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The role of emerging technologies in rapidly changing demand for mineral raw materials

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15 The role of emerging technologies in rapidly changing demand for mineral raw materials

Luis A. Tercero Espinoza

The adoption of emerging technologies plays a central role among the many factors influencing demand for mineral raw materials, especially for the so-called "technology metals". These metals, mostly used in relatively small quantities to provide special functionality, have comparatively small markets which are often not transparent, making them prone to overreacting to changes in both supply and demand. This chapter explores the magnitude of the changes in demand expected for a variety of technology metals and sets this in relation to the supply risks associated with those metals (from today's perspective) as well as in relation to the size of the respective markets, both important pieces of information in evaluating the need for action to secure supply and identifying possible sources of conflict.

15.1 Introduction

The future demand for demand for mineral raw materials, especially for the so-called "technology metals" is, among other important factors of influence, driven by emerging technologies. These metals (e.g. tantalum, tellurium or the rare earths) are often enablers, providing functionality currently unattainable by other means or attainable only at the expense of diminished performance. At the same time, the markets for technology metals are small and often not transparent, making them prone to overreacting to changes in both supply and demand. In the following pages, a survey of expected changes in demand for a series of metals is presented, together with an examination of the perceived supply risks (from today's perspective) and the corresponding market sizes.

15.2 Expected magnitude of changes in demand for technology metals until 2030

In view of the many interacting factors affecting supply and demand of mineral raw materials, it is not a simple task to draw reasonable pictures of future demand. Nonetheless, it is possible to ask the following question: how much of a metal/mineral would be required to fulfill societal needs and wishes addressed by emerging technologies if the current technological outlook does not change significantly?

Different pieces of information (data and assumptions) are required to prepare the desired estimates. These include an understanding of the technology as a solution to a perceived problem (also compared to alternative solutions), an estimation of the overall market potential for such a solution and a consideration of the regulatory, economic and societal environment in which the solution is deployed. As a consequence, such an analysis can only be done on a case by case basis and may either be limited to an emerging technology and the related raw material(s) or may be done for a raw material and encompass all of its uses. The former type of analysis is considered in this section, the latter in the next.

Several recent studies have dealt with the expected changes (mostly increases) in demand associated with particular technologies. The analyses are based either on market outlooks, on industry and political targets, or a mixture thereof.[1] The results of these studies are scenarios for the future demand of selected raw materials. The significance of these changes may be evaluated by comparing them to the current supply as well as the current demand structure. An additional dimension of information may be gained by assigning risks to the supply of each raw material considered. Such an analysis is presented in Figure 1. Here, the demand for each raw material in the selected technology or group of technologies is placed in the context of the total demand in the base year (assuming production equals demand and ignoring changes in stocks which are notoriously difficult to quantify) by computing the ratio of demand for each technology to total demand. This means that, for the base year, all ratios must be in the range $0 \leq \text{ratio} \leq 1$ but may be greater than one for the future (demand > current production).

Inspection of the expected changes in demand (length of the arrows in Figure 1) due to the (more widespread) adoption of the selected emerging technologies reveals a mixed picture. Technological change is expected to bring very large increases in demand for a number of raw materials, in many cases exceeding the current total supply for the base year (i.e. for Te, Li, Ta, In, Ga, Ge, Pt and the rare earth elements Dy, Sc, and Nd). The largest relative increases compared to total demand in the base year are expected for indium (used e.g. in flat panel displays) and gallium (e.g. for thin-film photovoltaics), with demand possibly reaching three to four times the total demand for the base year. The demand for germanium, dysprosium and scandium could be twice as large as total demand in the base year by 2030, while the demand for tellurium, tantalum, platinum and neodymium in the emerging technologies considered could surpass the total supply in the base year by 2025/2030.

