Investing in Critical Metals

June 2011

Critical Metals: Rare Earths, Indium, Gallium, Tellurium, Tantalum; and Graphite

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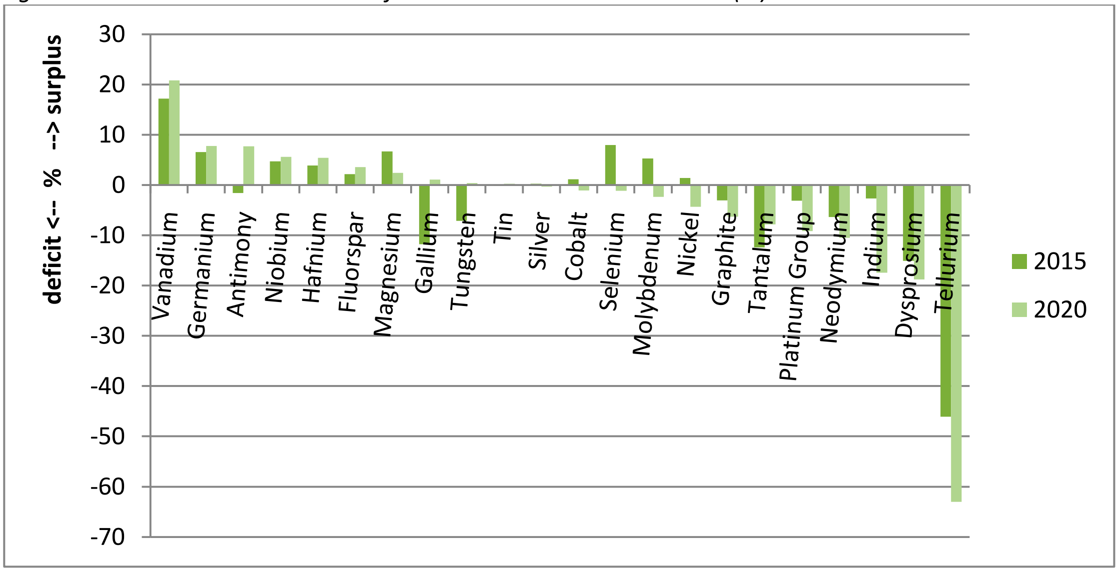
'Critical' metals are those for which there are limited commercially viable substitutes for certain applications, and risks of supply disruptions from the major producing countries. Several of these critical metals are experiencing conditions of constrained supply and burgeoning demand that we expect to lead to substantial deficits over the next five years; in most instances considerably longer (Figure 1).

Figure 1: Market Balance Forecasts for 20 Critical Materials in 2020 (%)



Source: Oakdene Hollins review of various forecasts

Having highlighted, in a report in early 2010[1], the medium-term risk to supply for certain rare earth elements, this summary report revisits the market forces behind those rare earths (**neodymium** and **dysprosium**) for which we see the greatest supply-demand imbalances for 2015-2020, as well as **gallium, indium, tellurium, tantalum** and **graphite.** We believe that the impact of Chinese production and export policies has simply brought forward the inevitable supply deficit by a few years, and that there may be lessons that can be learnt for other critical materials (Figure 2). After all, there is a precedent for price moves greater than those experienced for rare earths over the past year: witness gallium (1999-2001; +500%), indium (2003-2005; +1,000%) and tantalum (2000-2001; +1,000%).

In this report, we outline the unique factors behind future supply and demand for each of these seven elements and identify possible investment opportunities in publicly-listed metal recycling and mining companies. However we expect that there are findings that will be of interest to investors in unlisted assets and clean technologies. There are also implications for consumer supply-chains which we have explored (but which are not covered in this report).

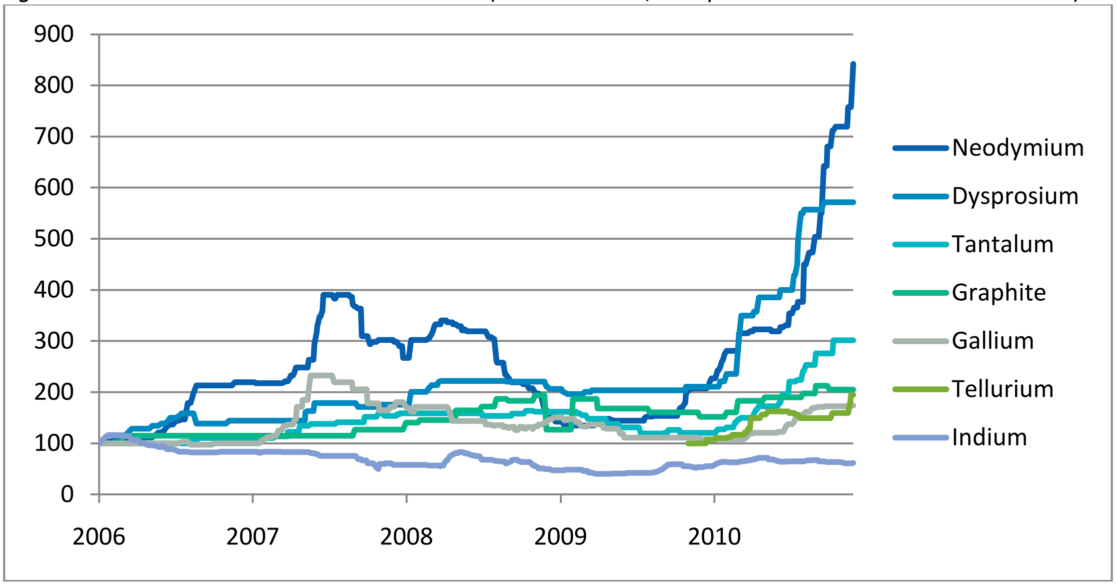
[1] Oakdene Hollins (2010), Lanthanide Resources and Alternatives

