Study to investigate state of knowledge of deep sea mining

Final report Annex 3 Supply and demand

FWC MARE/2012/06 – SC E1/2013/04

Client: DG Maritime Affairs and Fisheries

Rotterdam/Brussels,

28 August 2014

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Annex 3

Final Report Economic Analysis

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ECORYS

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List of abbreviations

ASM	Artisanal and Small-scale mining
COMEX/NYMEX	Commodities Exchange/NY Mercantile Exchange
DRC	Democratic Republic of Congo
EC	European Commission
EOL-RR	End of Life Recycling Rate
EU	European Union
GDP	Gross Domestic Product
HHI	Herfindahl-Hirschman Index
LBMA	London Bullion Market
LME	London Metal Exchange
Mn	Manganese
OTC	Over-the-counter
PGM	Platinum Group Metal
RC	Recycled content
SHME	Shanghai Exchange
SMM	Shanghai Metal Markets
UNEP	United Nations Environment Program
US	United States
WEEE	Waste electrical and electronic equipment
WTO	World Trade Organisation

1 Summary

Market conditions vary significantly between minerals and metals, but some common characteristics in metals markets and terrestrial mining can be observed. The common “flaw” of the (land-based) mining industry is its boom-and-bust cycles: mining operations are inflexible in the short and medium term and therefore the market often fluctuates between states of oversupply and supply shortage, as could also be observed recently. Following a demand surge starting in the early 2000s, prices increased substantially. In search of an increasing quantity of ores, companies have turned to lower ore grades, thus increasing costs which in the current situation of a moderate demand outlook may already be too high. Another development that most materials have in common is that we observe an increase in state-owned mining (mainly driven by China) or attempts of the state to secure mining rents. Deep sea mining can be seen as part of the move towards more difficult ores..

Despite these general observations, market conditions and main players differ strongly per material or material group. Precious metals (gold, silver) are characterised by low production concentration and existing market exchanges, which however are only marginally influenced by physical demand and supply (due to the role of these metals as investment and hedging vehicles). Therefore additional supply from deep-sea mining is not expected to have an influence on the price. The markets for base metals (copper, nickel, zinc) are functioning well, but deep-sea operations would not produce the quantities to make a difference on the market. In markets for minor metals (cobalt) deep-sea mining could make a difference because they are traded in relatively low quantities and with a low elasticity of supply; in the case of cobalt, deep-sea mining has a role to play as this material has a high supply risk and expected tonnages from deep-sea mining are comparatively high in comparison to global production.

Looking at the economic viability of deep sea mining in this context, a basic economic model was developed and tentative commercial viability calculations were made for each deposit based on assumptions on capital expenditure, operational costs and revenues. Assumptions regarding these costs have been based on a range of available sources, but should be treated with caution as no actual operations have yet taken place, and technologies have not yet been fully developed and proven. The results show that polymetallic sulphides are expected to show the highest commercial viability, whereas nodules and crust are only marginally or not commercially feasible. Key uncertainty regarding polymetallic sulphides is that it assumes an operation of 15 years to generate returns on investment, whereas most resources and proven reserves seem to point to smaller sizes and a strain of operations on different locations needs to be established.

Apart from the overall uncertainty within the assumptions, a specific uncertainty exists regarding potential revenue streams for manganese, which is abundantly present in these latter two types of deposits, but for which the commercial viability of the additional processing costs are highly uncertain. This directly point to the importance of further efficiency increases not only in mining itself but in particular in processing as this would allow additional revenue streams (also potentially including REEs). Finally obviously, scarcity and increasing prices will have a direct impact on the commercial viability of deep sea mining operations, although this will obviously also trigger further terrestrial (including recycling) developments. Deep sea mining operations in itself are not expected to directly influence global prices of most metals, except for cobalt. This will limit the number of operations that can be exploited in parallel in crust and nodules to avoid boom and bust developments.

Security of supply policies

In addition to the rising demand for metals, geo-political issues can also limit the availability of metal resources. With China claiming ownership over a large quantity of terrestrial mineral reserves for specific critical raw materials, ensuring access to ores of sufficient quality and maintaining a predictable price level with acceptable ranges of volatility becomes a challenge. Exploration into new resources takes time and the bargaining power is on the side of the – relatively few - suppliers who are confronted with a large demand.

This may be further influenced by the phenomenon where metals are pledged in as collateral to obtain financing from banks. Anecdotal evidence suggests that in China copper and aluminium were used to raise capital (Yuan) on a secured basis[1]. If the same stock of metal is used as collateral for different loans, banks could ask to freeze this inventory and even seize the collateral which in return (depending on the quantity) which can have a direct impact on global prices[2]. A further consequence could be increasing control of specific countries over commodity prices[3]. These aspects carry the risk of monopolistic behaviour (prices) but also may pose a supply risk (strategic behaviour and impact on critical industries and sectors in Europe's economies). Bringing in a new source for metal supply, particularly if located in international waters, may alleviate the price competition and provide more security for Europe.

[1] The Wall Street Journal (2014): BHP Calms China Commodity Fears, http://online.wsj.com/articles/bhp-calms-china-commodity-fears-1404296229.

[2] Financial Times (2014): China probe sparks metals stocks scramble, http://www.ft.com/cms/s/0/7928cdaa-f07e-11e3-8f3d-00144feabdc0.html#axzz36sQePuuI.

[3] Ke Tang, Haoxiang Zhu (2014): Commodities as collateral, http://www.mit.edu/~zhuh/TangZhu_CommodityCollateral.pdf.

2 Introduction

This Annex describes the specific market characteristics for the metals that have been selected as relevant for deep-sea mining. It includes the following metals:

Type	Metals relevant in deep-sea mining	Price mechanism, transparency
Base metals	Copper, nickel, zinc	Prices linked to varying supply and industrial demand, traded at London Metal Exchange (LME).
Minor metals / by-products	Cobalt, manganese	Often mined as a by-product and thus lower price elasticity of supply; smaller quantities than base metals; most not traded at LME (exception: cobalt, molybdenum).
Precious metals	Gold, silver	Well established and transparent markets. Prices especially for gold often not clearly linked to demand and supply.
Platinum group metals (PGM)	Platinum	Prices set by sales offices of major producers.
Mineral sands and rare earths	Rare earths (light, heavy)	Occur frequently, but in low concentrations. Not publicly traded, but mostly directly via long-term or yearly to quarterly contracts.

Source: Ecorys based on http://metals.about.com/od/investing/a/Metal-Markets.htm, Dunbar (2012), http://www.infomine.com/investment/industrial-minerals/.

A simple economic model was developed to assess the economic feasibility of deep-sea mining. The main assumptions of the model are described in the main report. The Excel model itself is attached to this annex.

3 Base metals: Copper

3.1 Supply

Copper is a major industrial metal. In terms of quantities consumed, it is ranked third after iron and aluminum[4]. Copper is mainly mined using open pit mines, and totals a production of 16 million tonnes. Its largest producer is Chile, accounting for nearly a third (32%) of worldwide copper production. Other large producing countries are China (9%), Peru and the United States (both 7%); together, the 13 largest producing countries account for 87% of world production. The dominance of Chile means that copper supply is vulnerable to the situation in Chile, but the remaining two thirds of supply are relatively diversified.

The following table gives an overview of the worldwide reserves and production of copper.

Table A.3.2.1 Production, reserves and imports of Copper (2012)

	Production (in 1000 t / percentage of total)		Reserves (in 1000 t / percentage of total)		Imports of EU (in million € / percentage of total)	
Chile	5.370	32%	190.000	28%	4.400	27,85%
China	1.500	9%	30.000	4%	726	4,59%
Peru	1.240	7%	76.000	11%	544	3,44%
United States	1.150	7%	39.000	6%	991	6,27%
Australia	970	6%	86.000	13%	9	0,06%
Russia	720	4%	30.000	4%	2019	12,78%
Zambia	675	4%	20.000	3%	220	1,39%
D.R. of Congo	580	3%	20.000	3%	245	1,55%
Canada	530	3%	10.000	1%	45	0,28%
Mexico	500	3%	38.000	6%	234	1,48%
Indonesia	430	3%	28.000	4%	3	0,02%
Poland	430	3%	26.000	4%	*In EU27*	
Kazakhstan	420	3%	7.000	1%	198	1,25%
Other	2.100	13%	190.000	28%	6166	39,0%
World	16.615		680.000		15.800	

Source: USGS (2014) for data on reserves and production, pertaining to 2012, UN Comtrade website for import data.

Overall copper production has increased by 14.1% between 2000 and 2012 (see **Table A.3.2.2**). Some countries however showed a very large growth, especially Congo, where an increase of 1500% occurred from nearly no production to 580 thousand tonnes in 2012. Looking at available reserves, DRC copper production has the potential to grow even further. Also China (88.7%), Peru (102.9%) and Zambia (161.8%) showed large increases in the 2000 – 2012 period. Most declines in production occurred either in Western countries (United States -28% and Canada -24.2%) or countries with declining reserves (Indonesia -54.8%, Kazakhstan -9.3%) and Poland -16.2%).

[4] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

Not only geographically, but also in terms of ownership, supply of copper is relatively diversified, with a Herfindahl-Hirschman Index (HHI) value of 428[5].

Copper imports seem to be geographically explainable. Compared to total production, Russia is a relatively large partner in copper trade, whereas distant countries as Australia, Canada and Indonesia have a very low export into the EU compared to their production share.

[5] Ericsson, M. (2012): Mining industry corporate actors analysis. POLINARES Working Paper no. 16, http://www.polinares.eu/docs/d2-1/polinares_wp2_chapter4.pdf.

Table A.3.2.2 Production of copper ore (2000 -2012)

Country	Production (in 1000 t)													percentage growth
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2000 -2012
Chile	5073	5224	5049	5406	5966	5865	5909	6125	5873	5941	5973	5801	5370	+5,9%
China	795	802	780	816	977	998	1126	1043	1205	1171	1300	1402	1500	+88,7%
Peru	611	796	931	929	1142	1113	1156	1312	1398	1407	1375	1362	1240	+102,9%
United States	1598	1477	1256	123	1275	1257	1319	1288	1444	1302	1224	1227	1150	-28%
Australia	914	960	968	915	941	101	947	960	974	941	959	1058	970	+6,1%
Zambia	275	349	376	384	443	477	523	561	612	614	756	864	720	+161,8%
Russia	584	595	730	694	694	705	744	761	777	745	775	799	675	+15,6%
Congo	36	42	42	70	82	111	141	157	236	332	401	529	580	+1511,1%
Canada	699	698	665	615	620	656	665	657	669	540	579	624	530	-24,2%
Indonesia	1107	1155	1282	1106	929	1174	900	870	717	1098	962	599	500	-54,8%
Mexico	402	409	363	394	447	473	368	372	272	263	298	485	430	+7,0%
Kazakhstan	474	518	522	535	509	443	479	448	465	448	419	479	430	-9,3%
Poland	501	522	554	546	585	564	548	498	473	484	469	470	420	-16,2%
Other	1494	1473	1452	2544	1671	2684	1896	2005	2012	2253	2186	2263	2100	+40,6%
World	14563	15020	14970	15077	16281	16621	16721	17057	17127	17539	17676	17962	16615	+14,1%

Source: Copper Development Association Inc.[6]

[6] http://www.copper.org/reserouces/market_data/pdfs/annual_data.pdf.

Figure A.3.2.1 Distribution of copper refining capacity worldwide

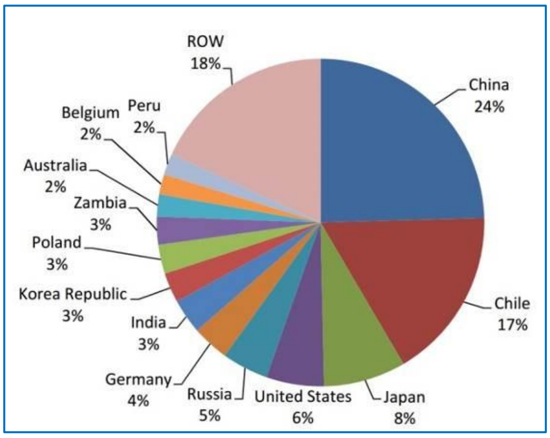

Figure source: Gateway Capital group.

Copper refinement is divided between mining countries and consuming countries. The largest shares in refinement of copper can be found with the largest user, China (24%) and the largest producer of copper ore, Chile (17%). Other refinement is split over a large number of different countries, both producers and users. Figure A.3.2.1 shows the distribution of the refining capacity worldwide.

The EOL recycling rate of copper globally is estimated at around 45% (in Europe it is around 41.5%[7]), caused by a low efficiency in gathering of scrap and separating it from other metals in recycling processes[8]. Given the long life-time of copper applications, an estimated 80% of all produced copper since 1900 is still used today, leading to an input of recycled copper that contributes 9% of copper demand[9].

There are some countries with export restrictions for refined copper. These tend to be countries that only produce small amounts of copper. Some major producing countries do have export taxes on copper scrap, but this scrap will come from all consuming countries, and is therefore not dominated by the ore producing countries[10].

For copper ore there are some trade restrictions, but these are mostly introduced to increase local refining of copper. Zambia has an additional export tax of 15% on copper ore in place to promote local refining of copper ore[11]. Indonesia also stimulates local refining of minerals, including copper, by making it more profitable to export refined minerals instead of ‘raw’, and therefore taxes ores. Governmental officials have stated that this tax (which is currently 25% but can rise to nearly 60%) can be avoided by companies by putting 5% of export into refining investments in Indonesia[12], which effectively makes it a 5% export taxation.

7 European Copper Institute (2014): recycling, http://www.copperalliance.eu/about-copper/recycling

8 International Copper Association (2013): Copper recycling, http://copperalliance.org/wordpress/wp-content/uploads/2013/06/ica-copper-recycling-1305-A4-lr.pdf.

9 USGS (2014): Mineral Commidity Summaries 2014, http://minerals.usgs.gov/minerals/pubs/mcs/2014/mcs2014.pdf.

10 OECD (n.d): Inventory of restrictions on raw materials.

11 World Trade Insitute (n.d.): Export restrictions on natural resources: policy options and opportunities for Africa, www.wti.org /fileadmin/user_upload/nccr-trade.ch/news/TRAPCA%20Paper%20(submitted1711)_BK.pdf.

12 Reuters (2014): Indonesia, Freeport deal allows copper exports to resume, http://www.reuters.com/article/2014/03/27/us-asean-summit-freeport-mc-idUSBREA2Q24I20140327.

3.2 Demand

Due to its low electrical resistance, copper is highly used in electrical appliances, which is its largest consumption sector (31% of copper usage). Second largest is construction (25%). Other main usages of copper are transport (12%) and machinery (10%)[13].

Several reports have noted that demand for copper is dominated by China with a market share in demand of 40% in 2011, which after that seemed to grow even more. The remaining usage of copper is widely spread, mainly because copper is used in construction and electricity, which makes it essential for each country. Developed countries tend to have more electrical appliances per household, and also use more electrical systems in houses, and therefore also tend to have higher demands for copper per capita. With large consumption sectors such as construction recovering from the economic crisis, and Chinese demand not expected to halt in its growth, total demand of copper is expected to keep growing in and after 2014[14].

China's large share in copper demand is partly caused by being a large country (and as said, all countries need copper for building/electricity), and furthermore increased by the production economy. Manufactured products which use a lot of copper, like the electrical appliances and industrial machinery accounting for respectively 31% and 10% of copper usage, are mainly produced in China. Its important role in copper demand is therefore unlikely to change unless China's production structure changes. Recent reports indicate that China is expected to grow to an even larger share of copper demand[15].

Over the long term, copper is expected to be increasingly substituted by cheaper materials such as aluminum, plastics and fiber optics. About 2% of copper usage per year was substituted in 2013[16], mainly due to high copper prices. Recovering demand markets of copper after the crisis (also explained in prices-section) however compensate for this substitution, sustaining copper's status as an important mineral for the worldwide economy.

3.3 Supply and demand interaction

Supply and demand of copper come together at commodity exchanges. There are three commodity exchanges at which copper is traded: the London Metal Exchange (LME), the Commodities Exchange/NY Mercantile Exchange (COMEX/NYMEX) and the Shanghai exchange (SHME). The exchanges facilitate the process of settling prices. This is done by bid and offer, which reflect supply and demand of copper. The exchange establishes a spot price (price for the present day) and the future price (price for a specified time in the future). The exchange allows producers and consumers to fix a price in the future and trade options on contracts[17]. This can however also cause problems with speculation, which was shown in 1996 when a copper trader used company money to keep copper prices high. Discovery of these wrong price signals led to a price drop to the actual supply-demand balance[18].

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[13] www.lme.com/en-gb/metals/non-ferrous/copper/production-and-consumption/.

[14] International Business Times (2014): Copper prices may be on the rise, in sharp contrast to the other much duller commodities market, http://www.ibtimes.com/copper-prices-may-be-rise-sharp-contrast-other-much-duller-commodities-markets-1550555.

[15] USITC (2012): CHINA'S DOMINANCE AS A GLOBAL CONSUMER AND PRODUCER OF COPPER, http://www.usitc.gov/publications/332/executive_briefings/2012-08_ChinaCopper(HammerLin).pdf.

