3%	60	1,2%	112.6	15,7%
Russia	NA		210	4,1%		
South Africa	41,000	18,1%	180	3,5%	180.3	25,2%
Spain	6,000	2,6%	110	2,2%		
others	110,000	48,5%	250	4,9%		
Total	**227,000**		**5,100**		**715**	

Source: USGS 2010; trade data provided by BGS based on EU comtrade (HS 252921and HS 252922)

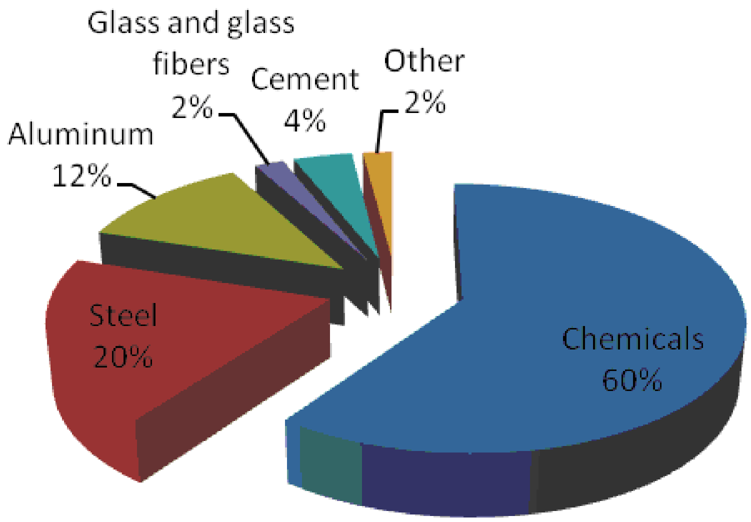
In 2007, 25% of the fluorspar consumption of the European Union was produced by EU member states, mainly by Spain, but also by Germany, UK and Romania.. A much larger amount was imported from states like China, South Africa or Mexico. Domestic fluorspar production is quite critical, for example fluorspar production ceased in France in 2006. Due to high dependence on Chinese imports and thereby caused huge price increases, there are new fluorspar operations in Bulgaria since 2009 and other projects are planned in Germany, Sardinia and Sweden.



European (32 countries) production of fluorspar 2007[77]:

[77] European Mineral Statistics, 2003-2007

14.3 Economic Importance



Main end-use markets for Fluorspar (worldwide)[78,79]

- Chemicals: Fluorspar is a starting material for the production of hydrofluoric acid, an important substance in many branches of the chemical industry. Hydrofluoric acid is used in the production process of electronics, computer chips, printed circuit boards, refrigerants and air-conditioning, and thermal insulation. Moreover aluminum fluoride is used as flux in the processing of aluminum.
- Steel, Aluminum: Fluorspar is also used in the aluminum and steel industry to lower the melting point and to increase the fluidity of the slag.
- Glass, glass fibers: Other consumers of fluorspar are producers of glass, glass fibers and enamels.
- Cement: Small quantities of fluorspar improve the characteristics of cement.

14.4 Resource Efficiency: Recycling & Substitution

In the last years, only a few thousand tons of fluorspar was recycled in the United States, primarily from uranium enrichment, but also from petroleum alkylation and

[78] USGS Mineral Commodity Summaries 2010: *Fluorspar*

[79] Ullmann's Encyclopedia of Chemical Technology: *Fluorine Compounds, inorganic*. Wiley-VCH Verlag, Weinheim, 2006

stainless steel pickling[80]. Compared to the total amount used, this is a very low percentage. Experts speak of less than 1% in the European Union and there is no increasing recycling potential conceivable.

Primary aluminium producers recycle HF and fluorides from smelting operations. HF is recycled in the petroleum alkylation process.[81]

Substitution possibilities are limited, only fluorosilicic acid from phosphate manufacture is used for aluminum fluoride[9].

Aluminium smelting dross, borax, calcium chloride, iron oxides, manganese ore, silica sand and titanium dioxide have been used as substitutes for fluorspar fluxes.

By-product fluorosilicic acid from phosphoric acid production has been used as a substitute in aluminium fluoride production and also has the potential to be used as a substitute in HF production[10], but only some 15% is used from this source worldwide, and the use is diminishing. However the production process uses 5-6 times more energy than the fluorspar process[82].

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80 USGS Mineral Commodity Summaries 2010: *Fluorspar*

81 USGS Mineral Commodity Summaries 2009: *Fluorspar*

82 EU BREF Large Volume Inorganic Chemicals - ftp://ftp.jrc.es/pub/eippcb/doc/lvic_bref_0907.pdf

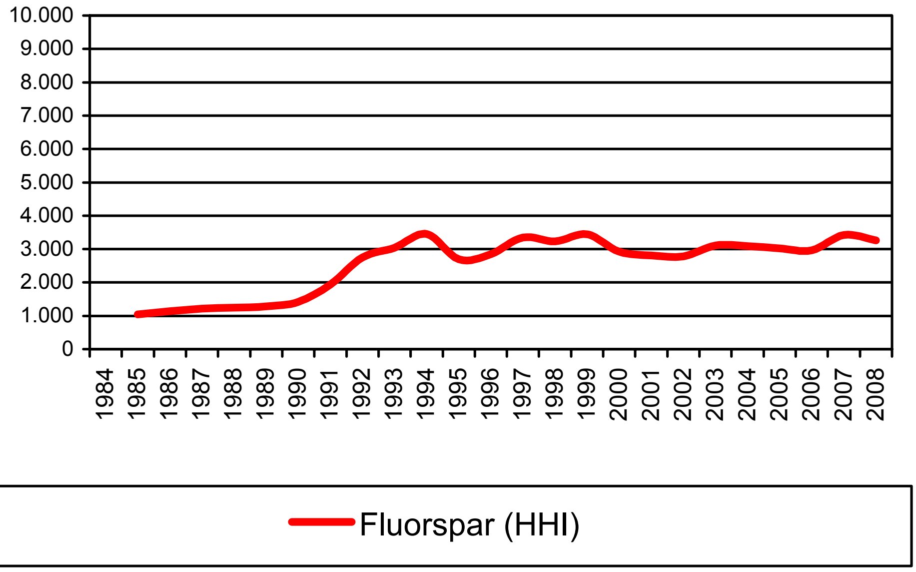
14.5 Specific Issues

According to the European Commission's inventory on export restrictions, Argentina applies a 10% export tax on fluorspar and China uses a mix of export quota and export taxes (15%) to limit exportations.

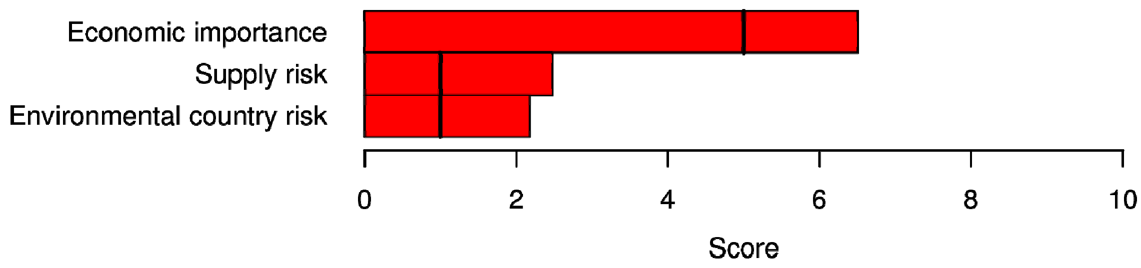
Use	Share	Megasector	Subst.
Hydrofluoric acid	52%	Chemicals	1,0
Steel	20%	Metals	0,7
Aluminum	12%	Metals	1

Substitutability	0,9
Recycling rate	0%
Import Dependence	69%

Results	
Economic importance	7,5
Supply Risk	1,6
Environmental Country Risk	1,5



Source: World Mining Data, 2010



15 Gallium

15.1 Introduction

Gallium is a silvery-white metal similar to aluminum, but with a low melting point (approximately 30 °C). Gallium is mainly used as a compound with arsenic as gallium arsenide (GaAs), which is important as a semiconducting material.[83]

15.2 Basic Supply & Demand Statistics

Gallium occurs in very small concentrations in ores of other metals. Most gallium is produced as a by-product of treating bauxite, and the remainder is produced from zinc-processing residues. Only part of the gallium present in bauxite and zinc ores is recoverable, and the factors controlling the recovery are proprietary. Therefore, an estimate of current reserves that is comparable to the definition of reserves of other minerals cannot be made. The world bauxite reserve base is so large that much of it will not be mined for many decades; hence, most of the gallium in the bauxite reserve base cannot be considered to be available in the short term.[84]

In many gallium containing minerals the amount of gallium is too low to be of economical interest. The concentration of gallium in bauxite ranges between 0.003 and 0.008%, making it uneconomical to mine bauxite for its gallium content.[1]

In 2009, world primary production was estimated to be 78 metric tons, 30% lower than the revised 2008 world primary production of 111 tons. China, Germany, Kazakhstan, and Ukraine were the leading producers; countries with smaller output were Hungary, Japan, Russia, and Slovakia. Refined gallium production was estimated to be about 118 tons; this figure includes some scrap refining. China, Japan, and the United States were the principal producers of refined gallium. Gallium was recycled from new scrap in Germany, Japan, the United Kingdom, and the United States.

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[83] Ullmann's Encyclopedia of Chemical Technology: *Gallium and Gallium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

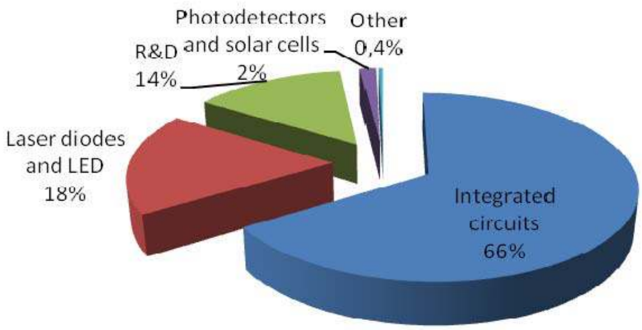
[84] USGS Mineral Commodity Summaries 2009: *Gallium*

There were 60 known producers of gallium in 18 countries for 2003.[85] 17 companies in seven EU32-countries (Czech Republic [1], France [4], Germany [5], Hungary [2], Norway [1], Slovakia [1], UK [3]) are named and nearly all produce gallium metal.

Although fairly widespread in the earth's crust, gallium never occurs in workable concentrations. It is occasionally found in zinc ores and bauxite in quite small contents. A further source of gallium is fly ash from the combustion of coal. The content is reported to amount to 1.5%.[3] Phosphate contains traces of gallium, too.[86]

This application structure experienced smaller changes that implicate an even more concentrated use. In 2009 67% of US gallium consumption was located in IC sector, 31% was used for optoelectronic devised. Only 2% were used for other purposes.

15.3 Economic Importance



Most Gallium is used as a compound with arsenic (GaAs). The main applications of GaAs are[87]:

- Integrated circuits: Because of the semi-conducting properties, GaAs is important for the production of integrated circuits. They were used in defence applications, high-performance computers and telecommunications.

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85 Moskalyk 2003

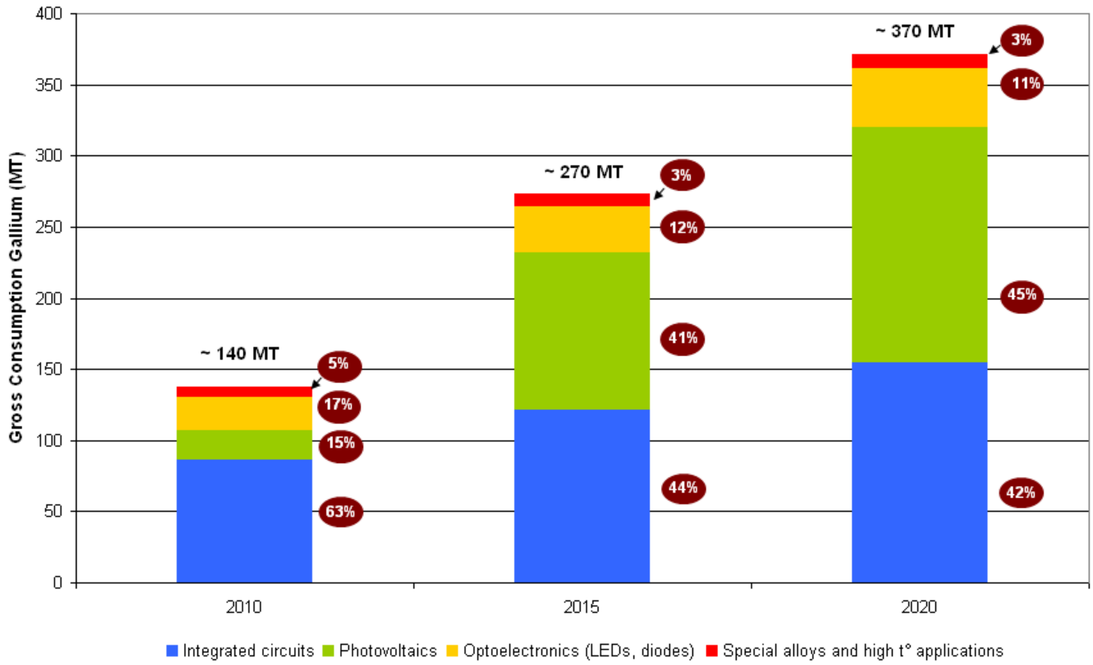
86 Feneau 2002

87 Fraunhofer Institut für System und Innovationsforschung and Institut für Zukunftsstudien und Technologiebewertung: *Rohstoffe für Zukunftstechnologien*, 2009, Fraunhofer IRB Verlag, Stuttgart

- Laser diodes, photodetectors, solar cells: Microelectronic devices used for manufacturing optoelectronic components, for example light emitting diodes and laser diodes, photodetectors and solar cells. Optoelectronic devices were used in areas such as aerospace, consumer goods, industrial equipment, medical equipment, and telecommunications.
- The remaining applications were in research and development, specialty alloys, and other applications.

Going forward, the gross consumption of Gallium is expected to more than double by 2015 (270 MT) and increase substantially further again to reach close to 400 MT by 2020 (370 MT) of which about 45% will be for the PV sector (Umicore, 2010). This forecast falls in the range of the scenario developed in the UNEP report[88] for a growth of Gallium of 10% yearly until 2020.

In the case of a stronger development of the PV sector, the gross consumption of Gallium would jump to about 480 MT with about 60% captured by the PV sector.



88 UNEP – Öko Institut – Critical Metals for Future Sustainable Technologies and their Recycling Potential

15.4 Resource Efficiency: Recycling & Substitution

Recycling

Temporarily Gallium is not recycled from old scrap. There is hardly any old scrap yet available. Substantial quantities of new scrap generated in the manufacture of GaAs-base devices are reprocessed[89].

Substitution

Liquid crystals made from organic compounds are used in visual displays as substitutes for LEDs. Researchers also are working to develop organic-based LEDs that may compete with GaAs in the future.

Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and GaAs competes with helium-neon lasers in visible laser diode applications.

Silicon is the principal competitor with GaAs in solar cell applications.

GaAs-based ICs are used in many defense-related applications because of their unique properties, and there are no effective substitutes for GaAs in these applications. GaAs in heterojunction bipolar transistors is being challenged in some applications by silicon-germanium.[7]

15.5 Specific Issues

According to the EU Commission's inventory on export restrictions, South Africa resorts to non-automatic export licensing to limit the quantities of metal exported (incl. waste and scrap). China uses a mix of export quota and export taxes (5%). Russia applies a 6.5% export tax on gallium waste and scrap.

Supply and demand seem to balance today on EU level but it is not certain that future EU needs could be met considering that 40 to 50% of produced Gallium will result from recycling in the future and that most of the recycling could take place mostly in Japan. In order to ensure that the EU industry is self sustaining in the future, it will be necessary to retain gallium-containing scrap and favour recycling processes.

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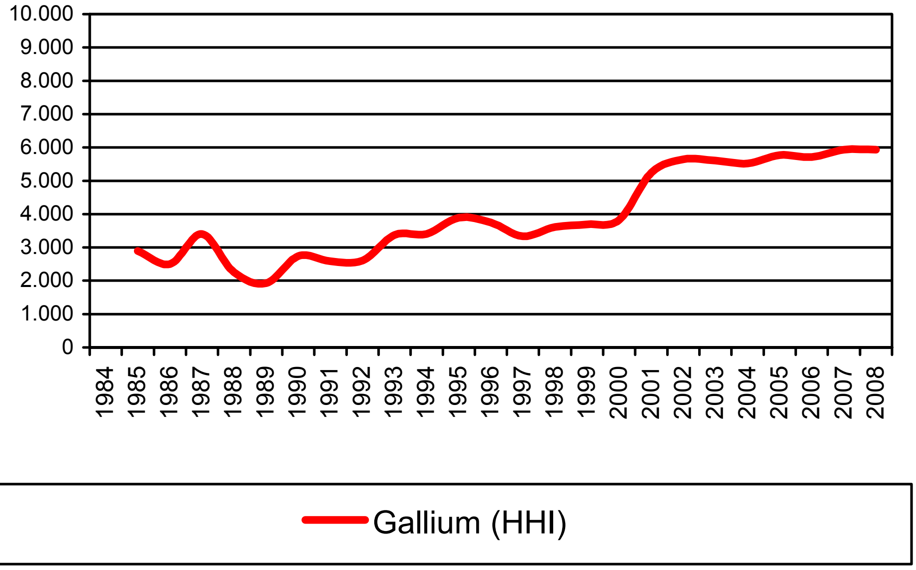
[89] USGS Mineral Commodity Summaries 2009: *Gallium*

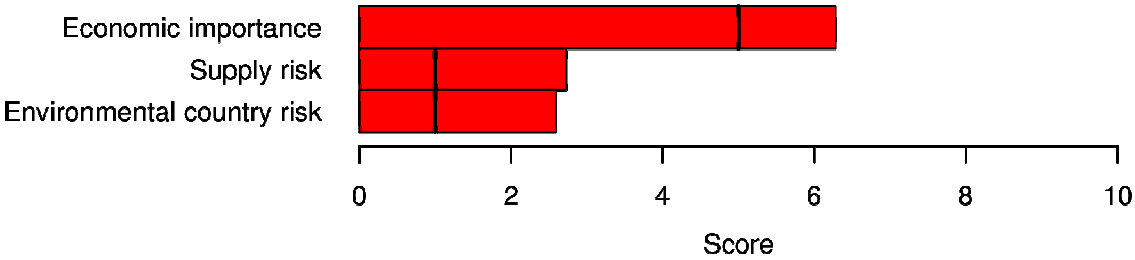
Use	Share	Megasector	Subst.
Integrated circuits	66%	Electronics & ICT	0,7
Laser diodes and LED	18%	Electronics & ICT	0,7
R&D	14%	Electronics & ICT	1
Photodetectors and solar cells	2%	Electronics & ICT	0,3
Other	0%	Other Final Consumer Goods	0,5

Substitutability index	0,74
Recycling rate (recycled content)	0%
Import Dependence	0%

Results	
Economic importance	6,5
Supply Risk	2,5
Environmental Country Risk	2,2



Source: World Mining Data, 2010



16 Germanium

16.1 Introduction

Germanium is a very brittle, grey-white shining semiconducting element, which shows volumetric expansion during solidification.[90] Historically it played an important roll in the development of transistors. Today it is replaced by cheaper silicon in this sector on a large scale. Nonetheless, there are a variety of other high-tech products using germanium.[91]

16.2 Basic Supply & Demand Statistics

Germanium can be recovered form minerals like germanite, renierite or argyrodite and also from coal ashes produced in power plants. Germanium today is nearly exclusively produced as a by-product of other metal mining. This includes the extraction of copper, lead or zinc. Traded germanium is mostly enriched in refineries.[2]

	Reserves (in t; 2010)	Production (in t; 2009)		EU imports (in t; 2007)	
USA	450	4.6	3,3%	5.8	18,6%
China	NA	100	71,6%	22.5	72,3%
Hong Kong	NA			2.2	7,1%
South Korea	NA			0.2	0,6%
Japan	NA			0.2	0,6%
Singapore	NA			0.2	0,6%
Russia	NA	5	3,6%		
others	NA	30	21,5%		
Total	NA	**139.6**		**31.1**	

Source: USGS 2010; trade data from ComExt (CN 8112 92 95).

90 Römpp Online: *Germanium.* Georg Thieme Verlag, Stuttgart, 2007

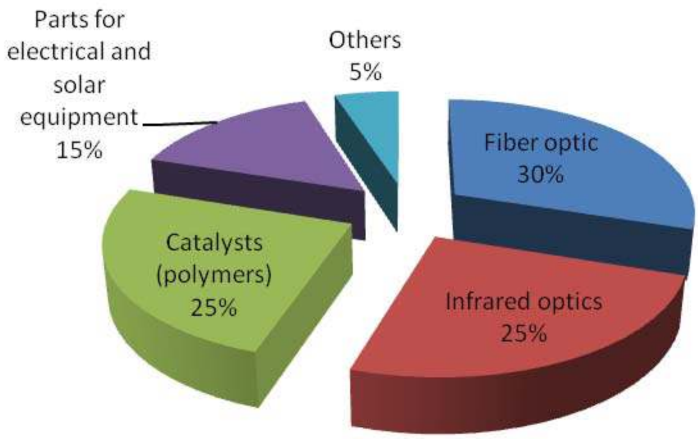
91 Ullmann's Encyclopedia of Chemical Technology: *Germanium and Germanium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

Germanium reserves are associated with zinc and zinc-lead-copper sulfide ores.[92] There is no quantitative data available concerning germanium resources.

Germanium raw material is not recovered within the European Union, though imported ores are refined and germanium metal is exported[93]. The main import source for the EU is China.

There are 24 known producers of germanium in 10 countries. Moskalyk names seven companies in five EU32-countries (Belgium [1], France [1], Germany [3], Spain [1], UK [1]). Four of them exclusively produce germanium metal while two produce germanium metal as well as germanium dioxide. One producer solely produces germanium dioxide. Special production figures are not available.

16.3 Economic Importance



Main end-use markets for germanium products (worldwide)[2,3,94]:

- <u>Fiber optic systems:</u> About 30% of worldwide germanium consumption is used in this sector, for example for telecommunication optical fibers.

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2 Ullmann's Encyclopedia of Chemical Technology: *Germanium and Germanium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

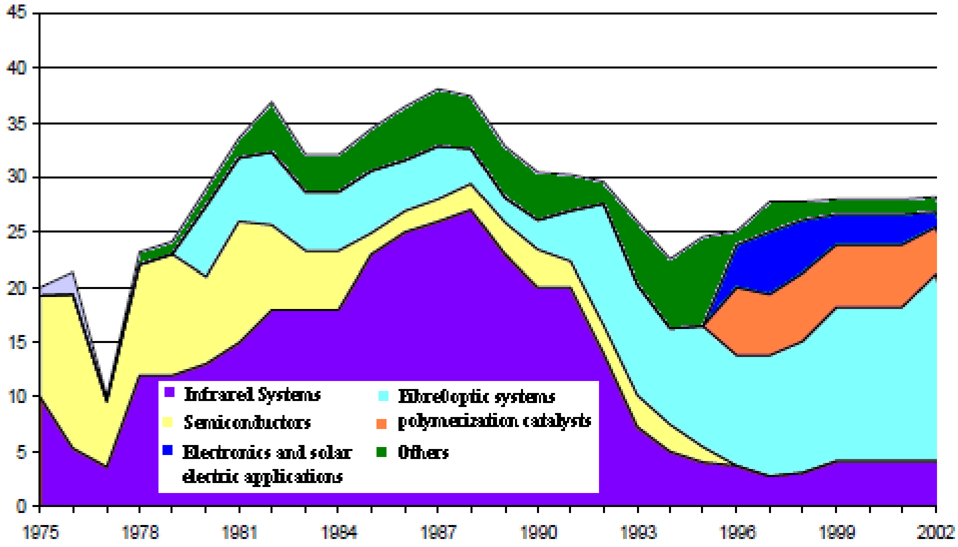
92 USGS Mineral Commodity Summaries 2010: *Germanium*

93 USGS 2006b

94 Fraunhofer Institut für System und Innovationsforschung and Institut für Zukunftsstudien und Technologiebewertung: *Rohstoffe für Zukunftstechnologien*, 2009, Fraunhofer IRB Verlag, Stuttgart

- Infrared optics: 25% of produced germanium is used for high quality lenses and window material for infrared applications.
- Polymerisation catalysts: Germanium is an important catalyst in the production of polyesters and synthetic textile fibers (also 25%).
- Parts for electrical and solar equipment: 15% are used for electric and solar electric applications (solar cells, LEDs, photodetectors...)
- Other: Minor applications (5%) are in metallurgy and medicine.

The demand for germanium for optical fibers is estimated to be eight times higher in 2030 than today. In that case demand would add up to 220 tons, whereas total world production in 2009 was approximately 140 tons. A growing demand for other technologies is also expected, for example for night sight devices in automobiles.



Source: Fraunhofer ISI 2009 (adapted & translated)

It can be seen that the application of germanium in the field of semiconductors disappeared in the middle of the 1990s because more efficient and cheaper sources where available. The use of germanium in fibre-optic systems increased in recent years. There was a downturn of using germanium in fibre optics after 2002 as worldwide production decreased.

Nonetheless Fraunhofer estimates the future demand of germanium in fibre optics as follows:

- Demand in 2006: 28,000 kg (on third of production in 2006)
- Demand in 2030: 220,000 kg

In conclusion, it is expected that the global demand of germanium only in one field of application will octuplicate until 2030. This is nearly the double amount of the worldwide refinery production in 2008.

16.4 Resource Efficiency: Recycling & Substitution

Worldwide, about 30% of the total germanium consumed is produced from recycled materials.

During the manufacture of most optical devices, more than 60% of the germanium metal used is routinely recycled as new scrap. Germanium scrap was also recovered from the window blanks in decommissioned tanks and other military vehicles. In the European Union, recent technological advancements in the production of optical fibres has reduced, somewhat, the available supply of germanium scrap.[95]

The less expensive silicon can be a substitute in some electronic applications in the future, like it is in transistors today. Nevertheless germanium is still the most reliable material for high-frequency applications. Indeed it is even more economical for LEDs than most possible substitutes.

For infrared applications, zinc selenide and germanium glass are suitable if a loss in performance is acceptable.

Titanium might be a potential catalyst for polymerisation.[6]

16.5 Specific Issues

According to the EU Commission's inventory on export restrictions, Algeria resorts to non-automatic export licensing to limit the quantities of germanium waste and scrap exported. Russia applies a 6.5% export tax.

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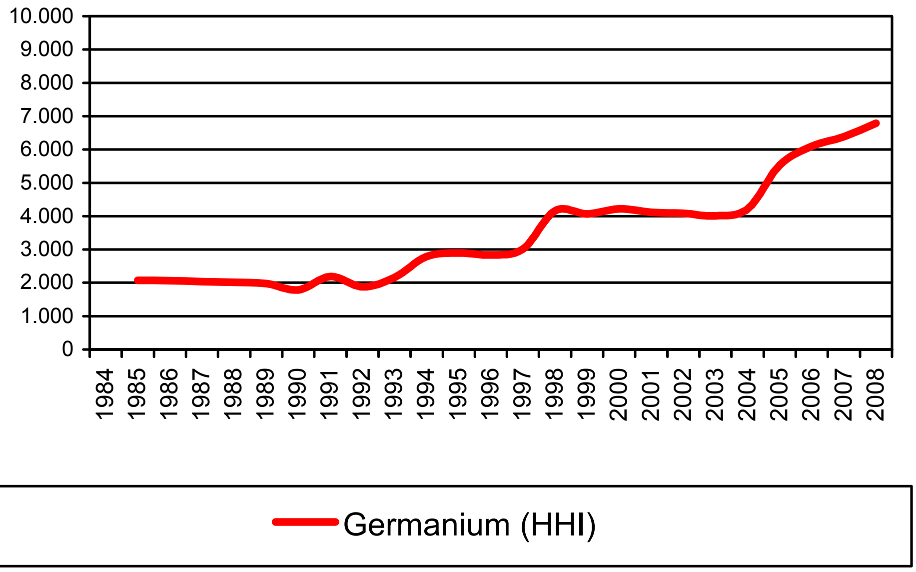
[95] USGS Mineral Commodity Summaries 2009: *Germanium*

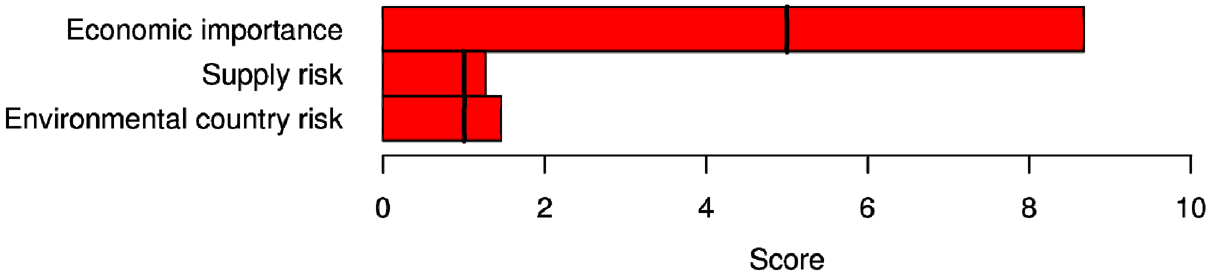
Use	Share	Megasector	Subst.
Fiber optic	30%	Electronics & ICT	1
Infrared optics	25%	Electronics & ICT	0,7
Catalysts (polymers)	25%	Chemicals	0,5
Parts for electrical and solar equipment	15%	Electronics & ICT	0,7
Others	5%	Other Final Consumer Goods	0

Substitutability index	0,8
Recycling rate (recycled content from old scrap)	0%
Import Dependence	100%

Results	
Economic importance	6,3
Supply Risk	2,7
Environmental Country Risk	2,6



Source: World Mining Data, 2010



17 Graphite

17.1 Introduction

Natural Graphite has properties of both metals and non-metals that make it suitable for many industrial applications. The metallic properties include electrical and thermal conductivity. The non-metallic properties include high thermal resistance, inertness, and lubricity. The many useful properties of graphite give rise to a wide variety of products (30 different applications with hundreds of formulations).

The term 'Natural graphite' refers to three types of graphite: vein graphite (1% market share), flake graphite (38% market share) and microcrystalline graphite (61 % market share). The industrial focus for high end application is on flake graphite.

17.2 Basic Supply & Demand Statistics

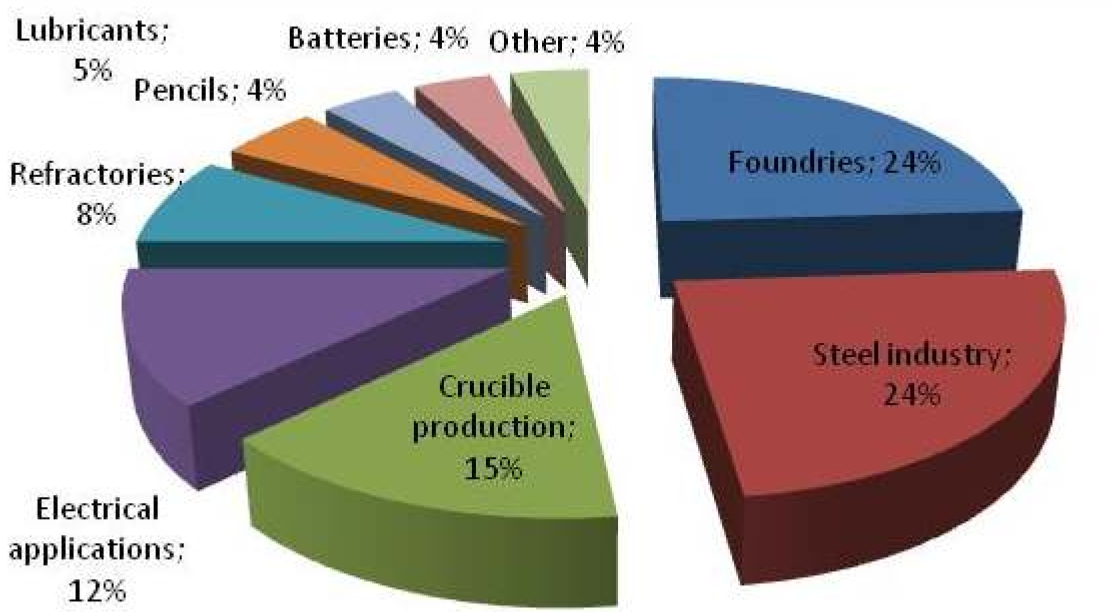
Although there is an abundance of graphite reserves, trade is dominated by China.

	Reserves (in 1000t)		Production (in 1000t; 2008)		Imports to EU (in 1000t; 2007)	
China	55,000	77.5%	810	72.3%	90	74.1%
India	5,200	7.3%	140	12.5%	1	0.9%
Mexico	3,100	4.4%	10	0.9%		0.0%
Brazil	360	0.5%	77	6.9%	9	7.7%
Other Countries	7,340	10.3%	83	7.4%	21	17.3%
Total	**71,000**		**1,120**		**122**	

Source: USGS, 2010; UN Comtrade HS 2504

While there are proven reserves of about 5,000,000 t in Norway, Sweden, Czech Republic, Austria and Germany, Europe produces very little natural graphite, As such, import dependence is in the region of 95%. In terms of production evolution, world production of natural graphite amounted to 11,200,000 tonnes in 2008, up significantly from circa 7,500,000 tonnes in 1995.

17.3 Economic Importance



As can be seen above, steel, refractories, foundries, crucible production and electrical applications are the highest-volume applications for graphite.

- Other uses include lubricants, batteries, and pencils.

In terms of future demand possibilities:

- Hybrid and electric vehicles are expected to increase demand for high-purity graphite in fuel cell and battery applications.
- Others are heat storage in solar systems, building climatisation and high purity powders in nuclear reactors.

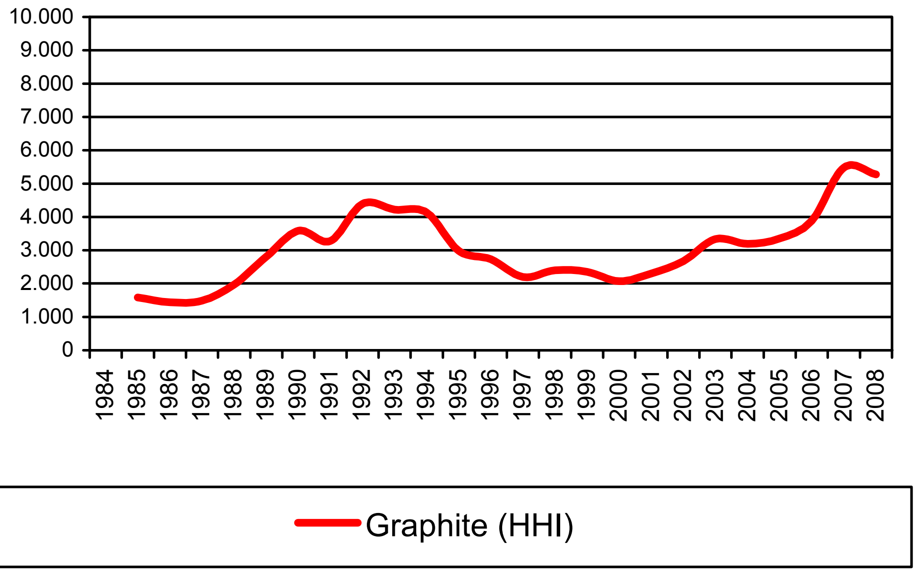
17.4 Resource Efficiency: Recycling & Substitution

Recovering high-quality flake graphite from steelmaking (kish graphite) is technically feasible, but not practiced at the present time. The abundance of graphite in the world market inhibits increased recycling efforts. Information on the quantity and value of recycled graphite is not available.

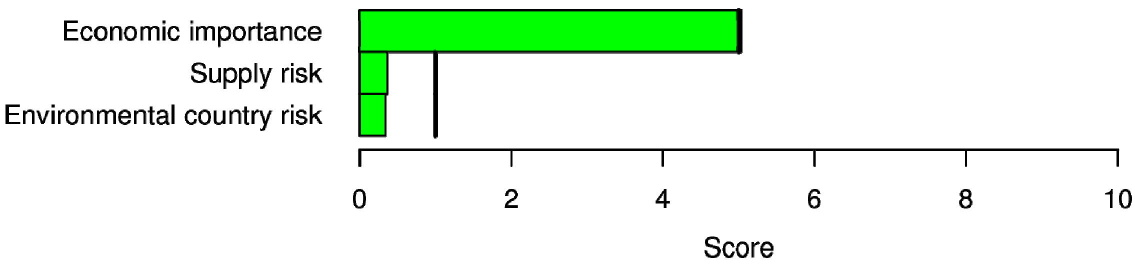
Use	Share	Megasector	Subst.
Foundries	24%	Metals	0,7
Steel industry	24%	Metals	0,3
Crucible production	15%	Metals	0,7
Electrical applications	12%	Electronics & ICT	0,7
Refractories	8%	Mechanical Equipment	0,7
Lubricants	5%	Chemicals	0,3
Pencils	4%	Other Final Consumer Goods	0,3
Batteries	4%	Electronics & ICT	0,3
Other	4%	Other Final Consumer Goods	0,5

Substitutability	0,5	
Recycling rate	0%	no information available
Import Dependence	95%	

Results	
Economic importance	8,7
Supply Risk	1,3
Environmental Country Risk	1,5



Source: World Mining Data, 2010



18 Gypsum

18.1 Introduction

Gypsum is a system of the mineral calcium sulfate and water molecules ($CaSO_4$-$2H_2O$) that can be transformed into semi-hydrate (CaSO4-1/2H2O) or anhydrite ($CaSO_4$) by dehydration (heat supply). Anhydrite occurs in four different solid phases.[96] It can be partly retransformed into gypsum by adding water (rehydration). These mechanisms are the basis for gypsum products.

18.2 Basic Supply & Demand Statistics

Gypsum deposits can be found in several countries and reserves are large in parts of the world but absent for example in whole Scandinavia, though data is incomplete for a number of countries.[97] In 2009, 86 countries produced gypsum.[98]

	Reserves (in 1000t; 2010)	Production (in 1000t; 2009)		Imports to EU (in 1000t; 2007)	
USA	700,000	9,400	6.1%	3	1%
Australia		4,000	2.6%		
Brazil	1,300,000	2,100	1.4%		
Canada	450,000	5,500	3.6%	0.15	>0.1%
China		42,000	27.3%		
France		4,800	3.1%		
Germany	390,000	4,000	2.6%		
Iran		12,000	7.8%		
Italy		5,400	3.5%		
Japan		5,800	3.8%		
Mexico		4,500	2.9%		
Spain		11,500	7.6%		
Thailand		8,000	5.2%	20.1	6.5%
Turkey		3,000	1.9%		
Bosnia-H.				33.8	10.9%

96 Römpp Online: *Gips.* Georg Thieme Verlag, Stuttgart, 2009

97 Ullmann's Encyclopedia of Chemical Technology: *Calcium Sulfate.* Wiley-VCH Verlag, Weinheim, 2006

98 USGS Mineral Commodity Summaries 2010: *Gypsum*

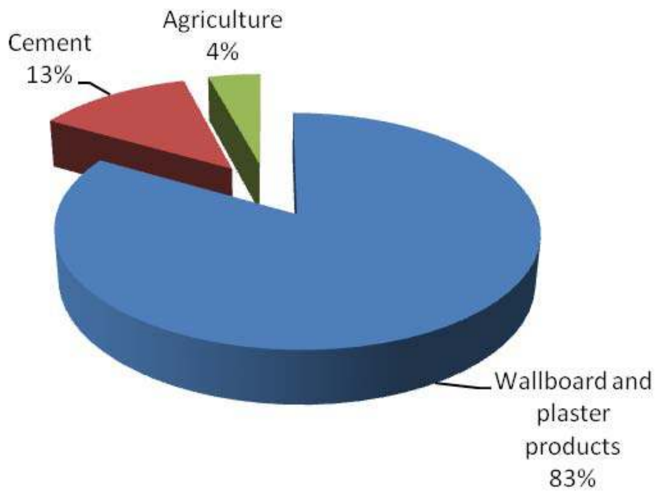
Croatia				4.8	1.5%
Jamaica				3.1	1.0%
Morocco				140.5	45.3%
Norway				56.5	18.2%
Ukraine				48	15.50%
Other		34,000	22.1%		
Total	Large	154,000		310	

Source: USGS 2010; trade data provided by BGS based on EU comtrade (HS 252010); production figures for Germnany based on data provided by Knauf Gips KG

The European Union is nearly independent from imports. In 2007, 99% of total EU gypsum consumption was produced within the European Union (30,904,000 metric tonnes), mainly by Spain (39% of EU production) and France (16%).