The metals are grouped by:

1. Mining by-products: gallium, indium and tellurium;
2. Mined (other): tantalum and graphite; and
3. Rare earths: neodymium and dysprosium.

A brief description of each of the materials can be found in the Appendix (except for rare earths, where this information is now widely available).

Figure 2: Price Trends For 6 Critical Materials (Jan 2006=100, except Tellurium where Nov 2009=100)



Source: Metal Pages & Industrial Minerals Magazine

Gallium, indium and tellurium

Gallium, indium and tellurium are all by-products of base metal production (aluminium, zinc and copper respectively). Further to the existing applications for these metals (see Appendix), demand from photovoltaic applications is increasing rapidly. Whilst there are opportunities to increase the amount of extraction of these metals from smelting waste, there are barriers which mean that these opportunities may not be realised, at least in the medium term. The fact that these metals are produced as by-products (and have a negligible, if any, impact on diversified miners profits) and that their markets are relatively small (a few hundred million dollars for each) makes it difficult to gain investment exposure via this route. However it is possible to gain significant exposure through speciality metal recycling and smelting waste refiners.

Recycling of post-industrial waste already represents a major source of global supply for these metals, due to the high production losses that occur during the manufacture of their main products. For gallium the recycling of waste from the production of semiconductors accounts for around a third of global supply. For indium this share of production is even higher, with over half of the world's indium supply being produced from indium-containing wastes from the manufacture of flat screen displays.[2] For tellurium, limited data is available regarding extraction from recycled scrap from the production of photovoltaic applications, although it is not likely to exceed a quarter of world tellurium supply.

[2] Oakdene Hollins (2011), Assessing Rare Metals as the Critical Supply Chain Bottleneck in Priority Energy Technologies

We have modelled the potential impact on profits (EBIT) of a price move in these speciality metals of similar magnitude to that which has occurred in rare earths, on the following metal recyclers/ smelting waste refiners:

- Umicore (UMI:BB): tellurium and indium;
- 5N Plus (VNP:CN): tellurium and indium;
- Dowa Mining (5714:JP): gallium and indium; and
- Asahi Holdings (5857:JP): indium.

We conclude that relative impact of such a price move would be: 5N Plus > Dowa Mining > Umicore > Asahi Holdings.

Furthermore we would expect there to be other long-term supply responses to these price moves, of which these companies are well positioned to take a significant share. Firstly, the rising demand for these metals in photovoltaic applications will increase the availability of scrap to be recycled by these companies. Secondly, opportunities to recycle post-consumer scrap are likely to increase over time - particularly for indium - as consumers begin to replace first- and second-generation flat screen TVs and computers. Currently the recycling technologies are being developed and are likely to be available in the next few years. For gallium and tellurium, the post-consumer recycling opportunities are likely to be lower due to dissipative usage and the long lifetimes of the associated products.[3] Barriers to entry for recycling are comparatively high for integrated refiners such as Umicore (large investments and knowledge required), and so competition will be more on the collection and pre-processing side rather than the refining and recycling side.

Tantalum and graphite

Growth in tantalum demand is expected to be strong over the coming decade at around 5% per annum, helped by the trend towards greater miniaturisation within electronics for its main market of capacitors and also by increasing usage in aerospace superalloys. The current supply side has been constrained by a number of the major mines being put into care and maintenance following weak demand during the recession. However, supply inventories are rapidly being run down, and new mine openings will be needed to meet the growing demand even once the ‘moth-balled’ mines have been reopened.

Although currently a minor use of graphite, the forecast growth of Lithium-ion batteries in hybrid and electric vehicles could have a significant impact going forward due to the quantity of high quality graphite required in the anodes of the batteries. Supply for graphite is relatively constrained due to the rarity of the high-quality crystalline (flake) form required for batteries and the physical complexities involved in processing natural graphite to ensure the consistency and size of the flakes.