[1] For example: Fraunhofer ISI / IZT: *Rohstoffe für Zukunftstechnologien* (2009); U.S. Department of Energy: *Critical Materials Strategy* (2010); EU JRC / Oakdene Hollins / HCSS (2011): *Critial Metals in Strategic Energy Technologies*. The latter two studies focus only on changes in demand due to the increased adoption of politically desired energy technologies; the former study takes a broader approach and examines 32 different technologies in the areas of transportation (land, air, space), communications and microelectronics, energy generation (e.g. photovoltaics) and use (e.g. industrial electric motors), process technology (chemical, mechanical, environmental), medicine, and materials science.

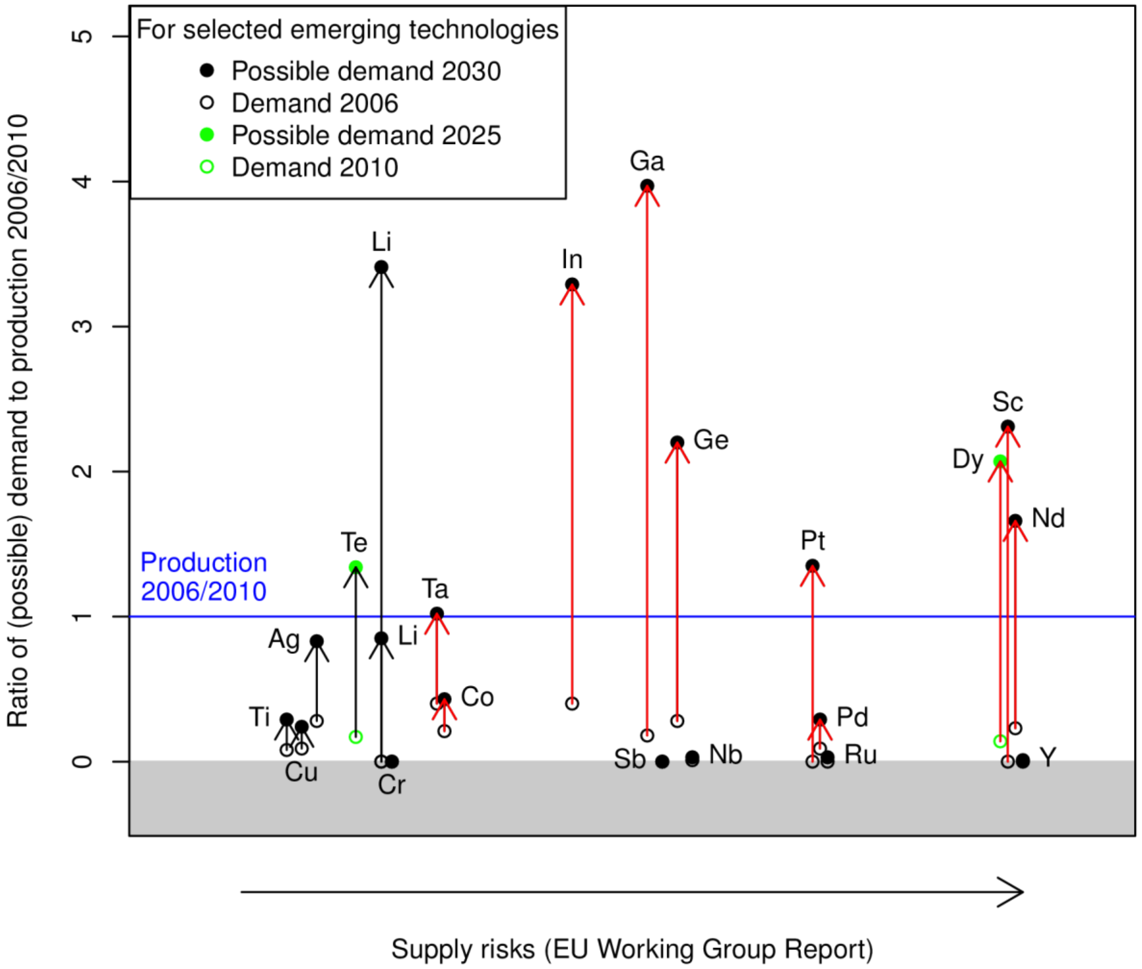

Figure 1: Expected increases in demand for selected raw materials in relation to current supply and corresponding supply risks. The horizontal axis is a combined supply risk including concentration of production at the level of countries, political stability of the producing countries, current recycling rates and an estimate of the substitutability of each raw material in each relevant field of use. The vertical axis gives the ratio of demand to production, and scaled such that the production in the base year is equal to 1. Thus, all raw materials have an initial ratio < 1 (a ratio of 1 would mean the entire production of the raw material was used in the technologies considered). The ratio for the future (2025 or 2030) may exceed 1 and presumes there is enough supply to satisfy demand. The length of the arrows indicates the magnitude of the expected change. The arrows are colored red for raw materials included in the current EU list of critical raw materials. Source: Fraunhofer ISI based on Ad-hoc Working Group on Defining Critical Raw Materials (2010), Fraunhofer ISI / IZT (2009), BGR (2010), Fraunhofer ISI (2009), U.S. DoE (2010).

In the discussion above, it is important to keep two things in mind: the first is that a high expected ratio of demand in 2025/2030 to total demand in the base year (2006/2010) does not necessarily imply there will be a shortage of a particular raw material. However, it is an indication of the extent to which production capacities (both primary and secondary) must be expanded to meet demand. The second is that the values of the expected demand can vary strongly depending on the underlying assumptions. This latter point is illustrated by the case of lithium: the increase in demand for lithium for large lithium-ion batteries used in hybrid and electric vehicles depends on the market penetration of electric vehicles. The results are drastically different for different scenarios: a ratio of close to one is reached for a moderate scenario but a ratio greater than three is the result of a more aggressive market penetration scenario. The case of lithium and different market penetration scenarios is revisited in the next section.

