Resource Risks associated with Raw Materials for the Energy Transition

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Abstract

The energy transition with its focus on additional capacities of renewable energies in electricity production changes the nature of relevant supply risks in the energy sector. The most prominent supply risk of wind and solar based electricity is that its hourly availability depends on natural conditions. Beyond these well analysed (however not yet mastered) challenges of the energy transition, there are additional risks related to raw material supplies that have not been sufficiently addressed yet. These risks become relevant as new technologies like windmills, solar panels, and stationary or mobile batteries increase the demand for certain resources, especially metals, significantly. These raw material supply risks should be analysed by using eight indicators that represent different risk perspectives. Five of these are quantitative indicators, which are composed of various publicly available data sources. The qualitative indicators are based on literature and expert interviews.

Based on literature, we define the following elements as relevant for further investigation as demand will grow significantly caused by modern energy system technologies: cobalt, lithium, magnesium, molybdenum, nickel, scandium, vanadium, tin, and the groups of rare earth elements dysprosium / terbium (heavy rare earth elements / HRE) as well as neodymium / praseodymium (light rare earth elements / LRE). The elements have very different supply risk profiles. However, there are some similarities: A very high degree of relevance for future technologies is not surprising, as relevance for energy technologies was a selection criterion. Another common characteristic is that substitution is hardly possible – and impossible in many cases. Furthermore, concentration on company and / or country level is very high, while political risks are medium to high in average. Price risks are lower and range from low to high risks like rising and fluctuating prices. In geologic terms, resource scarcity is not the mayor problem. Reserves-to-production ratios are high in many cases, while investments in exploration and mining are necessary in other cases – and will become more pressing when demand will rise as projected in the next two decades.

Among the energy technologies in the different sectors, electro mobility and battery technologies are of special importance as this is the most promising technological option of decarbonisation in the sector. Therefore, lithium is a resource of strategic importance, especially for a country with high value added in the automotive industry. The current and potential future risks increase the need for global technology corporations to develop strategies to secure long-term lithium supply. Asian producers of batteries and motor

vehicles have already made efforts to implement diversified supply through strategic cooperation and joint ventures with resource firms. Furthermore, initiatives to develop recycling strategies for lithium from batteries are necessary. Today, recycling of lithium-ion cells is not very common, but growing markets for batteries and rising lithium prices will make the production of secondary lithium more relevant. However, other elements – from the well-known metals tin and nickel to less known resources as molybdenum – the rare earth elements and the politically discussed cobalt are relevant for the future development of our energy systems as well. Security of supply of these elements has to be further investigated in order to secure supply of the resources necessary for future energy technologies.

1 Background: Resource Risks in the Energy System

Traditionally, security of supply of natural resources for the energy production or conversion has been discussed with respect to oil, gas, coal and nuclear fuels. The peak oil controversy is the most prominent example of the question regarding long-term availability of energy resources. The oil crises of the 1970s as well as the Russian-Ukrainian conflicts and their consequences for oil transport from the Middle East to the world markets respectively gas transport from Russia to Central and Western Europe are examples of short-term supply risks in the traditional energy systems.

These traditional risks of energy security will be reduced by integrating more renewable energies into the system as demand for fuels will be reduced (Schaefer et. al., 2016). However, the energy transition with its focus on additional capacities of renewable energies in electricity production changes the nature of relevant supply risks in the energy sector. The most prominent supply risk of wind and solar based electricity is that its hourly availability depends on natural conditions: Wind can be stronger or weaker, sunshine depends on daytime and distribution of clouds. The results are fluctuations in the supply and therefore the need to install extra capacity, storage technologies or to strengthen demand side reactions to changes in short time supply.

Beyond these well analysed (however not yet mastered) challenges of the energy transition, there are additional risks related to raw material supplies that have not been sufficiently addressed yet. These risks become relevant as new technologies like windmills, solar panels, and stationary or mobile batteries increase the demand for certain resources, especially metals, significantly. These raw material supply risks should be analysed briefly in this paper.