Tantalum and graphite are both mined as single products, making it possible to gain investment exposure via mining companies. For tantalum, these are micro-caps: Noventa (NVTA:LN); Gippsland (GIP:AU); and Solid Resources (SRW:CN). The market for graphite is substantially larger than for tantalum, and whilst there are large producers they are typically in China (responsible for approximately 70%), India (12%) or Brazil (7%) and are not publicly listed. Graftech (GTI:US) is by far the biggest listed producer, although China Carbon Graphite (CHGI:US) and soon to be listed Northern Graphite are micro-cap opportunities. Recycling is unlikely to form a significant proportion of supply for either tantalum (highly dissipative usage of capacitors) or graphite (tends to be consumed by major usages).

[3] Oakdene Hollins (2011), Study into the Feasibility of Protecting and Recovering Critical Raw Materials through Infrastructure Development

Neodymium and Dysprosium

The forces driving markets for rare earth elements are well documented, and we would direct readers to our 2010 report for an in-depth appraisal of these. The only significant change is that the forecast decrease in Chinese export quotas has now become reality. With Lynas (LYC:AU) and Molycorp (MCP:US) rising rapidly on the back of rare earth prices it is worth reflecting on the recent price changes of the individual rare earths, the reason for these and the medium term outlook for demand.

Chinese policy limits rare earth exports to 14,508 tonnes for H1-2011 and has clamped down on the illegal smuggling of rare earths through greater inspection of containers and restricting companies holding export quotas. Greater control of production is also evident, particularly in southern China where there are deposits richer in neodymium and heavy rare earths such as dysprosium. The policies are designed to increase China's share and competitiveness in the production of magnets and other growth products which use predominantly neodymium and dysprosium.

However the export quotas are not explicit by individual element and, due to the higher prices of metals such as neodymium and dysprosium, Chinese producers have met their quotas by withholding exports of less valuable cerium. The unintended consequence of this has been a dearth of cerium outside China; one UK catalysts manufacturer we spoke to recently was struggling to find any cerium oxide for its process. As a result global cerium prices (for which we see no medium-term supply problem) have increased even more rapidly than those of dysprosium and neodymium (for which we forecast a medium-term deficit; see Table 1).

Table 1: Change in Rare Earth Oxide Prices, 2009 to 2011 (YTD to 11 April 2011)

Rare earth oxide	Price change (multiplier) 2009-2011 (YTD)
Samarium oxide	35
Cerium oxide	31
Lanthanum oxide	25
Praseodymium oxide	12
Neodymium oxide	12
Dysprosium oxide	6
Terbium oxide	3
Europium oxide	2

Hence currently the market is being distorted in a way that China presumably did not envisage, and we expect this to be corrected in the short term. As with most rare earth deposits, Mount Weld (Lynas) and Mountain Pass (Molycorp) have high concentrations of cerium oxide (47% and 49% respectively). Growing applications such as Molycorp's XSORBX water filter notwithstanding, we expect this to result in a global over-supply of cerium when these mines are at full production. The average neodymium output of Mount Weld is 19% and of Mountain Pass it is 12%. Heavy rare earths are approximately 2% and 1% respectively. Therefore while the average price of these mines' rare earth output has recently increased more rapidly than the median rare earth price, in the medium term we would expect the opposite to be true.

Recycling technologies for rare earths continue to be explored. Among the promising options are semi-commercial technologies to recycle permanent magnet scrap from production and from post-consumer hard-disk drives.

Conclusion

Chinese policy has caused sharp rises in rare earth metal and related stock prices. However for neodymium and dysprosium, we believe this has simply accelerated a process that would have occurred via market forces over the medium term. As such it can be used as a guide to what could happen to other critical materials for which we forecast supply deficits, especially since there is already historic precedent for such moves in these materials. These deficits will be driven by the emergence of new demand, predominantly from clean technology products, while supply will remain constrained based on current industry investment plans. For gallium, indium and tellurium the investment opportunity is within the recycling companies, whereas for tantalum and graphite it is in the primary producers.

Background to this report:
Oakdene Hollins has considerable expertise in researching critical metals having authored the following major studies for the UK Government, EU Commission and other clients:

- *Critical Metals and Minerals: A Review,* (forthcoming 2011). This study reviews and conducts meta-analysis of different studies that have assessed the criticality of metals.
- *Assessing Rare Metals as the Critical Supply Chain Bottleneck in Priority Energy Technologies for Institute for Energy*, (forthcoming, 2011). This study quantified and analysed the importance for renewable and nuclear energy of 60 metals.
- *Study into the Feasibility of Protecting and Recovering Critical Raw Materials through Infrastructure Development*, (March 2011). A review of the recycling potential of the 14 materials designated as being 'critical' to the EU.
- *Recycling Strategic & Speciality Metals (17 March 2011),* Presentation at Objective Capital Rare Earths, Speciality & Strategic Metals Investment Summit.
- *Lanthanide Resources and Alternatives*, (May 2010). This study highlighted the (now widely known) supply risks of rare earths for the uptake of hybrid/electric vehicles.
- *Material Security: ensuring resource availability for the UK economy, (2008).* An assessment of the supply and material risks associated with 69 materials.