According to the EU Commission’s inventory on export restrictions, Argentina applies a 10% export tax on gypsum, anhydrite and plasters consisting of calcined gypsum or calcium sulphate, whether or not colored, with or without small quantities of accelerators or retarders.

18.3 Economic Importance



Depending on the temperature which is used for burning the gypsum, there are different forms of the material with different applications:[99,100,101]

- Wallboards an plaster products: Gypsum is used for manufacturing wallboards and plaster products. Most quantities of gypsum are used in the building industry.
- Cement: Gypsum is used as setting retarder in the production of cement.
- Agriculture: Also large quantities are used to improve properties of soils for agricultural reasons.
- Modeling forms: Gypsum is a useful material to model forms for many substances, such as ceramics, metals, rubbers and plastics. It is also used for dental applications. Although only small quantities are used in this sector, these applications are lucrative export products.

18.4 Resource Efficiency: Recycling & Substitution

Some of the gypsum that is used in the building sector is recycled, yet the percentage is very low (approximately 1%). Recycled gypsum is mainly used for agricultural purposes.

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 wall(boards). In contrast, gypsum has no sufficient substitute in cement production. Synthetic gypsum (FGD), a waste product of some industries (desulfurization of smokestack emissions), is an important substitute for mined gypsum, but due to current climate policy this source, together with coal power stations, will eventually vanish.[6] In 2008, about 36% of total gypsum consumption was covered by synthetic gypsum.[102]

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99 Römpp Online: *Gips.* Georg Thieme Verlag, Stuttgart, 2009

100 Ullmann's Encyclopedia of Chemical Technology: *Calcium Sulfate*. Wiley-VCH Verlag, Weinheim, 2006

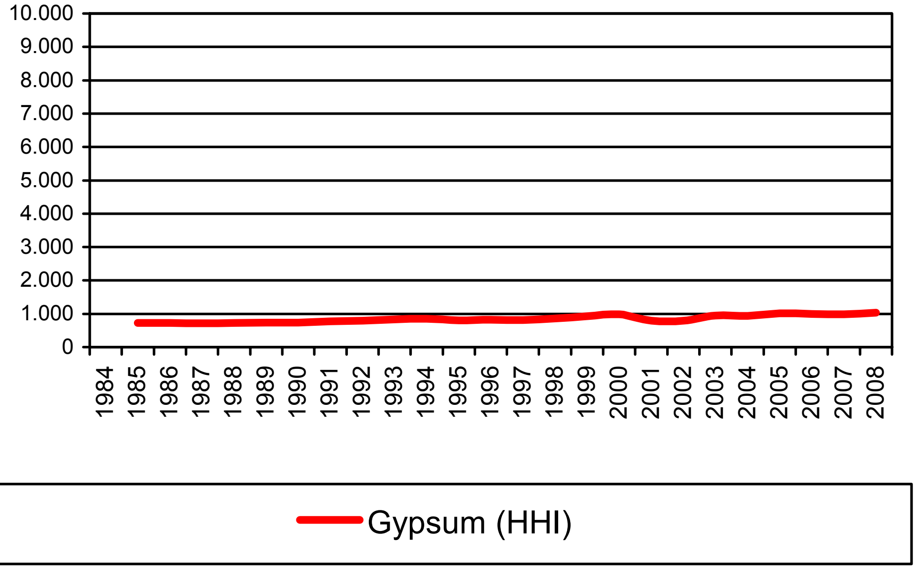
101 USGS Mineral Commodity Summaries 2010: *Gypsum*

102 Roskill

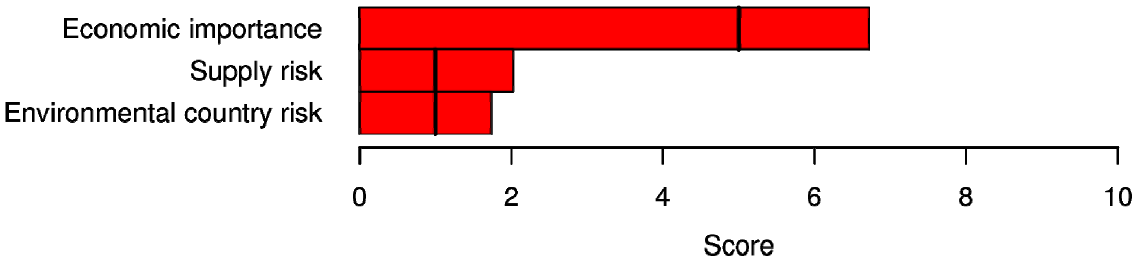
Use	Share	Megasector	Subst.
Wallboard and plaster products	82%	Construction Material	0,7
Cement	14%	Construction Material	1,0
Agriculture	3%	-	0,7
Modelling	1%	Other Final Consumer Goods	1,0

Substitutability	0,7
Recycling rate	1%
Import Dependence	1%

Results	
EI (GVA/Megasector)	5,0
Supply Risk (HHI mod. WBI)	0,4
Environmental Risk (HHI mod. EPI)	0,3



Source: World Mining Data, 2010



19 Indium

19.1 Introduction

Indium is a silvery-white, brightly shining heavy metal which is softer than lead.[103] Indium forms alloys with most other metals and generally increases the strength, corrosion resistance and hardness of the alloy system.[104] Indium tin oxide is both transparent and conducting, which makes it essential for display applications.[105]

19.2 Basic Supply & Demand Statistics

Indium is widely spread, generally in low concentrations[2]. Most quantities are recovered from sphalerite, a lead-zinc-sulfide mineral. Therefore indium production is connected to lead-zinc production.[106]

In 2007, indium reserves were estimated at only 6,000 tons, a figure which contributed to significant price increases. Since then, new deposits have been identified or have become economical, so that the range of reserves is not that critical today and prices dropped about 50%. Indeed, Indium Corporation has determined that indium reserves (proven and probable, measured and indicated, and inferred) in identified base metal mines in the world amounted to close to 50,000 MT of Indium (26,000 MT in western world, 23,000 in the rest i.e. mostly China and former Soviet Union).

Nevertheless indium is still quite expensive[3].

As indium is a minor metal with no primary mining, the mining data for the host of indium are relevant here. In order to simplify these considerations and to provide reasonable overview, only the major hosts lead and zinc will be taken into account here.

- Lead: There were 12 EU32-countries contributing to world mine production in 2007. They totally produced 269,300 tones (metal content) of lead. This meant a total share of world production of around 7.5 per cent. In total, EU32 has to be considered to be a net-importer of lead.

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103 Römpp Online: *Indium.* Georg Thieme Verlag, Stuttgart, 2006

104 Ullmann's Encyclopedia of Chemical Technology: *Indium and Indium Compounds.* Wiley-VCH Verlag, Weinheim, 2006

105 Materialwissenschaften: "Engpässe bei Hightech-Metallen"

106 USGS Mineral Commodity Summaries 2009: *Indium*

- Zinc: There were 11 EU32-countries contributing to world mine production in 2007. They totally produced 945,000 tones (metal content) of zinc. This meant a total share of world production of around 8.6 per cent. In total, EU32 has to be considered to be a net-importer of zinc ore (BGS EMS 2008).[107]

	Production (in t; 2008)		EU imports (in t; 2006)	
Belgium (1)	30	5,3%		
Canada	50	8,8%		
China	330	58,1%	47,3	81,3%
Japan (1)	60	10,6%	0,5	0,9%
Korea	50	8,8%		0,0%
Peru	6	1,1%	1,5	2,6%
Russia	12	2,1%	1,6	2,7%
Hong Kong			2,3	4,0%
Norway			0,6	1,0%
USA			2,2	3,8%
Singapore			2,2	3,8%
Switzerland				
others	30	5,3%		
Total	**568**		**58**	

Source: USGS 2010; trade data provided by ComExt (CN 8112 92 81)
(1) Imports of lend and zinc

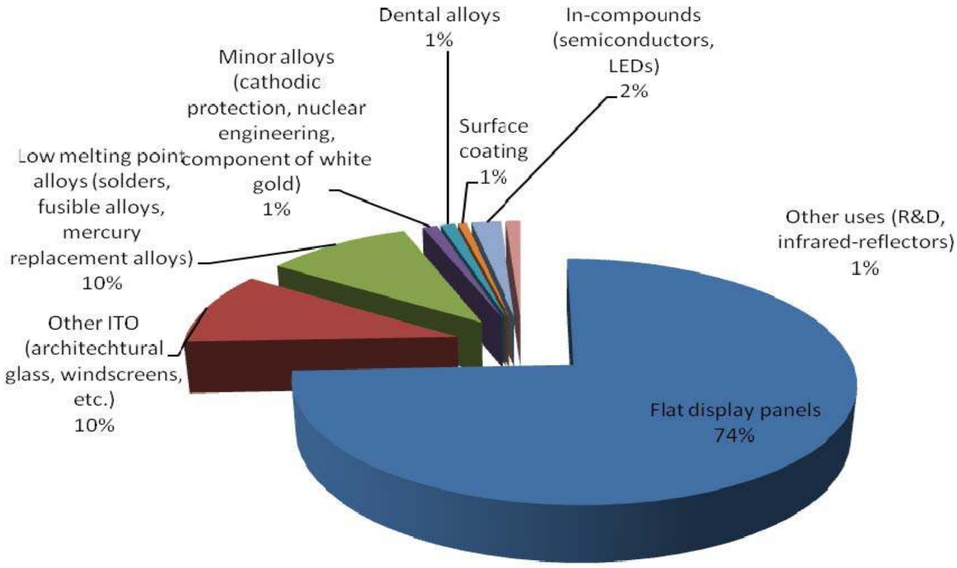
As Europe is import dependent on the hosts of indium, it can be stated that Europe is import-dependent on Indium, too. This observation will be amplified by the fact that Belgium seems to be the only European country active in refining indium metal.

There are two different reasons for these developments:

- 30% of indium-containing base metal concentrates still do not reach “indium-capable” smelters and this indium continues to be lost;
- 70% of the indium-containing concentrates that do reach indium-capable smelters are only extracted at a final average rate of about 50%.

107 European Mineral Statistics 2008, BGS

19.3 Economic Importance



Main end-use markets for indium products worldwide are[2,108,109]:

- Flat display panels: 74% of indium are used for display panels which are part of many high-tech products.
- Low melting point alloys: Indium metal is used for low temperature alloys, which are used as solders, for temperature indicators in fire-control systems and other applications.
- Minor alloys: Other alloys are used for jewelry, dental applications, as nuclear reactor control rods or as corrosion inhibitors.
- Compounds: Intermetallic compounds are used as semiconductors for laser diodes and for photomultipliers.
- Other ITO: Indium is also used for architectural glass and windscreens.

Fraunhofer expects the following fields of applications to be the major driver of future demand for indium:

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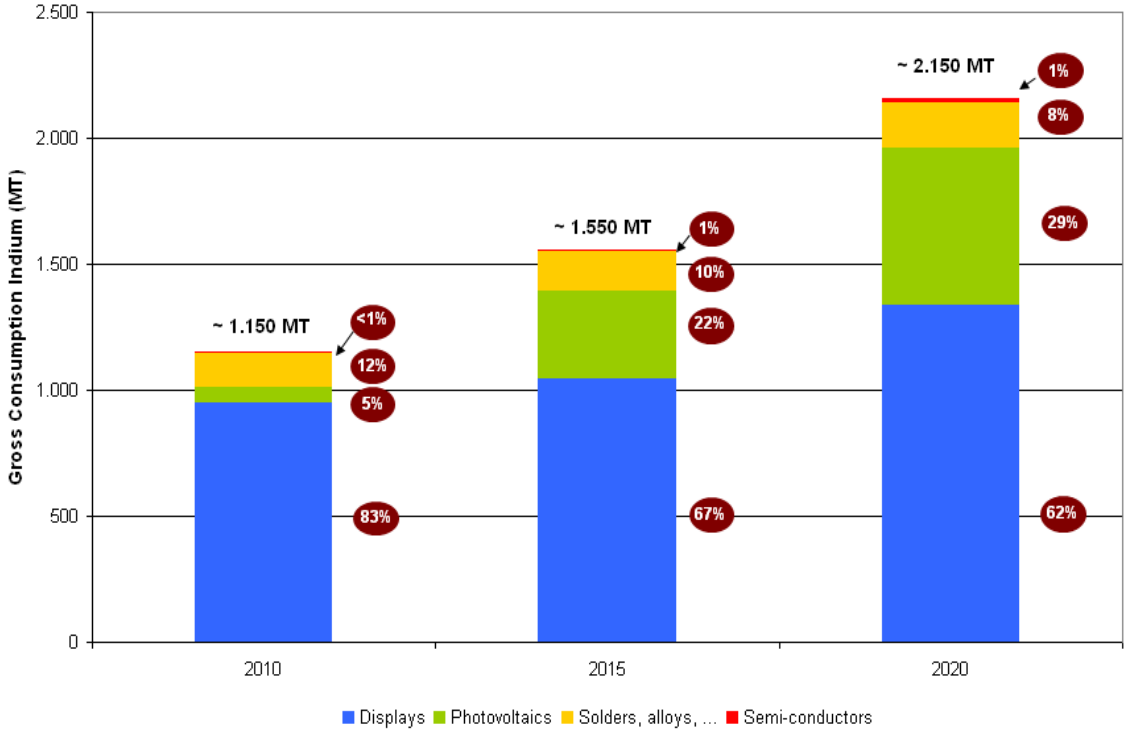
2 Ullmann's Encyclopedia of Chemical Technology: *Indium and Indium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

108 Roskill Information Services: *The Economics of Indium*, London, 2003

109 Fraunhofer Institut für System und Innovationsforschung and Institut für Zukunftsstudien und Technologiebewertung: *Rohstoffe für Zukunftstechnologien*, 2009, Fraunhofer IRB Verlag, Stuttgart

- Thin-film ITO coating (keeps it dominant position)
- CIS thin-film solar cells (copper-indium-selenide, a currently research new kind of solar cell for more easy, sustainable and cheap production)
- InGaN-applications (indium-gallium-nitrite; used for LEDs, Blue-ray discs)

Indium use for photovoltaic applications is expected to show significant growth in the next 10 years due to strong development of CIS technology (Umicore, 2009).



Forecast of gross consumption of Indium across main utilization segments.

Indium is important for many emerging technologies, including thin-layer photovoltaic cells, displays and white LEDs. The demand for indium in these applications is expected to increase by a factor of eight until 2030[110].

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110 Fraunhofer Institut für System und Innovationsforschung and Institut für Zukunftsstudien und Technologiebewertung: *Rohstoffe für Zukunftstechnologien*, 2009, Fraunhofer IRB Verlag, Stuttgart

19.4 Resource Efficiency: Recycling & Substitution

Recycling possibilities for indium are limited. Only very small quantities of indium are recycled from old scrap, in fact less than 1%, mainly from indium tin oxide (ITO) products, such as scrap LCD panels. Nevertheless ITO recycling is highly inefficient[111].

A number of smelters have accumulated large amounts of tailings and slags over the years and continue to do so. These indium-containing materials are more difficult and thus more expensive to treat. However, they can be treated if demand and price warrants. A recent Indium Corporation study has identified that the total residue reserves worldwide amount to over 15,000mt of indium and that another 500 mt of indium is generated every year in residue form.

Indium Corporation therefore concludes that based on mining reserves (100 years at a rate of 500mt of virgin indium per year), plus residue reserves (30 years at a rate of 500mt per year), combined with continued improvements in recoveries of virgin and reclaimed materials, and on-going exploration, indium will be available for a long period of time.

Indium's recent price volatilities and supply concerns made antimony tin oxides interesting as substitute for ITO in LCD panels. Carbon nanotube coatings are an alternative to ITO coatings in flexible displays, solar cells and touch screens. There are some more substitutes for ITO depending on the application. Moreover indium can be replaced by gallium arsenide in some semiconducting products and by hafnium in nuclear reactor control rod alloys[9].

19.5 Specific issues

According to the EU Commission's inventory on export restrictions, China applies a combination of export quotas and export tax (5%), while Russia applies a 6.5% export tax. South Africa applies a non-automatic export licensing system. Tanzania has set up an export ban on indium.

Supply and demand seem to balance today on EU level but in order to ensure that the EU industry is self sustaining in the future, it will be necessary to retain indium-containing scrap, increase recovery (primary and secondary) and recycling / refining processes.

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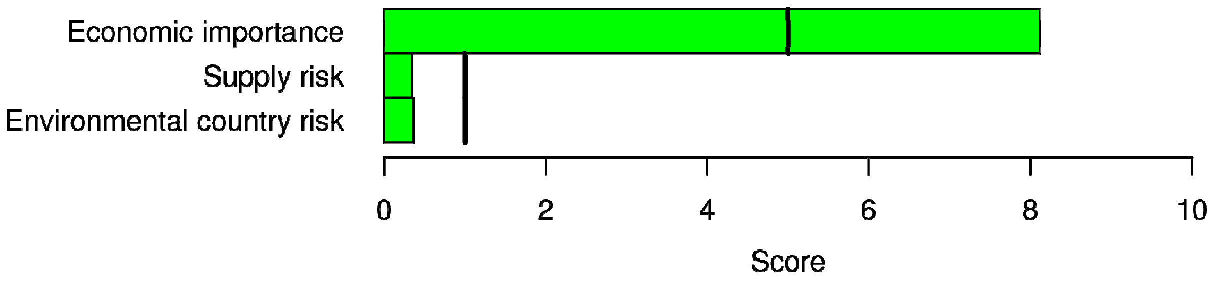
[111] USGS Mineral Commodity Summaries 2009: *Indium*

Use	Share	Megasector	Subst.
Flat display panels	74%	Electronics & ICT	1,0
Other ITO (architechtural glass, windscreens, etc.)	10%	Rubber, Plastics & Glass	0,7
Low melting point alloys (solders, fusible alloys, mercury replacement alloys)	10%	Metals	0,7
Minor alloys (cathodic protection, nuclear engineering, component of white gold)	1%	Metals	0,3
Dental alloys	1%	Pharmaceuticals	0,3
Surface coating	1%	Metals	0,3
In-compounds (semiconductors, LEDs)	2%	Electronics & ICT	0,3
Other uses (R&D, infrared-reflectors)	1%	Other Final Consumer Goods	1,0

Substitutability index	0,9
Recycling rate (recycled content from old scrap)	0,3%
Import Dependence	100%

Results	
Economic importance	6,7
Supply Risk	2,0
Environmental Country Risk	1,7



20 Iron

20.1 Introduction

Iron is one of the most common metals in nature. It is a silver-white or gray metal that is malleable and ductile. In a pure form, it is relatively soft and slightly magnetic. When hardened, it becomes much more magnetic. Iron is the most widely used of all metals. Prior to its use, however, it must be treated in some way to improve its properties or it must be combined with one or more other elements to form an alloy. By far the most common alloy of iron is steel.[112]

20.2 Basic Supply & Demand Statistics

Iron is one of the most abundant metals on earth, though it is not found in nature in a metallic form. The natural iron-bearing mineral in which's concentration of iron is sufficient to be commercially usable is called iron ore, thus metallic iron, is normally extracted from it. Normally, iron and steel are by far the least expensive of the world's metals.

In 2008, the world’s production of iron ore was 2,190 million tons of usable ore, of which 35% was produced by China.

	Reserves (in million t; 2008)		**Production (in million t; 2008)**		**EU imports (in 1000 t; 2009)**	
United States	6,900	4.5%	54	3.1%		
Australia	16,000	10.4%	342	19.4%	9,175	6.2%
Brazil	16,000	10.4%	355	17.8%	75,500	50.7%
Canada	1,700	1.1%	31	1.8%	12,250	8.2%
China	21,000	13.6%	366*	20.1%		
India	6,600	4.3%	220	12.5%	1,350	0.9%
Iran	1,800	1.2%	32	1.8%		
Kazakhstan	8,300	5.4%	23	1.3%		

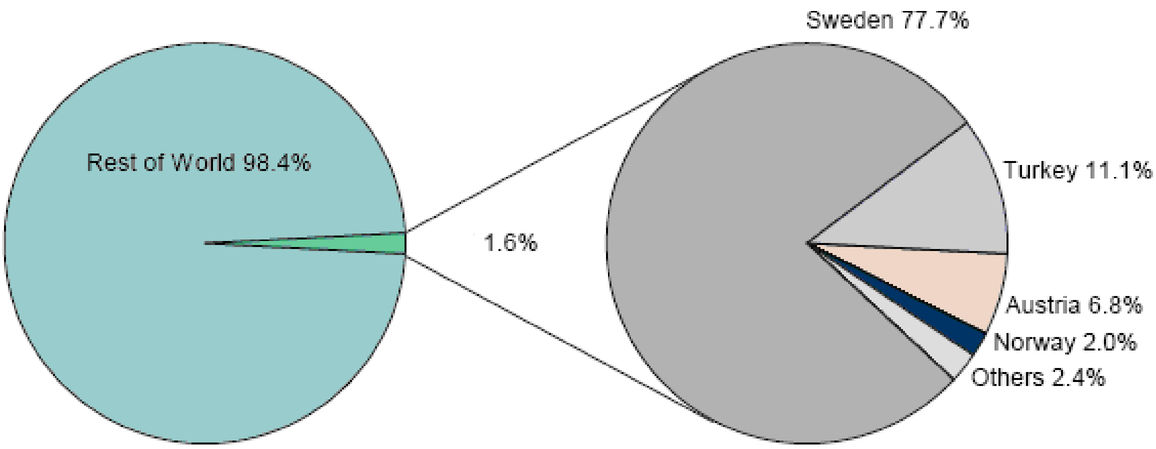
112 http://science.jrank.org/pages/3686/Iron-General-properties.html

Mauritania	700	0.5%	11	0.6%	9,900	6.7%
Mexico	700	0.5%	12	0.7%		
Russia	25,000	16.2%	100	5.7%	14,500	9.7%
South Africa	1,000	0.6%	49	2.8%	7,000	4.7%
Sweden	3,500	2.3%	24	1.4%		
Ukraine	30,000	19.5%	73	4.2%	13,100	8.8%
Venezuela	4,000	2.6%	21	1.2%	3,000	2.0%
Other countries	11,000	7.1%	47	2.7%	3,000	2.0%
World total	160,000		2,220		149,000	

Source: USGS, UNComtrade HS 2601 11; HS 2601 12

European iron ore production, including Turkey and Norway - was only 1.6% of the world total in 2007. Sweden was the largest European producer (78% of the total European production).

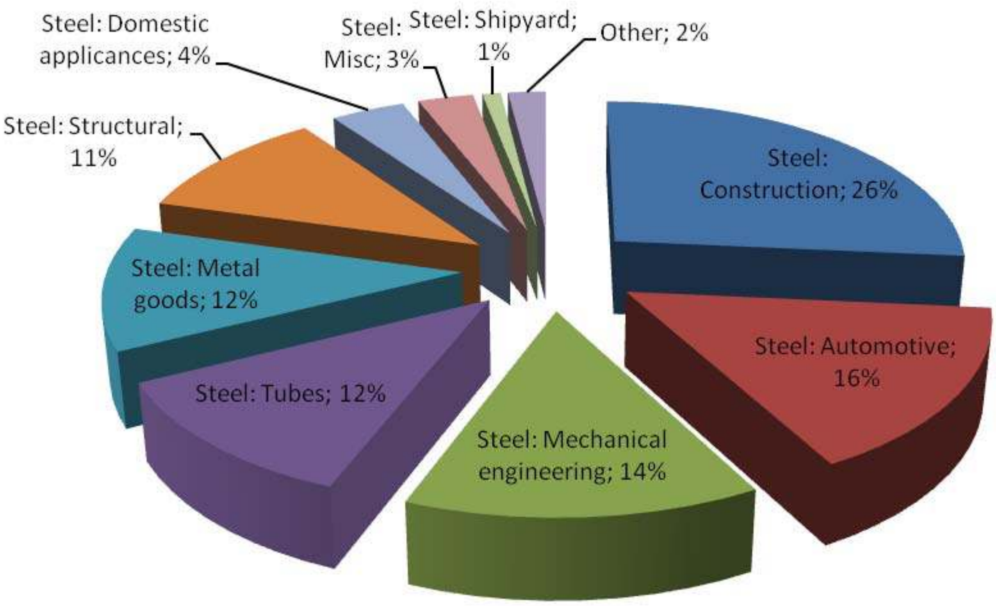
There is production only in Austria and Sweden and very small amounts also in Germany and the Slovak Republic. The production in Bulgaria and Romania has been closed down.



Currently, there are in total 14 EU mining projects[113], 12 of them take place in Sweden and 2 in Slovakia. Out of the total, 13 projects are in conceptual phase, 1 is in pre-feasibility phase[114].

There has been a steady rise of 15% in European Union imports of iron from 1999 (where the it imported 128,972,883 tons) to 2008 (where it imported 151,906,935 tonnes), but due to the economic crisis the EU imports of iron in 2009 fell 45.39% to a record low value of 82,952,878 tons.

20.3 Economic Importance



Ninety-eight percent of iron ore are used for the manufacture of iron and steel. The remaining 2% are used, for example, for dyes and chemicals[115].

Some of the industries that require iron and steel are the construction industry for steel framing of large buildings, construction of railways, shipbuilding industry, car industry, construction of pipelines, among others.

20.4 Resource Efficiency: Recycling & Substitution

Recycling

113 As elsewhere in this report,. the term 'EU-32' here refers to EU-27 as well as associated countries such as Turkey and Norway.

114 Raw Materials Data. Copyright: Raw Materials Group, Stockholm, 2009

115 USGS 2006c

Primary iron ore is not recyclable, only steel can be recycled.

According to the data received by the Fraunhofer Institute, the worldwide recycling rate of iron is approximately 40% (56% at EU level). This value is very important as by recycling iron and steel there is a significant reduction in energy and cost. While there is great potential in increasing this rate (70 percent recuperated within a 20-year period), in practice this is difficult due to product life cycles, e.g.:

- 10 years for electrical goods
- 12 years for vehicles,
- 20 years for railway equipment

Iron ore, used directly, as lump ore, or converted to briquettes, concentrates, pellets, or sinter, is the only source of primary iron. In some operations, ferrous scrap may constitute as much as 7% of the blast furnace feedstock. Scrap is extensively used in steelmaking in electric arc furnaces and in iron and steel foundries, but scrap availability can be an issue in any given year. In general, large price increases for lump and fine iron ores and iron ore pellets during 2008 were offset by price increases in the alternative scrap. The margin between iron ore and scrap import prices decreased between 2004 and 2006, but remained level for 2007 and 2008; therefore, the relative attractiveness of scrap compared to iron ore has changed little since 2006[116].

Competing materials

Due to the reciprocal substitution possibilities of aluminium, steel and plastic, which is described as a “classic substitution triangle”, steel is in great competition with these other two materials. In the past, aluminium, plastics and even ceramics have increasingly come to replace steel, as these materials possess advantages compared to steel[117].

For example, gas installations are increasingly adopting plastic pipes.

The use of magnesium in motor components is also playing an increasingly significant role. New manufacturing techniques make it possible to produce thinner and nevertheless high-strength steel panels, e.g. “tailored blanks” that can replace aluminium in vehicle construction without any disadvantage with regard to weight and rigidity[118].

The materials manufactured from HSD steel (HSD: high strength and ductility) weigh less than aluminium parts with the same performance characteristics[119].

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[116] USGS 2009

[117] Matthes and Ziesing, 2005

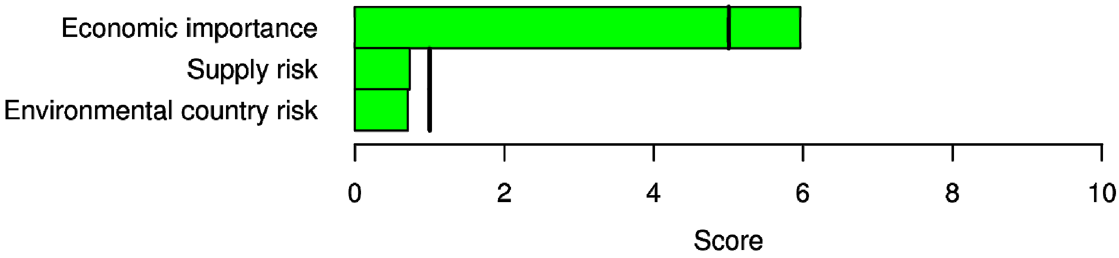
[118] Röhrle 2005

[119] DBR 2005, BMWi 2007

Use	Share	Megasector	Subst.
Steel: Construction	26%	Construction materials	1,0
Steel: Automotive	16%	Road Transport	0,7
Steel: Mechanical engineering	14%	Mechanical Equipment	0,7
Steel: Tubes	12%	Metals	0,7
Steel: Metal goods	12%	Metals	1,0
Steel: Structural	11%	Metals	1,0
Steel: Domestic applicances	4%	Electrical Equipment + Domestic Appliances	0,7
Steel: Misc	3%	Metals	0,5
Steel: Shipyard	1%	Aircraft, Shipbuilding, Trains	1,0
Other	2%	Metals	0,5

Substitutability index	0,70
Recycling rate (recycled content from old scrap)	22%
Import Dependence	85%

Results	
Economic importance	8,1
Supply Risk	0,3
Environmental Country Risk	0,4



21 Limestone

21.1 Introduction

Limestone is a pervasive, naturally-occurring crystalline mineral, which mostly consists of calcium carbonate ($CaCO_3$). Magnesium carbonate is often present as a secondary component while a variety of impurities may also be present, depending on the location of the deposit. These impurities have a considerable influence on the properties and therefore, on the possible applications of a particular type of limestone.[120]

The term 'lime' refers to quicklime and sometimes to hydrated or slaked lime, which are produced from limestone. Lime is not mined as such or as a by-product of limestone. The calcium carbonate is extracted in order to be primarily transformed into lime/dolime when the quality of the material is sufficiently high. The smaller parts of the raw material resulting from the blasting and crushing operations are sold in other markets (e.g. filler for construction or environmental applications). Quicklime is produced by thermal decomposition of limestone. Hydrated or slaked limes are produced by reacting quicklime with water.[1]

Extremely pure and bright deposits are mined to be used directly in the paper, paint, and plastics industry.

21.2 Basic Supply & Demand Statistics

Limestone is distributed all over the world, occurs in many different forms and is mostly produced by open-cast quarrying[1]. Although calcium carbonate is abundant as a resource all over the world, good quality suitable for lime production is less available. Furthermore, due to environmental and logistic reasons, operators prefer large deposits located close to water communication channels. For some lime application such as the production of precipitated calcium carbonate, PCC, only some highly pure deposits are suitable. Deposits bright enough to be used in paper paint plastics are rare (less than 50 in Europe).

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[120] Ullmann's Encyclopedia of Chemical Technology: *Lime and Limestone*. Wiley-VCH Verlag, Weinheim, 2006

Limestone reserves are adequate for all listed countries and for projected worldwide demands as well.[121]

	Lime Production (in 1000 t; 2008)		Lime Production (in 1000 t; 2009)	
USA	19,900	6.7%	15,000	5.3%
Austria	2,000	0.7%	1,700	0.6%
Belgium	2,200	0.7%	1,800	0.6%
Brazil	7,400	2.5%	6,000	2.1%
Canada	2,070	0.7%	1,500	0.5%
China	180,000	60.8%	190,000	67.2%
France	4,000	1.4%	3,000	1.1%
Germany	7,000	2.4%	5,600	1.8%
Iran	2,700	0.9%	2,200	0.8%
Italy	6,000	2.0%	5,000	1.8%
Japan (quicklime only)	9,500	3.2%	8,000	2.8%
Mexico	6,500	2.2%	5,000	1.8%
Poland	1,900	0.6%	1,600	0.6%
Russia	8,200	2.8%	7,000	2.5%
South Africa (sales)	1,590	0.5%	1,300	0.5%
Turkey (sales)	3,600	1.2%	3,000	1.1%
UK	2,000	0.7%	1,800	0.6%
Vietnam	2,200	0.7%	2,000	0.7%
others	27,200	9.2%	22,000	7.8%
Total	**295,960**		**282,900**	

Source: USGS 2010; trade data provided by BGS based on EU comtrade, Data are for quicklime, hydrated lime, and refractory dead-burned dolomite

These figures only represent the production of final products after calcination of the limestone and dolomite. In order to assess the related raw material production, figures have to be multiplied by a factor 3; this means a total of around 900,000 kilotonnes calcium carbonate.

EU 27 Net Imports of Limestone [Metric Tonnes]:

Country	Quantity (2006)
Croatia	12,292
India	3,735
Norway (incl,SJ excl,1995,1996)	137,442

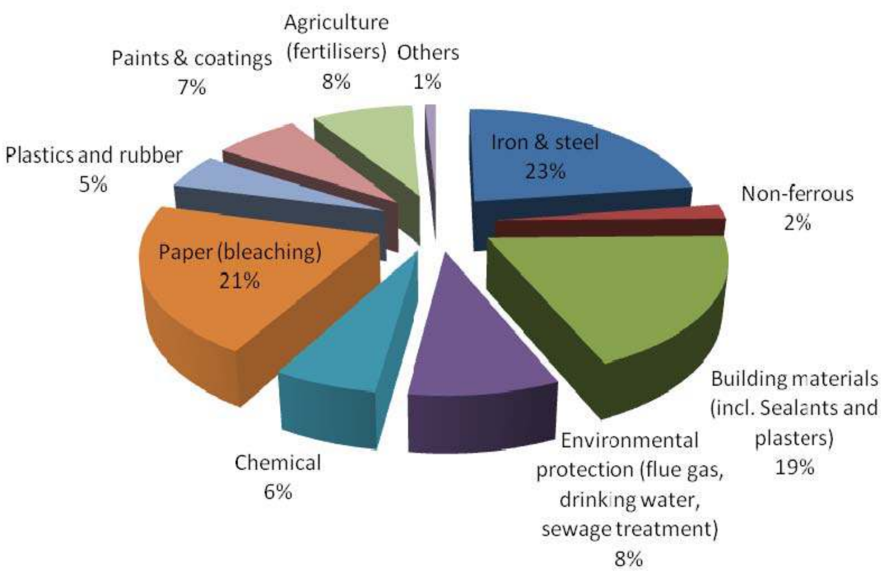
121 USGS Mineral Commodity Summaries 2010: *Lime*

Total	**153,470**

Source: ComExt (CN 2521)

Two thirds of the worldwide lime consumption is produced by China where it is also consumed, There are many lime producing countries, In the EU-27 Germany, France, Poland, Italy, Spain and Belgium are the largest producers of lime, In only 4 EU Member States no lime is produced (Cyprus, Malta, Luxemburg and the Netherlands), At present the lime trade intensity is relatively insignificant, Imports of raw materials in the EU are currently limited due to the cost of transportation, This situation can however change in the future if lime production is significantly impacted by the ETS (Greenhouse Gas Emissions Trading Scheme) in Europe compared to the absence of constraints in areas like North Africa, Middle East and former Soviet Union countries, , About 7% of worldwide consumption was produced within the European Union in 2009, The EU imports around 2% of total EU supply.[122]

21.3 Economic Importance



Main end-use markets for lime and limestone products[1,123]:

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[122] Potential Impacts of the EU ETS on the European Lime Industry NERA, 2008

[1] Ullmann's Encyclopedia of Chemical Technology: *Lime and Limestone*. Wiley-VCH Verlag, Weinheim, 2006

[123] (IMA Europe)

- Building materials: Most quantities of limestone are used in construction as crushed rock. But also marble, which is a highly crystalline form of limestone, is a popular building material since the antiquity.
- Paper: Limestone is used for bleaching in the paper industry.
- Chemical: As described above, quicklime and hydrated lime are produced of limestone. These products are readily available and cost effective alkaline chemicals and play an important role in the chemical industry.
- Agriculture: Limestone is used to neutralize acid soils and to replace calcium and magnesium which is replaced by the crops. It is also used in animal feeds.
- Iron & Steel: limestone and quicklime are used in the production of metals, mainly for iron and steel, but also for zinc, lead, copper and antimony.
- Environmental protection: A growing amount of limestone is used to remove sulfur dioxide from flue gases, for sewage treatment and for drinking water.
- Other: Limestone is used in many other products, such as alumina, glass, wood pulp, ceramics, mineral wool, fillers, whiting and filters.

In general lime and limestone are increasingly contributing to environmental applications and support the increasing the lifespan of infrastructure and buildings.[124]

Lime consumption has been pretty stable during the last decade until the economic crisis Europe is currently facing, Decreasing markets, such as steel, have been compensated by new applications as environment protection, soil treatment and paper industry. The lime industry considers that demand should be stable in the mid- term.

21.4 Resource Efficiency: Recycling & Substitution

While limestone by itself is not directly recyclable some products made with limestone are recyclable or reusable: steel, paper, plastics, gypsum produced by flue gas desulfuration, alumina, glass, etc.

Limestone is extensively recycled in the paper pulp industry where it is converted to lime, lime is used for the pulp purification and transformed back into limestone ($CaCO_3$) that is placed back in the lime kiln.

In the case of lime/dolime production, resource efficiency mainly concerns the total amount of raw material that can be transformed. The ratio raw material / lime product is

[124] Ullmann's Encyclopedia of Chemical Technology: *Lime and Limestone*. Wiley-VCH Verlag, Weinheim, 2006

improved by the use of various technologies capable to combine expected quality and physical forms. These technologies involveextraction methods, crushing, screening, sorting and calcining. Calcination technology is mainly based on two main families of kilns: vertical and horizontal.

Vertical kilns are the most efficient in terms of fuel consumption and therefore CO_2 emissions. But for technical reasons vertical kilns are less suitable for small stones. In some parts of the EU the stones have very specific features and cannot be burnt in a vertical kiln due to their ability to break into very small pieces. In general, the productivity of a vertical shaft kiln decreases when pebble size decreases. Below ~30 mm, pressure drops and preferential gas streams become a hurdle for cost effective and efficient production of quality lime. Even if they are less efficient in terms of fuel consumption and CO2 emissions, the rotary kilns however can cope with small-sized stones, which are abundant in many quarries, because the horizontal position of the kiln reduces the risk of the kiln getting clogged. In other words, rotary kilns contribute to a more efficient use of raw materials.

Lime and limestone are often forming new products by reaction with e.g. sulfur and silica which are entering new product cycles (FGD-gypsum, steel slag, glass cullets, etc.). Lime is recycled by paper mills, water treatment plants and in the carbide industry. As part of the FGD-gypsum, lime based products are widely used in renovation and new buildings. Steel slags are used in agriculture as fertiliser[125].

Waste occurring during the lime production process is mainly recycled in applications which enable the incorporation of recycled products. Moreover, the residues of lime applications can also be recycled as new products: e.g. lime is used to capture SO_2 from industrial emissions. The reaction of sulfur emissions with lime generates sulfogypsum which can then be utilized in the production of construction materials.

In many applications limestone can substitute the more expensive lime. Among these are agriculture, fluxing and sulfur removal. Calcined gypsum is an alternative material in industrial plasters and mortars. Cement, cement kiln dust, fly ash, and lime kiln dust are potential substitutes for some construction uses of lime. Magnesium hydroxide is a substitute for lime in pH control, and magnesium oxide is a substitute for lime as a flux in steelmaking[126].

