

TNO report

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Materials in the Dutch Economy

- A vulnerability analysis –

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Management Summary

Background to this study

The Ministry of Economic Affairs asked a consortium comprising of TNO, EY, NEVI (Dutch Association of Purchasing Management), HCSS and Leiden University/CML to conduct a study to examine the extent to which the Dutch economy depends on the supply of 64 abiotic raw materials (minerals and metals) and consequently make this data available for use by the Dutch business community. This report deals with the first part of this request; the second part is to be completed by the development of a web-based tool which is expected to become available in the course of 2016.

This study takes place against the background of global concern regarding the short and long-term availability of raw materials. In particular, the shift of power in the world has contributed to importing countries having a perceived decrease in security of supply of raw materials. In Europe this has led to a criticality analysis, in which currently 20 materials have been designated as critical to the European economy.

Dutch policy regarding this has been set out in the policy document on Raw Materials and the programme 'From Waste to Raw Material' (parliamentary paper 33 043, no. 28) both of these are committed to the transition to a circular economy. This enables vulnerabilities in terms of raw materials supply to be turned into opportunities for the circular economy. Part of this process comprises of mapping the risks and opportunities involved, as done in this study.

This study focuses on 64 abiotic resources

After two previously published preliminary reports (CBS, 2010; TNO, 2014), this report gives a complete picture of how much the Dutch economy is interwoven with the availability of 64 abiotic materials. In broad terms, this report can be divided into:

- A description of the 64 raw materials;
- An overview of indicators which determine the degree of criticality;
- An analysis of the criticality;
- An action and research agenda.

The method used in this analysis links raw materials with their use in the global production of intermediate and final products, and to sectors which provide added value in the Dutch economy. This method also makes it possible to make a distinction between Dutch imports in the form of raw materials, intermediate products and final products. In the broad category of intermediates, there is also a sub-category of 'first intermediates': these are intermediate products in the value chain which still have a raw material as input and still bear the raw material name within the category name (for example: zinc ore is a raw material, zinc oxide a first intermediate product).

The raw materials included in this study are given below (NB: *: rare earth metals; o: platinum-group metals):

Aluminium	Graphite	Rhenium	Dysprosium*
Antimony	Iron ore/iron	Selenium	Neodymium *
Barytes	Indium	Silicon	Praseodymium *
Bentonite	Industrial sand (silica)	Strontium	Samarium *
Beryllium	Limestone	Talc	Europium*
Borates/boron	Clay (Kaolin)	Tantalum	Yttrium*
Chrome	Cobalt	Tellurium	Terbium*
coking coal	Copper	Tin	Cerium*
Diatomite	Lithium	Titanium	Lanthanum *
Feldspar	Magnesite/magnesium	Uranium	Ytterbium*
Fluorspar	Manganese	Vanadium	Gadolinium*
Phosphorus	Molybdenum	Tungsten	Scandium*
Gallium	Nickel	Silver	Platinum ⁰
Germanium	Niobium	Zinc	Palladium ⁰
Gypsum	Perlite	Zircon	Iridium ⁰
Gold	Ruthenium	Osmium ⁰	Rhodium ⁰

Which indicators were investigated and applied?

Although the consequences of security of supply form the core of this study, the broader context of sensitivities that companies may face in relation to the purchase of raw or intermediate materials has also been examined. Companies are not only concerned about the security of supply but also the effects raw materials can have on their operations and possibly also on their corporate reputation. To this end, a set of indicators has been established for each of the raw materials which is summarized in the table below:

Influence on.	Indicator
Long-term Security of Supply (> 10y)	Number of years of uninterrupted production (Reserves/Production (R/P))
	Companionality (degree to which a raw material is a by-product)
	Concentration of raw material reserves (HHI _{res})
Short-term security of supply	Concentration of raw material extraction (HHI _{prod})
	Stability and quality of governance in source countries represented by WGI
	Existing export restrictions (OECD data)
	End-of-life recycling rate
Operating profit	Price volatility of raw materials/materials (MAPII)
Corporate Reputation	Environmental impact of extracting and refining of raw materials
	Performance of source countries in terms of human development (HDI)
	Regulations concerning conflict minerals

The methodology used in this study makes it possible to establish the relationship between raw materials, products and sectors, which also means that data regarding issues such as the environmental impact of raw materials and problems surrounding conflict minerals (a theme currently under discussion in the European Parliament and Commission) can be linked to their potential impact on each one of these levels (raw materials, products, sectors).

Which raw materials are most critical to the Dutch economy?

With regard to security of supply

In order to be able to give a verdict on the most critical raw materials in terms of security of supply, this report follows in outline the same approach taken by the European Commission: a resource becomes critical when there is a high degree of associated economic importance and reason to suspect that the level of supply uncertainty is high. The most recent (2014) European Commission analysis led to the identification of the 20 most critical materials for the EU-28, as shown in the figure below.

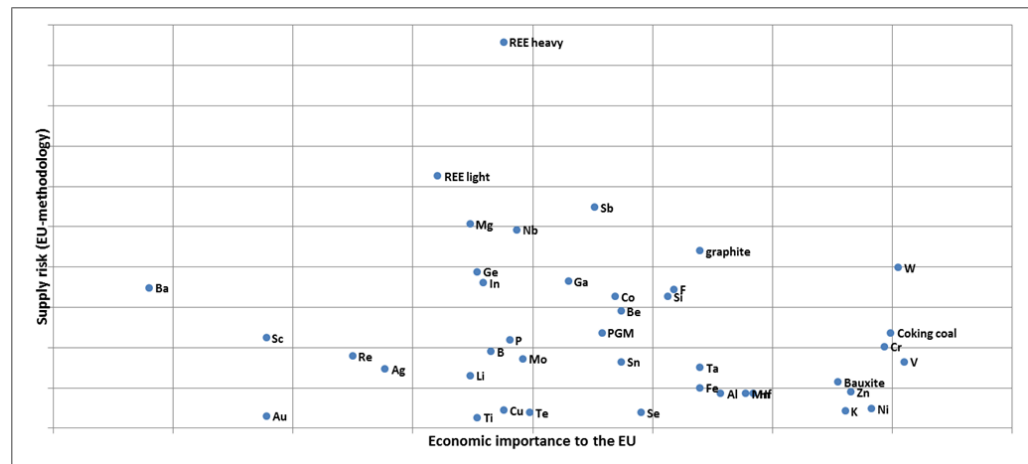


Figure-MS 1 Selection critical materials according to the EC

Two groups of indicators are presented successively: security of supply in the **long-term** and security of supply in the **short-term**.

The uncertainty of supply **long-term** is given by:

$$\text{Criticality}_{LT} = \text{HHI}_{res} + 1/(R/P) + \% \text{ companionship}$$

A material is regarded as critical in the long-term when reserves are only present in a few countries, when the extraction mainly occurs as a 'companion', or when the geo-economic reserve is small.

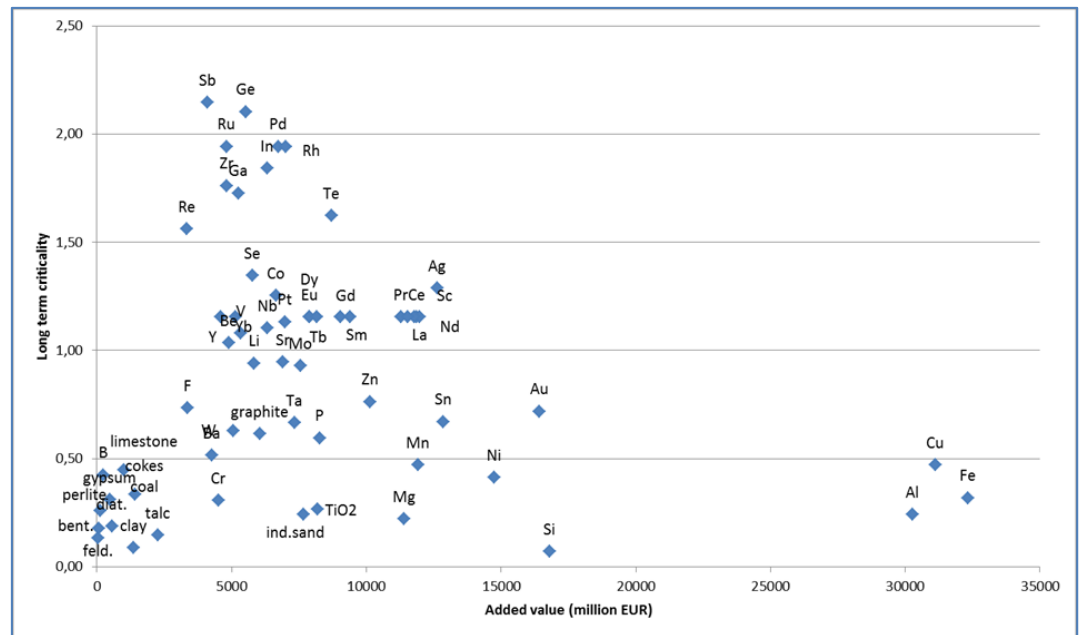


Figure-MS 2 Long-term supply uncertainties vs. importance of materials for the Dutch economy

In Figure-MS 2 a high value on the y-axis represents a high degree of supply uncertainty. The materials with the highest long-term supply uncertainty are antimony (Sb), germanium, indium, gallium, zircon and minor elements of the platinum group metals. The materials with greatest significance for the Dutch economy are iron (Fe), copper (Cu) and aluminium (Al).

The degree of 'criticality' in the **short-term** for the Netherlands is represented by the following formula:

$$\text{Criticality}_{KT} = \text{HHI}_{\text{prod}} * (\text{WGI}_{\text{Weighted}} + \text{OECD restrictions}_{\text{Weighted}}) * (1 - \% \text{EOL-RR})$$

This formula contains: HHI_{prod} which represents the degree of concentration of material extraction in source countries, WGI for the (weighted) World Governance Index, OECD restrictions, the extent to which commodities are affected by export restrictions of mining countries, and the %EOL-RR for the degree of recycling that takes place at the end of product life-span. Materials are critical when they have a high country concentration in countries with a dubious WGI score which have applied export restrictions in the past, and have a low recycling rate. Unlike in the EU context, the ease of substitution of raw materials has not been included in this analysis.

The short-term security of supply for the Netherlands is compared with economic importance in Figure-MS 3.

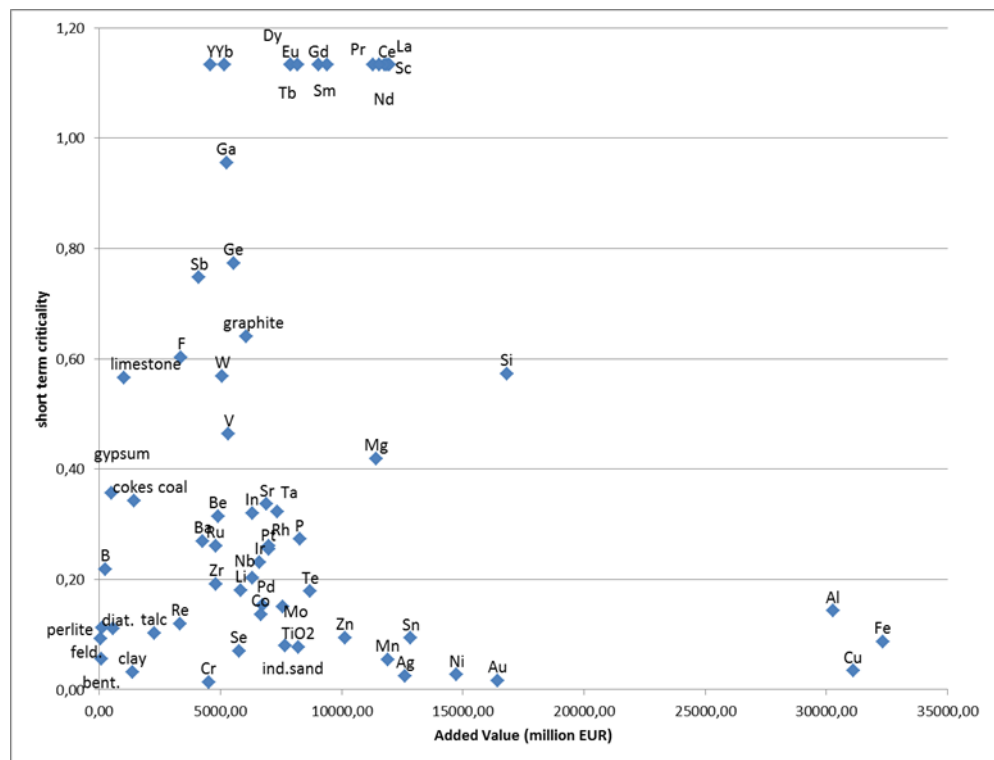


Figure-MS 3 Criticality for the Netherlands, based on short-term supply uncertainties

In Figure-MS 3 a high value on the y-axis represents a high degree of supply uncertainty. The materials with most supply uncertainty in this study are also the rare earth metals, followed by gallium, germanium and antimony (Sb).

By linking the raw materials to sectors it also becomes clear which sectors have the most to fear from short term supply insecurity of materials investigated here: the Manufacture of computer, electronic and optical products, Manufacture of electrical equipment, Manufacture of transport equipment, and the category of Manufacture of furniture and other manufacturing (such as jewellery, games, sports goods, furniture) (see Figure-MS 4). These are followed by the manufacture of metal products and the Manufacture of machinery and other equipment.

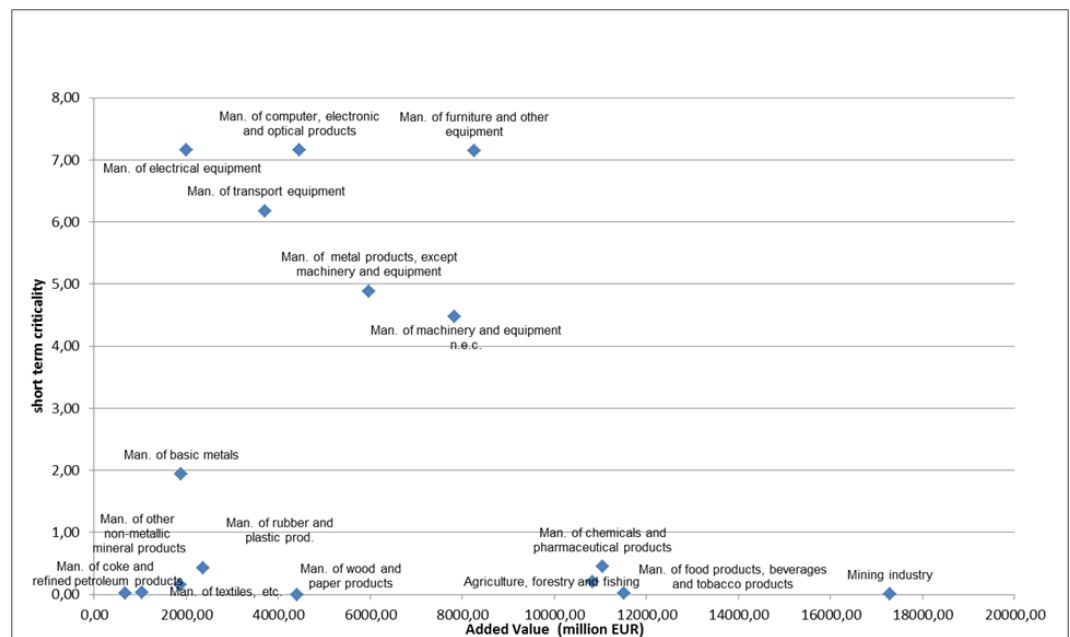


Figure-MS 4 Overview of short-term supply uncertainties at sectoral level

With regard to operating profit

All the materials examined here have a certain price volatility (expressed by the MAPII, the index for the maximum annual increase). Since materials can be linked to product groups by means of their characteristic constituents, we are able to estimate the influence of material price volatility on the Dutch economy as a whole, and on each sector in which these materials are used. Aggregation of data per raw material enables an estimation to be made of what the maximum price increase of each individual raw material would mean for price increases of all purchased goods and products within that sector.

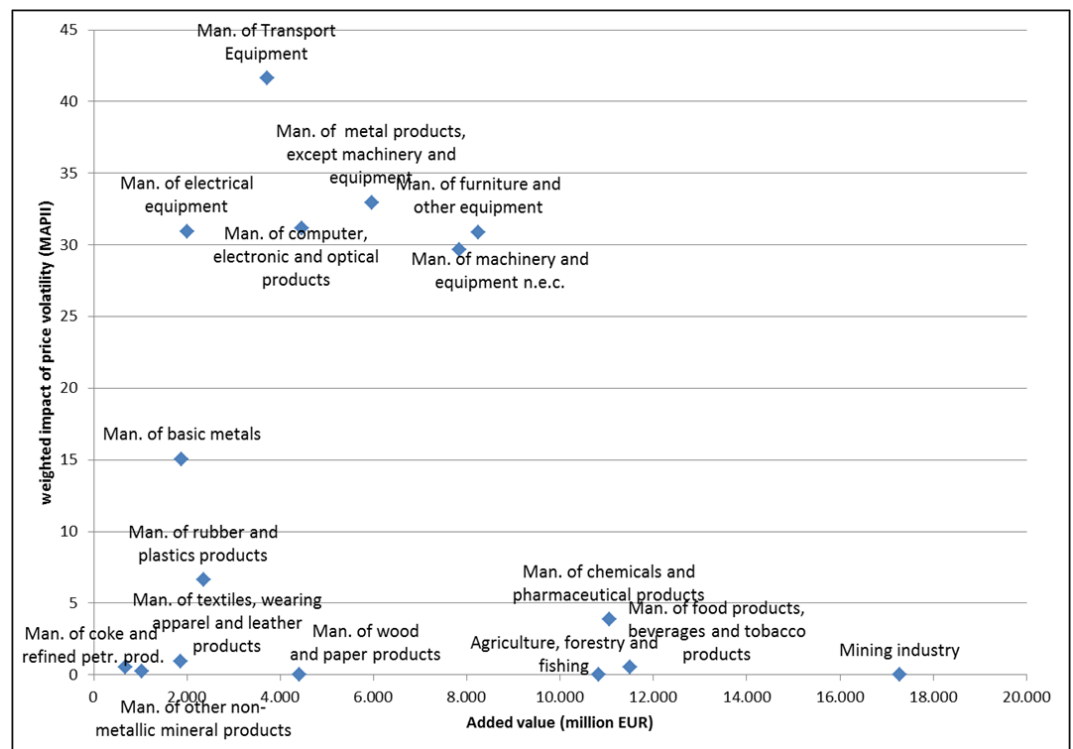


Figure-MS 5 Influence of maximum raw material price increase on cost of goods purchased per sector

Given the relatively small proportion of materials in many end products, the impact of price volatility in most sectors is minimal (<1%) to small (<5%).

The potential impact of price volatility is considerably greater in the Manufacture of transport equipment, of metal products, of machinery and equipment, of computer, electronic and optical products, of electrical equipment and general manufacturing. These sectors use many of the materials which are included in this study. The price volatility calculation is based on the worst-case scenario: it is assumed that the maximum price increase that each material has incurred over the last twenty years, occurs simultaneously for all materials used in that sector. From this perspective, the position of these sectors reflects their overall high consumption of materials.

With regard to corporate reputation

The main indicators under the term 'corporate reputation' put us in a position to determine the relationships between the extent to which different sectors use materials with a substantial environmental impact, materials from countries that are known for their moderate human development, or use of the conflict minerals tin, tantalum, tungsten and gold (the TTTG group). This report provides insights into these relationships at commodity and sector level.

An overview of the extent to which sectors make use of raw materials with a moderate CSR score is given in figure –MS-6.

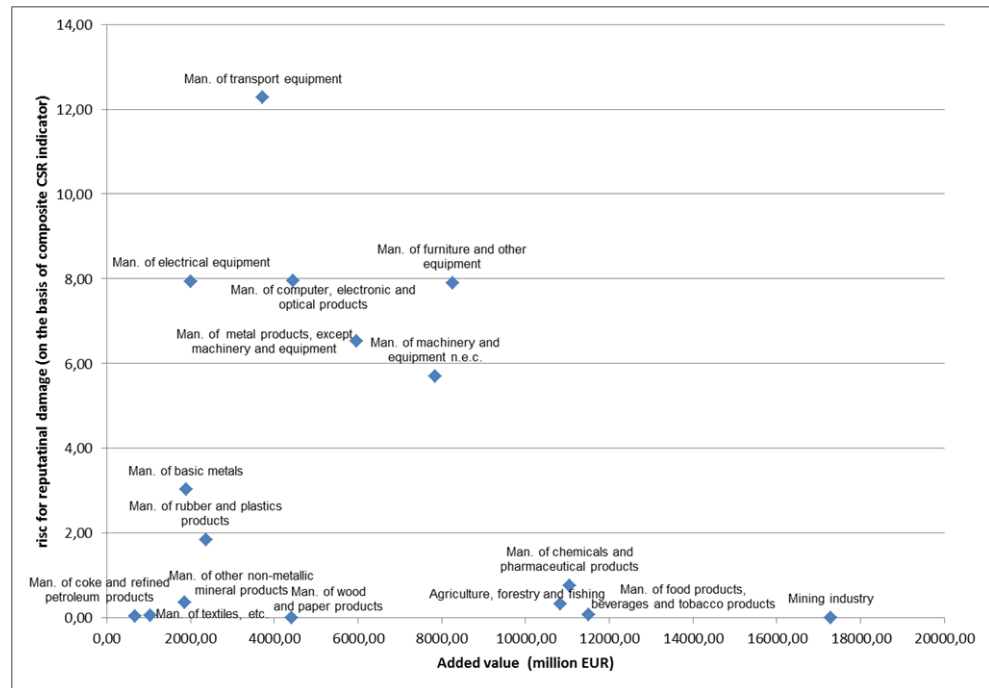


Figure-MS 6 Risk of reputation damage to sectors

Due to the use of a large amount of materials, it is not surprising that many sectors that may suffer from experiencing short-term supply uncertainty are also those at risk from suffering reputational damage. The sector Manufacture of Transport Equipment stands out above the rest. The underlying constituent data shows that this sector stands out due to, on the one hand, using considerable amounts of the raw materials that are examined here and on the other the widespread use of tantalum (16% contribution to the total CSR indicator) Gold (12% contribution) and tin (11% contribution). This sector is therefore closely linked to the debate concerning conflict minerals.

The Netherlands in the value chain: import as raw material or as final product?

Dutch industry is largely dependent on the import of intermediate and final products, and less on the import of raw materials.

Figure-MS 7 shows the percentage of Dutch imported raw materials entering the Netherlands in the form of raw materials (the darker bars): this includes industrial minerals such as talc, gypsum, clay, limestone and industrial sand alongside some metals which are processed in the Netherlands. The vast majority of raw materials examined here enter the Dutch economy as part of a (first) intermediate product, as a final product, and (in some cases including coke) as a material which is consumed in a production process instead of being used as part of a final product .

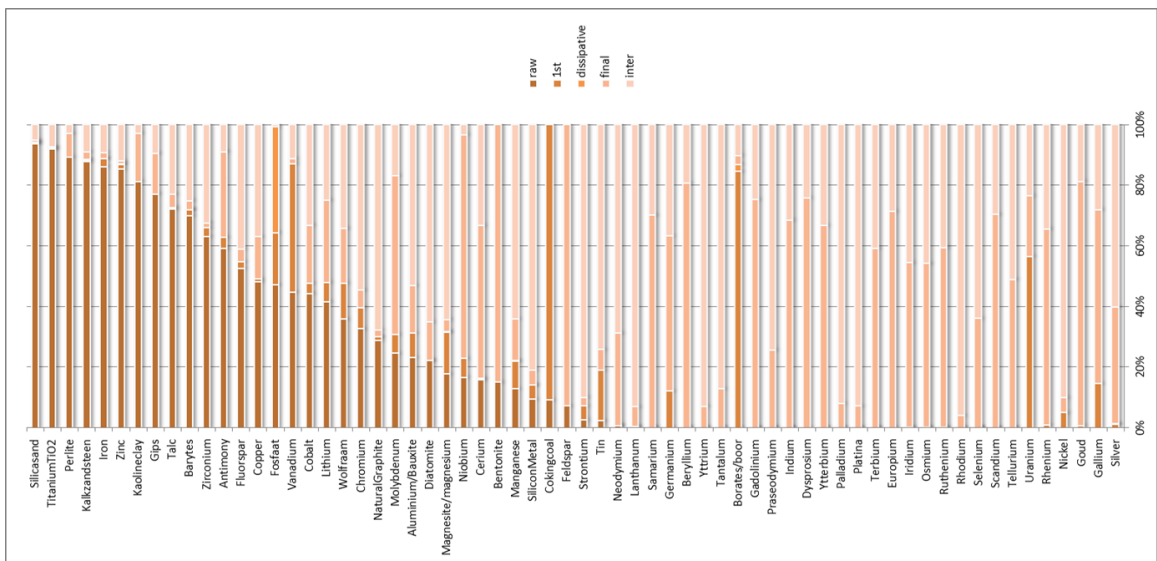


Figure-MS 7 Imports to the Netherlands in the form of raw material, 1st intermediate, intermediate, final product or dissipative use

Figure-MS 8 shows that for those raw materials entering the Netherlands as a constituent of a final product, Germany, Belgium and China are predominantly the source countries.

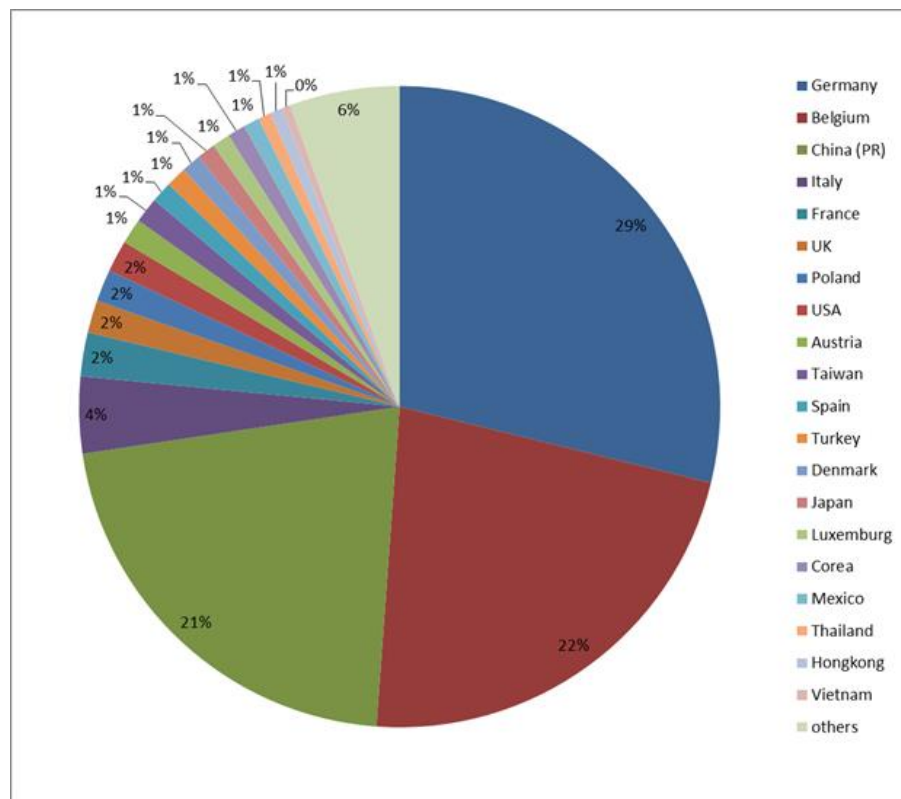


Figure-MS 8 Source countries for imports of raw materials as a constituent of intermediate products

This means that a good understanding of the material situation in these source countries can provide an important insight into the (indirect) vulnerability of the Netherlands.

This report goes into more detail about the relationship between the Netherlands and Germany regarding the supply of raw materials, (first) intermediate products and final products. Figure-MS 9 shows the extent to which raw materials (as constituent of intermediate products), enter the Netherlands via Germany. For a large number of materials, more than 30% of imports enter our country via Germany. This situation is similar to Germany's role in relation to first intermediate and final products. This involves many of the materials which are known to be most critical, such as various rare earth metals, germanium, antimony, vanadium.

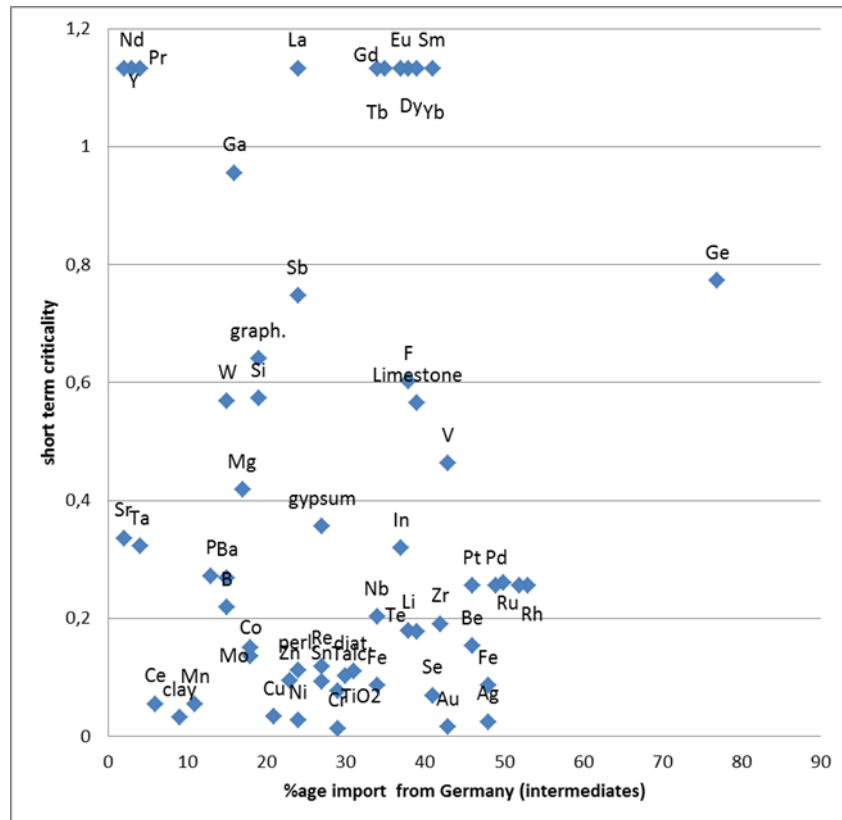


Figure-MS 9 Germany's share in the supply of raw materials (as constituent of intermediate products) in relation to short-term supply uncertainties

The important role that Germany plays in our integrated supply of raw materials has led to close cooperation with Germany in the field of raw materials security.

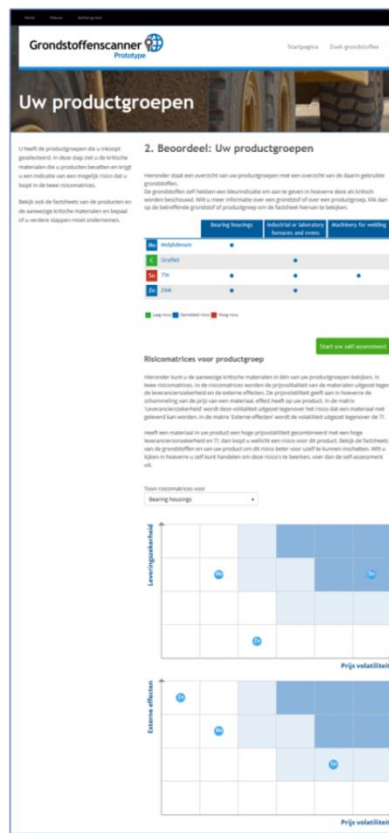
Security of supply and the circular economy

The aim of the circular economy is to reduce the use of materials and associated environmental impact by maintaining high-grade circulation for as long as possible. This classification (and the data collected to this end) enables us to relate the potential intensification of the circular economy to its potential impact on Dutch material use and in turn to security of supply. The methodology assumes that each product group in its own unique way, can be subject to an increasing degree of circularity (more maintenance and repair, remanufacturing and recycling). By linking products and materials together in this way, it can be estimated whether increasing circularity can make a significant contribution to security of supply. This estimate can be made for a representative sample of products, by assuming that, in a more circular economy, the recycling rate has increased by 20% and the level of repair, second-hand use and sharing has also increased by 20% compared to current levels, this then gives the following picture: in total, the total use of the 64 materials decreases by 0.44 million tonnes. In particular, the used volume (all materials combined) of the automotive industry and the electrical equipment industry (together responsible for a decrease in volume of 0.43 million tonnes) decreases by 16% and 24%, respectively compared to the current material use of these industries.

Development of a web-based tool based on advanced data

In early 2016 ICT suppliers to the government will make data concerning raw materials and the composition of products and product groups available, in the form of a web-based tool, to Dutch entrepreneurs who want to get a better idea of the vulnerability of their supply chain. Furthermore, a first framework for action will be outlined and customised to the greatest extent possible to fit the specific circumstances. This action framework primarily responds to options available through highly improved procurement management and substitution by other materials offering more supply security. In addition, this will be combined with the opportunities offered by adopting circular economic principles.

Here are two screenshots from the tool currently under development. There is an example of a risk analysis based on one product group and a fact-sheet concerning a particular raw material.



1 Introduction: raw materials and the Dutch economy

1.1 The global increase in raw material requirements and pressure on supply security

Global population growth and the increasing prosperity of the world population go hand in hand with a strong increase in the demand for a wide range of raw materials. This need is growing most rapidly in emerging economies, where raw materials are required for both building basic infrastructure as well as to meet the growing demand for consumer goods. Partly as a result of the changing geopolitical relations caused by this, the degree of certainty regarding the supply of raw materials for economies which are net importers of materials, is decreasing. This is generally the case for all EU-28 countries, including the Netherlands.

It was already evident from a study commissioned by the FME in 2012 (conducted by TU Delft, TNO and M2I) that these concerns regarding security of supply were more than just theoretical. In this study, which asked 30 companies from the metal and high-tech sectors about their potential concerns about critical raw materials, it was found that 24 of the 30 companies surveyed had recently encountered supply problems. The underlying causes of these problems included a sharp increase in consumption in the Far East (and with this the buying up of full capacities) to sudden failures in industrial capacity (due to natural disasters and exacerbated by monopolies in the supply chain).

This growing pressure on adequate and timely supply of raw materials (and other materials further up the value chain) also leads to rising prices and increasing price volatility. In the previously mentioned FME study several entrepreneurs reported having encountered problems with sharp price rises of various grades of steel, copper, zirconium, nickel, chromium, lithium, titanium and aluminium. Although the effect of price increases and price volatility is strongly dependent on business operations (such as the proportion of material costs in the total costs and the potential ability to pass price fluctuations on to customers), such shifts, particularly in the absence of a level-playing-field, can lead to a loss of competitiveness of the Dutch economy.

Numerous governments around the world are responding to the increasing pressure on the stability of raw material supply by participating more in primary mining, focusing on their own mining industry, stock piling, more commitment to research and development into alternative materials, more efficient use of materials and intensifying recycling. In addition to this transparent trade in raw materials with a vital arbitrating role for the WTO, is becoming increasingly important. EU policy focuses on these last two elements in addition to the intensification of mining in the EU itself.¹

¹ European Commission, Commission Staff Working Document Accompanying the Communication from the Commission to the European Parliament and the Council - The Raw Materials Initiative - Meeting our Critical Needs for Growth and Jobs in Europe.

Dutch policy is set out in its policy document on Raw Materials and the programme From Waste to Raw Material (parliamentary paper 33 043, no. 28)² which are both committed to the transition to a circular economy. These turn vulnerabilities in terms of raw materials supply, into opportunities for the circular economy. They follow an integrated approach (economics, geopolitics and the environment) not only for metals and minerals, but also for green resources.

The progress report of 'From Waste to Raw Material', indicates that this government programme has three main goals: maintaining the vitality of our natural capital, improving supply security and strengthening the earning power of the Dutch economy. One of the new initiatives targeted at entrepreneurs is a 'knowledge platform' where businesses can analyse their vulnerabilities and risks in the field of raw materials by means of a self-scan and consequently be offered options on how best to deal with these.

1.2 The CSR aspects of resource extraction are becoming increasingly important.

Even when supply is guaranteed and price volatility has no major impact on business operations, conditions in source countries may still have an adverse effect on business and therefore the economy. This is particularly an issue when the mode of primary mining (financing local conflicts, poor working conditions and local environmental pressure) can cause a negative image among users of these materials (even when the business involved is much further down the value chain, and is not primarily involved in mining or processing of these raw materials).