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About Oakdene Hollins:
Oakdene Hollins is a research and consulting company working to support change toward less carbon-intensive and more sustainable products, processes, services and supply chains. The business sectors we work with include food & drink, textiles & clothing, metals & mining, chemicals & materials, wastes management, sustainable innovation, and European and UK policy. We have built a strong reputation for integrity, reliability and excellence with public sector and private industry clients alike. We operate at a European scale and manage the Ecolabel scheme in the UK in collaboration with TUV/NEL.

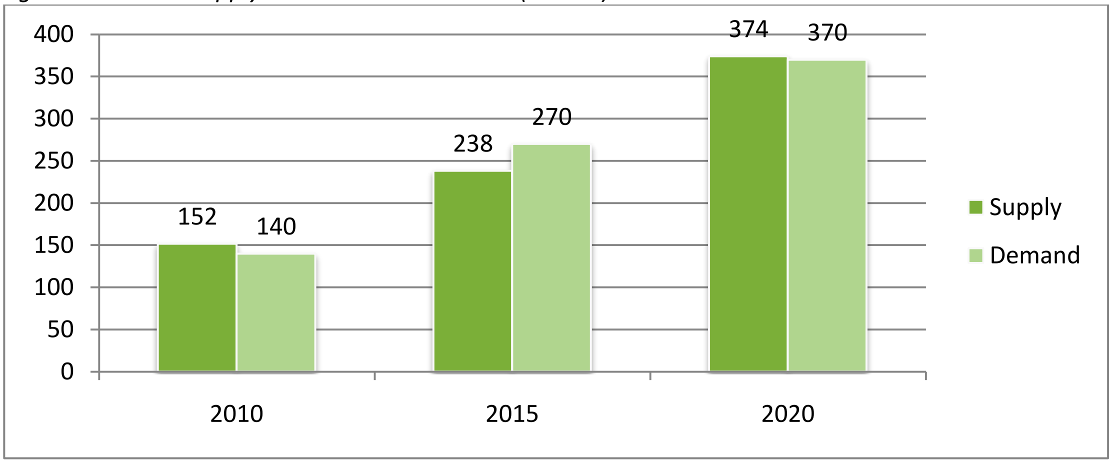
Oakdene Hollins employs people with science, economics, business administration and manufacturing disciplines, so that within each industry sector we can offer the following core services: market and technology appraisal, protocol and standards development, economic modelling, Lean Manufacturing projects, financial impact assessment, management of research projects, ecolabelling advice, carbon footprinting, and critical review of life cycle assessments.

APPENDIX

Gallium:
Gallium is a minor metal that can be refined as a by-product from alumina production, although only a fraction of that contained in the alumina is actually refined. Current estimates of world production are around 150 tonnes per year (including recycled sources), with China, Japan and Germany being the major producing countries.

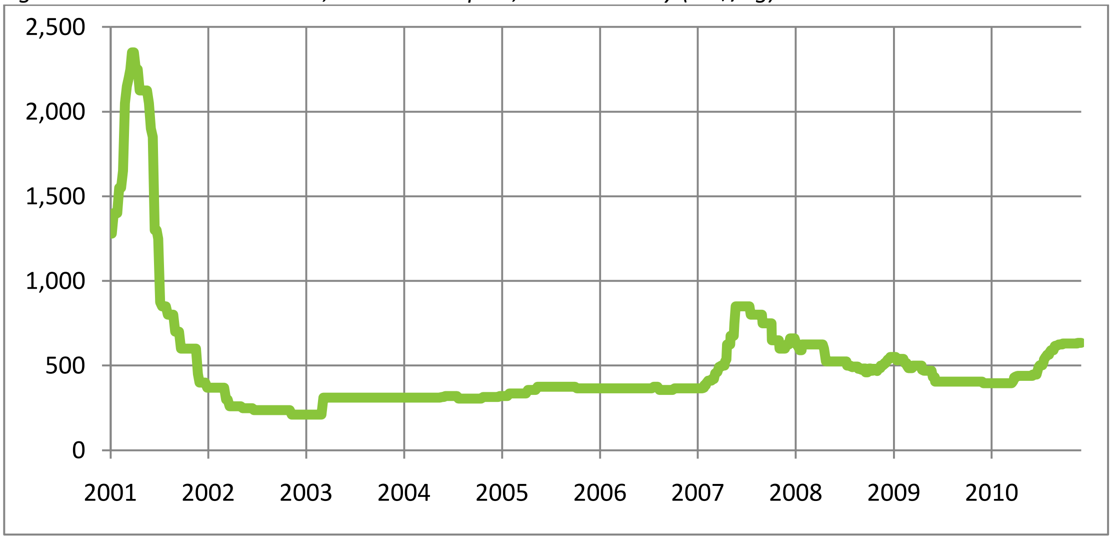
The major application for gallium is presently within integrated circuits, although thin-film photovoltaic cells are the major long-term growth area. A significant deficit is forecast for gallium for 2015, although this will be met by 2020 if sufficient base metal refiners begin to extract gallium. Prices for gallium have been rising and are currently near $1,000/kg (as of April 2011). This represents a doubling over the course of a year, although prices still remain well below their previous peak during the dot-com boom.