Over the last few years, companies and public authorities have become increasingly concerned about the security of supply of mineral resources (Bardt, 2008). The main driver for this increased attention was the steep rise of prices before and after the global economic crisis 2008/2009. Numerous elements are needed for all kinds of production in building, manufacturing and even the service sector, but also for modern energy technologies in a more climate friendly energy system.

Resource-consuming industries face various risks regarding security of supply of natural resources. According to surveys among about 2,000 companies from various sectors in Germany, most decision makers consider increase and volatility of prices as most important resource risks. Short-term reduction of supply is also among the most important risks

(Table 1). Although many other risks are not top priority of most companies, it seems to be important to analyse these less obvious sources of insecurity.

Table 1: Supply Risks for Metals
Answers from companies on a scale from 1 (very little risk) to 6 (very high risk)

	Total
Price rise	4.3
Price volatility	4.2
Short-term loss of supply	2.9
Insufficient supply	2.7
Discrimination compared to competitors	2.6
Political risks	2.5
Bureaucracy	2.5
Trade barriers	2.4
Transport risks	2.3

Source: Bardt / Kempermann / Lichtblau, 2013

2 Methodology: Measuring Resource Risks

Since about ten years ago, several attempts have been made to identify critical resources and to measure resource supply risks with a focus on metals and other mineral resources (e.g. Bardt, 2008; vbw / IW Consult 2017; European Commission 2010 [first assessment]). The results in the classification of certain elements as critical vary in detail, but there is a broad consensus in most of the cases.

In this paper, we use the methodology of vbw / IW Consult (2017) as described in Bardt (2016). To analyse the risk profile of the elements, we use eight indicators that represent different risk perspectives. Five of these are quantitative indicators, which are composed of various publicly available data sources. The qualitative indicators are based on literature and expert interviews.

The quantitative indicators are as follows:

- *Reserves-to-production ratio*
  Although the absolute level of the reserves-to-production ratio is no adequate indicator for a current or coming shortage of natural resources, it is part of the RRI because a low ratio indicates the need for exploration and investment in the near future.

- *Country risks*
  Resource countries can provide difficult conditions for long-term investment and this is typical for the mining industry. Political stability, quality of the rule of law, investment security and political interference are relevant factors that can promote or restrict efforts to increase supply in the resource markets. The RRI includes results of the Heritage Index, the AON Political Risk Map, the Transparency International Index and the Fraser Index. The country risks are multiplied with current shares of world production for each resource in order to have one value representing the total country risk associated with a specific element.

- *Three-countries concentration*
  The combined market share of the three largest countries of production is a measure of the competition between and dependency on certain production nations.

- *Three-companies concentration*
  The total market share of the three most important companies is used as an indicator of the competition between suppliers.

- *Price risks*
  This indicator combines the price rise between 2013 and 2016 and the volatility of prices in the same period of time.

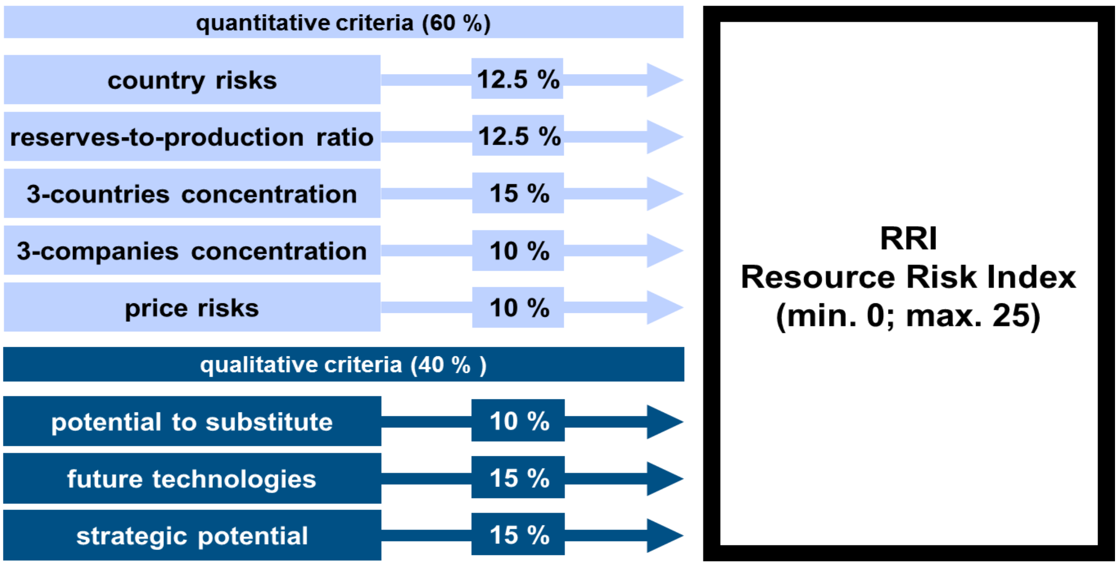
Three qualitative indicators complement the data set:

- *Relevance for future technologies*
  The economic relevance of specific resources and the potential damage of supply risks are closely associated with technological development and international demand. The rating of relevance for future technologies is based on studies (Angerer et al., 2009) and results of expert interviews.

- *Strategic potential*
  Some countries can use their national resources not only to earn income on international markets, but they can also use it for political purposes. This could lead to a boycott of some or all industrialised countries. Although this extreme is rarely used, export restrictions for natural resources are increasing in many parts of the world.

- *Substitution potential*
  The option to substitute a resource with another material reduces the dependency on a specific resource. Resources that can be substituted are associated with fewer risks than those that cannot be replaced. However, the availability of adequate substitutes depends on the specific technology and therefore can change over time.

Figure 1: Composition of the Resource Risk Index (RRI)



Source: vbw / IW Consult, 2017

The eight indicators are standardised and multiplied by their respective weight factor (figure 1). The total is the Resource Risk Index, which can reach a maximum value of 25. The Index (RRI) is constructed to give guidance regarding the level of risks. We use it to group 45 elements and define three classes of criticality: critical (red), less critical (orange) and not critical (yellow). All elements with an RRI score of more than 15 have to be considered critical. Currently, the most critical resource is Yttrium with a value of 21.3 (vbw / IW Consult, 2017).

3 Addressing Resource Risks

As many companies see resource risks as a potential threat for their businesses, many private companies have taken measures to reduce supply risks. The three most important approaches followed by more than 40 percent of companies are long-term contracts with suppliers, diversification of supply and higher resource efficiency (Table 2).

As supply of natural resources is significantly relevant for economic success, almost nine out of ten companies take measures against supply risks. The survey shows that large companies are more active in reducing risks than small enterprises. Almost 25 percent of companies with a turnover of less than one million euros do not take any action. On the other hand, more large companies use financial instruments against price risks. Nearly half (48 percent) of the large companies try to hedge risks, while less than 10 percent of small companies follow this approach. Another huge gap between large and small companies is the use of long-term supply contracts: almost 70 percent of large companies rely on long-term relations with their suppliers compared to only 30 percent of smaller companies covered in the survey.

Which instruments are used to reduce supply risks also depends on the specific resource. Companies that only depend on using standard metals like copper or aluminium focus on instruments to reduce price risks, while companies that need special metals focus on research, substitution or other measures to secure supply chains. The choice of the instrument depends on the risks of the respective resource.

Table 2: Measures to Cope with Supply Risks
Answers from companies, in percent

	Small company	Medium company	Large company	Total
Long-term supply contracts	31.9	59.1	69.2	59.5
Diversification of supply	38.4	48.4	57.0	49.9
Increase in resource efficiency	31.5	42.7	40.4	41.0
Price hedging	9.5	28.7	47.7	32.3
Research and development	8.6	18.6	28.0	20.3
Substitution and secondary resources	6.4	13.0	18.6	14.0
Recycling	11.0	12.5	17.1	13.7
Pooling of demand to increase market power	8.3	10.9	16.7	12.3
Nothing	24.7	9.5	6.1	10.0
Investment in resource-rich countries	0.7	1.5	3.1	1.9
Investment in mining companies	0.4	0.7	1.4	0.9