That it is important to include such external effects when determining raw material vulnerability is evident in the report "Taking Conflict Out of Consumer Gadgets - Company Rankings on Conflict Minerals, 2012"³. This report explicitly mentions electronics companies in relation to their actions to avoid using conflict minerals in their value chain. The figure below shows how this report was conducted. Insight into the origin of the materials in such a case, is clearly of great value to the reputation of an enterprise. Apple now publishes which of their suppliers obtains minerals from conflict areas.⁴

² Commodities Note, July 15, 2011, Parliamentary paper 32 852, no. 1.
Waste To Raw Material, January 28, 2014, parliamentary paper 33 043, no. 28.
Progress Report From Waste to Raw, April 15, parliamentary paper 33 043, no. 28.

³ Reports of The Enough Project, www.enoughproject.org, Sasha Lezhnev authors and Alexandra Hellmuth, August 2012.

⁴ <http://www.bbc.com/news/technology-26144981>.

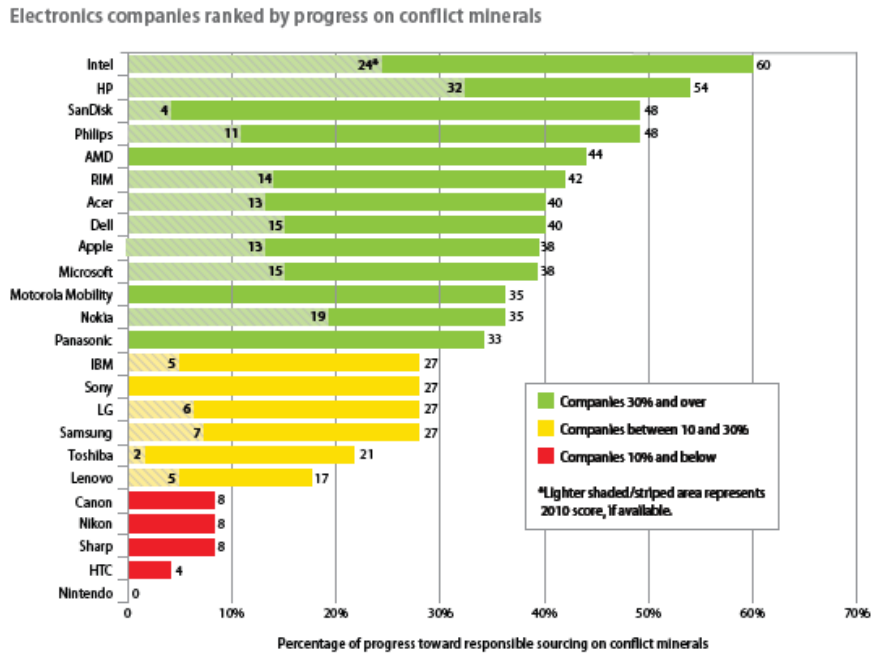


Figure 1 Ranking of behaviour of electronics companies in relation to conflict minerals

The decision whether to take action or not regarding conflict mineral use, has received a boost by the US Dodd Frank Act (2010): part of this legislation has made it mandatory for US listed companies to report over the extent to which they have taken steps to prevent the procurement of four conflict minerals (tin, tantalum, tungsten and gold, the so-called TTTG group) resulting in the financing of armed conflicts in the Great Lakes region in Africa (DRC and surrounding countries). In 2014 a watered-down version of this was proposed by the European Commission: this would only concern voluntary agreements with parties who only import these same four minerals as raw material (i.e. not as part of a more complex component). However, the geographic scope has been widened to cover imports from "conflict-affected and high-risk areas". SOMO (Centre for Research on Multinational Corporations) suggests the link between minerals and conflict areas needs broader interpretation and should not be confined to the aforementioned TTTG group.⁵

The relationship between local environmental pressures caused by raw material extraction and business reputation is not just imaginary. The Groene Rekenkamer (Green Auditors) has denounced the environmental impact rare earth element mining has on local populations: "*We will not rest until national politics and politicians take responsibility and especially that the Dutch population continues to be faced by the facts, so that every time they walk past a windmill they immediately think of the humanitarian disaster which has been unfolding for years in Baotou, and will be further exacerbated in the coming years by every new wind turbine built and erected in the Netherlands and on the Dutch Continental Shelf.*"⁶

⁵ There is more than 3TG - The need for the inclusion of all minerals in EU regulation for conflict due diligence - SOMO paper 2015.

⁶ Groene Rekenkamer - Wind power in the Netherlands - the deadly downside of wind energy (November 10, 2013).

These examples show that it will become increasingly important for government and industry to appear to have a greater awareness of these aspects of the supply chain. In any sound risk analysis, CSR aspects should be given an ever increasingly important role.

1.3 There is a need for a risk analysis specifically focusing on the Netherlands

The global developments outlined above put the countries of the European Union, including the Netherlands, as net importers of raw materials, in a vulnerable position. Therefore there is a clear need for an in-depth risk analysis of the Dutch situation to identify supply risks to the Dutch economy.

In 2014 the European Commission conducted a risk analysis (an update based on the methodology first presented 2010) looking at the economic importance of a selection of mainly mineral raw materials for the European economy markets in relation to the risk of supply interruption.⁷

Figure 2 shows the result of the 2014-EU-revision of this study. It shows the economic relevance of the displayed materials set against supply risk.

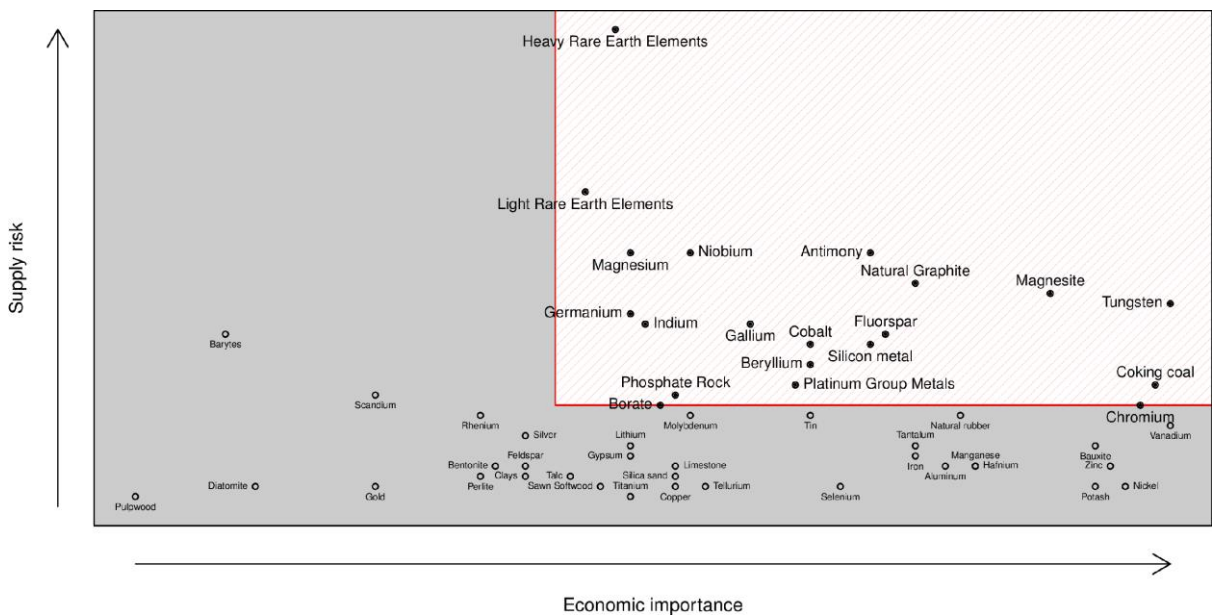


Figure 2 EU criticality analysis (April 2014)

The EU study is based on a highly aggregated picture of the whole EU economy and has a strong focus on supply risks associated with concentration of mining in source countries, combined with a lack of alternatives for these raw materials and recycling infrastructure.

Obviously it is also relevant for the Netherlands to know the risks concerning security of supply and to establish their relation to the Dutch economy.

⁷ REPORT ON CRITICAL RAW MATERIALS FOR THE EU - Report of the Ad hoc Working Group on defining critical raw materials -May 2014.

To be able to analyse the vulnerability of businesses, the consequences raw material price fluctuations have on business performance are also relevant. This requires knowledge of the quantities of raw materials used in products and thus the cost structure of products. The methodology employed here makes it possible to ascertain these.

A third perspective concerns environmental and social risks associated with the use of raw materials, materials or components that may affect the corporate reputation, as was extensively sketched in the previous section 1.2.

To do justice to these three perspectives, a broader set of indicators is needed than those used in the EU study. An overview and explanation of these indicators is provided in chapter three.

Earlier publications concerning raw material risks to the Dutch economy. In 2010 the Central Bureau of Statistics (CBS) published: 'Critical Materials in the Dutch Economy'⁸, this gave insight into the industries that would potentially be most affected by raw material supply disruption. In April 2014 a TNO study was published entitled: "Materials in the Dutch economy"⁹, where the dependence of the Dutch economy on 22 raw materials was assessed. This current study builds on this recent research and expands the analysis in such a way that we can refer to it as a criticality study, forming the basis from which the most critical abiotic raw materials for the Dutch economy can be selected.

1.4 Raw material risks and position in the value chain

This study examines the supply security of raw materials. For a country like the Netherlands, industrial production is only partially directly dependent on the availability of raw materials, but it is rather and most of all, dependent on the availability of processed materials (such as steel and other alloys), components and other intermediate products (intermediates), as schematically shown in the figure below.

⁸ CBS, ISSN 1877-3036.

⁹ TNO 2014 R10686 | Materials final report in the Dutch Economy, Ton Bastein Elmer Rietveld, Stephan van Zyl.

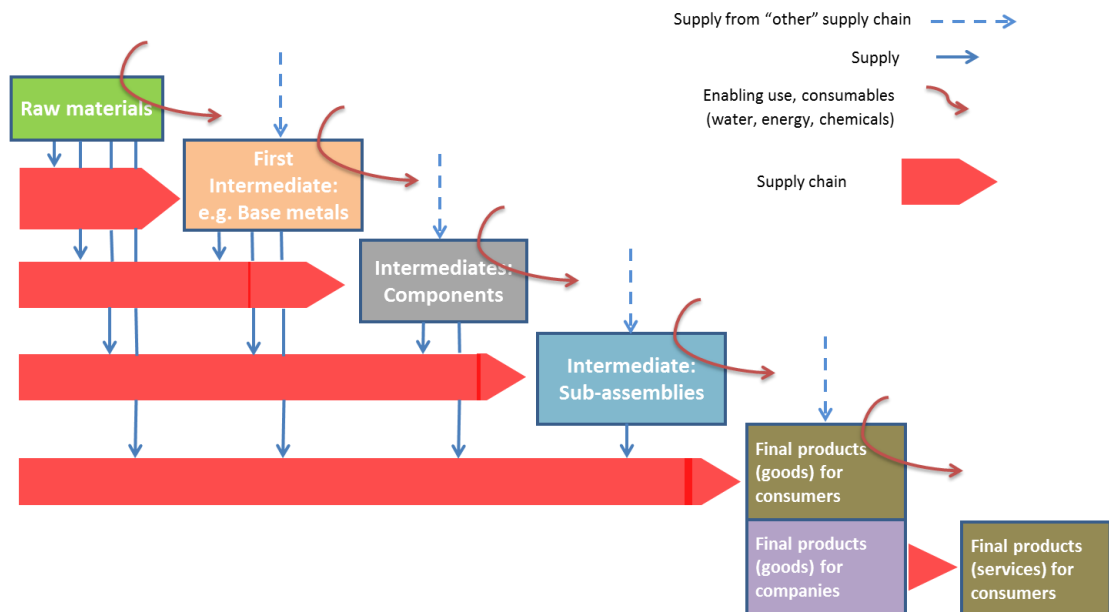


Figure 3 Value chain

Companies in Netherlands may be involved at each of these levels and obtain their materials and goods from each of these higher levels. Therefore an analysis of the vulnerabilities of raw materials only provides a limited perspective of the overall vulnerabilities found in the supply chain. A wide availability of basic raw materials, combined with a bottleneck in the supply chain (e.g. the presence of a very limited number of suppliers of intermediate products) can cause a vulnerable situation, such as indicated by the previously mentioned study commissioned by the FME¹⁰: that study reported an abundance of acute supply disruptions which were unrelated to raw material supply disruption, but in fact were connected to other problems found further up the value chain.

Despite this fact, this study focuses on supply risks and frameworks for action open to companies or governments to reduce them. This study further develops the links between raw materials in intermediate and final products. The method is covered in Chapter 3.

1.5 Following on from a risk analysis comes offering courses of action.

By setting up indicators for security of supply of raw materials and linking raw materials to intermediate and final products, a risk analysis can be performed at both sector and company level. This information will be made available through a self-assessment tool to entrepreneurs (government) purchasers and policy makers.

¹⁰ T. Bastein and D. Bol, Critical materials— a view from the industrial- technological sector in The Netherlands, June 2012, commissioned by FME-CWM, Nederland.

This research will not only highlight supply security risks, but will also offers perspectives for enterprises to minimize the potential impact of these risks. Roughly speaking, there are three ways to reduce raw material sensitivity:

- Making the supply chain more robust
- Changing the need
- Reducing the need

The aforementioned 2012 FME study shows that the majority of businesses with acute problems unsurprisingly, resort quickly to implementing measures in the supply chain.

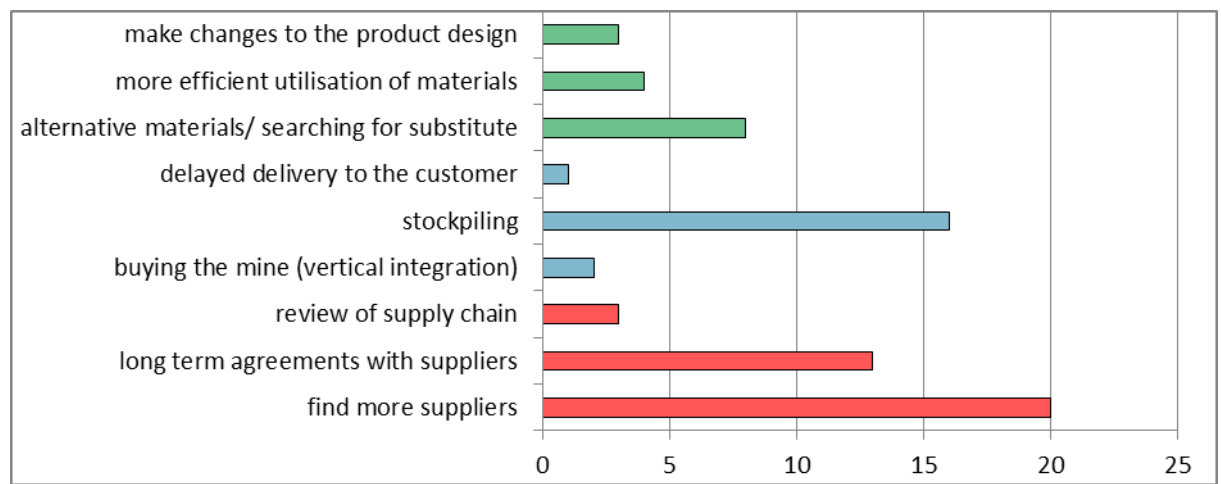


Figure 4 company actions due to supply problems (Source: FME-study)

NEVI (the Dutch Association of Purchasing Management) has extensive experience in procurement measures implemented by businesses and the above mentioned actions also fit in this picture. Roughly speaking in NEVI's view, the procurement measures boil down to:

- Business continuity plans;
- Dual sourcing strategy;
- Global & regional sourcing;
- Supplier collaboration (1st and 2nd level);
- Hedging strategy and;
- Vertical integration.

These measures are contained in the procurement risk model supported by NEVI. These will not be further elucidated here, but the above perspectives will form part of the self-assessment tool.

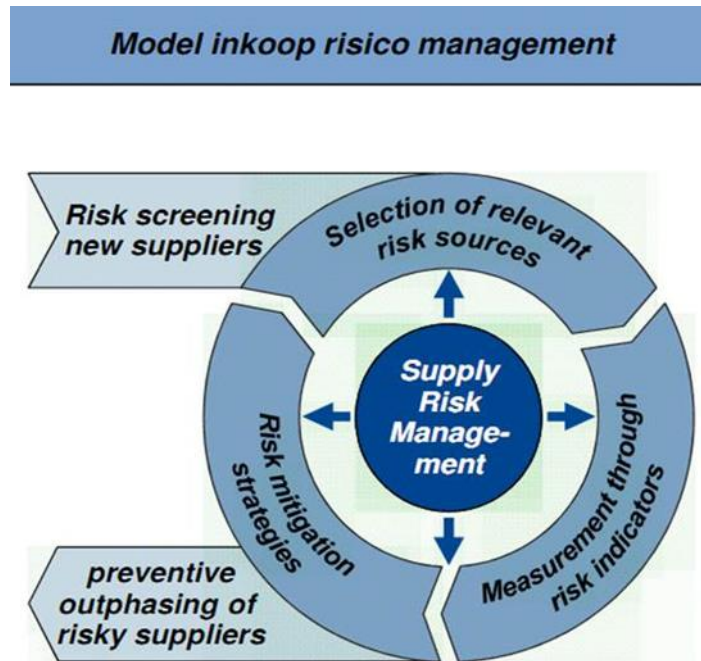


Figure 5 NEVI procurement risk model

The change in raw material needs is referred to as substitution. Substitution may take many forms, such as substituting one (critical) material for another, or the introduction of a new technology which replaces an existing technology but gives the same functionality. An example of this, is the choice made during the installation of large wind turbines, the power generation can be carried out by strong and permanent magnets based on rare earth metals, or on the basis of advanced development of more conventional technology, based on electro-magnets. In many cases substitution will turn out to be a major operation: the introduction of a different material, or other technology will, in general, require a substantial research and marketing effort. In many industries material choices are tied to strict requirements and require lengthy test programmes. This particularly plays a role when there are large risks associated with the failure of equipment (e.g. aerospace, defence technology, electronics, building materials). In short, substitution based on supply risks is truly a strategic management decision, and not an easy option.¹¹

The reduction of the need for raw materials is a many faceted strategy. On the one hand this aspect may be seen as business-as-usual for manufacturing businesses where the economical use of resources in view of the cost component of a production process, is already commonplace.

Also reducing raw material requirements is a part of the wider debate regarding the circular economy.

¹¹ The company Granta Design, is a spin-off of the University of Cambridge, which offers software that can assist entrepreneurs in material choices, and so with substitution options. Granta Design connects knowledge of materials with a large database of detailed composition data from thousands of alloys, and knowledge with respect to the degree of "criticality" of the raw materials used.

The 2011 Ellen MacArthur Foundation report 'Towards the Circular Economy' represents an inspiring and appealing portrayal of the circular economy. A circular economy is an economic and industrial system based on the reuse of products and materials and the regenerative capacity of natural resources. Retaining value is key to the whole system. In this way the circular economy contributes towards reducing our material consumption and environmental footprint.

An ideal circular economy is perhaps aiming too high. The VANG-note (From Waste to Resource) from the Ministry of Infrastructure and the Environment¹² distinguishes three steps towards a circular economy:

- i. A conventional linear economy with take-make-waste;
- ii. A chain economy with feedback loops;
- iii. A circular economy with sustainable use of natural resources.

These stages are further elaborated in the Dutch response to the consultation of member states of the European Commission on circular economy ('Consultation of Member States on the Circular Economy')¹³

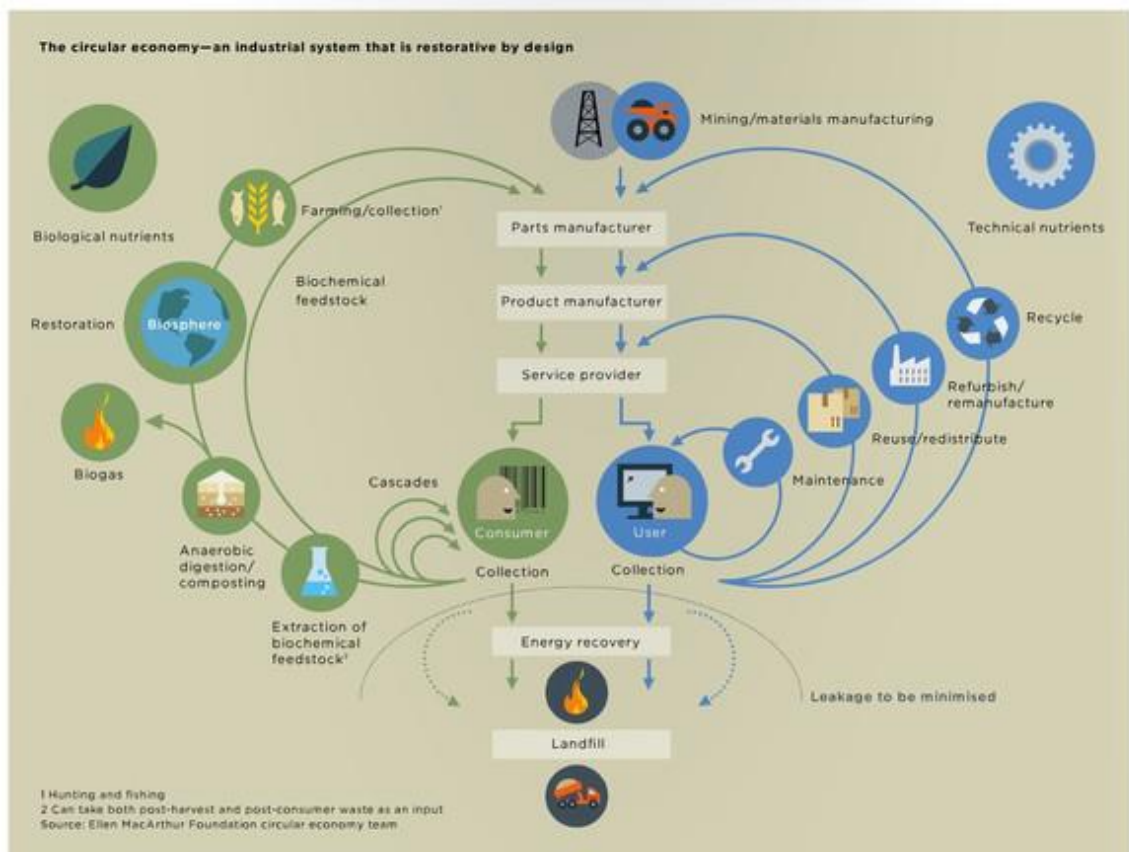


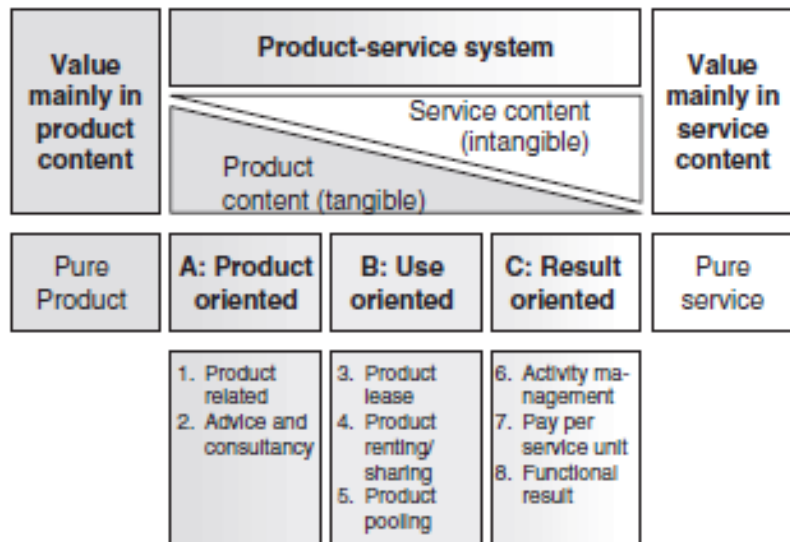
Figure 6 Schematic representation of the circular economy (source: Ellen MacArthur Foundation)

¹² Note From Waste To Raw Material (NAB), Ministry of I and M & M / BSK-2013/104405, June 20, 2013.

¹³ http://www.tweedekamer.nl/parliamentary/paperken/brieven_regering/detail?id=2015Z19182&did=2015D39012; the complete text of this public consultancy is added to this report as Annex H.

Meanwhile it is widely recognized that our society is characterized largely as a "chain economy with feedback loops." It should be clear that the extension of the service life of goods and materials, for example, by repair and maintenance, by re-use, repair and recycling is already embedded for many materials and sectors. An intensification of these feedback loops (including the inclusion of circularity in the design stage) could provide benefits at national level, since the total import of goods and materials decreases and local employment is stimulated. At company level, the transition to a more circular business model means there is less need for purchased components and materials. This can be done for example, by switching to a business model involving the use of an item as a value proposition in the market, rather than relying on the sale of the article (e.g. the revenue model of photocopiers in the business market).

The various varieties of business models with which businesses may put a different value proposition in the market and so provide increased visibility and control over products, was already published in 2004 by Tukker in: "EIGHT TYPES OF PRODUCT SERVICE SYSTEM: EIGHT WAYS TO SUSTAINABILITY?"¹⁴ This presented the wide range of so-called Product-Service Systems, along with an analysis of the business opportunities, barriers and possible environmental impact.



Pressure on security of supply can also work in this way as an incentive to the circular economy and vice versa. This study examines the extent to which an intensification of feedback loops can cover the material needs of Dutch industry and hence reduce vulnerabilities caused by supply risks. Although the emphasis is on the Dutch situation, the fact that most of the goods are exported within the EU-28 indicates that circular approaches to foreign consumers and customers also provides a framework for action based on the EU-28.

This research also forms the basis of the self-assessment tool which makes data and its accompanying prospects available for entrepreneurs (national) purchasers and policy makers. In order for companies to reach a selection of suitable options, the position in the value chain (see Figure 3) is very important: examples:

¹⁴ Arnold Tukker, EIGHT TYPES OF PRODUCT SERVICE SYSTEM: EIGHT WAYS TO SUSTAINABILITY? EXPERIENCES FROM SUSPRONET, Business Strategy and the Environment. BUSH STRAT -env 13, 246-260 (2004).

- Only companies that directly process raw materials or first intermediates in their manufacturing process will benefit from process-efficiency improvements;
- Only raw materials and material processing companies benefit by being actively involved in recycling;
- Companies that operate as suppliers will have great difficulty in adapting product specifications in order to accommodate the use of other raw materials;
- Only end producers will be able to reduce their raw material needs by focusing on other business models which lead to longer life, more maintenance and keeping ownership of the products (sharing and leasing constructions). And the latter is then still of course dependent on the type of product which is put in the market.

An effective tool focussed on Dutch businesses disclosing such possible steps needs to take into account the position in the value chain. This tool will become available in the course of 2016.

1.6 Summary

Global developments in the field of raw material use encourage import-dependent countries, such as the Netherlands, to identify supply risks to its economy in terms of raw materials, intermediate and final products (security of supply, price trends and corporate social responsibility-related risks). If the risk analysis provides reason to do so, then a framework for action will be provided in order to reduce these risks. The choice of options available largely depends on the position in the value chain and the processes carried out.

2 Raw materials in this study

The purpose of this study is to gain a better insight into the extent to which the Dutch economy is dependent on the availability of abiotic materials. By examining the economic relevance of these materials, their availability, price volatility and the ecological or ethical issues surrounding their extraction, it can be determined which products and materials need to be given policy priority.

The materials being investigated are presented in this chapter.

2.1 Selection of raw materials for this study

In the previous study 22 raw materials were selected based on the revised EU list of critical raw materials. This study will determine which abiotic raw materials are most critical to the Dutch economy. The premise of this study is therefore a much broader list materials, which is strongly influenced by the materials included in the EU study, with some minor adjustments.

The raw materials investigated are presented in the table below.

The materials in bold-type are those which are labelled as critical in the most recent (2014) European study on critical raw materials.

Table 1 Raw materials in this study

Aluminium/Bauxitee	Graphite	Rhenium (Re)	Dysprosium* (Dy)
Antimony (Sb)	Iron ore/iron (Fe)	Selenium (Se)	Neodymium* (Nd)
Barytes	Indium (In)	Silicon (Si)	Praseodymium* (Pr)
Bentonite	Industrial sand	Strontium (Sr)	Samarium* (Sm)
Beryllium (Be)	Limestone	Talc	Europium** (Eu)
Borates/boron (B)	Clay (Kaolin)	Tantalum (Ta)	Yttrium** (Y)
Chrome (Cr)	Cobalt (Co)	Tellurium (Te)	Terbium** (Tb)
Coking coal	Copper (Cu)	Tin (Sn)	Cerium*** (Ce)
Diatomite	Lithium (Li)	Titanium dioxide (TiO ₂)	Lanthanum *** (La)
Feldspar	Magnesite/ magnesium (Mg)	Uranium (U)	Ytterbium**** (Yb)
Fluorspar (F)	Manganese (Mn)	Vanadium (V)	Gadolinium**** (Gd)
Phosphorus (P)	Molybdenum (Mo)	Tungsten (W)	Scandium**** (Sc)
Gallium (Ga)	Nickel (Ni)	Silver (Ag)	Platinum^o (Pt)
Germanium (Ge)	Niobium (Nb)	Zinc (Zn)	Palladium^o (Pd)
Gypsum	Perlite	Zircon (Zr)	Iridium^o (Ir)
Gold (Au)	Ruthenium (Ru)	Osmium^o (Os)	Rhodium^o (Rh)

* Rare earth elements related to the production of permanent magnets, and therefore used in energy generation from wind or movement/cars

** Rare earth elements related to the production of energy-saving bulbs and LEDs

*** Rare earth elements coupled with energy storage/batteries

**** Rare earth elements: other applications (alloys, lasers, optics)

^o These raw materials belong to the platinum group metals or PGM

For the purposes of this study rare earth elements and the platinum group metals will not be treated as a single group (as is conventional in many reports), but -as far as the available data will permit- as individual components, taking into account their individual field of application and therefore individual relevance to the Dutch economy.

The distinction between different rare earth elements was made earlier in the extended criticality studies carried out by the Department of Energy (DoE) in the United States¹⁵; this focuses on the future relevance of energy technologies (Figure 7). The different types here concern: dysprosium, neodymium, praseodymium and samarium (all related to the production of permanent magnets, and therefore in energy generation from wind or movement/cars), europium, yttrium, terbium (related to the production of energy-saving lamps, and LEDs), cerium, lanthanum (linked to energy storage/batteries). In addition, a separate analysis of ytterbium (laser application), gadolinium (lasers, alloys), and scandium (optical elements) is relevant. The more extensive analysis of individual elements of the rare-earth group is also justified by the high criticality of rare earth metals which has emerged from various other studies: this debate often becomes somewhat obscured by putting all of these materials and applications together in one heap.

The platinum group metals include the materials platinum, palladium, iridium, rhodium, ruthenium and osmium. These are also used in different ways in the production of (different types of) catalysts, jewellery, and alloys, and wherever possible in this study, are examined in greater depth as individual materials.

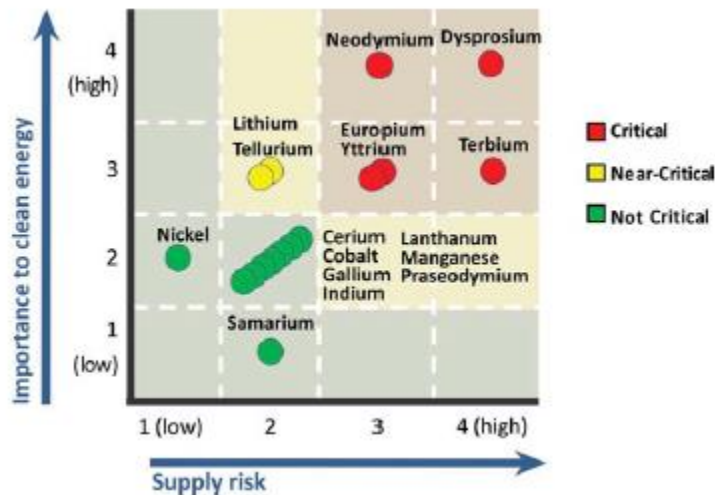


Figure 7 Criticality-matrix of the Department of Energy (US)

The following sections provide insight into data on primary production. Most of this data is used to in relation to the indicators which are covered more extensively in Chapter 3.

¹⁵ U.S. DEPARTMENT OF ENERGY, CRITICAL MATERIALS STRATEGY, DECEMBER 2011.

2.2 Production and reserves¹⁶

2.2.1 World production

The selected raw materials differ significantly in terms of absolute annual production volumes (see Figure 9). World mining production is dominated by the production of iron ore, with over 1 billion tonnes of iron ore per year this takes up 67% of all mined mineral extraction. Furthermore, 95% of all mining production comes at the expense of only 6 minerals: in addition to iron ore these are calcareous sandstone, gypsum, silica, bauxite, and phosphate rock (see Figure 8). Data regarding the development of world production can be found in Appendix E.

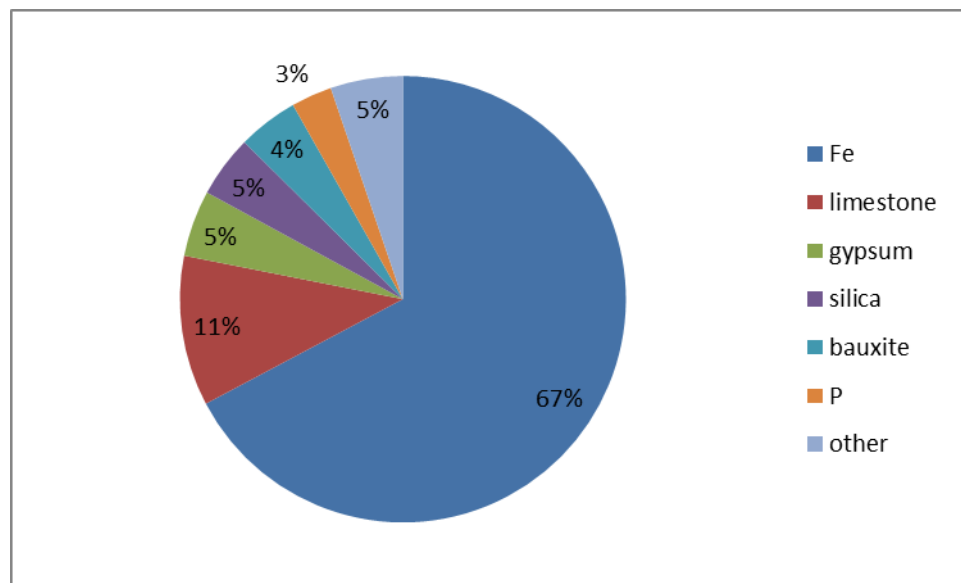


Figure 8 Distribution mining production

¹⁶ Unless otherwise stated, all data concerning primary production of raw materials from Mineral Commodity Summaries and Mineral Commodity Yearbooks as published by the US Geological Survey on the Internet.