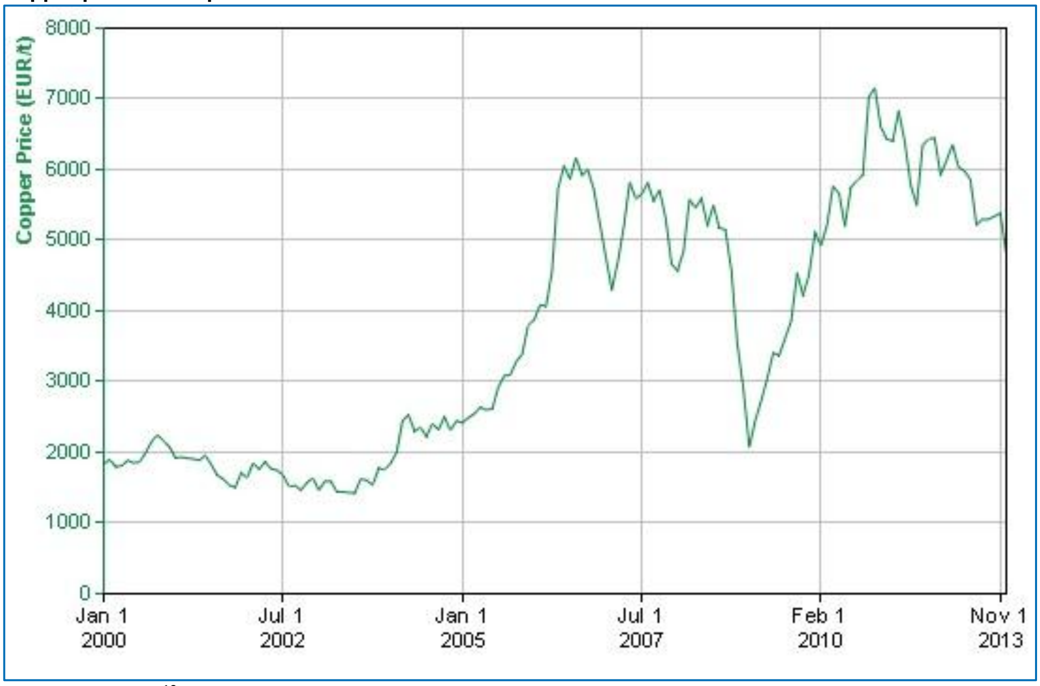
[16] Bloomberg (2013): Copper substitution seen by KME accelerating on slow growth, http://www.bloomberg.com/news/2013-03-05/copper-substitution-seen-by-kme-accelerating-on-slow-growth-1-.html

[17] http://www.solfotaramining.com/copper/commodity-exchanges-trading-copper/.

[18] USGS (2008): Factors that influence the price of A, Cd, Co, Cu, Fe, Ni, Pb, Rare Earth Elemetns, and Zn, http://storage.globalcitizen.net/data/topic/knowledge/uploads/201110179575705.pdf.

Copper sales contracts can be established for varying amounts of time, also varying in unit price as stability of longer contracts tends to be preferable for sellers, and a lower price can then be accepted. To give a view on price developments, a contract period of 3 months is mostly used. **Figure A.3.2.2** shows the price of 3 month-contracts.

Figure A.3.2.2 Copper price development since 2000



Source: Infomine[19].

Price developments since 2000, as displayed in figure 1.2, show a high fluctuation, with a factor 4 difference between highest (2011) and lowest (2002) prices. Economists are not quite certain which effect has had most influence on the large price increase in 2005-2006, but some aspects that played a role were increasing demand in China, and strikes for better working conditions in some large mines in Chile[20], which caused a rise in consumption on one side, and fall in production on the other. A USGS report about earlier price fluctuations stated that copper price changes are mostly caused by either deficit or excess of copper production. The price fall in 2009 has to do with the economic crisis, by which especially construction sectors were harmed, which support the USGS hypothesis that copper demand is vulnerable to recessions, in which some copper consuming sectors tend to get more influenced (e.g. construction due to high investment and electrical appliances due to being a secondary need)[21]. After the crisis, copper prices quickly went back to pre-crisis levels and beyond.

3.4 Important aspects for deep-sea mining:

- Demand for copper is expected to remain high, and prices usually reflect the balance of supply and demand;

[19] www.Infomine.com.

[20] Electrical Wholesaling: http://ewweb.com/materials-pricing/red-metal-raging.

[21] USGS (2008): Factors that influence the price of A, Cd, Co, Cu, Fe, Ni, Pb, Rare Earth Elemetns, and Zn, http://storage.globalcitizen.net/data/topic/knowledge/uploads/201110179575705.pdf.

- With copper production concentrated in a few relatively unstable countries and inelastic demand, disruptions have happened in the past (reflected in price spikes) and diversification of supply would be welcome;
- However, copper is consumed and produced in such large quantities (they are comparable to those of aluminum, at roughly half the amount) that a role for deep-sea mining as a game changer is unlikely; moreover, cost-intensive extraction technology with high environmental impacts, as in the case of deep-sea mining, appears less justified for copper then for other materials.

4 Base metals: Zinc

4.1 Supply

Zinc can be mined in open pit mines, but only if top layers contain zinc. Therefore, most mining is done in underground mines. Zinc ore is often contained in layers that also contain other minerals. This is mostly lead, which causes most ore to be iron-zinc ore, but can also be gold and silver. In latter cases some valuable by-products can be obtained during refinement[22].

Table A.3.3.1 Production, reserves and EU imports of zinc (2012)

	Production (in 1000 t / percentage of total)		Reserves (in 1000 t / percentage of total)		Imports of EU (in million € / percentage of total)	
China	4.900	38%	43.000	17%	99,5	10,0%
Australia	1.510	12%	64.000	26%	0,19	0,0%
Peru	1.280	10%	24.000	10%	162,6	16,4%
India	758	6%	11.000	4%	12,3	1,2%
United States	738	6%	10.000	4%	22,1	2,2%
Mexico	660	5%	18.000	7%	56,1	5,7%
Canada	641	5%	7.000	3%	0,63	0,1%
Bolivia	405	3%	5.200	2%	n.a.	n.a.
Kazakhstan	371	3%	10.000	4%	72,4	7,3%
Ireland	338	3%	1.300	1%	n.a.	n.a.
Other	1.280	10%	57.000	23%	565,1	57,0%
World	12.881		250.500		990,9	100,0%

Source: USGS (2014) for data on reserves and production, pertaining to 2012. UN comtrade website for EU import data.

The largest producer of zinc is China, accounting for 38% of all worldwide zinc production. Other big mining countries are Australia (12%) and Peru (10%). In total, 10 countries contribute to 90% of worldwide production. In terms of ownership, zinc production shows medium concentration, with a HHI value of 1041 in 2009[23].

EU imports of zinc are geographically well diversified. 57% of imports into the EU are not coming from large producing countries. The largest producer China contributes to only 10% of EU imports, explainable by China's large own demand for zinc. Australia also has a very low share (rounded 0.0%) in EU imports, probably because it is geographically more suitable to export to China.

Reserves of zinc are running quite short. At the current rate of production, all zinc reserves would run out in 19 years, with some countries, including large-producer China, in an even shorter period of time. This shows the need to search for additional reserves to keep satisfying the demand for zinc[24].

[22] US department of energy (2013): Lead and Zinc, http://energy.gov/sites/prod/files/2013/11/f4/lead_zinc.pdf.
[23] Ericsson, M. (2012): Mining industry corporate actors analysis. POLINARES Working Paper no. 16, http://www.polinares.eu/docs/d2-1/polinares_wp2_chapter4.pdf
[24] USGS (2014): Mineral commodities yearbook 2014.

Currently, 75% of zinc usage is mined, 25% comes from recycled zinc. Zinc is very well recyclable (estimates of the EOL-RR range between 35 and 75% and are reportedly increasing steadily), but the recycled content of current production is low due to the long average lifetime of zinc products.[25]

[25] http://www.zinc.org/basics/zinc_recycling; UNEP (2011): Recycling rates of metals; European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

Table A.3.3.2 Production of zinc ore (2000 -2012)

Country	Production (in 1000 t)													percentage growth
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2000 -2012
China	1710	1700	1550	1650	2300	2450	2600	2900	3200	3100	3700	4310	4.900	+186,55%
Australia	1420	1520	1150	1480	1300	1330	1380	1520	1480	1290	1480	1520	1.510	+6,34%
Peru	910	1060	1100	1250	1200	1200	1200	1440	1600	1510	1470	1260	1.280	+40,66%
India	-	-	-	-	-	-	-	-	610	695	700	710	758	n/a
United States	829	842	780	738	739	748	727	803	778	736	748	769	738	-10,98%
Mexico	393	429	475	460	460	470	480	430	400	390	518	632	660	+67,94%
Canada	936	1000	894	1000	790	755	710	620	750	699	649	612	641	-31,52%
Bolivia	-	-	-	-	-	-	-	-	-	422	411	427	405	n/a
Kazakhstan	-	-	390	395	360	400	400	390	460	480	500	495	371	-4,87%
Ireland	-	-	-	-	-	-	-	-	400	386	342	340	338	n/a
Other	2530	2300	2020	2040	2400	2400	2500	2800	1920	1490	1490	1730	1.930	-23,72%
World	8728	8851	8359	9013	9549	9753	9997	10903	11598	11198	12008	12805	13531	+55,03%

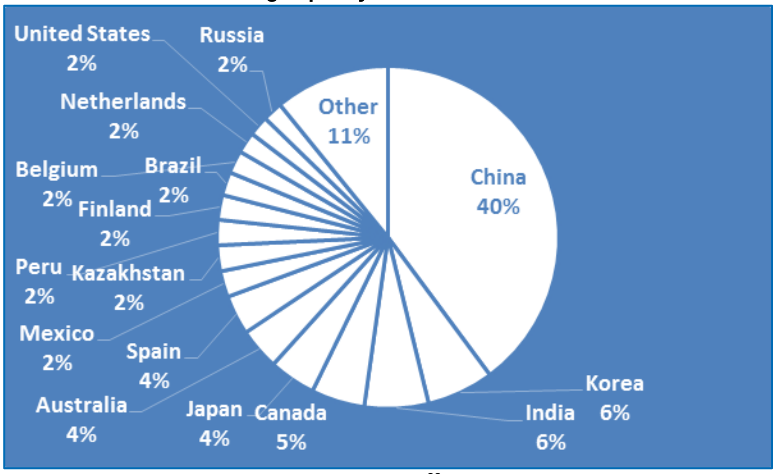
Source: USGS Zinc Statistics and information[26].

Zinc production has been increasing steadily since the 1940s and more sharply from 2000 when global production output of over 8 million tonnes was recorded. More recently a 12% rise in production output was registered between 2009 to 2013[27]. This growth in mining can for a great part be attributed to China, which showed a growth of more than 180% in 12 years. Other growing countries are Peru (40%) and Mexico (67%). Figures for India were only known from 2008, but did also show growth.

[26] Several documents, available at http://minerals.usgs.gov/minerals/pubs/commodity/zinc/.

[27] International lead and zinc study group (2014): Lead and Zinc Statistics, http://www.ilzsg.org/static/statistics.aspx?from=1

Figure A.3.3.1 Distribution of zinc refining capacity worldwide



Source: Own representation based on USGS[28].

Like in mining, China has a very large share in refinement of zinc. When not taking into account China, refinement of zinc is widely spread over a large number of countries. **Figure A.3.3.1** shows countries with currently 200 kton or more of yearly refinery outputs.

China has established an export tax whose quantitative effects are uncertain, as it is flexible. For a lot of companies/governments it is unclear how high this tax would be for them, as different criteria may apply. This tax has mainly been introduced to prevent low-value products from leaving China without value being added (refining). The WTO however already ruled against this export tax in China and decided that China should adjust its export regulations[29].

Russia has also imposed an export tax, which is however only relevant for zinc waste and scrap for recycling, which is taxed 30% when exported[30].

4.2 Demand

The main demand for zinc, using 50% of world zinc production, comes from industries galvanizing iron or steel to keep it from corroding. This makes demand for zinc highly linked to demand for galvanized steel, which is in turn closely related to car sales, as cars are mainly made of galvanized steel. Another important use of galvanized steel is construction. Two other large uses for zinc are diecasting (17%) and creation of alloys (17%) of copper with zinc (creates brasses/bronze).

When looking at consuming countries, China again takes the largest share (43%). This consumption can be seen as a consequence of the production economy in China, which makes it a large user of nearly all materials. Other large consumers of zinc are the United States (7%), South Korea, India and Japan (all 4%). With the exception of India, these other large consumers are countries with large automobile production, which shows the clear link between car manufacturing and usage of zinc. India's large consumption of zinc can be explained by its large steel producing sector. Some steel plants also have integrated galvanizing installations, delivering galvanized steel as product. Other galvanization is done in separate factories or at customers (for instance car manufacturers).

[28] USGS (2012): 2011 Minerals Yearbook Zinc [Advance release].

[29] BDO (2014): WTO RULES AGAINST CHINA ON 'RARE EARTHS' EXPORT RESTRICTIONS, http://www.bdoebrahim.com.pk/index.php?option=com_content&task=view&id=713&Itemid=0.

[30] OECD (n.d) Inventory of restrictions on raw materials.

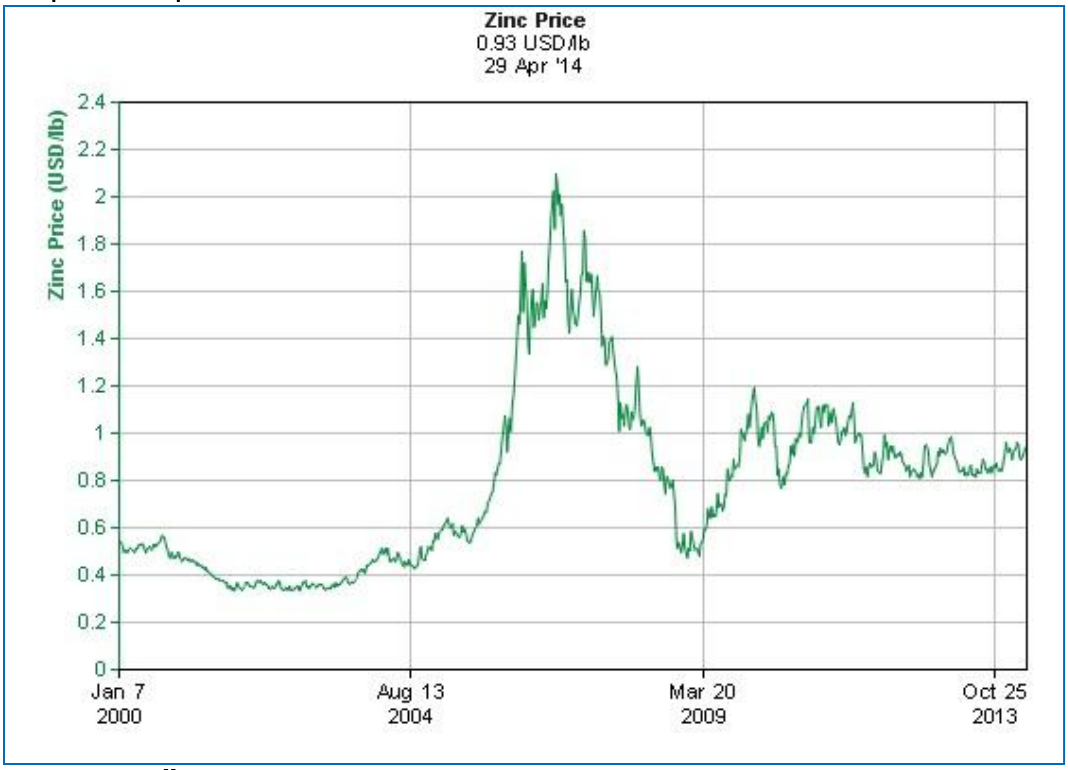
Four of the five large consuming countries also have large refining installations. It thus seems that refinement is mostly taking place at the user side of the value chain. The exception is the United States, although this is balanced by the large refinement share of Canada.

Substituting zinc is rather difficult. In almost all uses, zinc is replaceable by either aluminium or plastics, but this would lead to different product specifications[31]. Zinc coatings can be substituted, but at high cost; for zinc casting alloys, depending on the application zinc can be substitutable at low or high costs, or not be substitutable; and finally, in most zinc compounds applications, there are no substitutes for zinc available[32].

4.3 Supply and demand interaction

Zinc is one of the metals that is tradable at metal exchanges, which work with spot prices, but also have a market for longer term contracts for zinc trading. Prices may vary on a daily basis, and economic change is reflected in zinc prices. For example, the economic crisis lead to a price drop for zinc, as can be seen in **Figure A.3.3.2**. As a result of the open exchange, zinc prices are very transparent, as contract prices can be considered to coincide with the exchange price.

Figure A.3.3.2 Zinc price developments



Source: Infomine[33].

The lowest price of zinc since 2000 occurred in 2001-2003. This price depth can be explained by a drop in car production in 2001, which lowered demand for zinc. Lowered mining investments from that period, combined with growing consumption in China, led to a price peak around 2006. The increase in demand was reacted upon by increasing supply also from China, which led to a price

[31] From http://www.reuters.com/article/2011/06/28/zinc-statistics-idUSN1E75R0UL20110628.

[32] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

[33] http://www.Infomine.com.

decrease after 2006. Although both automotive and construction sectors were severely influenced by the economic crisis, prices haven't seen large variations since late 2009.

4.4 Important aspects for deep-sea mining:

- Supply of zinc, and particularly imports into the EU, are quite diversified geographically, and trading takes place at open exchanges. Deep-sea miners would find themselves in a market environment where industry concentration is not a major issue;
- Zinc is an important material in steel applications, in particular cars and construction. Its demand is closely linked to these uses;
- Looking at the importance of zinc in car manufacturing, its limited substitutability, and currently low reserves, there is a significant role for deep-sea mining to increase supply sources and secure access to zinc for EU manufacturers.

5 Base metals: Nickel

Nickel is the fifth most common element found on Earth with only iron, oxygen, silicon and magnesium being more abundant. Nevertheless, the reserves that can be mined from an economic point of view are more limited. Non-profitable resources on land are estimated to be double the amount of reserves (which are profitably mineable resources). The current reserves on land are expected to be sufficient for 100 years, at the current mining rate[34]. Nickel is used for its corrosion resistance, high melting point, ductility and malleability properties[35].

5.1 Supply

Total production of nickel was 2,100 thousand tons in 2012. Production is divided over many countries. The largest producers are the Philippines with 330 thousand tonnes (16%), Russia with 270 thousand tonnes (13%) and Australia with 230 thousand tonnes (11%). The total reserves of nickel are 75 million tonnes. Australia has the largest reserves, 20 million tonnes, which is 27%. The second largest reserves are in New Caledonia (a Pacific archipelago belonging to France) with 12 million tonnes (16%), and third comes Brazil with 7.5 million tonnes (10%).