Figure 3: Gallium Supply and Demand Forecasts (tonnes)



Sources: Umicore; Own Calculations based on USGS, Öko-Institut, US Dept of Energy

Figure 4: Gallium Metal Prices, CIF Main Airport, 99.99% Purity (US$/kg)



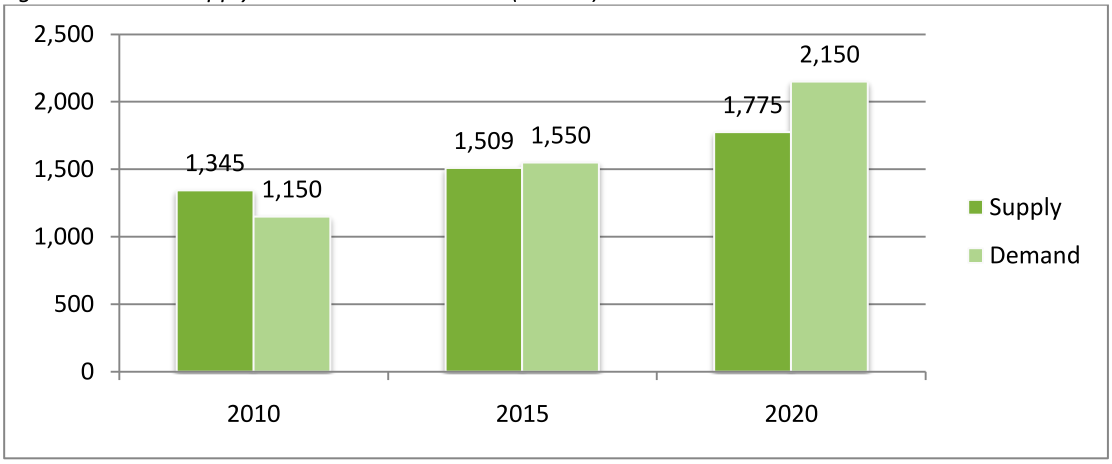
Source: Metal Pages

Indium:

Indium is a minor metal refined mostly as a by-product from zinc production. Current estimates of world production are around 1,300 tonnes per year, of which over half is produced from recycled sources (mostly industrial scrap from manufacturing processing). China, Japan and Korea are the largest producing countries, although it is noteworthy that Peru and Bolivia represent major sources for indium-containing zinc ore.

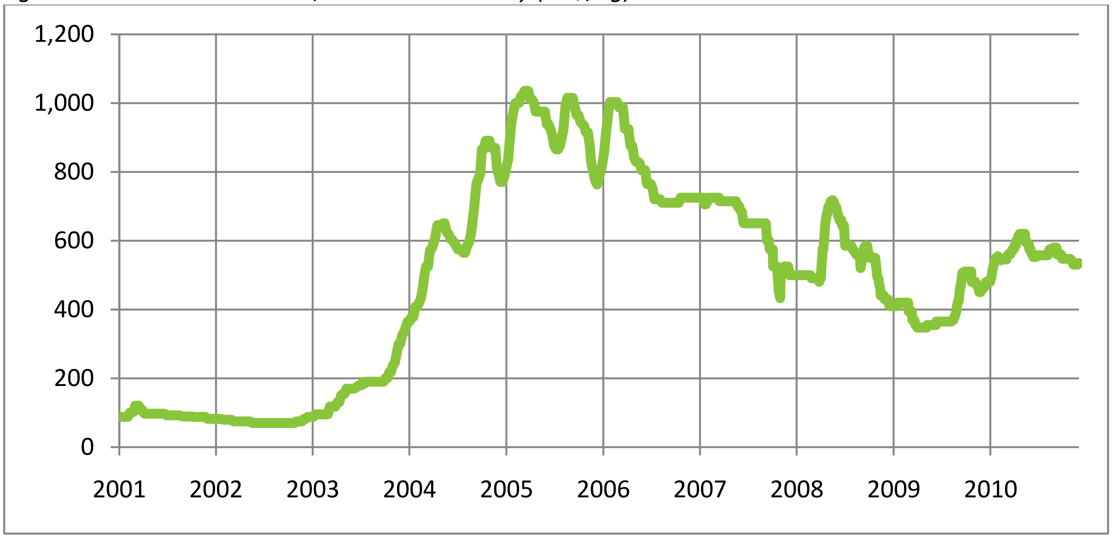
The major application for indium is presently within flat panel displays e.g. televisions and computer monitors, although thin-film photovoltaic cells are the major long-term growth area. A significant deficit is forecast for indium for 2020 as supply growth is expected to struggle to keep pace with demand. Prices for indium have been rising and are currently near $725/kg (as of April 2011), although they remain below the 2005 peak of $1,000/kg.