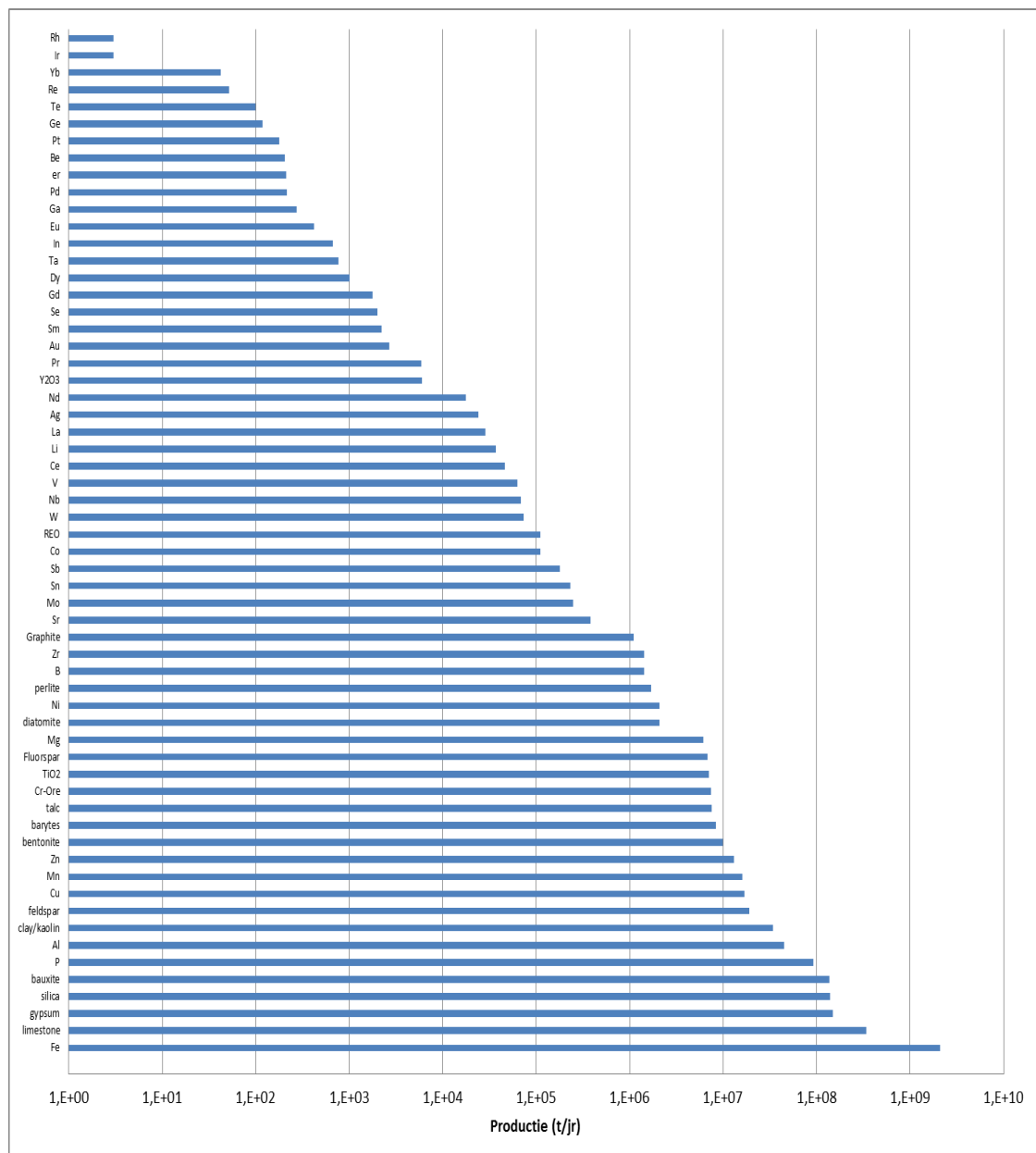


Figure 9 Production volume

2.2.2 Mineral Reserves

For any potential problems concerning the security of supply, the level and growth of existing production is not necessarily decisive. However the situation is different for the so-called (economic) reserve, which is often expressed in the R/P ratio: this is the ratio between reserves and production, or the number of years of continued production left under unchanged technical and economic conditions. Without a doubt, this R/P ratio is in itself interesting, although it is highly questionable whether it is indicative of future scarcity and therefore relevant to a supply analysis. Although major inaccuracies exist in the estimation of (economically recoverable) reserves, it could be argued that a reserve (R/P) of more than 100 years, means that stocks are apparently simple to demonstrate, that there are sufficient proven reserves and that

supply in the short term is not compromised on the basis of geological availability or existing mining capacity.

On the other hand, a low R/P ratio does not necessarily mean that the supply is at stake. For a lot of raw materials the data on reserves remains constant despite the fact that significant production takes place and no remarkable finds have been reported. Exploration of new ores is a costly affair and mining companies are reluctant to invest in exploration when increases in proven reserves will not lead to increased market value for these companies.

In addition, many raw materials are extracted as a by-product of other ores (see section 2.2.3). The meaning of the R/P ratio in that case says little, since no independent determination of such a by-product-reserve is possible, and production depends on the current installed production capacity for these by-products, and not from the geological reserve.

Despite these objections it can be argued that a low R/P ratio in all cases is a reason for vigilance. When reserves are low, no exploration efforts are made, and a sharp increase in demand may be expected (e.g. through new applications) then there is said to be a higher risk profile.

The R/P ratio for those raw materials for which data is available from the USGS Commodity Summaries is shown in Figure 10. This figure does not include data for many industrial minerals (such as bentonite, clay, diatomite, feldspar, gypsum, perlite, limestone, silica and talc), since due to their abundant availability their reserve levels are irrelevant. The R/P ratio is therefore 'infinite'. For some by-products (such as indium and gallium) as stated, no reserve valuations are available. With regard to the R/P the platinum-group metals and rare earths are now taken as one group, since no distinction can be made between the components of these composite ores.

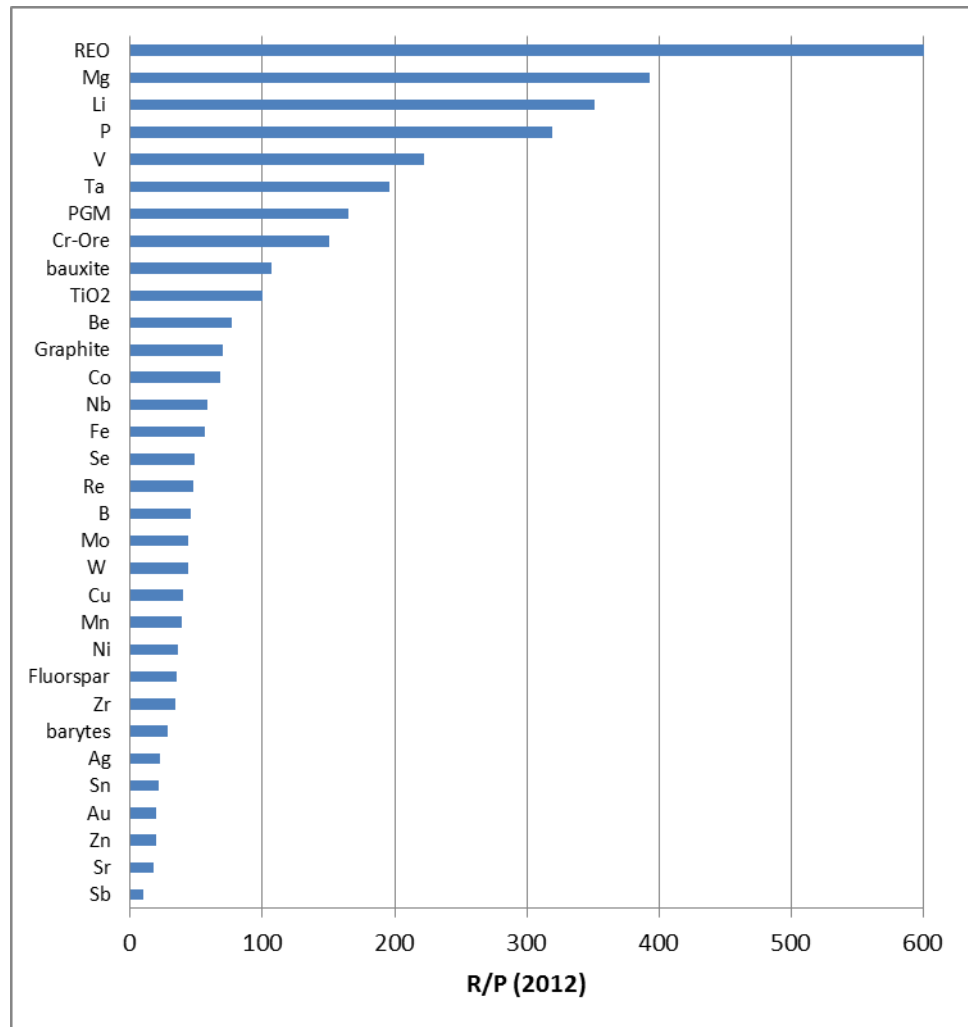


Figure 10 R/P ratio (2012; source: USGS Mineral Commodity Summaries)

In spite of the relevant criticism of the significance of the R/P-ratio, the situation with respect to antimony (Sb), strontium, zinc, gold, tin and silver (all with an R/P ratio of 20 years or less), certainly needs attention.

2.2.3 *Production as main or by-product: the degree of 'companionship'*

Many mineral resources are only extracted as by-products ('companions') of other raw materials (the so-called 'hosts'). In such cases, the profitability of the mine will not depend on the extraction of the companion. In addition, most of the companions can only be extracted during the refining (for example, during electrolytic extraction of copper and zinc), which, in many cases, takes place at other locations and even often in other countries than where the ore is mined. Such a connection can lead to a lack of market elasticity: a sudden increase in demand (for example due to a technological innovation) will in the case of a by-product or 'companion' not lead to an increase in or the start of new mining activities. The production can only increase when the process efficiency of the companion extraction increases or when currently no full use is made of the quantity of producible companion material. The consequence is that if the global demand for a host material stabilizes or even decreases (as in the case of lead), the extent to which companions can be won also decreases, even if the demand increases accordingly.

Many of the materials contained in this study are companion resources. A comprehensive study by Nassar and Graedel¹⁷ sheds light on the extent to which raw materials are companions.

A summary of their results is given in Figure 11, the raw materials listed are all extracted for more than 5% as a companion.

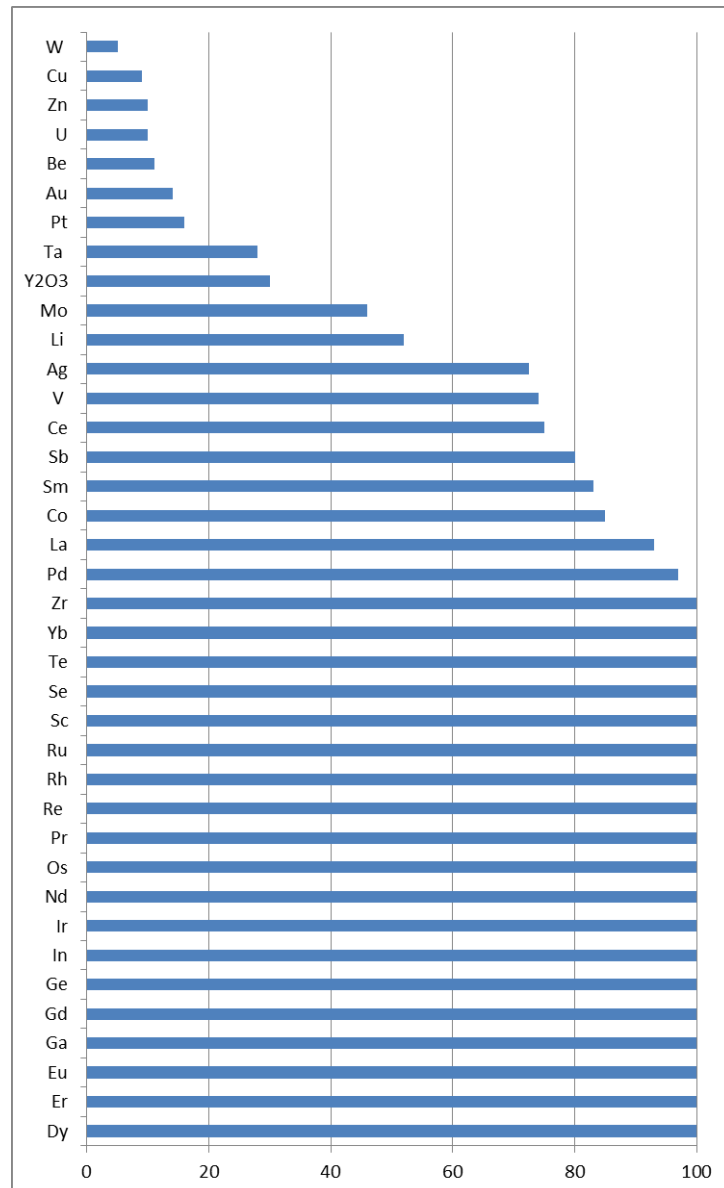


Figure 11 Share of companionality: part of production that takes place as a companion of another metal

19 Raw materials only occur as companion, and therefore their production is completely dependent on the extraction of the host. In total, 27 of the raw materials seen here are for more than 70% dependent on their host.

¹⁷ Nassar NT, TE Graedel, EM Harper, By-products are technologically essential but have problematic supply, *Advances Science* 2015; 1: e14-180, April 2015.

The platinum group metals rhodium, iridium and osmium are, for more than 95%, companion to platinum-mining. Palladium is a companion of nickel (53%) and of platinum (44%).

The rare earths are extracted as companions of iron mining or jointly extracted in the so-called ion adsorption deposits in the southern Chinese provinces. The only rare earth element recovered largely as a host is yttrium (Y).

The other important hosts are given in the following table.

Table 2 Relationship host-companion

Companions	Host									
	Al	Ti	Fe	Ni	Cu	Zn	Lead	SN	K	
Gallium	95									
zircon		100								
Gd, Eu, Nd, Pr, Sc, La, Sm, Ce			24-67							
Vanadium			62							
cobalt				50	35					
Rhenium					100					
Selenium					90					
tellurium					60					
As molybdenum					46					
Germanium						60				
Indium						80				
Antimony							40			
Scandium								50		
Lithium										52

Despite the suggestion put forward by Nassar and Graedel among others, that a high companionship yields a fragile supply, the reverse can also be true. If only a small part of the possible host materials are used to extract companions, -in contrast to the case of host-raw materials- a relatively rapid increase of production can take place with relatively low investment. Data on the extent to which the total capacity is used can be an important indication of the vulnerability of supply or inflexibility of production increase. Such data is not available.

An indication of the dependence of the production of hosts and companions can be obtained by looking at the increase in production of both. When production of companions is increasing faster than that of the host material, there was evidently unused 'capacity' which is being increasingly exploited due to market influence. Figure 12 shows how the production of a number of materials (in particular, cobalt, gallium, and indium), is growing faster than those of their hosts. In particular the situation regarding cobalt requires attention: the production of this material which is 85% dependent on the extraction of nickel and copper mining, is growing considerably faster than that of its hosts.

Also, for gallium, indium, silver, antimony, and germanium, additional extraction-capacity has evidently arisen since 2000.

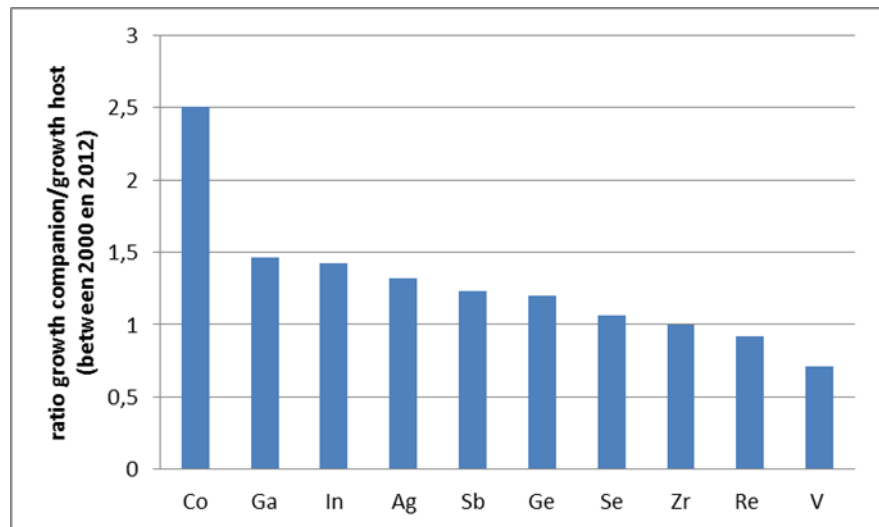


Figure 12 Relative growth in production of companions compared to their 'host' (between 2000 and 2012)

3 Risk analysis indicators relevant to the Netherlands

3.1 Introduction

In recent years there have been a large number of publications in which the impact on the economy or on the implementation of certain policy goals (such as, for example, the implementation of alternative sources of energy) has been viewed in relation to the potential risk of supply disruptions. A review of these criticality analyses has been published by Erdmann and Graedel¹⁸.

Graedel et al.¹⁹ state that criticality indicators at corporate level and at national level differ from long-term indicators for the worldwide availability of raw materials. According to Graedel, the relevant timeline for companies is a maximum of five years. Insight into geopolitical questions, the intensity of competition and future technological changes is also crucial. He proposes the working method shown schematically in Table 3.

Table 3 Graedel's proposal for criticality indicators at corporate level

	Components	Indicator
delivery risk	Geological,	Exhaustion time (R / P)
	technological, economic	Accompanying metal fraction
	Social aspects	Human development index
	Geopolitics	WGI
		Global supply concentration
Vulnerability to supply constraints	Interest	Percentage of income that is affected
		Ability to pass on cost increases
		Importance for the company strategy
	substitutability (chemistry)	Performance replacement products
		Availability replacement products
		Environmental Impact Ratio
		Price Ratio
innovation capacity	Business Innovation	

These suggestions from Graedel et al. are based in part on an assessment of criticality by General Electric (GE)²⁰ with regard to their own materials (of which 11 were eventually assessed in great detail). Additional indicators in the GE assessment are:

- Historical price volatility;
- Demand risks: the assessment of future increases in use of a material;
- Substitutability of materials in the most important applications and markets outside of GE.

¹⁸ L. Erdmann and T.E. Graedel, Criticality of Non-Fuel Minerals: A Review of major Approaches and Analyses, *Env. Sc. & Techn.* 2011, 45, 7620 – 7630.

¹⁹ T. E. Graedel, Rachel Barr, Chelsea Chandler, Thomas Chase, Joanne Choi, Lee Christoffersen, Elizabeth Friedlander, Claire Henly, Christine Jun, Nedal T. Nassar*, Daniel Schechner, Simon Warren, Man-yu Yang and Charles Zhu, Methodology of Metal Criticality Determination, *Environ. Sci. Technol.*, 2012, 46 (2), p. 1063–1070.

²⁰ S.J. Duclos, J.P. Otto, D.G. Konitzer, *MECHANICAL ENGINEERING*, 2010 Vol. 132 Nr. 9, 36-40.

The supply risk indicators suggested by Graedel apply to aspects of the medium term, which makes them useful for both governments and companies. Graedel suggests indicators for geological availability, human development in source countries and geopolitical questions (using the methodology proposed by the EU).

In this current study, we also propose that the level of risk for a company or country can be determined by the economic impact on the one hand (on the national economy or per company) and on the other by the likelihood that problems may arise in the supply chain. These problems may have a direct effect on the security of supply, but also on operating profits or on corporate reputation.

In this chapter we will discuss the method used to assess aspects of the security of supply of raw materials on the basis of the chosen indicators. In the following chapter we will discuss how the economic impact of raw materials can be assessed, which will then permit a complete criticality analysis for the Netherlands.

3.2 Assessment of the vulnerability of raw materials

As stated in chapter 1, industry concerns regarding raw materials do not simply relate to security of supply but also to any potential effect on competitiveness as a result of price increases or on the reputation of an individual company. Companies are becoming ever more sensitive to the influence of pressure groups and the environmental movement as a consequence of the rapid spread of information via social media, which can affect the reputation and thus the market value of products. In such cases, the quantities of (raw) materials deployed and whether these are directly imported or simply present in the product range are not of primary importance.

The three perspectives from which raw materials may be considered can be described as follows:

- Influence on business security;
- Influence on operating profit, and;
- Influence on corporate reputation.

Table 4 gives an overview of the indicators and data that allow an interpretation of these three perspectives²¹. Four categories are given in this table: long-term and short-term security of supply, operating profit and corporate reputation.

²¹ An analysis in which these indicators are compared with the OECD guidelines is carried out in Appendix D of this report.

Table 4 Overview of the indicators and data for a complete vulnerability assessment in this study

Influence on.	Indicator
Long-term Supply (> 10y)	Geo-economic: Reserve / Production (R / P)
	Geo-economic: Companianality (extent to which raw material is a by-product)
	Geopolitics: Concentration of reserves of raw materials (HHI _{res}) in source countries
Short-term security of supply	Geopolitics: Concentration of extraction of raw materials (HHI _{prod}) in source countries
	Geopolitics: the stability and the quality of the administration of source countries represented by WGI
	Geopolitics: Existing export restrictions (OECD data)
	End-of-life recycling rate
Operating profit	Price volatility of (raw) materials (MAPII)
Corporate reputation	Environmental impact of raw materials
	Performance of source countries for human development (Human Development Index HDI)
	Regulations with respect to conflict minerals

This study intends to generate a clearer picture of the risks involved at both national and corporate level. As regards the use of the above indicators, there is no real difference between corporate level and the level of the national economy when the latter is considered as the sum total of the added value of individual companies. This means – for example – that a potentially large impact on price volatility of certain companies or sectors and therefore also on competitiveness, may result in having a sizeable impact on the national economy. Since national governments are concerned with the systematic risks to and opportunities for the economy, the long-term perspective is also relevant.

Timescale is a critical dimension when considering vulnerabilities. In the long term (more than 10 years), vulnerability is closely connected to the basic availability of raw materials. Although uncertainties exist (such as developments in supply via new mining projects or revolutionary changes in demand as a result of technological innovation), indicators that provide information about geological and geo-economic availability (such as the R/P ratio, the current estimate of years of uninterrupted production) do nevertheless provide useful information.

In the short term (<10 years), factors such as the reliability of suppliers are more likely to determine the “criticality” of stable supply.

In the analysis of the indicators and their use, we will make these timescales clear and will make use of them in the final vulnerability assessment.

In the following sections, the indicators and data sources will be examined in more detail.

3.3 Indicators focused on long- and short-term supply

Disruptions to supply are perhaps the most drastic problem for industry. In an FME study quoted earlier, a large proportion of the companies interviewed indicated that they had experienced problems as a result of disruptions to the supply of their most critical materials. These were mostly related to problems of their intermediate suppliers and were thus seldom related to genuine problems in the supply of raw materials. The chance of disruptions to the supply of (qualitatively correct) raw materials can well be affected by geo-economic and by geopolitical factors.

3.3.1 *Geo-economic factors: the R/P ratio*

In principle, supplies of fossil and mineral raw materials are finite. However, the quantities of mineral raw materials that could still theoretically be extracted are not really relevant to this discussion. What is important is whether the combination of available exploration and extraction technologies on the one hand and economic reality on the other, allow the extraction of sufficient quantities of the minerals in question per unit of time. Estimating worldwide reserves is therefore a complex and dynamic activity. Adjustments to estimates of reserves (such as those published in the USGS Mineral Commodity Summaries) appear most often to be carried out on the basis of administrative actions rather than on the basis of an analysis of new proven reserves. An estimate of future consumption plays no part whatsoever in the determination of reserves.

In determining a framework for action at corporate level, the R/P ratio is only relevant when the strategic vision of companies stretches to a period longer than 10 years. For this reason, the R/P ratio was not included in the analysis given in the EU ad hoc commission reports. For governments, awareness of proven reserves can lead to monitoring of international mining operations. This study will therefore include the **R/P ratio** as an indicator of long-term vulnerability in further analyses. The relevant data with regard to the R/P ratio is presented in section 2.2.2.

3.3.2 *Geo-economic: Companionality*

Another important geological-economic characteristic of mineral raw materials is the degree to which they are extracted as the main product (or co-product) of mining operations or as a by-product. Many mineral raw materials are only extracted as by-products (“companions”) of other raw materials (the so-called “hosts”). In such cases, the profitability of the mine will not depend on the extraction of the companion. Such dependence can lead to a lack of market elasticity: a sudden increase in demand (for example as a result of technological innovation) will not – if it concerns a by-product or “companion” – immediately lead to an increase in production or the establishment of new mining operations, unless the process efficiency of the companion extraction increases or if full use is not yet made of all the companion raw material that can be extracted. A further consequence is that, if global demand for a host raw material stabilises or even decreases (as is the case with lead), the extent to which companions can be extracted will decrease, even when demand increases.

A recent analysis by Nassar and Graedel²² provides an extensive overview of the degree of “**companionality**” of raw materials. These authors define

²² N. T. Nassar, T. E. Graedel, E. M. Harper, By-product metals are technologically essential but have problematic supply, *Sci. Adv.* 2015;1:e1400180, 3 April 2015.

companionality as the extent to which the extraction of a metal is responsible for covering the “cost of sales” of a mining operation. A high degree of “companionality” can be linked to both price volatility and availability problems: “*One aspect of companionality of note is that when a metal is obtained largely or completely as a companion, its production is often unable to respond quickly to rapid changes in demand and, as a result, its price can fluctuate widely.*”

The fact that producers of by-products cannot react “independently” to market conditions can therefore contribute to disruptions in the security of supply in the medium and long term.

Details of this companionality which are relevant to this study are described in section 2.2.3.

Criticality in the EC report.

Existing studies into “criticality” place considerable emphasis on the supply risks associated with a high production concentration in just a few source countries, or with a limited number of mining companies. As such, the EU ad hoc commission reports on critical raw materials defines a **supply risk** as the result of a combination of factors, namely:

- The source country concentration (quantified by the Herfindahl-Hirschmann Index HHI^1), potentially weighted by the governmental structure or stability of that country (e.g. by making use of the World Governance Indicator from the World Bank).
- A lack of substitutes.
- Low recycling rates.

The total supply risk is then calculated as

$$SR_i = \sigma_i(1 - \rho)HHI_{WGI}$$

Where σ_i represents the lack of opportunities to substitute the raw material, ρ the proportion of demand which is currently met through recycling, and HHI_{WGI} defines the production concentration at country level and governance in those countries (by multiplying the concentration factor HHI by the weighted World Governance Indicator).

Geopolitics: Concentration of materials (HHI) in source countries

Many authors point to the influence of changing balances of power in the world and the risks associated with these, in combination with the fact the extraction of many mineral raw materials is limited to just a few source countries. Data from the USGS Mineral Commodity Summaries and Yearbooks shows that, with the exception of gold, for silver, tellurium, copper and nickel, more than 50% of all raw material supply considered here comes from just three source countries. China is obviously the dominant player. Other very dominant players (>80% of global production) are Brazil (for niobium, Nb) and the US (for beryllium, Be).

The formation of monopolies undoubtedly leads to an increase in risks with regard to the security of raw material supply. Monopolies lead to greater market power and to the ensuing potential effects on price. Monopolies also lead to portfolio risk (all eggs in one basket). Risks that are by no means correlated (for example environmental disasters) lead to greater supply risks where regional concentration is greater.

The degree of monopoly forming is expressed in most studies using the so-called **Herfindahl-Hirschman Index (HHI)**, which is composed of the total sum of squares of the extraction concentrations per source country. This is an accepted standard for concentrations in a sector (in this case, source countries). The HHI is the sum of squares of the production percentages. The maximum value is therefore 10,000 (one country produces 100% of the total volume). The EU study into critical materials subsequently weighs the contributions to this HHI per country to the **World Governance Index (WGI)**. This increases the contribution of

unstable countries to this risk factor. In this study, the (weighted) WGI per raw material is included separately as an indicator (see following section). The

concentration of production in source countries is included as a relevant indicator of supply insecurity in the short term: this is referred to as the HHI_{prod} .

The same comparison can also be incorporated into a risk analysis for the long term: in determining the concentration and thus the HHI, this means that the estimation of the geographical distribution of economically viable resources (as reported in the USGS Mineral Commodity Summaries; the data reported in 2015 is included here) is relevant, rather than current production: this is referred to hereafter as the HHI_{res} .

An overview of the HHI_{prod} and the HHI_{res} of those raw materials which are largely mined or with proven reserves in only a few countries ($HHI > 2,500$) is given in Figure 13. A value greater than 2,500 is seen (by the US Federal Trade Commission at least²³) as highly concentrated.

The HHI_{prod} or HHI_{res} is less than 2,500 for just 18 of the 64 materials considered here; all other materials are therefore to be regarded as a highly concentrated.

For a number of materials, the estimation of the concentration of recoverable reserves per country is substantially lower than that of current production. This is particularly true for magnesium, the rare earths group, tungsten, iron ore, antimony and tin, all materials where China currently plays a dominant role in production.

There are also a number of materials for which the geographical concentration of reserves is significantly higher than the current concentration of production. This is especially true for the platinum group metals (South Africa holds virtually all reserves), phosphate (P_2O_5 , with considerable concentration in Morocco and Western Sahara), lithium (high concentration of reserves in Chile and China) and zircon.

²³ www.justice.gov/atr/public/guidelines/hmg-2010.pdf.

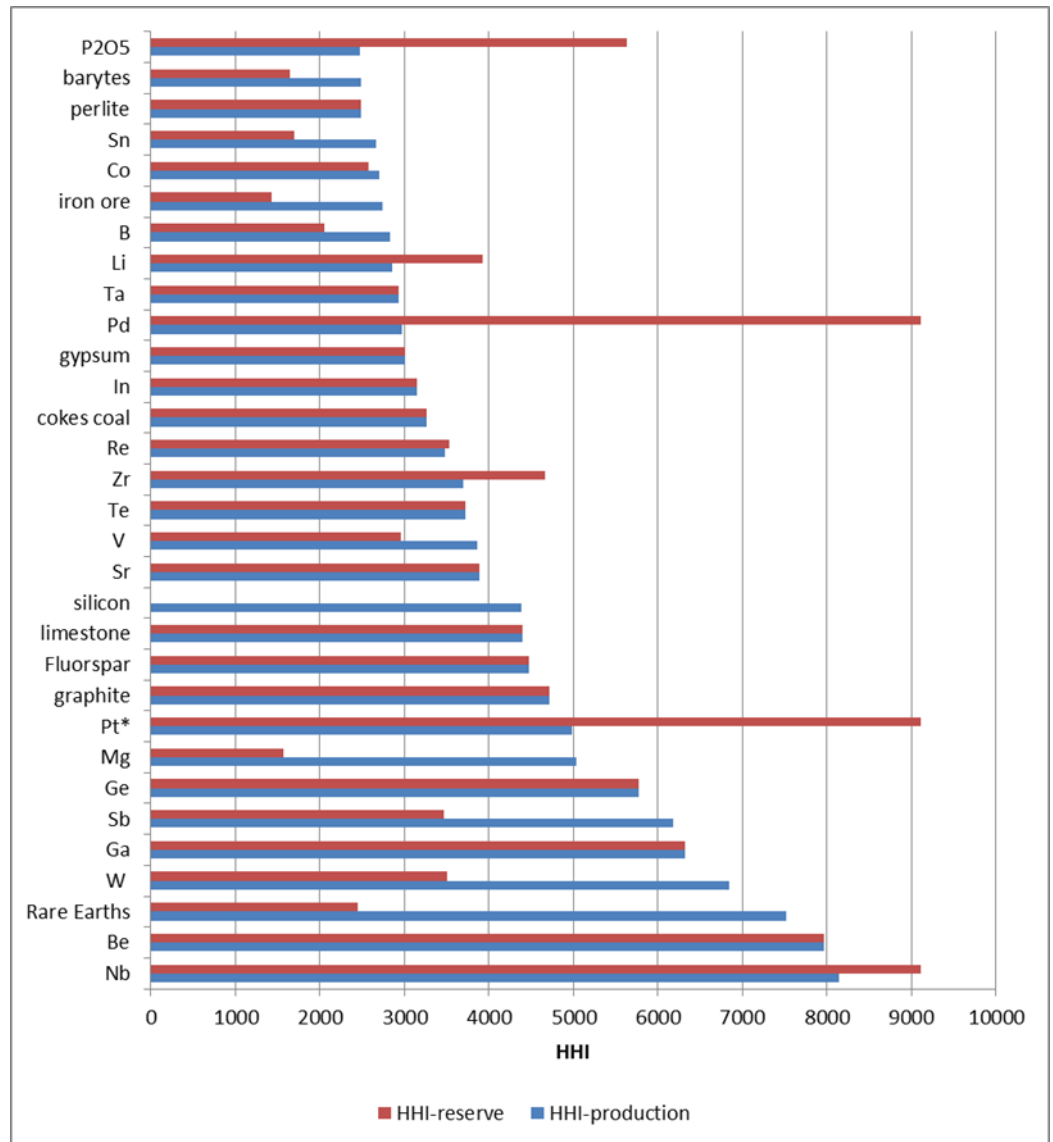


Figure 13 Raw materials with an HHI in excess of 2,500

3.3.4 Geopolitics: The stability and quality of governance in source countries as indicated by the WGI

A weighted approach to determining the potential adverse effects of a high source country concentration is to relate this to indicators designed to assess the stability and reliability of countries as trading partners. The potential adverse effects of high raw material concentration are greater where the government of the source country is less reliable. A commonly used indicator for this is the World Governance Indicator (WGI, an indication of the form of government in a country) (based on World Bank data) of the source country. The World Governance Indicator is based on indicators for 215 economies between 1996 and 2012²⁴, in which six aspects of government are measured:

²⁴ From <http://info.worldbank.org/governance/wgi/index.aspx#home>: "These aggregate indicators combine the views of a large number of enterprise, citizen and expert survey respondents in industrial and developing countries. They are based on over 30 individual data sources produced by a variety of survey institutes, think tanks, non-governmental organisations, international organisations and private sector firms."

- Voice and accountability;
- Political stability and absence of violence;
- Governmental effectiveness;
- Regulatory quality;
- Rule of law;
- Control of corruption.

In this study, the weighted WGI per raw material is calculated on the basis of the WGI score of a given country and the share of raw material production in that country. The WGI is included only in the short-term (and medium-term) vulnerability assessments, in respect of the fact that local governance may change considerably over a period of ten years or more.

To illustrate the significance of the WGI, the 10 source countries with the highest (i.e. most stable) WGI score and the 10 source countries with the lowest (<0) scores are shown in the table below (note: when used as an indicator, the WGI score is converted such that the poorest performing countries receive the highest score).

Table 5 Countries exhibiting best and worst WGI scores

WGI 10 best scores among raw material suppliers	WGI 10 worst scores among raw material suppliers
Denmark	Burma
Finland	Zimbabwe
Sweden	Iraq
Norway	Uzbekistan
Australia	Venezuela
Canada	Burundi
Austria	Guinea
Iceland	Iran
Republic of Ireland	Pakistan
Germany	Syria

An important country such as China has a score of -0.59 and therefore takes 21st place, on a par with Kazakhstan.

In Figure 14, the weighted average WGI for each raw material versus the HHI_{prod} for the raw material in question²⁵ is shown. It should be clear that the combination of a high HHI_{prod} and a low (<0) weighted WGI contributes to supply risk.

²⁵ An index more focused on mining investment is the Policy Potential Index (PPI), which is produced annually by the Fraser Institute on the basis of hundreds of surveys completed by mining investors. The questions focus on aspects such as uncertainty in legislation and regulations, pricing etc. Although potentially a very relevant parameter, and one which is also more closely related to the mining sector, the PPI will not be included as a weighting factor in the current study: of the 88 countries that play a role in the supply of the raw materials considered here, the PPI is known for only 42. There is therefore insufficient coverage for this index to be taken into account as an indicator of security of supply.

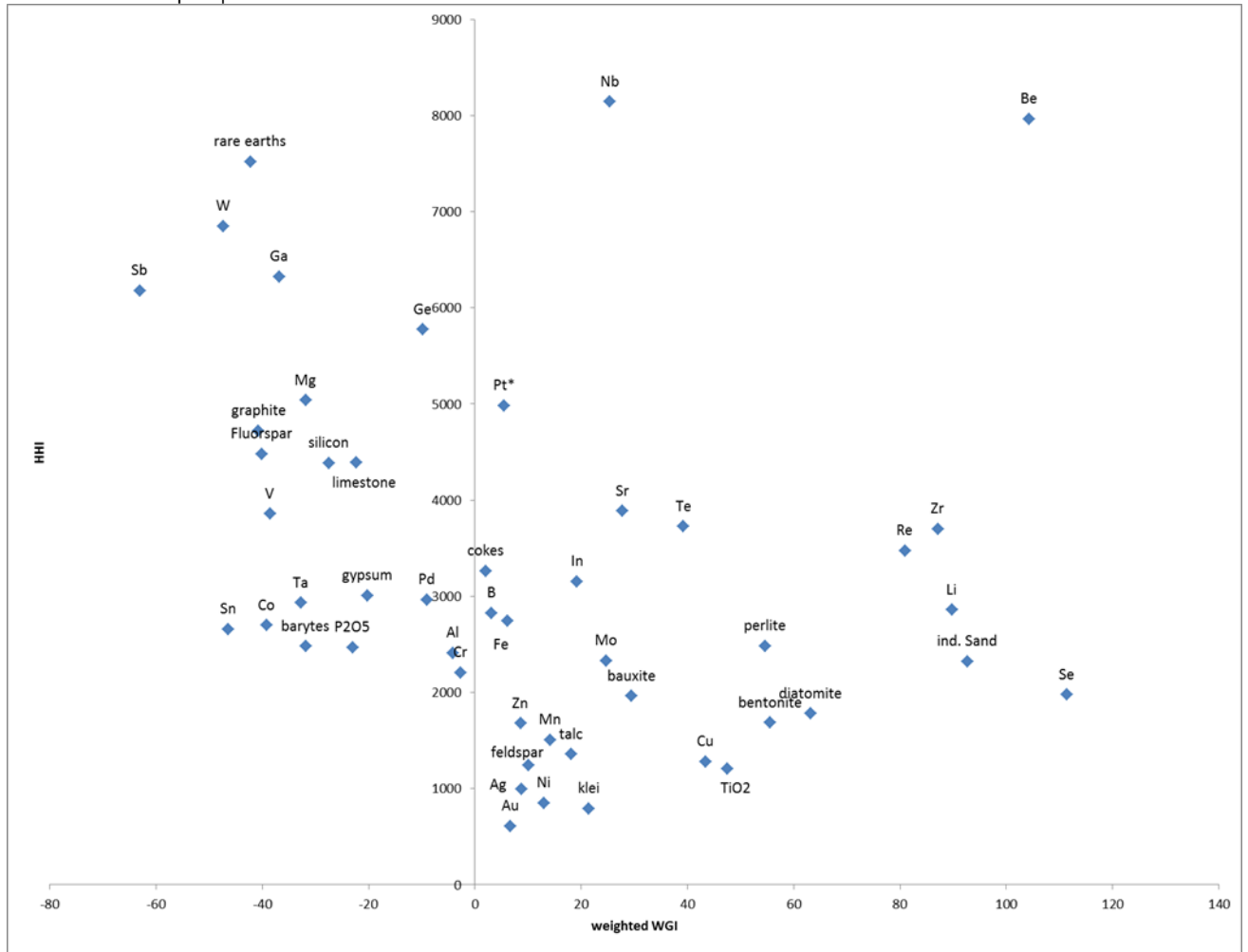


Figure 14 Weighted WGI vs. HHI_{prod} ; upper left quadrant: high concentration in countries with low (=poor) WGI

The 5 materials with the highest country concentration and a low (<0) weighted WGI are the rare earth metals (as a group), tungsten (W), antimony (Sb), gallium (Ga) and germanium (Ge). Other metals with a low weighted WGI are tin (Sn), cobalt (Co), vanadium (V), fluorspar, graphite and tantalum (Ta).