Table A.3.4.1 Production, reserves and EU imports of nickel (2012)

	Production (in 1000 t / percentage of total)		Reserves (in 1000 t / percentage of total)		Imports of EU (in million € / percentage of total)	
Philippines	330	15,71%	1.100	1,47%	0	0,0%
Indonesia	320	15,24%	3.900	5,20%	52	0,8%
Russia	270	12,86%	6.100	8,13%	1660	26,9%
Australia	230	10,95%	20.000	26,67%	548	8,9%
Canada	220	10,48%	3.300	4,40%	888	14,4%
Brazil	140	6,67%	7.500	10,00%	200	3,2%
New Caledonia	140	6,67%	12.000	16,00%	217	3,5%
China	91	4,33%	3.000	4,00%	43	0,7%
Colombia	80	3,81%	1.100	1,47%	12	0,2%
Cuba	72	3,43%	5.500	7,33%	0	0,0%
South Africa	42	2,00%	3.700	4,93%	10	0,2%
Botswana	26	1,24%	490	0,65%	n.a.	n.a.
Dominican Republic	24	1,14%	970	1,29%	n.a.	n.a.
Madagascar	22	1,05%	1.600	2,13%	n.a.	n.a.
Other countries	120	5,71%	4.600	6,13%	2532	41,1%
Total	2.100		75.000		6162	

Source: USGS (2013) for data on reserves and production, pertaining 2012. UN comtrade site for EU import data.

Although some countries have relatively large shares in nickel imports of the EU (Russia 26,9%, Canada 14,4% and Australia 8,9%), the market is not dominated by certain countries. 41,1% of EU nickel imports come from countries not in the top 14 nickel producers. The two largest producing

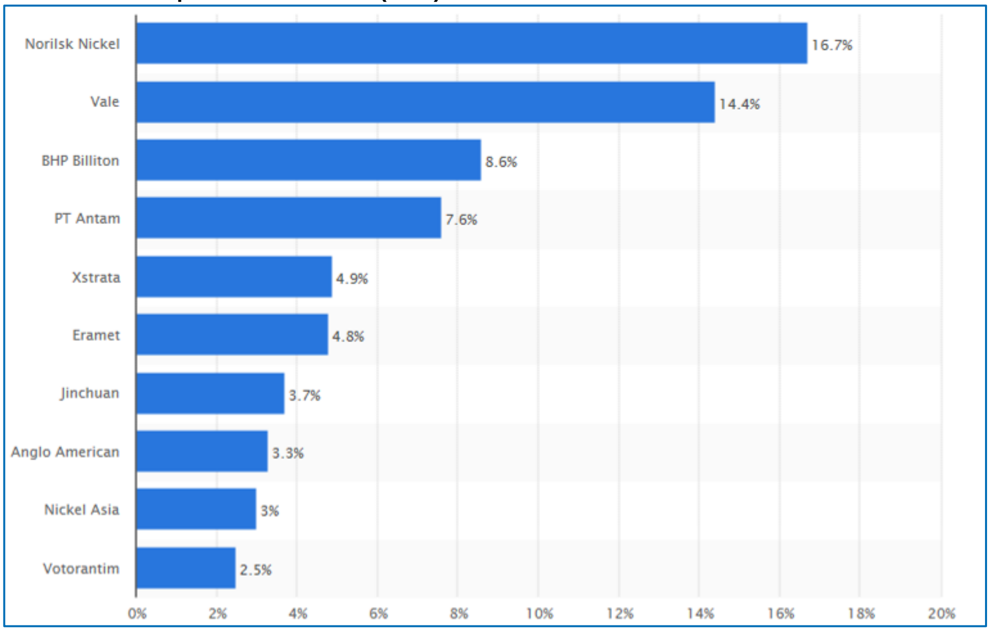
[34] See http://www.incorholdings.com/holdings/incor-technologies/nickel-market/.

[35] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

countries, the Philippines and Indonesia, have almost no export to EU countries. Presumably nickel is traded through other countries before entering the EU, reflecting a large role of intermediaries in the market. Not only geographically, but also in terms of ownership, supply of nickel is relatively diversified, with a HHI value of 750[36].

Figure A.3.4.1 presents the market shares of the largest producers of nickel in 2011. The largest producers of nickel are Norilsk Nickel and Companhia Vale do Rio Doce. Although the name suggests differently, Norilsk Nickel is also a diversified mining company, making Nickel Asia the only pure nickel focused mining company in the top 10 of nickel producers.

Figure A.3.4.1 Market shares of producers of nickel (2011)



Source: http://www.statista.com/statistics/260817/market-share-of-top-companies-in-nickel-production-2011/.

[36] Ericsson, M. (2012): Mining industry corporate actors analysis. POLINARES Working Paper no. 16, http://www.polinares.eu/docs/d2-1/polinares_wp2_chapter4.pdf.

Table A.3.4.2 Production of nickel in tons (2000-2012)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Percentage growth (2000-2012)
Australia	166.500	205.000	207.800	190.210	174.700	191.710	175.177	184.900	199.200	165.000	168.500	215.000	230.000	38,14%
Botswana	38.420	26.714	28.600	38.230	35.163	39.305	38.000	27.600	28.940	28.595	28.000	26.000	26.000	-32,33%
Brazil	45.317	47.097	45.029	44.928	51.886	74.198	82.492	58.317	67.116	41.059	108.983	109.000	140.000	208,93%
Canada	190.793	194.058	189.297	163.244	186.694	199.932	232.948	254.915	259.651	136.594	158.376	219.612	220.000	15,31%
China	50.300	51.500	53.700	61.000	75.600	72.700	82.100	67.000	79.500	84.800	79.600	89.800	91.000	80,91%
Colombia	58.927	52.962	58.196	70.844	75.032	89.031	94.105	75.864	64.200	79.900	76.200	76.000	80.000	35,76%
Cuba	68.064	72.585	71.342	74.018	71.945	73.753	75.000	104.000	96.600	92.500	94.000	97.500	72.000	5,78%
Dominican Republic	39.943	39.120	38.859	45.253	46.000	53.124	47.516	47.125	31.300	n.a.	n.a.	21.693	24.000	-39,91%
Indonesia	98.200	102.000	123.000	144.000	136.000	135.000	157.000	229.200	219.300	202.800	235.800	290.000	320.000	225,87%
Madagascar	n.a.	n.a.	n.a.	5.555	5.300	8.141	10.942	n.a.	n.a.	n.a.	2.000	5.900	22.000	n.a.
New Caledonia	128.789	117.554	99.650	112.013	118.279	111.939	102.986	125.364	102.583	92.570	129.894	131.071	140.000	8,70%
Philippines	17.388	27.359	26.532	19.537	16.973	26.636	64.705	152.300	84.000	161.300	233.000	270.000	330.000	1797,86%
Russia	315.000	325.000	310.000	131.550	135.252	138.575	167.691	279.770	266.569	261.791	269.277	267.393	270.000	-14,29%
South Africa	36.616	36.443	38.546	40.842	39.851	42.392	41.599	37.163	31.675	34.605	39.960	39.810	42.000	14,70%
Total	1.290.000	1.350.000	1.350.000	1.330.000	1.360.000	1.460.000	1.560.000	1.740.000	1.610.000	1.450.000	1.710.000	1.960.000	2.100.000	62,79%

Source: USGS mineral yearbook.

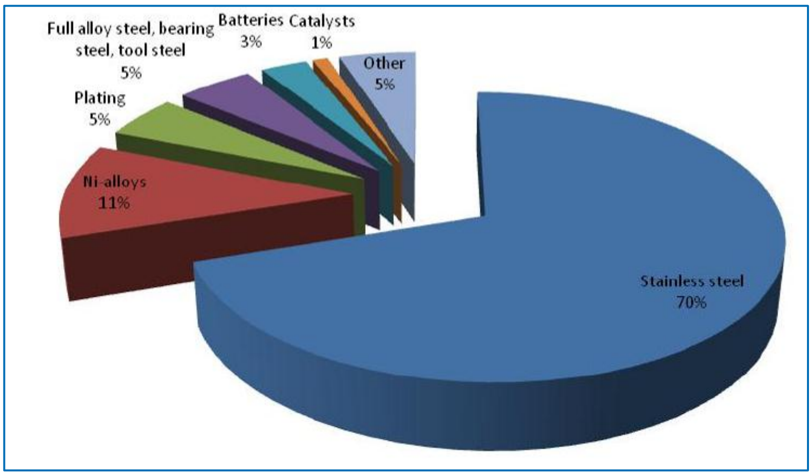
Production of nickel increased by 63% since 2000, going from 1.290.000 to 2.100.100 tons. In 2008 and 2009 total production decreased. In 2010 production was back at the level of 2007. The Philippines showed the largest growth: 1797%, which they could achieve by starting mining nickel (from nearly no production) as response to demand growth from China[37]. Production increased from only 17.388 in 2000 to 330.000 in 2012. Indonesia and Brazil more than doubled their production in 2012 compared to 2000. Dominican Republic, Botswana and Russia decreased their production of nickel.

Nickel is very suitable for recycling, due to its corrosion resistance and its high price. Nickel is mostly recycled in the stainless steel sector. The end-of-life recycling rate is circa 56%, higher than for most other metals. The recycled content is 41%[38].

5.2 Demand

Nickel is mostly used for production of stainless steel. Furthermore it is used for alloys, batteries and catalysts.

Figure A.3.4.2 use of nickel

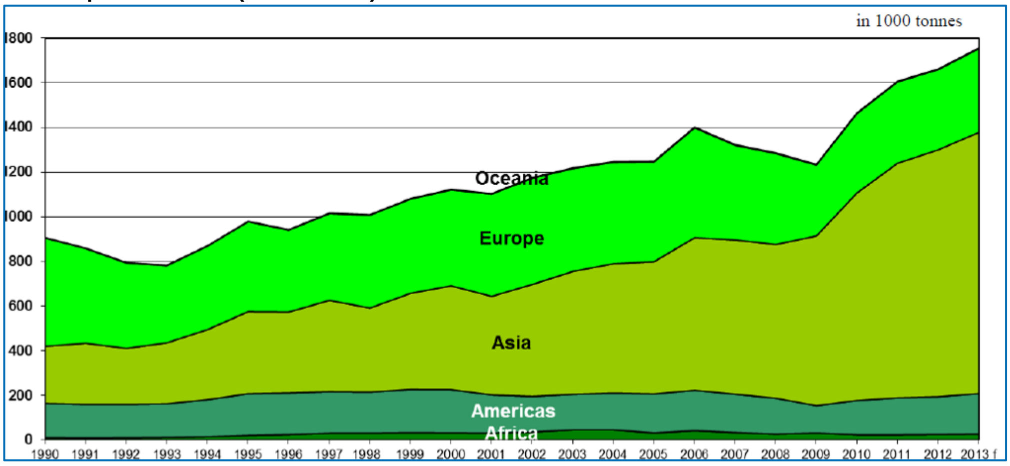


Source: European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

[37] International Nickel Study Group (2012): Nickel ore shipments to China, http://www.insg.org/%5Cdocs%5CINSG_Insight_16_Nickel_Ore_2012.pdf.

[38] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

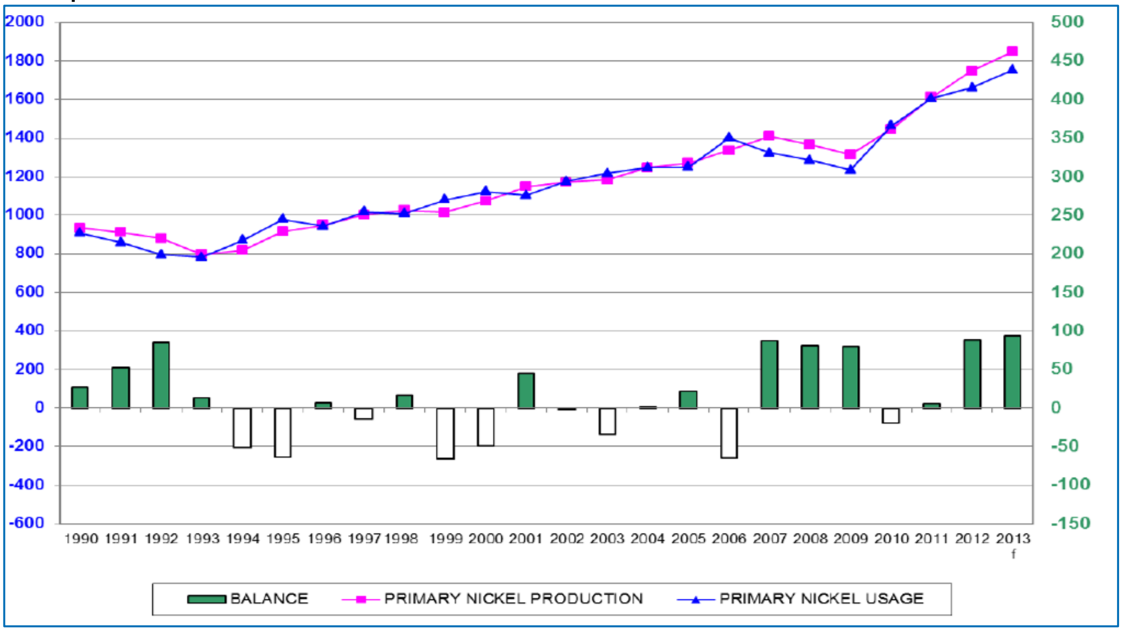
Figure A.3.4.3 Consumption of nickel (1990 – 2013f)



Source: UNCTAD Multi-Year Expert Meeting on Commodities and Development 2013 Recent developments and new challenges in commodity.

Figure A.3.4.3 shows consumption of nickel in the period 1990 – 2013. The data of 2013 is a forecast. Consumption of nickel almost doubled since 1990. Consumption is highest in Asia. From 2006 onwards, consumption decreased as a result of the economic crisis. Starting in 2009, consumption increased massively, which is completely driven by Asia. This is due to increases in the steel production, in order to meet demand from the construction sector in emerging Asian economies. Consumption in China is expected to keep growing[39]. It is expected that demand will continue to grow since Europe will face a gradual demand recovery, with positive consumption growth. This is also the case for the United States. In general, there seems to be correlation of nickel use and economic development[40].

Figure A.3.4.4 Nickel production and use



Nickel is not easily substituted for the production of steel alloys, since any reduction in nickel will result in a reduction of performance. In batteries, nickel is already partly substituted by lithium and other materials. Furthermore, low-grade laterite ore is substituted by nickel pig iron, a low grade

[39] International Nickel Study Group (2012). Nickel ore shipments to China, http://www.insg.org/%5Cdocs%5CINSG_Insight_16_Nickel_Ore_2012.pdf.

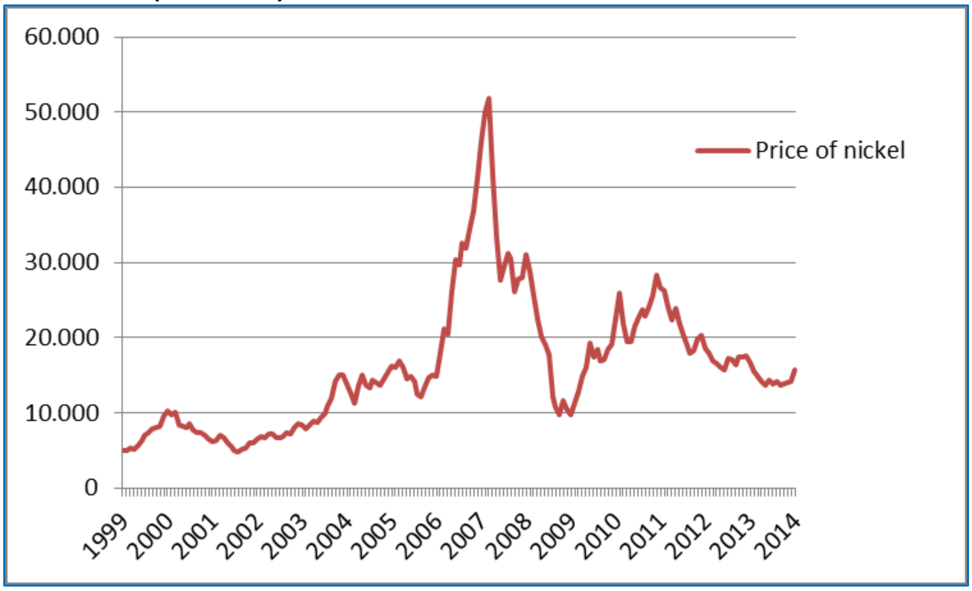
[40] From http://www.insg.org/prodnickel.aspx.

alternative to nickel metal. The drawback of this substitution is that nickel pig iron has a more negative impact on the environment than refined nickel. In some applications, like hot parts or jet engines, there are no suitable substitutes for nickel[41].

5.3 Supply and demand interaction

Nickel is traded on exchanges like the London Metal Exchange (LME) and the Shanghai Metal Markets (SMM). As shown in **Table A.3.4.1**, trading intermediaries seem to play a large role also in the physical trade of nickel.

Figure A.3.4.5 Price of nickel (2000 – 2014)



Source: World Bank.

Figure A.3.4.5 represents monthly data of the price of nickel from January 1999 to March 2014. Most remarkable is the giant price peak in 2007. This peak was caused by estimations of, amongst others, the London Metal Exchange that stocks of nickel were nearly depleted. Real stocks were actually quite low, but not as low as estimated. With demand for nickel increasing, this led to a drastic price increase. When it turned out that stocks weren't as depleted as thought, prices dropped again[42]. This shows that stock (and demand) are important factors influencing the price, but also speculation about changes, for instance in demand, can influence the price of nickel.

Also the price increase starting from 2009 can be explained by expectations of supply and demand. Rather than looking at actual supply and demand, opinions of analysts about future price change seem to have large impact on nickel price[43].

5.4 Important aspects for deep-sea mining:

- Nickel is economically important for steel manufacturing and the corresponding products, including EU producers;

[41] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

[42] See http://news.goldseek.com/GoldSeek/1183932000.php.

[43] See http://rt.com/business/nickel-prices-supply-fears/.

- Deepsea miners would face prices which are volatile and influenced by expectations of supply, demand and stocks, with demand expected to increase alongside economic development / recovery;
- Supply of nickel is diversified and can be accessed via market intermediaries;
- The direct impact of nickel extraction through deep-sea mining for EU users is therefore estimated to be low; it can contribute to a lower world market price by increasing expectations of supply.

6 Minor metals: Manganese

6.1 Supply

Manganese is the 12th most abundant element in the earth's crust, but the reserves are irregularly distributed. South Africa (28%) contains the largest share of the global reserve base, closely followed by the Ukraine. The difference between the two countries is that the reserves in South Africa mostly contains high manganese grades (greater than 44% Mn.), while Ukraine contains lower ore grades (less than 30% Mn.)[44]. The production of manganese is more diversified. South Africa is the largest producer, together with Australia and China. Although Ukraine has large reserves, the production of manganese is rather low (1%). Manganese was recycled as a minor part of ferrous and non-ferrous scrap, but the scrap recovery for manganese was negligible. Manganese is now recovered along with iron from steel slag. Old scrap results in 12% to 25% recycled manganese according to the EC report on critical raw materials;[45] the USGS estimates the recycled content (RC) for manganese at 37%, and the EOL-RR at 53%.