Figure 5: Indium Supply and Demand Forecasts (tonnes)



Sources: Umicore; Own Calculations based on Economist Intelligence Unit, USGS, Öko-Institut

Figure 6: Indium Metal Prices, min. 99.99% Purity (US$/kg)

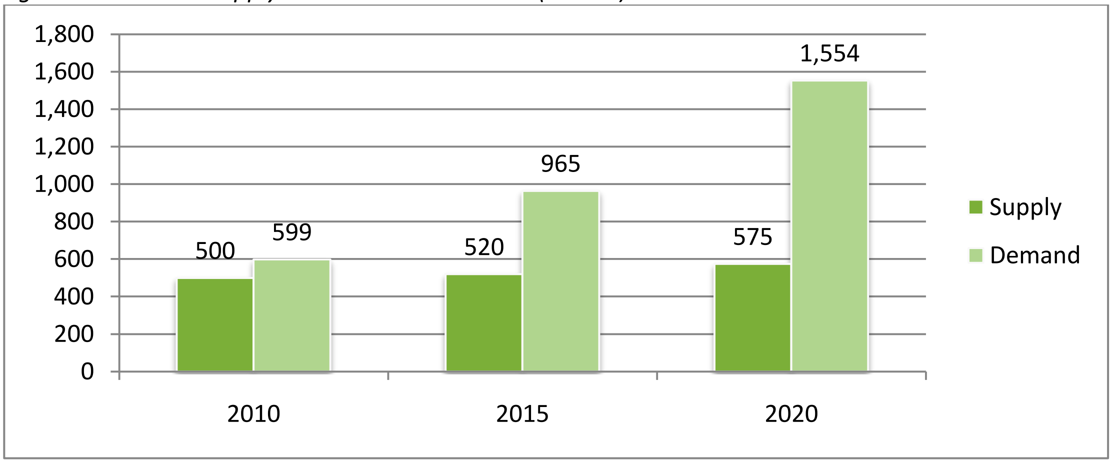


Source: Metal Pages

Tellurium:
Tellurium is generally refined as a by-product from copper production. Current world production is estimated around 500 tonnes per year although, due to secrecy among producers and consumers, limited information is available regarding geographic breakdown. At present only a portion of the tellurium extractable from copper production is actually refined.

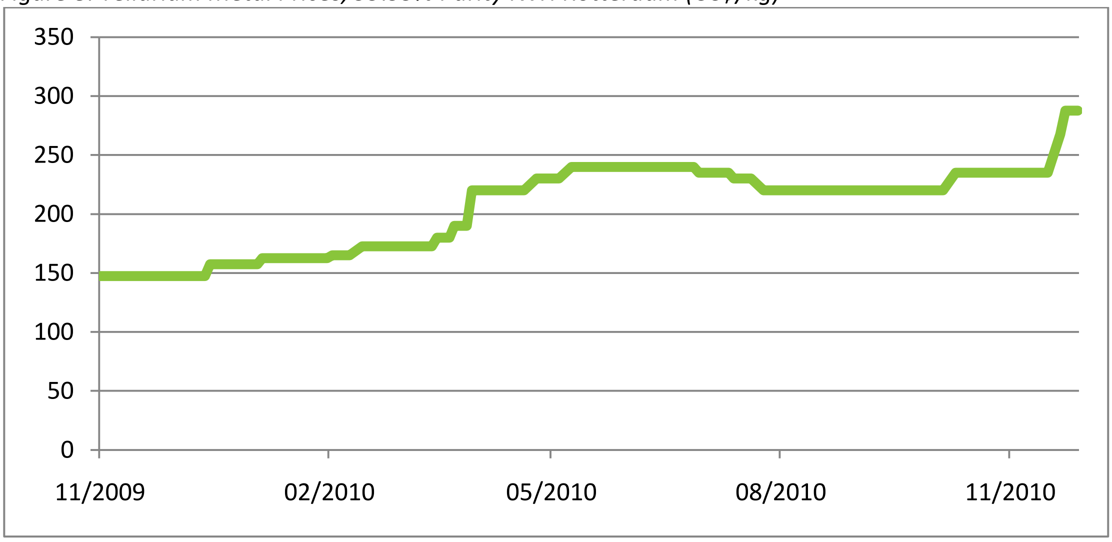
Demand growth for tellurium is expected to be strong because of its role as the dominant metal in thin film photovoltaic cells. By 2020 it is estimated that demand will be close to the theoretical limits of extraction from conventional sources. Consumers of tellurium are investigating new sources for tellurium and the potential to substitute its lower value applications. Prices for tellurium have doubled over the past year from $150/kg to around $300/kg.