The position of tin, tantalum and tungsten in this summary is notable. These raw materials – along with gold (Au), which has a very low country concentration – form part of the so-called TTTG group and are known as conflict minerals for which US regulations pertaining to the transparency of the supply chain already exist and for which EU regulations are being considered.

3.3.5 Geopolitics: Existing export restrictions (OECD data)

An interesting indicator for use in relation to a dominant position is the extent to which **export restrictions are imposed by a source country**. The data held by the OECD covers 72 countries (the EU is considered as one region) for the period 2009-2012 and 80% of the global production of minerals, metals and timber. The measures cover prohibitions on export and export restrictions, export duties, licensing requirements and obligations in relation to the local market. There is a strong dynamic and growth in such measures: 75% of all the measures that were in effect in 2012 had been introduced after 2007.

The work of the OECD on export restrictions on raw materials²⁶ shows that, for a large number of materials, China has indeed imposed such measures.

Table 6 Summary of measures reported by OECD (year: 2011) by source countries

	Export Quota	Export taxes	Licensing Requirement
Au	-	China (ore)	Russian Federation
Silver	China (5522t) (temp)	China (ore) (temp)	-
feldspar	-	-	Malaysia
barytes	-	China (10%) (temp) India (20%, according to neighbours)	-
Tungsten	China (17.3 kt)	Bolivia China (5%)	China
Germanium		China (5%)	China
molybdenum	China (4000t)	China (5%)	China
fluorspar	China (550 kt)	China (15%)	-
magnesite	China (1230 kt)	China (5%)	China
zircon	-	China (10%)	-
Niobium	-	China (30%)	Russian Federation
Vanadium	-	China (30%)	Russia, South Africa,
tantalum	-	China (30%)	Rwanda
antimony	-	China (10-20%), Bolivia	China, Russia, Tajikistan
RE metals, yttrium, scandium	China (31 kt)	China 25 India (20%)	China
Cerium compounds	China	China (15%)	China

This means that, for the 22 minerals for which China's share of global production exceeds 30%, nine raw materials are subject to export restrictions. These include materials where Chinese dominance is the greatest: rare earth metals, antimony, tungsten, magnesium and germanium.

Aside from China, export restrictions are only known for Bolivia, Russia, South Africa, Malaysia and Tajikistan. Export quotas are only in relation to China.

²⁶ See: <http://www.oecd.org/tad/benefitlib/export-restrictions-raw-materials.htm>.

A corresponding indicator to be used in determining criticality consists of the proportion of raw materials in global production that has been affected by prohibitions or restrictions on export during the past five years. The data for this can be found in Figure 15.

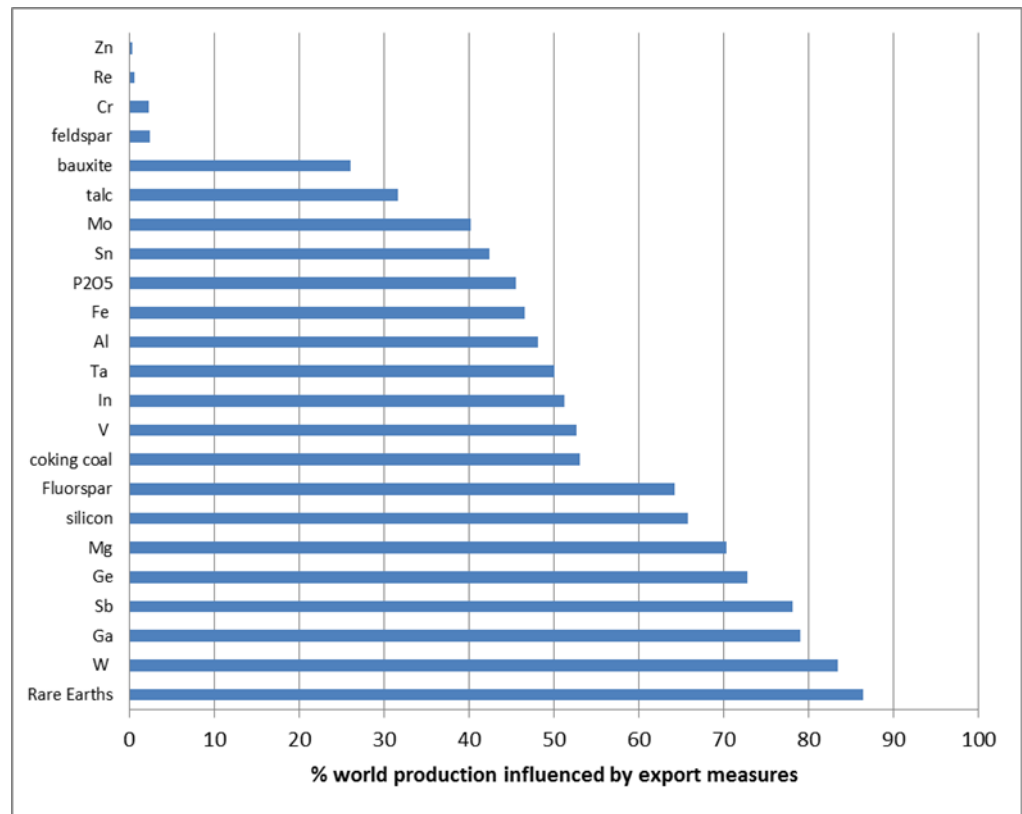


Figure 15 Share of world trade affected by export restrictions

3.3.6 *End-of-life recycling rate*

The current study focuses on the problems associated with the supply of raw materials. The import of materials and goods leads to the formation of a so-called “urban mine” in our society, a supply of raw materials stored in our infrastructure, capital investments and the products we consume. In the coming decades, recycling will become an ever more important source of materials and must ensure that the depletion of resources proceeds at a slower pace²⁷.

²⁷ It is important to note that the role of recycling is important here because of the large proportion of metals in the list investigated. Thanks to good process technologies, metals often retain their quality. For biotic materials, this situation is more complex. Where recycling does take place, it will often lead to a decline in quality and hence value. The recycled material is in such cases no substitute for “virgin” material.

When such materials become available through recycling processes, our dependence on source countries will be reduced, provided that recycling and any subsequent processing of the recycled materials takes place here. The precise details of the nature and above all the location of recycling are currently very unclear. An overview of so-called end-of-life recycling rates (EOL-RR, the degree to

Challenges in recycling

Recycling is at present mainly commercially driven and is therefore limited to materials that produce sufficient returns from recycling, which in many cases means that they must be present both in sufficient quantities and in sufficiently high concentrations in the supplied waste. Many of the elements in modern electronics are only present in limited quantities and/or in a complex matrix with many other materials. As a result, only a small proportion of the materials in complex equipment is recycled. This is less true for materials in a variety of steels and other alloys and for so-called production waste. Both of these types of waste reach processors in acceptable concentrations such that commercially viable recycling is possible. The complex metallurgy of materials means that it is not necessary to present metals in their purest form for recycling; when metals in ores can be separated from one other (see section 2.2.3, addressing companionship), a recycling process that can separate such materials is generally available.

which recycling at the end of life of used goods occurs) – based on the data in the UNEP report “Recycling Rates of Metals”²⁸ – is given in Table 7. In this table, EOL-RR represents the percentage of materials concerned that are recycled in the end-of-life stage. RC stands for Recycled Content and represents the percentage of material on the market that consists of recycled material. The table is sorted in order of decreasing volume of end-of-life recycling.

Table 7 Overview recycling rate

	EOL-RR (%)	RC (%)		EOL-RR (%)	RC (%)
Cr	90	19	W	46	40
Sn	75	22	Al	43	35
Fe	70	40	Zn	40	23
Pt²⁹	70	20	Mg	39	33
Ag	65	30	In	0	38
Pd²¹	65	21	Co	32	68
Ni	60	35	Mo	30	33
Rh	55	40	Ir	25	17
Mn	53	37	Sb	20	5
Nb	53	22	Ta	5	20
Au	50	30	Re	17	60
Cu	50	30	Ru	10	55

²⁸ UNEP report Recycling Rates of Metals, editor: International Resource Panel; lead author: M. Reuter, 2011.

²⁹ For platinum and palladium, the detailed information about recycling taken derived from the 2015 Status Reports by Thomson Reuters. Recycling of these materials comes almost entirely from the recycling of automotive exhaust catalysts.

On the basis of this data, an estimation can be made of how much material should in principle be available based on imported goods.

The data can also be used to give a more detailed picture of the number of “source countries” that supply refined materials to the market. “Source countries” in this case are countries where recycling itself takes place. However, the data necessary for such a detailed view is lacking. The large number of companies that carry out metal recycling in Europe (from innumerable scrap processors to highly specialised companies such as Umicore that recycle materials including the platinum group metals, copper, silver, gold, antimony, tellurium, selenium, indium, nickel, tin, germanium, zinc and cobalt from production waste and electronics using metallurgical process technology) suggests that the supply of several of these materials from secondary sources can occur within Europe. This portrays the global supply situation in a more positive light. The situation for platinum and palladium (source: 2015 status reports from Thomson Reuters) is illustrative: whereas the weighted WGI for platinum and palladium as raw materials is 5.5 and 13 respectively, the weighted WGI improves to 25 and 35 respectively when the supply of recycled materials is taken into account. It is this argument in particular which has led to the decision to directly incorporate the EOL-RR in this study as a factor that reduces the criticality of raw materials.

3.4 Impact on operating profit: price volatility of (raw) materials

Increasing and varying raw material costs affect operating profits and – particularly in the case of an uneven playing field – competitiveness. Concerns about operating profits are therefore important at both corporate and national level.

It is a fact that the price volatility of mineral resources is high and has increased since the turn of the century. Price volatility can have various causes. It may arise as a result of an imbalance between supply and (for some applications rapidly) increasing demand, export restrictions or speculation on the commodities market.

The effects on the supply side include uncertainty of the profitability of mining investments, which leads to shortages in the long term. In this sense, price volatility could be an indicator of a risk of supply uncertainty in both the short and long term. The same applies to the phenomenon of “supply shocks” (moments where a sudden decline in production leads to an immediate price increase).

On the demand side, price volatility may lead to problems when prices cannot be passed on to customers and where a “level playing field” for producers in different countries does not exist. The influence of this depends strongly on the contribution made by the cost of this raw material to the cost of the final product.

To determine effects on operating profits it is sufficient to know the price volatility per raw material and an estimation of the quantities of a raw material that are used. The latter estimate can be obtained using the methodology given in Appendix A. Price volatility can be expressed in different ways. In a previous report³⁰ we introduced the **MAPII, the Maximum Annual Price Increase Index**, a measure of

³⁰ MIDNE1

the maximum relative price increase that has occurred during the past 20 years. The MAPII represents the highest price increase per year in that period, divided by the price of raw materials at the beginning of the year with the highest price increase. A MAPII of 1.0 means that the price rose by 100%, i.e. doubled, during a given year during this period. Using the MAPII, the impact of price volatility on a product or product group can be determined as follows:

$$\sum_{x=n}^m ((MAPII_x \cdot P_{2011_x}) \times TS_x) \times \frac{W(import)}{V(import)}$$

In this formula, $MAPII_x$ is the maximum annual percentage increase in the price of a raw material (determined for the period 1990-2011), P_{2011_x} is the price level in 2011 of the raw material, TS_x is the characteristic proportion of a raw material in a particular product group, $W(import)$ is the weight of the volume of imports of all products within a product group and $V(import)$ is the value of imports of all products within that product group. The price developments are based on fragmentary data gathered from the USGS Mineral Commodity Summaries. The price developments reported there are based not only on a variety of sources but also on different product qualities. Notwithstanding these limitations, however, it is possible to generate a clear picture of the extent to which prices may fluctuate from year to year in the worst-case scenario.

The impact of such price increases is dependent upon the situation, the sector and the position of the company in the value chain. As such, the impact is greater as the proportion of the total product range increases, and when any price increases cannot be passed on to customers.

An overview of the MAPII for the raw materials considered here is given in Figure 16.

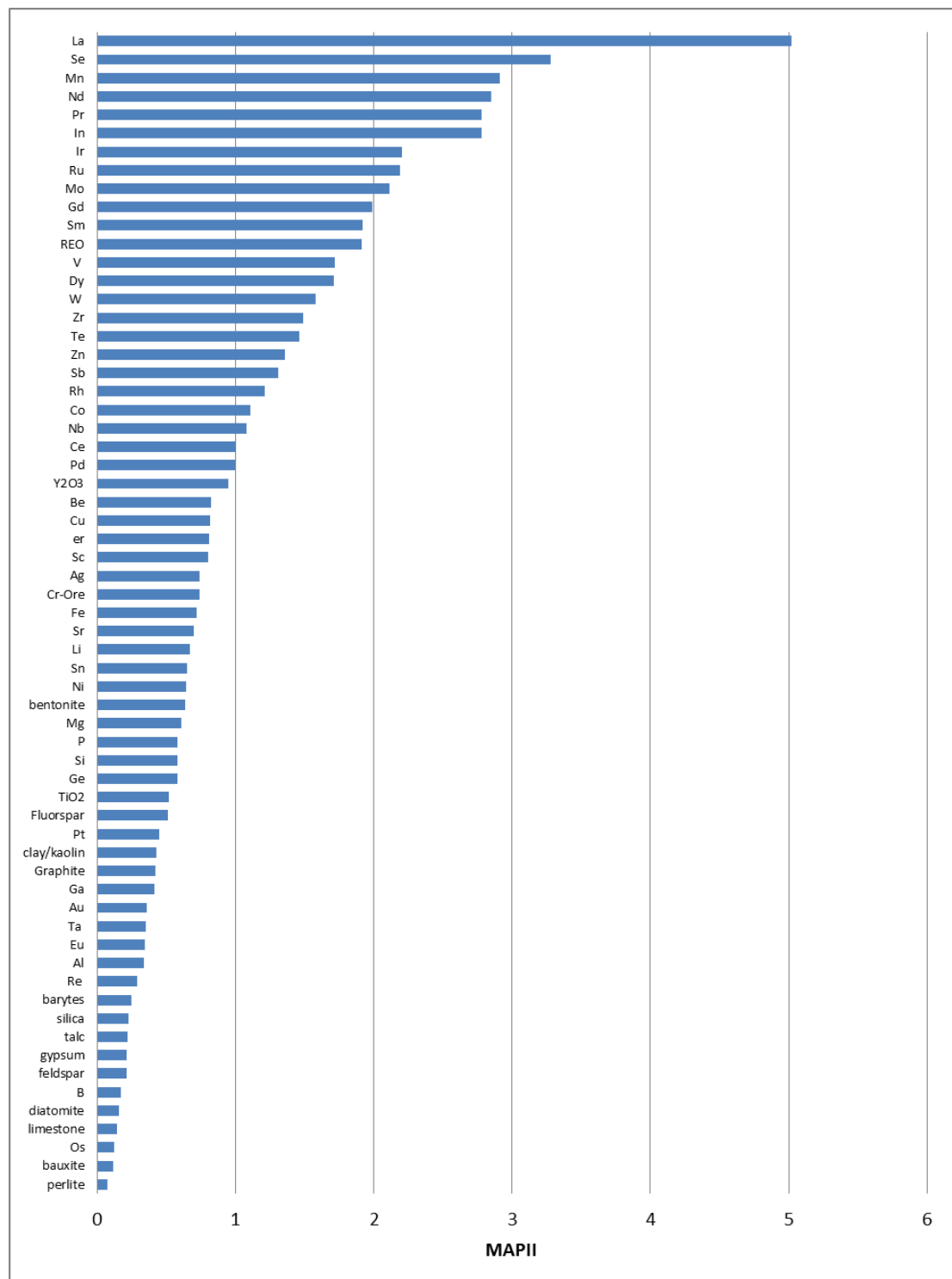


Figure 16 MAPII of selected raw materials

3.5 Impact on corporate reputation

In chapter 1, reference was made to the fact that certain aspects of raw material extraction (for example the impact on the environment or on local working conditions) can have a negative impact on corporate reputation. Such external

effects in the extraction of raw materials may also determine the direction of the foreign policy of national governments.

Below we will discuss various aspects that may affect corporate reputation.

3.5.1 *Environmental impact of resource extraction*

Awareness of the environmental impact of the mining and refining of raw materials can be important in – for example – being prepared for criticism and in seeking possible alternatives that are less damaging to the environment. Since this study links raw materials with their use in products (including when an individual company may not be aware of this), such information with regard to raw materials at the product level will be included in the self-assessment tool to be made available to companies³¹.

3.5.1.1 *Introduction and methodology*

Raw material extraction is a process that necessitates the intensive use of water, energy and chemicals. This process can be seen as potentially damaging to the environment. Increasingly, information about the environmental impact of raw materials is important for companies that want and need to take account of the impact of their (direct or indirect) raw material needs.

In order to arrive at an understanding of the environmental impact of the raw materials considered here, the environmental impact of extraction and of that part of the production stage necessary to arrive at a basic product are included; (emissions during) usage, maintenance, replacement and disposal scenarios are not included. Determining the environmental impact is not therefore a complete life-cycle assessment (LCA). However, the methods for data collection and analysis that are customary in LCAs have been followed. This means that all inputs and outputs to the entire extraction process of a particular raw material are summed and divided into various environmental effects so that the total environmental burden may be determined. The inputs in this case are the raw materials and also intermediate products. Outputs include emissions to the soil, water and atmosphere and waste.

Methodology used to determine environmental impact

In Appendix C: Environmental impact of raw material extraction, the methods and principles used in the calculations are described in detail; this section includes an abbreviated description. The data sources were the leading international LCA database ecoinvent 3.0 and (scientific) LCA articles on raw material extraction. The environmental impact was determined on the basis of the LCA program SimaPro v8.0.6 and the impact assessment method ReCiPe v1.11 (Cheap, et al., 2009). The results have been determined both at midpoint level (measurable environmental effects such as CO₂ emissions, acidification, etc.) and at endpoint level (damage at a higher level such as to ecosystems, health and resources). Weighting has been applied in order to summarise the results and to compare different effects with one another. When considering the endpoint results, there is an overlap with other indicators. This is because “resources” are included in the endpoint calculations. There is no overlap in the midpoint results, since “resource depletion” is multiplied by a weighting factor of 0.

³¹ This study employs an LCA methodology based on ReCiPe midpoints; other methods such as the EPI (Environmental Performance Index) are discussed in chapter 5 as part of a research agenda.

3.5.1.2 Results and interpretation

The results of the environmental analyses are shown in Figure 18; detailed results can be found in Appendix C. The figure shows all environmental impact categories at midpoint level (weighted by means of shadow prices).

The degree of uncertainty in the results is considerable (margin of error factor 2). A number of conclusions may nevertheless be drawn:

- In terms of environmental impact, gold and the platinum group metals stand out far beyond other raw materials (caused by greenhouse effect but also particulate matter formation; see Figure 17). A major cause of this high score is the high monetary value of these materials, which plays a role in the distribution of environmental effects across various co-products.
- In contrast, the rare earth metals have, in all regards, a strikingly low environmental impact.

In order to make meaningful statements about the differences in environmental impact per extraction region, or to find more environmentally friendly alternatives, a more comprehensive LCA study is recommended.

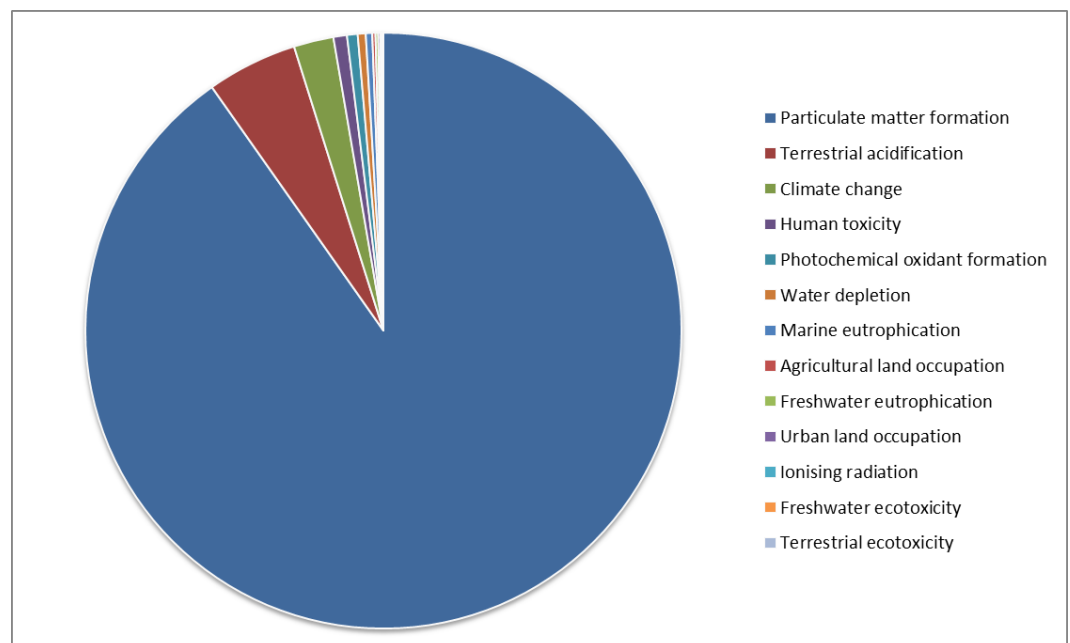


Figure 17 Structure of the environmental impact of platinum (total: € 33.58 / kg)

Materials in the Dutch economy

- A vulnerability analysis -

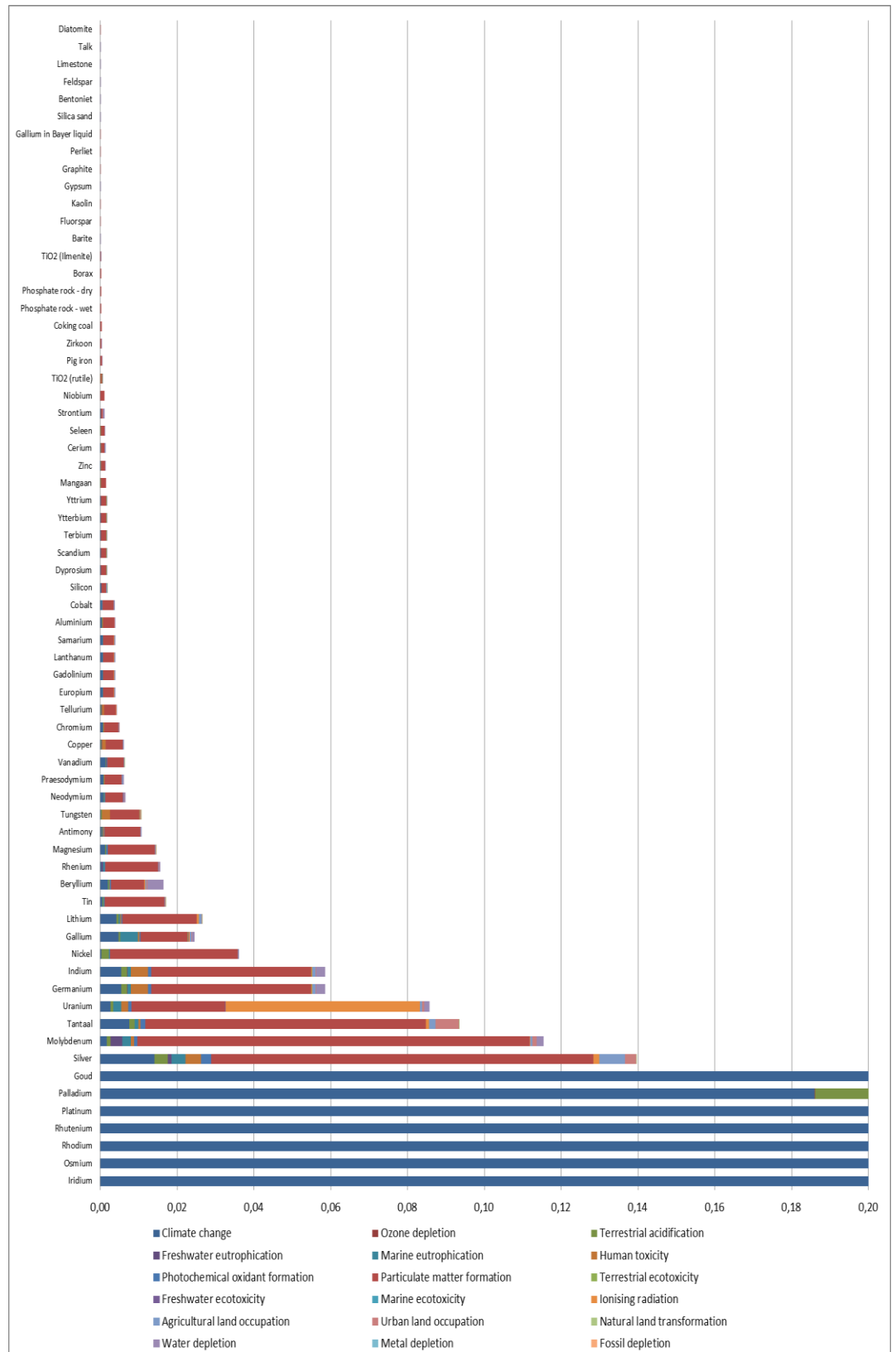


Figure 18 Environmental analysis of raw material extraction on the basis of midpoint effects on the environment and shadow prices per kg of raw material extracted. (The Y axis has been truncated due to the extremely high scores for gold and the platinum group metals).

3.5.2 Performance of source countries in terms of human development (Human Development Index HDI)

One of the factors indicating the relationship between potential social problems and raw materials is the human development index (HDI)³². The HDI is roughly composed of: life expectancy, average years of schooling, expected years of schooling and gross national product per capita.

In Figure 19, the HHI_{prod} for the chosen raw materials is compared with the weighted HDI for those materials. (Note: when using this indicator for criticality analysis, the HDI is recalculated so that the best performing countries have a low HDI score).

Tantalum and cobalt are prominent: the important role of the African Great Lakes Region and the extremely low HDI in that area means that these materials stand out negatively.

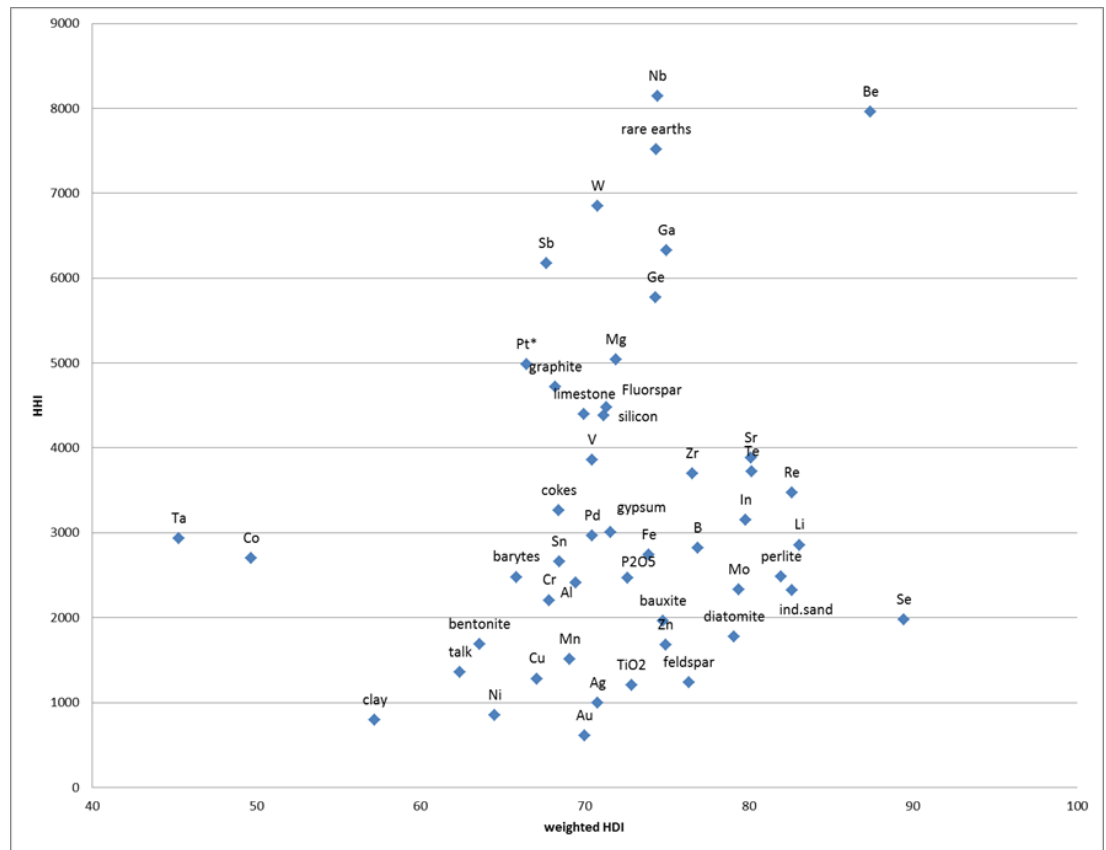


Figure 19 HHI_{prod} vs. weighted HDI

3.5.3 Regulations pertaining to conflict minerals

A factor with a particular influence on corporate reputation, with repercussions for the entire supply chain, is the debate on the import of conflict minerals. The European Commission has designed a system that should lead to an end to imports of certain minerals (tin, tantalum, tungsten, gold (TTTG)) from conflict areas (“‘conflict-affected and high-risk areas’ means areas in a state of armed conflict,

³² “The Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living.” The HDI is compiled and reported by the UN Development Programme

fragile post-conflict as well as areas witnessing weak or non-existent governance and security, such as failed states, and widespread and systematic violations of international law, including human rights abuses”) by European refiners and smelters. These regulations are similar to those adopted by the US government via the Dodd-Frank Act. The Dodd-Frank Act imposes specific requirements for the traceability of tin, tantalum, tungsten and gold in respect of the export of products containing these materials to the United States. That means that information about these four materials is relevant not only to reputation but also as regards the export situation.

The consequences of these regulations for individual companies are obvious. The implications this issue has for the Dutch economy can be demonstrated by making the link between the use of these materials and sectors. This will be described in more detail in chapter 4.

3.6 Indicators: A global overview and/or one focused on the Netherlands

Existing publications on critical materials are based on data from global databases of production, reserves, and information about (for example) the stability of source countries. These are relevant overviews as they give a global impression of the potential risks to the global availability of raw materials.

This study provides a detailed picture of the situation with regards to raw materials in the Netherlands. By establishing a link between materials, products and subsequently sectors, it is possible to form an impression of the (first) countries of origin both at the level of imports of raw materials and first intermediates (these are materials made from raw materials that include the name of the raw material in the nomenclature, e.g. copper ore is a raw material, copper sulphate and copper wire are first intermediates) and on the import of intermediate and final products (and the raw materials they contain). Such a detailed overview may differ significantly from the overall picture. For example, the number of countries from which imports are sourced is in general smaller than is possible at the global level (i.e. a larger HHI_{prod} at national level), but the reliability of the environmental performance of these countries may be better than the global picture. This can lead to a risk analysis focused on the Netherlands that differs from a global analysis or an EU-oriented analysis.

3.7 Prioritisation of vulnerabilities

A complete analysis of the extent to which the Dutch economy is dependent on the various raw materials is carried out in the following chapter. In this section, the 64 metals and minerals are prioritised on the basis of both the indicators for the long-term and short-term security of supply and indicators related to the Corporate Social Responsibility (CSR) of companies (influence on corporate reputation). Section 3.4 included a prioritisation on the basis of price volatility (impact on operating profits). In the table below, a distinction is made between a set of indicators aimed at the long-term security of supply (more than 10 years, indicated by ‘L’) and the shorter term (indicated by ‘S’).

Indicator	Scale	period
Geo-economic: Reserve / Production (R / P)	Highest R/P = 0 Lowest R/P = 1	L
Geo-economic: companionality (extent to which the raw material is a by-product)	100% companion = 1 0 % companion = 0	L
Geopolitical: country concentration of reserves of materials (HHI _{res})	HHI 10000 = 1 HHI 0 = 0	L
Geopolitical: country concentration of extraction of materials (HHI _{prod})	HHI 10000 = 1 HHI 0 = 0	S
Geopolitical: the stability and quality of governance of source countries indicated by WGI	100% of raw materials from country with worst WGI score = 1 100% from country with best WGI score = 0	S
Geopolitical: existing export restrictions (OECD data)	100% of production affected by restrictions = 1 0% affected by restrictions = 0	S
Impact Recycling	0% EOL-RR = 1 100% EOL-RR=0	S

The long-term security of supply of raw materials is considered low in this study where geo-economic reserves are low OR where country concentration (for reserves) is high OR where raw materials consist largely of “companions”, such that production facilities are relatively limited. In a formula:

$$\text{Criticality}_{LT} = \text{HHI}_{res} + 1(\text{R/P}) + \% \text{companionality}$$

This system leads to the following table of long-term critical materials:

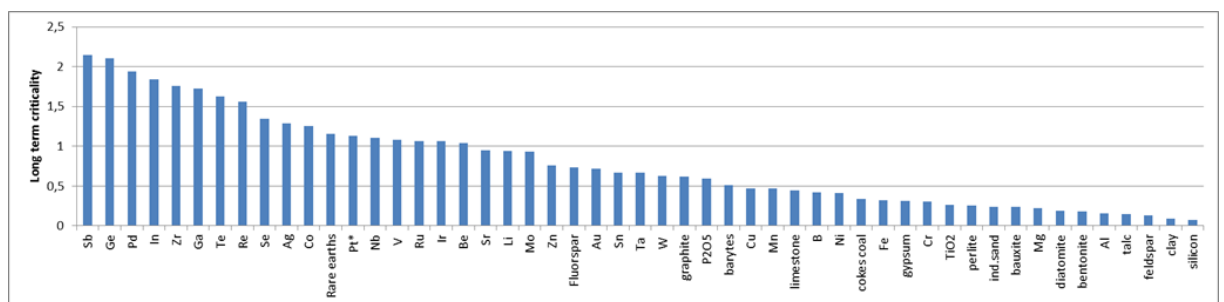


Figure 20 Long term criticality of raw materials

Construction minerals with high and therefore undefined reserves now emerge as the least critical materials.

The short-term security of supply of raw materials is considered low in this study where the source country concentration is high AND where the source countries have a mediocre World Governance Index and have proven willing to impose export restrictions AND where recycling of end-of-life products is low. In a formula:

$$\text{Criticality}_{KT} = \text{HHI}_{prod} * (\text{WGI}_{weighted} + \text{OECD restrictions}_{weighted}) * (1-\% \text{EOL-RR})$$

On the basis of this system, the order of criticality of the materials studied here is as follows:

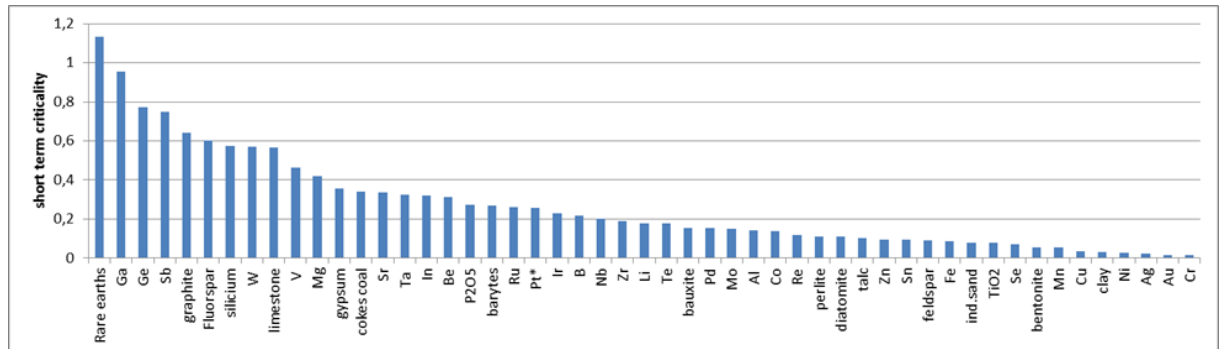


Figure 21 Short-term criticality of raw materials

Materials to which a high recycling rate is attributed have low criticality. Materials without recycling and a high source country concentration with active politics concerning resource nationalism have a higher criticality.