Table A.3.5.1 Production, reserves and EU imports of Manganese (2013)

	Production (in 1000 t / percentage of total)		Reserves (in 1000 t / percentage of total)		Imports of EU (in million € / percentage of total)	
South Africa	3.5	15%	150	28%	n.a	n.a.
Australia	3.4	14%	97	18%	0	0,0%
China	3	13%	44	8%	244,6	86,8%
Gabon	2	8%	27	0%	n.a	n.a%
Brazil	1.1	5%	110	0%	0,55	0,2%
India	0.81	3%	4	9%	1,47	0,5%
Kazakhstan	0.39	2%	5	1%	0	0,0%
Ukraine	0.31	1%	140	26%	0,19	0,1%
Burma	0.230	1%	n.a.	n.a.	n.a	n.a
Malaysia	0.230	1%	n.a.	n.a.	n.a	n.a
Mexico	0.17	1%	5		0,15	0,1%
Other countries	1.74	7%	Small	n.a.	34,74	12,3%
World	16		630		281,7	

Source: USGS (2014) for data on reserves and production, pertaining to 2012, UN comtrade website for EU import data.

Although China's production of Manganese is only 13% of world total, it supplies 86.8% of EU use of Manganese. Later on in this section, it is shown that this isn't due to relatively low demand from the EU, as some EU countries are among the top 9 manganese users. This means the EU is currently extremely dependent on China for Manganese.

The mining of manganese is characterized by a medium level of company concentration, with the HHI at 1113.[46] The largest supplier in South Africa is Assmang, which is jointly owned by African Rainbow Minerals Limited (50%) and Assore Limited (50%). BHP Billiton is the largest supplier of

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[44] CPM Group (2012): Manganese Market Outlook.

[45] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

[46] Ericsson, M. (2012): Mining industry corporate actors analysis. POLINARES Working Paper no. 16, http://www.polinares.eu/docs/d2-1/polinares_wp2_chapter4.pdf.

seaborne manganese. Furthermore the company has two producing assets, in Australia and South Africa and is a global producer of manganese alloy[47].

[47] See http://www.mbendi.com/indy/ming/mang/af/sa/p0005.htm.

Table A.3.5.2 Production of manganese ore (2000 -2013)

Country	Production (in 1000 t)														percentage growth
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2000 -2013
Australia	787	948	983	1.247	1.570	1.500	2.192	2.540	2.320	2.140	3.100	3.200	3080	3.100	294%
Brazil	1.250	1.210	1.095	1.286	1.346	1.370	1.370	520	1.280	928	1.048	1.209	1.330	1.440	15%
Burma	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	19	143	243	300	234	115	120	n.a.
China	700	860	900	920	1.100	1.500	1.600	2.000	2.200	2.400	2.600	2.800	2.900	3.100	343%
Gabon	804	830	810	873	1.090	1.290	1.350	1.532	1.441	881	1.416	1.858	1.650	2.000	149%
India	590	600	601	620	630	927	811	726	826	845	1.013	895	800	850	44%
Kazakhstan	280	350	440	580	570	540	550	360	400	360	390	390	380	390	39%
Malaysia	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	22	209	183	351	225	429	250	n.a.
Mexico	156	100	88	115	136	133	133	152	170	119	175	171	188	200	28%
South Africa	1.578	1.479	1.504	1.585	1.905	2.100	2.300	2.600	2.900	1.900	2.900	3.400	3.600	3.800	141%
Ukrain	930	930	840	880	810	770	820	580	492	317	540	330	416	350	-62%
Other	126	152	149	144	198	250	213	421	611	592	855	801	920	950	651%
World	7.490	7.800	7.770	8.780	9.910	10.980	11.900	12.000	13.200	11.200	15.100	16.000	15.800	17.000	127%

Source: USGS minerals yearbook.

Overall the production of Manganese increased by 127% over the last 13 years. Production increased in every country except for Ukraine, which had a decrease of 62%. The largest growth took place in China. Production increased by 343% since 2000. Australia realized a growth of 294%. The production of Brazil almost remained constant over the years. In the beginning, South Africa and Brazil were the largest producers of Manganese. In 2013 South Africa, Australia and China are the largest producers. Some reports state that that manganese ore bodies are shrinking in China. China will lose 500 to 700 thousand tonnes of capacity in the next 3 to 5 years, if no new resources are found[48].

[48] Montgomery (2013): Manganese battery technology, http://manganeseinvestingnews.com/1569/manganese-battery-technology/.

There are some restrictions on the export of manganese. In China and Russia, manganese is subject to export taxes of 20% and 6.5% respectively. In Algeria and South Africa, manganese waste and scrap is subject to a system of non-automatic export licensing. In Tanzania, the export of manganese waste and scrap is banned.

6.2 Demand

Of the total manganese production, 89% is upgraded into alloyed manganese and foundry products. This category includes high, medium and low carbon ferromanganese and silicomanganese. The remaining share of manganese ore is used in the production of metallurgical and chemical products, like electrolytic manganese metal, electrolytic manganese dioxide, lithium manganese oxide, manganese sulfate and other chemicals[49].

The demand of manganese is thus mostly driven by steel production, since approximately 90% of the manganese ores are used in the steel production, mostly as a deoxidizing and desulfurizing agent. The share of manganese in steel production is declining over the years, due to technological improvement. However, it is expected that the demand of manganese will increase, since the demand for steel will continue rising on a worldwide level. This means the rise in demand for steel outweighed the efficiency effect. In the foreseeable future, this is expected to continue[50].

Other important uses of manganese are for[51]:

- Corrosion protection: it is used to make aluminum more resistant against corrosion;
- Other metallurgy: it is used in copper and nickel smelting for the same purpose;
- Non-metallurgy applications: it is used for the production of dry cell batteries, fertilization of plants and animal feed.

In the future, manganese is likely to play a larger role in the production of batteries. This type of battery consists of litium, nickel, manganese and cobalt. Due to the outstanding cycling stability, they are excellent for consumer electronic applications and hybrid electric vehicles[52], Since hybrid vehicles become more popular, the demand for manganese will increase. This increase is small compared to the overall production of manganese, but it can start a positive feedback loop: with improving technology, the use of manganese will become more efficient, resulting in a cost reduction. Due to the reduction of costs, demand for manganese will increase even more. Since the new technologies will also reduce the costs of hybrid vehicles, the demand for these vehicles will increase as well[53].

Table A.3.5.3 Consumption of manganese ore (2007-2011)

Country	2007	2008	2009	2010	2011
Brazil	654,90	210,50	309,00	149,00	285,70
China	5.784,80	6.564,60	6.818,80	7.511,60	9.268,80
France	178,10	242,70	22,00	249,20	215,60
Japan	455,90	469,00	387,10	473,30	401,90
Norway	456,30	523,90	227,30	471,30	459,30

[49] CPM Group (2012): Manganese Market Outlook.
[50] African Development Bank (2011): Manganese industry analysis: implications for project finance.
[51] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.
[52] See for information on different types of batteries: http://batteryuniversity.com/learn/article/batteries_for_electric_cars.
[53] Montgomery (2013): Manganese battery technology, http://manganeseinvestingnews.com/1569/manganese-battery-technology/.

Country	2007	2008	2009	2010	2011
South Africa	798,90	645,20	251,10	549,10	735,90
South Korea	295,10	363,40	309,30	398,90	598,00
Spain	159,50	274,10	14,90	179,60	206,90
Ukraine	1.259,30	1.410,90	511,00	994,60	870,90
Other countries	3.573,50	2.870,00	2.286,80	2.726,80	3.480,00
Total	12616,3	13.574,30	11.137,30	13703,7	16.523,00

Source: International manganese institute (2011): Annual market research report 2011.

China is by far the largest consumer of manganese ore. It accounts for approximately 56% of the total consumption in 2011. The second largest consumers are Ukraine (5%) and South Africa (4%).Since 2000, global demand of manganese more than doubled, with Chinese demand increasing its share[54].

Manganese has no substitutes. It is used as a substitute for other commodities like chromite or vanadium[55].

6.3 Supply and demand interaction

Manganese is not exchange traded. The trade of manganese is facilitated through annual bilateral contracts. The major supplier and major customer start negotiations about the price of the manganese. The other suppliers and customers will use this price as a guideline for their own negotiations[56]. The price provides a solid image of underlying supply and demand. Because the prices are not exchange traded, they are less influenced by speculative activities than other metals like copper. This could be seen in the manganese price reacting to decreased demand in the wake of the financial / economic crisis[57].

The following graph represents the prices of Manganese ores in US Dollar. It shows that prices are generally not very volatile, reflecting the status of manganese as a purely industrial metal without influence from speculation. Nevertheless, the spike in 2008 is striking. The iron & steel industry – the largest user of manganese – was growing more steadily between 2005 and 2008, and then showed the same sharp drop and recovery.[58] So in general, manganese prices show to be closely linked to the iron & steel industry. Nevertheless, the rise in prices came quite late and was quite large. This may be caused by the prevalence of long-term contracts, which prevented a price increase in line with increased demand, and caused the price to increase disproportionately and with a time lag, once new contracts were entered: given the limited substitutability, price elasticity of demand is rather low. The prices are thus rather stable in the short run, but can fluctuate heavily once they respond to earlier demand changes.

[54] Kevin Fowkes (2011): Feeding the growth of Asia: Emerging sources of manganese ore. Presentation at the 12th Asian Ferro-Alloys Conference, http://www.alloyconsult.com/files/MB_HK_Mn_Mar_2011.pdf.

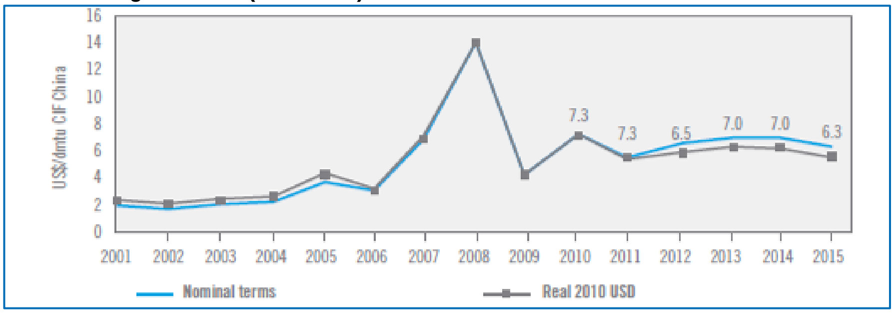
[55] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

[56] Radetzkik, M. (2010): A Handbook of Primary Commodities in the Global Economy.

[57] See Terazono, E. (2011): Weak demand hits non-exchange traded metals., http://www.ft.com/intl/cms/s/0/43475ac4-1b49-11e1-8b11-00144feabdc0.html#axzz2zDvwLktc.

[58] See www.worldsteel.org.

Figure A.3.5.1 Price of manganese ore (2001-2015)



Source: Shaw River Manganese Ltd: Manganese factsheet, with data of CRU, Deutsche Bank and Macquarie Bank.

In the foreseeable future, prices for medium and high grade manganese ores are very favorable, as a result of the increased consumption of steel in the developing world and the increased market for steel products. Furthermore the high grade ores attract a premium price because of its value in use in steel making[59].

6.4 Important aspects for deep-sea mining:

- Due to its dominant use in steelmaking and the lack of substitutes, demand is quite price inelastic and manganese prices are closely related to steel prices, and thus also coupled with the general economic environment;
- However, the long-term contracts prevalent in manganese trade mean that these developments are translated into manganese prices with a lag, and can be more pronounced than the (daily fluctuating) steel price development. Demand is "inelastic with a time lag";
- Significant demand for manganese comes from EU countries such as France or Spain;
- Future demand from non-steel uses is expected to increase, especially in batteries for e-mobility;
- Supply is diversified, but EU imports are predominantly sourced from China. Deep-sea mining could play a role in diversifying supply for the EU, and in contributing to the needs of "green industry" sectors.

[59] Shaw River Manganese Ltd: Manganese factsheet. http://www.shawriver.com.au/IRM/Company/ShowPage.aspx?CPID=1318&EID=34269788.

7 Minor metals: Cobalt

Next to molybdenum, cobalt is one of two main minor metals[60]. It is very hard, remains strong at high temperatures and has a low thermal and electrical conductivity. Since cobalt is ferromagnetic, it can be magnetized[61]. Cobalt is ranked 33 in abundance, so it's not a very rare metal. It is normally associated with copper and nickel. Only in Morocco and Canada, cobalt is extracted alone[62]. Cobalt extraction is associated with the nickel Industry for 57%, with the copper industry & other for 37%, and with primary cobalt operations for 6%[63].

7.1 Supply

In 2012, the total production of cobalt was 110.00 tons. Congo (Kinshasa) is by far the largest producer, with a production of 60.000 tons, which is 54,55% of the total production. The second largest producers are Canada and China, which each contribute only 6% of the total production. Congo also owns the largest reserves of cobalt, 45% of the total reserves. Russia and Zambia are next with about 3%.

Table A.3.6.1 Production, reserves and EU imports of cobalt (2013)

	Production (in 1000 t / percentage of total)		Reserves (in 1000 t / percentage of total)		Imports of EU (in million € / percentage of total)	
Congo (Kinshasa)	51	49%	3.400	47%	174,7	37,3%
China	7	7%	80	1%	26,6	5,7%
Canada	6,63	6%	260	4%	41,8	8,9%
Russia	6,3	6%	250	3%	23,2	4,9%
Australia	5,88	6%	1.000	14%	1,2	0,3%
Brazil	3,9	4%	89	1%	5,8	1,2%
Cuba	4,9	5%	500	7%	n.a.	n.a
New Caledonia	2,62	3%	200	3%	0,1	0,0%
Zambia	4,2	4%	270	4%	28,1	6,0%
Morocco	1,8	2%	18	0,25%	n.a.	n.a
Other countries	8,82	9%	1.100	15%	167,3	35,7%
World Total	103		7.203		468,8	

Source: USGS (2014) for data on reserves and production, pertaining to 2012. UN comtrade site for EU import data.

Mining in Congo is not without any problems. Since the mid-1990s, eastern Congo had several conflicts which were caused by the mineral riches in the region. The human rights campaign ' The Enough Project' estimates that 60% of the minerals is mined illegally, in dangerous conditions with long hours and often with the use of child labor. Despite these problems, cobalt is not considered a 'conflict mineral' since the mining of cobalt is not controlled or traded by armed groups. Cobalt is mined in the relatively stable region of Katanga[64], which is a two hour flight away from the conflict

[60] Richard Mills (n.d.): The Cobalt Story, http://www.aheadoftheherd.com/Newsletter/Cobalt%20Story.pdf.
[61] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.
[62] See http://www.thecdi.com/about-cobalt.
[63] Cobalt Development Institute: http://www.thecdi.com/cobaltfacts.php.
[64] Arieff, A. (2014): Democratic Republic of Congo: Background and U.S. Policy.

zones[65]. These unstable conditions in Congo can however influence cobalt supply if either the conflict spreads to other parts of the country, or when mining will be restricted to stop illegal mining. This makes the supply from Congo very unstable. One complication is that there are not enough producers outside of Congo to meet the global demand of cobalt.

Nevertheless, in terms of ownership, supply of cobalt is relatively diversified, with a HHI value of 345[66].

Import data of the EU show a few disparities with production. Canada and Zambia have a larger share in EU trade than production, where Congo, Australia, Brazil and New Caledonia have relatively low exports to the EU. The amount of export of cobalt of other countries into the EU is however quite large, which may suggest that exports of the latter four countries might be shipped through other countries before entering the EU.

[65] http://www.metalbulletin.com/Article/2813364/Cobalt-is-not-a-conflict-mineral.html.

[66] Ericsson, M. (2012): Mining industry corporate actors analysis. POLINARES Working Paper no. 16, http://www.polinares.eu/docs/d2-1/polinares_wp2_chapter4.pdf.

Table A.3.6.2 Production of cobalt in tons (2000-2012)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Percentage growth 2000-2012
Australia	5600	6200	6700	6000	5600	5600	6000	4.730	4.780	4.340	3.850	3.850	4.500	-19,64%
Brazil	900	1100	1200	1300	1400	1400	1100	2.725	2.631	2.075	3.139	3.500	3.700	311,11%
Canada	5298	5326	5148	4327	5060	5767	7115	8.692	8.953	3.919	4.636	7.071	6.700	26,46%
China	90	150	1000	700	1260	2100	1840	6.100	6.630	6.000	6.500	6.800	7.000	7677,78%
Congo (Kinshasa)	11000	15000	14500	14800	20200	24500	27100	25.400	32.300	40.000	60.000	60.000	60.000	445,45%
Cuba	2943	3411	3124	3274	3554	3768	3500	4.540	3.175	3.600	3.700	4.000	3.700	25,72%
Morocco	1305	1242	1335	1391	1600	1600	1500	1.800	1.700	2.200	3.110	2.159	1800	37,93%
New Caledonia	1200	1400	1400	2602	2726	1769	1629	2.250	2.110	2.000	2.850	3.240	3500	191,67%
Philippines	n.a.	n.a.	n.a.	100	100	100	700	1.000	1.200	1.500	2.200	2.200	n.a.	n.a.
Russia	4000	4600	4600	6100	6000	6300	6300	6.300	6.200	6.100	6.200	6.300	6200	55,00%
South Africa	580	550	540	480	610	620	600	600	590	610	1.800	1.600	n.a.	n.a.
Zambia	4600	8000	10000	11300	10000	9300	8000	7.500	7.000	4.900	6.200	5.400	3000	-34,78%
Total	38300	47800	50300	52900	58600	63400	65900	73.700	79.100	78.800	106.000	109.000	110000	187,21%

Source: USGS minerals yearbook.

Overall the production of cobalt increased by 187%. Production increased every year. The largest growth was in 2010, production increased by 38%, compared to 2010. The largest growth was achieved in China, production increased by 7678% between 2000 and 2012, and has been stable around 6000-7000 tonnes for the last six years. Congo and Brazil also faced a large growth of production, 445% and 311% respectively. Australia and Zambia produced less in 2012 than in 2000.