Figure 7: Tellurium Supply and Demand Forecasts (tonnes)



Sources: Öko-Institut; Own Calculations based on Economist Intelligence Unit, USGS,

Figure 8: Tellurium Metal Prices, 99.99% Purity IWH Rotterdam (US$/kg)

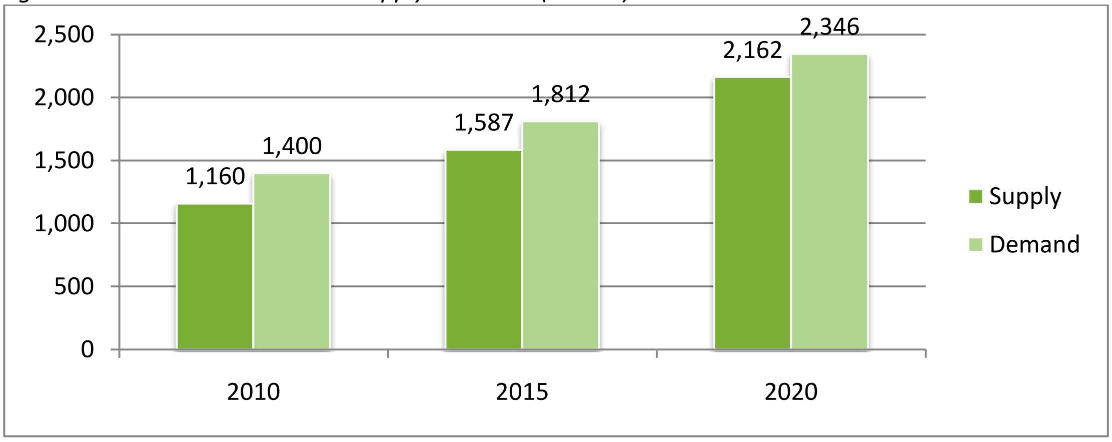


Source: Metal Pages

Tantalum:
Tantalum is a minor metal which is commonly mined as a single product, although it can also be produced as a by-product of niobium or other minerals. Current production levels are around 1,200 tonnes per year, having been boosted by the return to the market of a major Australian producer, Global Advanced Metals (formerly part of Talison Minerals). Another source includes the low-cost conflict source of Congo (Kinshasa), which represented around 10% of supply in 2008, although consumer electronics companies are keen to distance themselves from this source.

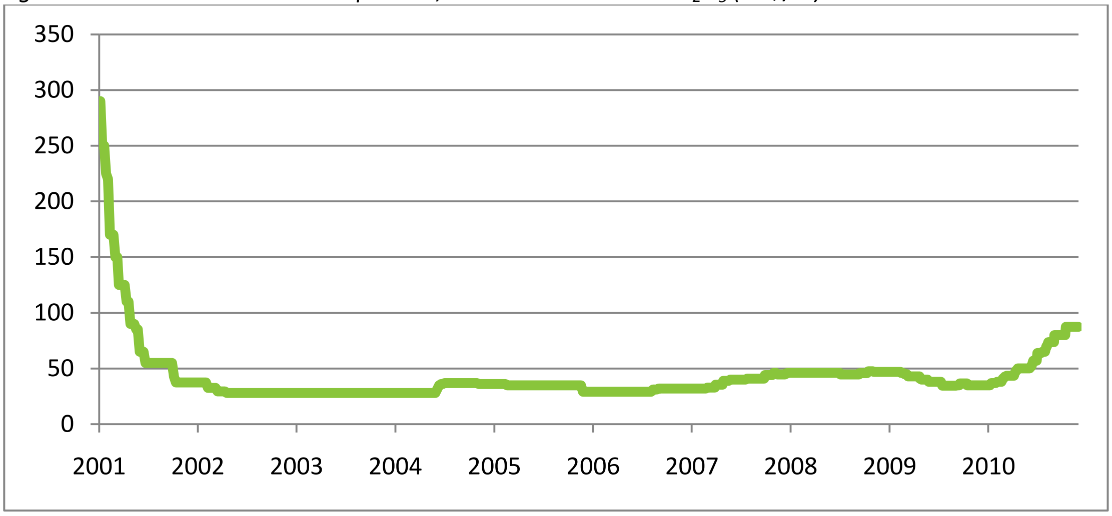
The major - and growing - application for tantalum is in electronics for capacitors, with future demand driven by the trend towards miniaturisation. Aerospace superalloys represent an additional growth market. At present a significant deficit exists in the market for tantalum, with manufacturers currently using up their limited stocks to meet demand. New mine openings will meet some of the rising demand, narrowing the deficit somewhat by 2020. Tantalum metal is not publicly traded, but tantalite mineral prices have trebled over the past year, (currently standing at around $130/lb as of April 2011), although well below their previous peak during the dot-com boom.

Figure 9: Tantalum Demand and Supply Forecasts (tonnes)



Sources: Own Calculations based on Öko-Institut & E&MJ

Figure 10: Tantalum Price Developments, Tantalite basis 30% Ta_2O_5 (US$/lb)