The available data can also be used to prepare a composite CSR indicator. On the basis of the indicators from Table 4, a CSR indicator can be composed from the normalised values of the weighted HDI for a raw material (corrected for 100% production from the land with the highest HDI: 0.994), the degree to which a raw material is regarded as a conflict mineral (1 or 0), and a normalised value for the environmental impact (between 0 and 1, based on data given in Figure 18). The result is given in Figure 22.

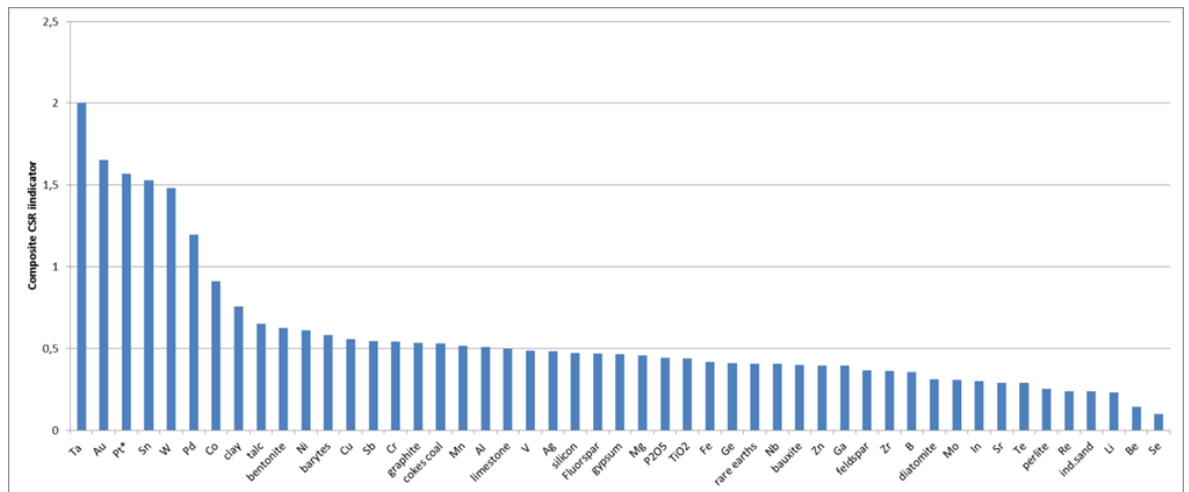


Figure 22 Composite CSR indicator for raw materials investigated

With this calculation method it is not surprising that the most unfavourable CSR indicators are recorded for tantalum, gold, tin and tungsten (all four conflict minerals), platinum and palladium (and other PGM materials) (by far the greatest environmental impact) and cobalt (and tantalum), due to the most adverse HDI scores.

Figure 23 shows this CSR indicator for each raw material against short-term criticality.

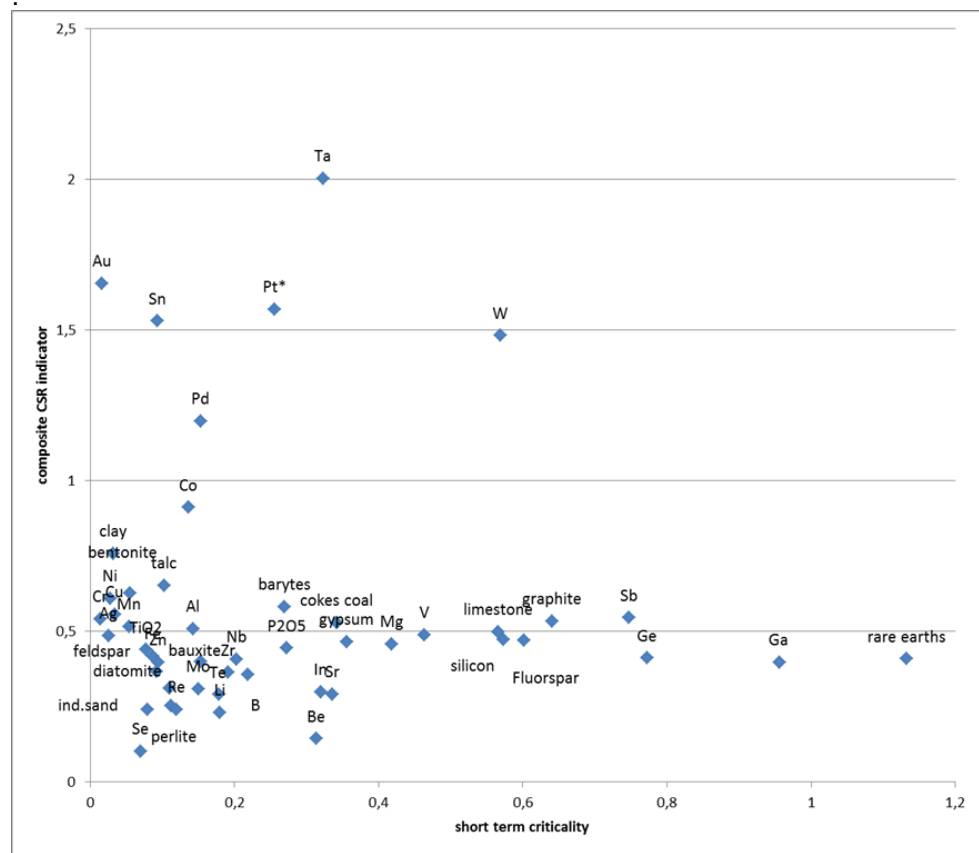


Figure 23 Short-term criticality vs. CSR indicator

4 Critical materials for the Dutch economy

4.1 Economic importance of raw material use

The Dutch economy is largely a service economy. In terms of industrial output and exports, the economy is foremost dependent on the extraction of natural gas and oil, and the production of agricultural crops and food products. When it comes to the use of abiotic materials, the Dutch high-tech equipment industry is at the forefront. The core question here is to what extent this sector makes use of raw materials in crude or processed form, and in the case in processed materials to what extent in components and sub-assemblies.

To get a clear picture of both the direct and indirect dependence of the Dutch economy on raw materials, the relation needs to be determined between raw materials and their application in processed materials, intermediate and final products. In particular, the complex information regarding their application in final products is not available.³³ A model has been developed, described in Appendix A,

which establishes links between raw materials and their level of application in products, economic sectors and the Dutch economy in general.

In the first place it is necessary to understand the application of these raw materials in intermediate and final products. An individual assessment of the application is impossible given the enormous complexity of trade and products. However, the method used as the approach in this study involves allocating resources to the more than 5000 product categories of the Harmonized System (partly on the basis of product databases, Life Cycle Analysis databases, insight into global statistics regarding applications and overall production volumes, detailed explanations and literature references are given in Appendix A) and then linking these products and product groups to economic sectors (the coupling matrix). The latter is possible because the official product classifications correspond to official sector classifications.

This analysis is initially concerned with the qualitative link between raw materials on the one hand and products on the other. When estimating the economic impact, we assume that the quantity of material does not matter, but that each material is essential for the quality of the delivered product and therefore the related competitiveness of the company concerned.

On the basis of the analysis, however, a rough idea can be obtained of the so-called typical share of a raw material in the

The value of qualitative and quantitative composition data

For a vulnerability analysis of the Dutch economy, in many cases a qualitative assessment OR a material used in a given product is sufficient. For example, as actuators in cars (for example for electric windows) magnets based on rare earth elements are relevant, although in this case weight and costs are irrelevant, only availability is relevant. Since, no magnets means no electric windows, which drastically undermines competitiveness. This applies to many products where no easy substitute is available: when foreign parties do have access, but we do not to certain semi-finished products, then the Dutch products will find themselves in a poor competitive position.

A quantitative assessment is important if we want to know the effect of price increases or volatility in competitive: at a weight moderately low stakes (like the example above) will have an increase little to no effect on competitiveness, while a high weight sensitivity to price is high.

Qualitative assessments can be carried out here with greater precision, making them of considerable valuable to a thorough vulnerability analysis.

³³ This is confirmed in the report "Data Needs for a Full Raw Materials Flow Analysis" published by DG Enterprise & Industry on September 7, 2012, conducted by Risk & Policy Analysis Ltd. (RPA) under Framework Contract ENTR / 2008/006, Lot1.

final product. For typical important products of or for the Dutch economy, this material share can be given in more detail based on databases such as Ecoinvent. These quantitative assessments can be used to investigate the impact of price volatility in sectors or to provide an estimate of the extent to which the Netherlands could meet its raw material needs by recycling.

4.2 Imports of mineral raw materials in the Dutch economy

It is generally assumed that the Netherlands imports considerably more mainly intermediate products and components for industrial production than it does pure raw materials. However, this is an oversimplification. The data derived from the coupling matrix provides a much more complete picture of the total import and hence forms of materials entering the country.

Official statistics distinguish raw materials, intermediate and final products. In particular the group of intermediate products include goods at different stages of production: refined raw materials, base metal products, plastics, components, assembly parts etc. We propose an additional group of substances, called the 'first' intermediate products (1st intermediates). This relates, in general, processed materials, such as chemical compounds. In identifying these 1st intermediate products the criterion is used that the name of the actual raw material forms part of the label of the product group.

In the following sections, an overview is given of each of these four goods flows (raw materials, 1st intermediate products, intermediate and final products) and their relationship to the Dutch economy.

4.2.1 *Import as raw material: volume and origin*

Figure 24 gives a visual representation of the total volume of imports of materials investigated here as raw material, in the true sense of the word: i.e. in the form of raw materials (at least according to the qualification attributed to this by Eurostat).

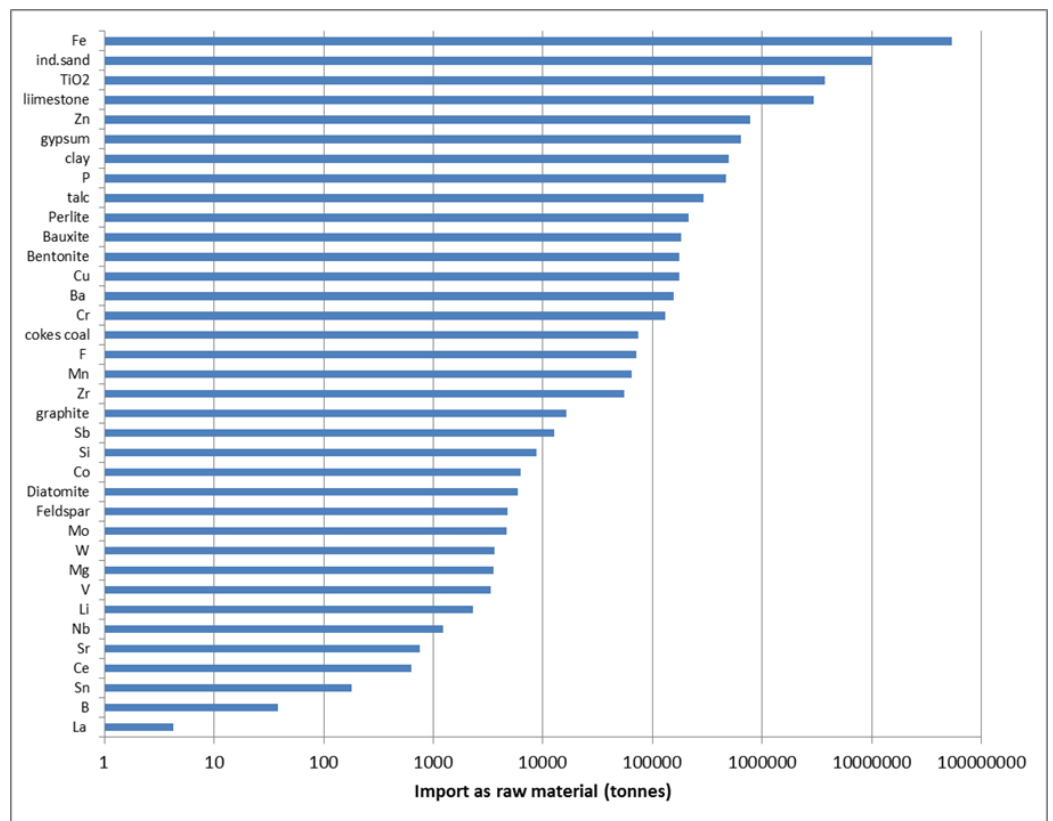


Figure 24 Imports of raw materials to the Netherlands

This summary does not compensate for the so-called re-exports.

These figures have more context when compared to the annual global production; in this way we obtain a better picture of the relative importance of Dutch raw material imports (Figure 25; included: those materials where the import is more than 1% of world production). Incidentally, these figures are also not adjusted for re-exports of raw materials.

These figures should be seen in the light of the importance of the Dutch economy relative to the world economy (approximately 2%).

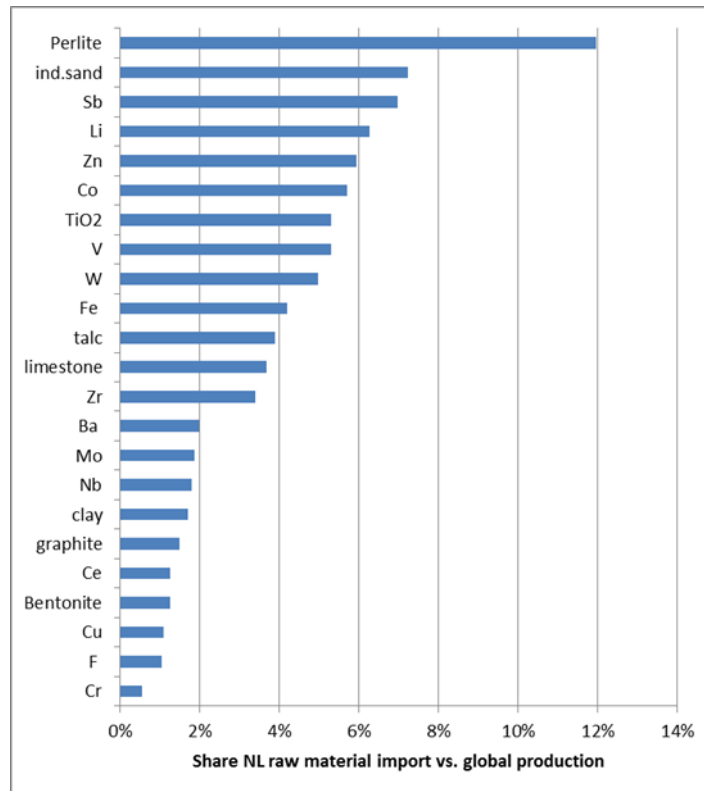


Figure 25 Share NL raw material imports compared to global production

The degree of vulnerability depends in part on the source country concentration, and partly by the quality of governance in the source country, as measured by the WGI. The fact that source country concentration for the Netherlands is higher than that of the total global concentration of possible source countries is obvious (the Dutch raw material need is met by fewer source countries than the total of available source countries worldwide). More interesting though, is to look at the relationship between the WGI-weighted value of the commodities imported into the Netherlands and WGI-weighted value of the global raw material production. In other words, does the Netherlands' direct import of raw materials come from countries with a better administrative environment than the global average?

This comparison is shown in Figure 26. Herein is the scaled WGI score for the countries from which the Netherlands imports plotted against the WGI scaled weighted score for the worldwide production (please note the WGI-scaling means that a higher WGI represents a worse score for governance). Not surprising but remarkably consistent, is the picture that the weighted WGI score of Dutch imports is better (i.e. lower) than the global score. This means that the origin of Dutch imports comes on average, from better governed countries. This may be due to the fact that the involvement of trade countries plays a role here. What is being analysed here, is after all, the last country before the material enters the Netherlands, and not necessarily the original source country. This impression also appears to result from Figure 27 which shows that in percentage terms Cyprus is the main raw material supplier of the Netherlands.

A similar picture emerges regarding the import of raw materials through first intermediates, intermediate and final products.

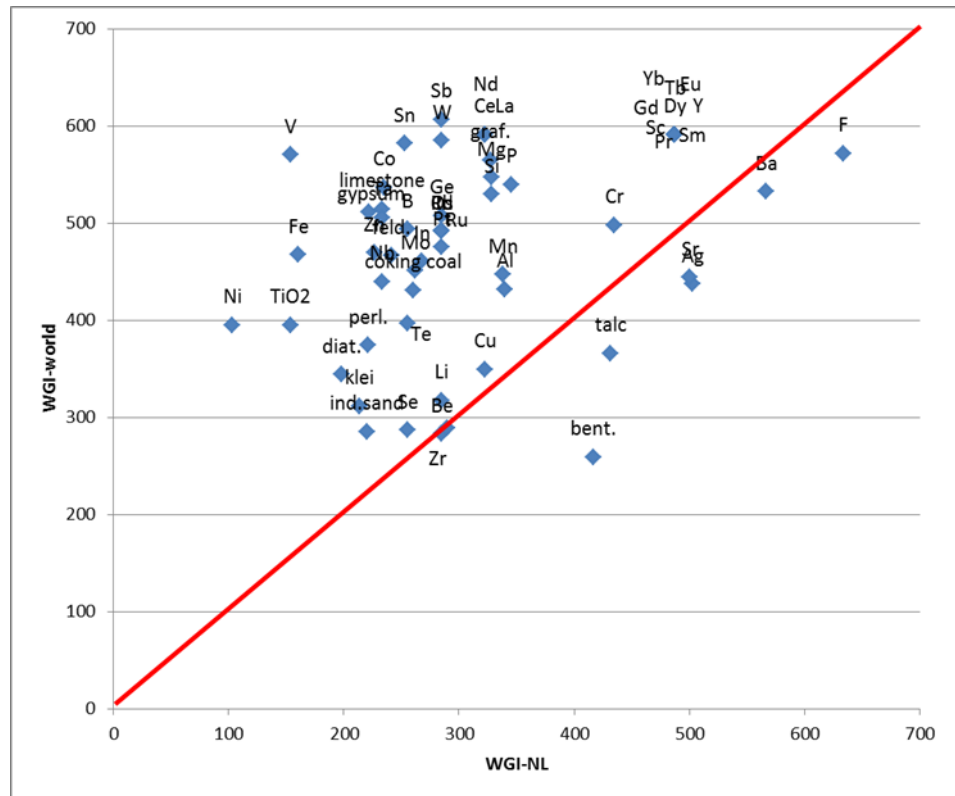


Figure 26 Comparison of the scaled and weighted WGI for imports to Netherlands vs. global source of raw materials

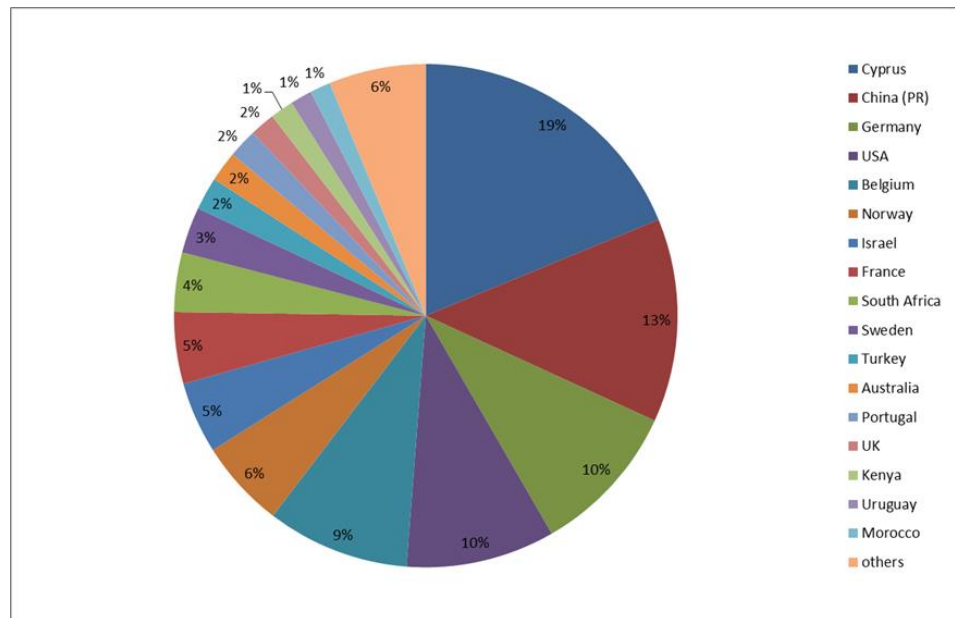


Figure 27 Distribution of import raw material source countries

4.2.2 *Import as first intermediate: volume*

Our definition of 1st intermediates mainly includes processed materials (metals, salts) that have undergone the first processing steps abroad, and come to the Netherlands for further processing (or for re-export). The overview of imported raw materials in the form of 1st intermediates is given in Figure 28 (Note: a logarithmic scale is used).

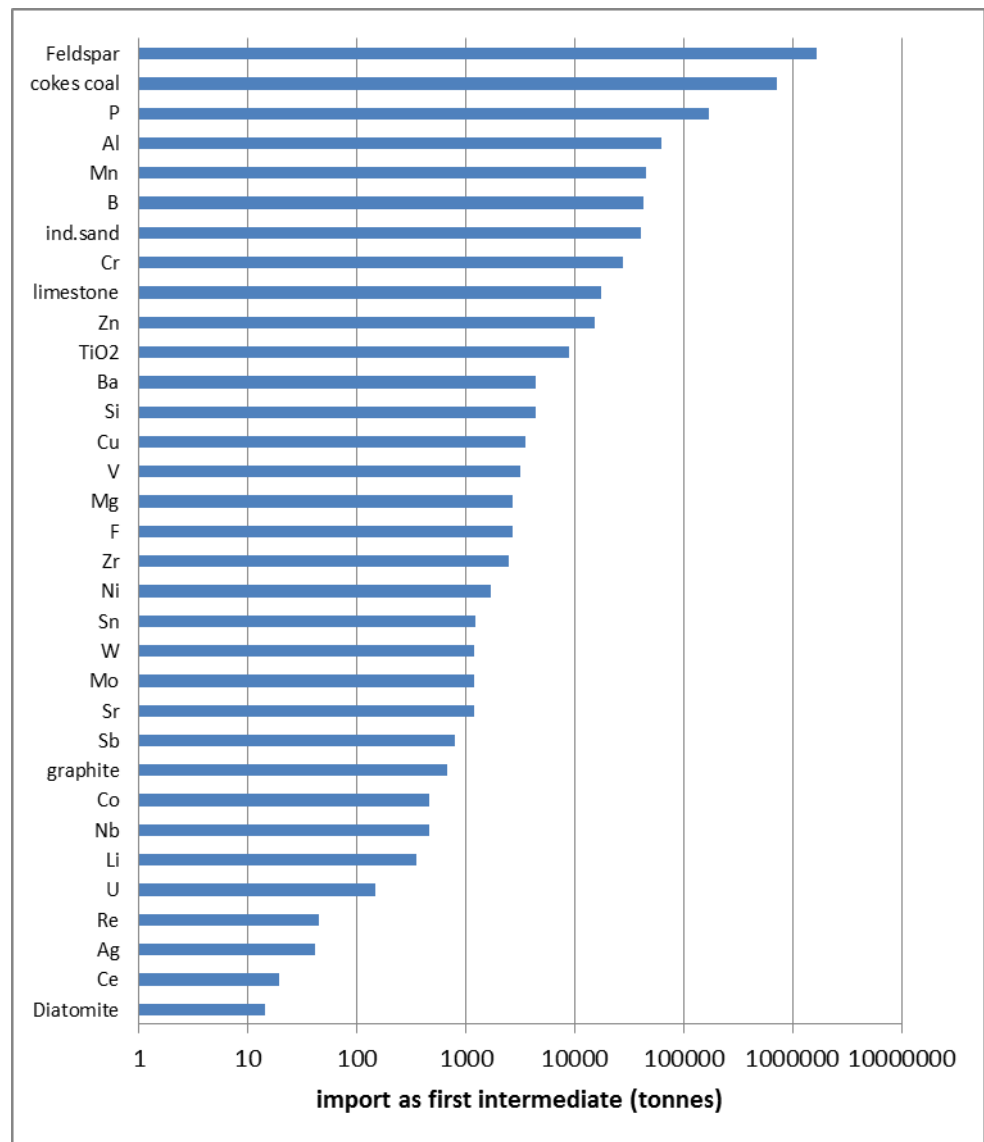


Figure 28 Import of raw materials in the form of 1st intermediates

4.2.3 *Import as intermediate: volume*

Figure 29 is a summary of the quantities of raw materials imported to the Netherlands in the form of intermediates (Note: a logarithmic scale is used).

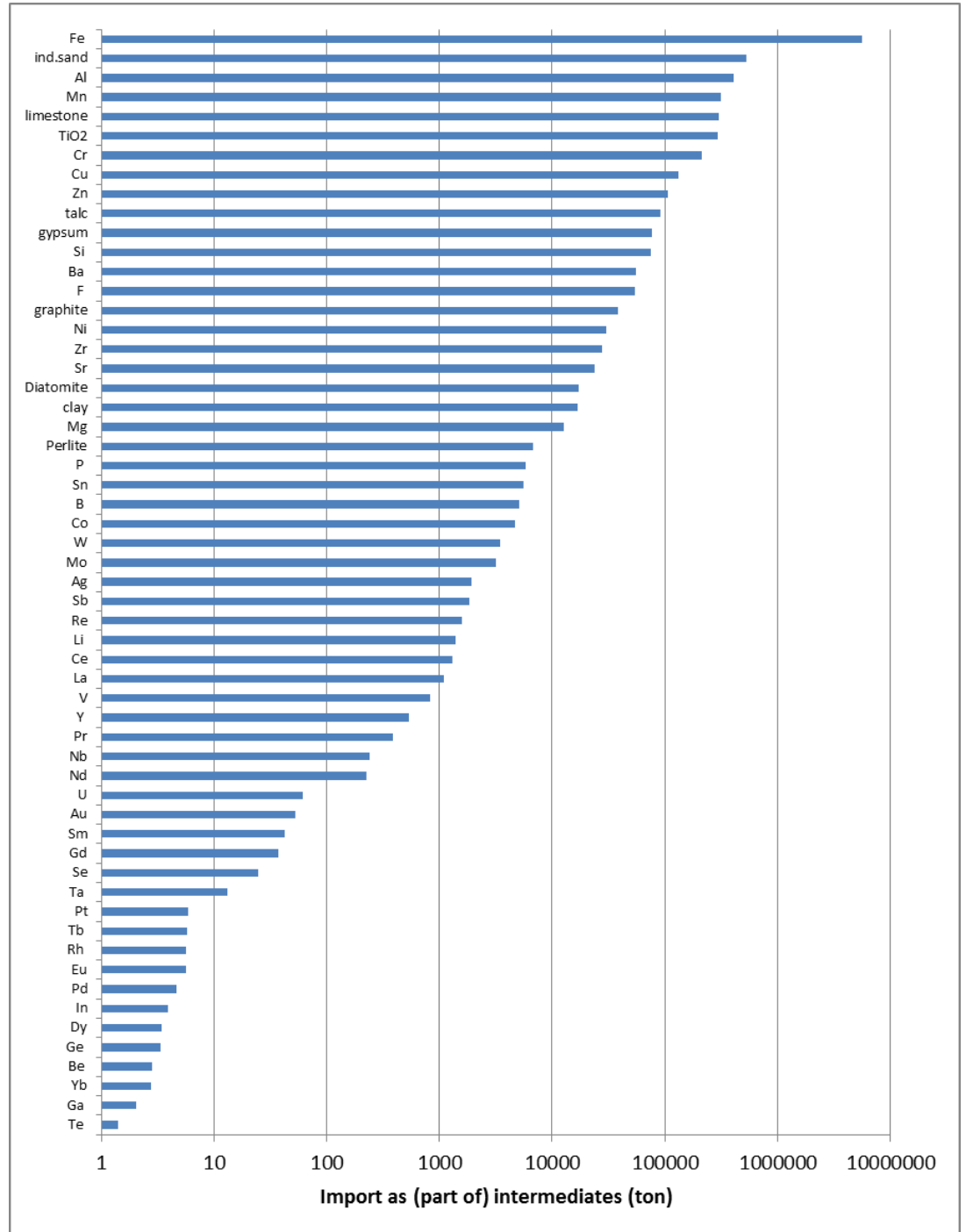


Figure 29 Import of raw materials in the form of intermediates

4.2.4 *Import as a final product: volume and source*

The list of imported raw materials coming to the Netherlands in final products is given in Figure 30 (Note: a logarithmic scale is used).

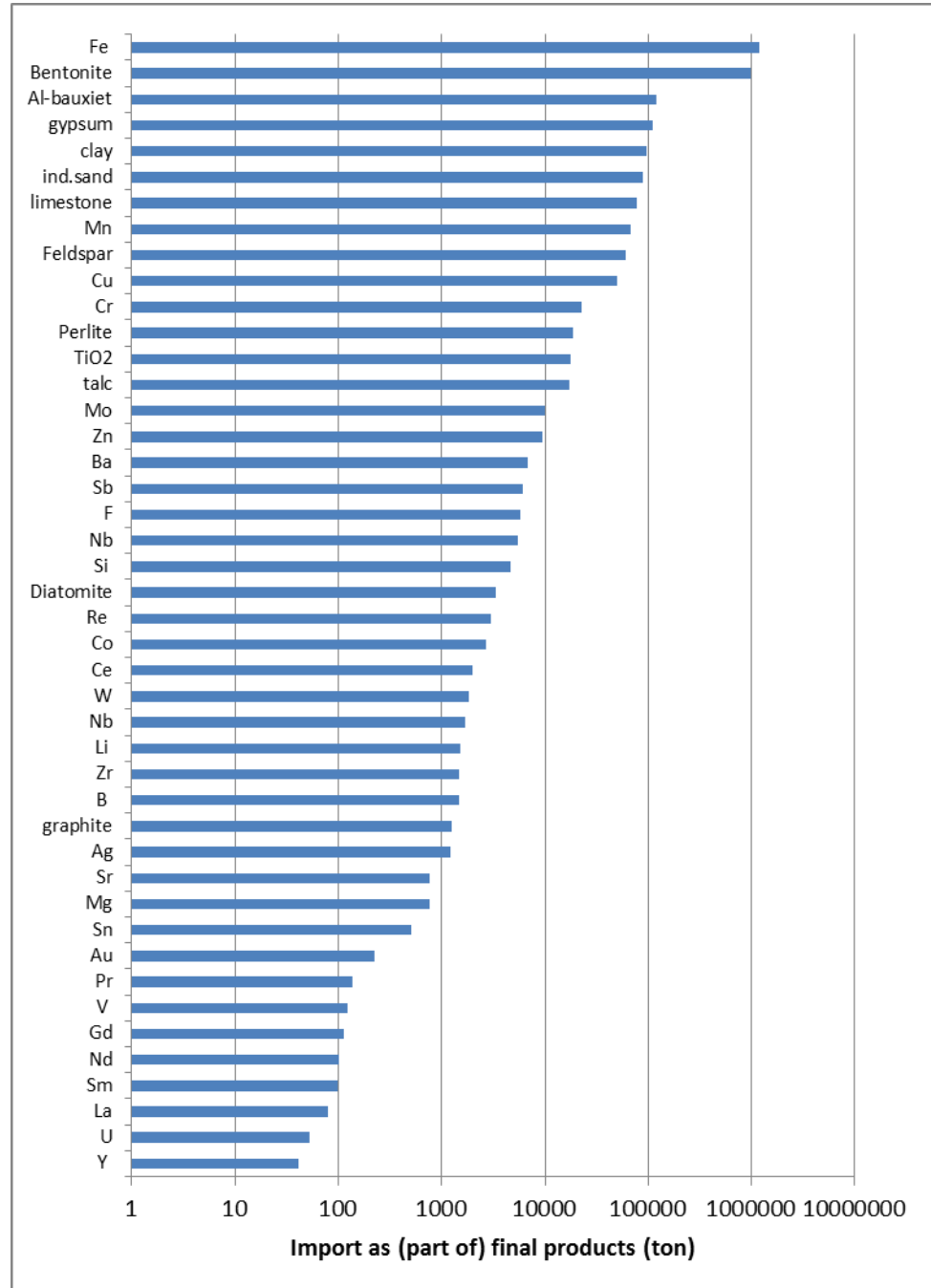


Figure 30 Import of raw materials in the form of final products

The source of these embedded materials gives a very different picture than that of the import of raw materials (see Figure 31).

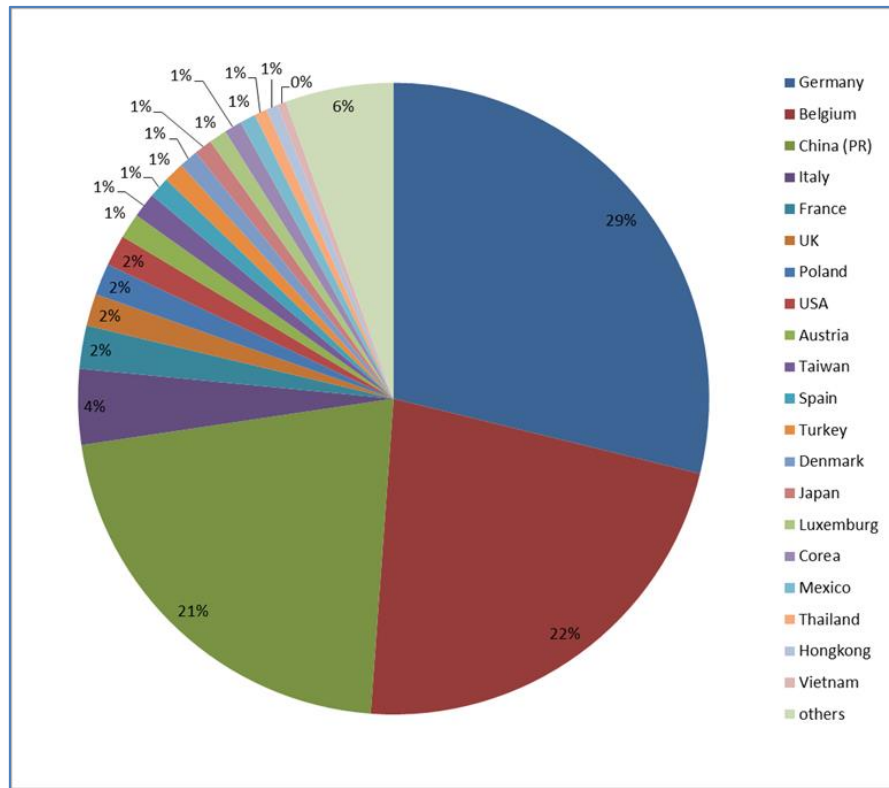


Figure 31 Source of raw materials imported in final products

Three trading partners are now dominant, namely Germany, Belgium and China, which together account for 72% of the total volume.

4.2.5 A complete overview: the forms of imported raw materials in the Netherlands

The Netherlands imports raw materials in the form of raw (unprocessed) materials, as 1st intermediates, intermediate and final products. Moreover, there is a set of raw materials that are imported in a form which we shall refer to as 'dissipative use' (these are immediately used in the process and do not accumulate in society). Based on the details described above, we are now able to generate a complete overview of raw material types with respect to the Dutch economy.

The collected data makes it possible to assess for each material the country from which it is imported (regardless of the import form: as raw material, 1st intermediate, intermediate or final product). These estimates can be used in prioritizing trade relations related to aspects of supply or the CSR aspects of raw material imports.

In this section we will briefly focus on the main countries from which (64) raw materials are imported into the Dutch economy, and the trade relations that are involved in the import of conflict minerals tin, tantalum, tungsten and gold, the so-called TTTG group.