Small companies: less than 1 million euro turnover; medium companies: 1 to 50 million euro turnover; large companies: more than 50 million euro turnover
Source: Bardt / Kempermann / Lichtblau, 2013

4 Resources relevant for the Energy Transition

The selection of raw materials relevant for energy transition technologies, which will be covered in the risk assessment of this paper is based on works of Fraunhofer IZM. The first study "Resources for Future Technologies" was published in 2009 (Angerer et al., 2009) and recently updated (Marscheider-Weidemann et al., 2016). These studies cover various technologies; some of them are relevant for the energy system (Table 3).

We filter the relevant technologies and compile the resources associated with these future developments. We only include technologies that will lead to a significant increase of demand for raw materials with a relatively low current production. In other words: future increases of demand that can be easily satisfied should not be considered in our analysis as the influence of future technologies on the resource markets is neglectable. Furthermore, we only take the raw materials covered in our RRI-Analysis.

Table 3: Elements with high additional demand caused by new energy technologies
potential additional demand until 2035 as share of 2013 mining production (high demand scenarios)

Technology	Element	Additional demand up to…
solar-thermal power plant	Magnesium	12 %
Stationery fuel cell (SOFC)	Scandium	122 %
Lithium-Ion batteries for passenger cars	Cobalt	84 %
	Nickel	7 %
	Lithium	368 %
Vanadium-Redox batteries	Vanadium	37 %
Micro harvesting	Dysprosium	9 %
	Neodymium	4 %
Windmills	Molybdenum	6 %
	Tin	6 %
	Neodymium / Praseodymium (Light Rare Earths)	48 %
	Dysprosium / Terbium (Heavy Rare Earths)	50 %

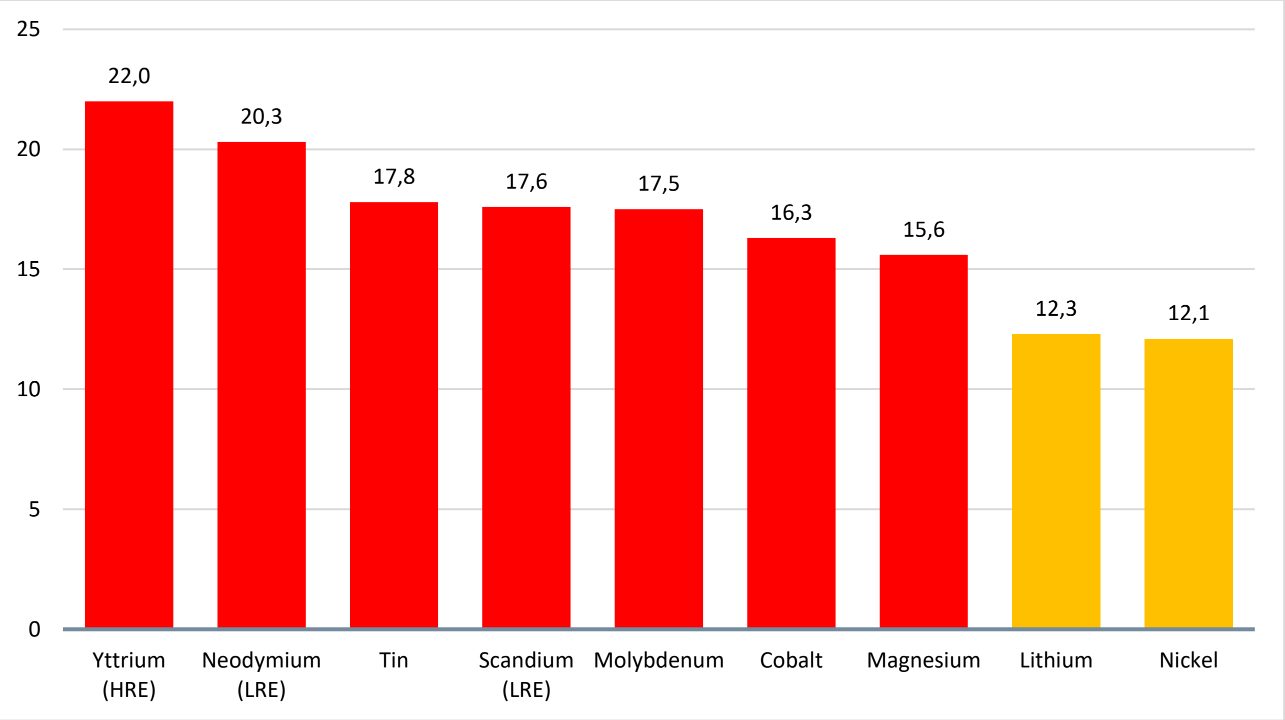
Source: based on Marscheider-Weidemann et al., 2016