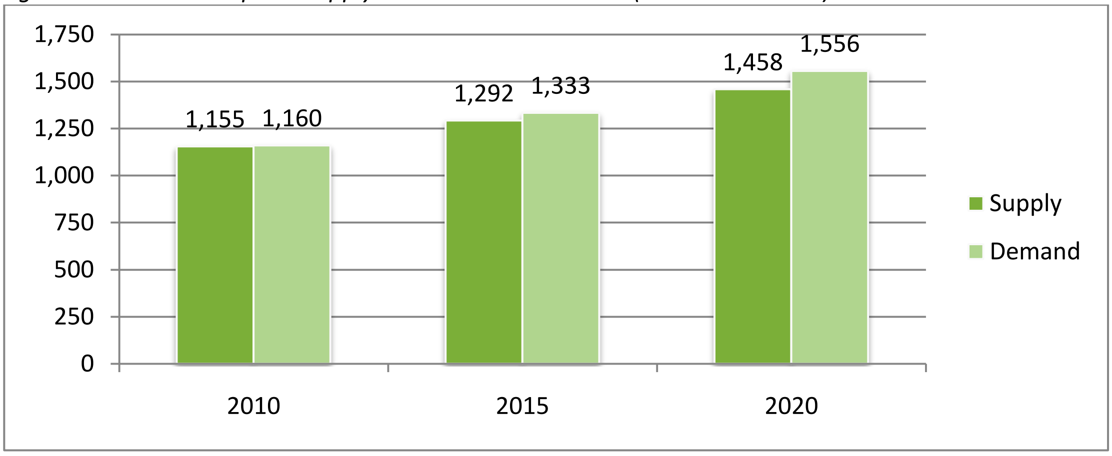


Source: Metal Pages

Graphite:
Although graphite is a form of a common element (carbon), its supply is relatively constrained, particularly for the rarer and more valuable crystalline (flake) forms. Current levels of production are around 1,200,000 tonnes per annum, of which China is the world's largest source, followed by India and Brazil. Currently the major applications for graphite are in industrial processes such as steel production.

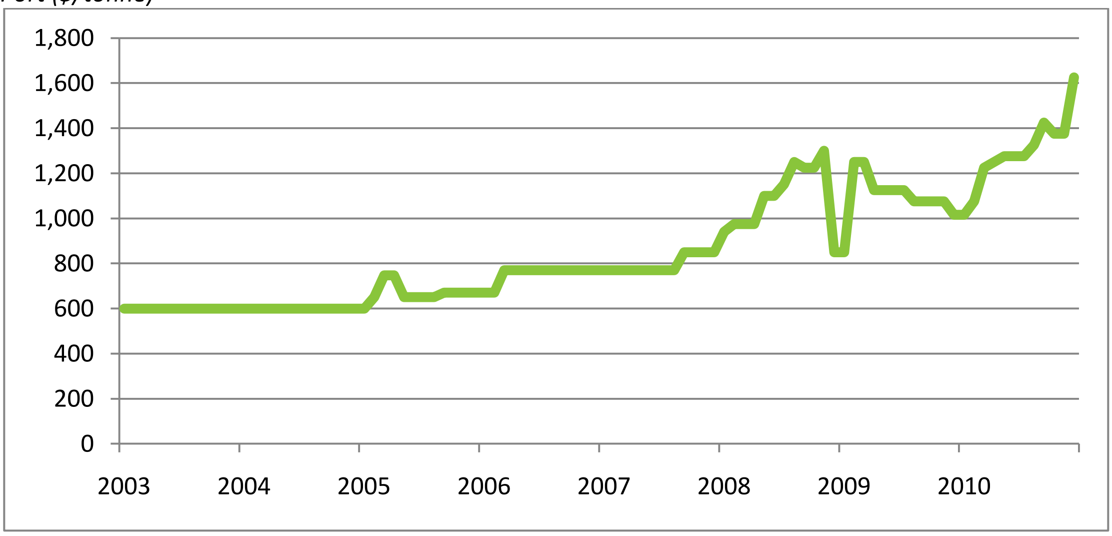
Lithium-ion batteries is a small but fast-growing market for graphite: the graphite content of Li-ion batteries is around ten times that of lithium. The supply response is expected to be slow due to the complexities of processing graphite and the dependence on the higher grade and rarer flake varieties. This is expected to result in a significant deficit for the material and prices have been rising in response over the past year. Synthetic graphite is a potential substitute; albeit available at a higher cost.

Figure 11: Natural Graphite Supply and Demand Forecasts (thousand tonnes)



Source: Oakdene Hollins Calculations based on Roskill (2009) & Industrial Minerals Magazine

Figure 12: Crystalline Graphite Prices, medium flake, 94-97% C, +100 mesh-80 mesh, FCL, CIF European Port ($/tonne)



Source: IM Magazine

About the authors:

Alastair MacGregor BSc MSc CFA
Our Senior Consultant (Economist), Alastair holds an MSc from Cranfield University in Economics for Natural Resource and Environmental Management and previously worked for 10 years as an investment manager. His understanding of corporate accounts and product substitution was used in development of producer surplus methodologies in this study. In his capacity as an environmental economist he has produced reports on recycling economics, resource efficiency sustainable materials management.

Peter Willis BSc MSc
Part of our in-house economics team, Peter joined us with a first class degree in economics from the London School of Economics and an MSc with distinction from University College London. He has considerable experience in developing an evidence base for government policy or business strategy. His range of expertise includes the metals sector, food and drink supply chain, innovation economics and recycling. Major studies which Peter has co-authored include *Protecting and Recovering Critical Raw Materials through Infrastructure Development* and *Assessing Metals as Supply Chain Bottlenecks in Priority Energy Technologies (2011)*.

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