An increase in demand for an abundant and easily accessible resource can hardly be considered a threat. The situation–and the corresponding pressure to act–is different, however, when the expected increases in demand are for raw materials for which the supply is not seen as secured today or in the future. This aspect is explored in the horizontal axis of Figure 1, where the raw materials are ranked according to their perceived supply risk calculated following the methodology used by the Ad-hoc Working Group on Defining Critical Raw Materials.[2] This methodology includes the concentration of production at the level of countries and their corresponding governance rating[3] as well as the contribution of post-consumer recycling to total supply and the possibility of substituting the raw material in the relevant applications. Raw materials identified as critical by the Ad-hoc Working Group are identified by red arrows in Figure 1.
It is immediately clear upon inspection of Figure 1 that most raw materials with a large expected increase in demand until 2025/2030 are also considered critical by the Ad-hoc Working Group in light of their economic importance to the EU manufacturing economy and of the perceived supply risks as described above. Exceptions to this are only tellurium and lithium. Indium, gallium, germanium, platinum, and the rare earth elements dysprosium, scandium and neodymium are all seen as "critical" today[4] and their use mostly in high-tech and green-tech applications is expected to increase considerably in the coming decades.

Despite this combination of increasing importance and use on the one hand and high perceived supply risks on the other hand, and although the challenges in securing supply at reasonable terms (economic, ecologic and social) are significant, the overall situation is far from hopeless. Indium, gallium and germanium are mostly obtained as by-products of lead, zink, aluminum and copper, all of which have a very large mining base. Therefore, increased demand is likely to be covered by increased refining capacity which is cheaper and faster to establish than new mining operations. There is considerable activity around new rare earths mines and, in view of the wide distribution of reserves, there is a reasonable expectation that the security of supply for rare earth metals may improve in the medium term. Platinum, however, is likely to present a long-term challenge given that the natural deposits are not abundant, highly concentrated and its mining requires considerable effort.