The largest producer of refined cobalt is Freeport in Finland, with a production of 10. 547. Next comes Chambishi from Zambia with 5,435 tons, followed by Umicore from Belgium, with a production of 4.200. In most cases, cobalt is exported from Congo as ore, and refined in the countries of the refinery companies. Another large refining country, in which a lot of smaller refiners are located, is China, with a production of 30,200 tons[67].

The recycling of cobalt emerged naturally due to economic drivers, like price volatility and cost benefits and the geopolitical structure of supply. The End of Life Recycling Rate (EOL-RR) of cobalt is estimated at 68% by UNEP (higher than for most other metals), while the Recycled Content (RC) rate is estimated at 32% (lower than most other metals). This low RC rate in comparison to the EOL RR shows that demand for cobalt has been increasing and cannot be covered by recycling alone.

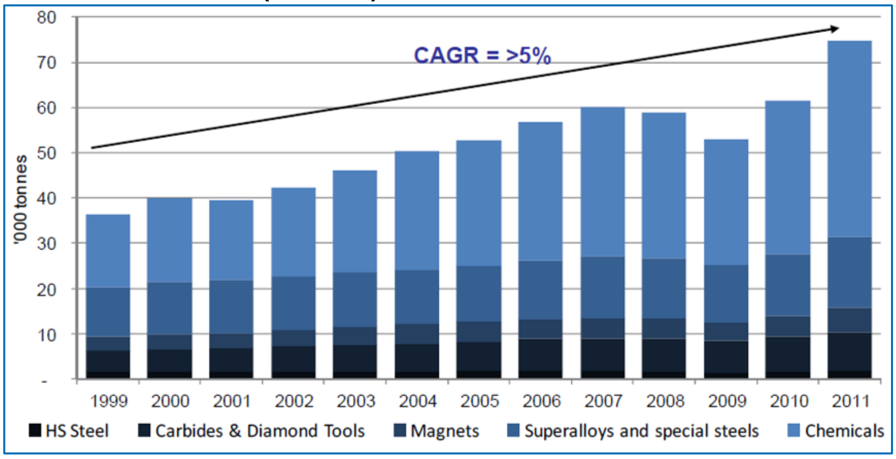
The same economic drivers provide incentives for the search of substitutes. Nevertheless, options are limited, due to the unique properties of cobalt. Almost every substitute results in a reduced product performance[68].

7.2 Demand

Worldwide, cobalt is mostly used for rechargeable batteries, superalloys and magnets.

The consumption in the European Union is different from this pattern. There is no production of rechargeable batteries and 33% of the cobalt is used for hard metals[69].

Figure A.3.6.1 Demand of cobalt in tons (1999-2000)



Source: David Weight (2013)[70].

As shown in **Figure A.3.6.1**, demand for cobalt has shown a relatively stable increase over the years. Only in 2009 demand decreased due to the economic crisis. Demand for chemicals shows the most growth over the years, reflecting the use of cobalt in rechargeable batteries demanded for IT applications. All other sectors are much more constant.

Future consumption of cobalt is affected by two major developments:

1. Market demand will shift to Asia, due to the growth of use sectors;

[67] Minor metals trade association (n.d.): Cobalt market overview, http://www.mmta.co.uk/cobalt-market-overview.

[68] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

[69] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

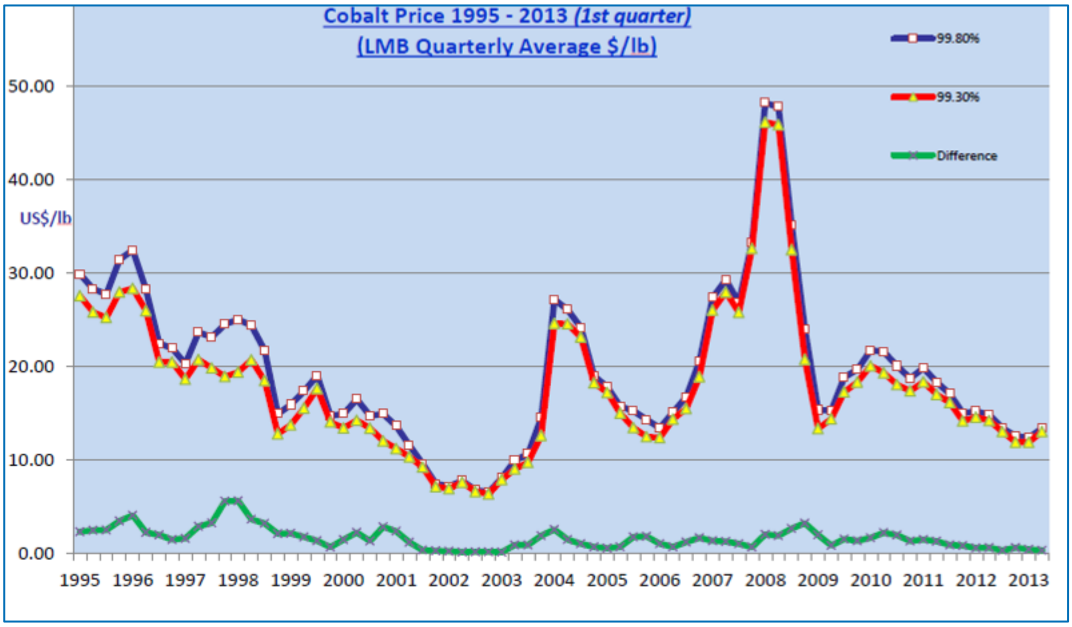
[70] Weight, D. (2013): Cobalt CDI review and future challenges, http://www.insg.org/presents/Mr_Weight_Apr13.pdf.

2. Demand for cobalt-based chemicals will increase due to the growth of chemical applications. This is mostly due to increasing demand for rechargeable batteries – in IT applications and in the future also in e-mobility, which is expected to offset some substitution of cobalt by manganese and nickel[71].

7.3 Supply and demand interaction

Cobalt is traded in exchanges, the largest being LME. The LME uses 3 types of contracts: cash, 3-months and 15 months.

Figure A.3.6.2 Prices of cobalt 1995-2013



Source: Cobalt Development Institute[72].

The graph represents the free market price of cobalt for 99.8% (HG) and 99.3% (LG) minimum cobalt. Since the graph is based on quarterly averages, short-term price fluctuations are not included. The graph shows that the price of cobalt is very volatile. After 2008, the price of cobalt decreased vastly as a result of the economic crisis, causing a drop in demand as was already visible in **Figure A.3.6.1**. After a short recovery in 2010, prices started to decline again afterwards due to increases in supply[73].

7.4 Important aspects for deep-sea mining:

- Supply of cobalt is quite concentrated in the Democratic Republic of the Congo, where concerns about the stability of the country and the social circumstances of mining are frequently voiced, making the reliability of supply from Congo questionable – however, so far supply has increased steadily and China is building up production as well;
- Demand for cobalt is expected to increase due to its use in rechargeable batteries (IT and e-mobility);

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[71] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

[72] Cobalt Development Institute: http://www.thecdi.com/cdi/images/documents/Cobalt%20Facts%20-%20Supply%20%20Demand%20-%2012.pdf.

[73] See Table A.3.6.2 and USGS (2014), p. 47.

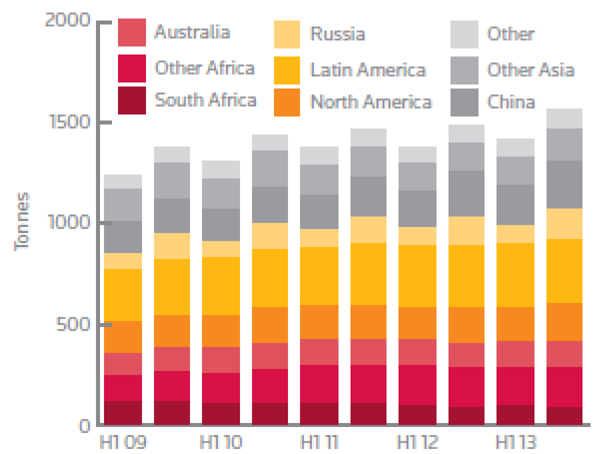
- The use of cobalt in the EU, however, differs from the worldwide demand structure: EU demand for cobalt comes mainly from hard metal production, which is not expected to increase;
- Mining of cobalt in the deep -sea can therefore be expected to generate revenues and provide additional supply to IT and green industry products. The relative importance of the direct EU demand market is however expected to decline. Nevertheless, supply from deep-sea mining **can contribute to a decrease in prices** also for EU producers, and for EU manufacturers further down in the value chain.

8 Precious metals: Gold

8.1 Supply

Mine production was responsible for around 63% of the supply of gold in 2013[2]. In total 2,982 tonnes of gold were mined that year. The main gold producing countries are China, Australia, the United States, Russia and South Africa[74]. In **Figure A.3.7.1** the production and reserves of the leading gold producing countries can be observed. Both production and reserves are geographically diversified: there is no country that is responsible for more than 14% of the worldwide production or that possesses more than 15% of the reserves.

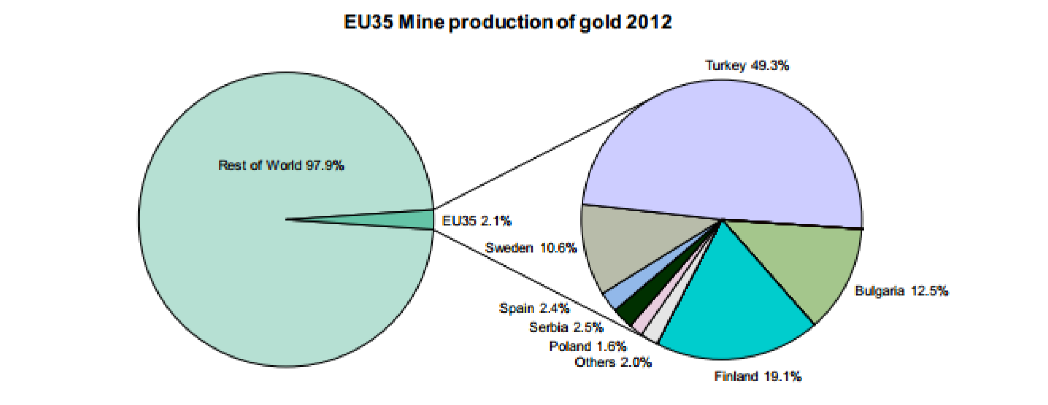
Figure A.3.7.1 Global mine production of gold



Source: Thomson Reuters GFMS.

Production of gold is almost equally divided between the different continents (only Europe is missing). There are no European countries among the leading gold producing countries. There are some countries within the EU35 (EU28 plus EU associates Switzerland and Norway, and 5 candidate countries) that produce gold, especially Turkey, however together they make up only 2.1% of worldwide gold production (see **Figure A.3.7.2**).

Figure A.3.7.2 EU35 Mine production of gold



Source: British geological survey 2008-2012 European mineral statistics.

[74] USGS (2013): Mineral commodity summaries.

Table A.3.7.1 Worldwide production, reserves and EU imports of gold

	Production (in 1000 t / percentage of total)		Reserves (in 1000 t / percentage of total)		Imports of EU (in million € / percentage of total)	
China	0.37	13.7%	1.9	3.65%	16	0,0%
Australia	0.25	9.26%	7.4	14.23%	3903	6,2%
United States	0.23	8.52%	3	5.77%	8337	13,2%
Russia	0.205	7.59%	5	9.62%	2724	4,3%
South Africa	0.17	6.3%	6	11.54%	6857	10,9%
Peru	0.165	6.11%	2.2	4.23%	240	0,4%
Canada	0.102	3.78%	0.92	1.77%	10420	16,5%
Indonesia	0.095	3.52%	3	5.77%	0,2	0,0%
Ghana	0.089	3.3%	1.6	3.08%	2	0,0%
Mexico	0.087	3.22%	1.4	2.69%	1208	1,9%
Other countries	0.896	33.19%	19.4	37.31%	29000	46,5%
World	2.7		52		63014	

Sources: USGS (2014) for data on reserves and production, pertaining to 2012, UN comtrade website for import data (2012).

Although China is the largest producer of gold, almost no gold is exported to the EU from there. Countries with most trade in gold with the EU27 are Canada (16,5%), the United States (13,2%) and South Africa (10,9%). Almost half of EU imports come from countries other than the top 10 producers; this reflects the fact that gold tends to be traded via triangular trade, in which a third country comes between producer and 'user' of gold. Global production fluctuates and has shown moderate growth from 2.5 million tonnes in 1998 to 2.7 million tonnes in 2013[75].

In addition to geographical production and trade, gold also shows diversification in terms of ownership, with a HHI value of 266[76].

The second most important source of gold supply comes from gold scrap. It was responsible for around 29% of gold supply in 2013[77]. The supply of gold scrap is price elastic. In 2013 when the gold price dropped with 16 percent, the global scrap supply fell by 14 percent. Apart from the drop in the gold price the strong economic global performance could also be an explanation for the lower supply of gold scrap in 2013. Scrap recyclers and individuals have less of an incentive to liquidate gold assets when gold prices are low and the economy is performing strongly.

Gold is in general efficiently recycled because of its high value. The degree to which gold is recycled depends on the sector in which it is used. In the jewellery sector where the metal value for a single product is high, the EOL-RR is estimated to be around 90-100%. Within the electronics sector, the EOL-RR is estimated to be around 10-15%. The low recycling rate in electronics is caused by the small quantities of gold being used in electronic devices. Therefore the metal value in a single device is low, reducing the incentive for recycling. The global average recycled content of gold is estimated to be around 30%.

The proportion of artisanal and small scale gold mining as part of world production is estimated to be 25% (2011)[78]. Of the 2700 tonnes of worldwide gold produced annually, around 675 tonnes are

[75] USGS statistics on gold, http://minerals.usgs.gov/minerals/pubs/commodity/gold/goldmyb02.pdf
[76] Ericsson, M. (2012): Mining industry corporate actors analysis. POLINARES Working Paper no. 16, http://www.polinares.eu/docs/d2-1/polinares_wp2_chapter4.pdf.
[77] Thomson Reuters GFMS: Gold Survey 2013.
[78] ICMM(2012): Mining's contribution to sustainable development.

produced by artisanal and small-scale mining (ASM). Due to the low capital intensity, ASM supply is able to react quickly upon changes in the price of gold.

8.2 Demand

The most important uses of gold are:

- Jewellery (46% of total demand[79]);
- Physical bar and coin investment (28.2 %[2]);
- Electronics and other industrial applications (16% of total demand[2]);
- Net official sector purchases (around 8 % of total demand[2]).

Most demand for gold comes from the demand for jewellery. The largest consumer of jewellery worldwide is China, whose demand made up around 33% of total jewellery demand in 2013[2].

The second source of gold demand is caused by investments in physical gold bars and coins. Gold bar and coin is the most important form of investment by volume. It made up 82% of total investment demand in 2012. Gold is a widely accepted and liquid form of exchange. It is valued as protection against weak currencies and high domestic inflation[80].

The most important industrial use of gold is in electronics[81]. It makes up 70% of industrial demand. Gold is a highly efficient conductor and therefore electronic components made with gold are reliable. Gold is used in connectors, switch and relay contacts and connecting wires.

Another source of gold demand is from governments and central banks (the official sector). In 2013 the official sector were net buyers (official sector purchases), while they have been net suppliers in other years. The demand from the official sector in 2013 was historically high. This was caused by the desire of emerging economies to diversify their portfolios away from currencies[2].

There are different substitutes for gold. In bonding wire fabrication, gold is losing ground to more affordable alternatives such as bare copper, palladium coated copper wires and silver and aluminium wires. Besides using substitutes, producers also try to use less gold in their products. For example in electrical and electronic products, base metals clad with gold alloys are widely used; in jewellery, producers try to economize on gold by continually redesigning the jewellery to maintain high-utility standards with lower gold content. For gold as trading material (which is itself a substitute for currencies) other precious metals can be considered as alternatives[82], but these are currently not widely used.

8.3 Demand and supply interaction

Most trading in gold and silver takes place on the OTC market. The London Bullion Market (LBMA) is the predominant location for OTC trading. A bidding process results in a daily reference price called fix. In November 2008 18,3 million ounces worth 13,9 billion dollars was cleared on the LBMA OTC market. This means that the annual gold mine production in 2008 was cleared at the LBMA every 4.4 days[8]. These figures show the importance of gold in investment markets and the importance of investors in determining the gold price.

[79] Percentage of total demand is 46% according to Thomson Reuters: Gold Survey 2013. More than 50% according to UNEP (2011).

[80] PWC (2013): The direct economic impact of gold.

[81] http://geology.com/minerals/gold/uses-of-gold.shtml.

[82] MarketWatch (2010): Five alternatives to gold, http://www.marketwatch.com/story/five-alternatives-to-gold-2010-10-08.

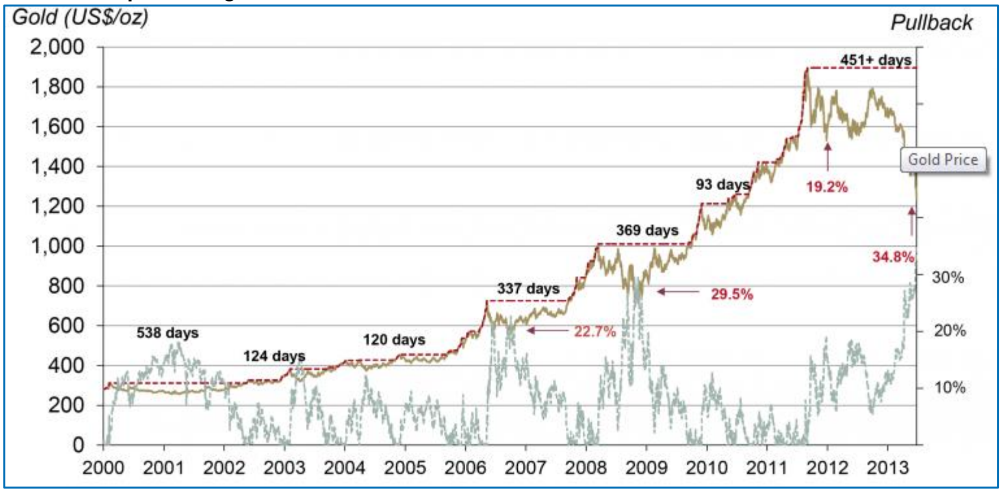
Exchange traded transactions are growing in importance. The largest exchange traded markets are Comex in New York, Tocom in Tokyo and MCX in India[83]. Only a small percentage of the futures market turnover ever comes to physical delivery of the gold represented by the contracts traded.