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125 USGS, MCS 2010, Lime

126 USGS, MCS 2010, Lime

In its main uses limestone is needed either for its chemical composition or as the product having the best ratio cost/physical characteristics .As such its substitution will have a strong negative impact on the supply chain.

21.5 Specific issues

The main market for lime/dolime products is steel production. This customer segment has been strongly reorganized during the last 20 years with the creation of global huge companies controlling most of the production capacities in Europe, Another large market segment is represented by power plants or incinerators where the production is also quite integrated in Europe.

Supply side

No important modification of the EU lime/dolime production is expected in the mid-term.

Environmental issues

Limestone extraction is well regulated: water protection, noise, mining waste, IPPC derived national regulations, etc, An emerging issue will be the capacity of the limestone quarries to bring its appropriate contribution to the halting of the loss of biodiversity in Europe, Numerous cases are available to demonstrate that the opening/extension of limestone/dolomitic quarries can be compensated by the creation of a unique habitat for endangered species during the reclamation of exploited zones.

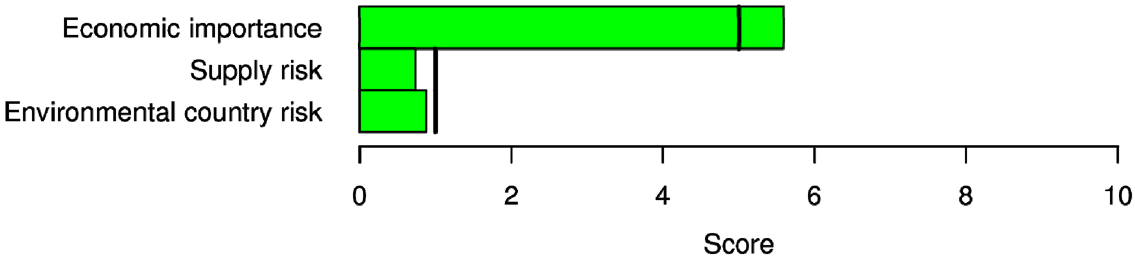
Quarrying of limestone can also contribute to improve the management of another natural resource: i,e, underground water, In many cases, the extraction of a raw material under the water table is enabled by pumping large amounts of underground water, In these cases, collaboration with water production companies to valorize these amounts of water will help to better manage this resource.

Lime production facilities are regulated by various EU Directives and their national implementation, Main legislations are IPPC and Emissions Trading (ETS), Emissions Trading is one of the most challenging issues for the lime industry, notably because more than two thirds of the emissions are related to the decarbonation of calcium carbonate (process emissions), which can hardly be reduced, The lime industry is expected to gradually implement the new constraints and emission limit values defined by a very recent revision of the BREF related document.

Use	Share	Megasector	Subst.
Iron & steel	21%	Metals	1
Non-ferrous	2%	Metals	1
Building materials (incl. Sealants and plasters)	19%	Construction material	0,7
Environmental protection (flue gas, drinking	9%	Construction material	1
Chemical	5%	Chemicals	1
Paper (bleaching)	22%	Paper	0,7
Plastics and rubber	5%	Rubber, Plastics & Glass	0
Paints & coatings	8%	Chemicals	0,7
Agriculture (fertilisers)	8%	Chemicals	1
Others	1%	Other Final Consumer Goods	0,5

Substitutability index	0,80	
Recycling rate (recycled content)	0%	no information available
Import Dependence	56%	

Results	
Economic importance	6,0
Supply Risk	0,7
Environmental Country Risk	0,7



22 Lithium

22.1 Introduction

Lithium is a very reactive alkali metal and has the lowest density of all known solids at room temperature. It is silvery shining, tough, soft and is able to form strong alloys with other metals.[127]

22.2 Basic Supply & Demand Statistics

With a share of 60 ppm in the earth's crust, lithium is the 27th most abundant element. The most important lithium containing mineral is spodumene, but recently also brines in salt lakes, for example in Chile, become more important as commercial sources for lithium.[128] World resources are estimated 25.5 million tons mainly located in Bolivia and Chile, but also in Argentina, China and in the United States.[129]

	Reserves (in 1000t; 2010)		Production (in 1000t; 2009)		EU imports (in t; 2007)	
USA	38	0.4%	NA		776	16,7%
Argentina	800	8.1%	2.2	12.4%	37	0,8%
Australia	580	5.9%	4.4	24.8%	10	0,2%
Brazil	190	1.9%	0.1	0.6%		
Canada	180	1.8%	0.5	2.7%		
Chile	7,500	76.1%	7.4	41.7%	2.977	63,9%
China	540	5.5%	2.3	13.0%	747	16,0%
Portugal	NA		0.5	2.8%		
Zimbabwe	23	0.2%	0.35	2.0%		
Russia					114	2,4%
Total	**9,851**		**17.7**		**4,660**	

Source: USGS 2010; trade data provided by BGS based on EU comtrade (HS 282520, 283691)

Lithium is produced in the EU by Portugal and Spain (not listed above). The most important import sources were Chile, the United States and China.

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127 Ullmann's Encyclopedia of Chemical Technology: *Lithium and Lithium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

128 Römpp Online: *Lithium.* Georg Thieme Verlag, Stuttgart, 2006

129 USGS Mineral Commodity Summaries 2010: *Lithium*

The top 5 companies producing lithium contributed nearly 78% of world production.

Mine production of Lithium in Europe:

Production of lithium minerals tonnes

Country	2003	2004	2005	2006	2007
Portugal					
Lepidolite	24 606	28 696	26 185	28 497	34 755
Spain					
Lepidolite	6 333	3 226	6 751	8 339	9 000

Production of lithium minerals in Europe(Source: European Mineral Statistics 2003-2007, BGS)

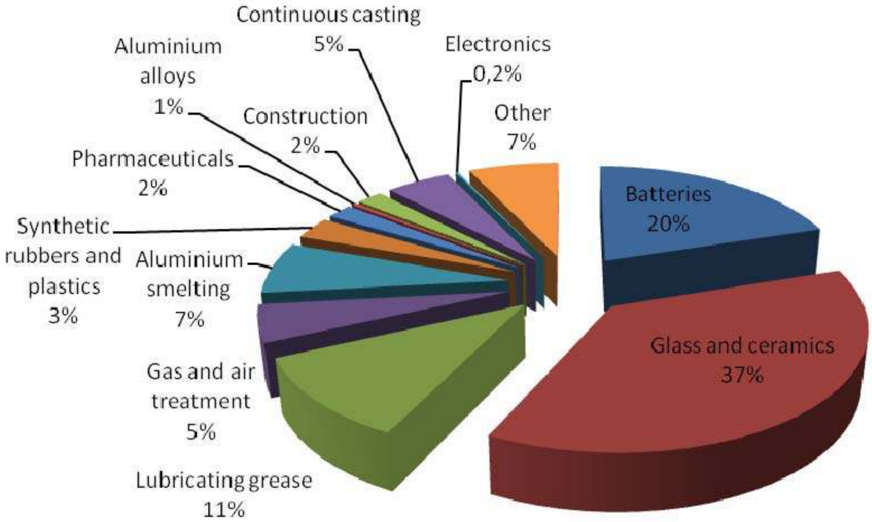
USGS reports two mining projects for lithium minerals in Europe. A spodumene mine is under development in EU27-country Finland and a jadarite mining operation in the EU *potential candidate* country Serbia. Jaradite is a quite new mineral species which was discovered in 2004 in Serbia. It contains high amounts of lithium oxide.

Pegmatite containing lithium minerals have been identified in Austria, France, Ireland, Spain and Sweden but economic conditions are not favourable for the development of these deposits.[130]

The Chilean Salar de Atacama (the greatest saline lake in the world) is the worldwide largest single deposit of lithium in terms of economically viable extraction.

[130] USGS Minerals Yearbook 2008

22.3 Economic Importance



Main end-use markets for lithium products (worldwide) in 2008[2,131]:

- Ceramics and Glass: About 37% of lithium is used for ceramics and glasses.
- Batteries: 20% is used for batteries, especially for rechargeable high-performance batteries in potable electronic devices.
- Metallurgy: For aluminum smelting, aluminum alloys and continuous casting 12% of lithium consumption is used. Lithium-aluminum alloys are used in the aircraft industry and are considered to be an important future technology.
- Greases: Another 11% is used for lubricating greases for automotive and industrial purposes.
- Other: The remaining 15% is used for air and gas treatment, pharmaceuticals and other applications.

Recent scenario projections for the use of Lithium see car batteries becoming the dominant use for Lithium by 2050. Comparison of the expected Lithium demand with current known reserves shows that no physical scarcity of lithium is to be expected in the foreseeable future.

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2 Römpp Online: *Lithium.* Georg Thieme Verlag, Stuttgart, 2006

131 Roskill Information Services: *The Economics of Lithium*, London, 2009

22.4 Resource Efficiency: Recycling & Substitution

Most lithium recycling is done in the field of batteries. The EU has set a mandatory target of 45% of batteries in portable electronics in EU MS to be recycled by 2016.[132]

Substitutes for lithium compounds are possible in batteries, ceramics, greases, and manufactured glass.

Examples are:

- calcium and aluminum soaps as substitutes for stearates in greases;
- calcium, magnesium, mercury, and zinc as anode material in primary batteries; and
- sodic and potassic fluxes in ceramics and glass manufacture.
- Lithium carbonate is not considered to be an essential ingredient in aluminum potlines.
- Substitutes for aluminum-lithium alloys as structural materials are composite materials consisting of boron, glass, or polymer fibers in engineering resins.[133]

22.5 Specific issues

According to the European Commission's inventory on export restrictions, only South Africa applies a non-automatic export licensing system on lithium ore.

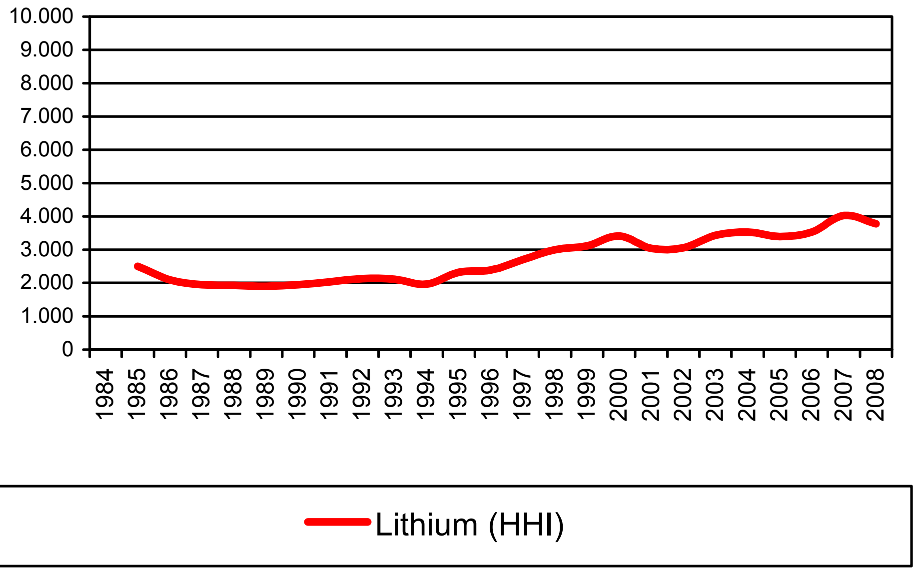
132 Swedish Geological Survey 2009

133 USGS Mineral Commodity Summaries 2009: *Lithium*

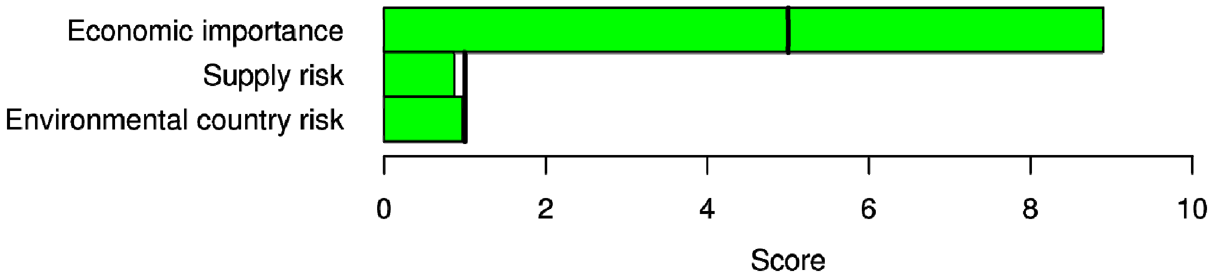
Use	Share	Megasector	Subst.
Batteries	20%	Electronics & ICT	1,0
Glass and ceramics	37%	Rubber, Plastic & Glass	1,0
Lubricating grease	11%	Refining	0,7
Gas and air treatment	5%	Chemicals	0,3
Aluminium smelting	7%	Metals	0,3
Synthetic rubbers and plastics	3%	Rubber, Plastic & Glass	0,7
Pharmaceuticals	2%	Pharmaceuticals	0,3
Aluminium alloys	0,4%	Aircraft, Shipbuilding, Trains	0,7
Construction	2%	Construction material	0,7
Continuous casting	5%	Metals	0,7
Electronics	0,2%	Electronics & ICT	0,3
Other	7%	Other Final Consumer Goods	0,5

Substitutability index	0,80
Recycling rate (recycled content from old scrap)	0%
Import Dependence	74%

Results	
Economic importance	5,6
Supply Risk	0,7
Environmental Country Risk	0,9



Source: World Mining Data, 2010



23 Magnesite

23.1 Introduction

Magnesite is an industrial mineral composed of magnesium carbonate (MgCO3). Pure magnesite is theoretically 47.8% magnesia (MgO) and 52.2% carbon dioxide (CO2).

Most importantly magnesite is used to produce magnesia (MgO) as the commercial grades of caustic calcined magnesite (CCM), dead burned magnesite (DBM) and fused magnesia (FM)

DBM and FM are used predominantly in the refractory industry, CCM is used mostly in chemical-based applications such as fertilizer and stock food, pulp and paper, iron and steelmaking, hydrometallurgy and waste/water treatment.

23.2 Basic Supply & Demand Statistics

An estimated figure of 50% of all crude magnesite output takes place in China although significant amounts are also produced in Russia, Turkey, Slovakia and North Korea.

Turkey as the largest supplier of magnesite for the EU market, accounting for almost 69% of total EU imports in 2006.

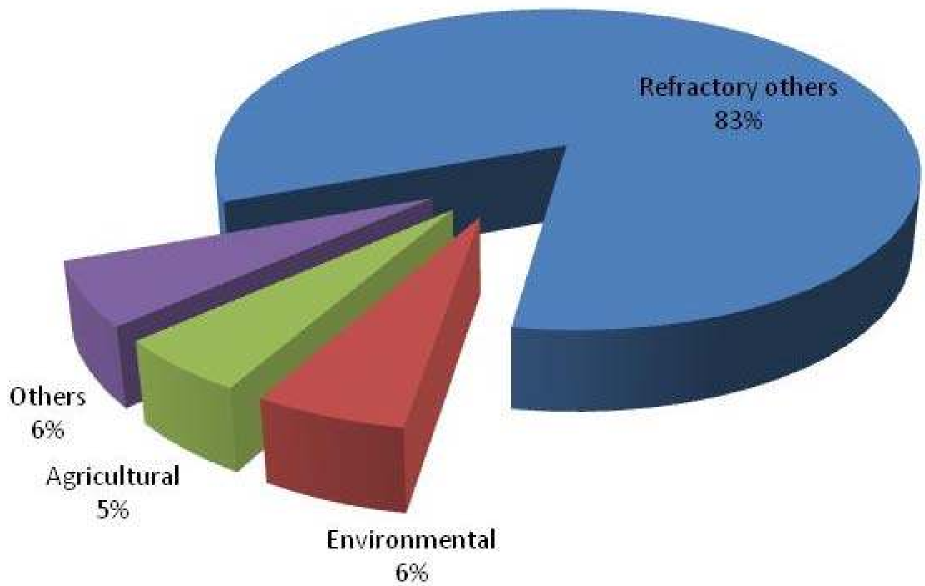
	Reserves (in 1000t)		Production (in 1000t; 2008)		EU imports (in 1000t; 2006)	
Australia	120,000	3.3%	126	0.6%		
Austria	20,000	0.6%	837	4.1%		
Brazil	65,000	1.8%	387	41.9%	5.9	10.4%
China	860,000	23.9%	10,000	49%	10.2	17.9%
Greece	30,000	0.8%	530	2.6%		
India	55,000	1.5%	247	1.2%		
Korea, Dem. People's Rep. Of (e)	750,000	20.9%	1,200	5.9%		

Russia	730,000	20.3%	2,600	12.7%		
Slovakia	319,000	8.9%	1,439	7.1%		
Spain	30,000	0.8%	443	2.2%		
Turkey	160,000	4.5%	2,143	10.5%	39.1	68.7%
USA	15,000	0.4%	W		0.7	1.2%
Other countries	440,000	12.2%	455	2.2%	1.0	1.8%
World Total	**3,594,000**		**20,407**		**57**	

Source: World Magnesite Producers and Fraunhofer ISI; Roskill Report[134], UN Comntrade HS 251910;

World Mining Data 2010 W – Information withheld / confidential

23.3 Economic Importance



Magnesite is mainly used for the production of Magnesia for the refractory industries (steel, cement and other refractory totalling estimated 80 - 87%). An estimated 13-20% of the magnesia world production is used for environmental, agricultural and other applications (e.g. sports). Magnesite is mainly used for the production of Magnesia. Magnesite is rarely used

134 Roskill Report: Magnesium Compounds & Chemicals: Global Industry Markets & Outlook

without being calcined into Magnesia although small amounts are sold for construction (slag conditioning, hydraulic construction etc)

23.4 Resource Efficiency: Recycling & Substitution

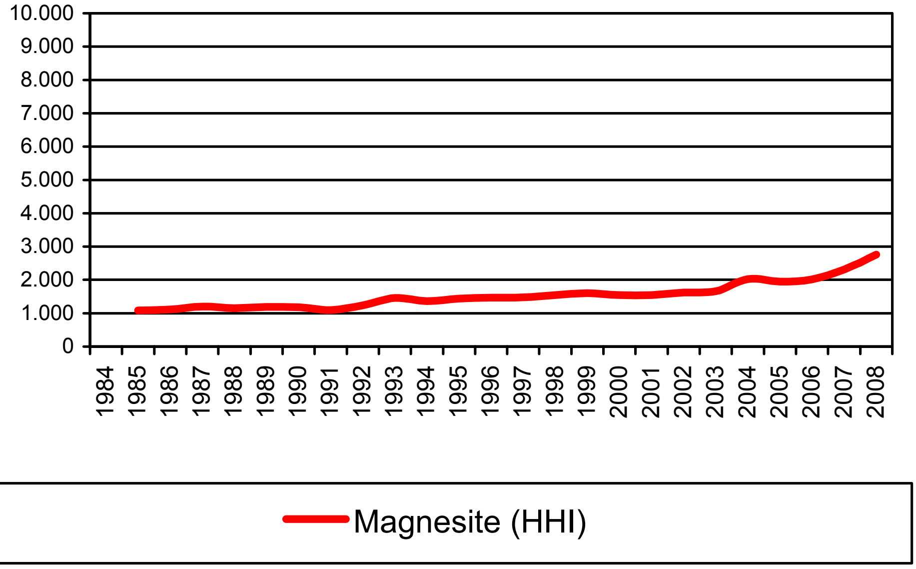
As Magnesite is only used in the calcined form as Magnesia it can not be recycled. Animal feed and fertilisers are consumed, so there is no way of recycling. But refractory bricks are recycled up to 10%.

The substitution factor for magnesia is considered to be very low in the steel industry (an estimated 5%), while in the cement industry the factor could be as high as 30% (e.g. bauxite or alumina).

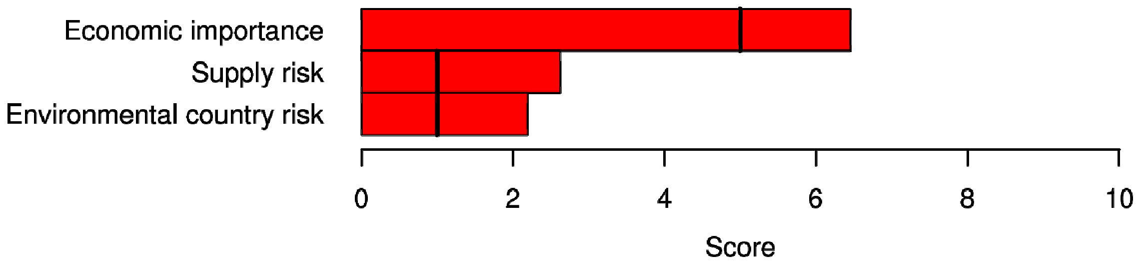
Use	Share	Megasector	Subst.
Refractory others	83%	Metals	0,7
Environmental	6%	Chemicals	0,7
Agricultural (animal feed & fertilizers)	5%		1,0
Cement-industry	1%	Construction Material	0,7
Others	5%	Other Final Consumer Goods	0,8

Substitutability index	0,72	
Recycling rate (recycled content)	0%	No information available
Import Dependence	2%	

Results	
Economic importance	8,9
Supply Risk	0,9
Environmental Country Risk	1,0



Source: World Mining Data, 2010



24 Magnesium

24.1 Introduction

The alkaline earth metal "Magnesium" cannot be found as a free element (Mg) naturally on earth.

Although magnesium is found in over 60 minerals, only dolomite, magnesite, brucite, carnallite, and olivine are of commercial importance. Magnesium and other magnesium compounds are also produced from seawater, well and lake brines and bitterns.

Magnesium metal is used in the metallurgical process, as a fire starter, in pyrotechniques and military and in electronic components. Magnesium alloys are used as compounds of alluminum alloys, in medicine and aerospace/automotive/truck construction.

24.2 Basic Supply & Demand Statistics

According to USGS, resources from which magnesium compounds can be recovered range from large to virtually unlimited and are globally widespread. Identified world resources of magnesite total 13 billion tons, and of brucite, several million tons. Resources of dolomite, forsterite, magnesium-bearing evaporite minerals, and magnesia-bearing brines are estimated to constitute a resource in billions of tons. Magnesium hydroxide can be recovered from seawater.

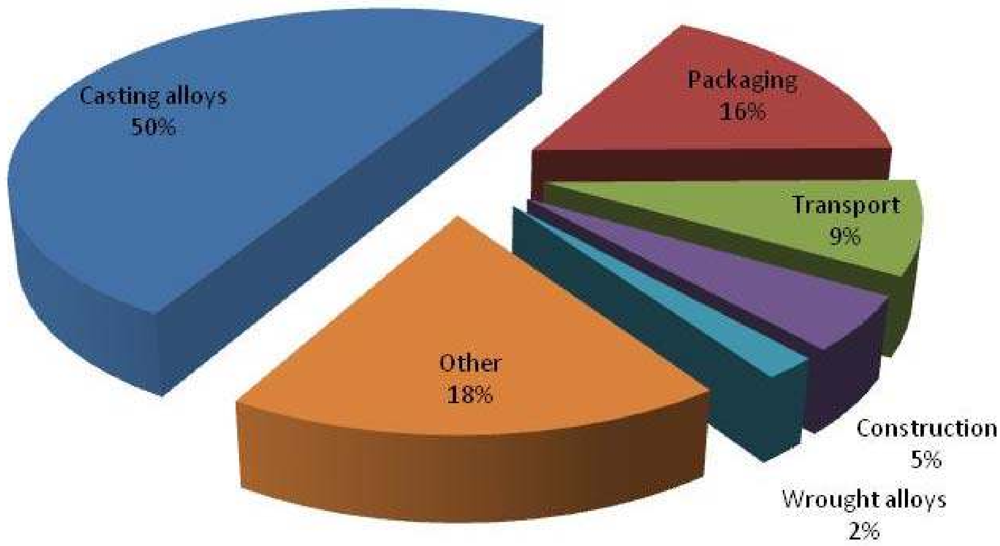
	Magnesite Reserves (in 1000 t)		Magnesite Production (in 1000t; 2009)		EU imports (in 1000t; 2006)	
United States	10,000	0.4%	N/A			
Australia	100,000	4.4%	130	2.6%		
Austria	15,000	0.7%	200	4.0%		
Brazil	99,000	4.4%	100	2.0%		
China	400,000	17.7%	2,800	56.1%	1,156	81.5%
Greece	30,000	1.3%	100	2.0%		
India	14,000	0.6%	100	2.0%		
Korea, North	450,000	19.9%	50	1.0%		
Russia	650,000	28.9%	350	7.0%	44	3.1%
Slovakia	36,000	1.6%	270	5.4%		

Spain	10,000	0.4%	130	2.6%		
Turkey	49,000	2.2%	600	12.0%		
Other countries	390,000	17.3%	160	3.2%	218	15.4%
World total	2,253,000		30,190		1,418	

Source: USGS; ComExt Data CN 8104 19 00; CN 8104 11 00

The figures above refer to magnesite production and not to magnesium metal. Production of later in 2009 is estimated at 570,000 tonnes, of which 470,000 was produced in China.

24.3 Economic Importance



Magnesium metal's principal use is as an alloying addition to aluminium, and these aluminium-magnesium alloys are used mainly for beverage cans. Magnesium alloys also are used as structural components of automobiles and machinery. Magnesium also is used to remove sulphur from iron and steel.

- 50% of Magnesium is used for Casting alloys: Traditionally, magnesium alloys have been driven in the market due to the required needs of aerospace industry for lightweight materials. The low density of magnesium alloys have been a major factor in the far flung usage of wrought products and magnesium alloy castings. Now in recent times, premium corrosion performance and dramatic advancements have been exhibited for new magnesium alloys. These improvements have led to greater interest in aerospace and specialty applications. Even, in some popular programs like McDonnell Douglas MD 500 helicopter, magnesium alloys have been specified and utilised.

- Magnesium is also used for Al-alloys: Packaging (beverages). It is used for the coating of the aluminum beverage packages.

24.4 Resource Efficiency: Recycling & Substitution

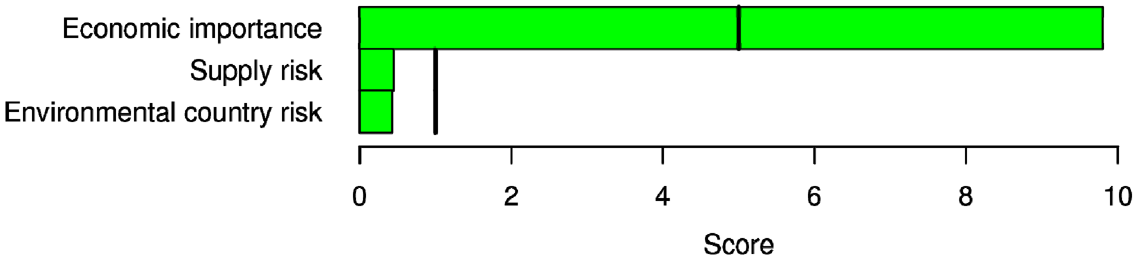
The recycling rate for magnesium is 33%. As with most other metals, recycling helps reduce energy costs and import dependency. This rate should increase in the coming years.

Aluminum and zinc may substitute for magnesium in castings and wrought products, while chromite and silica substitute for magnesia in some refractory applications.

Use	Share	Megasector	Subst.
Casting alloys (mainly car parts)	50%	Road transport	1
Wrought alloys	2%	Metals	0,7
Al-alloys: Packaging (beverages)	17%	Beverages	0,7
Al-alloys: Transport	9%	Road transport	0,7
Al-alloys: Construction	5%	Construction material	0,7
Al-alloys: Other	3%	Metals	0,7
Other	15%	Other Final Consumer Goods	0,5

Substitutability Index	0,82
Recycling Rate (recycled content from old scrap)	14%
Import Dependence	100%

Results	
Economic Importance	6,4
Supply Risk	2,6
Environmental Country Risk	2,2



25 Manganese

25.1 Introduction

Manganese is probably one of the most important heavy metals due to it's indispensability in steel production.[135] The principal manganese use is in steel industry as a desulphurization agent and an alloying agent, where it provides hardness and wear resistance. If the manganese-content in steel exceeds a certain value, non-magnetic steel can be produced. It finds application as retainer rings for turbo alternators and collars on oil rigs.

Manganese is also an important constituent of many aluminium alloys which contains up to 9% manganese.

Manganese dioxide is a component of dry-cell batteries; other compounds are used in the chemical industry.

25.2 Basic Supply & Demand Statistics

Manganese is the second most common heavy metal in the earth's crust (950 ppm). As it is a base metal, it always occurs in compounds. To be of economical interest, the ores should have manganese content between 30 and 55%.[136] Deposits of manganese containing ores are large but irregularly distributed in many parts of the world. 80% of the identified resources are located in South Africa, 10% are located in the Ukraine.[137]

	Reserves (in 1000t; 2010)		Production (in 1000t; 2009)		EU imports (in 1000t, 2007)	
Australia	87,000	16.2%	1,600	16,6%	9.5	0,7%
Brazil	29,000	5.4%	990	10,2%	504	37,6%
China	40,000	7.4%	2,400	24,8%		
Gabon	52,000	9.7%	810	8,4%	337	25,1%
India	56,000	10.4%	960	9,9%		
Mexico	4,000	0.7%	94	1,0%		

135 SBB insight, issue 113, 2010

136 Römpp Online: *Mangan.* Georg Thieme Verlag, Stuttgart, 2006

137 USGS Mineral Commodity Summaries 2010: *Manganese*

South Africa	130,000	24.2%	1,300	13,5%	426	31,8%
Ukraine	140,000	26.0%	310	3,2%	25	1,9%
USA					0.5	0,0%
Norway					38	2,9%
Georgia					0.06	<0,1%
other	small		1,200	12,4%		
Total	**538,000**		**9,664**		**1,340**	

Source: USGS 2010; trade data provided by BGS based on EU comtrade (HS 2602)

Among some 300 minerals containing manganese, only a dozen are of mining significance. Current estimates of world manganese reserves including low grade ore, reach several billion tons. But if only high grade ores (defined as having more than 44% Mn content) are considered then reserves are in the range of 540 million tons of ore, essentially situated in the southern hemisphere, with Australia, Brazil, Gabon and South Africa, supplying over 90% of the international market. Ghana and India, both large suppliers in the past, are now exporting only limited quantities of low or medium grade ore. The ore mined in Mexico is mostly for internal usage.

The CIS, which as the USSR was the largest supplier of manganese ore at the beginning of the century, is now left with low grade ore reserves which have to be upgraded for commercial use. Only a limited amount of these reserves is exported. Manganese ore deposits are widely distributed in China, but there is neither high grade ore nor important reserves, and mines are generally situated far from the end-user industries. In consequence, China imports high grade ores to blend with domestic material.

In addition to these land-based deposits, there are also large manganese reserves in the form of poly-metallic nodules off shore in depths around 5000 m. Nodules contain on average 25% Mn (their main constituent) and lie in thin layers at a depth of approximately 5.000 meters. Recovery will be difficult and very expensive. They are seen as potentially valuable resources for the long-term future[138] for which the EU would have eventually major access through France and is already developing technology.

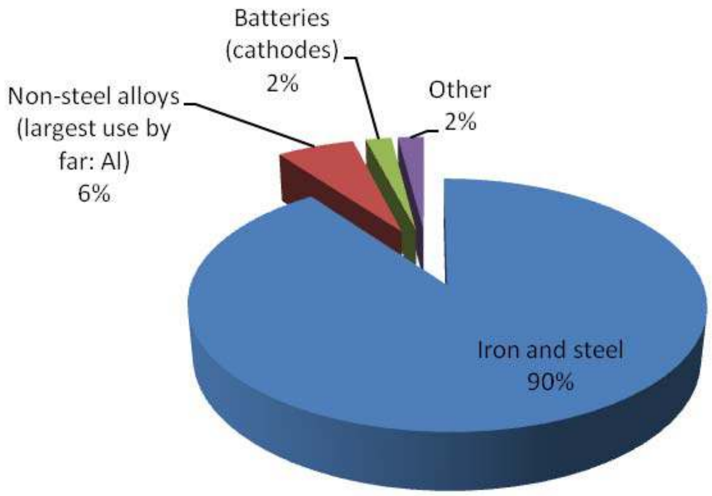
In 2007, 128,000 tons of manganese were produced within the European Union, by Hungary (40% of EU production), Romania (38%) and Bulgaria (22%). In the same year imports added up to 1.3 million metric tons, which is 84% of the consumption of EU member states. Together they produced some 32,195 tones of manganese (content).

[138] International Manganese Institute

European based companies Anglo-American, Eramet and Areva are involved in the manganese business.

As the demand for manganese exceeds the production, Europe has to be considered import dependent.

25.3 Economic Importance



By far the largest use of manganese (approx. 90%) is in steel metallurgy[139], where it is used as a deoxidising and desulfurising agent. Other uses are[140]:

- Other Metallurgy: Used in copper and nickel smelting for the same purpose.
- Corrosion protection: Used to improve the corrosion resistance of aluminum alloys.
- Non-metallurgy applications: Production of dry cell batteries, plant fertilisers and animal feed and as brick colorant.

To specify the use-structure, some innovative applications shall be mentioned in the following, each containing a more or less important amount of manganese[141]:

- tailored blanks (reducing weight in car bodies);
- airframe light weight construction (reducing weight in aviation);
- micro-electronic capacitors;

139 Roskill Information Services: *The Economics of Manganese*, London, 2008

140 Römpp Online: *Mangan.* Georg Thieme Verlag, Stuttgart, 2006

141 Source: BMWi-study: *Rohstoffe für Zukunftstechnologien* and International Manganese Institute

- some forms of Li-ion batteries use manganese as cathode (lithium-manganese batteries);
- corrosion-resistant material that find application in desalination of seawater;
- (e.g. stainless steel NIROSTA® contains between 3.5-6.5% manganese[142]);
- super-alloys;
- potassium permanganate (multi-use chemical, e.g. disinfectant, algicide, odour-control);
- ‘Maneb’ (manganese-ethylene bisdithiocarbamate, agricultural fungicide);

25.4 Resource Efficiency: Recycling & Substitution

Manganese was recycled incidentally as a minor constituent of ferrous and non-ferrous scrap. However, scrap recovery specifically for manganese was negligible. Manganese is recovered along with iron from steel slag.[143] Estimations differ from 12%[144] to 25%[145] of recycled manganese content from old scrap.

Manganese has no satisfactory substitute in its major applications.[146]. Furthermore, it is used as a substitute for other commodities like chromite or vanadium.

25.5 Specific issues

According to the EU Commission’s inventory on export restrictions, manganese in general is subject to export taxes in China (20%) and Russia (6.5%). Manganese waste and scrap in particular is subject to a system of non-automatic export licensing in Algeria and South Africa, and to an export ban in Tanzania.

142 ibid.

143 USGS Mineral Commodity Summaries 2009: *Manganese*

144 Estimated by Working Group

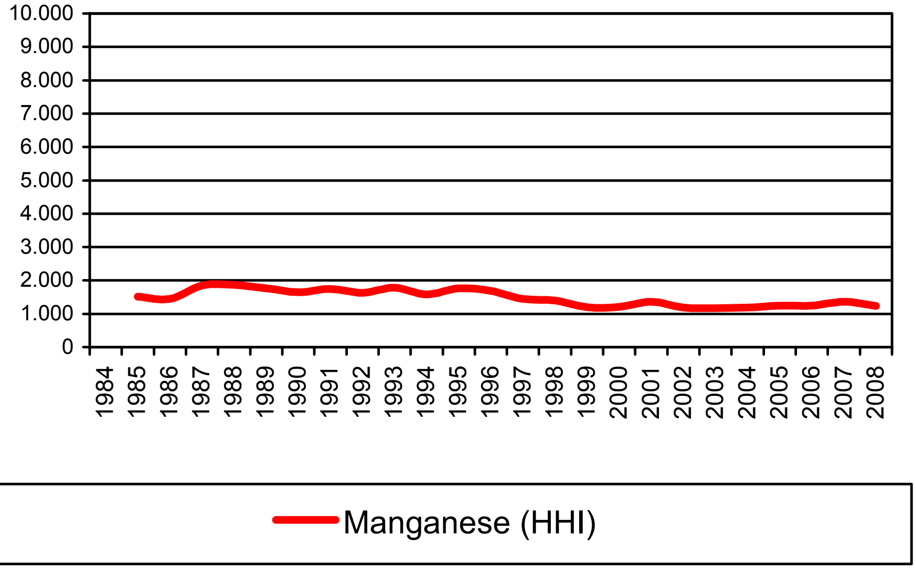
145 Jones, USGS (2004)

146 ibid.

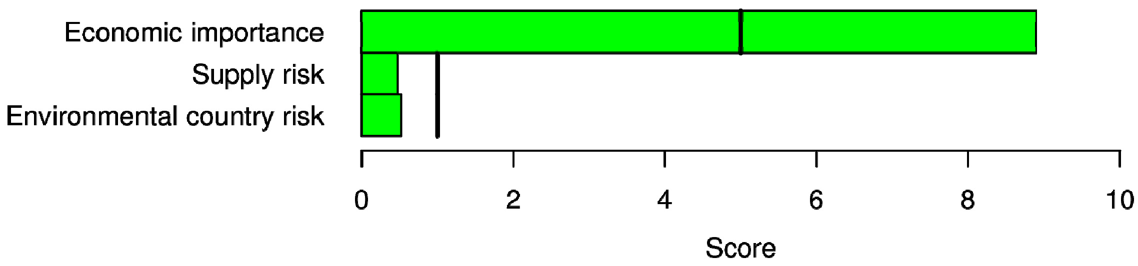
Use	Share	Megasector	Subst.
Iron and steel	90%	Metals	1,0
Non-steel alloys (largest use by far: Al)	6%	Metals	0,7
Batteries (cathodes)	2%	Electronics & ICT	0,0
Other	2%	Other Final Consumer Goods	0,5

Substitutability	1,0
Recycling Rate (recycled content from old scrap)	19%
Import Dependence	91%

Results	
Economic Importance	9,8
Supply Risk	0,4
Environmental Country Risk	0,4



Source: World Mining Data, 2010



26 Molybdenum

26.1 Introduction

Molybdenum is a lustrous silver-white, hard and brittle metal with many favorable properties. Among these are its high mechanical strength even at high temperatures, a low coefficient of thermal expansion and its good heat conductivity.

Molybdenum occurs as the principal metal sulfide in large low-grade porphyry molybdenum deposits and as an associated metal sulfide in low-grade porphyry copper deposits. Resources of molybdenum are adequate to supply world needs for the foreseeable future.[147]

Molybdenum forms alloys with many other metals such as aluminum, tungsten, lead, niobium, chromium, manganese and iron.[148] In many of these alloys a small share of molybdenum increases the hardenability, strength, toughness and corrosion resistance, which explains its importance in the iron, steel and superalloy industry.[149]

26.2 Basic Supply & Demand Statistics

With an estimated abundance of 1 to 1.5 ppm in the earth's crust, molybdenum belongs to the rare elements.[1] The most important molybdenum ore is molybdenite, which can be found all over the world, but in fact the content of MoS_2 is only between 0.25 and 0.5%, even in ores which are of economical interest.[3] Due to its importance in metallurgy, demand for molybdenum is strongly correlated to the demand for steel products.[2] Molybdenum is mined both as primary product and as a byproduct of copper mines.[1]

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147 USGS Mineral Commodity Summaries 2010: *Molybdenum*

148 Römpp Online: *Molybdän.* Georg Thieme Verlag, Stuttgart, 2006

149 Ullmann's Encyclopedia of Chemical Technology: *Molybdenum and Molybdenum Compounds*. Wiley-VCH Verlag, Weinheim, 2006

	Reserves (in 1000t; 2010)		Production (in 1000t; 2009)		EU imports (in 1000t; 2006)	
USA	2,700	31,0%	50	24.6%	46.6	47.0%
Armenia	200	2,3%	4	2.0%		
Canada	450	5,2%	7	3.5%	2.9	3.0%
Chile	1,100	12,6%	32	15.8%	31.4	31.5%
China	3,300	37.9%	77	37.9%	9.9	10.0%
Iran	50	0.6%	3	1.5%	0.8	0.8%
Kazakhstan	130	1.5%	0.4	0.2%		
Kyrgyzstan	100	1.1%	0.25	0.1%		
Mexico	135	1.6%	7.2	3.5%	1.2	1.2%
Mongolia	100	1.1%	3	1.5%		
Peru	140	1.6%	15	7.4%	6.2	6.2%
Russia	240	2.8%	3.4	1.7%		
Uzbekistan	60	0.7%	0.4	0.2%		
United Arab Emirates					0.4	0.4%
Total	**8,705**		**202**		**99.2**	

Source: USGS 2010; trade data provided by BGS based on EU comtrade (HS 2613)

According to the BGS and the USGS there is no molybdenum production in Europe. Also the Austrian World Mining Data 2009 does not mention any EU-based production.