A final point is that comparatively small additions to production capacity (be it primary or secondary) can make a large difference in these markets because of their small size. World production of gallium and germanium is on the order of 100 t per year; for indium and platinum this is higher but < 1000 t per year; all 17 rare earth metals combined (and expressed as oxide) amount to approx. 100.000 t per year. These are small markets compared to e.g. copper and zinc (both on the order of several million tons per year). The issue of market size is further explored in the following section.

In short, the results presented in Figure 1 are to be seen rather as a call to action (especially for the affected industries) than a cause for panic.

[2] Ad-hoc Working Group on Defining Critical Raw Materials: *Raw Materials for the EU*. Brussels (2010).
[3] According to the World Bank's World Governance Index.
[4] The results of criticality studies offer only a snapshot of a complex and dynamic system.

15.3 Scenarios and market size

Two points were postponed in the previous section and are dealt with here: the effect of different assumptions and how this effect is tied to market size. Because these two issues are most easily explored with the help of an example, we consider the case of increased demand for both lithium and copper due to the expected deployment of electric cars in the coming decades.

Because no data can exist regarding future market shares of hybrid and electric vehicles, we must resort to assumptions and scenarios. Here, we consider two scenarios (Figure 2):

1. A moderate ("pluralism") scenario in which different technologies (internal combustion, hybrid, plug-in hybrids and fully electric vehicles) coexist in the coming years despite significant adoption of electrified mobility, and
2. An optimistic ("dominance") scenario in which hybrid and electric cars essentially displace conventional cars from the market.

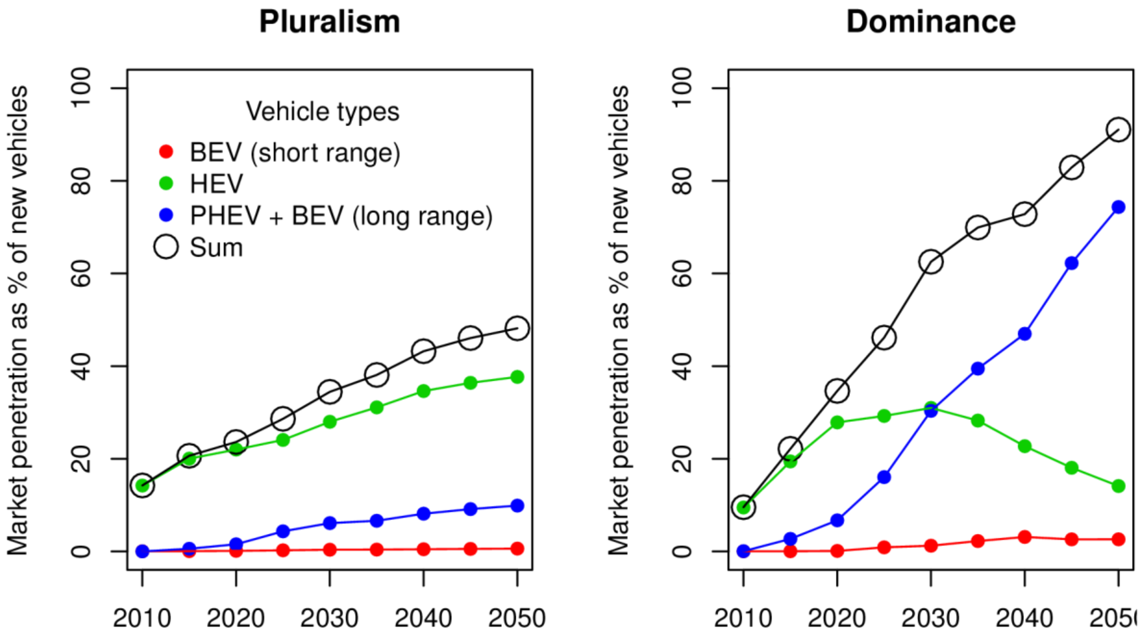

Figure 2: Example market penetration scenarios for the spread of electric vehicles. BEV (short range) = battery electric vehicle (20 kWh); HEV = hybrid electric vehicles (1.4 kWh); PHEV = plug-in hybrid electric vehicles (20 kWh); BEV (long range) assumes an exchangeable 20 kWh battery. All batteries are assumed to be lithium-ion batteries. Source: Fraunhofer ISI (2009).