Based on the analysis of Marscheider-Weidemann et al. (2016), we define the following elements as relevant for further investigation as demand will grow significantly caused by modern energy system technologies: cobalt, lithium, magnesium, molybdenum, nickel, scandium, vanadium, tin, and the groups of rare earth elements dysprosium / terbium (heavy rare earth elements / HRE) as well as neodymium / praseodymium (light rare earth elements / LRE).

As the RRI dataset does not cover vanadium, we have had to exclude them from our panel of elements investigated. Furthermore, we use scandium and neodymium as examples for light rare earth elements and yttrium as example for heavy rare earths.

The RRI data show that the heavy rare earth element yttrium is the one with the highest resource supply risks (figure 2). The RRI-value is 22 out of 25 points, followed by the light rare earth element neodymium with 20 points. Tin, scandium, molybdenum, cobalt, and magnesium are in the range between 15 ½ and 18 RRI-points. Lithium and nickel are the two energy technology resources covered in this paper, which are in the yellow group of elements. These elements are not risk free but have a littler lower risks profile than those in the red group.

Figure 2: Resource Risk Index (RRI) of Energy Technology Resources
RRI-scale from 0 (no risks) to 25 (maximum risks)



Source: vbw / IW Consult, 2017

5 Specific Risk Profiles of Energy Technology Resources

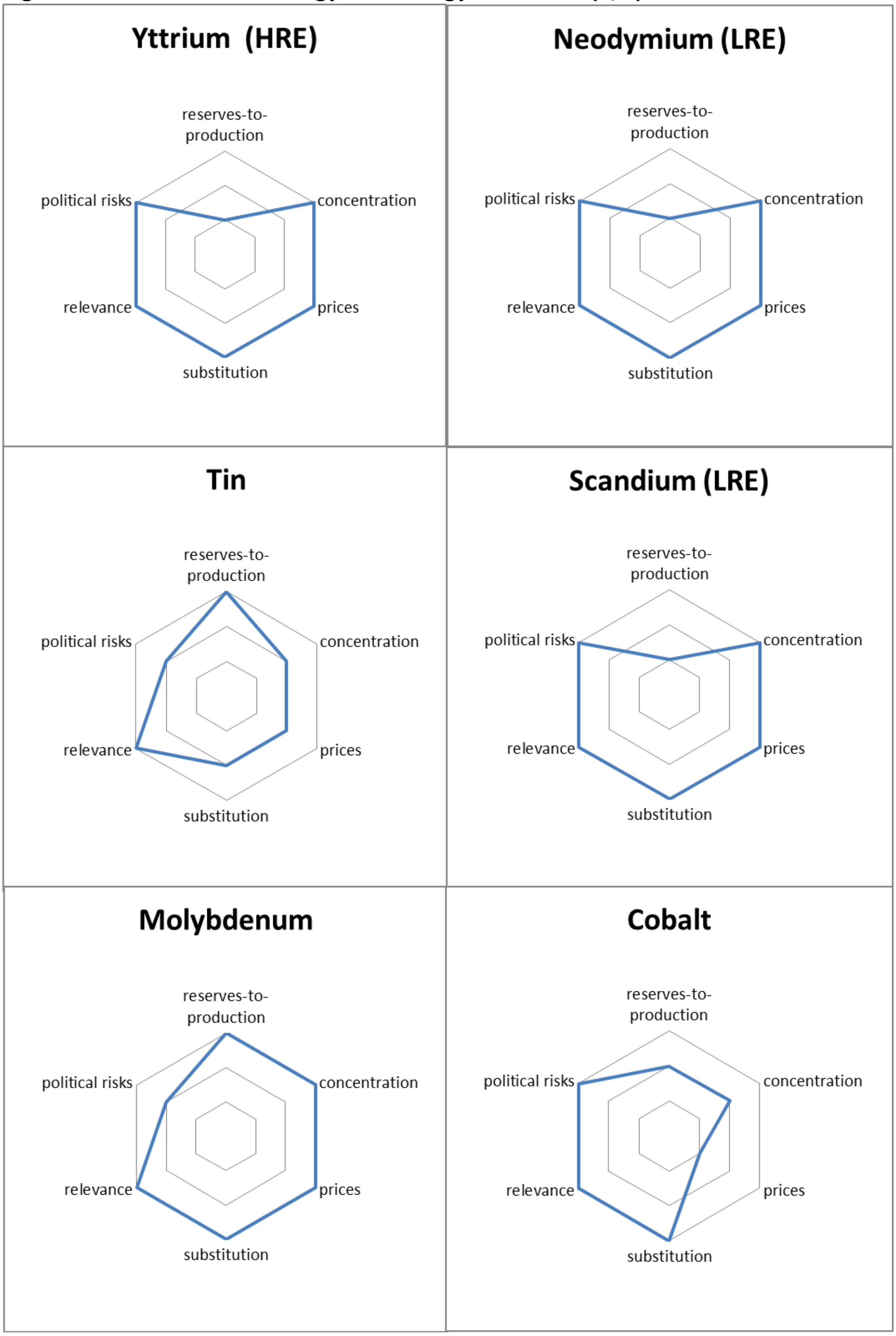
The elements covered in this paper have very different supply risk profiles (figures 3 & 4). However, there are some similarities: A very high degree of relevance for future technologies is not surprising, as relevance for energy technologies was a selection criterion. Another common characteristic is that substitution is hardly possible – and impossible in many cases. Furthermore, concentration on company and / or country level is very high, while political risks are medium to high in average. Price risks are lower and range from low to high risks like rising and fluctuating prices. In geologic terms, resource scarcity is not the mayor problem. Reserves-to-production ratios are high in many cases, while investments in exploration and mining are necessary in other cases – and will become more pressing when demand will rise as projected in the next two decades.

Yttrium
The main supply risks of yttrium (as example of heavy rare earths) is the high concentration of mining facilities in China with a market share of about 90 percent. Political risks in terms of potential or existing trade restrictions are very high; many trade restriction measures have been introduced in the last decade. As substitution possibilities are very low, dependence on these suppliers is critical. High price fluctuations define substantial price risks. Production itself is sufficient and the potential for additional supply is high – but new mining projects outside China do not focus on heavy rare earth elements.

Neodymium
The main supply risks of neodymium (as example of light rare earths) is the high concentration of mining facilities in China with a market share of about 90 percent. Political risks in terms of potential or existing trade restrictions are very high; many trade restriction measures have been introduced in the last decade. As substitution possibilities are very low, dependence on these suppliers is critical. High price fluctuations define substantial price risks. Production itself is sufficient and the potential for additional supply is high – several new mining projects have been started outside China that focus on light rare earth elements.