However, there are two EU based companies involved in this business: Rio Tinto and Anglo-American.

In contrast to these reports, the German BGR[150] states that there is some small molybdenum ore production in Bulgaria. This is said to be limited to 0.2% of worldwide production. As molybdenum is a by-product in copper mining and Bulgaria is mining some copper, this figure is possible.

Apart from the mine production, some companies in Belgium, the Netherlands and UK roast molybdenum concentrates to molybdenum trioxide.

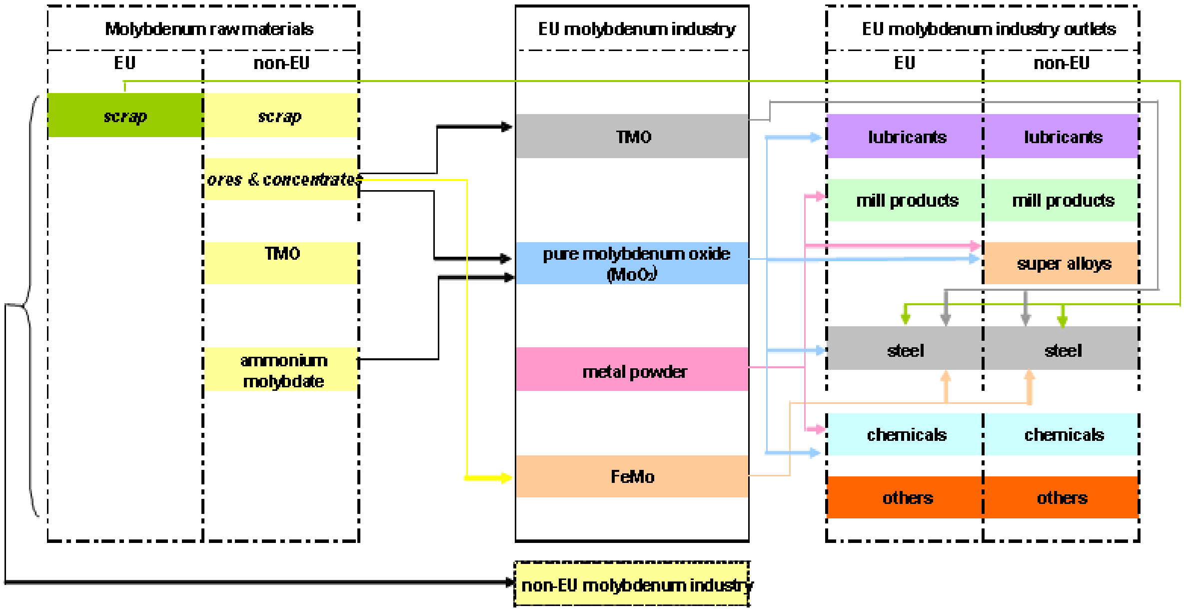
The biggest deposit of molybdenum in Europe is situated in Norway, though there is no molybdenum production within the EU at the moment.[151] As a consequence the EU's molybdenum consumption is covered by imports, mainly from the United States and

[150] Rohstoffwirtschaftliche Laenderstudien Heft XXXVIII (raw materials situation of the Federal republic of Germany 2008), published in German

[151] Römpp Online: *Molybdän.* Georg Thieme Verlag, Stuttgart, 2006

from Chile. Though, it is announced that a copper mine in Sweden will start producing molybdenum as a byproduct in 2010.[152] World resources are adequate for projected demands in the foreseeable future.[153]

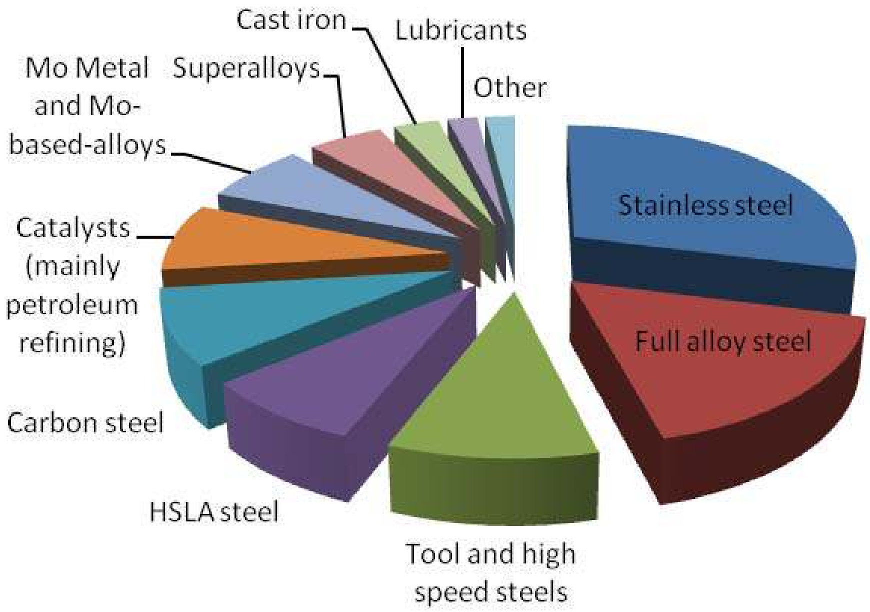
Due to its importance in metallurgy, demand for molybdenum is strongly correlated to the demand for steel and superalloy products (Roempp, Molybdän, 2006). However, the EU molybdenum industry, which consists of only a few companies, features not only ferro-molybdenum production, but also molybdenum oxides (technical molybdenum oxide and pure molybdenum oxide) and metal powders and products. Their combined annual output is hovering between 65.000 t to 75.000 t molybdenum. Their feed supplies (ores and concentrates, technical oxide and scrap) are imported meaning that they are entirely dependent on access to raw materials on the international market. The industry's structure is as follows:



[152] SVERIGES GEOLOGISKA UNDERSÖKNING, Carl-Magnus Backman

[153] USGS Mineral Commodity Summaries 2010: *Molybdenum*

26.3 Economic Importance



As mentioned above, molybdenum improves the properties of alloys and therefore it is used for several metallurgical applications:

- Cast iron
- Constructional steel
- Stainless steel
- Tool steel
- Superalloys

Molybdenum compounds are also used for catalysts, pigments, corrosion inhibitors, lubricants, refractories and other applications.[154]

While molybdenum mill products are, in terms of volume, of lesser importance than molybdenum as an alloying element in the steel industry, in terms of strategic importance, they are significant as many ordinary, products require Molybdenum mill products which are in many cases not substitutable. Such high-tech applications are for example the following:

- High temperature heating elements, radiation shields, extrusions, forging dies, etc;
- Rotating X-ray anodes used in clinical diagnostics;

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[154] Römpp Online: *Molybdän.* Georg Thieme Verlag, Stuttgart, 2006

- Glass melting furnace electrodes and components that are resistant to molten glass;
- Heat sinks for semiconductor industry;
- Sputtered layers for LCD displays;
- Sprayed coatings on automotive piston rings.

26.4 Resource Efficiency: Recycling & Substitution

There is no information available on Europe. Although molybdenum is not recovered from scrap steel, recycling of steel alloys is significant, and some molybdenum content is reutilized. The amount of molybdenum recycled as part of new and old steel and other scrap may be as much as 30% of the apparent supply of molybdenum.

Due to its availability and its favorable properties there have been only little efforts to substitute molybdenum in its major applications, yet.

Possible substitutes are:

- chromium, vanadium, niobium and boron in alloy steels;
- tungsten in tool steels; graphite, tungsten, and
- tantalum for refractory materials in high-temperature electric furnaces; and
- chrome-orange, cadmium-red, and organic-orange pigments for molybdenum orange.[155]

German BGR states that sources for recycled molybdenum were used catalysts from the oil industry and – to a smaller amount – superalloy scrap. The estimated recycling rate was around 10 per cent. Used catalysts contain between 2-10% of molybdenum.

26.5 Specific issues

Trade Issues:

According to the European Commission’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. South Africa also applies a licensing system to molybdenum ore and concentrates. China resorts to a combination of export quotas and export taxes (from 15 to 20%) on ores and concentrates, technical oxide, molybdates, unwrought metal and scrap.

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[155] USGS Mineral Commodity Summaries 2010: *Molybdenum*

Market Issues:

On the supply side, the EU molybdenum industry is sourcing all primary feed of raw material from outside the EU, with a strong reliance on Chinese producers as regards ores, concentrates, oxides and molybdates.

The major concern is that China is endowed with the largest reserve base of molybdenum-bearing minerals in the world (44 % of world resources, whilst the USA and Chile account for 28 % and 13 % respectively). A sizeable mine production developed on this reserve base over the years and China became top ranking world molybdenum producer in 2007, ahead of the USA and Chile.

Several measures are however affecting China's exports of molybdenum:

- Exports are operated under a system of export quota and licences – the quota and licences concern raw materials and unwrought molybdenum products whilst wrought products (wire, rods, shaped parts) are free of any constraint on exports (i.e. not included in the export quota).
- In addition, the *differentiation of the taxation regime on export* (VAT refund on export and export tax) according to the type of material/product provides a very effective support to the development of downstream products production for export. In this respect, molybdenum wrought products, including *wire, benefit from the most favorable treatment* along the value chain with a *VAT rebate on export of 5 percentage points and no export tax* whilst there is no VAT rebate on export for most molybdenum raw materials a 5% to 20% export tax applies.

This means that China has put in place a system whereby there is dual pricing on raw materials to the benefit of its domestic producers and there is a clear encouragement to the export of value added mill products whose market is far more narrow than the metallurgical market (steels, alloy steels and alloys).

On the demand side, the EU molybdenum industry has historically developed a world leadership as top ranking suppliers on the global market for mill products. The EU market is the industry's natural outlet but many industry consuming molybdenum based products are located in the USA and Asia. These markets are increasingly important markets for the EU molybdenum industry.

Demand growths within and outside the EU and competitiveness on the export market is essential to the development of the EU molybdenum industry. It is increasingly confronted on export markets with Chinese competition whose pricing policy is destructive of the normal price structure (prices for value added products are quoted below metal price) which is related to the impacts of State macro-control measures applied to the value chain in China:

Rather than restricting the development of the domestic molybdenum industry, the State macro-control measures enable it to consolidate and diversify whilst sheltering it from the operation of international market forces. They also actually result in a distortion of the latter in two particular respects:

- conditions are created for the arising of dual pricing of the raw material (technical molybdenum oxide), and

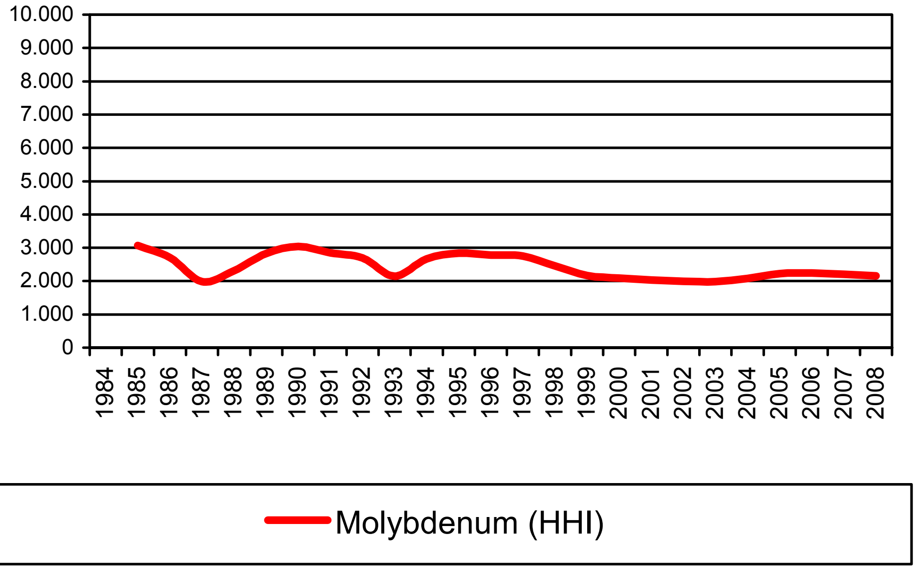
- export flows of certain products only are artificially inflated, thereby creating abnormal competitive pressure on the markets for these products.

Under these circumstances, securing a level playing-field in access to tungsten raw materials is increasingly seen as vital conditions for ensuring the future viability of the EU tungsten industry.

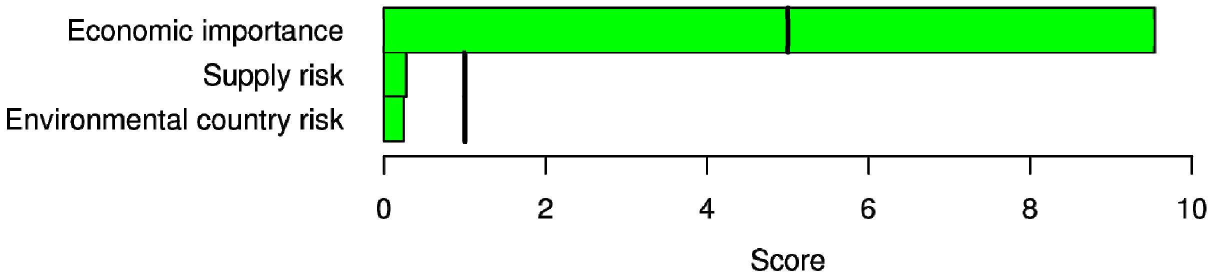
Use	Share	Megasector	Subst.
Stainless steel	29%	Metals	1,0
Full alloy steel	17%	Metals	0,3
Tool and high speed steels	10%	Metals	0,7
HSLA steel	8%	Metals	0,7
Carbon steel	9%	Metals	0,3
Catalysts (mainly petroleum refining)	8%	Refining	0,7
Mo Metal and Mo-based-alloys	7%	Electronics & ICT	1,0
Superalloys	5%	Metals	0,7
Cast iron	3%	Metals	0,7
Lubricants	2%	Chemicals	1,0
Other	2%	Other Final Consumer Goods	0,5

Substitutability index	0,71
Recycling rate (recycled content from old scrap)	17%
Import Dependence	100%

Results	
Economic Importance	8,9
Supply Risk	0,5
Environmental Country Risk	0,5



Source: World Mining Data, 2010



27 Nickel

27.1 Introduction

Nickel is a ferrous metal which is hard, tough ductile, and malleable. Nickel-bearing alloys are valued for their corrosion resistance, high melting point, ductility, malleability and magnetic properties.

27.2 Basic Supply & Demand Statistics

The vast majority of reserves are found outside of the European Union, most notably in Oceania (Australia and New Caledonia), Russia and the Americas (Canada, Cuba, Brazil). More than 10% of the reserves are located in New Caledonia which is part of the French territory.

As a result, mine production mainly takes place outside the EU whose mine output (in New Caledonia, Greece, Spain and Finland) represents only 8.6% of world total. Between 1995 and 2008, world production almost doubled from 920,000t in 1995 to almost 1.6 billion tonnes. Currently, there are in total 22 EU mining projects, 16 of them take place in Finland and 6 in Sweden. Out of the total, 14 projects are in conceptual phase, 8 are in pre-feasibility phase[156].

	Reserves (in 1000 t; 2009)		Production (in 1000t; 2008)		Imports to EU (ore) (in t, 2006)	
Australia	26,000	36.9%	200	12.7%	168	89.6%
New Caledonia	7,100	10.1%	103	6.6%		
Russia	6,600	9.4%	277	17.6%		
Cuba	5,500	7.8%	67	4.3%		
Brazil	4,500	6.4%	57	3.6%		
Canada	4,100	5.8%	260	16.5%	4.5	
South Africa	3,700	5.2%	32	2.0%		

156 Raw Materials Data. Copyright: Raw Materials Group, Stockholm, 2009

Indonesia	3,200	4.5%	193	12.3%		
Columbia	1,700	2.4%	76	4.9%		
China	1,000	1.4%	68	4.3%		
Philippines	940	1.3%	84	5.3%		
Dominican R.	840	1.2%	31	2.0%		
Botswana	490	0.7%	38	2.4%		
Greece	490	0.7%	19	1.2%		
Venezuela	490	0.7%	13	0.8%		
Spain	57	0.1%	8	0.5%		
Others	3,800	5.4%	46	2.9%	15	
Total	**70,507**		**1,572**		**188**	

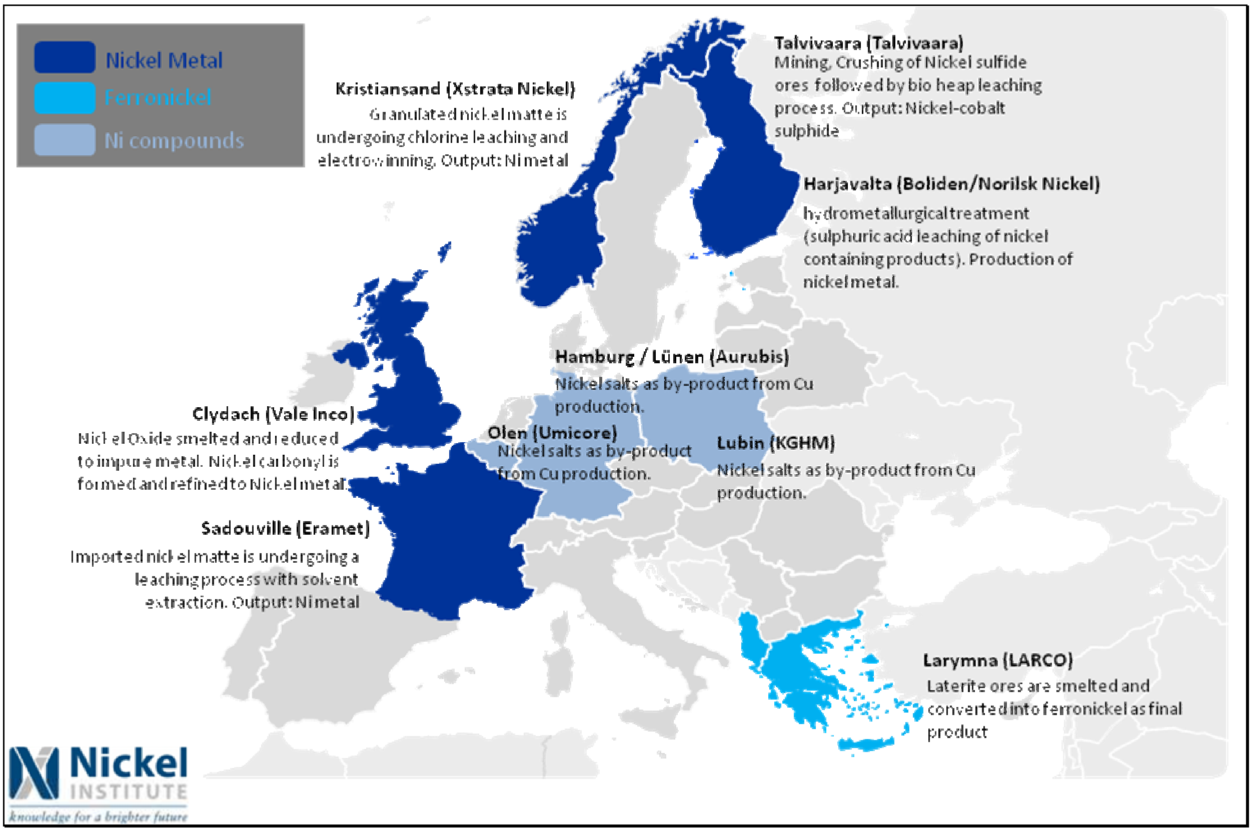
Source: USGS, 2010; UNComtrade HS 2604

In 2007, a total 15 companies accounted for around 75% of the global nickel metal production. Main nickel producing companies are:

- Norilsk Nickel (17.9%)
- Companhia Vale do Rio Doce (17.1%),
- BHP Billiton Group (8.2%),
- PT Antam Pk (6.9%)
- Xstrata plc (5.3%)

These five companies account to more than 50% of the global nickel production.

Several of them have operations in Europe, in fact. This is the case of Vale in the UK (Vale Inco) and Norilsk in Finland (in addition to Talvivaara). Other major EU nickel producers can be found in France (Eramet), Greece (Larco) and New Caledonia (Eramet, Vale Inco, Xstrata). In addition, there is a nickel production site in Norway (Xstrata). All the sites are characterized by different technologies, input material as well as output.

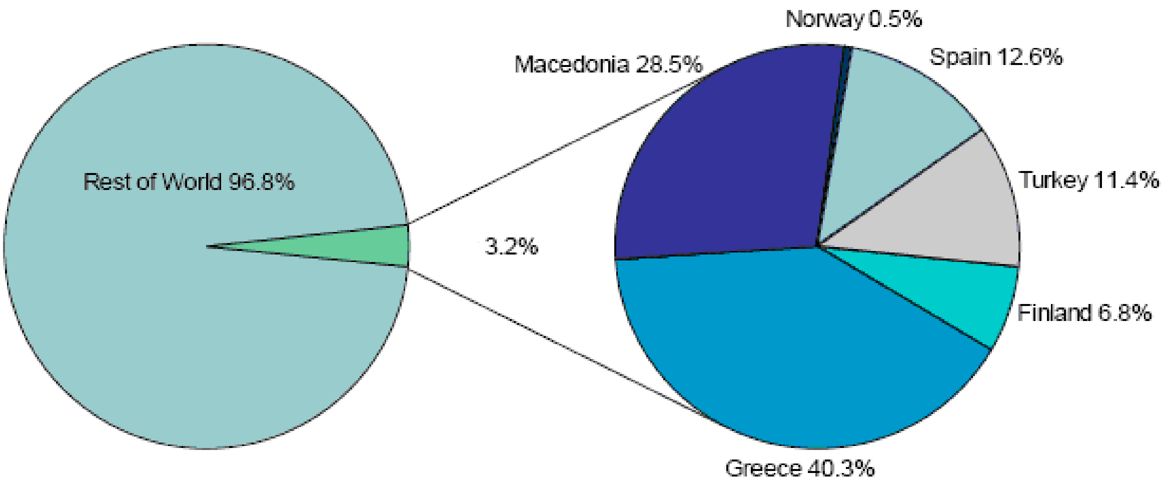


Besides these producers, there are a number of companies where nickel compounds occur as a by-product of other base metals refining (Aurubis (Germany), Umicore (Belgium), KHGM (Poland)). The Ni compounds are converted into nickel metal, sold to galvanizers or used as feedstock for special chemicals.

The industry structure is such that the European Union is a net importer of mine product (on average 20% of total world mine production) but it is also a net importer of both nickel metal and nickel containing intermediates, such as oxides, mattes and sinters for refining.

Nickel demand in the EU is quite important: five out of the top 10 nickel-using markets are located in the European Union. Germany is the fourth most important nickel-using market. Other countries with high nickel demand are Italy, Belgium, Spain and Finland. Nickel use in these markets is essentially linked to stainless steel production, the main downstream use of nickel.

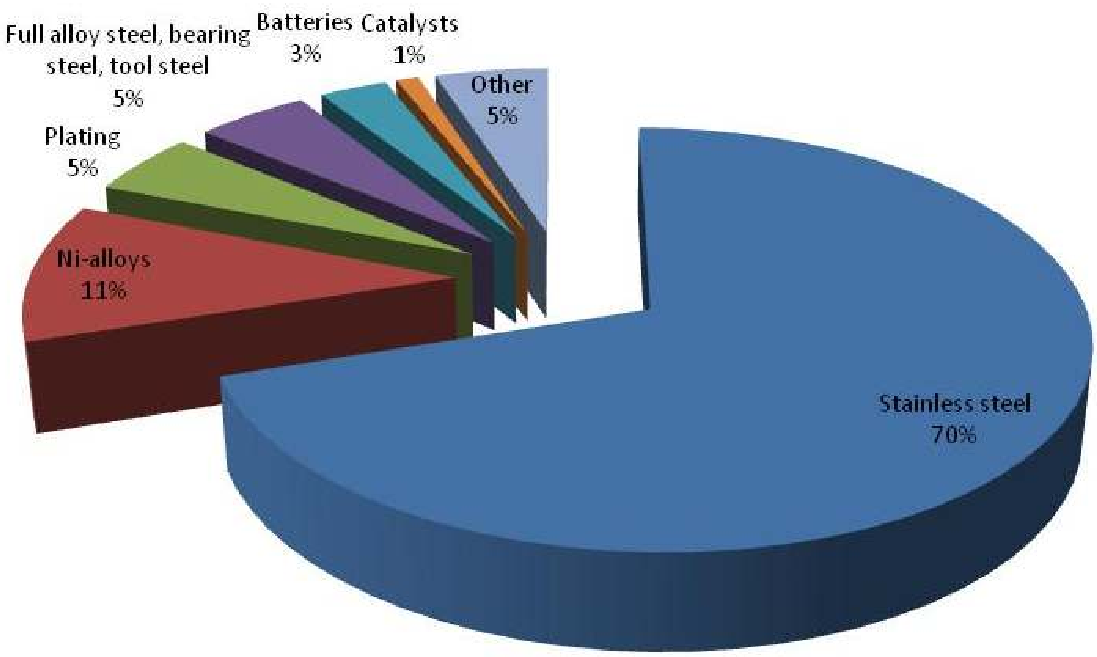
In 2007, Europe (32 countries) produced 3.2% of the total nickel ore world production. The largest European producer was Greece with 40.3% of the EU nickel ore production.



Currently, there are in total 22 EU mining projects, 16 of them take place in Finland and 6 in Sweden. Out of the total, 14 projects are in conceptual phase, 8 are in pre-feasibility phase[157].

157 Raw Materials Data. Copyright: Raw Materials Group, Stockholm, 2009

27.3 Economic Importance



- Stainless Steel: Nickel is used in steel to increase strength. For instance, nickel-containing alloys are essential in such applications (turbines, jet engines). Nickel alloys are also resistant to corrosion.
- Non-ferrous Alloys: about 11% of Nickel is used as an alloy with non-ferrous metals – various applications.
- Plating: Nickel is used in plating to increase corrosion resistance, especially in medical equipment, construction materials and household cutlery/fittings. Plating is also used in CD/DVD manufacture.
- Batteries Nickel, with other metals such as cadmium, is used to make batteries.
- Catalysts: Nickel is used in a wide range of chemical processes, including hydrogenation of fats and fertiliser production.
- Other: Nickel can be fabricated into desired forms and shapes by every major metalworking technique—casting, drawing, extrusion, forging, machining, or rolling.

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 €. The nickel value chain also supports large numbers of jobs in the EU, estimated to be in the order of 1.25 – 1.5 million jobs.

Nickel and nickel based platform technologies provide a range of additional socio-economic benefits to the EU and its citizens. Nickel plays an important role in underpinning the competitiveness of major industrial and service sectors in the EU such as aerospace, automotive, oil refining, and optical media, and in supporting economic efficiency and innovation across large parts of the EU's economy. Platform technologies based on nickel and nickel compounds also help deliver real world solutions to the environmental challenges facing Europe today.

Nickel, because of its wide-ranging properties and applications, is an “enabling technology”, not simply an industry processing primary materials.

27.4 Resource Efficiency: Recycling & Substitution

The corrosion resistance of nickel makes it suitable for recycling and its high price provides a significant incentive for this.

For the most part, nickel is recycled within the stainless steel loop, thereby preserving the value-added properties of nickel. Some nickel, however, gets combined with other metals and is recovered as a minor constituent of carbon steel scrap.

As stainless steel is the main use for nickel, sources of nickel scrap are linked to end-of life steel scrap. The end-of-life recycling rate is circa 56%, higher than for most other metals. The recycled content rate is 41%.

Given its unique characteristics, nickel is difficult to substitute for the production of alloys – any reduction in use results in a reduction in performance. However, the use of nickel in Batteries has been on the decline due to increased use of lithium and other materials.

To offset high nickel prices, engineers have always sought alternatives to nickel containing materials. For examples low nickel stainless steels may be substitutable for nickel containing grades in some applications.

Substitution also covers conversion of low-grade laterite ore to nickel pig iron – a low grade alternative to nickel metal. Unfortunately, this has a higher environmental impact than the production of refined nickel (British Geological Survey, 2008).

In other applications, such as the hot parts of jet engines, there may be currently no suitable alternative to a nickel containing material.

27.5 Specific issues

Environmental Issues[158]

Nickel is covered by Commission Regulation (EC) N° 552/2009 amending Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards Annex XVII. More info at: http://ecb.jrc.ec.europa.eu/classification-labelling/search-classlab/

Market Issues:

On the supply side - The operation of the nickel industry in Europe is challenged by high operating costs related amongst other factors to a strict regulatory framework especially in the field of EHS legislation. Moreover, supply with nickel containing concentrates and intermediates is challenged by inappropriate classifications, affecting transport as well as storage and processing. All these factors will lead as a consequence to nickel production shifting to countries outside EU, resulting in higher import dependencies and competitiveness advantages for downstream user industries in regions outside EU.

On the demand side, nickel finds application in a number of downstream uses which are highly critical for the future of the EU. Engineering, chemical processing, automotive sector, aerospace and aircraft industry as well as electronics are some of the end use markets where nickel cannot be adequately substituted. In addition, most of the technologies and practices which are playing a central role in mitigating the climate change will rely on nickel and nickel containing alloys as iillustrated in the table below.

Climate Change:

Table on Nickel in technologies and practices for mitigation of climate change: (based on IPCC Working Group III Fourth Assessment Report 2007).

Mitigation strategy	Nickel´s contribution
More fuel efficient vehicles	Batteries: nickel metal hydride batteries are used in hybrid electric vehicles and all electric plug-in vehicles.
Fuel switching from coal to natural gas	Sweetening of sour gas: due to their corrosion resistant properties, nickel containing alloys are critical in the cleaning, or ‘sweetening’ of sour gas– natural gas that contains significant amounts of sulphur.

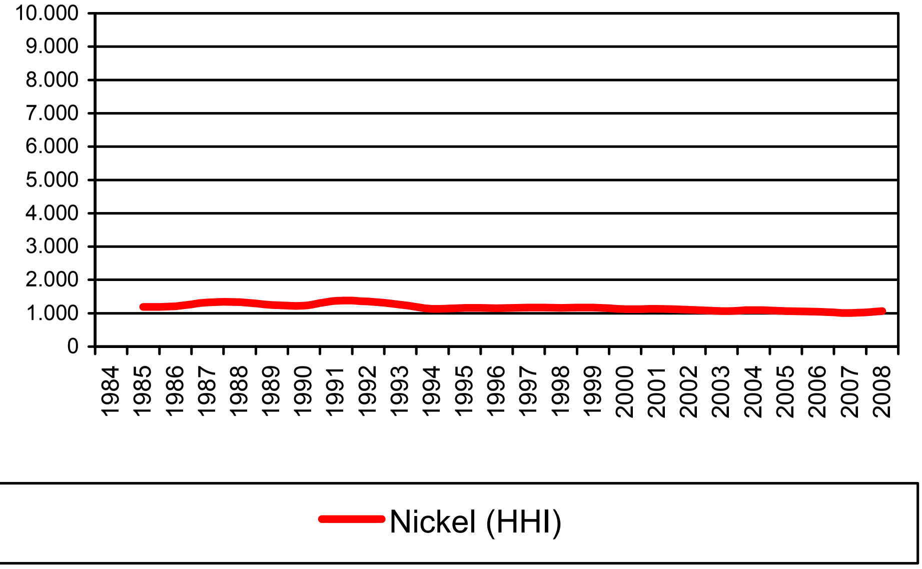
158 Not specific to Nickel

Carbon capture and storage (CCS)	Piping and vessels: long term storage of the CO_2 is envisaged either in deep geological formations, such as saline aquifers or oil fields, in deep ocean masses, or in the form of mineral carbonates. Nickel containing alloys would be required in the piping and vessels of each of these processes as they all involve corrosive environments.
Nuclear power	Tubing in steam generators: specialized nickel based alloys are used as tubing for steam generators in nuclear power plants, as they perform well in these high temperature, high pressure environments. They are likely to play an important role in producing power by nuclear fusion.
Wind power	Tough steels: many of the components of a wind turbine, such as the rotor hub, are cast in ductile iron, with 1% nickel added for added impact strength at low temperatures.
Solar power	Tower systems: the heat transfer fluid used in solar power tower systems is typically molten salt. Due to the corrosive nature of this material, nickel containing alloys are typically used in the tubing that contains the salt.
2nd generation biofuels	Pre-treatment: sulphuric acid is commonly used as a pre-treating agent in cellulosic ethanol production, necessitating the use of stainless steels. Other processes use high temperature, requiring higher nickel containing alloys.

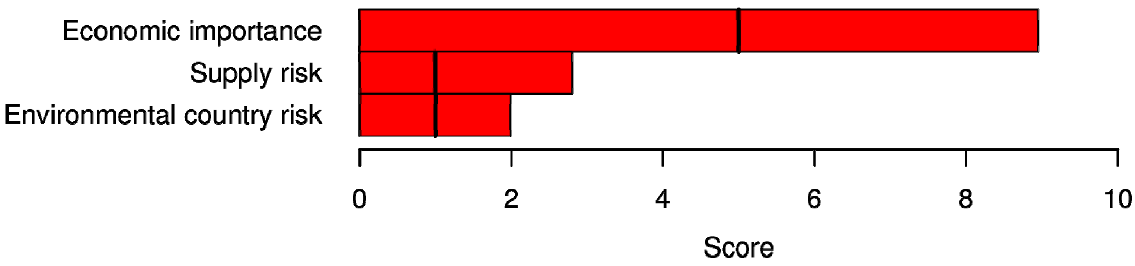
Use	Share	Megasector	Subst.
Stainless steel	70%	Metals	1,0
Ni-alloys	11%	Metals	0,7
Plating	5%	Metals	1,0
Full alloy steel, bearing steel, tool steel	5%	Metals	0,7
Batteries	3%	Electronics & ICT	0,7
Catalysts	1%	Chemicals	0,7
Other	5%	Other Final Consumer Goods	0,5

Substitutability	0,90
Recycling rate (recycled content from old scrap)	32%
Import Dependence	55%

Results	
Economic Importance	9,5
Supply Risk	0,3
Environmental Country Risk	0,2



Source: World Mining Data, 2010



28 Niobium

28.1 Introduction

Niobium, also known as Columbium (Cb), is a metallic element which is very similar to tantalum concerning its chemical properties. One of these is a good resistance against most organic and inorganic acids.[159] Niobium is only found in connection with the transition metal tantalum. They have to be separated from each other in a complex chemical procedure.

Niobium is a soft and ductile metallic element that is used mainly in special steels and superalloys.[160]

The steel industry is by far the largest consumer of niobium.[161]

28.2 Basic Supply & Demand Statistics

Niobium can be found in many locations, but rarely in economically recoverable quantities. It ranks 33[rd] place in natural abundance (24 ppm) in the earth's crust. About 60 niobium containing minerals are known[162], of which pyrochlore and columbite are the most important ones (accounting for 90 % and 7.5% of the global supply respectively).[1]

World resources are more than adequate to supply projected demand. The global market leader in niobium production is Brazil.[163]

	Reserves (in 1000t; 2010)		Production (in 1000t; 2009)		Imports to EU (in 1000t; 2006)	
Brazil	2,900	98,4%	57	92,4%	16.6	84.1%
Canada	46	1,6%	4.3	7,0%	3.1	15.8%
Russia					0.009	0.05%
others	NA		0.4	0,6%		
Total	**2,946**		**61.7**		**19.7**	

159 Ullmann's Encyclopedia of Chemical Technology: *Niobium and Niobium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

160 European Mineral Statistics 2003-2007, BGS

161 Roskill Information Services: *The Economics of Niobium*, London, 2005

162 Römpp Online: *Niob.* Georg Thieme Verlag, Stuttgart, 2006

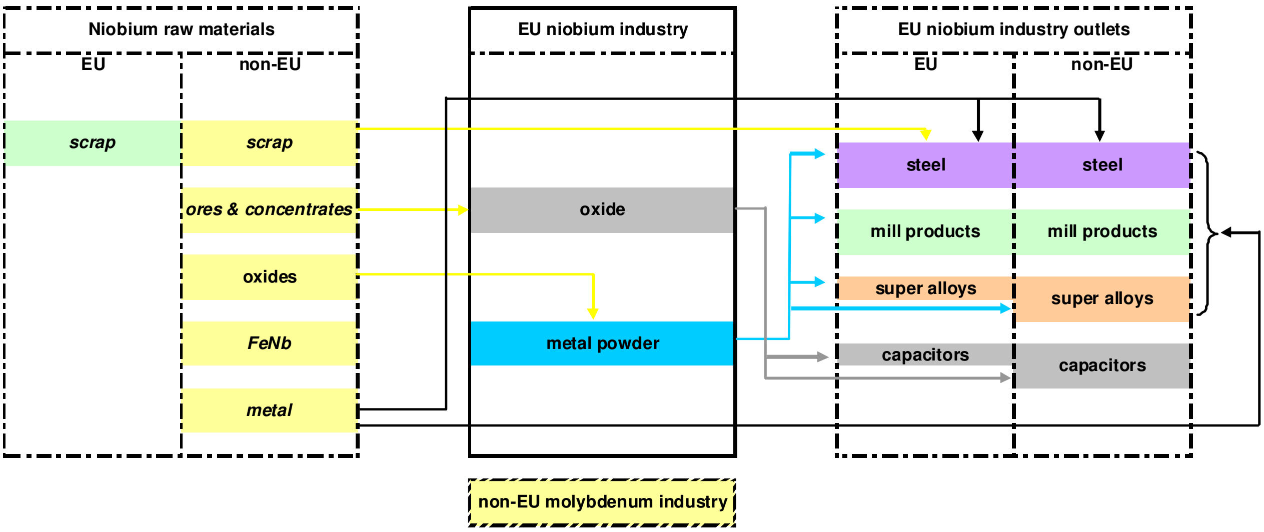
163 USGS Mineral Commodity Summaries 2010: *Niobium*

Source: USGS 2010; trade data from ComExt (CN 7202 93 00 Ferro-niobium)

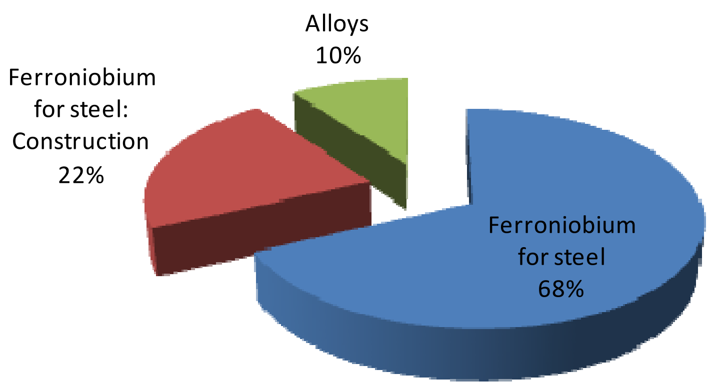
Main import source is Brazil, with smaller quantities being imported from Canada.

European countries exported some tantalum and niobium, although there is no domestic production.

The Moreira Salles Group controlled in 2007 nearly 85% of Niobium production, followed by Anglo American plc (8%) and Iamgold corp (7%).