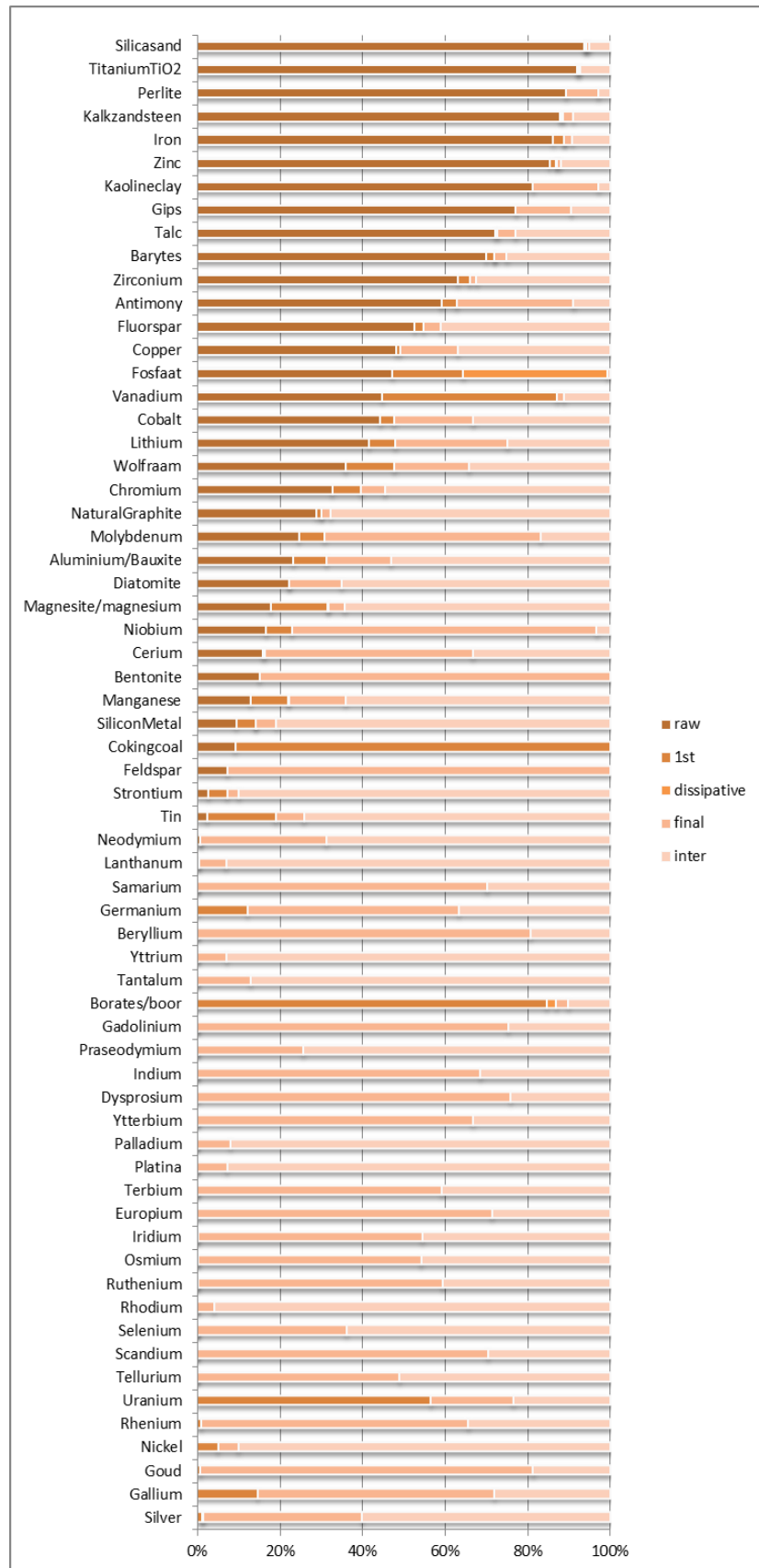


Figure 32 Composition of volume of imports shown by decreasing share of unprocessed raw materials

This list contains 13 materials which are imported for more than 50% in the form of raw materials. All the other materials reach the Netherlands for the most part as part of a processed material, an intermediate or final product. Despite the fact that apparently raw materials are obviously imported, their value is negligible compared to the value of all imported final products (66%), and intermediate products (33%).

When we look at this import information as a whole, across all 64 commodities in each stage (raw material, (first) intermediate, end product) it reveals which countries are the main trading partners of the Netherlands based on import values. Figure 33 shows for all countries (above) and only for those outside the EU-28 (bottom). The main trading partners for the 64 materials in the EU-28 are Germany, Belgium, the UK and France. Outside the EU-28 the major trading partners are China, USA, Russia, Japan and Norway.

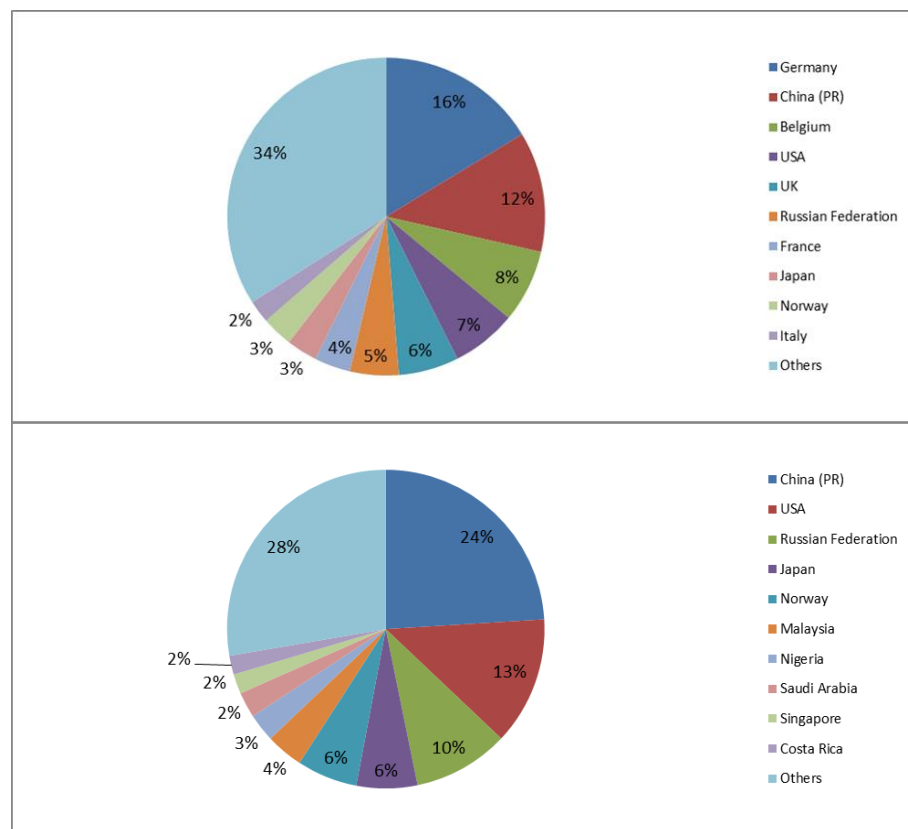


Figure 33 Distribution of material source countries (as raw materials, intermediates and end products); above: total distribution; below: all countries outside the EU-28

The data available allows us to zoom in on trade relationships that are linked to a selection of materials. A relevant option here, is to investigate via which route the so-called conflict raw materials tin, tantalum, gold, and tungsten (the so-called TTTG group) enters the Netherlands. Figure 34 offers more insight into this.

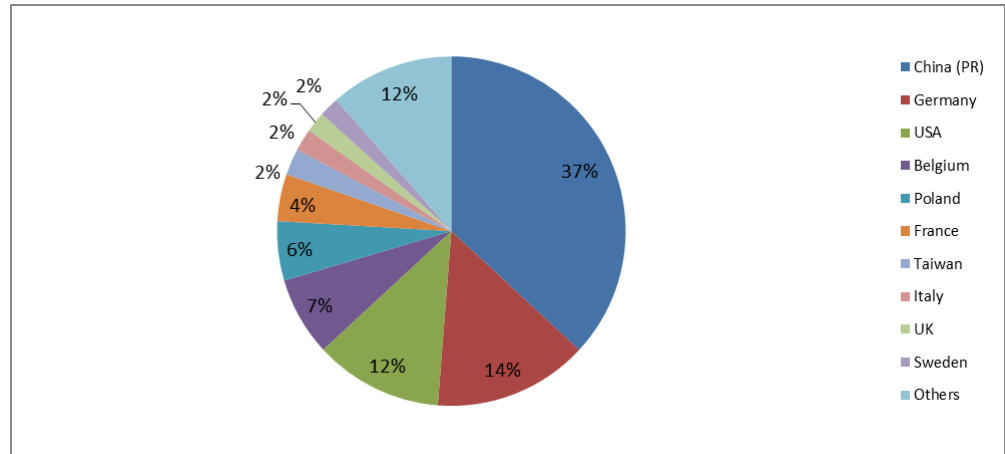


Figure 34 Source countries for the TTTG group

Now an overview has been obtained of the total amount of imported materials, it is possible to give an outline of the total environmental impact of the materials imported in the Netherlands included in this study (Figure 35).

If we only look at the overall environmental impact of the materials imported to the Netherlands, it appears that materials with a relatively low environmental impact on an absolute scale, still make a major contribution due to the sheer volume that is involved. Examples of these are (cast) iron, aluminium, titanium and copper.

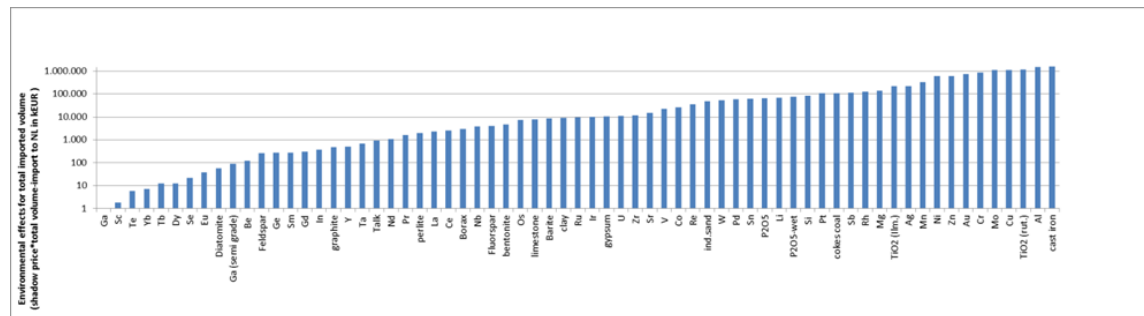


Figure 35 Total environmental impact of imported raw materials in Netherlands

4.2.6 A closer look at the trading relationship Netherlands - Germany

As already shown in previous sections, Germany's role as a supplier (or last intermediate station) to our direct and indirect import of raw materials is of paramount importance.

The role of Germany in the direct import of raw materials is especially prevalent with regard to minerals having a low value density, such as gypsum (58%) and industrial sand (60%). The situation is very different regarding the indirect import through first intermediates, intermediates and final products. For a number of high-tech materials, Germany's contribution to our material import is well over 50% and up to nearly 90%. This is the case for e.g. antimony, fluorine, lithium, germanium, vanadium, tin and zirconium. A complete list of these import figures (including per raw material and through final products) is given in Appendix B.

An example is given in Figure 36 . This shows the percentage of imported raw materials in the form of intermediates set against the short-term criticality of these raw materials.

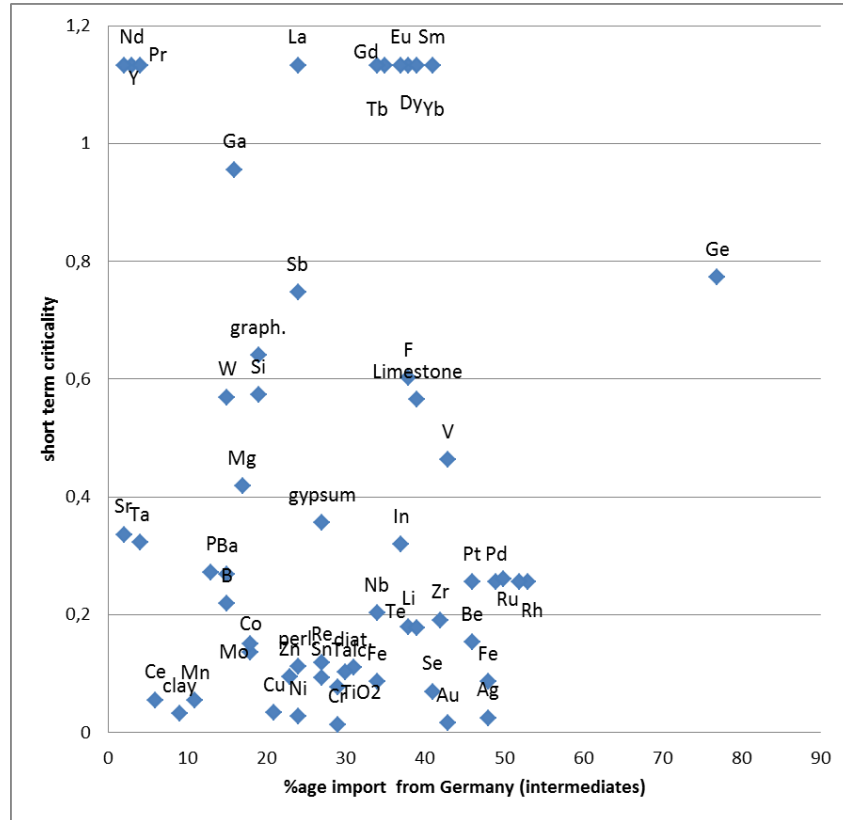


Figure 36 Short-term criticality of raw materials imported from Germany (as constituent of intermediates)

Given this dependence, considerable attentions certainly needs to be paid to the German situation with regard to their policy on critical materials which are vital for our economy. The possibilities that can be created by recycling to reduce the demand for raw materials, could become a good example of a joint German-Dutch collaboration.

Appendix B gives an overview of the share of exports to Germany per material. This insight, combined with the data on the importance of Germany as a 'supplier' of raw materials can form the basis of German-Dutch talks concerning the security of raw material supply.

4.2.7 *Regional 'scarcity': what role do transportation costs play?*

The determining of criticality (and thus, for example, determining the source country concentration in the form of the HHI) is generally based on the availability of raw materials at the global level. Yet it can be suggested that this paints too rosy a picture of global availability. When this concerns a raw material with a relatively low value density it is easy to imagine that the burden of transport costs imposed on the cost price of the material to be imported is so great, that the raw material in question can only be used within a limited action radius. In such a case, the

practical source country concentration would end up being higher (and less favourable) than would be concluded based on the global mining industry. The analysis of import flows enables us to make an assessment of whether this transport constraint could have implications for the evaluation of the criticality for the Netherlands. It is based on transport costs for inland waterway transport of 0.008 euros/tonne-kilometre and bulk cargo shipping³⁴ of 0.0033 euros/ tonne-kilometre³⁵. The question is: how far can the transport distance increase when it is assumed that the cost resulting from transport by water may not rise by more than 30%? The results of this analysis are shown in Figure 37.

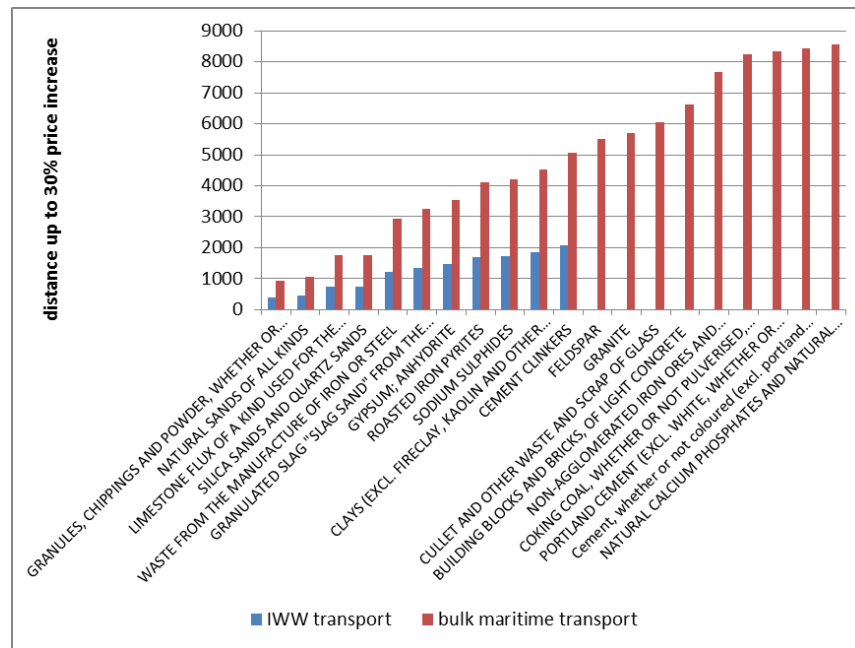


Figure 37 Possible additional transport distance by water with a maximum cost increase of 30%

For transportation on inland waterways within Europe we have a limit of 2,000 km. For only seven materials does a 30% increase in transport costs result in a maximum permissible increase in the operational range of 2,000 km (the density value of these commodities is not more than 0.04 euro/kg). This means that in principle, for these raw materials only those source countries are eligible which fall within the specified distance radius. This is particularly true for a number of materials such as natural and industrial sand, limestone, gypsum, and certain types of clay.

For maritime transportation, due to the lower ton-km cost a greater range is possible. Relevant distances here are the distance from Halifax (Canada: about 5,000 km) and Cartagena (Colombia: approximately 8,500 km). For 20 raw materials an increase in distance to 8,500 km leads to more than 30% increase in cost. This also means that for all other raw materials (as well as all intermediate products which have a higher density value than 0.1 EUR/kg), an increase in the

³⁴ Transport by trucks is estimated at € 0.14 / Tonne and rail at € 0.11 / Tonne; for the current analysis, these figures are not used because the resulting calculated range is extremely small.

³⁵ Data from TNO Sustainable Transport and Logistics; estimated cost bulk sea transport from Improving the Representation of Maritime Transport in the EXIOBASE Mrio Dataset, Jørgen Thorsen Westrum, NTNU, Trondheim, 2013.

transport distance to more than 8,500 km leads to a price increase of less than 30%. This means that for all these materials the global supply is certainly relevant from a Dutch perspective.

For the first 20 materials, it is therefore not surprising that the vast majority of the import originates from Belgium and Germany; only imports of feldspar, coking coal, iron ore and iron pyrite from these countries is negligible and for gypsum only 1/3rd comes from these two countries.

4.3 Which raw materials are most critical to the Dutch economy?

4.3.1 With regard to security of supply

The analyses carried out in chapters 3 and 4 have enabled us to give an outline of the vulnerability of the Dutch economy as a result of declining supply security.

In Figure 38 the short-term supply security of the investigated abiotic raw materials is compared to their value added in the Netherlands.

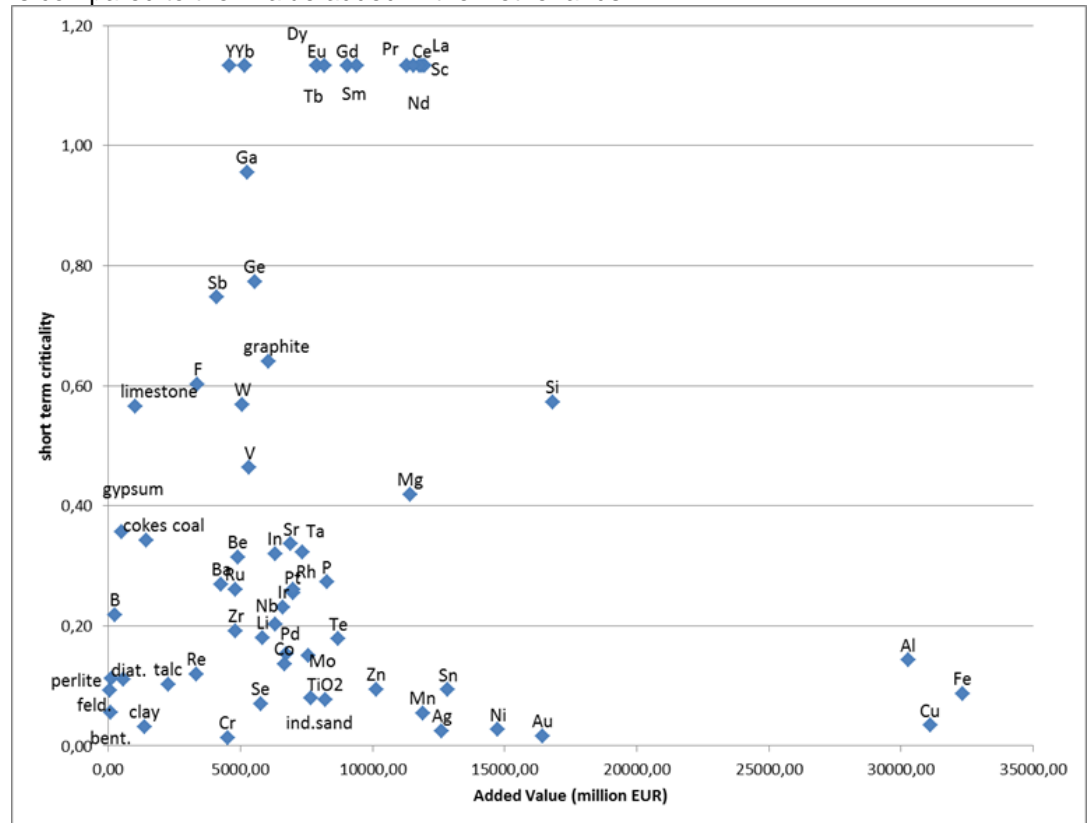


Figure 38 Short-term criticality for the Netherlands: security of supply in relation to added value per raw material

The importance of iron, copper and aluminium exceeds that of other raw materials. These materials are used in a large number of products which have added value in almost all sectors, this makes them the most important materials in our economy.

Furthermore, the significant importance of silicon, gold, silver and important alloying elements such as nickel, tin, magnesium and zinc stands out. In addition, a group of

rare earth metals (lanthanum, cerium, neodymium, praseodymium and scandium) have been identified as important to the Dutch economy.

The method developed in this study allows us to link the use of these raw materials to the added value of sectors. Sectors which make extensive use of raw materials with relatively high supply uncertainty will be relatively more vulnerable compared to others. The results are shown in Figure 39. Given the use of many of the more critical raw materials, the sectors 'Manufacture of computer, electronic and optical products', 'Manufacture of electrical equipment', 'Manufacture of transport equipment' and 'Manufacture of furniture and other manufacturing'³⁶ are relatively fragile.

Following close behind are the 'Manufacture of metal products (except machinery and equipment)' and the 'Manufacture of machinery and other equipment'.

Biotic resources and fossil fuels are not examined in this study. In that case it is no surprise that those sectors which make use of such raw materials do not emerge as being vulnerable here (such as food and beverage industry, chemical and pharmaceuticals). A more complete picture of the impact of raw material security on the Dutch economy would be given by also taking account of and including biotic resources in this study. This is further discussed in section 5.6.

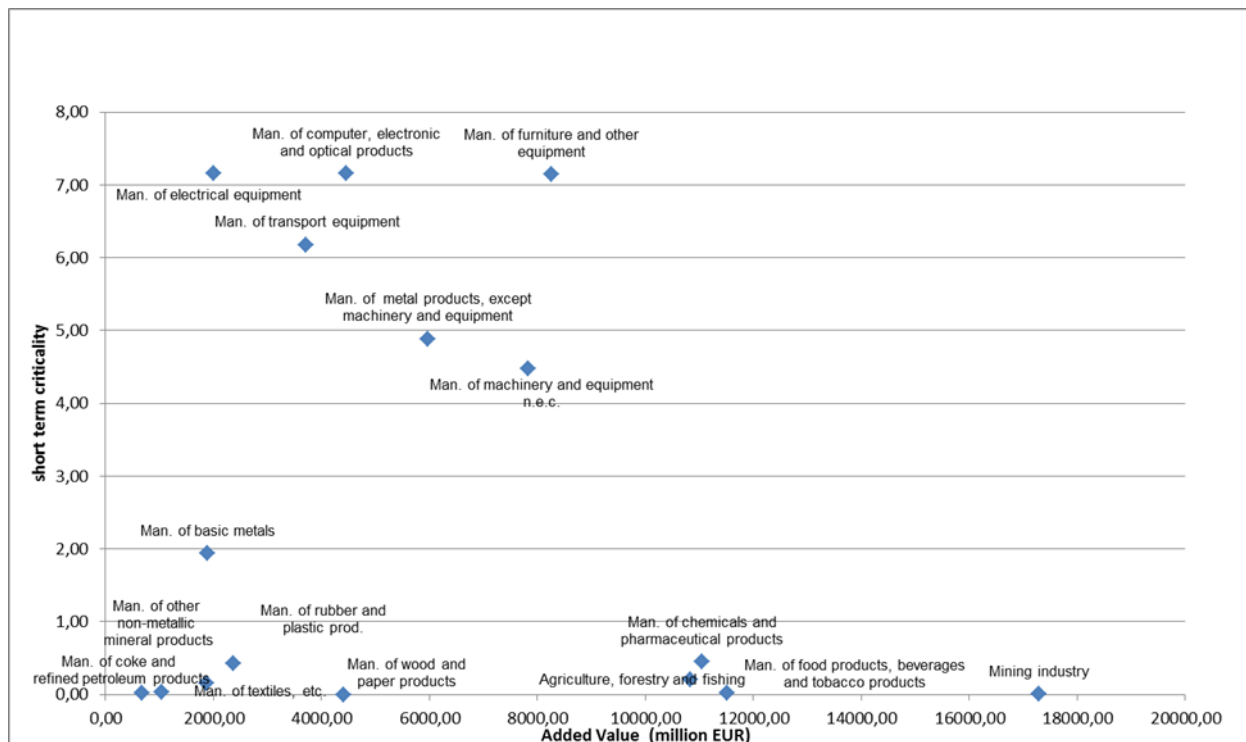


Figure 39 Short-term supply uncertainties at sector level (value-added expressed in million euros)

In a similar way to that used in plotting the economic importance of raw materials is against short-term criticality, this can also be done for long term criticality (wherein

³⁶ This concerns the SBI2-sector Manufacture of furniture; manufacture of other goods N.O.S. (not otherwise specified); these include the production of (parts of) furniture, jewellery, coins, musical instruments, sports equipment and toys.

country concentration, number of years reserve valuation and degree of 'companionality' also play a role).

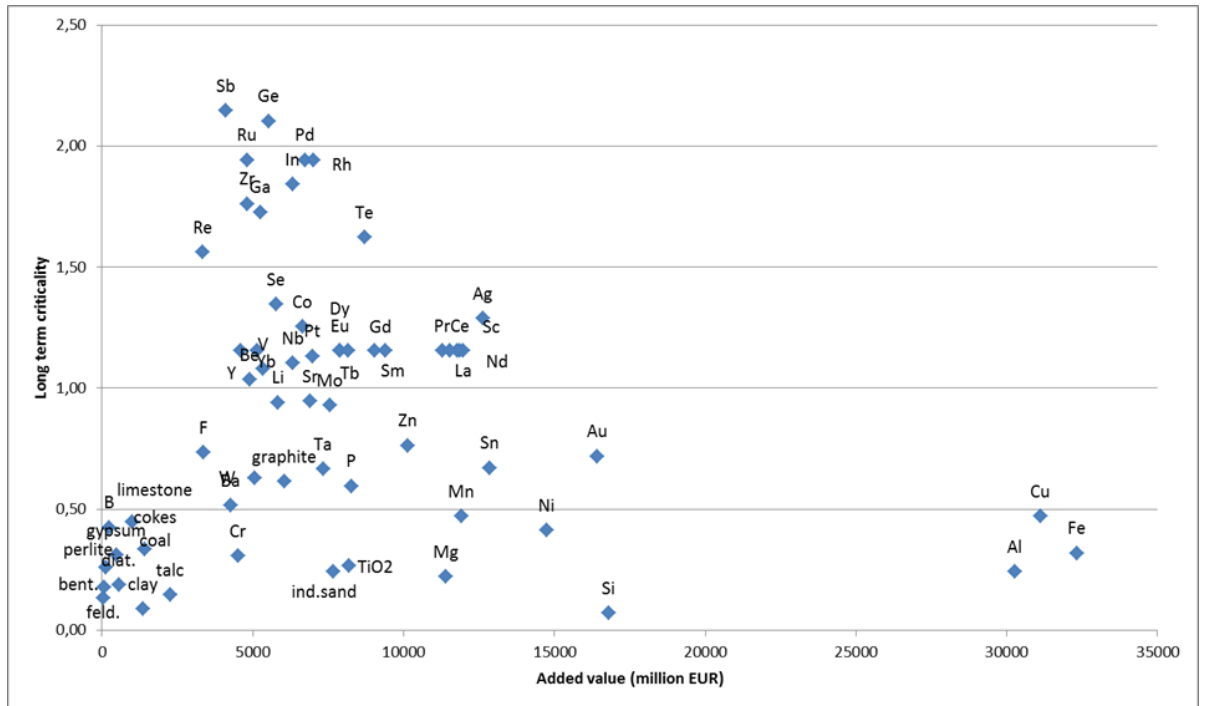


Figure 40 Long term criticality vs. economic importance of raw materials

4.3.2 *With regard to operating profit*

All materials examined here have a certain price volatility (expressed by the MAPII, the index for the maximum annual increase). Since materials can be linked to product groups through certain shared characteristics, we are able to estimate the influence of price volatility of materials in the Dutch economy as a whole, and in each sector where these materials are used.

The separate effect each of these materials has on the Dutch economy is shown in Figure 41.

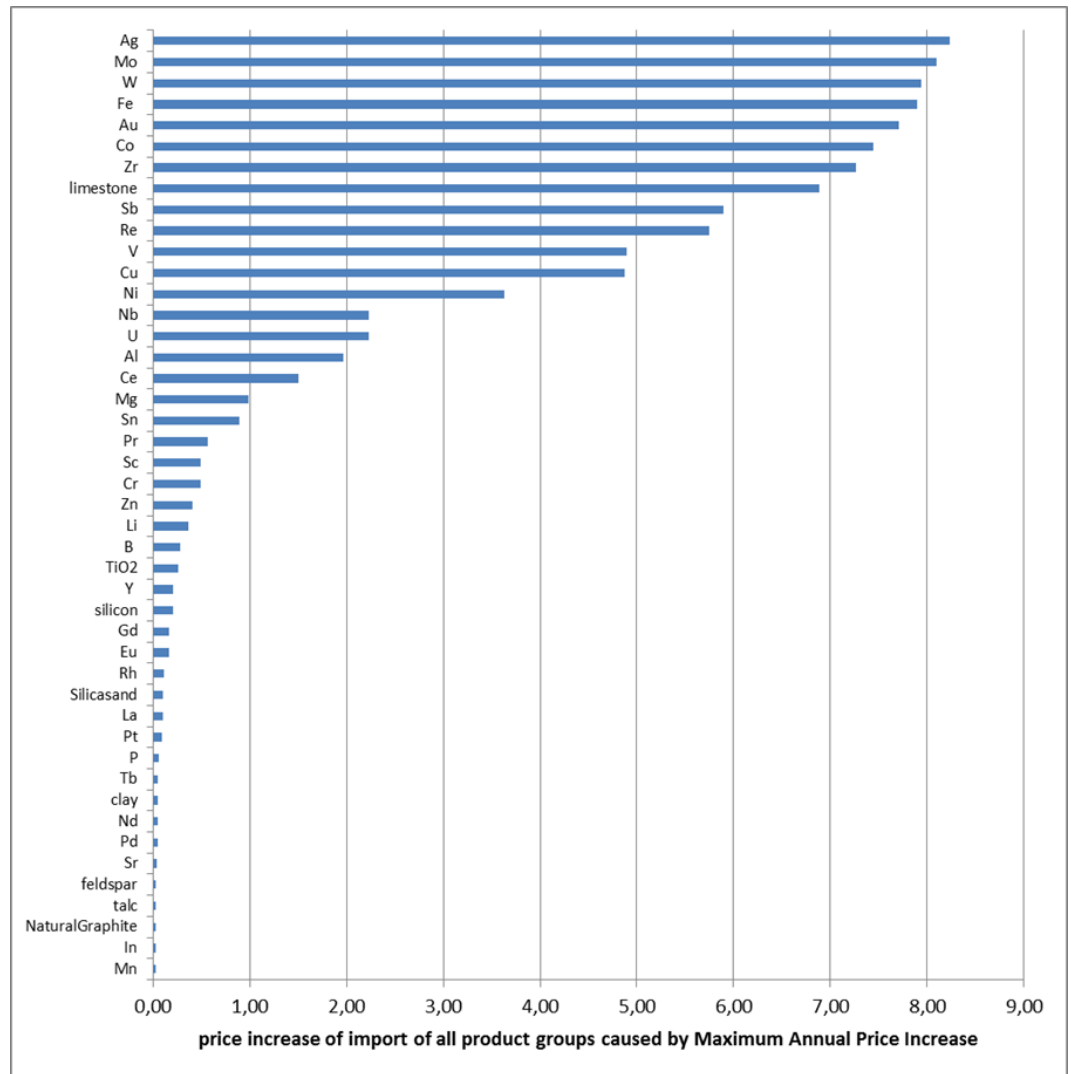


Figure 41 Price increase of import as a result of Maximum Annual Price Increase of raw materials (materials not shown have an effect less than 0.03%)

Raw materials where the effects of the maximum (historical) price increase is smaller than 0.03% in all product groups have not been included in this figure. This data indicates that a maximum price increase of silver (the worst case scenario, i.e. the MAPII = 0.74, meaning that the maximum increase in the price of silver over the last 15 years has been 74%) resulting in an overall price increase of more than 8% in all product groups using silver. The influence of the (maximum) price volatility of raw materials in each sector can be determined separately for each of these sectors due to 'shared characteristics' of commodities which has been determined in these sectors. Aggregation of data per raw material results in an assessment of what the maximum increase in prices of each commodity would mean for all costs of purchased goods and products within that sector (the explanation of this methodology is given in paragraph 3.4).

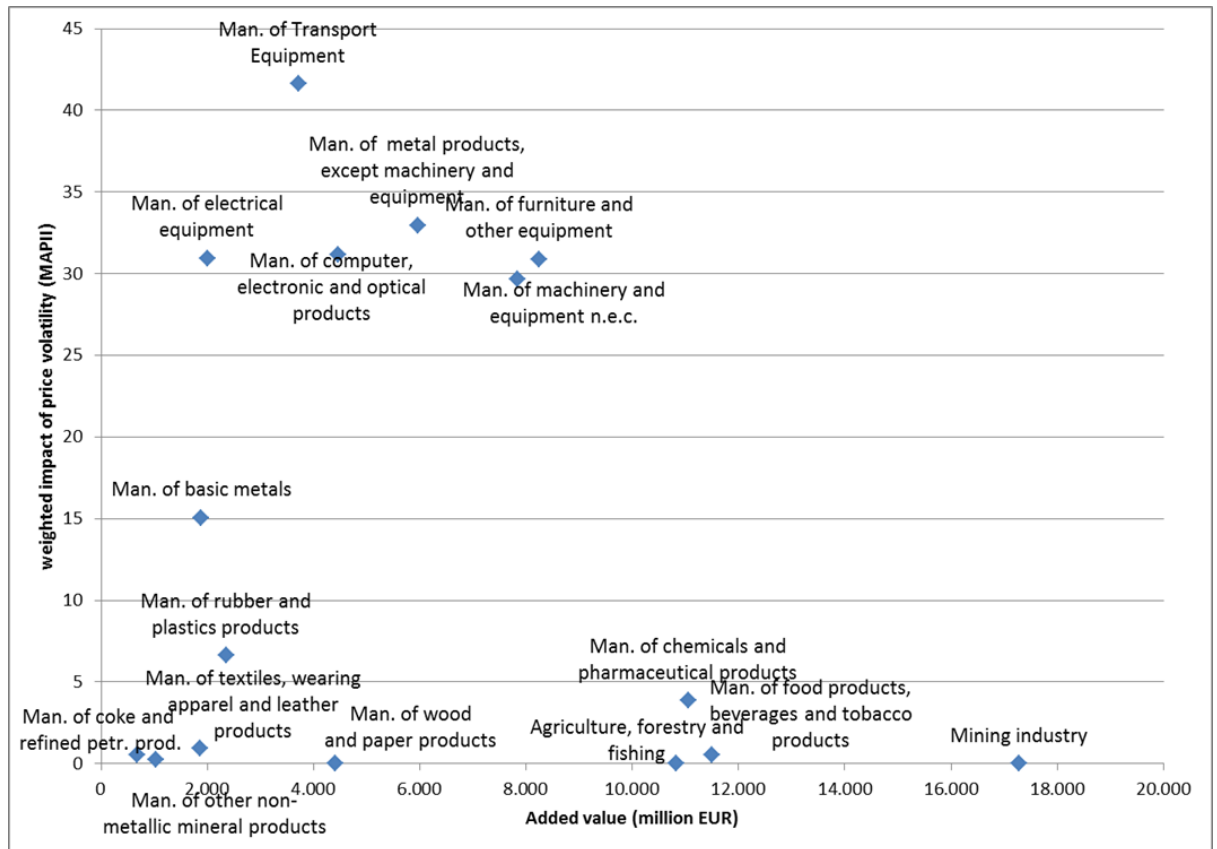


Figure 42 Influence of maximum raw material price increase on cost of goods purchased per sector

Given the relatively small proportion of materials in many final products, the impact of price volatility in most sectors is minimal (<1%) to small (<5%).