There are no big supply risks from trade restrictions. Worldwide the maximum value for export taxes on gold is 10%, the median value is 2,5%[84]. Although there are large differences between countries, gold is relatively freely traded. There are taxes and regulations in place on gold imports in certain countries. India for example imposed restrictions in 2013 on gold imports to curb its current account deficit. China is trying to regulate its 'shadow banking' system, a number of organizations offering services equal to or comparable to those of the regulated financial sector. This may put additional downward pressure on prices as gold is used as collateral in the financing deals. [85]

The price of gold is not clearly linked to physical demand and supply. The gold price is heavily dependent on the (expected) policies by central banks, macroeconomic variables and world economic stability/ uncertainty. The global economic instability that began in 2008 caused more investments in Gold Exchange-Traded Funds. Investors saw gold as a safe-haven investment[7]. Price increases for gold after economic instability are a recurring phenomenon.

Expected policies of the US Federal Reserve had a major influence on the gold price in 2013. After investors expected the US Federal Reserve to reduce its monetary stimulus, investments in exchange traded funds for gold saw a large outflow. ETF holding fell by 33%. This happened in the first half of 2013 and as a consequence the price of gold dropped significantly[86]. The gold price fell for the first time in twelve years.

Figure A.3.7.3 Price development of gold



Source: Obel 2013/06 International Business Times.

Figure A.3.7.3 shows the development of the price of gold. The gold price decreased sharply in 2013. In the last quarter (2014Q1) the gold price increased with 1.8 percent. There is no clear consensus on the future price of gold. There are enough macroeconomic threats to prevent the gold price to significantly decrease. A lower gold price can be expected due to the decision at the end of 2013 of the US Federal Reserve to lower their monetary stimulus. But on the other hand the

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[83] IFSL Research (2009): Bullion Markets 2009, http://www.thecityuk.com/assets/Uploads/Bullion-Markets- 2009.pdf.

[84] Fung, K. (2013): Economics of export restrictions as applied to industrial raw materials.

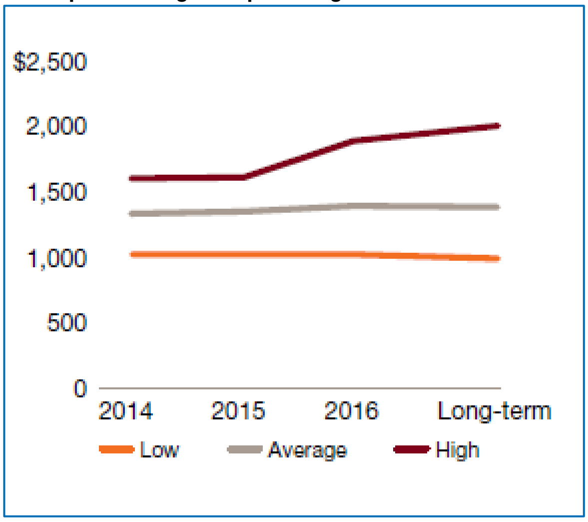
[85] World Bank: Commodity Markets Outlook April 2014.

[86] PWC (2013): Global gold price survey, http://www.pwc.com/ca/en/mining/publications/pwc-global-gold-price-survey-results-2013-12-en.pdf.

central banks of Japan and the Eurozone are expected to fight deflation with a loose monetary policy increasing the gold price.

In a survey among gold miners, 47% expect the gold price to increase in 2014, 46% expect the price to remain roughly the same and 7 % thinks the price will decrease[7]. The expected development of the gold price according to the gold mining companies can be observed in **Figure A.3.7.4**. In the nearby future the physical demand for gold is expected to remain stable, although it is difficult to say this with certainty.

Figure A.3.7.4 The expected long term price of gold



Source: PWC: Global Gold Price Survey 2013/12.

8.4 Important aspects for deep-sea mining

- The global supply of gold is geographically diversified. There are however no European countries among the leading producing countries. Deep-sea mining has no role to become a global game changer but may contribute to reducing European dependency on foreign gold;
- Gold prices are to a limited extent influenced by physical demand and supply. (Expected) policies by central banks, macroeconomic variables and world economic stability/ uncertainty have a significant influence on the gold price, making it hard to predict but also giving it the advantage of sometimes non-cyclical behaviour.

9 Precious metals: Silver

9.1 Supply

In 2012, around 75% of silver supply came from mine production[87]. 60% of mined silver is mined as a by-product of copper and lead-zinc ores, and 11% as a by-product of gold ores; only 29% come from genuine silver ores. Therefore many of the leading producers of silver are equivalently leading producers of the mentioned metals, such as Peru, Mexico, and China[88]. The same pattern is visible in Poland, the largest European silver producer, where silver is mostly mined from copper ores[89]. With a production of 1,190 tonnes in 2008, Poland provides around 40% of European silver supply.

The following table gives an overview of the worldwide reserves and production of silver, as well as EU imports by country.

Table A.3.8.1 Production, reserves and EU imports of silver (2012)

	Production (in 1000 t / percentage of total)		Reserves (in 1000 t / percentage of total)		Imports of EU (in million € / percentage of total)	
Mexico	4.25	22%	37	7%	22	0,5%
China	3.8	16%	43	8%	65	1,5%
Peru	3.45	14%	120	22%	n.a.	n.a.
Australia	1.9	13%	69	13%	198	4,6%
Russia	1.5	8%	n.a.	n.a.	345	8,0%
Bolivia	1.3	7%	22	4%	n.a.	n.a.
Poland	1.17	5%	85	16%	*In EU*	.
Chile	1.13	4%	77	14%	n.a.	n.a.
USA	1.05	1%	25	5%	500	11,6%
Canada	0.53	2%	7	1%	163	3,8%
Other countries	3.9	16%	50	9%	3035	70,1%
World	24		540		4328	

Sources: USGS (2013) for data on reserves and production, pertaining to 2012. UN comtrade website for EU import data.

The table shows that supply of silver is relatively diversified; Latin America has a large market share, but China, Australia and the US are important players as well, which means that political risk is also diversified. Notably, Poland had 5.6% of world production in 2008, but a significantly higher share of international reserves (13.9%), which shows its potential to contribute to diversification and further EU import independence.

When only looking at producing countries, 70,1% of EU imports come from 'other countries'. Silver tends to be highly traded via triangular trade, in which a third country comes between producer and 'user' of silver. EU imports are then officially coming from countries were marketplaces for silver are

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87 Thomson Reuters GFMS / The Silver Institute (2013): World Silver Survey 2013. A Summary, http://www.silverwheaton.com/files/docs_quick%20links/World%20Silver%20Survey%202013%20Summary.pdf.

88 European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

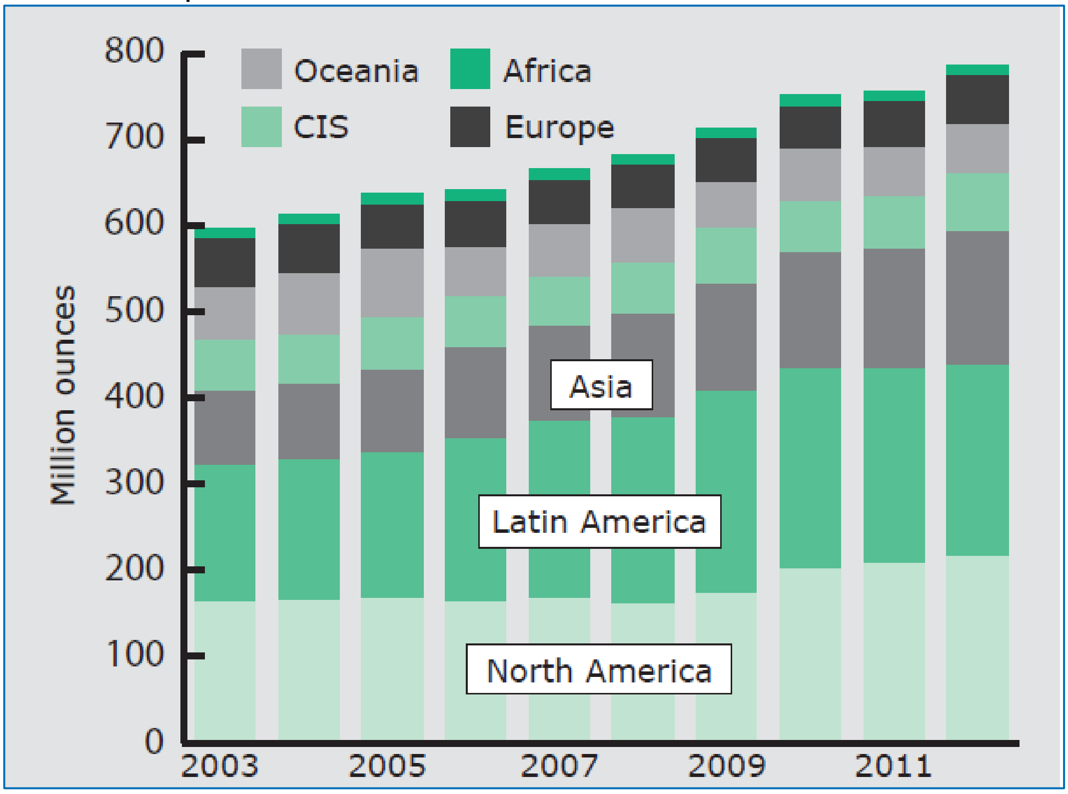
89 http://geoportal.pgi.gov.pl/surowce/metaliczne/rudy_cu-ag.

based. The most important countries for EU imports because of this triangular trade are Switzerland (16.3% of EU imports), Japan (10.6%), Korea (7.0%) and Hong Kong (4.9)[90]. 'Asia other countries' even has an 18% share of EU imports, which seem to originate mainly from the Singapore Precious Metals Exchange. Triangular trade may also explain the relatively large share of the USA in EU imports (11,6% compared with 1% of world production produced in USA), as New York also has a large trading station for silver, COMEX.

In addition to geographical production and trade, silver also shows diversification in terms of ownership of production, with a HHI value of 208[91].

Figure A.3.8.1 shows the development of silver mine production from 2003 until 2012, with respective regional shares.

Figure A.3.8.1 World silver mine production



Source: Thomson Reuters GFMS / The Silver Institute (2013).

Apart from mine production, silver supply comes from silver scrap (around 25% in 2012) as well as sometimes government sales and private sector disinvestment; notably governments and private investors can be net suppliers, but also net buyers, which would put them on the demand side.

Some export taxes on ores and concentrates are in place, e.g. China taxes silver ore exports with 10%. Indonesia introduced a 20% export tax in 2012, very specifically on unrefined ores, aiming at securing more rents in the processing. There are also cases of non-tariff measures, such as licensing / approval requirements for exporting unwrought precious metals in South Africa and other African countries[92].

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90 Data from Worldbank WITS (World Integrated Trade Solution) database, wits.worldbank.org.

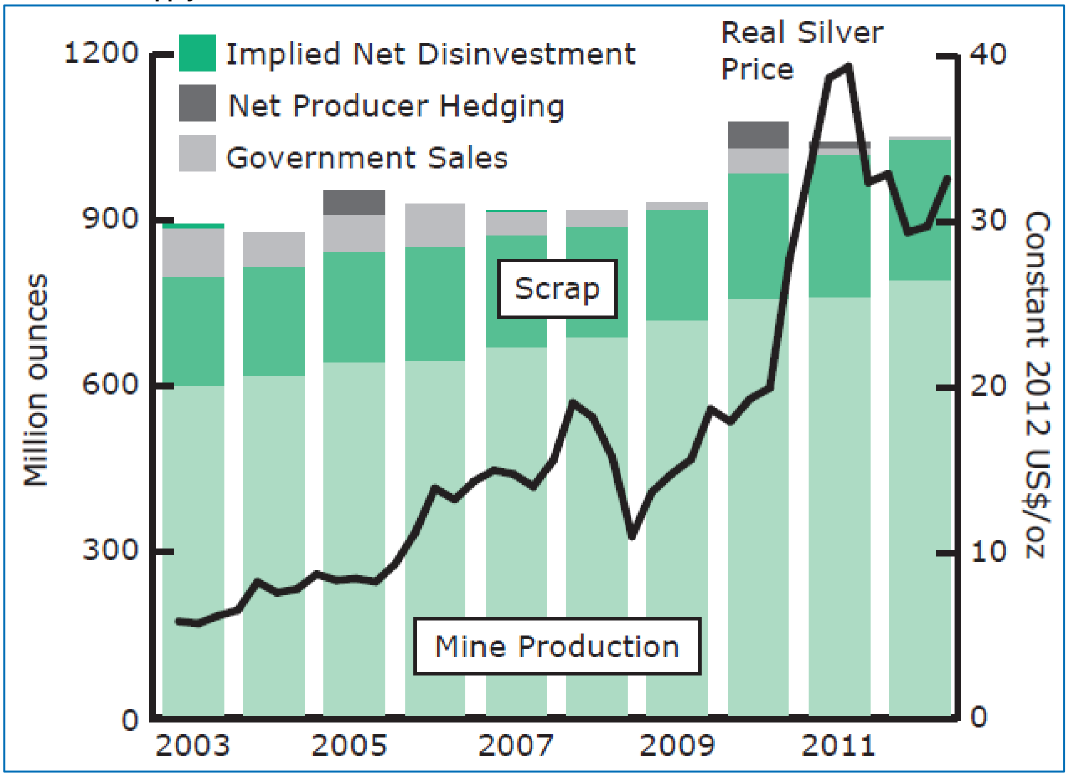
91 Ericsson, M. (2012): Mining industry corporate actors analysis. POLINARES Working Paper no. 16, http://www.polinares.eu/docs/d2-1/polinares_wp2_chapter4.pdf.

92 See OECD (2010): The Economic Impact of Export Restrictions on Raw Materials. OECD Trade Policy Studies; and Kim, J. (2010): Recent Trends in Export Restrictions, OECD Trade Policy Papers, No. 101, OECD Publishing, http://dx.doi.org/10.1787/5kmbjx63sl27-en.

The EOL-RR of silver is between estimated at around 50%[93], varying significantly between end products. More than 90% of jewellery, silverware and coins are recycled. But especially recycling rates of WEEE (waste electrical and electronic equipment) are low, which shows potential of increasing scrap silver supply if recycling is triggered. However, for some products recycling is not expected to become economically interesting, such as RFID, textiles, mirrors, glass or solar panels[94]. This is mainly because of the relatively small amounts of silver in these products.

Figure A.3.8.2 shows the development of total silver supply by different sources, plotted against the silver price development. It is clear from this figure that the price development cannot be explained sufficiently by supply.

Figure A.3.8.2 World silver supply



Source: Thomson Reuters GFMS / The Silver Institute (2013).

9.2 Demand

The most important uses of silver are for:

- Industrial applications (electric/electronics), due to its high connectivity, accounting for 44% of demand in 2012;
- Jewellery (18%of demand in 2012), coins (9%), and silverware (4%), due to its decorative and bacteria-countering characteristics; coins function mainly as an investment vehicle nowadays[95], but their share of demand only reflects newly made coins;
- Analogue photography and mirrors (6%), using silver's highest optical reflectivity of all metals.

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[93] The European Commission (2010) states that the overall EOL-RR is between 30 and 50%, whereas UNEP (2011) puts it at above 50%.

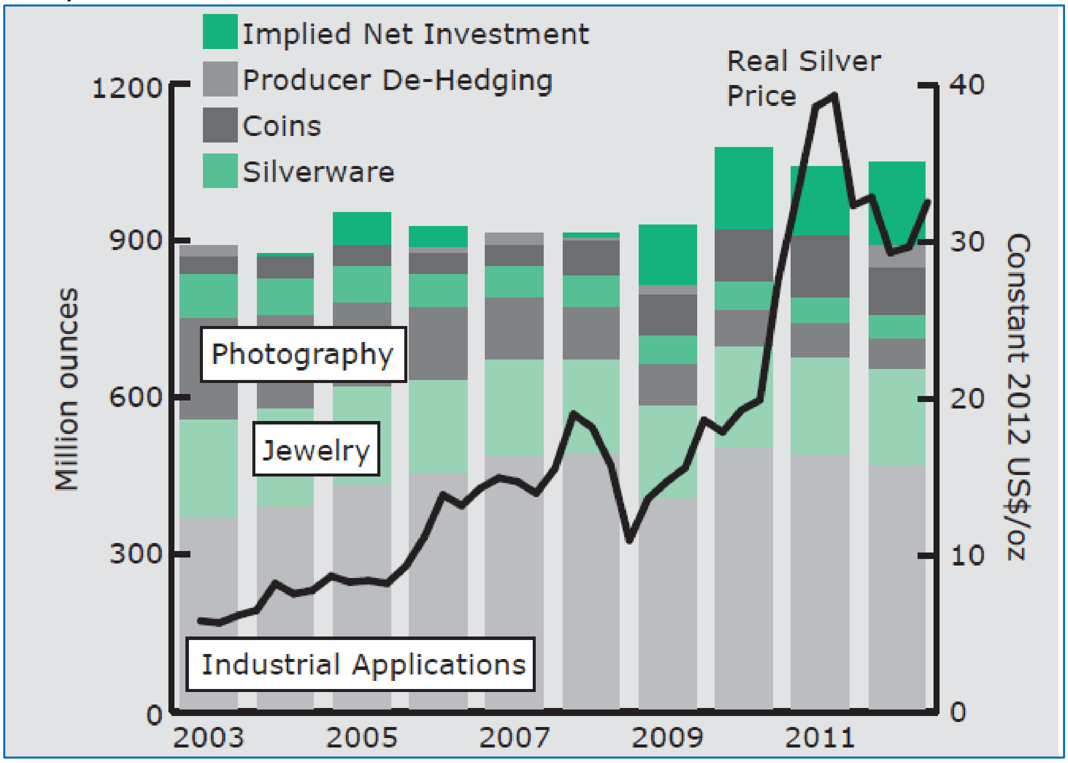
[94] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

[95] Thomson Reuters GFMS / The Silver Institute (2013): World Silver Survey 2013. A Summary, http://www.silverwheaton.com/files/docs_quick%20links/World%20Silver%20Survey%202013%20Summary.pdf.

The remainder of demand is comprised of investment and hedging uses.