28.3 Economic Importance



Main end-use markets for niobium worldwide[1,3,4]:

- Ferroniobium for steel: The vast majority of niobium is used in the steel industry for iron-niobium alloys (containing 40-70% Nb). In construction, they are valued for their strength, even at high temperatures. About 10 % of total steel production uses niobium.
- Ferroniobium for steel, Construction: Used in different indusrties for construction, for example car bodies, off-shore platforms and for pipelines.
- Alloys: Niobium is also used in special alloys which are used in the nuclear and in the aircraft industry (fuel cell cans, gas turbines...).
- Small applications: Moreover smaller quantities of niobium are used in many other applications, such as magnets, superconductors, jewelry, thermometers, capacitors or catalysts.

Due to the increased mechanical resistance and other beneficial characteristics of niobium-containing products, it finds application in the following fields:

- Pipeline construction
- Nuclear technology
- Aerospace construction
- Niob-electrolyte-condensators (used e.g. in notebooks or mobile phones)
- Potassium niobate (laser technology)
- Superconductors (below temperatures of 9.5 K, e.g. magnets used in the LHC at the CERN)

In 2030, the demand for niobium in the production of microcapacitors probably will be six times higher than today. Nevertheless that will be only 3% of total niobium consumption. High temperature resistant steel will be important for many other emerging technologies, but no quantitative projection is available[164]. There are also recent reports on new end-use, with a solid niobic acid catalyst included in the conversion of palm oil to bio-diesel, but this use will not affect significantly to the global demand.

28.4 Resource Efficiency: Recycling & Substitution

Niobium is recycled when niobium-bearing steels and superalloys are recycled; scrap recovery specifically for niobium content is negligible. The amount of niobium recycled is not available, but it may be as much as 20% of primary niobium.[165]

Though substitution of niobium is possible, it may involve higher costs and/or a loss in performance.

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164 Fraunhofer Institut für System und Innovationsforschung and Institut für Zukunftsstudien und Technologiebewertung: *Rohstoffe für Zukunftstechnologien*, 2009, Fraunhofer IRB Verlag, Stuttgart

165 USGS Mineral Commodity Summaries 2009: *Niobium*

The following materials can be substituted for niobium, but a performance or cost penalty may ensue:

- molybdenum and vanadium, as alloying elements in high-strength low-alloy steels
- tantalum and titanium, as alloying elements in stainless and high-strength steels
- ceramics, molybdenum, tantalum and tungsten in high-temperature applications[166].

28.5 Specific issues

Trade issues:

According to the EU Commission's inventory on export restrictions, niobium is subject to a 6.5% export tax in Russia and to a non-automatic export licensing system in South Africa.

Market Issues:

As niobium is mainly used as an alloying element for steel its position on the economic importance ranking is very high as niobium is attached straightly to the "metals"-megasector. Therefore the ranking result is not in the scale, but more like an indicative.

On the supply side**,** the EU niobium industry is sourcing its entire primary niobium feed from outside the Community as Europe is not endowed with any niobium resources. The main raw materials imported by the EU niobium industry are ores and concentrates. As the main resources and the main producer is located in Brazil the EU niobium industry is facing as quasi monopolistic situation on the supply side with indeed presents a certain risk.

On the demand side, the EU niobium industry has historically developed amongst the top ranking suppliers on the global market. The steel industry which is the main consumer of niobium is a very cyclical one and follows the demand pattern of the general industry.

Future demand will be influenced by growth sectors such as special HSLA steels for applications as special drilling equipment or pipeline construction which require specific R&D know how and high-tech production equipment. Also EU projects such as the XFEL linear accelerators or ILC on the international scale will to a certain extent influence future demand.

[166] USGS Mineral Commodity Summaries 2010: *Niobium*

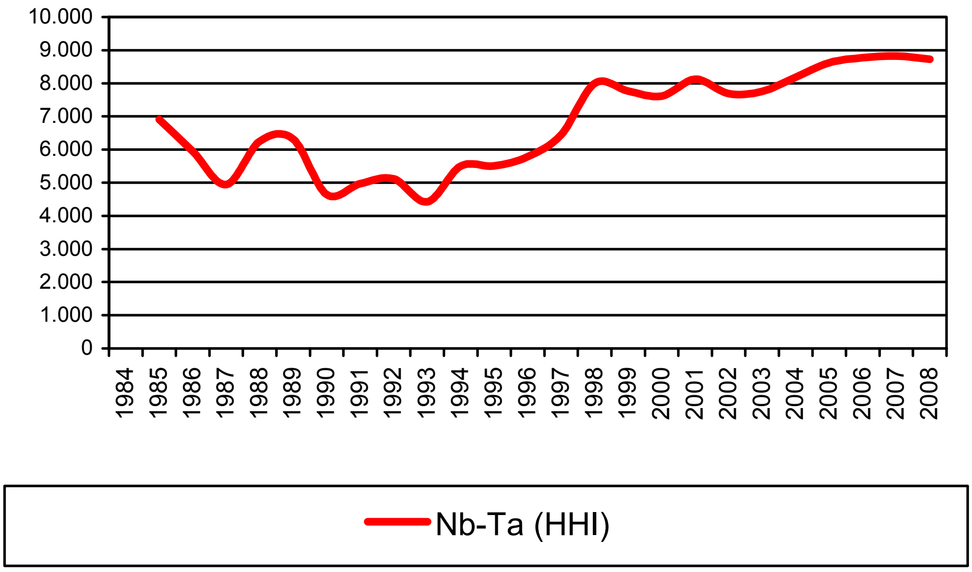
The EU niobium industry is increasingly confronted with Chinese competition whose pricing policy is erratic and destructive of the normal price structure (prices for value added products are quoted below metal price).

Under these circumstances, securing a level playing field in access to niobium raw material is increasingly seen as a vital condition for ensuring the future viability of the EU niobium industry.

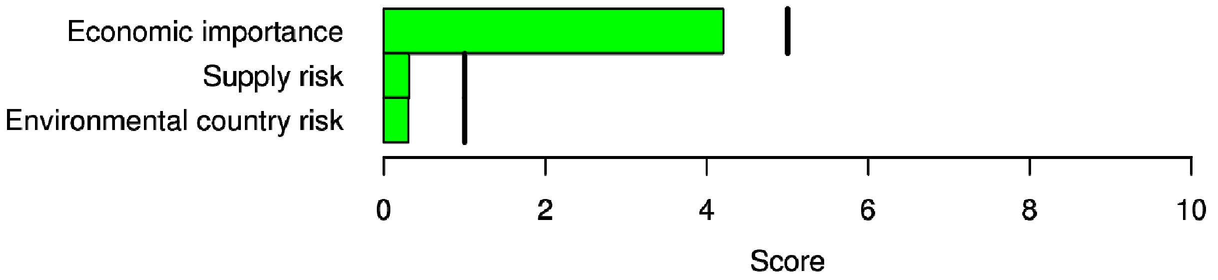
Use	Share	Megasector	Subst.
Ferroniobium for steel	68%	Metals	0,7
Ferroniobium for steel: Construction	22%	Construction material	0,7
Alloys	10%	Metals	0,7

Substitutability index	0,70
Recycling rate (recycled content from old scrap)	11%
Import Dependence	100%

Results	
Economic Importance	8,9
Supply Risk	2,8
Environmental Country Risk	2,0



Source: World Mining Data, 2010



29 Perlite

29.1 Introduction

Perlite is not a trade name but a generic term for naturally occurring siliceous rock. The distinguishing feature which sets perlite apart from other volcanic glasses is that when heated to a suitable point in its softening range, it expands from four to twenty times its original volume.

This expansion is due to the presence of two to six percent combined water in the crude perlite rock. When quickly heated to above 1600°F (871°C), the crude rock pops in a manner similar to popcorn as the combined water vaporizes and creates countless tiny bubbles which account for the amazing light weight and other exceptional physical properties of expanded perlite.[167]

29.2 Basic Supply & Demand Statistics

According to USGS, United States and Greece are the world's largest perlite producers, with more then 50% combined world production.

Turkey is the source of almost 98% of the EU's imports. Other countries include Morocco with 12.4 tonnes and Switzerland with 405 tonnes.

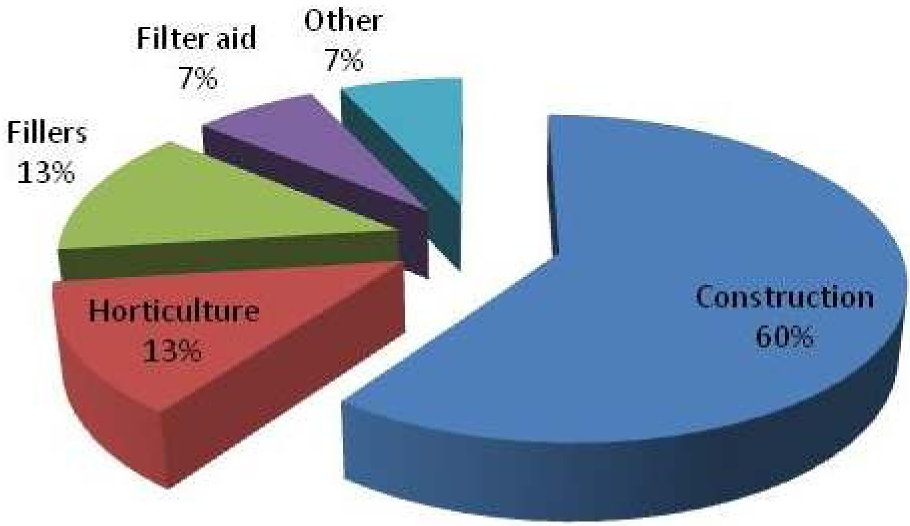
	Reserves (in 1000t)		Production (in 1000t; 2008)		EU imports (in 1000t; 2006)	
United States	50,000	7.1%	434	24.3%		
Greece	50,000	7.1%	525	29.4%		
Hungary	3,000	0.4%	70	3.9%		
Japan	*		230	12.9%		
Mexico	*		54	3.0%		
Turkey	*		270	15.1%	18.1	97.7%
Other countries	600,000	85%	205	11.5%	0.4	2.3%

167 http://www.perlite.net/

World Total	703,000		1,788		18.5	

Source: USGS; ComExt CN 2530 10 10; * - included in other countries

29.3 Economic Importance



- Construction: Because of perlite's outstanding insulating characteristics and light weight, it is widely used as a loose-fill insulation in masonry construction. In this application, free-flowing perlite loose-fill masonry insulation is poured into the cavities of concrete block where it completely fills all cores, crevices, mortar areas and ear holes. In addition to providing thermal insulation, perlite enhances fire ratings, reduces noise transmission and it is rot, vermin and termite resistant. Perlite is also ideal for insulating low temperature and cryogenic vessels. When perlite is used as an aggregate in concrete, a lightweight, fire resistant, insulating concrete is produced that is ideal for roof decks and other applications. Perlite can also be used as an aggregate in Portland cement and gypsum plasters for exterior applications and for the fire protection of beams and columns. Other construction applications include underfloor insulation, chimney linings, paint texturing, gypsum boards, ceiling tiles, and roof insulation boards.
- Horticultural Applications: In horticultural applications, perlite is used throughout the world as a component of soilless growing mixes where it provides aeration and optimum moisture retention for superior plant growth. For rooting cuttings, 100% perlite is used. Studies have shown that outstanding yields are achieved with perlite hydroponic systems. Other benefits of horticultural perlite are its neutral pH and the fact that it is sterile and weed-free. In addition, its light weight makes it ideal for use in container growing. Other horticultural applications for perlite are as a carrier for fertil-

izer, herbicides and pesticides and for pelletizing seed. Horticultural perlite is as useful to the home gardener as it is to the commercial grower. It is used with equal success in greenhouse growing, landscaping applications and in the home in house plants.

- Industrial Applications: Industrial applications for perlite are the most diverse, ranging from high performance fillers for plastics to cements for petroleum, water and geothermal wells. Other applications include its use as a filter media for pharmaceuticals, food products, chemicals and water for municipal systems and swimming pools.
- Other: Additional applications include its use as an abrasive in soaps, cleaners, and polishes; and a variety of foundry applications utilizing perlite's insulating properties and high heat resistance. This same heat resistant property is taken advantage of when perlite is used in the manufacture of refractory bricks, mortars, and pipe insulation.

29.4 Resource Efficiency: Recycling & Substitution

There is no known available data on the recycling of perlite.

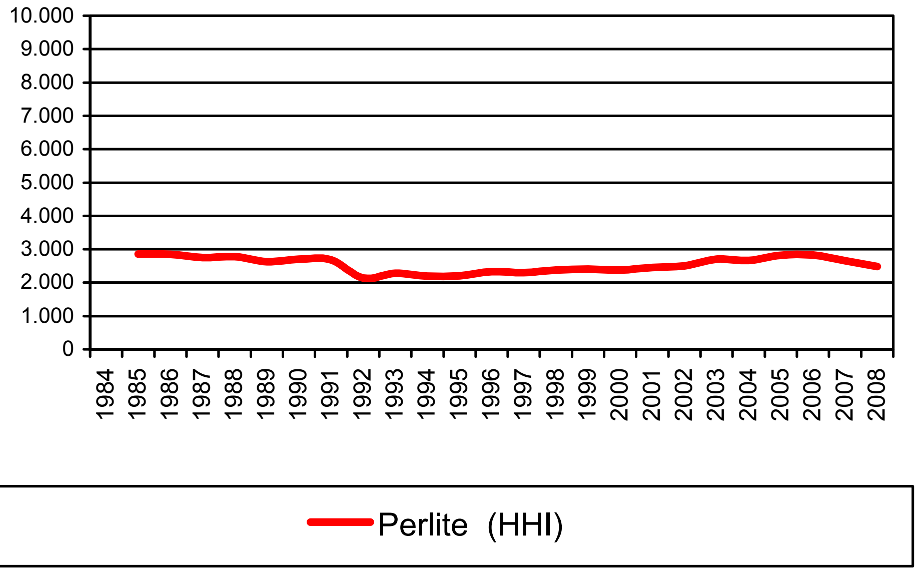
Alternative materials can be substituted for all uses of perlite if necessary. Long-established competitive commodities include diatomite, expanded clay and shale, pumice, slag, and vermiculite.

Perlite

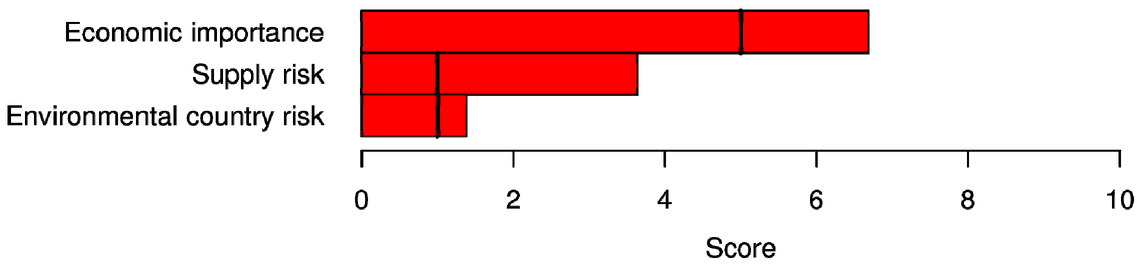
Use	Share	Megasector		Subst.
Construction	60%	Construction Material		0,3
Horticulture	13%		0	0,3
Fillers	13%	Rubber, Plastics & Glass		0,3
Filter aid	7%	Beverages		0,3
Other	7%	Other Final Consumer Goods		0,5

Substitutability index	0,31	
Recycling rate (recycled content)	0%	no information available
Import Dependence	13%	

Results	
Economic Importance	4,2
Supply Risk	0,3
Environmental Country Risk	0,3



Source: World Mining Data, 2010



30 Platinum Group Metals (PGM)

30.1 Introduction

Platinum Group Metals (PGM) is a collective name for six precious metals with similar properties. Of these, ruthenium (Ru), rhodium (Rh) and palladium (Pd) are known as light platinum metals (atomic numbers 44-46). In fact their density is even higher than that of lead, but low compared to that of the heavy platinum metals osmium (Os), iridium (Ir) and platinum (Pt) (atomic numbers 76-78)[168]. All of them have similar chemical and physical properties, such as high melting point, low vapor pressure, high temperature coefficient of electrical resistivity, and low coefficient of thermal expansion. Moreover all PGMs have strong catalytic activity[169].

30.2 Basic Supply & Demand Statistics

PGMs are very rare metals in the earth's crust, with estimated abundances for platinum and palladium of approximately 5 ppb and for rhodium, iridium and ruthenium of approximately 1 ppb.[170]

There is no direct PGM mining in EU27-countries according to the BGS[171], although there is some marginal production of platinum and palladium (as by-products) in EU27-countries[172] for 2007.

- For platinum there was production in two EU-countries Finland and Poland.
    - Finland: 800 kg (039% of world production)
    - Poland 10 kg
- For palladium, production was only reported for Poland (20 kg, contributing 0.01% to worldwide production).

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168 Römpp Online: *Platinmetalle.* Georg Thieme Verlag, Stuttgart, 2006

169 Ullmann's Encyclopedia of Chemical Technology: *Platinum Group Metals and Compounds*. Wiley-VCH Verlag, Weinheim, 2006

170 BGS Commodity Summaries, *Platinum*, 2009

171 European Mineral Statistics 2003-2007, BGS

172 World Mining Data 2009

Close to 90% of the world's PGM reserves are located in South Africa, which is also the global leader in platinum production[173]. PGMs occur and are mined always together as coupled elements, with Pt and Pd as major metals, while average Rh and Ru output is about factor 10 and Ir and Os about factor 50 lower than Pt/Pd. Deposits are further associated with Ni, Cu and Au. While the deposits in South Africa, Zimbabwe and the USA are mined for their PGM content, the Russian and Canadian PGMs are by-products from nickel mining (the latter ones are also poorer in Rh, Ru, Ir). Due to this character of coupled production, the supply of Rh, Ru, Ir (and Os) depends on the demand for (mining of) Pt and Pd and in case of the Russian and Canadian production on the respective nickel mining.[174]

	PGM Reserves (in t; 2010)		Palladium Production (in t; 2009)		Platinum Production (in t, 2009)	
USA	900	1.3%	12.5	6.4%	3.8	2.1%
Canada	310	0.4%	9.0	4.6%	5	2.8%
Russia	6,200	8.7%	80.0	41.0%	20	11.2%
South Africa	63,000	88.5%	79.0	40.5%	140	78.7%
Zimbabwe	NA		4.8	2.5%	6	3.4%
others	800	1.1%	9.8	5.0%	3.2	1.8%
Total	**71,210**		**195.1**		**178**	

Source: USGS 2010

The main sources for PGM for the EU are South Africa (approximately 60%) and the Russian Federation (over 30%)[175].

The general rise in the price of platinum over the last 20 years has led to renewed interest in several areas and deposits previously thought to be uneconomic, These include the Skaergaard Complex in Greenland, the Duluth Complex in the USA, and the Penikat and Keivitsa Complexes in Finland.[176]

Furthermore, PGMs can be found in copper shale, In the course of rising commodity prices, mining this sedimentary rock in Europe may become economic and provide further resources.

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173 USGS Mineral Commodity Summaries 2010: *Platinum Group Metals*

174 Hagelüken 2006, markets of PGMs

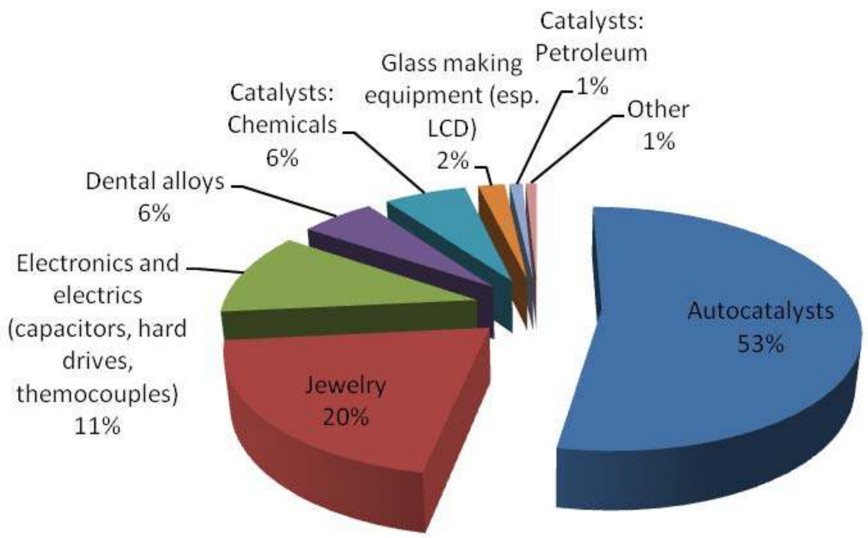
175 UN comtrade, HS 711011 and HS 711021

176 BGS profile PGMs, p.22

In Europe there are 7 projects for PGM metals in Finland, one is at the pre-feasibility stage, the others are at conceptual stage.

The three largest companies Norilsk Nickel Mining & Metallurgical Company, Anglo American plc and Impala Platinum Holdings Ltd control nearly 70% of the platinum market.

30.3 Economic Importance



Main end-use markets for PGMs are[4,177,178]:

- Autocatalysts: Pt, Pd and Rh are used for automotive catalytic converters and diesel particulate filters in order to reduce air pollution.
- Jewelry: Approximately 20% of PGMs are used for jewelry.
- Electronics and electrics: In this sector PGMs are used in a variety of applications, such as computer hard discs (Pt, Ru), multilayer ceramic capacitors (Pd) or hybridized integrated circuits.

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4 USGS Mineral Commodity Summaries 2010: *Platinum Group Metals*

177 Fraunhofer Institut für System und Innovationsforschung and Institut für Zukunftsstudien und Technologiebewertung: *Rohstoffe für Zukunftstechnologien*, 2009, Fraunhofer IRB Verlag, Stuttgart

178 Hagelüken

- Dental alloys: Their high corrosion resistance make PGMs interesting for dental applications.
- Catalysts: PGMs are not only used for autocatalysts, but also as catalysts in the chemical industry and for petroleum refining.
- Glass making equipment: Minor applications include glass making equipment, especially LCDs.
- Investment tools: Due to their high prices, PGMs are used as investment tools.

PGMs are expected to play an important role in emerging technologies. Especially for fuel cell driven vehicles, platinum demand in 2030 is estimated to exceed world production of 2006 by far.[179]

Beside the actual application distribution, new technologies and expanding markets can be estimated in the following fields:

- "Four way catalysts" in car engines to control the gas and particulate emissions in one single system
- increased use in emission control in stationary applications (generators, turbines and industrial processes such as cement, glass and nitric acid manufacture)
- fuel cells
- further increase of ruthenium and rhenium in nickel-based superalloys that are used in turbine blades for jet engines
- increased medical application in anti-cancer drugs or ICDs (Implantable Cardiac Defibrillator).

30.4 Resource Efficiency: Recycling & Substitution

Due to their high value, recycling of PGMs is quite efficient, especially from industrial process catalysts[180] and PGM equipment used in the glass industry.

Although not visible in demand statistics, these industrial PGM applications account for about 50% of the global gross PGM demand, In most applications, more than 90% of the PGMs originally used finally – also after lifetimes of many years – are recovered, Since most industrial users keep the property of the PGMs throughout their lifecycle (closed loop), they appear on the markets as net buyers only to cover lifecycles losses or market growth (expansion or new applications), The demands reported for the

[179] Fraunhofer Institut für System und Innovationsforschung and Institut für Zukunftsstudien und Technologiebewertung: *Rohstoffe für Zukunftstechnologien*, 2009, Fraunhofer IRB Verlag, Stuttgart

[180] Hagelüken 2006, Precious metals process catalysts

chemical, oil-refining or glass sector are net figures (=new demand), these reflect only a fraction of the much larger gross demand.

There is no universal technique for recovering PGMs from post-consumer scrap, such as electronic items, jewellery, and automotive catalysts.

- Automotive catalysts are particularly important sources for recycled PGMs and quantities continue to rise due to rising numbers of End-of-Life vehicles being catalyst equipped. On a global scale only between 50-60% of PGMs used in automotive catalysts finally are recovered; in Europe, this is well below 50%, mainly due to high exports of old cars/ELVs into regions without proper recycling systems. The EU mandatory removal of autocatalysts from ELVs is supportive for PGM recycling rates, however does not affect old cars exported from the EU.

- Recycling of PGMs from other consumer applications however is much worse, For PGMs in electronic applications, recovery rates are probably only in the range of 10%. The EU WEE directive currently provides here only little support since under the mass based recycling targets no incentives exist to secure optimum access to PGM containing components and their most appropriate recovery, and other than for autocatalysts the economic motivation for PGM recycling is much lower,

- The challenge in PGMs in autocatalysts and other consumer applications thus is the collection and channeling through the recycling chain to the metal recovery processes itself, The latter ones are highly efficient and obtain metal recovery rates of well over 95%[181].

-To a certain extent, PGMs are also used in a rather dissipative way which puts economic and technical challenges on recycling. Examples are Ru and Pt in hard disks (today about 80% of Ru and 5% of Pt), Pt in silicones, Pt and Ir in spark plugs, Pt in sensors, and PGMs in medical applications or galvanoplating.

PGMs in jewelry, coinage and other investment applications are usually manufactured for an “eternal life”, so here hardly any lifecycle losses occur and if e.g. old jewelry is handed in it is recycled with very high yields.

In automotive catalytic converters platinum can often be replaced by palladium and the other way round, driver is here often the current price ratio. However, a general substitution effort can just flip the prices as was the case end of the 1990s. Since Pd for many years was cheaper than Pt, the automotive industry widely switched to Pd domi-

[181] Hagelüken 2007, Challenge of open cycles

nated catalysts, with the effect that Pd reached an all time price high in 2000/01, surpassing Pt, before it fall back again in 2001. The European boom in diesel cars then further triggered the Pt demand, since originally diesel catalysts only worked with Pt. In the meantime, new technologies allow for a partial substitution of Pt with Pd in diesel (but Pt remains the dominating metal). Rh is not needed in diesel catalysts but so far cannot be substituted in catalysts for spark ignition engines and is there always used in combination with Pt or Pd or both.

Generally PGMs often can substitute for each other, but since Pt and Pd mine production is in the same magnitude this does not necessarily help but can shift the problem from one scarce metal to another. In some multi-layer ceramic capacitors (MLCC) used in electronic devices silver-palladium pastes have been substituted by base metals (Ni, Cu), but at the cost of a lower performance. So in many high tech electronic devices still Pd is used in MLCCs[182].

New developments in automotive catalyst technologies help to save PGMs, because they need smaller quantities than older models and still achieve better results[183]. However, tighter and tighter emission standards lead to almost constant PGM loading in car catalysts.

30.5 Specific issues

According to the EU Commission's inventory on export restrictions, Russia applies a 6.5% export tax on all PGMs.

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[182] Hagelüken 2006, markets for PGMs

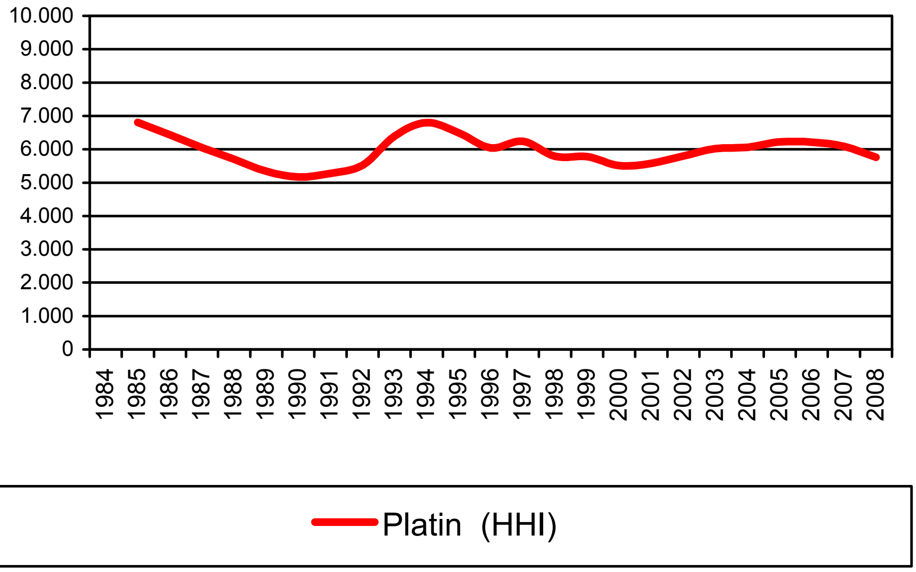
[183] USGS, MCS 2010, Platinum Group Metals)

Use	Share	Megasector	Subst.
Autocatalysts	53%	Road Transport	1,0
Jewelry	20%	Other Final Consumer Goods	0,0
Electronics and electrics (capacitors, hard drives, themocouples)	11%	Electronics & ICT	1,0
Dental alloys	6%	Pharmaceuticals	0,3
Catalysts: Chemicals	6%	Chemicals	1,0
Glass making equipment (esp. LCD)	2%	Mechanical Equipment	1,0
Catalysts: Petroleum	1%	Refining	1,0
Other	1%	Other Final Consumer Goods	0,5

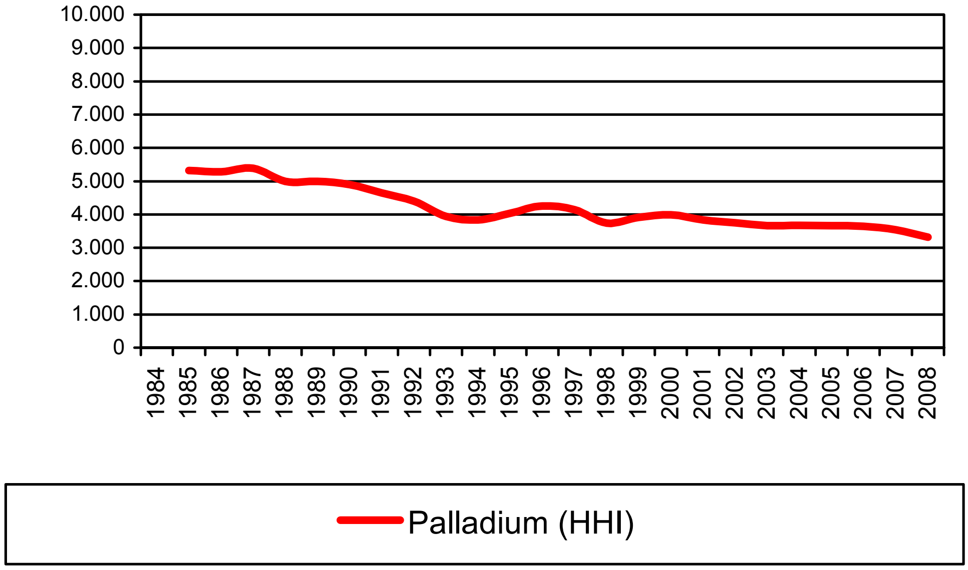
Substitutability index	0,75
Recycling rate (Recycled content from old scrap)	35%
Import Dependence	100%

Results

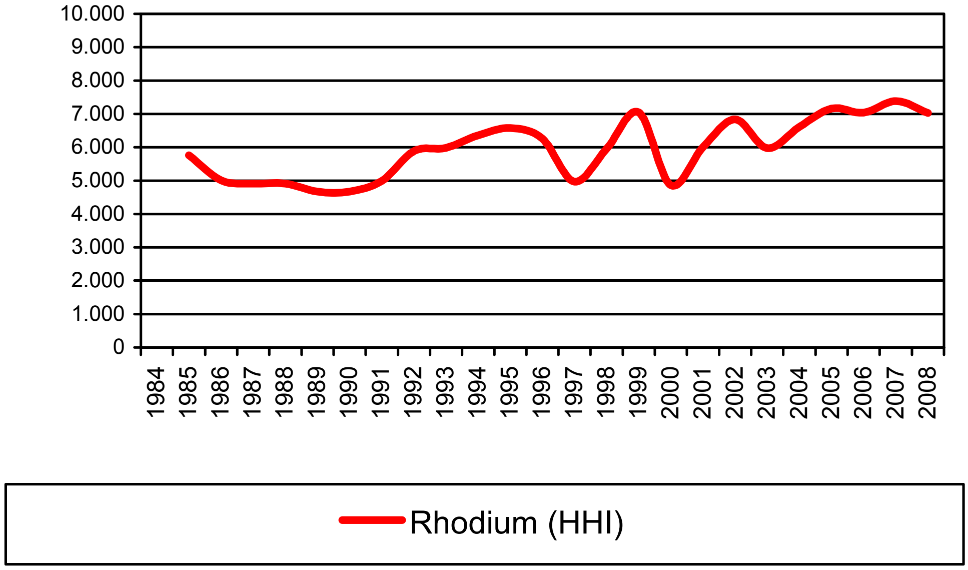
Economic Importance	6,7
Supply Risk	3,6
Environmental Country Risk	1,4 (Platinum)



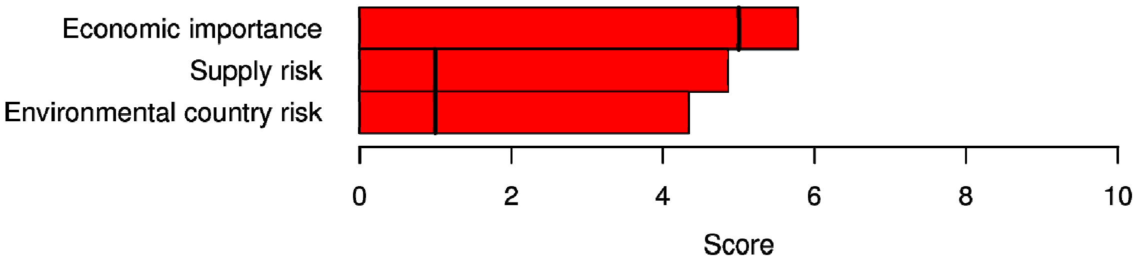
Source: World Mining Data, 2010



Source: World Mining Data, 2010



Source: World Mining Data, 2010



31 Rare Earth Elements

31.1 Introduction

The term “rare earth elements” is a collective name for the elements scandium (atomic number 21), yttrium (39), lanthanum (57) and the 14 elements following lanthanum in the periodic table (the so called lanthanides): Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, and Lutetium. In spite of their name, some of these elements are not as rare as their name suggests. For example Thulium, the rarest stable element of the group, is less rare than gold or platinum. They occur chiefly in the minerals bastnaesite and monazite, can only be mined together (their relative abundance varying between deposits) and their production in pure form is cost-intensive.[184,185,186] Often rare earths are split between ‘light’ rare earth elements[187] and ‘heavy’ rare earth elements[188].

31.2 Basic supply and demand statistics

The worldwide reserves of rare earth metals (excluding Scandium) are estimated to be around 99,000,000 tonnes. Although China has only about one third of the world’s reserves, it produced 97% of the rare earths in 2009.[189]

	Reserves (in 1000t; 2009)		Production (in 1000t; 2009)		EU imports (in 1000t; 2007)	
USA	13,000	13.2%	-			
Australia	5,400	5.5%	-			
Brazil	48	< 0.1%	0.65	0,5%		
China	36,000	36.5%	120	97,0%	15.8	89,7%
India	3,100	3.1%	2.7	2,2%	0.07	0,4%

184 Römpp Online: *Seltenerdmetalle.* Georg Thieme Verlag, Stuttgart, 2007

185 British Geological Survey: *European Mineral Statistics 2003-2007*.

186 Liedke & Elsner: *Seltene Erden*. BGR Commodity Top News Nr. 31, Hannover, 2009.

187 lanthanum, neodymium, praseodymium, samarium

188 dysprosium, erbium, europium, gadolinium, holmium, lutetium, terbium, thulium, ytterbium, yttrium

189 USGS Mineral Commodity Summaries 2010: *Rare Earths*

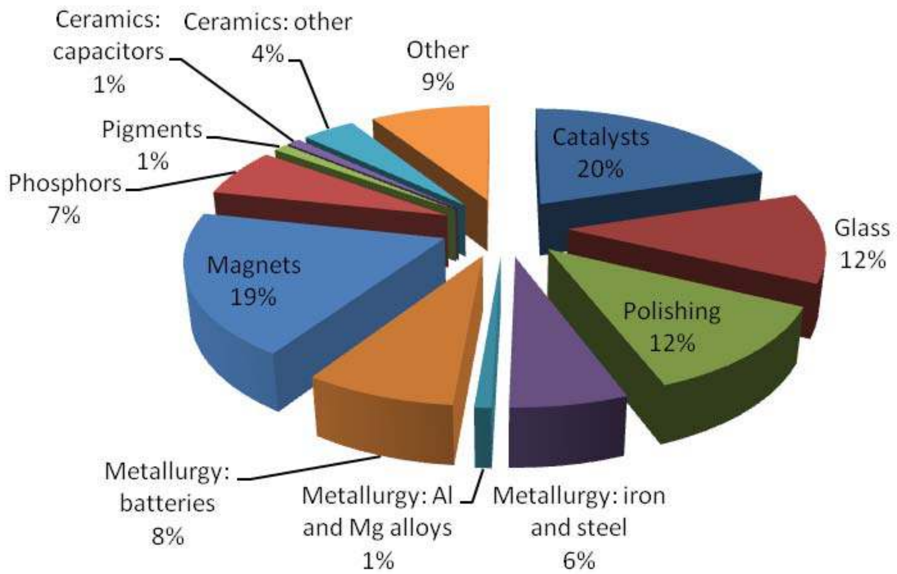
Malaysia	30	< 0.1%	0.38	0,3%		
Kazakhstan					0.1	0,6%
Russia					1.6	9,2%
Vietnam					0.01	0,1%
others	41,000	41.6%	NA			
Total	**98,578**		**123.7**		**17.6**	

Sources: USGS 2010; trade data provided by BGS based on UN comtrade (HS 280530, HS 284610, HS 284690

Rare earths are not produced within the European Union. However, known deposits in amounting to approximately 500.000 t exist in Sweden, with further prospecting underway.[190] In 2007, approximately 17.600 metric tons (14% of worldwide production) were imported, 14% less than in the year before. The main source country was China, followed by Russia.

Because China is expected to require all of its production in the foreseeable future, several additional mining projects are currently underway in the United States, Canada, India, Australia and Malawi, the largest of which are in the US (Mountain Pass, CA) and Australia (Mt. Weld, Nolans).

31.3 Economic importance



[190] Sveriges Geologiska Undersökning 2010.

As there are many different elements among the rare earths, there are many different uses as well. The most important ones are[1,3,191,192]:

- Catalysts: An important use for rare earth metals is in catalysts, for example Lanthanum are used in catalytic cracking in oil refineries and Cerium is necessary in catalytic converters for cars.
- Magnets: Many rare earth elements have interesting magnetic characteristics which makes them important for high temperature superconductors and permanent magnetic substances. For example, Neodymium-Iron-Boron magnets are the strongest known permanent magnets. Other rare earths used in these applications are Dysprosium, Samarium, Terbium and Praseodymium.
- Polishing and Glass: Cerium oxide is a widely used polishing agent.
- Batteries: Nickel metal hydride batteries (containing Lanthanum) are the first choice for portable tools and are extensively used in hybrid vehicles.
- Metallurgy: Rare earths (especially Cerium, Lanthanum and Neodymium) are used to improve mechanic characteristics of alloyed steel, for desulfurisation, and to bind trace elements in stainless steel. Smaller shares are also used for magnesium and for aluminum alloys.
- Other applications include the processing of phosphors and pigments and the manufacturing of capacitors and ceramics.

A number of merging technologies rely on the properties of rare earths, for example:

- The anodes of solid state fuel cells use either Scandium or Yttrium.
- Yttrium is also necessary for high temperature superconductors and is used in lasers.
- Neodymium will see increased use for high performance permanent magnets in the context of electromobility and for wind power generators.