The potential impact of price volatility is considerably greater in the sectors 'Manufacture of transport equipment', 'Manufacture of computer, electronic and optical products', 'Manufacture of electrical equipment', 'Manufacture of furniture and other manufacturing', 'Manufacture of metal products (except machinery and equipment)' and the 'Manufacture of machinery and other equipment'. These sectors use many of the materials which are included in this study and in relatively high amounts. The price volatility calculation is based on the worst-case scenario: it is assumed that the maximum price increase that each material in the last twenty has shown, occurs simultaneously for all materials used in that sector.

The extent to which this accumulated price volatility also poses a real risk to these sectors depends on various factors. The effect may be small if any price increases can be passed on to customers. By contrast, even small price increases could have an impact where there is no level playing field compared to production in countries that have access to cheaper raw materials.

4.3.3 With regard to reputation

A company's reputation is in danger if it uses raw materials from countries with a low Human Development Index (HDI), or conflict minerals or raw materials with a high environmental impact. The data for each of the tested raw materials here is

discussed in section 3.5. Since we assign each material to a sector, it is possible to give an aggregated picture of the extent to which a sector is at risk of reputation damage. More positively formulated: awareness of the use of raw materials with a questionable CSR character can help focus CSR policy on precisely those materials.

An overview of the extent to which sectors use raw materials with such a moderate CSR score is given in Figure 43.

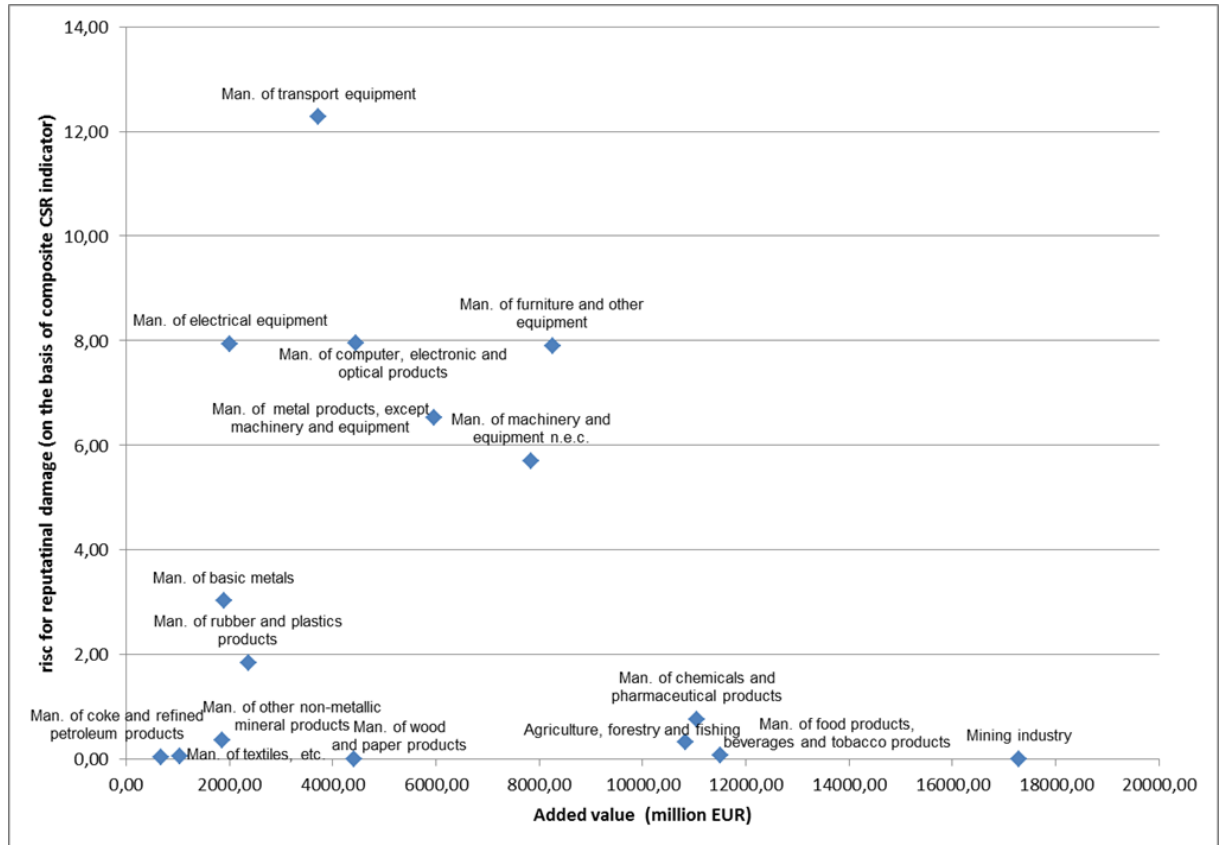


Figure 43 Risk of reputational damage to sectors

Many sectors that suffer from experiencing short-term supply uncertainty are also those at risk from suffering reputational damage. The sector Manufacture of Transport Equipment stands out above the rest. The underlying constituent data shows that this sector stands out due to, on the one hand using considerable amounts of the raw materials that are examined here and on the other the use in broad areas of this sector of tantalum (16% contribution to the total CSR indicator) gold (12% contribution) and tin (11% contribution). This sector is therefore closely linked to the debate on conflict minerals.

5 Recommendations for a research and action agenda

5.1 Impetus for an innovation agenda Dutch (top) sectors

The innovation agendas of Dutch industry are linked to the nine top sectors shown in the table below. Each of these top sectors has expressed its interaction with the research community in terms of a Top Institute for Knowledge & Innovation (TKI) under which fall several Knowledge and Innovation agenda (KIAs). As part of a study on 'Greening and Innovation'³⁷ it has been observed that at the 'road map' level of these top sectors, the term circular economy is barely mentioned and the term critical materials does not even occur.

The analysis in this study provides insight into the relative importance of critical raw materials for the Dutch economy and links this to specific sectors. In particular, the industrial sectors involved in the manufacture of electronic, electrical apparatus and automotive are relatively fragile. The results of this study give cause to check whether the theme of 'the future of critical materials' should become part of the research agenda for (at least) the high-tech top sector. In addition to this, it also seems advisable to check the Chemical and Energy sectors (due to for example, the criticality of rare earth elements and other raw materials relevant to the generation of renewable energy) to find out to what extent the reduction of dependency on critical materials could be adopted within part of their Knowledge and Innovation Agenda. Themes which could be a part of this KIA include:

- To what extent in the design stage of products can the reduction of dependency on critical raw materials be taken into account? For example, by focusing on such a modular design that maintenance and repair will be made simpler, or creating designs which to a greater extent only make use of non-critical materials.
- Following on from the previous theme, an approach can be applied that focuses on the functional understanding of the use of materials which in turn leads to planned substitution research. Substitution has become an essential part of the Knowledge and Innovation Community KIC Raw Materials, which also ensures good connections with the European research agenda.
- The top sectors could encourage research into more effective recycling, both through innovations in the field of reverse logistics (an obvious choice here is cooperation with top sector Logistics), and by focusing on metallurgical research which increases the so-called end-of-life recycling rates (EOL-RR). An increase in European recycling ensures a domestic, European source of raw materials which leads to a decrease in the dependence on non-European source countries.

What stands out from the above ideas is that they are all inspired by the aim to reduce dependence on critical materials, and at the same time be a stimulus for the development of a research agenda for a circular economy for these sectors.

³⁷ TNO study commissioned by PBL; Results will be delivered in 2016.

Top Sector	TKI	Knowledge and Innovation Agenda (KIA)	Roadmaps / Themes / Programme Lines
Agri & food	Agri & food	Agri & Food 2016-2019	9 roadmaps
Chemicals	Chemicals	Chemicals 2016-2019	4 roadmaps
Creative industry	CLICKNL	CLICKNL 2016 -2017	5 themes/research areas
Energy	Wind at Sea	Wind at Sea 2016-2019	5 programme lines
	Gas	Gas 2016-2019	5 programme lines
	Urban Energy	Urban Energy 2016-2019	5 programme lines
	ISPT	ISPT 2016-2019	14 innovation clusters
	BBE	Biobased Economy 2016-2019	4 programme lines
High Tech	HTSM	MVI Energy 2016-2019	3 Options
		System integration 2016-2019	3 Options
		HTSM 2016-2019	16 roadmaps (1 ICT)
Life Sciences & Health	LSH	ICT 2016-2019	16 roadmaps (1 ICT)
		LSH 2016-2019	3 themes/pillars
Logistics	Logistics	Logistics 2016-2019	6 roadmaps
Horticulture & Propagation Materials	Horticulture	T&U 2016-2019	5 themes
	Propagation materials		
Water	Delta Tech.	Delta Technology 2016-2019	10 themes
	Marine technology	Maritime technology 2016-2019	4 themes
	water technology	Water Technology 2016-2019	3 themes

5.2 Trade relations and raw material diplomacy

The Netherlands cannot solve security of supply issues on its own. The Dutch economy is highly interlinked with a host of global value chains. The EU-28 are undoubtedly extremely important when it comes to the formulation of an international policy to manage the supply risks for Europe as a whole.

Yet entering into talks with major trading partners is certainly worthwhile: in this way common concerns can be shared, common initiatives be developed (cross-border cooperation in the field of recycling and the circular economy for example). The results of this study indicate which trading partners for direct and in particular the indirect supply of raw materials are most important. The main trading partners for the 64 materials in the EU-28 are Germany, Belgium, the UK and France. Outside the EU-28 the major trading partners are China, USA, Russia, Japan and Norway. In the specific case of the conflict minerals tin, tantalum, tungsten and gold (TTTG) the situation is similar. While the main mining countries for these materials are Rwanda and Congo (for tantalum), China (for tin and tungsten), Peru and Indonesia (for tin) and Australia (gold), the main trading partners for the Netherlands in this field are China, USA and the EU-28 countries, Germany, Belgium, Poland and France. How they deal with this issue is relevant to the Dutch situation.

The detailed analysis on Germany reveals that for a number of critical materials we are dependent on Germany which supplies us with more than half of our needs in these. Thus their concerns in those areas are also our concerns.

It should be made clear that the methodology developed here for this detailed analysis, can also be applied to other countries.

In addition to knowledge concerning the relations with countries supplying critical materials more attention could also be paid to indicators related to the risks of resource nationalism. This includes looking at the importance of raw materials to the income of (unstable) countries, monopolies of state-owned mining or regulations that restrict investments by foreign mining companies. The extent to which a source country can be called to order by the WTO (World Trade Organisation) could also be covered here. The www.wto.org website provides detailed documentation on the nature and number of such disputes. Further consideration of this data shows that the number of disputes over specific 'raw materials' (and 'rare earth metals') pales into insignificance compared to disputes over a host of other products. At present, such data is beyond the scope of this study.

However an analysis of these indicators may shed a different light on which countries the Netherlands should pay most attention to.

5.3 Development of additional data sources and indicators

5.3.1 *Alignment with and use of other initiatives to map material dependency*

The current Dutch activities occupy a prominent place with regard to mapping of material flows that are critical to the economy. TNO is part of the research consortium (alongside BIO-IS and the BRGM and BGS) to participate in the next revision of the critical materials list for the European Commission. It is advisable to

encourage also in the long term that Dutch developments continue to remain part of the international discourse in this field. Currently, four prominent databases are being developed which in the future could create a synergy with the results of this project. Appendix G takes a closer look at some of these databases.

5.3.2 *Impact of raw material use on biodiversity*

It is difficult to establish a causal relationship between the impact of business activities on biodiversity. In this current study Biodiversity is a component in the endpoint analysis, as discussed in detail in Appendix C. The explicit linking of biodiversity to raw material use has not yet been done; it is valuable however to explore whether this relationship can be the subject of future studies.

The results of environmental impacts are determined at both midpoint (measurable environmental impacts such as CO₂ emissions, acidification, etc.) and at endpoint level (damage at a higher level, such as ecosystem health and resources). The differences between Midpoint and Endpoint analysis are illustrated in Appendix C. These differences arise from among others, complex concepts such as resource depletion and reduction in biodiversity. These differences are an indication of the relationship between extraction of raw materials and reduction of biodiversity.

CREM research agency has been commissioned by EZ (Ministry of Economic Affairs) and is currently analysing in a Social Cost Benefit Analysis (CBA) framework, the potential impact on biodiversity. The concept of Natural Capital is significant here, in addition to the capital concepts in the other two elements of sustainability. These are social capital (culture, institutions, knowledge) and economic capital (capital goods such as machinery, infrastructure, transport vehicles etc.) In this way the construction of causal relationships can be initiated with regard to the way measures and economic activities affect biodiversity

5.3.3 *Development of indicators with regard to sustainability issues*

It is important to keep being involved with international developments in the field of indicators. In other words:

- If the data needs to be interpreted on a European level, it is necessary to recalculate the results on the basis of the ILCD- instead of the ReCiPe method. Developments within the ILCD and the JRC should in any case be monitored, keeping an eye on European developments, cooperation and regulations in the LCA field;
- The activities of the Sustainability Consortium include maintaining the mapping of external effects and the harmonization of assessment methods in the field of sustainability and should be actively followed. As yet there is no universal standard method to this end; indeed, the Netherlands occupies a unique position in terms of the possession and use of shadow prices. From the perspective of LCA science, the UNEP/SETAC is also an important party to be closely followed.

5.3.4 *Additional environmental and health indicators: EPI*

EPI would be a valuable addition to LCA and HDI indicators, even though there is some overlap. EPI provides a different perspective than LCA and offers a more in depth coverage relative to HDI. The Environmental Performance Index (EPI) is a

composite index which measures environmental health and ecosystem vitality. The EPI was developed and is administered by Yale Center for Environmental Law & Policy (YCELP) and the Center for International Earth Science Information Network (CIESIN) at Columbia University in collaboration with the World Economic Forum and supported by the Samuel Family Foundation and McCall MacBain Foundation. The Environmental Performance Index (EPI) has 2 objectives, 9 issue categories and 20 indicators, as shown in Figure 44.

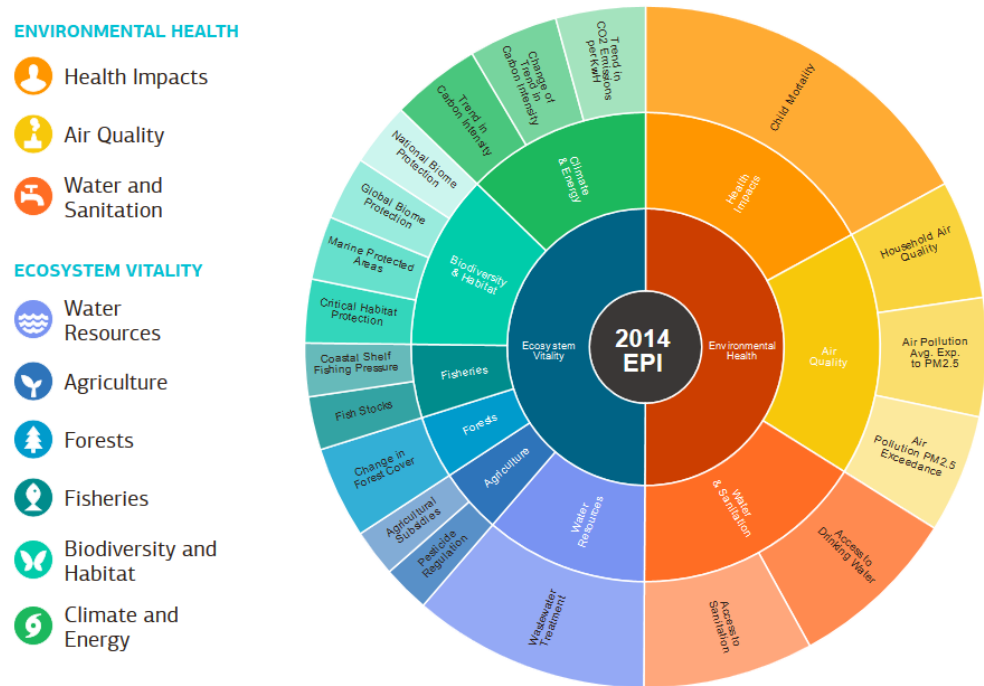


Figure 44 The Environmental Performance Index (EPI) consists of 2 objectives, 9 issue categories and 20 indicators. Source: Yale Center for Environmental Law & Policy³⁸.

The indicators of the EPI largely overlap with those of the LCA and HDI indicators that are described in this report; they also cover other areas to a lesser degree. The health indicators are largely covered by the HDI indicator: life expectancy; EPI could be used for a more detailed calculation of this indicator, since it differentiates between more separate indicators. Most indicators of "Ecosystem Vitality" are already indirectly in the LCA impact categories of ReCiPe: biome protection for example, is covered by ReCiPe because there is an environmental price tag for different forms of land use. Climate & Energy is also included in ReCiPe, namely at effect level (greenhouse gases expressed as CO₂ equivalents), whereas the EPI expresses these in terms of causes, namely, "Trends in carbon intensity". Water and pesticides and other agricultural activities are also expressed in ReCiPe in terms of consequences (e.g. acidification/eutrophication of water), but by the EPI at the level of regulations and subsidies. The only indicators which the EPI does use which are largely ignored by ReCiPe, are the fish indicators.

Thus in total the EPI includes more or less the same indicators as LCA (ReCiPe) and HDI, but shows the results from a different perspective. The main reason that

³⁸ Website YCELP about EPI: <http://epi.yale.edu/our-methods> (last visited 27-11-2015).

the EPI has a different way of looking at indicators than ReCiPe is because the EPI is based on country data, while ReCiPe is based on product data. When analysing raw materials and products, it is worthwhile considering both aspects, since both the specific production processes and the specific conditions in the country of origin are relevant factors in decision making. Thus, the EPI is a valuable addition to the already defined LCA and HDI indicators in the commodity tool. In further investigation a place should be given to EPI, or an analysis of complementarity and possible added value.

5.3.5 *Regulations with regard to toxicity and health aspects of raw materials combined with data from this study*

RIVM assisted in this study by sharing its extensive knowledge of toxic substances relevant to this study. The work of RIVM is represented by a series of databases ([Codex Alimentarius](#), [eChemPortal](#), [IPCS databases](#) etc.) For the study of dependence on materials, the ECHA (European Chemical Agency) database proves to be the most suitable link up. It is a valuable source of information regarding chemical substances manufactured in and imported into Europe. Amongst other things, it tells the user the dangerous properties of substances, the classification and labelling requirements and information on the safe use of substances. This information makes a valuable contribution to the safer use of chemicals and promotes the replacement of the most dangerous chemicals with safer alternatives.

Increasingly, companies are experiencing that health issues are playing an ever more significant role in decisions regarding product design and manufacturing processes. The database does not lend itself to a comprehensive analysis of the toxicity of the 64 materials. However, it is possible by means of a correspondence table to make the link between HS product codes and the CAS (Chemical Abstract Substance) numbers. In this way tool users can get a quick insight into the applicable laws and regulations for the product groups relevant to them.

5.4 **Complexity of the value chain and vulnerability of the economy**

In this study, a large number of indicators have been introduced and used to identify risks concerning raw materials. What does fall outside the scope of this study is the extent to which numerous indicators influence each other through the complex composition and structure of national and international economic networks.

Some examples of these nexus issues or system (dynamic) risks are noted here:

- The price of a primary raw material largely determines the business case for recycling;
- Successful recycling of the host materials may have a negative effect on the extraction of 'companions';
- In some value chains the extraction of raw materials, the processing and manufacturing of specific components is highly concentrated and limited. Disruptions can therefore affect multiple value chains simultaneously;
- The relationships between ecosystems and economic systems are highly interwoven (using features, services and raw materials). Ecosystems and their services are under pressure due to over exploitation.

A summary of these relationships and the extent to which they affect each other has not yet been mapped. In order to fill this gap in knowledge, it is possible to perform a complexity analysis for raw material flows.

A complexity analysis is relevant to the Dutch economy in general and to the Ministry of Economic Affairs in particular. The Netherlands, as an open trading nation, is susceptible to disruptions in supply chains. We are a major global player in agri-food chains and we also have a number of global players in electronics and exporting SMEs within our boundaries. Disruptions in commodity chains can reach us relatively quickly. Dutch policy on raw materials is directed at responding actively to systemic risks and guiding the international agenda with regard to this. This is consistent with the mid-term Green Growth report, which indicates that Top Sector policy needs to be directed more towards scarce raw materials and recycling technology.

A complexity analysis could be based on insights from the resilience literature. In the book 'Principles for Building Resilience'³⁹ it is found that, based on the resilience literature, seven principles for policy making can be formulated:

1. Maintain diversity (variety, balance, disparity) and redundancy;
 - a. Variety: how many elements?
 - b. Balance: how much of each element?
 - c. Disparity: how different are the elements from each other?
 - d. Redundancy: how many elements perform a similar particular function?
2. Manage connectivity;
3. Manage slow (and fast) variables and feedbacks;
4. Foster complex adaptive systems thinking;
5. Encourage learning;
6. Broaden participation;
7. Promote polycentric governance systems.

Based on these principles, the following research aspects can be formulated:

- Regarding connectivity;
 - quantitatively assess stability ('Eigen-values'⁴⁰) and topology of material flows and relationships of economic control⁴¹ (per chain phase)
 - use structural path analysis based on IO analyses of the Dutch economy⁴²
- with regard to "Slow/fast variables and feedbacks";
 - Influence of and on price elasticities (supply shocks) and pricing
 - Developing supply by mining and recycling
 - Technological development through which other material needs arise (e.g. substitution)
 - Dynamics in manufacturing (displacement, bankruptcies, takeovers).

³⁹ Biggs et al. (2015) Principles for Building Resilience: Sustaining Ecosystem services in Social-Ecological Systems, Cambridge University Press

⁴⁰ including Allesina and Tang (2012) Stability criteria for complex ecosystems, Nature, volume 483, no. 205.

⁴¹ See, e.g. the survey for the year 2012 which companies in the Netherlands are in foreign hands. This data can be combined with the ORBIS database of the University of Lausanne (S. Vitali, JB Glattfelder, and Stefano Battiston, 2011).

⁴² See methodology used in "chains for transition program Circular Economy - Substantiation of the selection of three chains for the transition program (theme 4 RACE) Circular Economy by TNO, The Circle Economy and CSR Netherlands.

5.4.1 *Influence of the value chain on monopolies*

An elaboration of the aspects which play a role in the complexity of the value chain is given below.

The present study focuses in particular on criticality which is related to raw material producing countries. Yet it is not the production of raw materials in all cases which forms the bottleneck as supply risk. This can be down to any one of the steps in production. Here, we are focusing on the first step which occurs after extraction, namely, refining. Many materials are not refined in the original country of extraction, but are shipped as ore to a small number of other countries. Based on literature data (e.g. in the USGS Mineral Commodity Year Book) the comparison may be made between the country concentration in this next step and the weighted WGI.

This does not apply to materials extracted entirely as a by-product (see section 2.2.3). The reported source countries for those by-products are in all cases the countries where the 'host' is refined and where the material concerned is extracted as a by-product.

The platinum group metals (PGM) and the group of rare earth metals take a special position.

The first refining of the PGM ores is carried out in the mining countries. That includes the refining of the rare earth elements: not only is the mining industry currently more or less monopolized by China, but also the further refining steps. For the situation regarding rare earth elements, the situation is illustrated by Figure 45, sourced from documents obtained from the US Department of Defense⁴³.

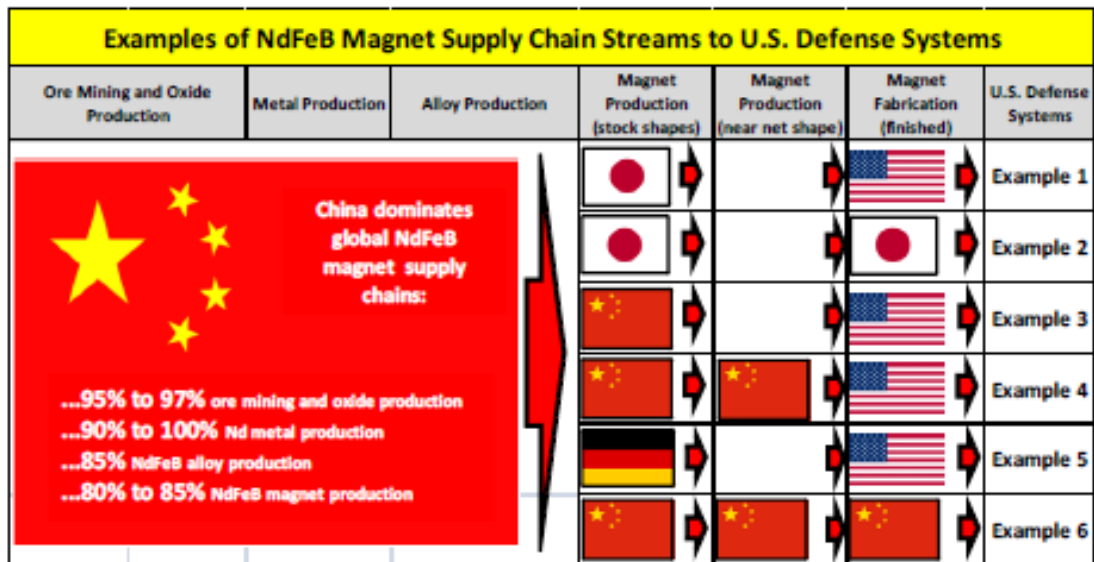


Figure 2. Examples of NdFeB Magnet Supply Chain Streams to Select U.S. Defense Systems

Figure 45 Representation of the supply chain of rare earths (Source: US Department of Defense)

For a number of raw materials the first steps from mining to refining, based on publicly available data, can be well assessed, namely iron (refining for cast iron and steel), aluminium (refined from bauxite), tin (Sn), cobalt (Co), chromium (Cr),

⁴³ Interim Report Assessment and Plan for Critical Rare Earth Materials in Defense Applications, Under Secretary of Defense for Acquisition, Technology and Logistics, August 2011

magnesium (Mg), manganese (Mn), nickel (Ni), zinc (Zn), copper (Cu), indium (In), and lithium (Li). The results are shown in the table below.

Table 8 Over HHI_{prod} and WGI in the value chain

raw material/ore	refined product	raw material/ore	refined product	raw material/ore	refined product
		HHI _{prod}	HHI _{prod}	WGI	WGI
iron ore	cast iron	2742	3302	6	-19
	crude steel	2742	2486	6	-4
bauxite	aluminium	1960	2409	30	-4
tin	metal	2658	2865	-46	-37
cobalt	metal	2699	1898	-39	5
chromite	FeCr	2206	2271	-3	-19
	metal	2206	2717	-3	-28
	Cr-chemicals	2206	2054	-3	-19
magnesium	Mg compounds	5121	1865	-32	-11
	primary Mg	5121	7743	-32	-53
manganese	ferro-manganese	1507	3260	18	-6
	silicon manganese	1507	3908	18	-36
nickel	ferro-nickel	849	2549	13	-17
	metal	849	1479	13	43
Zinc	Zn smelters	1677	1641	9	19
copper	Copper smelters	1282	1327	43	23
indium (from zinc)	Indium-refining	2326	2582	1	18
Lithium	lithium carbonate	2857	3798	90	75

This table shows in red when the step after mining step 'deteriorates', either caused by increasing the country concentration density (higher HHI), or by an apparent deterioration of the weighted World Governance Index (is lower).

Significant shifts in the negative sense do occur with iron, aluminium, chromium, magnesium, nickel, manganese and lithium.

The situation outlined here may also occur further along the value chain. For very specific applications, the distribution of producer countries can be less favourable than those of the original mining countries.

It is obvious that deeper knowledge of the relevant value chains from raw materials to intermediate and final products can give a very different picture of criticality and risk. The complexity analysis referred to in this section may contribute to this, as well as the further development of the databases mentioned in paragraph 5.3.1.

5.5 Predicting raw material security

A large but inevitable disadvantage of the criticality studies conducted around the world, is that they are all based on historical data, both in the field of the analysis of

the economic importance, as in the area of the relevant data concerning production and reserves, over the global distribution, and the degree of development of the source countries, recycling and substitution options. In essence, policy makers and industry stakeholders want to be able to rely on forecasts of raw material supply and demand and the tensions existing between them.

There are several options available to this end, some of which have already been published. Here are a few strategies.

5.5.1 *Relationship between raw material requirements and the development of Gross National Product*

Between 2008 and 2015 Halada and his co-workers wrote a number of articles describing the observed relationship between GNP and the rate of growth in consumption of some metals⁴⁴. From this a number of patterns are observable which are shown in the figures below. Characteristic of each of the growth patterns is that up to a certain break point, the consumption of metal grows equally in proportion to the increase in GNP. From that break point a number of patterns can be observed:

- i) An absolute decoupling occurs between GNP growth and metal consumption (observed for gold, tungsten, tin, chromium, manganese and zinc);
- ii) A stagnation in growth after the break (observed for copper and lead);
- iii) A relative decoupling between GNP growth and growth of metal consumption (i.e., after the break consumption growth decreases) (observed for aluminium, antimony, nickel, silver, molybdenum, palladium and steel);
- iv) No decoupling: a provisional straight proportional growth with GNP growth; this applies provisionally for a number of high-tech metals, which are mainly used in wealthier parts of the world for specific purposes (observed for platinum, gallium, rare earth metals, silicon metal, cobalt, lithium and indium).

⁴⁴ K. Halada, M. Shimada, K. Ijima, Forecasting of the consumption of metals up to 2050, *Mat. Trans Full49*, No.3 (2008) pp. 402-410; *ibid.*, Decoupling status or metal consumption from economic growth, *Mat. Trans Full49*, No.3 (2008) pp. 411-418; K.Halada, Historic Move or current global flow of strategic metals, *World Resources Forum*, Davos, October 2015.

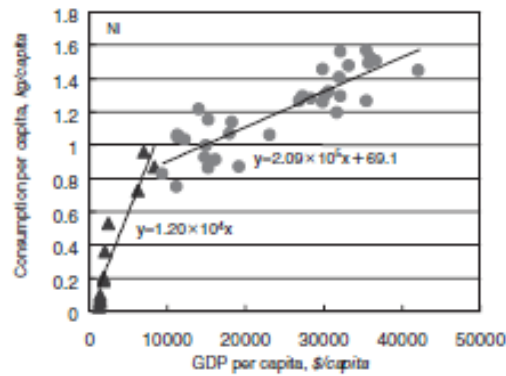


Fig. 4-2 Nickel

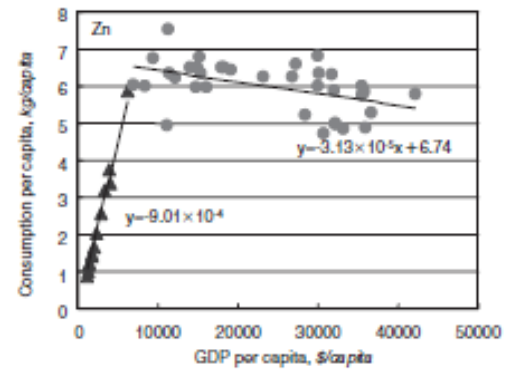


Fig. 4-9 Zinc

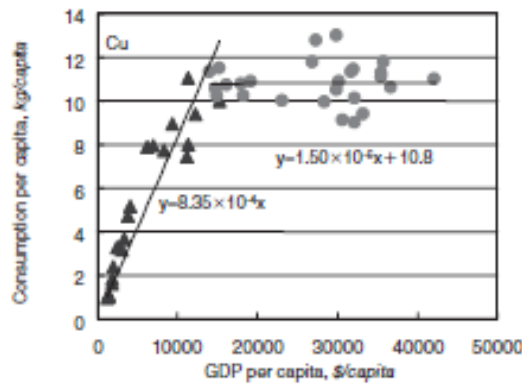


Fig. 4-11 Copper

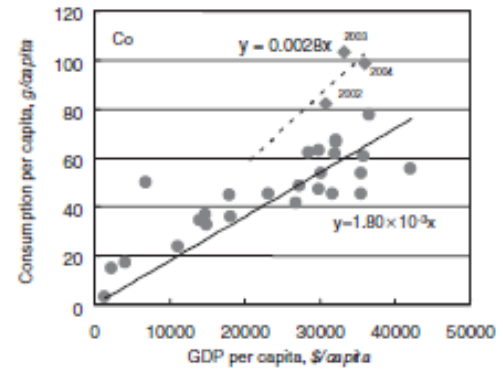


Fig. 4-19 Cobalt

Figure 46 Relation between GNP growth and growth of metal consumption for nickel, zinc, copper and cobalt

In his speech to the World Resources Forum in Davos (October 2015) Halada noted that the rapid growth of the world economy has ensured that much of the world is now at or above the turning point of \$ 10,000 /person with a correspondingly large increase of metal consumption. The relations Halada perceives and their consequences for pressurising the security of supply to Europe and the Netherlands deserves additional research attention.

5.5.2 *The impact of technology development on the need for raw materials*

In the book Rohstoffe für Zukunft Technologies⁴⁵ Angerer and his staff describe for 19 raw materials, what the consequences of demand would be if many of the new technologies in the coming decades would lead to huge growth (based on composition data of these technologies and roadmaps proposed by the industry). The conclusions of this study are that, in the period up to 2030, -already only based on the need of some new technologies such as the use of permanent magnets, PV cells, optical fibres, and displays- the production volumes for a number of materials will rise sharply. The strongest demand growth would be for gallium (required

⁴⁵ G. Angerer, F. Marscheider-Weidemann, A. Lüllmann, V. Handke, M. Merwede, Mr. Scharp, L. Erdmann, Rohstoffe für Zukunft Technologies, Fraunhofer IRB Verlag, 2009.

production growth factor 6), neodymium (factor 4), indium (factor 3), germanium (factor 2.5), scandium (factor 2.3) and platinum (factor 1.5).

The possible influence of alternative strategies which reduce or prevent the use of these materials (substitution strategies) is not included in this German study. To follow such developments further would be advisable in order to assess future security of supply.

The connection with the possible growth of the unexamined technologies is, of course, unknown. Also, the extent to which these future deficiencies would be detrimental to the Dutch economy, has not been further analysed.

5.5.3 *Development of supply from mining*

In determining the long-term criticality this report uses the R/P ratio (reported by the US GS); the R/P ratio indicates the number of years undisturbed production under constant technical and economic conditions. Due to developments in these conditions, it may be generally stated that the reserve valuation is an indicator which gives little concrete information about the future.

When it comes to the development of the reserves there should arise a relationship between the amount of resources put into detecting reserves (exploration phase) and the extent to which significant finds are made. Richard Schodde, Managing Director, Minex Consulting, noted in his presentation to the IMARC conference in 2014⁴⁶ that this is not the case, and that gives cause for concern. An analysis of expenditure in the exploration of metal and minerals could in principle contribute to gaining a better insight into long-term availability. After all, when there is no investment in the search for new supplies then no new supplies will be found.

An overview of investments in exploration is given in Figure 47. This shows that in 2012 an absolute peak was reached in investment in the materials shown. The number of large finds, however, is not keeping pace with this increased investment (Figure 48). This has remained for several decades at 60-70 finds per year (of which only some are characterised as 'giant discoveries' or > 1 Mt Ni, > 5 Mt Cu equiv). Gold investments dominate these, but investments in base metals (copper, zinc, nickel, lead) are also increasing. Investments in these 'host' metals also ensure (indirect) investments in the exploration of the by-products (companions) of these metals.

Due to the difficulty in predicting the relationships between exploration and eventual mining investment, and the fact that only sketchy data is available for a few commodities, the extent of investment in exploration can currently not be used as an indicator for long term supply security.

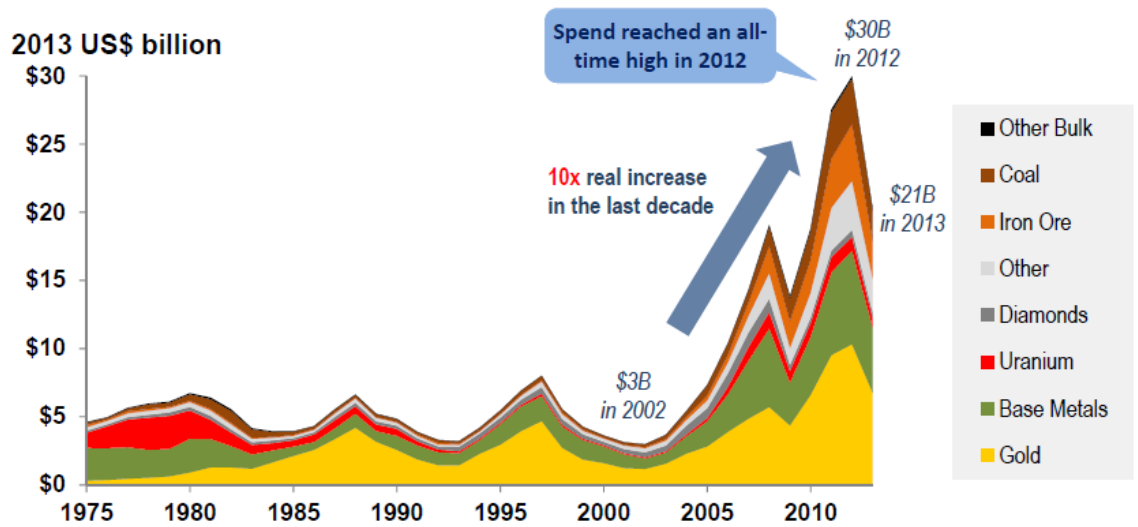


Figure 47 Investment in exploration by type of raw material (source: Minex Consulting)⁴⁶

In addition, detailed information is only available for a few metals. Building a better methodology to obtain more data and/or to collect information about demand development (due to exploration of new mining projects) should be covered at Dutch national level, and definitely at European level. Commercial Data Offices (RMG, PCI, Roskill) partly meet this need, but its relevance to policy level is meagre.