Although both scenarios are optimistic with respect to the near future, they generally represent plausible paths and imply vastly different raw material requirements per vehicle. On this basis, we explore the issues of impact of assumptions and their tie to market size with the help of Figure 3 using copper and lithium as examples.

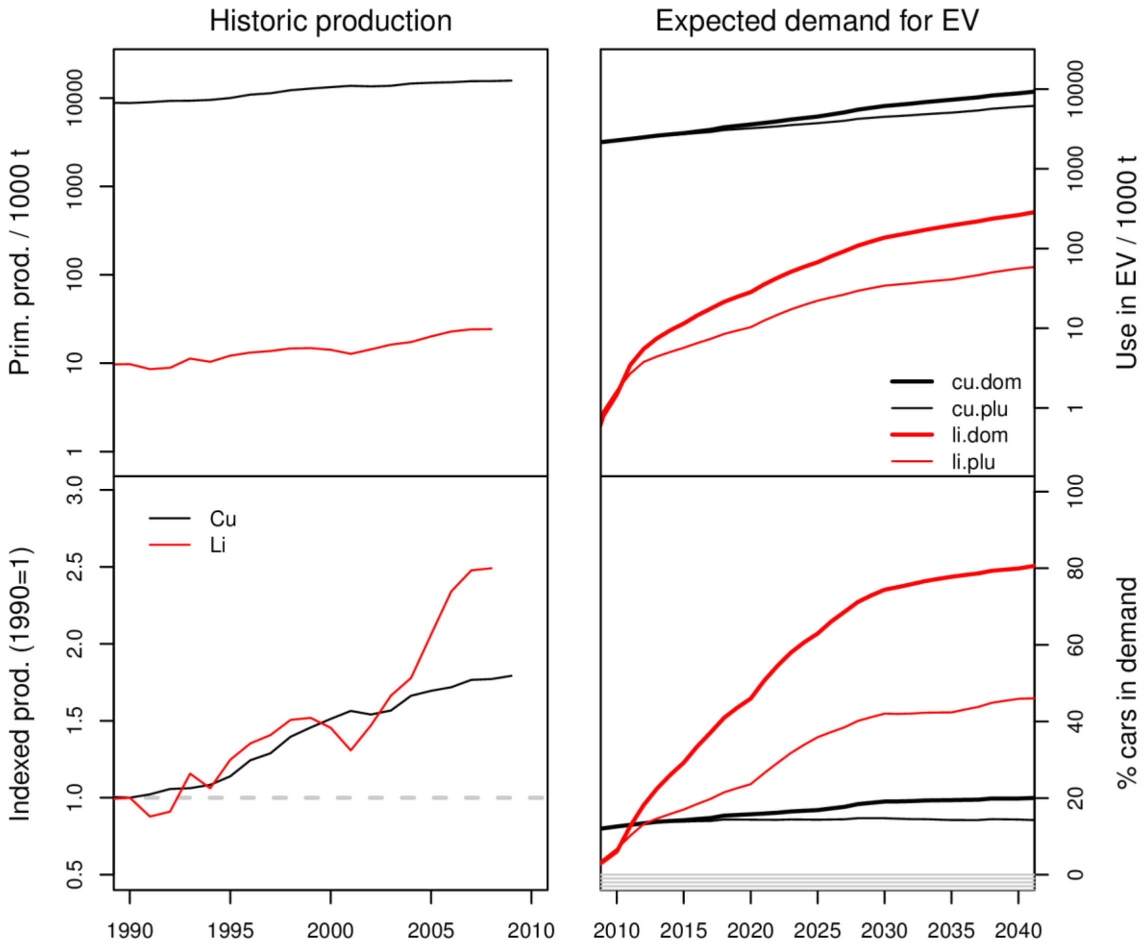

Figure 3: (left) Absolute and indexed primary production of lithium and copper. (right) Expected demand for lithium and copper in electric vehicles and corresponding share of vehicles in total demand for lithium and copper. Scenarios: cu.dom and cu.plu are the dominance and pluralism scenarios for copper, respectively; the naming is analogous for lithium. EV = electric vehicles. Please note the logarithmic scaling of the upper panels. Source: Fraunhofer ISI based on BGR (2011) and Fraunhofer ISI (2009 and 2010).