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1 Römpp Online: *Seltenerdmetalle.* Georg Thieme Verlag, Stuttgart, 2007

3 Liedke & Elsner: *Seltene Erden*. BGR Commodity Top News Nr. 31, Hannover, 2009.

191 Ullmann's Encyclopedia of Chemical Technology: *Rare Earth Elements*. Wiley-VCH Verlag, Weinheim, 2006

192 Fraunhofer Institut für System und Innovationsforschung and Institut für Zukunftsstudien und Technologiebewertung: *Rohstoffe für Zukunftstechnologien*, 2009, Fraunhofer IRB Verlag, Stuttgart

31.4 Resource efficiency, recycling and substitution

Only small quantities, circa 1% have been recycled from old scrap[193], mainly from permanent magnet scrap.[2]

For most applications substitutes for rare earths are available but with loss of performance.[2]

31.5 Specific issues

An intrinsic issue pertaining to rare earths is that their relative amounts in ore bodies is fixed (though different for each deposit) but the demand does not necessarily match these relative concentrations. Thus, while relative shortages are expected for Lanthanum, Dysprosium, Terbium, Neodymium and Europium, Cerium is expected to remain relatively abundant.[3]

China controls the exports of rare earths in a tight way. Quotas have been falling continuously since 2005, although due to the recession non-Chinese demand did not exceed supply during 2009. In particular the announcement that China will ban exports of unprocessed heavy rare earths by 2015 has raised major concerns. It seems that the underlying rationale is to bring more and more of the manufacturing chain into China. China is also known to have been stockpiling rare earths for its own consumption following the depressed prices. In addition, China introduced an export tax in 2006 with the effect of raising prices for rare earth raw materials by 31% and severely undermining the competitiveness of non-Chinese magnet makers for example. There is wide-scale concern that China may soon greatly restrict or even ban the export of particular rare earth elements in order to guarantee supply for its own rapidly expanding demand from wind energy, electric bikes and hybrids.[194]

There are currently many new mine projects outside of China in the pipeline that could ease the expected pressures on supply and demand. The new mine Mount Weld in Australia is scheduled to commence product next year; whereas other deposits have been identified in the US, Canada, Australia and Greenland. It is expected that the supply from the rest of the world will become a larger share of world demand. However, the development of new mines could take as many as 10 years. Hence some pressure

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2 USGS Mineral Commodity Summaries 2010: *Rare Earths*

3 Liedke & Elsner: *Seltene Erden*. BGR Commodity Top News Nr. 31, Hannover, 2009.

193 UNEP – The recycling of metals (upcoming)

194 Source: “Lanthanides Resources and alternatives”. Oakdene Hollins, UK. March 2010

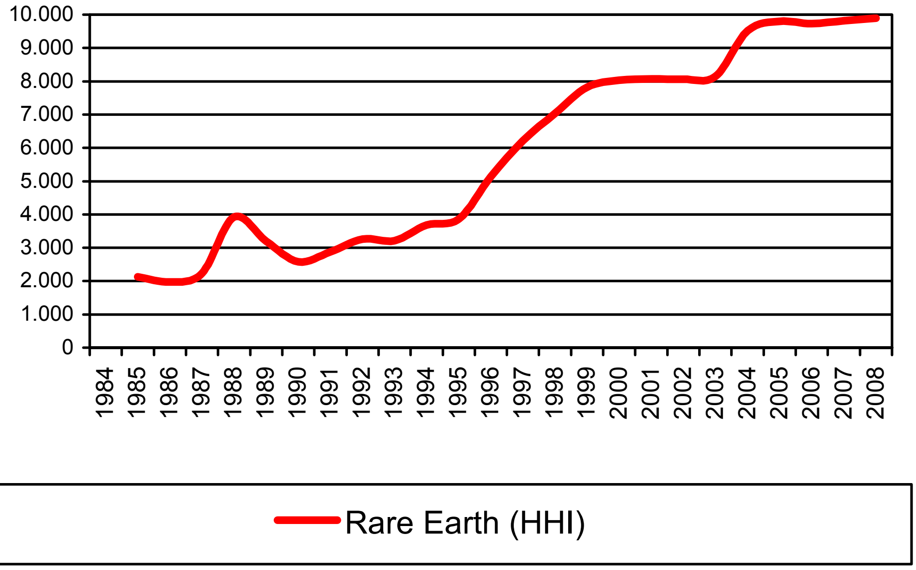
on supply and demand in the short term may be expected, although the situation can be quite different from one rare earth element to another.

The processing of rare earths raises a series of specific environmental concerns.

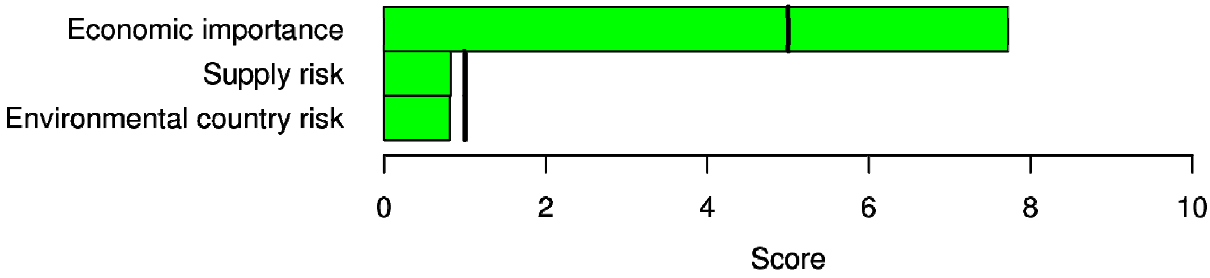
Use	Share	Megasector	Subst.
Catalysts	20%	Chemicals	1,0
Glass	12%	Rubber, Plastic & Glass	1,0
Polishing	12%	Electronics & ICT	0,7
Metallurgy: iron and steel	6%	Metals	0,7
Metallurgy: Al and Mg alloys	1%	Metals	1,0
Metallurgy: batteries	8%	Electronics & ICT	0,7
Magnets	19%	Electrical Equipment + Domestic Appliances	1,0
Phosphors	7%	Chemicals	1,0
Pigments	1%	Chemicals	0,7
Ceramics: capacitors	1%	Electronics & ICT	1,0
Ceramics: other	4%	Construction Material	1,0
Other	9%		0,5

Substitutability	0,87
Recycling rate (recycled content from old scrap)	1%
Import Dependence	100%

Results	
Economic Importance	5,8
Supply Risk	4,9
Environmental Country Risk	4,3



Source: World Mining Data, 2010



32 Rhenium

32.1 Introduction

Rhenium (Re) is a rare, silvery-white metallic element that is produced principally as a by-product of the processing of porphyry copper-molybdenum ores.

Rhenium – the last naturally-occurring element to be discovered – was discovered in Germany in 1925. The process was so complicated and the cost so high that production was discontinued until early 1950 when tungsten-rhenium and molybdenum-rhenium alloys were prepared. These alloys found important applications in industry that resulted in a great demand for the rhenium produced from the molybdenite fraction of porphyry copper ores. Important uses of rhenium have been in platinum-rhenium catalysts, used primarily in producing lead-free, high-octane gasoline and in high-temperature superalloys used for jet engine components[195].

32.2 Basic Supply & Demand Statistics

Chile is the world's largest rhenium producer, being responsible for half of the world production (more according to other estimates), being followed by the USA.

	Reserves (in t; 2009)		**Production (in t; 2008)**		**Imports to EU (100kg) 2006**	
United States	390	15.9%	7.9	14.0%	33,091	~100%
Armenia	95	3.9%	1.2	2.1%		
Canada	32	1.3%	1.6	2.8%	68	
Chile	1,300	53.0%	27.6	48.8%		
Kazakhstan	190	7.8%	7.7	13.6%		
Peru	45	1.8%	5	8.8%		
Russia	310	12.6%	1.5	2.6%		

195 USGS

Other countries	91	3.7%	4	7.1%		
World total	**2,453**		**56.5**		**33,159**	

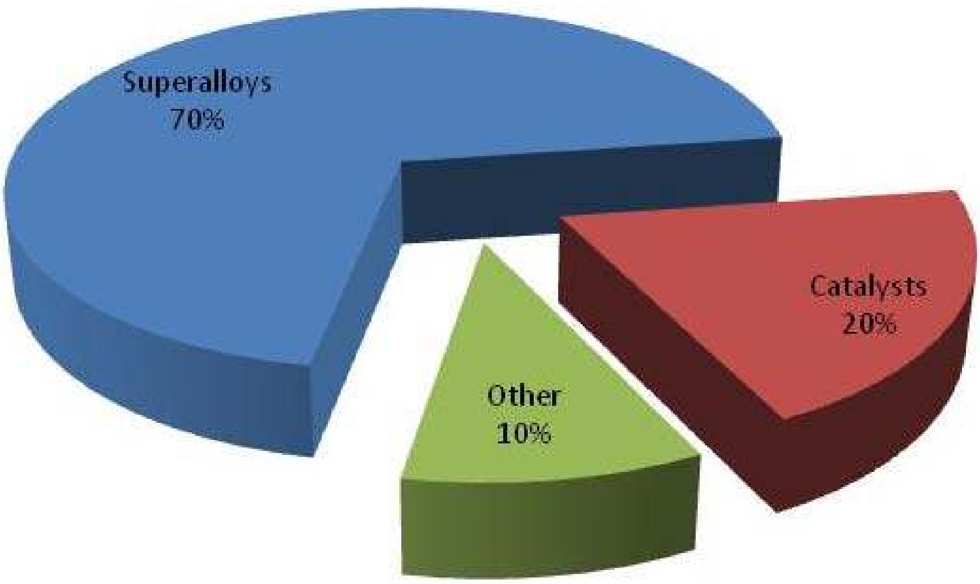
Source: USGS[196]; ComExt 2841 90 85

There is no reported mining of rhenium in any European country. Therefore, Europe is completely dependent on imports.

The reported largest producer of rhenium is Chilean company *Molymet*[197], accounting for about two-thirds of primary rhenium output in 2006. Although the company does not mine any materials, it just processes them. The Kazakh company *Kazakhmys Plc* – first of all a copper producer – is reported to be the second largest producer of rhenium in the world[198].

Other companies reported to produce rhenium are *Xstrata* in Chile and *Armenian Molybdenum Production LLC*[199]. The world's largest copper producer *Codelco* from Chile is reported to start their own production of rhenium in the middle of 2010[200].

32.3 Economic Importance



[196] As estimates vary considerably, the figures for Rhenium collected by USGS should be read with caution.

[197] Roskill: The economics of Rhenium. Outline

[198] http://www.thebulliondesk.com/content/reports/tbd/temp/LipmannRheniumApril2006.pdf

[199] USGS Minerals Yearbook 2007

[200] http://www.purchasing.com/article/439604-Codelco_to_restart_rhenium_in_2010.php

- Superalloys: 70% of rhenium is used as an important component in superalloys for blades in turbine engines. Due to its resistance to high temperatures rhenium is particularly suitable for rocket motors. Rhenium is added to tungsten and molybdenum to form alloys that are used as filaments for ovens and lamps. It is also used in thermocouples which can measure temperatures above 2000ºC, and for electrical contacts which stand up well to electric arcs.
- Catalysts: Rhenium, alloyed with platinum, is used in petroleum-reforming catalysis in the production of high-octane hydrocarbons, used for lead free gasoline.
- Other uses include rhenium-tungsten alloys used in X-raytubes and rotating X-ray anodes. Rhenium-molybdenum alloys are superconductors at a temperature of 10K. Rhenium has occasionally been used for plating jewellery.

32.4 Efficiency: Recycling & Substitution

The recycling rate of Rhenium (from old scrap) is 13%.

In the US, small amounts of molybdenum-rhenium and tungsten-rhenium scrap have been processed by several companies during the past few years. Equally, most spent platinum-rhenium catalysts were recycled.

The Polish company *KGHM Ecoren* is reported as operating the only facility for recovering rhenium from industrial waste in Europe[201]. KGHM produces ammonium perrhenate, which contains about 69% pure rhenium. According to company's data[202], the yearly output of ammonium perrhenate was at 1.5 tonnes in 2006 and is in planned to reach 5 tonnes;

Substitutes for rhenium in platinum-rhenium catalysts are being evaluated continually. Iridium and tin have achieved commercial success in one such application[203].

Other metals being evaluated for catalytic use include gallium, germanium, indium, selenium, silicon, tungsten, and vanadium. The use of these and other metals in bimetallic catalysts might decrease rhenium's share of the existing catalyst market; however, this would likely be offset by rhenium-bearing catalysts being considered for use in several proposed gas-to-liquid projects.

201 http://www.warsawvoice.pl/view/18687

202 http://www.ecoren.pl/en/rhenium.xml

203 USGS

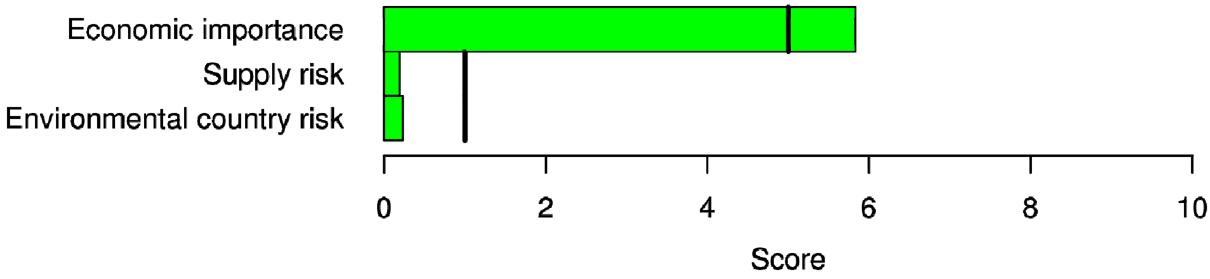
Materials that can substitute for rhenium in various end uses are as follows:

- 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, and
- Tungsten and tantalum for electron emitters.

Use	Share	Megasector	Subst.
Catalysts	20%	Refining	0,7
Superalloys	70%	Metals	1
Other	10%	Other Final Consumer Goods	0,5

Substitutability index	0,84
Recycling rate (recycled content from old scrap)	13%
Import Dependence	100%

Results	
Economic Importance	7,7
Supply Risk	0,8
Environmental Country Risk	0,8



33 Silica-sand / Glass sand

33.1 Introduction[204]

Industrial grades of silica sand are characterised by their high content of silica (up to 99,9%) normally in the form of quartz grains. Quartz is the most common crystalline form of Silicon Dioxide (SiO2) which comprises the two most abundant elements in the earths crust (silicon and oxygen). There are rarer crystalline forms of silica, one of which is called cristobalite. Silica sand is often produced from loosely consolidated sedimentary deposits but can also be concentrated by crushing and further processing of sandstones, quartzites and quartz containing rocks such as granite. Silica is hard, chemically inert and an essential natural component in many basic and high technological industrial applications.

Both the specific chemical and physical properties of silica sands are important to define the value for each specific industrial application. As well as having high silica content they must have a set of specifications ranging from a specific calibrated grain size distribution, a stable defined chemical composition esp. iron oxide and aluminium oxide, often at very low impurity levels, and other specific values such as low content of heavy minerals, metals like Ni, Cr, specific whiteness parameters and others.

The typical grain size distribution of silica sands is usually within the range of between 0 to 3mm. The sands have to comply with very tight specifications for particular uses and their quality must be consistent. As a result different grades of silica sand are not usually interchangeable for a particular end use. Often the specifications are tailored to meet expectations of individual customers.

The technical economical feasibility of the development of a silica sand resource depends on the deposit parameters, mainly the overburden thickness, the cost of processing or purification of the silica sand to render them suitable for the end use and customer specification and the proximity to the market.

204 Sources: http://www.scotland.gov.uk/Resource/Doc/178913/0050918.pdf; http://www.samsa.org.uk/silica.htm; http://www.mineralszone.com/minerals/silica.html; http://www.nepsi.eu

Regional importance of silica sand as an industrial mineral.

Silica sand is an industrial mineral which by definition needs an industrial market with a suitable logistical position. Usually silica sand is not transported over long distances and depends on regional customers. High quality niches such as ultra-low-iron sands and specialty calibrated sands do exist.

From an industrial minerals point of view, any silica sand mineral occurrence is important in the regional context of the industrial and the construction needs. For example, if a specific sand is absent in Italy, this will regionally affect the industry and its growth potential, because in most cases this sand can not be economically transported from Poland.

33.2 Basic Supply & Demand Statistics

Quartz is the most abundant mineral found in the crust of the earth. It forms an important constituent of practically all rock-forming minerals. Although it is found in a variety of forms, as quartz crystals, massive forming hills, quartz sand (silica sand), sandstone, quartzite, tripoli, diatomite, flint, opal, chalcedonic forms like agate, onyx etc., and in with numerous other forms depending upon colour such as purple quartz (amethyst), smoky quartz, yellow quartz or false topaz (citrine), rose quartz and milky quartz, this has nothing to do with the economics of silica sand supply and demand statistics.

According to the IndexMundi, United States are the world's largest silica-sand producer being responsible for approximately 23% of the world production, followed by Italy with approximately 11%. However the European data are not correct from the point of view of silica sand because the USGS category “Sand and Gravel, Industrial, Silica” may also include production of aggregates and possibly even building stones such as marble, which could explain the 13,8mio Tonnes Italy production. Examples such as Italy (Industrial sand production is max. 5mio Tonnes) and Belgium (minimal industrial sand production is 3.5mio Tonnes) show that the USGS-IndexMundi data are not suitable for the review of an industrial mineral like silica sand which requires a precise definition in case figures are compared.

Fraunhofer-Institute states that Italy was responsible for 20% and Germany for 16% of EU imports in 2006. These two countries were by far the largest consumers of silica-sand in Europe.

There is no reserves column in the beneath table, because according to USGS and other sources, the world reserves of silica-sand are very large. When however considering specific market needs, the European available reserves may regionally be scarce.

Industrial Sand and Gravel (Silica): World Production (By Country)

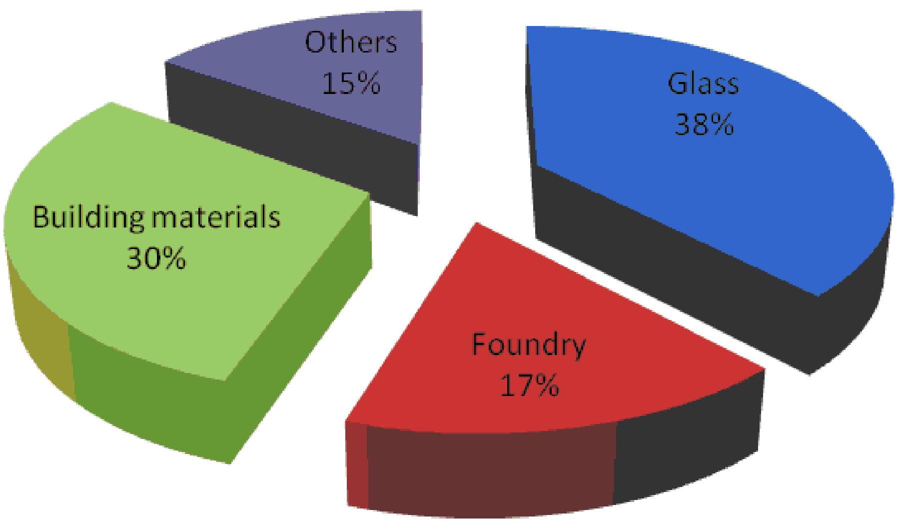
	Production (in 1000 t; 2006)		Imports to EU (in 1000 t; 2006)	
Australia	5,200	4.21%	26	
Austria	6,800	5.51%		
Belgium	1,800	1.46%		
Brazil	1,600	1.30%	6	
Bulgaria	1,495	1.21%		
Czech Republic	1,000	0.81%		
Dominica	N/A	N/A	746	
Egypt	650	0.53%	5,604	
France	5,000	4.05%		
Germany	7,703	6.24%		
Hungary	3,800	3.08%		
India	1,600	1.30%	87	
Italy	13,800	11.18%		
Jordan	416	0.34%	274	
Morocco		0.00%	1,214	
Poland	3,850	3.12%		
Serbia	260	0.21%	177	
Slovakia	2,000	1.62%		
Spain	5,100	4.13%		
Sri Lanka	N/A	N/A	9	
Tunisia	N/A	N/A	1,390	
Ukraine	N/A	N/A	70	

United Kingdom	5,600	4.54%		
United States	28,900	23.41%	170	
Other countries	26,887	21.78%		
World total	123,461			

Source: IndexMundi (based on USGS data); ComExt CN 2505 10 00

Note: Because of the regional and specific market correlation similar to many other industrial minerals, the supply and demand issues can only be studied when defining the quality niche. European cross country statistics are only useful in case the highest quality niches are being studied. In most cases a glass or foundry sand can economically not be transported from Spain till Poland, so that abundance in Poland can not compensate for scarcity in Italy.

33.3 Economic Importance



- Glass (flat & container glass): The most common use of quartz and glass-sand, also referred to as silica-sand, is in the manufacture of glass. Great advancement has been made in the manufacture of translucent, transparent, coloured and clear glass in sheets or in glassware.

  The size of the sand grains is important in glass industry. It should be between 40 to 80 mesh (BSS). It should be of high purity containing a minimum of 98% SiO_2. In the manufacture of colourless glass the iron content (Fe_2O_3) should not exceed 0.035%, where for flat glass it may go up to 0.06%.

  Iron and chromium are both objectionable impurities in glass-sand. The minute presence of these impurities gives colour effect in the glass melt. Glass is manufactured by melting a mixture in suitable proportion of felspar, dolomite, limestone and soda ash together with glass-sand at 1400º - 1500ºC in the furnace where clear molten glass is formed.

- Building materials (cement, concrete blocks, glues for tiles, etc.): Silica-sand in large quantities is used as a component in dry construction mixes, as body constituent in the ceramic industry in the preparation of glazes and sometimes added to the raw material for cement manufacture to balance SiO_2, Al_2O_3 and Fe_2O_3 percentages. Silica flour made by grinding silica sand is used in paints. Paint manufacturers generally prefer diatomite powder which has wide covering properties. The use of silica sand and more specifically its powder form is often related to generation of respirable crystalline silica. Guidance on the safe handling and use of respirable crystalline silica is developed by industry and accessible via NEPSI website.

- Foundry: Large quantities of high calibrated silica sand are used for moulding shells and cores in the foundry industry to manufacture engine blocks, turbines and wind mill blades, propellers, railroad wheels, etc. The chemical and physical properties of silica sand are of extreme importance for such use, especially the uniform size distribution and spherical shape of the grains.

- Other materials: Silica sand has some specific applications often requiring unique qualities and specifications, like fibreglass, engineered stone, chemicals, filtration, for natural and artificial grass filling, for producing water glass, for increasing the yield of oil and gas drillings, etc. For example, uniform grades of silica sand, in the rage of 0.5-1.0 mm are often used for filtration medium. Quartz and quartzite are used in making ferro-silicon for the manufacture of silicon steel.

33.4 Resource Efficiency: Recycling & Substitution

According to the Fraunhofer-institute, the recycling rate of silica-sand is 24%. Most of the silica sand recycling happens in the glass sector (the average recycling rate in Europe is around 62%) and foundry sector (in some countries it can go up to 90%).

The future demand for silica sand is expected to be more driven by the sustainability trends rather than by the traditional industries in Western Europe. However, the demand in glass manufacturing in Central and Eastern Europe is still expected to continue growing.

Substitutes: Silica sand continues to be the major material used for glassmaking and for foundry and molding sands; alternates in the foundry industry are zircon, olivine, staurolite, and chromite sands.

33.5 Specific issues

Little knowledge in the public of the numerous applications of silica sand beyond glass manufacturing determined sometimes the perception of silica sand being only glass sand. This also provokes the general opinion to look at silica sand as a traditional, low sophistication raw material since glass manufacturing has been around for more than twenty five centuries. As a result there is an overshadow on the recent developments that have seen silica sand making significant inroads into paint and polymers sectors, engineered stone, light-weight concrete, high-strength cements, precision casting.

Supply side

Silica sand supply is very much regional and market dependent. If in general silica sand resources are broadly spread, different sand deposits and different grades are not usually interchangeable in applications. This together with the cost for processing and logistics could make the resources fairly restricted. In the last twenty-thirty years for example, applications like solar energy, shale gas production, precision casting has required closely defined specification and consistency in quality of silica sand, some of which are rare resource and very expensive to produce.

Another aspect of the supply side is the access to resources, which is often restricted due to the location of that resource being Natura 2000 area or other land use designation. Unfortunately, the regulatory regimes in the Member States still vary significantly which adds a regulatory burden on the access, and in that perspective on the supply side, in some countries.

The companies producing and trading silica sand vary in size across Europe, from SMEs to multinational Industrial Group Companies. Some of them specialize in grades for the glass manufacturing, others choose to diversify with new sustainability or society driven applications. As already mentioned, specializing in silica sand products depends on the region and accessibility to raw material together with a proximity of market realization.

Demand side

The main drivers on demand side are construction, automotive and infrastructure, including glass making. Construction in Europe, especially Western Europe has been stable in the last years due mainly to economic situation and aging population. This leads to relatively stable demand in that part of Europe.

However, driven by sustainability trends there are new areas showing development opportunities, like renewable energy, aerospace and so on. Besides, people are looking for more leisure activities in their social life and more sportive involvements, which is a relatively new and increasing in demand application for silica sand.

Environmental issues

The environmental aspect of silica sand production relates mainly to nature conservation and biodiversity. However, the environmental conditions, including biodiversity vary between countries. For example there are countries designating almost half of their territory as Natura 2000 sites, which make the access to mineral resources practically impossible.

However, the public perception very often associate silica sand extraction with mining activities, which creates negative image for the industry, adding to the already mentioned burdens.

Average size of a sand quarry is <25ha and such size and type of business allows for nature friendly reconstruction.

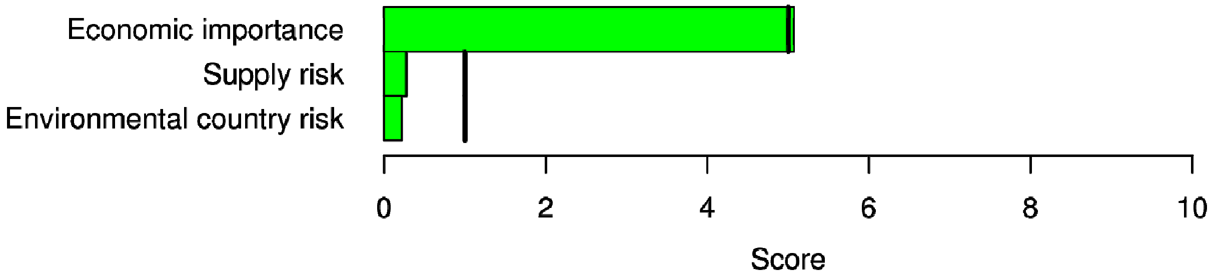
Silica sand extraction and nature go hand in hand. Industrial companies are working closely with universities and governments to follow and monitor the impact of their projects and reconstruction activities on the environment. There are numerous examples like deviation of a river or relocation of a whole plant to reduce the impact on biodiversity and natural habitats. There are also many examples of creating biodiversity . The very nature of the extraction activities put the sector in a unique position regarding biodiversity. The rare plant and animal species that settle down in quarries during and after operations, have led to many new areas of high biodiversity value.

Enrichment process of silica sand generally does not require use of chemicals and in such way the impact on the environment is limited.

Use	Share	Megasector	Subst.
Glass (flat & container glass)	38%	Rubber, Plastics & Glass	1
Foundry	17%	Metals	1
Building materials (cement, concrete blocks, glues for tiles, etc.)	30%	Construction Material	1
Others (fibreglass, chemicals, abrasives, leasure, filtration)	15%	Other Final Consumer Goods	0,5

Substitutability index	0,93
Recycling rate (recycled content)	24%
Import Dependence	14%

Results	
Economic Importance	5,8
Supply Risk	0,2
Environmental Country Risk	0,2



34 Silver

34.1 Introduction

Silver is one of the eight precious or noble metals; the others being gold and the six platinum-group metals (PGM). Aside from value in exchange and in jewellery, it has the highest electrical and thermal conductivity of all metals, has high photosensitivity to visible, x-ray, and gamma-ray wavelengths in the electromagnetic spectrum, and is chemical inert to oxygen. However, its use is restricted by its relatively high cost.

34.2 Basic Supply & Demand Statistics

Silver is mainly obtained as a by-product of copper and lead-zinc ores (60%) and of gold ores (11%), with only the remainder 29% coming from silver ores[205]. This is one reason why Peru, Mexico, and China are the world's leading producers. Nonetheless, within Europe, Poland is a very important source of silver, providing 6% of the world mine production and over 40% percent of the EU's needs.

	Reserves (in t)		Production (in t; 2008)		Imports to EU (in t; 2007)	
Chile	70,000	17.7%	1,400	6.6%	13	1.3%
Peru	59,000	14.9%	3,690	17.3%	1	0.1%
Poland	55,000	13.9%	1,190	5.6%		
Mexico	37,000	9.4%	3,240	15.2%		
China	34,000	8.6%	2,800	13.1%	36	3.7%
Australia	31,000	7.8%	1,930	9.1%		
United States	25,000	6.3%	1,230	5.8%	5	0.5%
Bolivia	18,000	4.6%	1,110	5.2%		

205 GFMS & The Silver Institute 2009, World Silver Survey 2009, p. 32

Canada	16,000	4.1%	730	3.4%		
Russia	N/A		1,300	6.1%		
Other Countries	50,000	12.7%	2,680	12.6%	918	94.8%
Total	**395,000**		**21,300**		**968**	

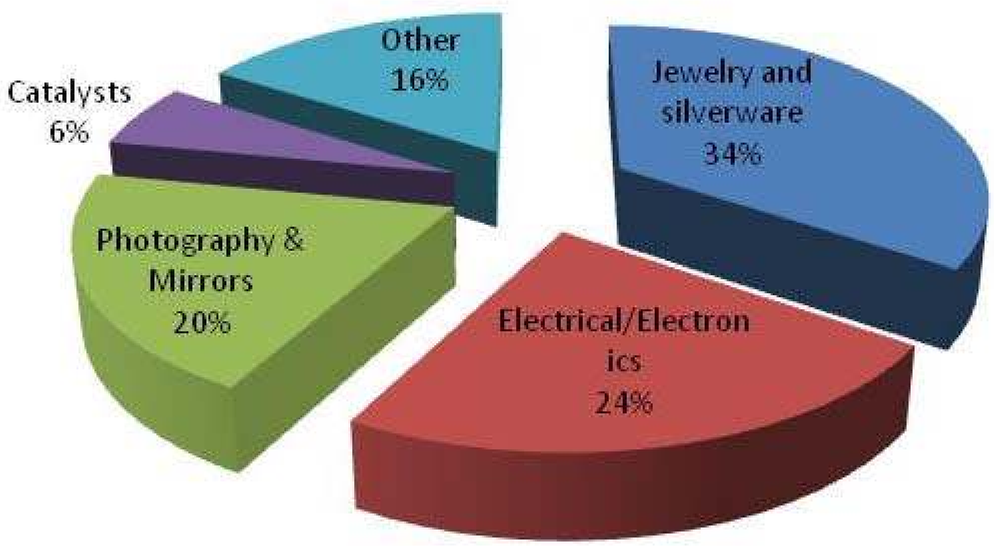
Source: USGS, 2010; UN Comtrade HS 2616 10

World production of silver has increased by 50% from 14,000t in 1995 to 21,300t in 2008. EU import dependence is relatively low at less than 40%.

In Europe there are 13 operating mines producing silver and 13 projects which are in progress:

- Bulgaria (2 operating, 1 prefeasibility)
- Finland (1 conceptual)
- Greece (1 feasibility)
- Poland (4 operating)
- Portugal (1 operating)
- Romania (2 conceptual)
- Spain (1 prefeasibility , 2 conceptual)
- Sweden (6 operating, 1 feasibility, 2 prefeasibility, 3 conceptual).

34.3 Economic Importance



- Coins/Jewellery/Silverware: The largest proportion of silver use goes into these non-industrial, decorative uses. While value in exchange is an important factor here, silver's advantage for silverware lies also in the fact that while it counters bacteria, it is not harmful to human health.

- Electric/Electronics: Although silver is more expensive than, say, copper, its high conductivity makes it an important component in electrical and electronic equipment.
- Photography & Mirrors: As silver has the highest optical reflectivity of all metals, its use in photography and mirrors is self-evident. However, regarding demand for silver in photographic equipment has been on the decrease since the introduction of digital cameras since the late 1990s.
- Catalysts: Silver's catalytic properties make it ideal for use as a catalyst in oxidation reactions, for example, the production of formaldehyde from methanol.
- Other: This includes Dental, Solar Panels, Water treatment, Batteries, Plasma displays, RFID tags among others.

In terms of future demand possibilities:

- The introduction of RFID-tags and the increased use of solar panels means that silver will remain important as a future enabling technology. The projected strong growth in production of silicon based solar cells will require in total large amounts of silver as contacting material on the panels.
- Silver could be a factor in the construction industry in the nearer future. Windows covered with an extremely thin silver layer can prevent the incoming and escaping of heat from rooms.
- Due to its bactericide and odour absorbing properties an increasing use of silver in textiles, wound care and medical might occur. Although this would imply very small Ag-quantities per piece, such mass application could have a significant leverage on total demand.[206]

34.4 Resource Efficiency: Recycling & Substitution

A significant proportion of silver is recycled due to its value and its ease of recycling in some major applications. As such the EOL-RR for silver is between 30 and 50%. However recycling rates vary significantly within the different use sectors. In case jewellery, silverware and coins one day are not used any more they are recycled with over 90%. Also recycling of industrial applications such as process catalysts and photographic residues (incl. X-ray films) is with 40-60% rather effective.

That said, the difficulty of recycling silver contained in WEEE means that EOL-recycling rates here currently are only in the 10-15% range. They could be much higher if collection of EOL-

[206] Cross, J. (2010), prospects for silver supply and demand, Alchemist vol 54, Jan. 2010, pp14-18.

devices would be more comprehensive and if collected goods would all be channelled into appropriate recycling chains, from which finally the silver bearing fractions would be directed into state-of-the-art metallurgical recovery operations. The biggest share of silver in WEEE is contained – in the form of solders and pastes – in the circuit boards, modern technologies are able to recover from these close to 100% of the silver. As in circuit boards besides silver also gold, palladium and copper make up for the lion share of the intrinsic metal value, their combined recovery offers an economic incentive, that principally can trigger recycling..

This is usually not the case for silver used in mirrors, glass or solar panels: In these applications other “paying metals” are largely missing and with the relatively low Ag concentration the economic driver for Ag recycling will remain small. Even worse is the case for the dissipative silver use in mass applications like RFID or textiles: Given the low concentration and the spread and flows of such products, it is unrealistic to assume any significant recycling for such applications.

Summing up, significant improvements in recycling of silver from WEEE can be achieved if frame conditions are adjusted accordingly. However, for most of the potential future silver applications closing the loop will become very difficult if not impossible.

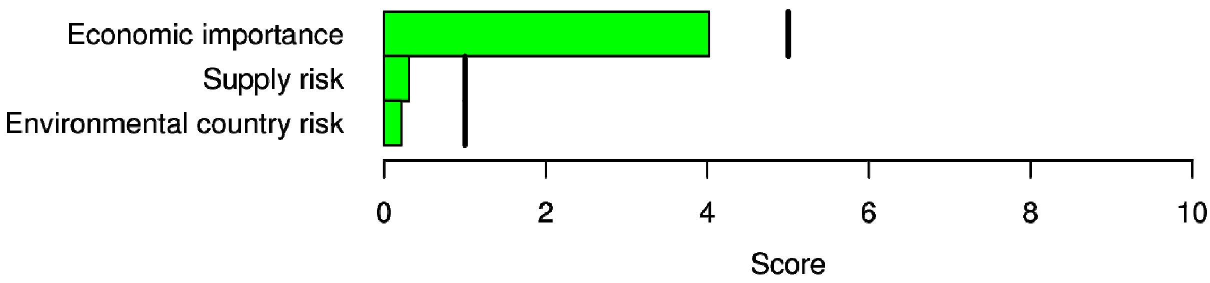
Concerning substitutes, aluminium, copper, gold, palladium, platinum, and several refractory metals can replace silver completely or partially in electrical and electronic uses. It has to be mentioned here that this also depends on the price that has to be paid for the substituent. Furthermore, silver has to be considered as the metal with the highest electrical and thermal conductivity of all metals, which means that certain looses in performance could arise if silver is substituted by other metals. The main focus of research for substitutes should be placed in the dissipative silver applications such as RFID and textiles.

As noted above, substitution in photography equipment has been improved due to improvements in digital technology, as pictures taken with digital cameras do not necessarily have to be developed.

Use	Share	Megasector	Subst.
Jewelry and silverware	34%	Other Final Consumer	0,7
Photography	18%	Chemicals	0,3
Electrical/Electronics (contacts)	23%	Electronics & ICT	1
Dental	5%	Pharmaceuticals	1
Catalysts	6%	Chemicals	0,7
Mirrors and reflective glass	2%	Rubber, Plastic & Glass	0,7
Solar panels	4%	Electronics & ICT	0,7
Batteries	2%	Electronics & ICT	0,7
Plasma displays	1%	Electronics & ICT	0,7
Water treatment	3%		0,7
RFID-tags	0%	Electronics & ICT	0,7
Coins	1%		1

Substitutability	0,71
Recycling rate (recycled content from old scrap)	16%
Import Dependence	45%

Results	
Economic Importance	5,1
Supply Risk	0,3
Environmental Country Risk	0,2



35 Talc

35.1 Introduction

Talc is the softest mineral on the Mohs' hardness scale at 1. Because it is soft, it can be easily ground into powder. Talc mineral is a phyllo-silicate with a perfect cleavage in one direction. This means that the mineral breaks into thin sheets. As a result, it feels greasy to the touch (which is why talc is used as a lubricant). It is formed in metamorphic environments as the result of changes in silica-rich dolomite.

Talc deposits result from the transformation of existing rocks under the effect of hydrothermal fluids carrying one or several of the components needed to form the mineral (MgO, SiO_2, CO_2).

Talc deposits can be classified into four main types according to the nature of their host rock:

- Transformation of carbonates (dolomite or magnesite) with silica addition (approx. 60-70% of the world production)
- Transformation of serpentine derived ore bodies (approx. 20% of the world production)
- Transformation of silica rocks and/or silica-aluminous rocks with addition of MgO (approx. 10% of the world production)
- Transformation of magnesium clays (none in operation)

35.2 Basic Supply & Demand Statistics

China is the world's largest producer of talc, with a 29% of the world production. China is also main exporter to the EU, with approximately 58% of the imports coming from China. Available reserves of talc are sufficient for many decades to come[207]

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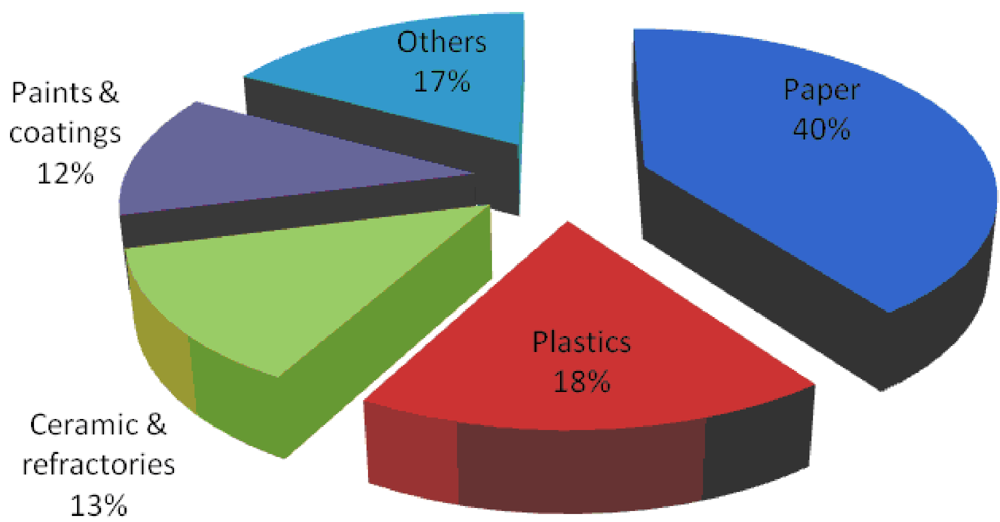
207 http://www.mii.org/Minerals/phototalc.html

	Reserves (in 1000t)	Production (in 1000t, 2008)		EU imports (in 1000t, 2006)	
United States1	140,000	706	9.4%	10.3	6.4%
Brazil	180,000	405	5.4%	2.8	1.8%
China	Large	2,200	29.3%	93.1	57.7%
Finland	Large	550	7.3%		
India	4,000	647	8.6%	6.6	4.1%
Japan	100,000	355	4.7%		
Korea, Republic of	14,000	825	11.0%	10.9	6.8%
Other countries	Large	1,820	24.2%	37.5	23.3%
World total	**Large**	**7,508**		**161.3**	

Source: USGS; UN Comtrade HS 2526

35.3 Economic Importance



Ground talc is used as an ingredient in ceramics, paper, paint, roofing, plastics, cosmetics, talcum and baby powders, and a variety of other assorted uses such as making rubber and plastics.