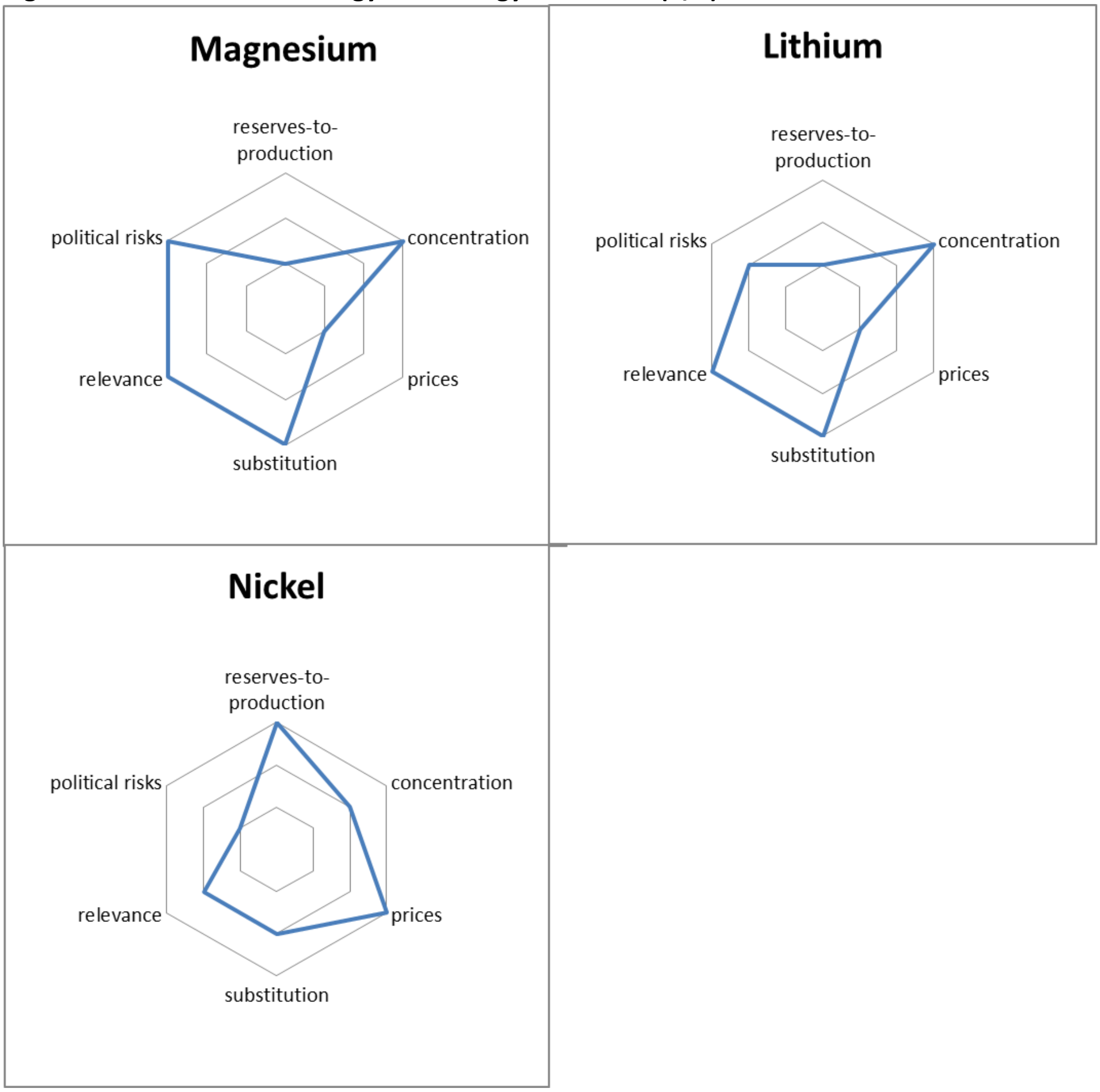
Tin
Tin is a classic metal used in many technologies and many industries. The reserves-to-production ratio of tin is low (15 years), which indicates that additional investments in exploration and mining are needed in the future. Price developments have been significant and must be considered as medium high risk. Concentration is not too high: seven companies have a total market share of 50 percent and five countries being responsible for 75 percent of global production. The high share of China and Bolivia of half of total production implies relevant political risks.