The chart below shows the development of silver demand over the last 10 years. It shows how with the financial crisis in 2009, industrial demand fell, but this was more than compensated by increased investment demand also related to the financial turmoil. "The traditional 'safe-haven' appeal of precious metals has attracted many investors to this asset class."[96] Industrial demand went back to pre-crisis levels as early as 2010, but has been declining since. What can also be seen is that while jewellery use of silver is relatively constant, its use in photographic applications "continued its secular decline"[97] due to technological development and the corresponding increase in digital camera use.

Figure A.3.8.3 Development of silver demand



Source: Thomson Reuters GFMS / The Silver Institute (2013)

Nevertheless, looking into the future, several areas for likely future growth in industrial silver demand can be identified:[98]

- The increased use of RFID tags and solar panels;
- The construction sector could use silver in windows as insulation;
- Mass application in small quantities as bactericide and odour-absorbing material in textiles and medical application.

We can therefore summarize future areas for usage growth into two categories, one related to climate/energy (renewables and energy efficiency) and the other to consumer goods with small amounts of silver used, but mass production.

96 IFSL Research (2009): Bullion Markets 2009, http://www.thecityuk.com/assets/Uploads/Bullion-Markets-2009.pdf.

97 Thomson Reuters GFMS / The Silver Institute (2013): World Silver Survey 2013. A Summary, http://www.silverwheaton.com/files/docs_quick%20links/World%20Silver%20Survey%202013%20Summary.pdf.

98 European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

As the past shows, industrial use of silver has been shown as relatively volatile, depending on the general status of the world economy, and on the development of particular industrial uses. Jewellery use remained quite constant – with emerging economies compensating for demand losses from developed countries[99] – whereas silverware seemed to respond to the low market environment as well, but its production is on a high level compared to historical standards. Net investment has clearly remained on a high level since 2009, in the same period when strong price increases could be observed.

Silver has some substitutes for its application in electrical and electronic uses, such as aluminium, copper, gold, palladium, or platinum, although their use would mean a loss of performance. Substitution in photography has already taken place due to a change in underlying technology. Substitutes for dissipative use, such as in RFID and textiles, are not available yet, but the research on this has the potential to change future demand for (physical) silver.[100]

9.3 Supply and demand interaction

The main markets for silver can be described as transparent, but old-fashioned and investment-driven. The largest over-the-counter (OTC) trading place for silver is the London Bullion Market, where a bidding process results in a daily reference price known as the fix. The trading is dominated by institutional investors. On average in November 2008, the London Bullion Market Association (LBMA) traded 107.6 ounces of silver daily, worth $1.1 bn. This means that an amount equal to the annual silver production was cleared at this market every 6.2 days.[101] These figures underline the importance of silver in investment markets, and at the same time, the importance of investors in determining the silver price. The production and EU import figures in **Table A.3.8.1** confirm the picture of silver as a multilaterally traded product with important intermediaries active in the transactions.

There is even an exchange concentrating on virtual trade: the Comex in New York is the main futures and options exchange, where most fund activity is focused.[102] "Only a small percentage of the futures market turnover ever comes to physical delivery of the gold or silver represented by the contracts traded."[103]

Notably, the market for silver is much smaller in money terms than that for gold, with gold turnover in London being more than 17 times larger than that of silver[104] (and 4 times as large in exchange trading[105]). This is one of the reasons often stated why the silver price is more volatile than that of gold. What is also peculiar about the market for silver, however, is that its price is closely linked to that of gold, but its industrial use plays a comparatively larger role. It is difficult to predict which of the two forces will dominate.

Volatility of the silver price can also be explained by the relatively low price elasticities of demand and supply: Demand's reaction to prices is limited, as silver is needed in certain industrial applications and even investors tend to take high prices into account when urgently looking for

[99] Thomson Reuters GFMS / The Silver Institute (2013): World Silver Survey 2013. A Summar., http://www.silverwheaton.com/files/docs_quick%20links/World%20Silver%20Survey%202013%20Summary.pdf.

[100] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

[101] IFSL Research (2009): Bullion Markets 2009, http://www.thecityuk.com/assets/Uploads/Bullion-Markets-2009.pdf.

[102] Thomson Reuters GFMS / The Silver Institute (2013): World Silver Survey 2013. A Summar, http://www.silverwheaton.com/files/docs_quick%20links/World%20Silver%20Survey%202013%20Summary.pdf.

[103] IFSL Research (2009): Bullion Markets 2009, http://www.thecityuk.com/assets/Uploads/Bullion-Markets-2009.pdf.

[104] http://goldnews.bullionvault.com/silver_case_032520106.

[105] IFSL Research (2009): Bullion Markets 2009, http://www.thecityuk.com/assets/Uploads/Bullion-Markets-2009.pdf.

“safe havens”. The price elasticity of supply is not very large either, as silver is mainly mined as a by-product of other materials (thus depending on their extraction, or indirectly on their price) and recycling of silver has also shown to be slow to react to price increases.

9.4 Important aspects for deep-sea mining

The following aspects are important to take away from this analysis in the context of deep-sea mining:

- The demand outlook for silver is positive (due to expected uses in the resource efficiency and renewable energy technologies and mass consumer products), but industrial demand has shown to be relatively volatile in the past;
- Low price elasticities and a multitude of factors influencing the price (in particular different types of demand) increase volatility and uncertainty;
- Global supply of silver is quite diversified, leaving no role for deep-sea mining as a global game changer in this market.

10 Platinum Group Metals: Platinum

10.1 Supply

Platinum group metals is a collective name for six precious metals with similar properties. It consists of ruthenium, rhodium, palladium, osmium, iridium and platinum. PGMs occur and are mined always together as coupled elements[3]. Platinum Group Metals are considered to be critical raw materials according to the EC (2010)[106]. The risks are caused by the high relative economic importance and high relative supply risk. In this section the focus is on one of the PGMs, platinum. For some information however only sources about PGMs in general are available.

Mine production was responsible for around 81 percent of total supply of platinum in 2012[107]. South Africa, Russia, Zimbabwe and Canada are the leading producing countries of platinum as can be observed in **Table A.3.9.1** and **Figure A.3.9.1**. The majority of production is concentrated in only two countries; South Africa (71.51%) and Russia (14.53%). The reserves of PGMs are mainly located in South Africa (95.45 percent). In the EU there is almost no production of Platinum-Group Metals (PGMs). The main sources for PGMs for the EU come from the two leading producing countries South Africa (about 60%) and the Russian Federation (over 30%)[1]. Within the EU there was some production of platinum (mined as byproduct) in Finland and Poland (data 2007). This contribution should not be exaggerated; Finland produced only 0.39% of world production and Poland even less[108]. The concentration of platinum in only two countries and the high import dependency rate in Europe make platinum a critical raw material. The annual global supply occupies the space of only about 10 cubic meters[109].

Table A.3.9.1 Production, reserves and EU imports of platinum

	Production (in t / percentage of total)		Reserves (in t / percentage of total)		Imports of EU (in million € / percentage of total)	
South Africa	133	72,76%	63.000	95,30%	1422	36%
Russia	24,6	13,46%	1.100	1,66%	651	16%
Zimbabwe	11	6,02%	n.a.	n.a.	n.a	n.a.
Canada	7	3,83%	310	0,47%	72	2%
United states	3,7	2,02%	900	1,36%	562	14%
Other countries	3,5	1,91%	800	1,21%	1239	31%
World total	182,8		66.110		3946	

Source: USGS (2014) for data on reserves and production, pertaining to 2012. UN comtrade website for EU import data.

EU imports seem to come mainly from the countries that also produce platinum. South Africa has a lower export to the EU then its share in world production. This is mainly compensated by shares of “other countries” and a high share of US trade in platinum the EU’s platinum imports.

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106 European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

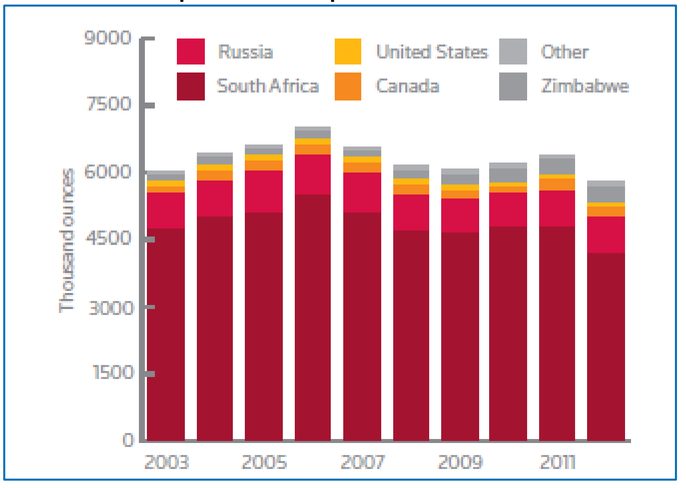
107 Thomson Reuters (2013): Platinum & Paladium survey 2013.

108 European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

109 Yang (2009): An impending platinum crisis and its implications for the future of the automobile. *Energy policy* 39, pp. 1805-1808.

Platinum is not only concentrated in one, maybe two main producing countries, but also exhibits a high market concentration in terms of ownership: the value of the HHI of concentration is 1883 for platinum[110].

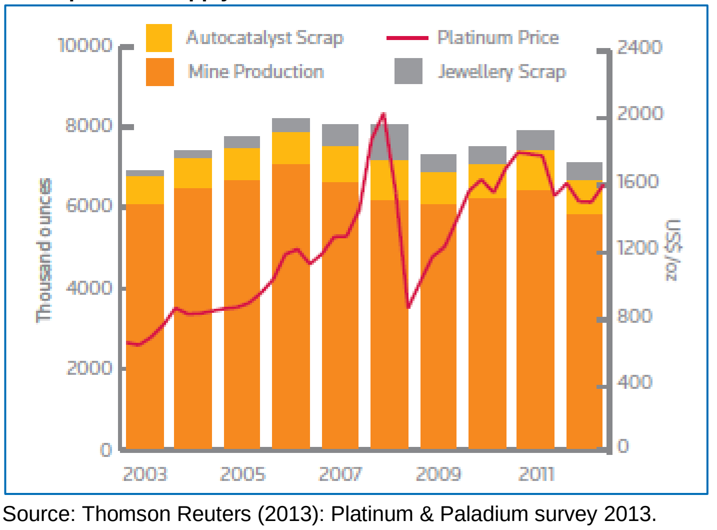
Figure A.3.9.1 Division of world platinum mine production



Source: Thomson Reuters (2013): Platinum & Paladium survey 2013.

The second supply source of platinum is platinum scrap from autocatalysts and jewellery. The recovery of platinum from consumer products is efficient due to its high value. The general EOL-RR for platinum is estimated between 60 and 70%. There is significant variety in EOL-RR between different sectors where platinum is used. Within the car manufacturing sector it is between 50 and 55%, within industrial applications between 80% and 90% and within jewellery between 90% and 100%[111]. The EOL recycling rates show that in the car industry more recycling can be a possible source for additional supply. The recycled content estimations for platinum vary, from 19%[112] to 50%[113]. This might however be caused by differences in use, as it seems that recycled content for jewellery tends to be higher than when used for autocatalysts.

Figure A.3.9.2 World platinum supply



Source: Thomson Reuters (2013): Platinum & Paladium survey 2013.

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110 Ericsson, M. (2012): Mining industry corporate actors analysis. POLINARES Working Paper no. 16, http://www.polinares.eu/docs/d2-1/polinares_wp2_chapter4.pdf.

111 UNEP 2011 Recycling Rates of Metals.

112 Thomson Reuters (2013): Platinum & Paladium survey 2013.

113 UNEP 2011 Recycling Rates of Metals.

The supplies of PGMs including platinum have been disrupted by strikes in the past. In 2012, the prices of PGMs increased two times during the year due to strikes at major PGM producers in South Africa. The strikes spread to several South African mining companies resulting in supply disruptions[114]. As South Africa is the main producer of Platinum, supply disruptions can have severe consequences.

The supply of platinum is not expected to grow significantly in the nearby future. The largest producer in South Africa (Amplats) is expected to reduce its production capacity. On the other hand, recycling is expected to increase and Zimbabwe is expected to increase its production[115].

10.2 Demand

Most demand for platinum originates from car manufacturers. They use platinum for the production of autocatalysts. Most platinum is used for diesel catalysts (96%), gasoline catalysts make up the residual. In 2012 platinum for autocatalysts made up around 41 percent of total demand. Europe leads in platinum autocatalyst demand as a consequence of the large European automotive industry (44% of world catalysts demand)[2]. In Europe the diesel market share in light weight vehicle production is relatively large. For diesel cars, higher PGMs loadings generally apply. This is an explanation for the significant demand for platinum in Europe[2].

New developments in the automotive catalysts technologies might decrease the use of PGMs, because smaller quantities of PGMs are used. On the other hand tighter emission standards demand that cars are equipped with advanced catalytic converters. This more advanced equipment requires higher loadings of PGMs[116]. The demand for platinum is to a large extent dependent on the car manufacturing industry. Production in this sector is very procyclical. Global economic developments therefore have a large influence on the demand and price for platinum. Demand for the auto industry is likely to increase in the nearby future due to increased limitations for exhaust gasses, which increase amounts of catalyst needed in vehicles[10]. In the long term this might change due to introduction of electric vehicles, but this is still uncertain.

After autocatalysts, jewellery is the second most important demand source for platinum. Demand for platinum from jewellery producers made up 32 percent of total demand in 2012[117]. The demand for platinum from the jewellery industry is price elastic. This was shown for instance in 2012, when jewellery demand for platinum increased mostly in China as a response to an earlier price decrease. China is the largest consumer of platinum jewellery (63 percent of platinum jewellery demand[7]). Other demand sources are the chemical industry, electronics (computer hard discs), glass and retail investment, together making up 17% of total demand[7].

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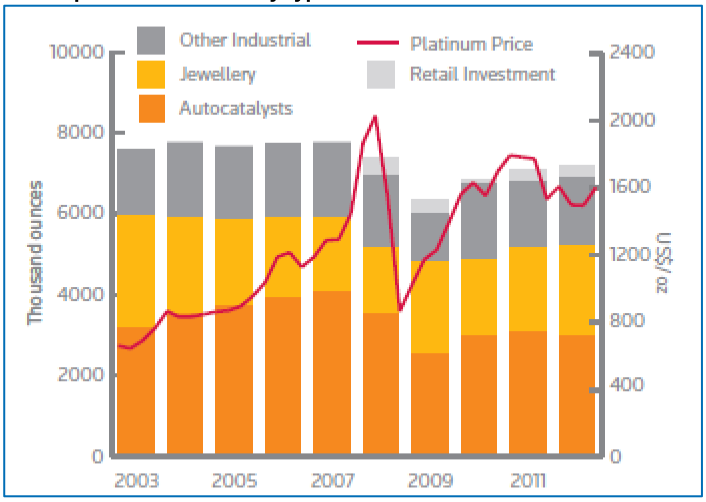
[114] USGS (2013: Mineral Commodity Statistics.

[115] KMPG (2013): Platinum, *Commodity Insights 2013.*

[116] European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf.

[117] Thomson Reuters (2013): Platinum & Paladium survey 2013.

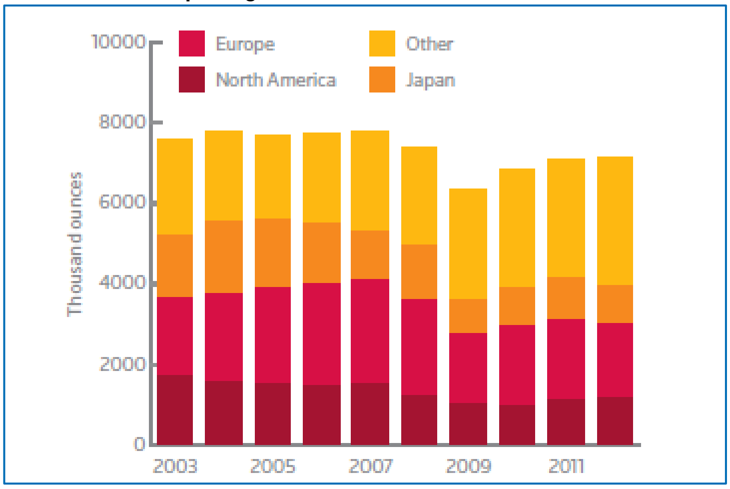
Figure A.3.9.3 World platinum demand by type of use



Source: Thomson Reuters (2013): Platinum & Paladium survey 2013.

The total demand for platinum is not dominated by certain regions of the world, as can be observed in **Figure A.3.9.4**, although Western Countries make up a large part of the total demand. Especially Japan is a relatively large user.

Figure A.3.9.4 Platinum demand per region



Source: Thomson Reuters (2013): Platinum & Paladium survey 2013.

In most industrial applications, platinum is irreplaceable. When it can be substituted, in most cases the only feasible substitutes are other PGMs. However those PGMs are not more abundant than platinum[118]. Therefore, shifting the use of platinum to another PGM does not necessarily help, but shifts the problem from one scarce metal to another.

An example is gasoline and diesel catalytic converters in motor vehicles, for which both palladium and platinum can be used. Palladium has recently been used more often instead of platinum in autocatalysts applications. A possible explanation for this is that the platinum-palladium ratio, traditionally lower in gasoline cars, is now becoming lower for diesel cars as well, owing to palladium's better properties in particulate matter filtering[119]. This development may decrease the demand for platinum.

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118 Yang (2009): An impending platinum crisis and its implications for the future of the automobile. Energy policy 39, pp. 1805-1808.

119 See http://www.stillwaterpalladium.com/autocatalysts.html.

10.3 Supply and demand interaction

The market for PGMs is characterized by a limited number of refiners and suppliers. The prices of the PGMs are traditionally set by the sales offices of major producers, of which the 2 largest (Anglo Platinum and Impala Platinum) both mostly mine in South Africa[120]. Producers set wholesale prices for each PGM at trading desks in the USA, Hong Kong and London[121]. OTC markets for Platinum also exist. The most important one is the London Platinum and Palladium Market. The prices are determined by a group of member dealers based on trades that occur around the world[122]. The combination of the mentioned limited amount of price setters for PGMs and dependence of platinum demand on a few markets mean that platinum price setting is not subject to speculation at exchanges, but it is also hard to get information on the price mechanisms at work.