The main uses of the talc products are:

- plastics (automotive applications, electrical appliances, packaging films, foils etc) to increase the stiffness and the dimensional stability and
- rubber to improve the flow in moulding and extrusion and tensile and tear properties
- coatings (decorative and industrial paints) talc has fundamental anticorrosion benefits and increases opacity, weather resistance and the barrier effect,

- paper as filler (now mainly in Asia) and also to prevent wood resin and latex agglomeration, to increase the runnability and printability for coated paper and the paper smoothness and water retention in filled paper
- ceramics as a flux and for thermal expansion control, talc is an essential ingredient in honeycomb cordierite for catalyst supports and diesel particulate filters
- cosmetics as a body powder for its softness and to improve perfume retention
- pharmaceuticals as an excipient or lubricant (European Pharmacopoeia talc monograph)
- food as:
  - an anti sticking agent (in the European Union, the talc additive number is E 553b)
  - olive pressing to improve oil extraction
  - asphalt as an anti-caking agent
  - animal feed as an anti caking agent and to improve pellet pressability

35.4 Resource Efficiency: Recycling & Substitution

Recycling

According to the MII, talc is not recycled. However certain plastic automotive parts that are manufactured with talc can be recycled. The same is true of paper that can contain talc**.**

Substitution

Depending on the required properties, there is potential to substitute talc with bentonite, chlorite, kaolin, and pyrophyllite in ceramics; in ceramic flux applications, the main substitute is feldspar; chlorite, kaolin, and mica in paint; calcium carbonate and kaolin in paper; ; in polymers, only mica or wollastonite can sometimes substitute for talc; and kaolin and mica in rubber.

Clays and pyrophyllite may be used in place of talc in the manufacture of ceramics. Kaolin (a clay mineral) and mica may be substitute for talc in the production of rubber, paint, and plastics. Kaolin may be used in place of talc in paper production. Available reserves of talc are sufficient for many decades to come although supplies of very bright talc ore are becoming more difficult to access.

35.5 Specific issues

Talc is one of the most environmentally-friendly minerals that exist. Industry is committed to ensuring that administrations understand the benefits talc brings to a myriad of everyday products and that customers find value in using talc in their formulations, while guaranteeing a high level of protection to the customers and the environment. The main issues identified by industry are the following:

- Deficit of indigenous high brightness talc resources in Europe
- Domestic use of Chinese talc is increasing due to urbanisation and supplies of Chinese talc for export markets are becoming tighter

Environmental issues: Access to European resources is being increasingly hampered by ever stricter environmental protection measures (e.g. water use reduction, emissions, waste management, etc.) as well as a restrictive approach due to a negative perception of the extractive industry in general by some administrations.

Administrative burden: too many different administrations involved in permitting procedures.

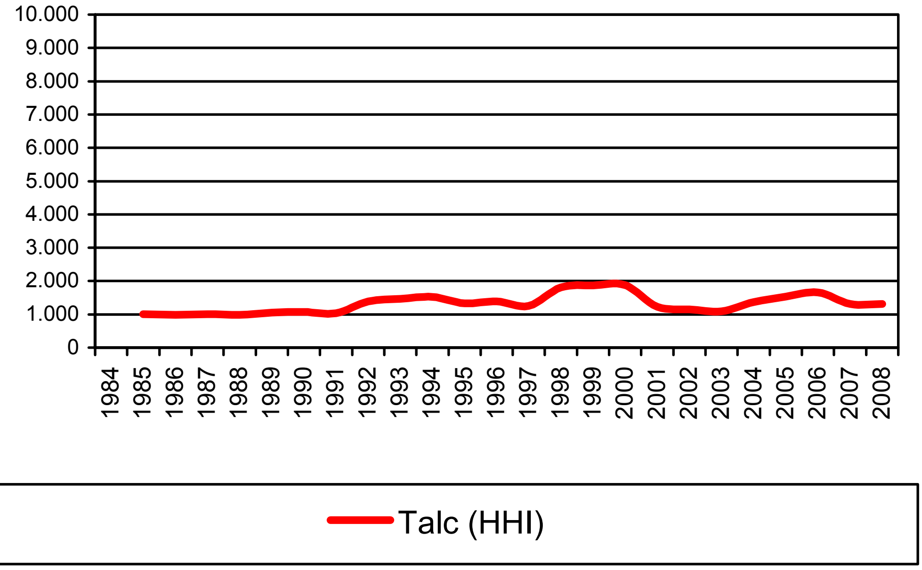
Occupational Health and Safety issues: Talc, like all minerals, is facing an increasingly burdensome regulatory environment. The mineral has regularly been evaluated by regulatory experts in the last decades (e.g. European Commission DG Environment C&L Working Group, US National Toxicity Program (NTP), the US Occupational Health and Safety (OSHA), ACGIH (American Congress of Governmental Industrial Hygienists)). While talc inhaled was evaluated in 2007 as not classifiable as a carcinogen by the International Agency for Research on Cancer (IARC), the Agency has ruled that there is limited evidence that the use of talc-based body powder is a possible risk factor for ovarian cancer. This remains a research hypothesis that requires additional study since there is no evidence that talc play a role in this.

Use	Share	Megasector	Subst.
Paper	40%	Paper	0,3
Plastics	18%	Chemicals	0,3
Ceramic & refractories	13%	Construction material	0,3
Paints & coatings	12%	Chemicals	0,3
Others (feed materials, personal care, rubber, roofing)	17%	Other Final Consumer Goods	0,5

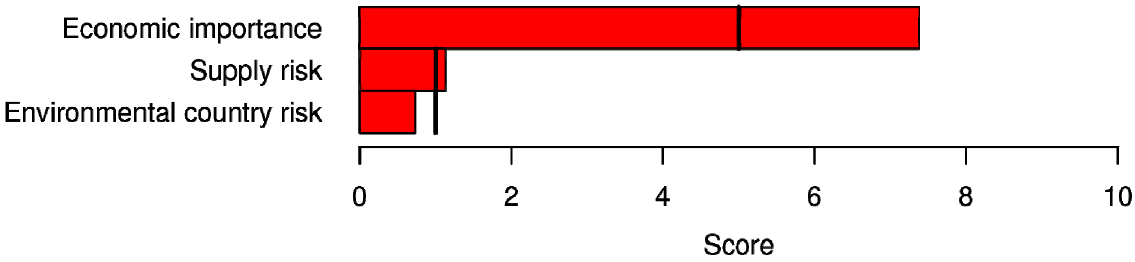
Substitutability index	0,33	
Recycling rate (recycled content)	0%	no information available
Import Dependence	11%	

Results

Economic Importance	4,0
Supply Risk	0,3
Environmental Country Risk	0,2



Source: World Mining Data, 2010



36 Tantalum

36.1 Introduction

Tantalum (Ta, atomic number 73) is a hard, tough and ductile element, belonging to the group of base metals.[208] In its chemical properties it is similar to Niobium and like that, it is extraordinary resistant to corrosion against many organic and inorganic acids below 100°C. The reason for this characteristic is a thin film of tantalum oxide, coating the metal. The tantalum oxide layer is also used as dielectric substance for electrolytic capacitors.[209] That makes tantalum to a very important raw material for many IT and telecommunication applications.[210]

36.2 Basic Supply & Demand Statistics

Tantalum often occurs together with niobium, nevertheless it is more than ten times less abundant than niobium (2.1ppm).[1] Tantalum containing minerals like tantalite, wodginite, microlite or columbite can be found all over the world, but rarely with significant tantalum content. Tantalum is also produced as byproduct during tin smelting[2].

Besides the main producers Brazil and Australia, the Democratic Republic of Congo also produces tantalum concentrates.

	Reserves (in t; 2010)		Production (in t; 2009)		Imports to EU (in t; 2006)	
Australia	40,000	38.1%	560	48.3%		
Brazil	65,000	61.9%	180	15.5%		
Canada	NA		40	3.4%		
DRC	NA		100	8.6%		
Rwanda	NA		100	8.6%		
China					17	13%
Japan					78	60%
Kazahstan					35	27%
others	NA		180	15.5%	2	
Total	**105,000**		**1,160**		**131**	

208 Römpp Online: *Tantal.* Georg Thieme Verlag, Stuttgart, 2007

209 Ullmann's Encyclopedia of Chemical Technology: *Tantalum and Tantalum Compounds*. Wiley-VCH Verlag, Weinheim, 2006

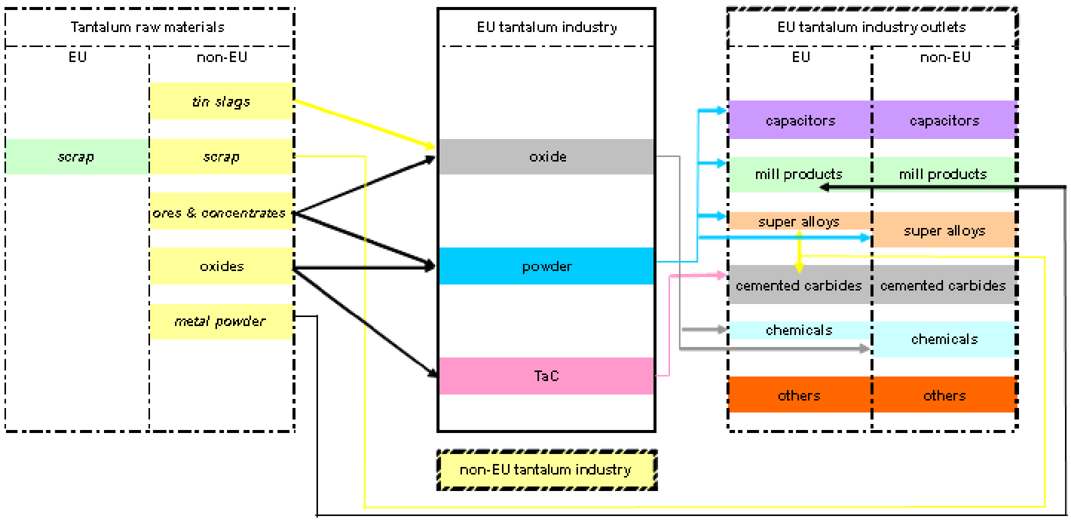
210 Materialwissenschaften, “Engpässe bei Hightech-Metallen”

Source: USGS 2010; trade data provided by BGS based on EU comtrade (CN 8103 20 00). Notice that trade data pertains to unwrought tantalum, not ores and concentrates because of data restrictions.

World resources, mainly located in Brazil and Australia, are considered to cover projected demands.[211]

Even though current world supply of Tantalum is mainly based on primary mineral sources (65 % Ta minerals and 13% Ta in tin slags in 2005), more than 20%arises from the recycling of of Ta containing secondary materials[212].

The EU's tantalum industry consists of only a few companies whose product range features tantalum oxide, metal powder, carbide and mill products. Their combined output is between 250 – 300 tonnes tantalum per year. Their entire feed supplies (concentrates, scrap and tin slags) are imported meaning that the EU tantalum industry is practically entirely dependent on access to raw materials on the international market (only small quantities of scrap are sourced from the EU market).



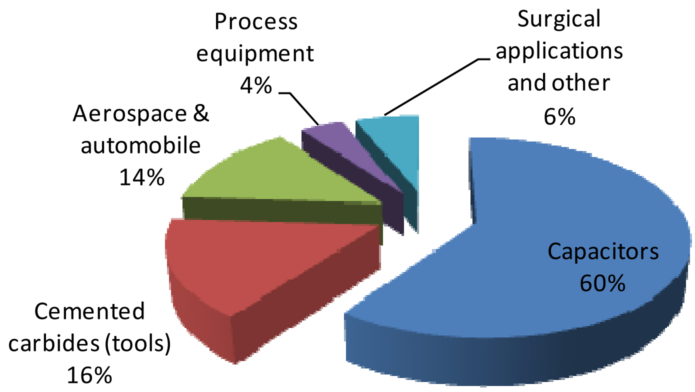
2Ullmann's Encyclopedia of Chemical Technology: *Tantalum and Tantalum Compounds*. Wiley-VCH Verlag, Weinheim, 2006

3 Materialwissenschaften, "Engpässe bei Hightech-Metallen"

211 USGS Mineral Commodity Summaries 2010: *Tantalum*

212 Roskill, The Economics of Tantalum, Ninth Edition, 2005

36.3 Economic Importance



The main end-use markets wordwide for tantalum (2005) in the are shown above. [213] In detail[2,3,214]:

- Capacitors: About 60% of total tantalum consumption is used in form of metal powder for electrolytic capacitors[215], which are basic components of modern IT and telecommunication devices (mobiles, notebooks, digital cameras...).
- Medicine: Because of its nontoxic character and its good compatibility with tissue, tantalum is used in a variety of medical applications.
- Alloys: Tantalum-tungsten alloys and also tantalum containing superalloys are valued for their high temperature resistance and strength. They are used for the construction of industrial chemical equipment, for aircraft engines and for stationary gas and steam turbines.
- Optical industry: Tantalum compounds, mainly tantalum pentoxide, is used for special glasses (heat-reflecting, high refractive index, low optical scattering).

The drivers of future tantalum demand will be segments such as superalloys, the coating industry and micro-electronics (tantalum demand for micro-capacitors will probably

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213 RWI/ISI/BGR (2007): *Trends der Angebots- und Nachfragesituation bei mineralischen Rohstoffen.*

214 Roskill Information Services: *The Economics of Tantalum*, London, 2005

215 Roskill, “The Economics of Tantalum”, 2005

triple in the next two decades[216]). Demand from the very price sensitive sector of electronics will be strongly influenced however by tantalum price developments which may enhance miniaturisation and trigger substitution.

The EU tantalum industry has historically developed amongst the top ranking suppliers of tantalum products on the global market. Although the EU market is the industry's natural outlet, its activity is very much export oriented as demand for tantalum and tantalum products is geographically widespread in the world (e.g. the electronics and automotive industries).

36.4 Resource Efficiency: Recycling & Substitution

Recycling of tantalum is operated in the cemented carbide and alloy sectors where tantalum is recovered from scrap in mixed or alloy form. Recycling from capacitors, the main user of tantalum, is difficult and insufficiently developed. Information about recycled content from old scrap differ form less than 1% to 9%.[217]

There are efforts to substitute tantalum in capacitors by aluminum and ceramics. Niobium might be used in carbides, and glass, niobium, platinum, titanium, and zirconium in corrosion-resistant equipment. Moreover hafnium, iridium, molybdenum, niobium, rhenium, and tungsten can be used for high-temperature applications. When tantalum is substituted, most applications loose some effectiveness.[218]

36.5 Specific Issues

Trade Issues:

According to the European Commission's inventory on export restrictions, South Africa applies a non-automatic export licensing system on Tantalum ores and concentrates as well as on Tantalum metal under various forms, including waste and scrap. Tantalum scrap is subject to an export ban in Tanzania.

Market Issues:

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216 Fraunhofer Institut für System und Innovationsforschung and Institut für Zukunftsstudien und Technologiebewertung: *Rohstoffe für Zukunftstechnologien*, 2009, Fraunhofer IRB Verlag, Stuttgart

217 UNEP (upcoming), The Recycling of Metals: A Status Report, Report of the Global Metal Flows Group to the International Panel for Sustainable Resource Management. Graedel T. et al.

218 USGS Mineral Commodity Summaries 2010: *Tantalum*

On the supply side**,** the EU tantalum industry is sourcing its entire primary tantalum feed from outside the EU as Europe is not endowed with any tantalum resources. The main raw materials imported by the EU tantalum industry are ores and concentrates, tin slags and scrap.

Shrinking demand for electronics brought on by the 2008 recession led to a drop in tantalum capacitor demand, which in turn forced primary tantalum producers to severely cut back production. The world's largest producer, responsible for about a third of total global production, Australia-based Talison, stopped operating in 2008 and was followed by two other major mining producers whose operations were made economically unviable by the recession. These closures lead to a 40 per cent cut in total world tantalum production.

World tantalum supply may appear to be seriously insufficient once demand picks up. Roskill Information Services reports that even a modest recovery in tantalum demand in the next few years could create a real supply squeeze by 2012. Some tantalum processors are already confronted with a lack of supplies.

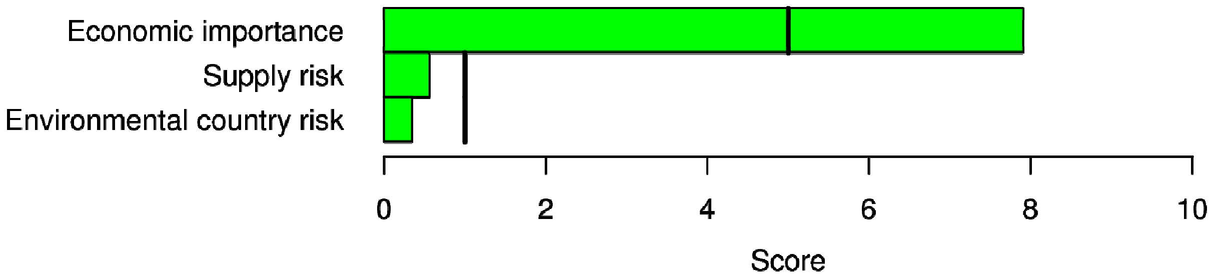
On the demand side**,** the EU tantalum industry is increasingly confronted with Chinese competition, both on the EU and world market, where demand growth actually occurs. China's pricing policy is extremely detrimental to the industry as it is erratic and destructive of the normal price structure (prices for value added products are quoted below metal price).

Under these circumstances, securing a level playing –field in access to tantalum raw materials is increasingly seen as a vital condition for ensuring the future viability of the EU tantalum industry.

Use	Share	Megasector	Subst.
Capacitors	60%	Electronics & ICT	0,3
Cemented carbides (tools)	16%	Mechanical Equipment	0,3
Aerospace & automobile	14%	Road transport	0,7
Process equipment	4%	Mechanical Equipment	0,7
Surgical applications and other	6%	Electronics & ICT	0,7

Substitutability index	0,40
Recycling rate (recycled content)	4%
Import Dependence	100%

Results	
Economic Importance	7,4
Supply Risk	1,1
Environmental Country Risk	0,7



37 Tellurium

37.1 Introduction

Tellurium is a metallic, silvery-white element. Tellurium is found pure or in combination with gold, silver, copper, lead or nickel in minerals like sylvanite, petzite, tetradymite. It is less common in rocks such as tellurite (TeO2).

Typical concentration of tellurium in one million tonnes of refined copper deposits is around 180 gr but tellurium extraction efficiency is today around 30%. Over the past 10 years, price of tellurium increased by about a factor 10 and this did not lead to a ramp up of tellurium output by copper industry. Valorization of copper can lead to profit that is thousand times higher than that from tellurium it contains. There is thus little economic incentive to valorize tellurium with revenues from it. Tellurium spreads over 25 – 30 mines across 20 countries. Copper industry is moving to cheaper methods (solvent extraction, electrowinning already representing 20% of Copper production in 2005) versus electrolytic recovery, which means that tellurium output may be lower on prorata of copper output in the future.

37.2 Basic Supply & Demand Statistics

The largest world producer of tellurium is Canada, with approximately 59% of the known world production. These figures are unfortunately not very precise, as there are several countries that do not report their production, thus making in very difficult to determine the exact world production.

The EU mainly imports from Norway (67%), followed by Morocco (20%). These countries are included in the other countries category in the table underneath.

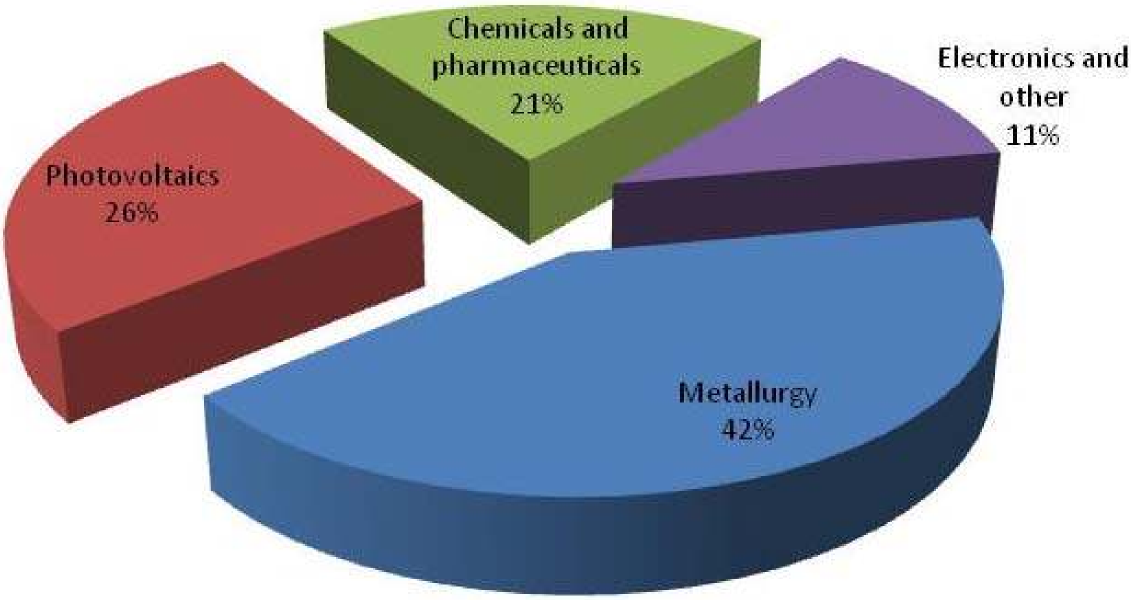
	Reserves (in t;2006)		**Refinery production (mio. tonnes) (2006)**		**Imports to EU (in t, 2006)**	
United States	3,000	14%	W			
Canada	700	3%	75	59%	37.2	5%
Japan	NA		20	16%	3.0	0.4%
Peru	1,600	8%	33	26%	14.0	2%

Other countries	16,000 75%	NA		706.5	93%
World total (rounded)	**21,300**	**128**		**760.7**	

Source: USGS; Comext CN 2804 50 90; W – Withheld or classified

The break-down of tellurium primary production capacities is as follows: China (33%), Belgium (33%), Philippines (16%), Japan (12%), Canada (4%) and Russia (2%). The capacity utilisation for production of tellurium runs high at 74 - 78%.

37.3 Economic Importance



- Tellurium's major use today is as an alloying additive in metallurgy. In steel to improve machinability, in copper alloys to improve machinability without reducing conductivity, in lead alloys to improve resistance to vibration and fatigue, in cast iron to control the depth of chill and in malleable iron as a carbide stabilizer.
- Tellurium is also used in Cadmium Telluride thin-film photovoltaics which haave grown significantly since 2008.
- Tellurium is also used in the chemical industry as a vulcanizing agent and accelerator in rubber processing, and as a catalyst for synthetic fiber production.
- Photoreceptor, thermoelectric (Bismuth Telluride) & electronic devices also make use of tellurium.

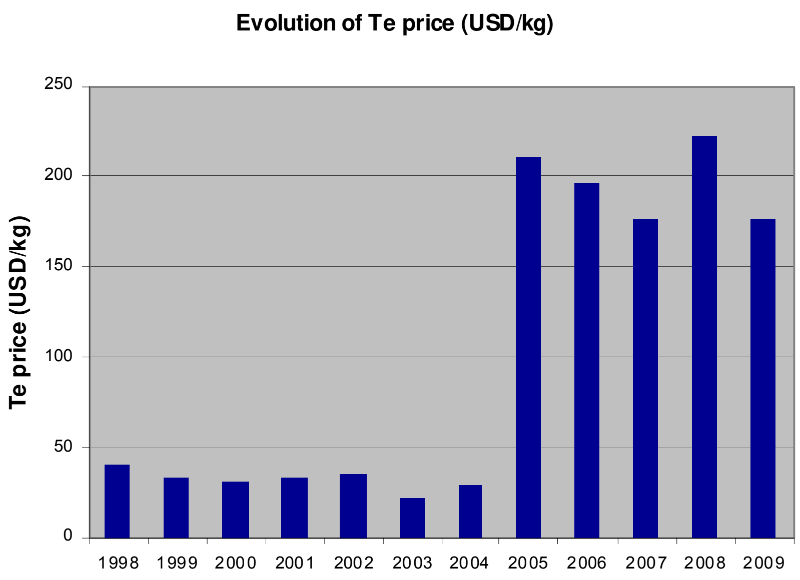
- Other minor applications include the use as a pigment to produce various colors in glass and ceramics.

Forecast for the periods 2010-2015 resp. 2016-2020 are as follows:

- Metallurgy: 3%, resp. 3%
- Photovoltaics: 8%, resp. -2%
- Chemicals & Pharma: 3%, resp. 3%
- Electronics (and others): 5%, resp. 5%

Competing applications as well as development of competing thin-film PV technologies account for the negative rate of growth in photovoltaic's post-2015.

From a mere 29 USD/kg in 2004, price of tellurium peaked in 2005 above the 200 USD limit and stayed ever since on average in the 150 – 220 USD/kg range.



Price evolution of tellurium (USD/kg)

37.4 Resource Efficiency: Recycling & Substitution

Recycling

Tellurium recovery through recycling is still embryonic but growing steadily (< 10% of supply). Recovery of industrial scrap from photovoltaic industry provides a growing stream of secondary tellurium expected to represent about 7% of total tellurium in 2010 decreasing though over time as deposition processes for photovoltaics become more efficient and its growth is levelling off.

Substitution

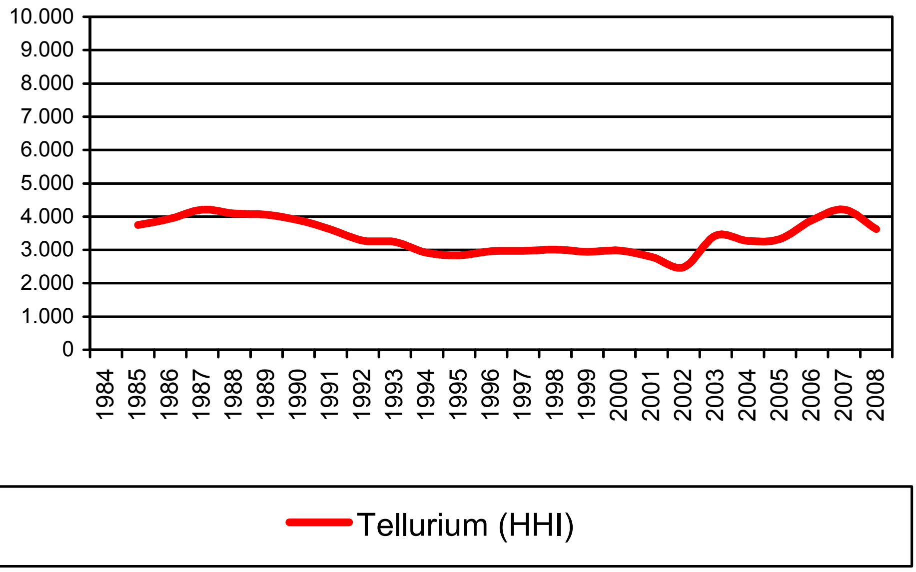
Several materials can replace tellurium in most of its uses, but usually with losses in production efficiency or product characteristics. Bismuth, calcium, lead, phosphorus, selenium, and sulfur can be used in place of tellurium in many free-machining steels. Several of the chemical process reactions catalyzed by tellurium can be carried out with other catalysts or by means of noncatalyzed processes. In rubber compounding, sulfur and/or selenium can act as vulcanization agents in place of tellurium. The selenides of the refractory metals can function as high-temperature, high-vacuum lubricants in place of tellurides. The selenides and sulfides of niobium and tantalum can serve as electrically conducting solid lubricants in place of tellurides of those metals.

The selenium-tellurium photoreceptors used in some xerographic copiers and laser printers have been replaced by organic photoreceptors in newer machines. Amorphous silicon and copper indium diselenide are the two principal competitors to cadmium telluride in photovoltaic power cells.

Use	Share	Megasector	Subst.
Metallurgy	42%	Metals	0,3
Photovoltaics	26%	Electronics & ICT	0,3
Chemicals and pharmaceuticals	21%	Chemicals	0,3
Electronics and other	11%	Electronics & ICT	0,5

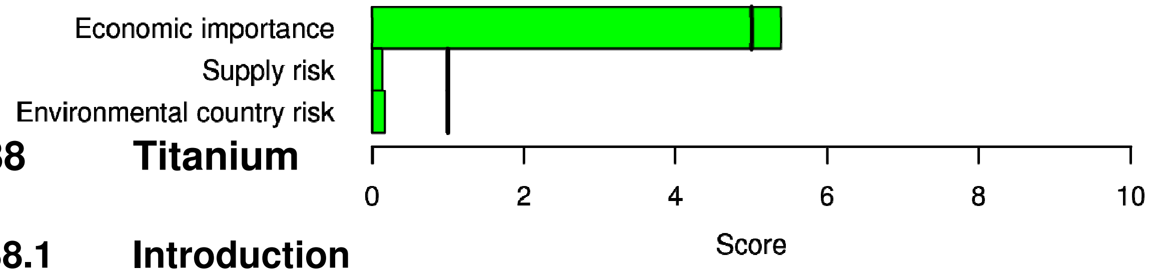
Substitutability index	0,32	
Recycling rate	0%	no information available
Import Dependence	100%	

Results	
Economic Importance	7,9
Supply Risk	0,6
Environmental Country Risk	0,3



Source: WORLD MINING DATA

38 Titanium



38.1 Introduction

Titanium (Ti, atomic number 22) is a light metal with many interesting properties, such as low weight, high mechanical strength, a high melting point, a low thermal expansion coefficient and high resistance against many substances, including acids and saltwater. These properties make titanium and titanium alloys important for many applications, for example in the aircraft industry or in medicine.[219]

The three minerals that are commercial sources for titanium metal and titanium dioxide (TiO_2) are Ilmenite, leucoxene and rutile. By far most quantities of titanium mineral concentrates are used by titanium dioxide producers, for example for pigments. [220] For the extraction of titanium dioxide, rutile is the most useful mineral. [221]

38.2 Basic Supply & Demand Statistics

Titanium, together with aluminum, iron and magnesium, belongs to the most common metals in the earths crust (0.56%). The biggest primal ores deposits (Ilmenite) are situated in Norway, in Russia, in Finland, in Canada and in the United States. Secondary ore deposits (Ilmenite- and rutile sands) are located in South Africa, Brazil, Malaysia, Egypt, Australia and India. In the following table, the column “reserves” represents Ilmenite and rutile reserves of contained TiO_2.

	Reserves (in 1000t; 2009)		Production (in 1000t; 2009)		EU imports (in 1000t; 2007)	
USA	6,400	0.9%	300	4.3%		
Australia	152,000	20.8%	1,737	24.7%	423	21.6%
Brazil	44,200	6.1%	95	1.4%	19.9	1.0%
Canada	31,000	4.2%	1,350	19.2%	551	28.1%
China	200,000	27.4%	715	10.2%		
Egypt	NA		66	0.9%	17	0.9%
India	92,400	12.7%	401	5.7%	105	5.3%
Kazakhstan	NA		16	0.2%		
Malaysia	NA		32	0.5%	0.005	>0.1%
Russia (Europe)	NA		34	0.5%		
Mozambique	16,480	2.3%	NA			
Norway	37,000	5.1%	374	5.3%	500	25.5%

219 Römpp Online: *Titan.* Georg Thieme Verlag, Stuttgart, 2007

220 USGS Mineral Commodity Summaries 2009: *Titanium Mineral Concentrates*

221 Ullmann’s Encyclopedia of Chemical Technology: *Titanium, Titanium Alloys and Titanium Compounds*. Wiley-VCH Verlag, Weinheim, 2006

Sierra Leone	2,500	0.3%	84	1.2%	39	2.0%
South Africa	71,300	9.8%	1,208	17.2%	187	9.5%
Sri Lanka	NA		39	0.6%	27	1.4%
Ukraine	8,400	1.2%	330	4,7%	94	4.8%
Vietnam	1,600	0.2%	253	3,6%		
Others	66,400	9,1%				
Total	**729,680**		**7,035**		**1,963**	

Source: Reserves USGS 2009; Production World Mining Data 2009; trade data provided by BGS based on EU comtrade (HS 2614)

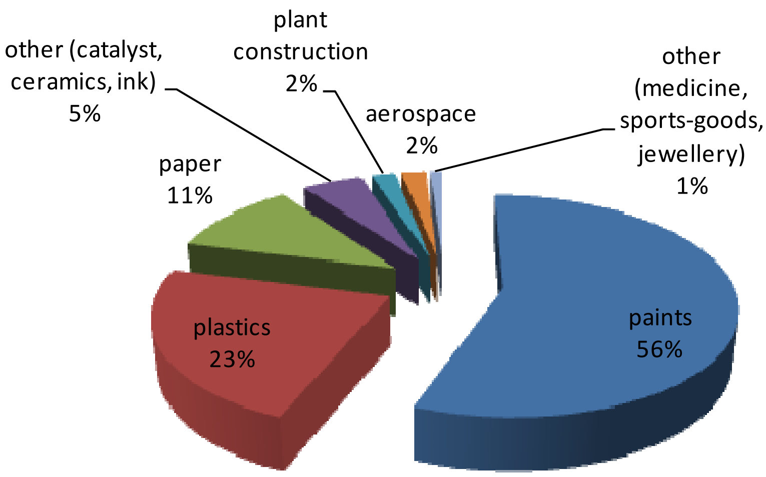
World resources of Ilmenite, anatase and rutile are estimated more than 2 billion tons. About 92% of the world's demand for titanium minerals is supplied by Ilmenite[222].

Titanium is not produced within the European Union. European production of titanium minerals is limited to Norway, which contributed 7% of worldwide production, although the country only mines ilmenite. Several ilmenite deposits are reported for Western Finland. Deposits in Sweden are not exploited currently, due to economical and environmental issues[223]. In 2007, the whole consumption was imported (about 28% of the world production) mainly from Canada, Norway and Australia.

Rutile:

The companies TRG (Titanium Resource Group) from Sierra Leone, Iluka from Australia and RBIT (part of the South African company Richards Bay Mining) controlled in 2008 2/3 of the world market.

38.3 Economic Importance



222 USGS, MCS 2009, Titanium mineral concentrates

223 SVERIGES GEOLOGISKA UNDERSÖKNING, Carl-Magnus Backman

The main end-use markets for titanium (titanium dioxide and titanium metal, worldwide) are shown above[224].

Main end-use markets for titanium dioxide[225]:

- Pigments: Titanium dioxide is mainly used for white pigments, which are non toxic and therefore useful in many applications (cosmetics, food industry, enamels).
- Plastics Titanium dioxide is also used in the manufacturing of plastics.
- Paper: Also the paper industry uses titanium dioxide.
- Other: Other applications include ceramics and currently titanium dioxide has a growing importance for catalysts.

And for titanium metal[226]:

- Aerospace: Due to its specific properties, titanium metal is valued in the aircraft industry. The vast majority of titanium metal is used in this sector. It is also used for deep sea devices and for submarines.
- Plant construction: Its high corrosion resistance is used for the construction of many different plants, for example in the chemical and food industry for desalination plants and for nuclear reactors.
- Other: Moreover titanium is used for medical applications, sport goods, jewelry and for lenses with high refractive power.

Some important technologies that are expected to increase the demand for titanium metal are microcapacitors, sea water desalination, orthopedic implants and dye-sensitised solar cells[227].

38.4 Resource Efficiency: Recycling & Substitution

Titanium minerals cannot be recycled as they are used in a dissipative manner. Nonetheless, the produced titanium metal can be recycled.

New scrap metal recycled by the titanium industry totalled about 33,000 tons in 2008. Estimated use of titanium as scrap and ferrotitanium by the steel industry was about 10,500 tons; by the superalloy industry, 1,200 tons; and, in other industries, 1,400 tons. Old scrap reclaimed totaled about 600 tons[228].

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224 Roskill Information Services, U.S. Geological Survey, expert interview.

225 Römpp Online: *Titandioxid.* Georg Thieme Verlag, Stuttgart, 2007

226 USGS Mineral Commodity Summaries 2009: *Titanium and Titanium Dioxide*

227 Fraunhofer "Rohstoffe für Zukunftstechnologien", 2009)

228 USGS Mineral Commodity Summaries 2009: *Titanium and Titanium Dioxide*

Today recycled content from old scrap makes up 6%[229] of the total consumption. In the future recycled material will only cover a small share in the future, due to a fast rising consumption[230].

Only few materials can compete with titanium concerning its strength-to-weight-ratio and its corrosion resistance. Aluminum, composites, intermetallics, steel, and superalloys can substitute titanium in high-strength materials. Aluminum, nickel, specialty steels, and zirconium alloys are suitable substitutes for applications where corrosion resistance is necessary. In the pigment sector, calcium carbonate, precipitated calcium carbonate, kaolin, and talc compete with titanium dioxide[231].

Ilmenite, leucoxene, rutile, slag, and synthetic rutile compete as feedstock sources for producing TiO_2 pigment, titanium metal, and welding-rod coatings. Among these, only ilmenite and rutile are mineral sources.

38.5 Specific issues

According to the European Commission's inventory on export restrictions, Russia applies a general 6.5% on titanium under various forms. Again more specifically titanium waste and scrap is subject to intense export restrictions with a 30% export tax in Russia and a 27% export tax in Ukraine.

229 UNEP (upcoming), The Recycling of Metals: A Status Report, Report of the Global Metal Flows Group to the International Panel for Sustainable Resource Management. Graedel T. et al.