The top left panel of Figure 3 presents historic production data for both lithium and copper and clearly shows the difference in market size: while the primary production of lithium is on the order of several 10.000 t (around 50.000 t in 2008 and 35.000 t in 2009), the primary production of copper is 300 to 425 times larger (around 15.5 million t both in 2008 and 2009).[5] As a consequence, absolute changes of similar magnitude have a much larger impact on total supply of lithium than of copper. This is reflected by the steadier curve for the indexed primary production of copper compared to that for lithium (bottom left panel in Figure 3).

The top right panel in Figure 3 shows the demand for lithium and copper in vehicles (conventional, hybrids and electric), while the bottom right panel gives the share of demand for vehicles compared to total expected demand. It is immediately clear that, while well under 1.000 t of lithium were used in vehicles in the base year (corresponding to approx. 1% of total

5 Weber et al., *World Mining Data*, Volume 26. Vienna (2011).

demand), the corresponding use of copper in vehicles is greater than 1.000.000 t (corresponding to more than 10% of global primary copper supply).

The widespread adoption of electric cars implies an increase in the use of both lithium and copper for lithium-ion batteries and (mainly but not only) electric traction motors, respectively. Depending on the market penetration scenario, the demand for lithium in electric vehicles may increase to over 55.000 t (pluralism scenario) or to over 260.000 t (dominance scenario) by 2040.[6] Correspondingly, demand for copper in cars (conventional, hybrid and electric) is expected to increase to close to 6.000.000 t (pluralism scenario) or 9.000.000 t (dominance scenario) by 2040.[7] While the absolute increase for copper is, in absolute terms much larger than that for lithium, the increase in lithium demand is larger in relative terms in each scenario because of the difference in market size. This is seen in the curves in the top right panel of Figure 3.[8] The difference in relative increase is also clear when comparing the scenarios to total primary production today.

A further consequence of the different market sizes is a difference in relative change in market structure due to the increased demand in vehicles. This relative importance of vehicle production for total demand of both lithium and copper are shown in the bottom right panel of Figure 3. Copper is a metal used in a wide variety of applications, such that car parts (mainly wiring) require approx. 11% of current total primary supply. With the large absolute increases in demand mainly due to the need for electric motors in hybrid and electric cars, the share of cars in total copper demand could increase to around 13% (pluralism scenario) or up to 20% (dominance scenario). For lithium, the share of cars in total demand could reach 45% in the pluralism scenario and approx. 80% in the dominance scenario. Thus, although the widespread adoption of hybrid and electric vehicles is tied to a larger absolute increase in demand for copper than for lithium, the end-use structure for lithium is more extensively changed by this emerging technology on account of the different market sizes.

Comparing the size of the lithium market (several 10.000 t per year) to the size of the markets for indium (≈ 575 t), gallium (< 100 t), germanium (< 100 t), platinum (≈ 185 t) and the rare earths (≈ 130.000 t for all 17 rare earth elements expressed as oxide), we may safely say that all of these are susceptible to large changes in terms of the relative importance of the industry sectors requiring the raw materials.[5,9]

6 Angerer et al., *Lithium für Zukunftstechnologien*. Fraunhofer ISI, Karlsruhe (2009).
7 Angerer et al., *Kupfer für Zukunftstechnologien*. Fraunhofer ISI, Karlsruhe (2010).
8 Note that a straight line in a logarithmic plot indicates exponential growth.
9 U.S. Geological Survey: *Mineral Commodity Summaries*. January, 2011.