10.4 Important aspects for deep-sea mining:

- Platinum is a highly important material for EU industry, especially car manufacturing, as long as gasoline and diesel cars are being built;
- Both production and reserves of platinum are heavily concentrated in South Africa;
- deep-sea mining of platinum could decrease the supply risks associated with geographical concentration of supply and the strong effects of instabilities caused by it.

[120] See http://metals.about.com/od/Top-10-Producers/tp/The-10-Biggest-Platinum-Producers.htm.
[121] See http://metals.about.com/od/investing/a/Metal-Markets.htm.
[122] Dunbar (2012) PWC Basics of mining.

11 Rare earth elements (REE)

Rare earth elements is the collective name for the following 17 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. The recent DG Enterprise study on critical raw materials has split rare earth elements into three categories: scandium, heavy and light rare earth elements[123]. Most of these elements are located in deposits of the minerals bastnaesite and monazite. Bastnaesite is the primary mineral while monazite is mostly recovered as a byproduct[124].

The name suggests these elements are very rare, but that is not the case. Thulium, for example, is less rare than gold or platinum, and other elements are more abundant than copper or lead. The problem is that from an economic point of view, the REEs are not exploited easily, since they are not very concentrated[125].

11.1 Supply

Table A.3.10.1 gives an overview of the worldwide reserves and production of REEs.

Table A.3.10.1 Production and reserves of REEs (2012)

	Production (in 1000 t)	Percentage of total	Reserves (in 1000 t)	Percentage of total
China	100	90,9%	55.000	39,2%
Australia	3,2	2,9%	2.100	1,5%
India	2,9	2,6%	3.100	2,2%
Russia	2,4	2,2%	n.a.	n.a.
United States	0,8	0,7%	13.000	9,3%
Vietnam	0,22	0,2%	n.a.	n.a.
Brazil	0,14	0,13%	22.000	15,7%
Malaysia	0,1	0,09%	30.000	21,4%
Other countries	n.a.	n.a	41.000	29,3%
World total	110		140.000	

Source: USGS (2014) for data on reserves and production, pertaining to 2012.

In 2012, the total production of REEs was 110 thousand tonnes. China was the largest producer with 90% of the total production. The second largest producer is Australia, with only 3% of the total production. China also holds the largest reserves, 39% of the total 150,000 thousand tonnes. Malaysia holds 21% of the reserves in REE, but their production is only 0.09% of the total.

123 European Commission, DG Enterprise & Industry (2014): Report of the Ad hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/crm-report-on-critical-raw-materials_en.pdf

124 Humhpries, M. (2013): Rare Earth Elements: The Global Supply Chain.

125 Humhpries, M. (2013): Rare Earth Elements: The Global Supply Chain.

Table A.3.10.2 Production of REEs in tonnes (2000-2012)

Country													percentage growth
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2000 -2012
Australia	n.a	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4.000	n.a.
Brazil	n.a.	n.a.	n.a.	n.a.	402	527	527	645	460	170	140	140	300	-25,37%
China	73.000	80.600	88.000	92.000	98.000	119.000	133.000	120.000	125.000	129.000	120.000	105.000	95.000	30,14%
India	2.700	2.700	2.700	2.700	2.700	2.700	2.700	2.700	2.700	2.700	2.800	2.800	3.000	11,11%
Malaysia	446	351	240	360	800	150	430	380	120	130	310	280	350	-21,52%
Total	**85.900**	**89.500**	**93.000**	**97.100**	**102.000**	**122.000**	**137.000**	**124.000**	**128.000**	**132.000**	**123.000**	**110.000**	**110.000**	**28,06%**

Source: USGS minerals yearbook.

Overall production of REEs increased with 28% over the last 13 years. The total production peaked in 2006, at a value of 137.000. Although production grew a little in the years following the economic crisis, in 2011-2012 it decreased to a level of 110.000. China showed the largest growth in production, which was 30%. The production of Malaysia fluctuated a lot through the years. In 2012, production was 22% less than in 2000, with significant ups and downs in between Production in Brazil decreased 22% compared to 2004. The table shows the production of Brazil used to grow until 2007. In 2008 and 2009 it decreased tremendously. In 2012 production of Brazil doubled compared to 2011. Production worldwide is much more constant.

Bayan Obo is the largest mine of REES in the world and is located in the west of Inner Mongolia (part of China). This mine produces 70% of worldwide REEs[126].The largest producer, Baogang Group is located at this mine. The group consist of two companies: Baogang Share and Baogang Rare Earth[127]. For 2013, the group had a revenue target of $9.6 billion[128].

There is no data available on the company concentration in REE mining; in terms of country concentration, rare earths are close to the 10,000 upper limit of the HHI[129].

126 IAMGOLD Corporation (2012): Rare Earth Elements 101.

127 See http://btsteel.com/web/index.html.

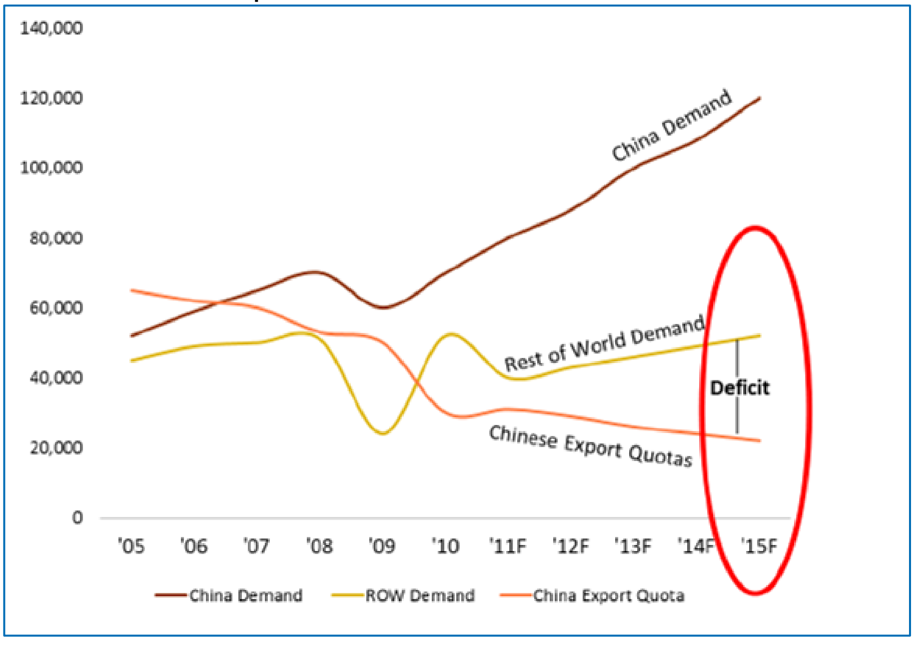
128 See http://www.steelorbis.com/steel-news/latest-news/baogang-group-sets-rmb-59-billion-sales-revenue-target-for-2013-736002.htm.

129 Maribus (2014): World Ocean Review 3. Chapter 2: Sea-floor mining, http://worldoceanreview.com/wp-content/downloads/wor3/WOR3_chapter_2.pdf.

In the future, Chinese exports of REEs will decline. It is expected that China will use more of its domestic REEs internally, as a result of economic growth and increased consumer demand. The REEs will be used in the production of wind turbines, consumer electronics and other sectors[130]. On the other hand, the resources in China are diminishing. The policy initiatives of China focus on protecting its own supply. It is even said that China will become a net importer, while they used to be a net exporter. China already started this policy in 2010. The export quota decreased by 40% compared to 2009. Since China is responsible for almost all production, the prices increased quickly as a result of panic buying and the threat of diminishing supply. As a result of the high prices, demand decreased. This restored the price balance[131].

The United States, Japan and the European Union complained that the export restrictions gave Chinese companies an unfair competitive edge. China stated the restrictions were necessary in order to prevent overmining and to protect the environment[132]. The WTO ruled that China's export limitations are against global trade rules. Therefore China has to make the transition to a quota-free trade arrangement for the REEs[133]. China will appeal this decision of the WTO[134].

Figure A.3.10.1 Demand development and forecast



As long as the export quota remains in place, the demand for REEs will remain higher than the export from China. This induces a large deficit that will continue to grow. The rest of world is now taking action to overcome this problem. The United States already started re-establishing the domestic rare earth industry. Molycorp signed a joint venture with Daido Steel and Mitsubishi to manufacture high power magnets, with use of REEs. It is expected that other non-Chinese joint venture will follow this example. As a result of the export quota and the actions undertaken by other countries, two separate markets have been created in most demand and supply overviews: China and Rest of the World[135].

REEs are recycled from old scrap in small quantities, approximately 1%. The main cause for this low recycling of REEs are the small amounts in which it is used in most products. To recover these

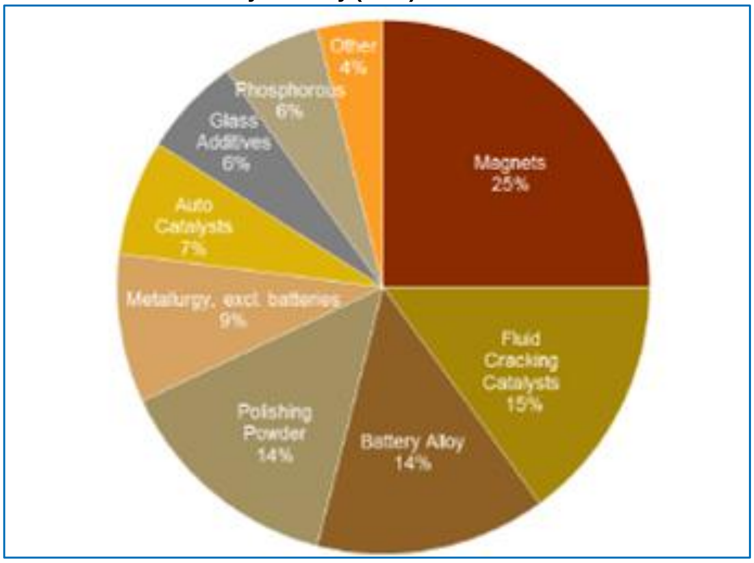
130 Humhpries, M. (2013): Rare Earth Elements: The Global Supply Chain.
131 IAMGOLD Corporation (2012): Rare Earth Elements 101.
132 See http://online.wsj.com/news/articles/SB10001424052970203513204576047041493111426.
133 See http://online.wsj.com/news/articles/SB10001424052702304527504579167132115793314.
134 See http://www.reuters.com/article/2014/04/17/us-china-wto-rareearths-idUSBREA3G08F20140417.
135 IAMGOLD Corporation (2012): Rare Earth Elements 101.

low amounts can be very cost-ineffective.[136] Nevertheless, increased efforts are starting to recycle, especially in the car industry.[137]

11.2 Demand

The demand of REEs is mostly driven by two fast growing sectors: energy and high-tech. The largest market of REEs is in magnets (25%). This market is expected to grow to 30% in 2015. Rare Earths are high in demand due to their strength, heat resistance and long life span. The magnets are made from neodymium, praseodymium, and dysprosium and are used in personal electronic devices like smart phones. Furthermore REEs are used for catalysts (15%), batteries (14%) and polishing powder (14%)[138].

Figure A.3.10.2 **Use of REEs by industry (2010)**



Source: CIBC World Markets in: IAMGOLD Corporation (2012): Rare Earth Elements 101.

REEs are also used in electric and hybrid cars. These cars contain twice as much REEs as the normal gasoline car. The REEs are used in the batteries, the regenerative braking systems and the electric traction motors.

Substitution of REEs is often possible, but results in a loss of performance. Nevertheless, due to the increasing problems with sourcing REEs, many manufacturers further down the value chain are increasingly looking into new technologies which do not require REEs, such as induction motors for electric cars, or alternatives for rare earths in LEDs.[139]

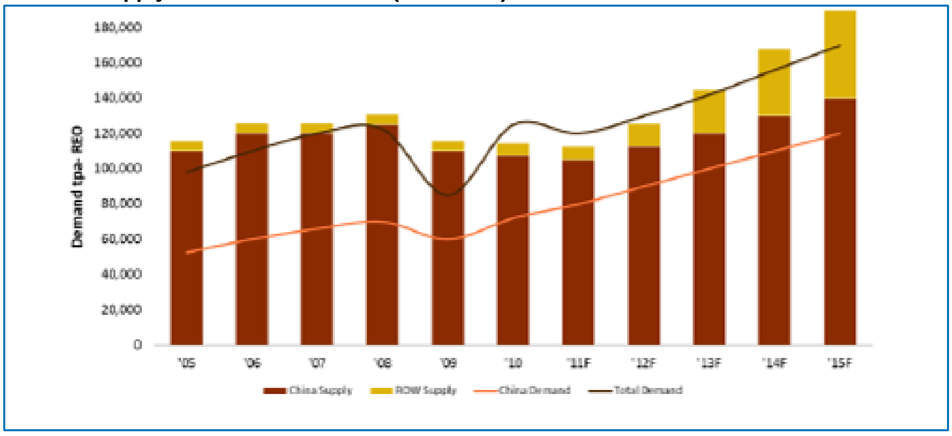
136 European Commission, DG Enterprise & Industry (2014): Report of the Ad hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/crm-report-on-critical-raw-materials_en.pdf

137 http://ec.europa.eu/digital-agenda/futurium/en/content/emerging-alternatives-rare-earth-elements.

138 IAMGOLD Corporation (2012): Rare Earth Elements 101.

139 European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials, http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf; see also http://news.thomasnet.com/IMT/2012/12/11/are-hybrid-vehicle-manufacturers-shifting-gears-away-from-rare-earth-elements/; http://www.ricardo-aea.com/cms/assets/Documents-for-Insight-pages/Resource-efficiency/Waste-Market-overview-RWM-2013.pdf, http://ec.europa.eu/digital-agenda/futurium/en/content/emerging-alternatives-rare-earth-elements.

Figure A.3.10.3 **Supply and demand of REEs (2005-2015).**



Source: IAMGOLD Corporation (2012): Rare Earth Elements 101, with use of IMCOA, Roskill, CREIC and discussions with rare earth industry stakeholder.

Figure A.3.10.3 provides an overview of the supply and demand of REEs. From 2011, the graph presents a forecast. Since China accounts for almost all supply and half the demand, China is added separately. The supply is more or less constant in the period 2005 to 2011. After 2011, supply of China is expected to increase slightly each year, while the supply of the rest of the world increases at a faster rate.

Demand of REEs increases every year. In 2009, there is a tremendous drop in total demand, while demand of China shows a relatively slow decrease. This is a result of the economic crisis that affected the total demand of consumer goods. In China the economic crisis had smaller effect, as shown by China even facing a growth of GDP in that period[140]. Demand recovers in 2010, but then faces a small decline again, showing that REE demand can be fluctuating within short periods of time.

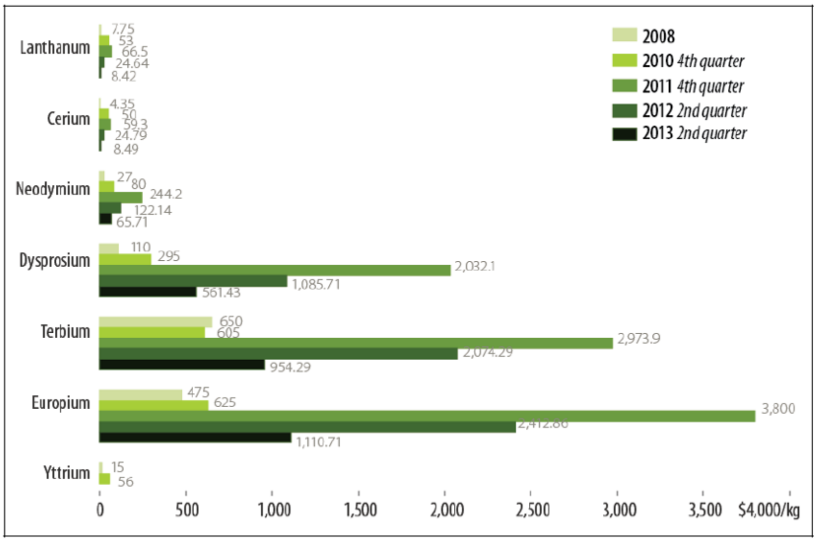
11.3 Supply and demand interaction

Rare earth elements used to be traded privately, without an exchange market. In the end of March 2014, China opened its first exchange market: The Baotou Rare Earth Products Exchange. This market is set up in order to regulate the country's rare earth market, improve the way prices are formed and promote development of the industry[141]. Although the market is mainly set up for the Chinese market itself, is does give a clearer view on prices of REEs, which are openly viewable[142].

For historical market analyses, not much data is available. In most analyses, forecasts are used from 2011 onwards.

[140] Worldbank Database.
[141] See http://www.wantchinatimes.com/news-subclass-cnt.aspx?id=20140329000115&cid=1203.
[142] At www.repe.com.cn.

Figure A.3.10.4 **Prices of selected REEs (2008-2013)**



Source: Marc Humhpries (2013): Rare Earth Elements: The Global Supply Chain, based on IMCOA, 2011, 2013 and METI, 2011.

The prices of the REEs increased tremendously in 2010. As said before, this is the result of the export restrictions of China, which led to less supply. In 2013 the price declined, because demand of REEs decreased. This was the result of substitution and the slow recovery from the economic crisis[143].

It is not clear how prices will develop in the future. It is likely that structural shifts take place in the global economy since half of the world's population is part of emerging economies. Their growth will induce upward pressure on the prices of REEs. This effect will be even larger when the producers have difficulties in meeting the increased demand. Furthermore the costs of mineral extraction will increase due to lower ore grades, higher costs of capital and due to the fact that China started to incorporate environmental and social costs in their production costs. Although production may become more efficient, using less material per output, overall prices are expected to be pushed upward, due to growth in demand and the lack of supply[144]. Breakthroughs in substitution technologies may be able to counterbalance this development, but this doesn't seem likely in the near future.

11.4 Important aspects for deep-sea mining:

- Supply of rare earths is heavily concentrated, resulting in a high supply risk;
- Demand for rare earths is expected to increase at least in the medium term, as long as no significant substitutes are found;
- REEs are a major factor in many technologies; in the EU, especially the automotive and lighting sectors depend on REEs;
- Deep-sea mining could therefore be a game changer in diversifying supply (together with other rare earth mines which are planned to be [re-] opened); particularly, deep-sea mining could secure access of EU industries to these materials.

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143 Humhpries, M. (2013): Rare Earth Elements: The Global Supply Chain.
144 Humhpries, M. (2013): Rare Earth Elements: The Global Supply Chain.

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