Figure 3: Risk Profiles of Energy Technology Resources (1/2)



inside: lower risk, outside: higher risk
Source: based on vbw / IW Consult, 2017

Figure 4: Risk Profiles of Energy Technology Resources (2/2)



inside: lower risk, outside: higher risk
Source: based on vbw / IW Consult, 2017

Scandium
The main supply risks of scandium (as example of light rare earths) is the high concentration of mining facilities in China with a market share of about 90 percent. Political risks in terms of potential or existing trade restrictions are very high; many trade restriction measures have been introduced in the last decade. As substitution possibilities are very low, dependence on these suppliers is critical. High price fluctuations define substantial price risks. Production itself is sufficient and the potential for additional supply is high – several new mining projects have been started outside China that focus on light rare earth elements.

Molybdenum
The main supply risk of molybdenum is its high concentration. 90 percent of global production is located in five countries only. China is the most important supplier with a market share of 38 percent. The five largest companies have an aggregated market share of 45 percent, the ten largest companies add up to 60 percent. Political risks are relevant, but

not very pressing. China has a very important role in supplying the world markets, but other countries are less critical. In many cases, substitution is hardly possible. The reserves-to-production ratio is relatively low. Price developments have been high, so price risks are very significant as well.

Cobalt

Cobalt is considered as one of the main conflict minerals, therefore specific risks of supply coming from specific or unknown sources are among the main problems of companies using cobalt. Therefore, political risks are high, even if concentration on the world markets is lower than the case of some other resources. 70 percent of the raw material comes from five countries; 50 percent from Congo. Additionally, substitution is hardly possible and global reserves-to-production ratio is not completely reassuring as well, although today's production can be continued for 60 years. However, increasing demand will add up pressure to the international markets.

Magnesium

Physical supply risks are not relevant in the case of magnesium; price risks also seem to be manageable. Concentration is critical as China has a market share of more than 70 percent. Therefore, political risks are high as well. Options to substitute magnesium are low, which adds up to the total risk assessment.

Lithium

Lithium is the base for future electric motor vehicles and therefore of strategic importance. Chile and Australia have a combined market share of more than 75 percent of total production. Argentina and China follow with 12 and 7 percent. Total resources are about 40 million tons while reserves are about 13 million tons – compared to the annual production of about 34,000 tons. More than half of the reserves and resources are located in South America, mainly in Chile and Bolivia (USGS, 2014). As prices for lithium remain rather moderate, recycling is hardly an economic option today. The share of total costs for batteries is only about 3 percent, and secondary lithium is five times as expensive as primary lithium from the most efficient sources. With rising demand and with rising prices, recycling will probably become an important option. Although total resource risks of lithium are moderate today, growing demand can add additional political risks when Bolivia enters the market. The high concentration of global lithium reserves and resources in South America could lead to higher political risks if demand rises significantly because of growing production of electric vehicles with lithium-based batteries. The Bolivian national government needs international cooperation to bring their lithium resources to the world markets, but it has a record of interference with international investors. Bolivia has a huge potential as a supplier, but this leads to additional supply risks for companies processing lithium.

Nickel

Nickel has a relatively low reserves-to-production ratio and high price risks, but the other risk factors are not very critical. Concentration is moderate, as five countries have a total market share of 50 percent. The share of the five largest companies adds up to 50 percent as well. As consequence of the supply structure, political risks are low. Substitution and recycling potential does not lead to additional supply risks either.

6 Conclusion

Among the energy technologies in the different sectors, electro mobility and battery technologies are of special importance as this is the most promising technological option of decarbonisation in the sector. Therefore, lithium a resource of strategic importance, especially for a country with high value added in the automotive industry. The current and potential future risks increase the need for global technology corporations to develop strategies to secure long-term lithium supply. Asian producers of batteries and motor vehicles have already made efforts to implement diversified supply through strategic cooperation and joint ventures with resource firms (USGS, 2014). Furthermore, initiatives to develop recycling strategies for lithium from batteries are necessary. Today, recycling of lithium-ion cells is not very common, but growing markets for batteries and rising lithium prices will make the production of secondary lithium more relevant.

However, other elements – from the well-known metals tin and nickel to less known resources as molybdenum – the rare earth elements and the politically discussed cobalt are relevant for the future development of our energy systems as well. Security of supply of these elements has to be further investigated in order to secure supply of the resources necessary for future energy technologies.

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