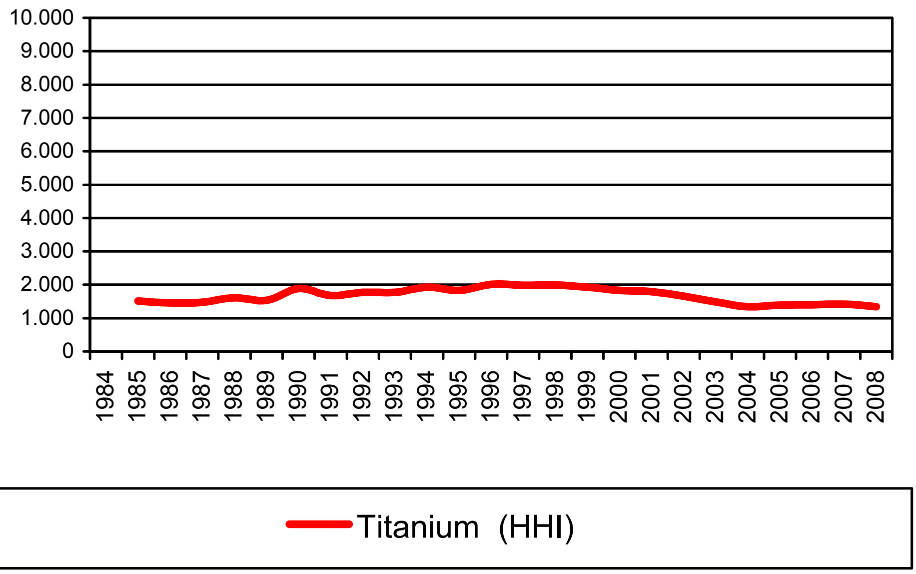
230 Fraunhofer "Rohstoffe für Zukunftstechnologien", 2009

231 USGS Mineral Commodity Summaries 2009: *Titanium and Titanium Dioxide*

Use	Share	Megasector	Subst.
Titanium Dioxide			
paints	56%	Chemicals	0,3
plastics	23%	Chemicals	0,3
paper	11%	Paper	0,3
other (catalyst, ceramics, ink)	5%		0,5
Titanium Metal			
plant construction	2%	Mechanical Equipment	0,7
aerospace	2%	Aircraft, Shipbuilding, Trains	0,7
other (medicine, sports-goods, jewellery)	1%		

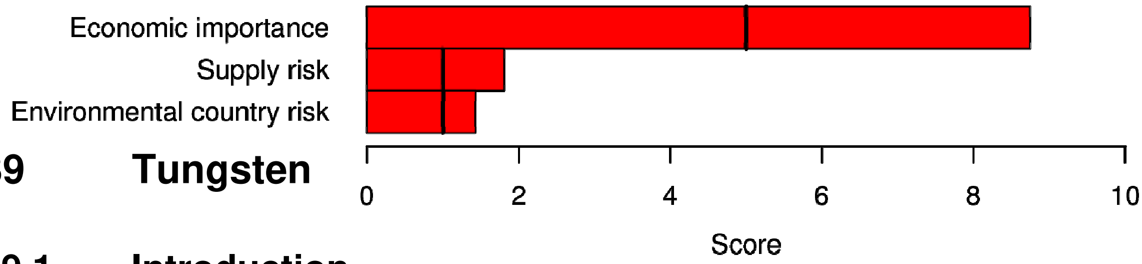
Substitutability index	0,32
Recycling rate (recycled content from old scrap)	6%
Import Dependence	100%

Results	
Economic Importance	5,4
Supply Risk	0,1
Environmental Country Risk	0,2



Source: WORLD MINING DATA

39 Tungsten



39.1 Introduction

Tungsten (W) occurs in nature only in the form of chemical compounds. Although more than thirty tungsten bearing minerals are known, only two of them are important for industrial use, namely wolframite and scheelite[232].

It is remarkable for its robust physical properties, especially the fact that it has the highest melting point of all the non-alloyed metals and the second highest of all the elements after carbon. Also remarkable is its very high density of 19.3 times heavier than water, and 71% heavier than lead. Tungsten is often brittle and hard to work in its raw state.

Tungsten is the only metal from the third transition series that is known to occur in bio molecules, and is the heaviest element known to be used by living organisms.

39.2 Basic Supply & Demand Statistics

World tungsten resources are geographically widespread. China ranks first in the world in terms of tungsten resources and reserves and has some of the largest deposits. Canada, Kazakhstan, Russia, and the United States also have significant tungsten resources.

Almost 78% of world's production of tungsten comes from China. However, China only exports tungsten in value added forms meaning that the main tungsten raw materials available for export are APT (ammonium paratungstate) and oxide.

Europe imports about 26% of World's production. Overall the EU is import dependent[233]

	Reserves (in 1000t)		Production (in t; 2008)		Imports into EU (in t; 2006)	
United States	140	5.1%	N/A	N/A		
Austria	10	0.4%	1,100	2.0%		
Bolivia	53	1.9%	1,100	2.0%	352	6.6%
Canada	110	4.0%	2,300	4.1%	22	0.4%
China	1,800	65.0%	43,500	77.8%	19	0.4%
Portugal	4	0.2%	850	1.5%		

232 ITIA www.itia.info

233 European Mineral Statistics 2003-2007, BGS

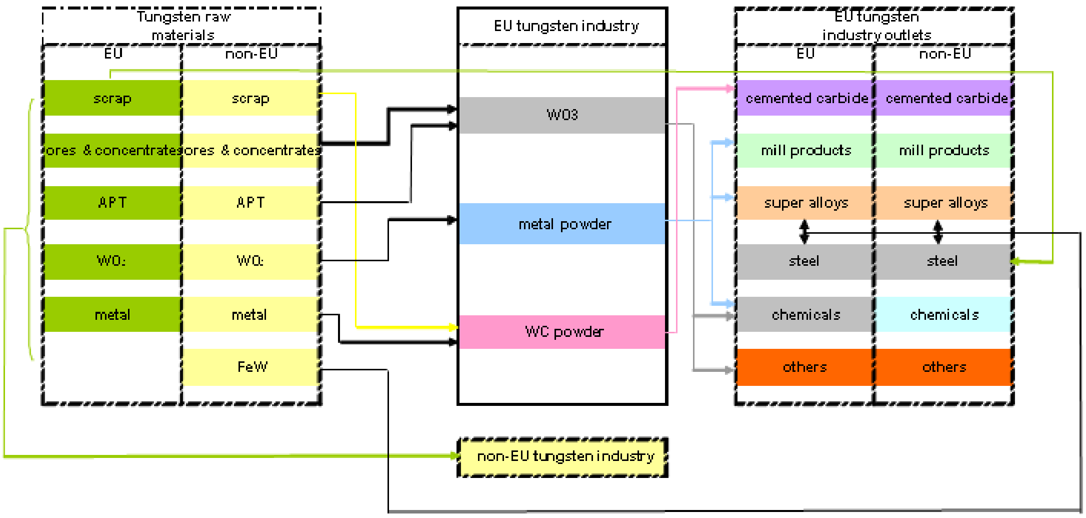
Russia	250	9.0%	3,000	5.4%	4026	75.6%
Other countries	400	14.5%	4,100	7.3%	910	17.1%
World total	**2,767**		**55,950**		**5,329**	

Source: USGS; UN Comtrade HS 2611

Origins	2007 EU Imports of Tungsten raw materials (in t)		
	Ores & concentrates	APT	Oxides
Russia	190	240	737
Kenya	68		
Tanzania	57		
USA	17	440	975
Canada	34		
China	1	1 470	2,531
Total	2,790	2,190	4,320

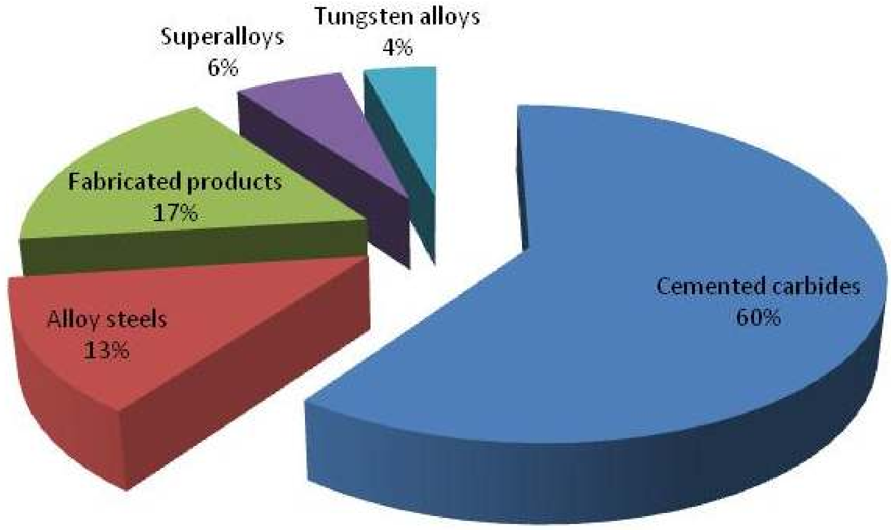
Source: 2841 80 and 2825 90 40 expressed in W content

As noted above, Europe imports about 26% of World's production: ~2 500 t W as ore, ~2 100 t W as APT and ~4 000 t W as oxides. There are two tungsten mines in production in the EU, in Portugal and in Austria (production of the latter is captive).



EU Tungsten Industry Structure

39.3 Economic Importance



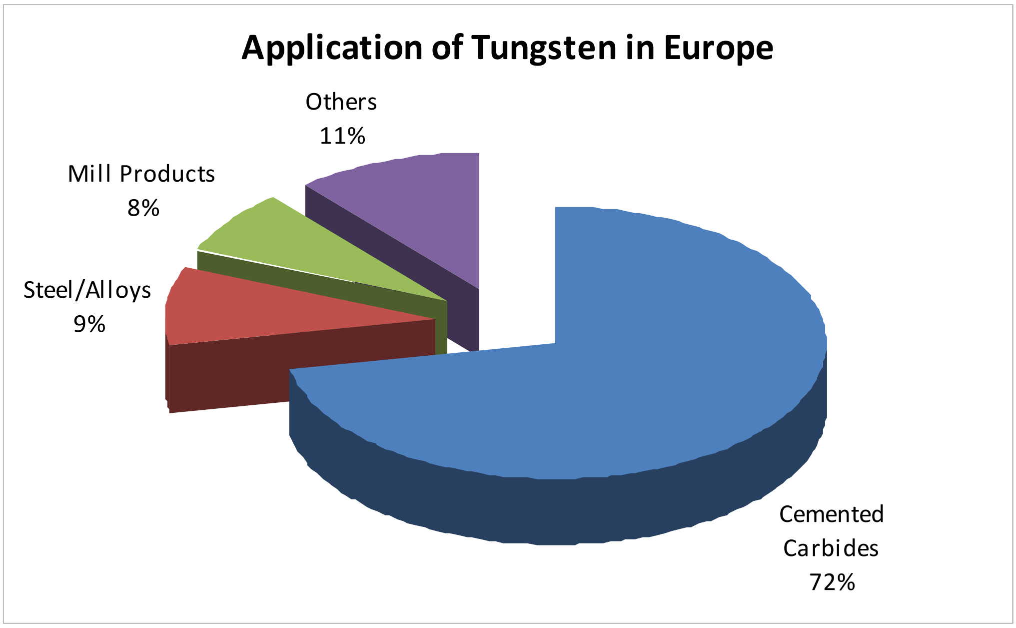
Tungsten is a metal with a wide range of uses, the largest of which is as tungsten carbide in cemented carbides. Cemented carbides (also called hard metals) are wear-resistant materials used by the metalworking, mining, and construction industries.

Tungsten metal wires, electrodes, and/or contacts are used in lighting, electronic, electrical, heating, and welding applications.

Tungsten is also used to make heavy metal alloys for armaments, heat sinks, and high-density applications, such as weights and counterweights; super alloys for turbine blades; tool steels; and wear-resistant alloy parts and coatings.

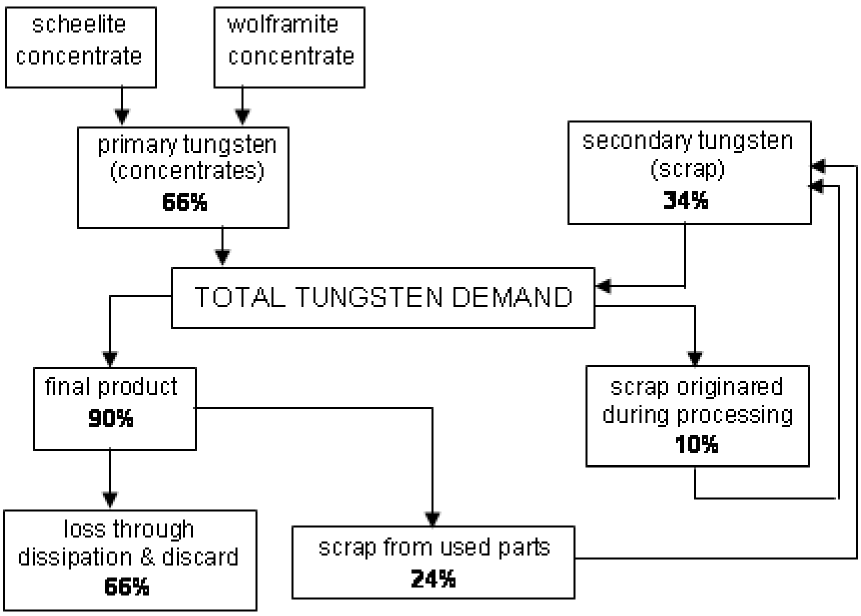
Tungsten composites are used as a substitute for lead in bullets and shot.

Tungsten chemical compounds are used in catalysts, inorganic pigments, and high-temperature lubricants.



39.4 Resource Efficiency: Recycling & Substitution

According to the ITIA, recycling is an important factor in the world's tungsten supply (see flow chart below), and the tungsten processing industry is able to treat almost every kind of tungsten-containing scrap and waste to recover tungsten, and, if present, other valuable constituents. Tungsten scrap, due to its high tungsten content in comparison to ore, is a valuable raw material. The recycling of scrap is very high in several countries but is probably in the range of 35-40% minimum as a global average depending on economic conditions.



Flowsheet of primary and secondary tungsten

Contaminated cemented carbide scrap, turnings, grindings and powder scrap are oxidised and chemically processed to APT in a way similar to that used for the processing of tungsten ores. If present, cobalt, tantalum and niobium are recovered in separate processing lines. Other tungsten containing scrap and residues might require a modified process.

Clean cemented carbide inserts and compacts are converted to powder by the zinc process (treatment with molten zinc which is dissolved in the cobalt phase and is then distilled off, leaving a spongy material which is easily crushed). This powder is added back to the manufacture of ready-to-press powder. By this process, not only tungsten carbide but also cobalt, tantalum carbide and other carbides are recycled.

Recycling of tungsten in high speed steel is high, and a typical melt contains 60 to 70% scrap, including internally generated scrap.

On the other hand, recycling in such applications as lamp filaments, welding electrodes and chemical uses is low. The reasons for this are that the use of tungsten in certain applications is dissipative (e.g. chemical applications) or the collection and recycling treatment of the products containing tungsten are insufficiently developed (e.g. lamps).

On the other hand, recycling in such applications as lamp filaments, welding electrodes and chemical uses is low.

Potential substitutes for cemented tungsten carbides include cemented carbides based on molybdenum carbide and titanium carbide, ceramics, ceramic-metallic composites (cermets), diamond tools, and tool steels.

Potential substitutes for other applications are as follows:

- molybdenum for certain tungsten mill products;
- molybdenum steels for tungsten steels;
- lighting based on carbon nano-tube filaments, induction technology, and light-emitting diodes (LEDs) for lighting based on tungsten electrodes or filaments;
- depleted uranium for tungsten alloys or unalloyed tungsten in weights and counterweights; and
- depleted uranium alloys for cemented tungsten carbides or tungsten alloys in armor-piercing projectiles.

In general, however, substitution would result in increased cost, a loss in product performance or more toxic and less environmentally friendly material alternatives.

In some applications, substitution would result in either increased cost or in a loss of product performance.

39.5 Specific Issues

Environmental Issues

According to the EU Directive 2005/32/EC, the sale of certain types of inefficient light bulbs will be forbidden in the EU since the September of 2009 with other types to follow. As these are tungsten-containing light bulbs, but this is a minor market and the import dependence can be lowered slightly.

Market Issues

On the supply side, the main concern relates to *competition with China for both access to raw materials and the sale of products*. The EU tungsten industry is sourcing a large part of its *primary tungsten feed* from outside the EU, with a strong reliance on Chinese producers as regards, APT and oxide. However, China has a dominant position in raw material supply as it has the largest tungsten deposits in the world (> 70 % of all reserves worldwide) and holds the main share in production (> 75 % of the world W-production)[234]. By means of State policy measures such as export restrictions (ban on ore exports, export duties and quotas) the Chinese government is restricting the exports of tungsten raw material (price and quantity distortions) which leads to dual-pricing raw materials. Chinese operators do not only benefit from a domestic purchasing edge on raw materials but also benefit domestic incentives to export valued added products as the Chinese government also operates a differentiated VAT refund policy on exports of value added products. This leads to situations where value added products are eventually sold by Chinese competitors on the international market, including the EU, at prices eventually lower than the input costs.

Another concern relates to the recycling of tungsten carbide scrap. The latter is complementing EU tungsten industry's primary feed supplies in increasing proportions and is purchased from both EU and international market. However, terms of competition for purchasing these materials are deteriorating rapidly as a result of the above-mentioned Chinese policy measures which also secure a purchasing edge for scrap to domestic producers whilst preventing the export of domestic scrap by means of export taxes..

On the demand side, the EU tungsten industry has historically developed a world leadership as top ranking suppliers on the global market. The EU market is the industry's natural outlet but the European tungsten resources are not sufficient to cover the demand of the European tungsten downstream industry.

Demand growths within and outside the EU and competitiveness on the export market is essential to the development of the EU tungsten industry. It is increasingly confronted on export markets with Chinese competition whose pricing policy is predatory and destructive of the normal price structure (prices for value added products are quoted below metal price).

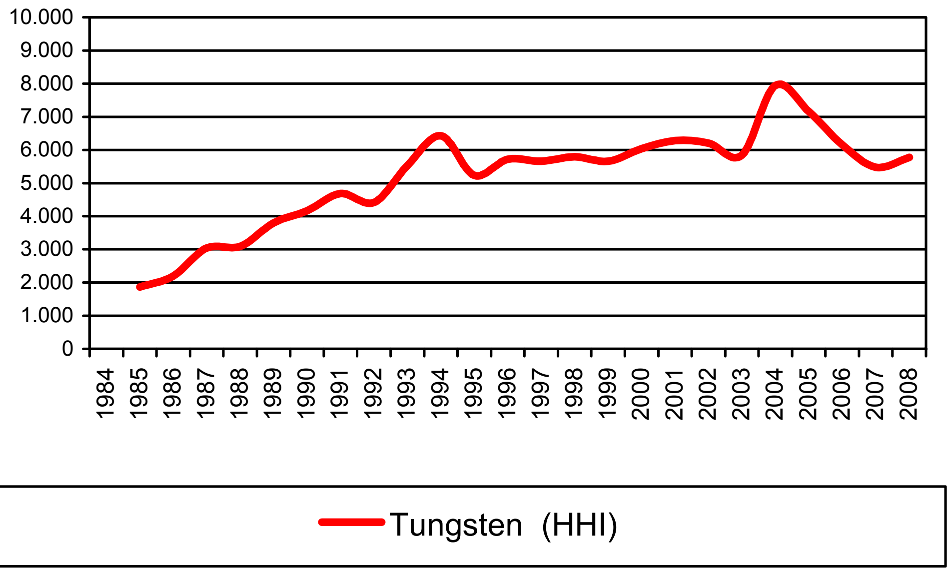
234 Source: CRUstrategies, Dirk Kotze, Tungsten – The outlook to 2013 with a focus on China, presentation ITIA-meeting 2009.

Under these circumstances, securing a level playing-field in access to tungsten raw materials is increasingly seen as vital conditions for ensuring the future viability of the EU tungsten industry.

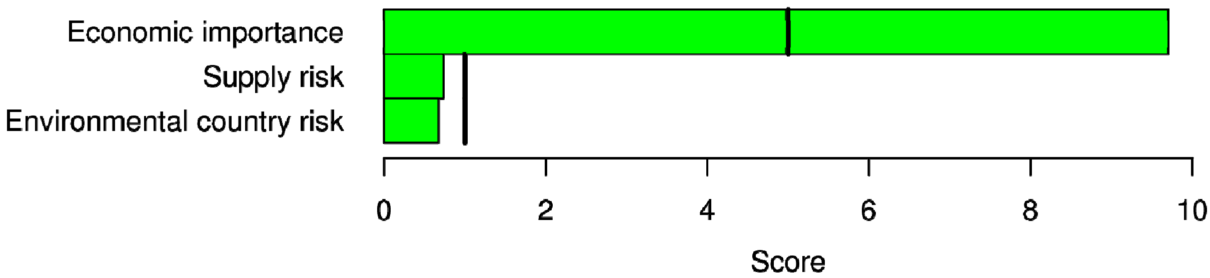
Use	Share	Megasector	Subst.
Cemented carbides	60%	Mechanical Equipment	0,7
Alloy steels (mainly tool steel, >80%)	13%	Mechanical Equipment	0,7
Superalloys	6%	Metals	1
Fabricated products	17%	Electrical Equipment + Domestic Appliances	1
Tungsten alloys	4%	Mechanical Equipment	0,7

Substitutability index	0,77
Recycling rate (recycled content from old scrap)	37%
Import Dependence	73%

Results	
Economic Importance	8,7
Supply Risk	1,8
Environmental Country Risk	1,4



Source: WORLD MINING DATA



40 Vanadium

40.1 Introduction

Vanadium is a soft, silver-gray metallic element. Its atomic number is 23 and symbol is V. Vanadium, when present in small amounts in certain ferrous alloys, can significantly improve their properties. Manufacturers of automobiles and machinery recognized the toughness and fatigue resistance of vanadium alloys as far back as the early 1900's, incorporating the alloys in axles, crankshafts, gears, and other critical components. Vanadium has been used together with aluminium to give the required strength in titanium alloys used in jet engines and high-speed airframes[235].

40.2 Basic Supply & Demand Statistics

China and South Africa are together responsible for more then 70% of the world production. In the third place is Russia with approximately 26% of the total world production.
South Korea is the largest exporter to the EU market, with a share of over 90%. Note that the EU imports in the table beneath include in other countries (Japan, South Korea and Venezuela)[236].

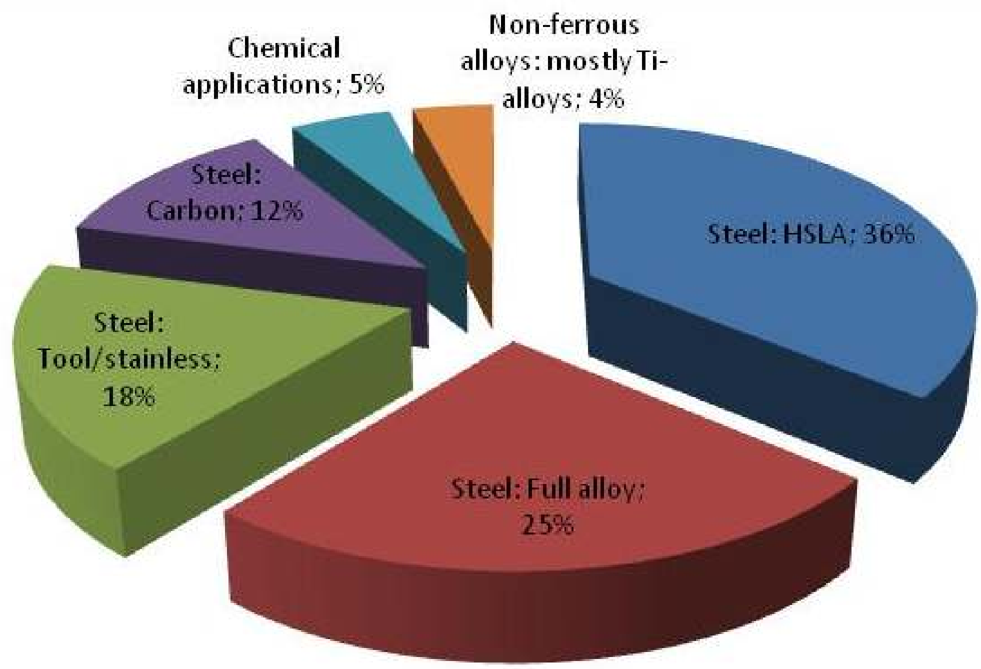
	Reserves (in 1000t)		Production (in 1000t; 2008)		Imports to EU (100kg) (2006)
United States	45	0.3%			
China	5,000	38.3%	20	36.0%	
Russia	5,000	38.3%	14	26.1%	
South Africa	3,000	23.0%	20	36.0%	
Other countries	NA		1	1.8%	1,166
World total	13,045		55.5		1,166

Source: USGS; ComExt CN 2615 90 90

[235] USGS

[236] Fraunhofer ISI

40.3 Basic Supply & Demand Statistics



- Steel (HSLA): Vanadium itself may be soft in its pure form, but when it is alloyed (that is, mixed) with other metals like iron, it hardens and strengthens them dramatically. 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, high-strength low-alloy steel, full alloy steel, and tool steel. These hard, strong ferrovanadium alloys are used to make armor plating 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. The steel “skeleton” or frames of high-rise buildings and oil drilling platforms must be very strong to support the weight of the building and its contents; vanadium steel has the strength to support such massive weight.
- 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 *catalyst* is a substance that assists in and often speeds up chemical reactions but is not consumed in the chemical reaction.) Compounds of vanadium are used to dye fabrics.

Scientists have discovered that a mixture of the elements vanadium and gallium are useful in making superconductive magnets.

40.4 Resource Efficiency: Recycling & Substitution

According to information from the USGS the recycling rate of vanadium is low. Vanadium can be recycled from certain tools and catalysts, but the rate is only a few percents. The bulk of vanadium used in special alloys is distributed in the dross during re-melting.

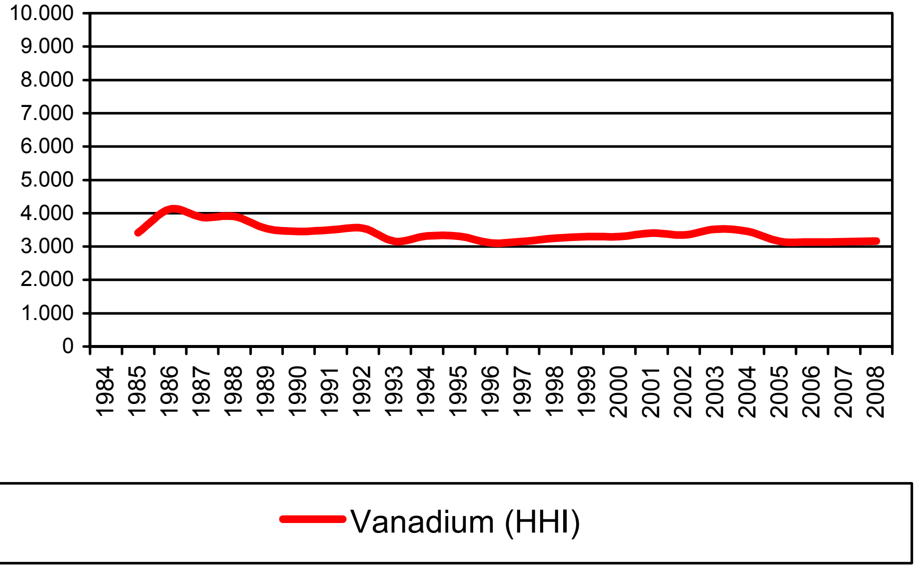
Regarding substitution, steel containing various combinations of other alloying elements can be substituted for steels containing vanadium. Certain metals, such as manganese, molybdenum, niobium (columbium), titanium, and tungsten, are to some degree interchangeable with vanadium as alloying elements in steel. Platinum and nickel can replace vanadium compounds as catalysts in some chemical processes. There is currently no acceptable substitute for vanadium in aerospace titanium alloys.

Use	Share	Megasector	Subst.
Steel: HSLA	35%	Metals	0,3
Steel: Full alloy	25%	Metals	0,3
Steel: Tool/stainless	18%	Metals	0,7
Steel: Carbon	12%	Metals	0,7
Chemical applications	5%	Chemicals	0,3
Non-ferrous alloys: mostly Ti-alloys	4%	Metals	1

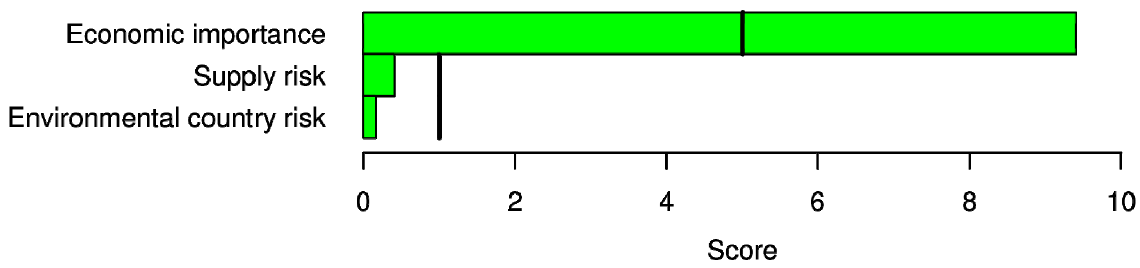
Substitutability index	0,45	
Recycling rate (recycled content from old scrap)	0%	no information available
Import Dependence	100%	

Results

Economic Importance	9,7
Supply Risk	0,7
Environmental Country Risk	0,7



Source: WORLD MINING DATA



41 Zinc

41.1 Introduction

Zinc is a lustrous bluish-white metal. It is brittle and crystalline at ordinary temperatures, but it becomes ductile and malleable when heated between 110°C and 150°C. It is a fairly reactive metal that will combine with oxygen and other non-metals, and will react with dilute acids to release hydrogen. Zinc is a natural component of the earth's crust and an inherent part of our environment. Zinc is present not only in rock and soil, but also in air, water and the biosphere: plants, animals and humans contain zinc.

Over 95% of the world's zinc is produced from zinc blende or 'sphalerite' (ZnS), which is and has been the principal ore mineral in the world.

41.2 Basic Supply & Demand Statistics

Zinc is an abundant element. Zinc reserves have increased significantly since the 1950's, as large new ore bodies have been discovered in many areas of the world. They increased by more than 50% between 1995 and 2005.

Zinc ore deposits are widely spread throughout the world. Zinc ores are extracted in more than 50 countries: China, Australia, Peru, Europe and Canada are the biggest zinc mining countries. Europe produces annually just above 1 million tons of zinc in concentrates, the most important producing countries being Ireland (400 kt.),

	Reserves (in 1000t; 2009)		Production (in 1000t; 2008)		EU imports (in 1000t; 2007)	
United States	14,000	7.5%	778	6.7%	436	16.4%
Australia	21,000	10.5%	1,480	12.7%	714	26.9%
Canada	8,000	4.0%	750	6.5%	216	8.1%
China	33,000	16.5%	3,200	27.6%	N/A	N/A
India	10,000	5.0%	610	5.7%	N/A	N/A
Ireland	2,000	1.0%	400	3.5%	N/A	N/A
Kazakhstan	17,000	8.5%	460	4.0%	N/A	N/A
Mexico	14,000	7.0%	400	3.5%	12	0.5%
Peru	19,000	9.5%	1,600	13.8%	865	32.6%
Other countries	62,000	31.0%	1,920	16.6%	414	15.6%
World total	**200,000**		**11,598**		**2,657**	

Sweden (200 kt.) and Poland (130 kt.).

Europe is also a major refined zinc metal producer and consumer in the world. The refined zinc production has been following the general trend of company mergers and partnerships observed in all the commodity sectors. The Western European production has been concentrated in large plants located in Spain, Finland, Germany, Belgium, the Netherlands and other countries as follows:

	Annual Totals:			
	2006	2007	2008	2009
Europe	**2,508**	**2,516**	**2,476**	**2,041**
Belgium	238	240	239	*26*
Bulgaria	95	100	102	*84*
Finland	282	306	298	294
France	120	125	118	158
Germany	317	295	292	153
Italy	109	102	107	*110*
Netherlands	238	219	241	*221*
Norway	161	157	145	139
Poland	134	142	*143*	*140*
Romania	44	58	62	*4*
Russian Federation	248	263	263	*202*
Serbia	15	0	-	-
Spain	507	509	466	*510*

Source: International Lead and Zinc Study Group

The zinc metal consumption has been rising at a rate of 2.1 % over the last 50 years with an annual growth of 3.7 in the last decade[237].

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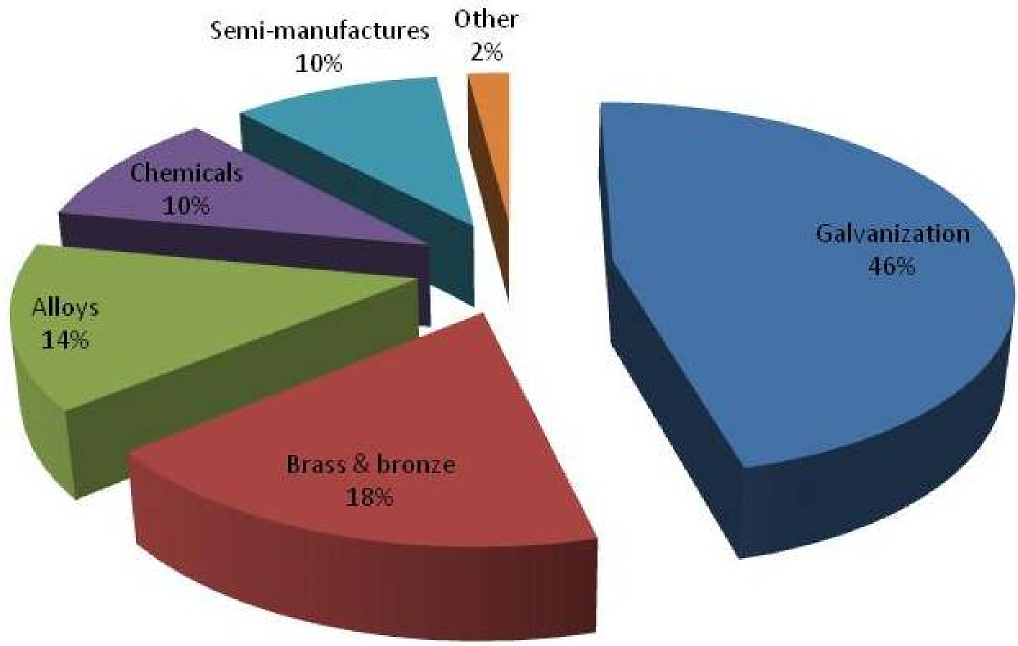
237 International Zinc Association

41.3 Economic Importance



Nearly 50% of zinc is used for galvanizing to protect steel from corrosion. Approximately 19% are used to produce brass and 16% go into the production of zinc base alloys to supply e.g. the die casting industry. Significant amounts are also utilized for compounds such as zinc salts and semi-manufactures including roofing, gutters and down-pipes.

These first use suppliers then convert zinc into in a broad range of products. Main application areas are: construction (45%) followed by transport (25%), consumer goods & electrical appliances (23%) and general engineering (7%). Zinc salts have various applications: textile industry, manufacturing of batteries, chemical industry, agriculture and animal feed, etc.

41.4 Resource Efficiency: Recycling & Substitution

Zinc-coated steel and other zinc containing products are slow to enter the recycling circuit due to the very nature of their durability. The life of zinc-containing products is variable and can range from 10-15 years for cars or household appliances, to over 100 years for zinc sheet used for roofing. All these products tend to be replaced due to obsolescence, not because the zinc has ceased to protect the underlying steel.

It is estimated that while the recycled content of zinc containing products is close to 35%, the recycling rate of the zinc available from products at the end-of life approaches the 75%. The level of recycling is increasing each year, in step with progress in the technology of zinc production and recycling. Today, over 75% of the zinc available for recycling is indeed recycled. Zinc is recycled at all stages of production and use.

Substitution:

- Coatings. Whereas the initial cost of protecting steel against corrosion is similar to the paint coatings, depending on the type of paint which is applied, the overall cost over the life-time (LCC) of the steel structure is much lower. This is due to the long life-time of the coating without maintenance and hence repainting costs, interruption of service, inflation costs. Zinc coatings have been classified as substitutable but at high cost for most of the coatings applications**.**
- Zinc casting alloys. They are used in many applications for which their substitutability can vary from substitutable at low or high costs to not substitutable.
- Zinc compounds. In most of their applications, zinc compounds cannot be substituted.

41.5 Specific issues

Environmental issues:

Despite the fact that the world's zinc production is still rising, data on time trends demonstrate the huge reduction in zinc emissions – global and European - to air as well as to water.

In the past, some rivers have been polluted with zinc, due to the presence of large quantities of zinc in the wastewater of industrial plants. This wastewater was not purified satisfactory. Since the 1970s, industrial zinc emissions have been progressively reduced, to result in near-background levels at present.

The EU risk assessment undertaken by The Netherlands in the frame of the EU Existing Substances regulation concluded that there was no risk related to zinc emissions for agricultural soils, and soils at road borders. A regional risk was identified because of the local exceedances of water quality standard in some rivers at some given locations. Further studies showed that the elevated levels of zinc measured at those places originated from zinc emissions from several sources, including current industrial emissions, local metal-enriched geology, historical pollution from industrial plants and mines, agricultural practices and emissions from the use of products. However, it was recognised that the input from the latter category had only very limited effect and was causing no risk to the environment.

Soluble zinc compounds are classified as N, R50/53 (“very toxic for water organisms with possible long term effect”). However, classification reflects the potential hazard of a substance on water organisms in the laboratory; the true potential impact of a substance on the environment is evaluated in risk assessment. As indicated above, the risk assessment has concluded that the use of zinc compounds in products does not per se result in risk to the environment. It is emphasized that zinc metal in massive form, and insoluble zinc compounds, are not classified.

Health:

Zinc is an essential trace element for humans, animals and plants. It is vital for many biological functions and is found in all parts of the body.

Zinc deficiency is a serious problem in many developing countries. It is ranked as the 5th leading risk factor in causing disease, especially diarrhea and pneumonia in children, which can lead to high mortality rates in these underdeveloped regions. Early zinc deficiency also leads to impaired cognitive function, behavioral problems, memory impairment and problems with spatial learning and neuronal atrophy. Public health programs involving zinc supplementation and food fortification could help overcome these problems. In industrialized countries cases of mild zinc deficiency can also be observed.

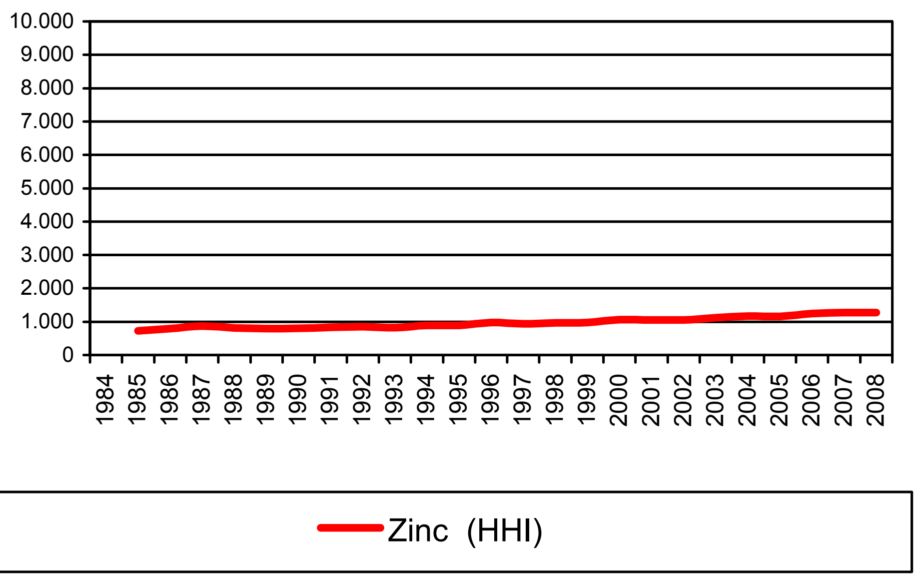
On the other side, some organisms can accumulate zinc in their bodies, e.g. when they live in (historically) zinc-contaminated environment. Zinc will however be regulated actively at each stage of the food-chain, so it has been recognized in conclusions of risk assessment that biomagnifications in the food chain and secondary poisoning is not observed.

The EU risk Assessment concluded in 2007 that there was no risk associated with zinc exposure for the general population and workers. However, special precautions must be taken by workers when exposed to high zinc dust or fumes emissions such as during soldering or metal working.

Use	Share	Megasector	Subst.
Galvanization	46%	Metals	0,7
Brass & bronze	18%	Metals	0,5
Zinc-based alloys (for casting)	14%	Metals	0,7
Chemicals (rubber, pharmaceuticals,...)	10%	Rubber, Plastic & Glass	1
Zinc semi-manufactures (rolled zinc, wire, pipes,...)	10%	Metals	0,5
Other	2%		0,5

Substitutability index	0,30
Recycling rate (recycled content from old scrap)	8%
Import Dependence	64%

Results	
Economic Importance	9,4
Supply Risk	0,4
Environmental Country Risk	0,2



Source: WORLD MINING DATA 2010