⁴⁶ Richard Schodde, Minex Consulting, Uncovering exploration trends and the future, Presentation to International Mining and Resources (IMARC) Conference 22nd September 2014 Melbourne.

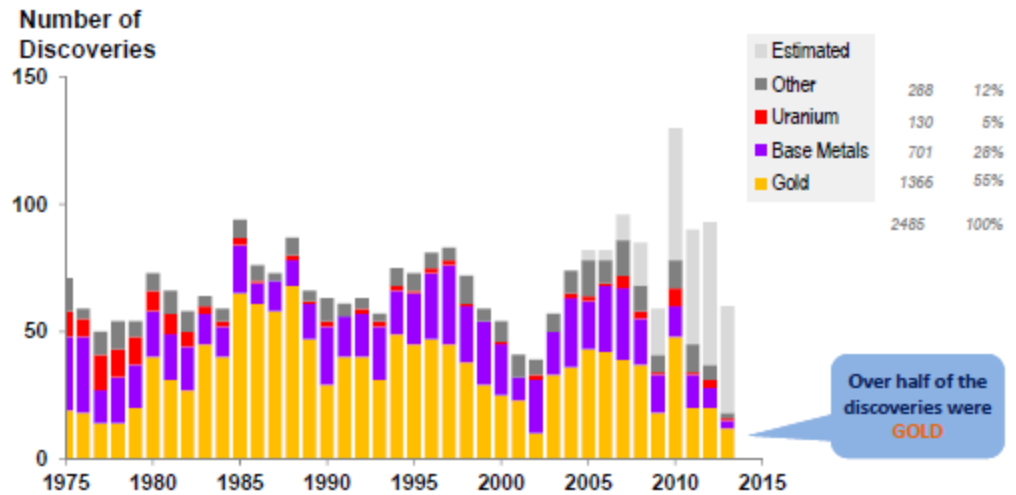


Figure 48 Number of actual ore discoveries (source: Minex Consulting, September 2014)

5.5.4 Research into future supply security

A forward-looking policy would also need to give an outline focused on the future concerns regarding supply and demand development of raw materials, materials and intermediates relevant to the Dutch economy. The European Commission has made 1 million euros available for its research programme 2016, for a study on 'Demand-supply forecast and raw materials flows at global level "(SC5-16a); The text reads: "Proposals should develop a common methodology to mineral raw material flows at global level which could be agreed and used at international level. As a pilot case, focus should be on critical raw materials and in particular the ones used in low-carbon technologies. The methodology should incorporate models on demand-supply forecast in order to allow for dynamic analysis of global material flows. Proposals should provide recommendations and feed into future policy developments".

A similar research programme focusing on Dutch requirements should comprise part of a commodities-research agenda.

5.6 Biotic raw materials

5.6.1 Biotic raw materials are important to the Dutch economy

This study examines the relationship between 64 abiotic raw materials and the Dutch economy. This of course gives a strong relationship with those sectors which use considerable quantities of critical abiotic raw materials such as the sectors involved in the manufacturing of electronic and electrical equipment and machines.

However, the economy of the Netherlands is also strongly intertwined with the biotic sectors, as is clear from the accompanying figure. This shows the distribution of added value for the entire processing industry for the Dutch economy in 2012. This reveals that approximately 25% of the export value comes from the food and beverage industry, chemical industry, wood processing and paper manufacturing industry. The often organic and biotic materials for these sectors are not included in

the current study, this in turn gives an incomplete and somewhat unbalanced picture of the security of supply issues facing the Dutch economy.

5.6.2 *Biotic raw materials are included in European criticality studies*

In the most recent EU study on critical materials some biotic resources were included in the analysis, namely: natural rubber, sawn softwood pulpwood. Using the same criticality parameters (a combination of source country concentration, recyclability and substitutability) none of these three biotic materials were labelled as critical. The study states that the method used is also applicable to biotic materials, but there are also a number of aspects which can specifically affect the availability of biotic resources. These aspects are: land use competition, current intensity of land use (how close is over-exploitation?), impact on biodiversity, impact of natural disasters and climate change, and the impact of disease.

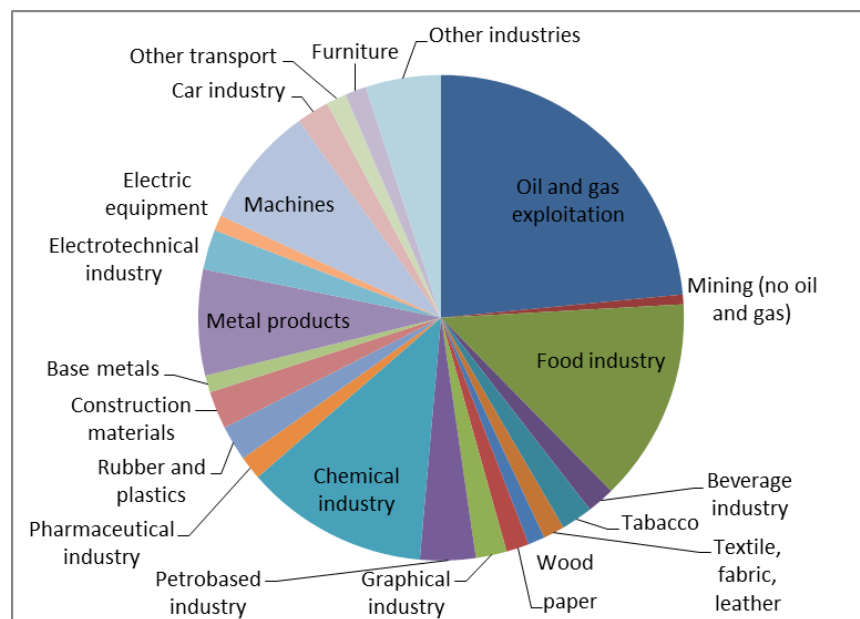


Figure 49 Distribution of added value in Dutch industry (2012)

Such aspects make clear that the current set of indicators are indeed suitable for use, but that a broader set of indicators is needed for a balanced picture regarding the security of both abiotic and biotic resources. In addition, it is noticeable that there are issues involved which are directly related to security of supply, as well as with corporate social responsibility.

5.6.3 *The first Dutch exploratory analysis of biotic resources has already been carried out.*

In 2014, the report "Control over raw materials: supply and biodiversity" was published, written by KPMG Sustainability (and supported by PBEE, CBL, FNLI, IUCN, Nature & Environment and VNO-NCW). In this report, sugar, soya and fish oil were examined in more depth and the supply of these raw materials was found to be under pressure and subsequently an action framework was provided for entrepreneurs involved. The named themes which play a role in reducing the supply immediately make clear that these are different sensitivities than when it comes to abiotic raw materials (loss, alteration and fragmentation of habitat, over-exploitation,

invasive species, pollution and climate change). All the more reason to provide a common set of indicators which enable more balanced mitigation policies.

5.7 Further research into the impact of the circular economy on security of supply?

The debate surrounding the circular economy is driven by the need to establish an economic process in such a way that our environmental and material footprint is greatly reduced, and then especially in a way which maintains as much value as possible in the cycle and so enhances economic potential.

One element which occupies an increasingly important place in the debate is whether a step towards greater circularity can also improve the security of supply of raw materials. In essence this is a simple question: process efficiency-improvement leads to a decrease in the quantity of purchased materials. The question is to what degree does the impact of an increasing circular economy have on the security of supply? To be able to answer this question in a sound manner requires further research in close collaboration with industry players who have gained practical experience with the impact that a circular transition can have.

In the current study a tentative analysis has already been carried out of the connection between circular economy and (short-term) security of supply.

5.7.1 The methodology to assess the impact of a more circular economy on security of supply.

An initial analysis of the potential impact of a more circular economy on security of supply has been carried out as part of this study. The analysis follows roughly the following steps:

- i. 70 products were examined as case studies, these were spread over 35 sectors and divided between final products and intermediates;
- ii. Each of these 70 products was given a score of 1 to 5 for 7 different characteristics, where the maximum number in each case indicates a large circular potential (or is already being yielded); these characteristics are:
 - a. Price
 - b. Absence of cultural dynamics
 - c. Absence of technical dynamics
 - d. Reparability/modularity
 - e. Potential use vs. ownership/control/collection/communication
 - f. Recyclability/dissipative use/pollution
 - g. Presence of existing infrastructure and/or systems.
- iii. Subsequently, three circular actions are focused on (recycling, reuse, repair/maintenance) and it is determined which of the aforementioned seven characteristics are essential to ensure economic potential. Requirement: Each of these points should score at least a four (i.e.: all characteristics simultaneously present). It is now known for each of the 70 products if circular potential can be expected: an all or nothing verdict per action framework;
- iv. It is assumed that in the coming years there will be a 20% improvement for each of the three perspectives; thereby the potential per product may therefore vary between 0 and 60% reduction in raw material import. The

cycles do not necessarily interfere with each other and all lead to less material use;

- v. The potential per product (group) is generally declared binding for the entire sector to which that product belongs.

Following this procedure gives rise to the following scenario: in total, the total use of the 64 commodities is reduced by 0.44 million tons. In particular, the used volume (of all the materials combined) of the automotive industry and the electrical equipment industry are reduced by 16% and 24% respectively, as compared to current material use.

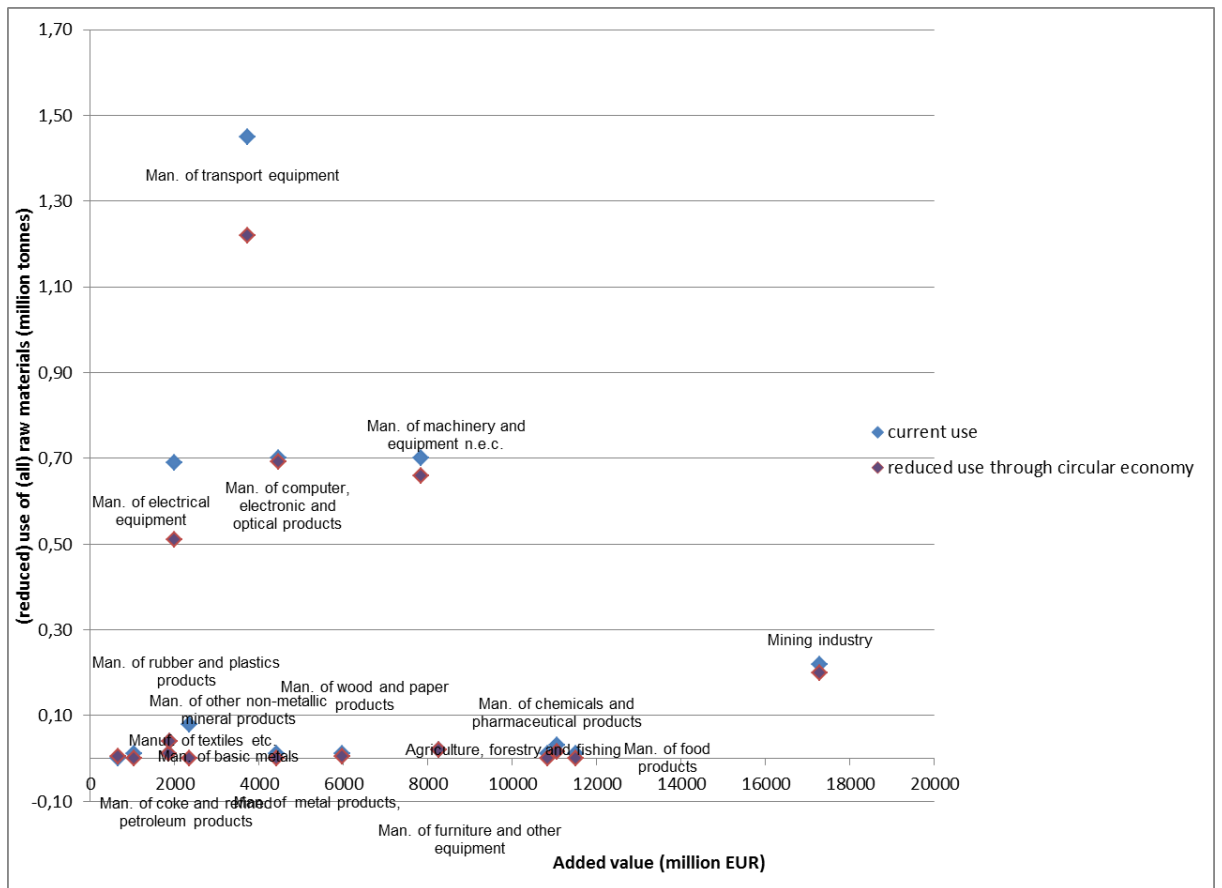


Figure 50 Impact of a 20% intensification of the circular economy across all action frameworks

A Method for determining the economic importance of raw materials

Step 1: determination of applications of selected materials in products and product groups; these product groups are divided into raw materials, intermediate and final products

- Based on the available data coming from a wide variety of sources, a selection will be made from product groups where the selected critical materials are found taken from the broad set of products and product groups included in the Harmonised System of BACI (for a description of BACI see Appendix C). The result is a matrix connecting raw materials and products.
- Sources used to this end include (annual) reports from specific material study groups (including the International Copper Study Group, ICSG⁴⁷, the International Lead and Zinc Study Group⁴⁸, and the International Platinum Group Metals Association⁴⁹), reports from consultants on specific metals (including from the Oeko-Institut and Oakdene Hollins on rare earths⁵⁰), in which “top-down” overviews are given of the principle applications of certain raw materials.
- In addition, we have made use of many detailed analyses from the LCA database from ecoinvent (which has the advantage that the information it contains is continuously updated) as well as details regarding the composition of products from the network of international partners Tecnalia (Spain) and SP (Sweden), Fraunhofer ISI (co-authors of the RMI studies into critical materials in the EU) and other German institutions (VDI, DERA, University of Bremen: <http://www.fb4.uni-bremen.de>, etc.), a study of product compositions from ES-KTN (UK, project partner in CRM_InnoNet; see www.criticalrawmaterials.eu) and details from the French P.E.P. (see: <http://www.pep-ecopassport.org/test-recherche>).
- In order to distinguish between raw materials, intermediate and final products, a list from Eurostat (“stage of production” per CN code) is used. A matrix is still prepared linking raw materials and product groups from the Harmonised System (HS). The HS goods must then be linked to the CN goods. The Dutch import and export of products is determined on the basis of the National Accounts and international trade statistics and not on the basis of BACI.
- For the 30 largest product groups (expressed by CN code) in the Dutch economy, we use detailed data for individual products to verify the mass balance. This gives an indication of the accuracy of the analysis for the most important products in domestic industry.

⁴⁷ <http://www.icsg.org/>

⁴⁸ <http://www.ilzsg.org/>

⁴⁹ <http://www.ipa-news.com/en/>

⁵⁰ Study on Rare Earths and Their Recycling, by the Oeko-Institut, tasked by The Greens in the European Parliament, January 2011; Lanthanide Resources and Alternatives, by Oakdene & Hollins, 2010, tasked by UK Department for Transport and Department for Business, Innovation and Skills.

Step 2: quantitative applications with the aid of mining data: mass balance

- The starting point for a global MFA is (roughly) that the annual quantity of raw material extracted results in an annual production volume of products: this means that the use of mining data makes it possible to arrive at a balanced mass balance and quantification of the amount of materials used in the selected product groups.
- The main sources of data are geological surveys, notably from the US Geological Survey and the British Geological Survey, and from commercial suppliers such as Roskill Information Services.
- The assignment of mining data (as input for the global economy) to selected product groups via the most important applications is determined in step 2.

Step 3: preparation of a trade flow analysis and, on the basis of this, a material flow analysis (MFA) for selected materials for 43 countries (and the “rest of the world”)

- We do this by combining detailed trade data from BACI for the selected products with composition data.
- We proceed on the basis of, and adjust for, country information and quantities such as those obtained from international trade statistics and the materials monitor.
- For the purpose of vulnerability assessments, time series of production data from 1998 to the present day are described.

Step 4: conversion of the MFA into a quantitative and validated picture of the importance of the selected applications to the Dutch economy (in collaboration with the CBS (Statistics Netherlands))

- TNO prepares a coupling matrix describing the relationship between raw materials and product groups per relevant CN code (result of steps 1 to 3). This matrix shows both the presence and absence of certain materials as a proportion of a “critical material” per kilo CN goods group (for explanation: see text box).
- Based on international trade data from the CBS, and with the help of the matrix, the absolute quantities of “critical materials” per CN goods group are determined. These are then linked to and aligned with the goods grouping of the National Accounts (NR) and the materials monitor. Tables can then be prepared showing the supply and use of “critical materials” per sector.
- The MFA must undergo two essential correction cycles. Firstly, a correction in respect of double counting must be performed by counting intermediates/semi-finished goods in a final product. Secondly, re-export must be included in order to know exactly where products really “end up” (where they are consumed). For both of these corrections, a link with the NR is required. We will employ the CPA format (used in the NR) and EXIOBASE (for explanation see Appendix B EXIOBASE) for all countries except the Netherlands. Due to the potential

confidentiality of the data, we propose that these activities take place at the offices of the CBS. The link with the CPA makes it possible to link the results of the TNO MFA to the National Accounts, Environmental Accounts and the Material Flow Monitor.

- The results of step 4 are “typical shares” of specific raw materials in product groups, expressed in grammes per tonne (parts per million). These typical shares are already linked in MIDNE1 to the products and sectors classification of the Material Flow Monitor. The CBS data concerning international trade and the supply-and-use structure of the monitor represent the foundation of the database. Future proofing is guaranteed by linking the results of the MFA (“typical shares”) to the monitor.

B Import of raw materials from and export of “raw materials”to Germany

The following table shows, for each of the four steps considered here, (raw materials, first intermediates, intermediate products, final products) the contribution made by Germany to the volume of the import in question (compared to imports from the rest of the world) and to the volume of our exports (compared to exports to the rest of the world).

	percentage of imports from Germany compared to world				percentage of exports to Germany compared to world			
	RM	1st IM	IM	final	Uncompressed	1st intermediate	final	al
Silver	0	20	48	26	0	12	14	22
Al	26	8	14	38	75	52	23	2
Au		13	43	23	0	0	57	1
B	3	60	15	40	0	1	12	21
BA	3	43	15	34	15	65	17	19
BE	0	6	46	8	4	26	18	15
one where you are insured.	1			32	72	0	0	24
CE	19	14	6	18	38	25	34	22
CO	7	9	18	10	4	13	19	20
coking coal	54	0			0	0	0	0
CR.	3	11	29	24	72	29	42	16
Cu	9	13	21	14	22	51	13	11
diat.	29	82	31	31	9	29	27	19
Dy	1		38	12	1	0	25	18
EU (disambiguation)	1		37	11	1	0	7	18
Fe	1	35	34	21	34	30	38	7
Feldspar	2			36	28	0	0	20
Fluorspar	0	57	38	47	16	5	31	16
Ga		21	16	12	0	1	32	16
GD	1	20	35	12	1	47	10	19
Ge	0	21	77	11	4	1	25	20
gypsum	58		27	49	15		19	10
lead	8	10	19	29	75	27	19	17
In	38	0	37	10	30	6	13	19
ind.zand	60	32	63	34	7	16	46	20
IR	0	17	48	18	4	4	18	65
limestone flux	18	65	39	37	59	20	31	30
clay	32		9	43	37	0	59	20
La	19	7	24	13	38	10	0	19

Li	0	58	38	23	4	13	28	20
MG	30	21	17	28	68	32	33	19
MN	24	15	11	39	66	42	34	7
Mo	0	10	18	35	10	20	14	7
NB	0	4	34	4	0	0	35	12
Neodymium	19	11	3	12	38	29	13	20
Ni	0	6	24	15	0	75	33	25
Oxen	0	17	53	17	4	4	20	71
P2O5	22	27	13		88	23	24	0
PD	0	7	49	25	4	12	19	25
Perl	60		24	67	5	0	40	12
PR:	1	26	4	12	1	22	5	18
PT	0	19	46	24	4	5	20	45
Re		63	27	2	0	2	5	1
Rhodium	0	19	52	15	4	5	24	22
Ru	0	19	50	15	4	5	20	10
Sb	0	56	24	15	4	12	45	24
SC	1	1	39	14	1	53	11	19
SE	3	47	41	19	0	0	16	12
Si	29	17	19	9	71	40	34	4
SM	1	25	41	11	1	27	17	18
SN	0	54	27	16	0	35	26	14
SR	0	14	2	26	1	32	20	29
Ta	0	36	4	12	0	10	5	14
talcum	1		30	39	65	0	25	20
TB	1	0	34	11	1	15	14	20
To	3	62	39	13	0	0	19	22
TiO2	0	39	29	25	67	44	21	19
V	0	88	43	30	67	18	12	31
W	0	1	15	14	4	18	13	8
Y	1	33	2	11	1	24	4	21
Ytterbium	1	0	39	10	1	15	9	21
Zn	3	11	23	19	0	26	28	8
Zirconium	0	24	42	59	73	37	18	21

C Environmental impact of raw material extraction

Introduction

In this appendix, the environmental impact of the extraction of critical materials is determined. The purpose of this exercise is to attach a global environmental profile to each material. A second and third objective is to deduce, on the basis of the available environmental data, what is known about the origin of the materials in question and the relationship between primary and secondary material flows.

Only the extraction and production phases considered necessary to arrive at a basic product have been considered; (emissions during) use, maintenance, replacement and disposal scenarios are not included. Determining this environmental impact is therefore not a full life-cycle assessment (LCA), although the methods for data collection and analysis that are customary in LCAs have nevertheless been followed. In LCAs, all inputs and outputs over the life cycle (in this case, the entire extraction process) of a product or service are summed, divided into different environmental effects, in order to determine the total environmental burden. The inputs in this case are the raw materials and also intermediate products. Outputs include emissions to the soil, water and atmosphere and waste.

When carrying out an LCA, three types of data are available: LCA databases with information on average products, articles in scientific literature (which often cover more specific products), and expert information. Expert information is often requested from companies, although that is not the case in this study. In this project ecoinvent 3.0, the world's leading LCA database, and (scientific) LCA articles about raw material extraction have been consulted.

Method

Scope

This analysis considers only the extraction and production phases of raw materials, which is referred to in LCA terms as a *cradle-to-gate* analysis. The use phase and the end-of-life phase are not considered, although these would be relevant to a full life-cycle assessment of a particular product. For the raw materials tool, only the extraction and production phases are relevant.

Products have not been considered (e.g. chair, LED lamp, etc.), nor unprocessed raw materials (e.g. iron ore, bauxite), but instead only the basic materials as available on the commodities market (e.g. aluminium consisting of a mixture of primary and secondary aluminium). These "raw materials" inhabit a grey area between unprocessed raw materials and products, and as such have no strict definition. We have nevertheless chosen to analyse these basic materials, as this gives a more complete picture of materials than would be obtained if only unprocessed raw materials were considered.

The Swiss database ecoinvent 3.0, which contains data from many countries, has been used. Where possible, worldwide product specifications have been used instead of country-specific specifications. Where possible, the market process (including balanced geographical mix and associated transport distances) has

always been selected in preference to production in just one country (in ecoinvent terms: “transformation process”). For most products, the primary production process was analysed and thus not production based on secondary (recycled) flows. Secondary processes have however been included where the secondary process has a significant environmental impact (e.g. with gypsum: the aggregated environmental score (shadow price) of plaster from citric acid production is higher than that of mined gypsum). Where certain materials were not present in ecoinvent, (scientific) articles were sought in literature and on the Internet.

The environmental impact was determined on the basis of the LCA program SimaPro v8.0.6 and the impact assessment method ReCiPe v1.11. (Goedkoop, Heijungs, Huijbregts, Schryver, Struijs, & Zelm, 2009). The results were determined both at midpoint level (measurable environmental effects such as CO₂ emissions, acidification, etc.) and at endpoint level (damage at a higher level such as to ecosystems, health and resources). We chose to look at both levels so that they could be compared and the effect of the choice of methodology shown. The reason that the European ILCD method was not selected is that, for the ReCiPe midpoint method, weighting factors (shadow prices) are available. This is not the case for the ILCD method.

Weighting was applied in order to summarise the results and to be able to compare different effects. For the endpoints, the standard set for European and average (“H/A”) weighting was applied; the midpoint results are weighted based on shadow prices from CE Delft (Bruyn, 2010) and Van Harmelen ((Harmelen, Korenromp, Deutekom, Ligthart, Leeuwen, & Gijlswijk, 2007) & (Harmelen, Horssen, Jongeneel, & Ligthart, 2012). When considering the endpoint results, there is an overlap with other indicators. This is because “resources” is included in the endpoint calculations. There is no overlap in the midpoint results, since “resource depletion” is multiplied by a weighting factor of 0.

Long-term emissions (>500 years) are not included in the analyses, but infrastructure processes (factories and machines) have been included. These supporting processes have not been included in the other analyses of this report and the tool.

Approach

Determination of the environmental profiles takes place via a number of steps:

- Step 1: Analysis of which materials from the raw materials tool can be found in the LCA database ecoinvent v3.0.
- Step 2: Information about basic materials that are missing in ecoinvent and for which no assumptions could be made on the basis of similar materials in ecoinvent is sought in (scientific) articles.
- Step 3: Analysis of these materials using the LCA-SimaPro v8.0.6 software and the ReCiPe methods. Verification and fine tuning where necessary.
- Step 4: Analysis of the results. Which materials and environmental effects stand out? Are there differences between the midpoint and endpoint results?

Step 5: Documentation of results, conclusions and data.

Results

Data Inventory

Table 9 shows the materials analysed and the data sources used. In many cases this is the database ecoinvent v3, in some cases it is an assumption (proxy) based on ecoinvent and in all other cases it is Nuss & Eckelman (Nuss & Eckelman, 2014). In cases where an assumption is made, caution should be exercised when interpreting; there is often a lack of clarity in the data sources with regard to the exact proportions and concentrations of certain substances in ores (e.g. “cerium, 60% cerium oxide”), and it is not always entirely clear how allocation issues have been handled⁵¹. A margin of error in the results of at least a factor of 2 must therefore be kept in mind.

The third and fourth columns in the table show that ecoinvent 3 contains a great deal of information regarding the origin of materials but provides only limited information about the relationship between primary and secondary flows. The information in column 4 is therefore of little use, aside from the conclusion that can be drawn as a result of it – namely that it would be preferable to seek data elsewhere. As regards geographic information, ecoinvent is certainly not complete (too few countries are mentioned for each material), but it forms a good starting point for further calculations.

⁵¹ Allocation is the LCA term for the distribution of effects of a given process that yields multiple products. In general, one of the products is considered to be the main product and the others to be lower-value by-products, which are allocated a smaller proportion of the total environmental impact. One way of carrying out this distribution (=allocation) is on the basis of economic value; however, this basis and the subsequent calculation procedure is sometimes difficult to determine.

Table 9 Analysed materials and associated data source⁵²

Equipment	Data source:	Geographical origin (indicative)	Mixed primary / secondary (indicative)
Aluminium Bauxite	Ecoinvent; Aluminium, primary, GLO ingot {} market for Alloc Def	100% Canada, 0.01% RoW	100% prim
Antimony, Utah	Ecoinvent; Antimony GLO {} market for Alloc Def	5% China, 95% RoW	100% prim
Barytes	Ecoinvent; Barite GLO {} market for Alloc Def	0.4% Canada 33.1% Europe 66.5% RoW	100% prim
Bentonite	Ecoinvent; Bentonite GLO {} market for Alloc Def	6% Germany, 94% RoW	100% prim
Beryllium	Nuss & Eckelman 2014	no info	no info
Borates / boric [proxy]	Ecoinvent; Sodium borates GLO {} market for Alloc Def	57% USA, 43% RoW	100% prim
Cerium	Ecoinvent; Cerium concentrate, 60% cerium oxide GLO {} market for Alloc Def	China 98%, 2% ROW	no info
Chromium	Ecoinvent; Chromium GLO {} market for Alloc Def	33% Europe, 67% RoW	100% prim
Cobalt	Ecoinvent; Cobalt GLO {} market for Alloc Def	100% Global	99% prim, 1% from used Li-ion batteries
Coking coal	Ecoinvent; Coke GLO {} market for Alloc Def	Overall, 99.2%, Germany 0.7%, <0.1 petroleum	100% prim
Copper	Ecoinvent; Copper GLO {} market for Alloc Def;	1% Germany, Australia 2%, 11% Asia, Europe, 5%, 11% Latin America, North America 8%, 0.3% Sweden, 2% Overall, Russia 1%, 0.09% South Africa, 52% RoW	Sec 22%, 78% prim
Diatomite [proxy]	Proxy: copy Ecoinvent's perlite (perlite quarry operation RoW), as seems	no info	no info

⁵² Geographic information according Ecoinvent and ratio of primary and secondary materials in the world mix according Ecoinvent. Origin and mix were taken from Ecoinvent, which primarily an environmental database and therefore not necessarily fully up to date in terms of market data; these columns are therefore mainly indicative. "RoW" means Rest of World.

Equipment	Data source:	Geographical origin (indicative)	Mixed primary / secondary (indicative)
Dysprosium [proxy]	Proxy: Ecoinvent's Rare earth concentrate, 70% REO, from bastnasite GLO {} (2 kg because samarium has two kg of rare earth concentrate as input)	China 98%, 2% ROW	no info
Europium	Ecoinvent; Samarium europium, gadolinium concentrate, 94% rare earth oxide GLO {} market for Alloc Def	China 98%, 2% ROW	no info
Feldspar	Ecoinvent; Feldspar GLO {} market for Alloc Def	33% Europe, 67% RoW	no info
Fluorspar	Ecoinvent; Fluorspar, 97% purity GLO {} market for Alloc Def	100% Global	100% prim
Phosphorus / Phosphate Rock - dry	Ecoinvent; Phosphate rock, ash P2O5 beneficiated, dry GLO {} market for Alloc Def	9% Morocco 91% RoW	100% prim
Phosphorus / Phosphate Rock - law	Ecoinvent; Phosphate rock, ash P2O5 beneficiated, law GLO {} market for Alloc Def	9% USA, 91% RoW	100% prim
Gadolinium	Ecoinvent; Samarium europium, gadolinium concentrate, 94% rare earth oxide GLO {} market for Alloc Def	China 98%, 2% ROW	no info
Gallium in Bayer liquor	Ecoinvent; Gallium, in Bayer liquor from aluminum production GLO {} market for Alloc Def	100% Global	no info
Gallium semiconductor grade	Ecoinvent; Gallium, semiconductor-grade GLO {} market for Alloc Def	100% Global	no info
Germanium [proxy]	Proxy: copy Ecoinvent's Indium (market for indium GLO) since won together. Ecoinvent allocates it between zinc and indium, but this ratio is not adjusted.	no info	no info

Equipment	Data source:	Geographical origin (indicative)	Mixed primary / secondary (indicative)
Gold	Ecoinvent; Gold GLO {} market for Alloc Def	10% Australia, Canada 6%, 2% Tanzania, 10% US, 11% of South Africa, Peru 4%, 1% Papua NG, Sweden 0.2%, 0.1% Chile, 57% RoW	no info
Gypsum	Ecoinvent; Gypsum, mineral GLO {} market for Alloc Def	Switzerland 0.2%, 99.8% RoW	75% van citroenzuurpr oductie; 3% van rookgas, 22% primair
Indium	Ecoinvent; GLO indium {} market for Alloc Def	11% Europe, 89% RoW	100% prim
Iridium [proxy]	Proxy-based Ecoinvent's Rhodium (GLO {} marketplace for Alloc Def) as being both won as platinum group metal	no info	no info
Iron, Aisne	Ecoinvent; Pig iron GLO {} market for Alloc Def	no information (or process information: 5% beneficiation in Canada, 95% RoW)	no info
Kaolin (clay)	Eoinvent; Kaolin GLO {} market for Alloc Def	33% Europe, 67% RoW	no info
Lanthanum	Ecoinvent; Lanthanum oxide GLO {} market for Alloc Def	China 98%, 2% ROW	no info
Limestone (chalk)	Ecoinvent; Limestone crushed, washed GLO {} market for Alloc Def	Switzerland 0.8%, 99.2% RoW	no info
Lithium	Eoinvent; Lithium GLO {} market for Alloc Def	100% Global	"100% prim"
Magnesite / magnesium	Ecoinvent; Magnesium GLO {} market for Alloc Def	Israel 4%, 83% China, 13% RoW	no info
Manganese	Ecoinvent; Manganese GLO {} market for Alloc Def	Europe 25%, 75% RoW	no info
Molybdenum	Ecoinvent; Molybdenum GLO {} market for Alloc Def	1.6% Europe 98.4% RoW	100% prim
Natural Graphite	Ecoinvent; Graphite GLO {} market for Alloc Def	33% Europe, 67% RoW	100% prim

Equipment	Data source:	Geographical origin (indicative)	Mixed primary / secondary (indicative)
Neodymium	Ecoinvent; Neodymium oxide GLO {} market for Alloc Def	China 98%, 2% ROW	no info
Nickel	Ecoinvent; Nickel, 99.5% GLO {} market for Alloc Def	Overall, 65%, 28% Russia, South Africa, 4%, 0.05% Sweden, 3% RoW	no info
Niobium	Nuss & Eckelman 2014	no info	no info
Osmium [proxy]	Proxy-based Ecoinvent's Rhodium (GLO {} marketplace for Alloc Def) as being both won as platinum group metal	no info	no info
Palladium	Ecoinvent; Palladium GLO {} market for Alloc Def	49% Russia, 40% of South Africa, Europe, 0.7%, 0.07% Sweden, 10% RoW	89% of this is prim
Perlite	Ecoinvent; Perlite GLO {} market for Alloc Def	6% Germany, 94% RoW	no info
Platinum	Ecoinvent; Platinum GLO {} market for Alloc Def	15% Russia, 82% of South Africa, Europe 1%, 2% RoW	97% of this is prim
Praseodymium	Ecoinvent; Praseodymium oxide GLO {} market for Alloc Def	China 98%, 2% ROW	no info
Rhenium [proxy]	Proxy-based Ecoinvent allocation; 13.5% of Molybdenum GLO {} market for Alloc Def	no info	no info
Rhodium	Ecoinvent; Rhodium GLO {} market for Alloc Def	17% Rusland, 61% Zuid-Afrika, 7% Europa, 14% RoW	87% of this is prim
Ruthenium [proxy]	Proxy-based Ecoinvent's Rhodium (GLO {} marketplace for Alloc Def) as being both won as platinum group metal	no info	no info
Samarium	Ecoinvent; Samarium europium, gadolinium concentrate, 94% rare earth oxide GLO {} market for Alloc Def	China 98%, 2% ROW	no info

Equipment	Data source:	Geographical origin (indicative)	Mixed primary / secondary (indicative)
Scandium [proxy]	Proxy: Ecoinvent's Rare earth concentrate, 70% REO, from bastnasite GLO {} (2 kg because samarium has two kg of rare earth concentrate as input)	China 98%, 2% RoW	no info
Selenium	Ecoinvent; Selenium GLO {} market for Alloc Def	33% Europe, 67% RoW	no info
Silica sand	Ecoinvent; Silica sand GLO {} market for Alloc Def	Market sand is apparently 7% German and 93% RoW, but winning is 4% Swiss and 96% RoW	no info
Silicon Metal / Silicon	Ecoinvent; Silicon, metallurgical grade GLO {} market for Alloc Def	Norway 25%, 75% RoW	100% prim
Silver	Ecoinvent; Silver GLO {} market for Alloc Def	0.08% Canada 0.2% Peru 0.2% Papua NG, Sweden 1.6%, Chile 0.7%, 32% Overall, 67.7% RoW	69% prim, 31% sec
Strontium	Nuss & Eckelman 2014	no info	no info
Talk [proxy]	Proxy; talc resembles lime. Ecoinvent: Limestone, crushed, washed GLO {} market for Alloc Def	no info	no info
Tantalum	Ecoinvent; Tantalum, powder, capacitor-grade GLO {} market for Alloc Def	100% Global	no info
Tellurium	Ecoinvent; Tellurium, semiconductor-grade GLO {} market for Alloc Def	Canada, 37%, 63% RoW	no info
Terbium [proxy]	Proxy: Ecoinvent's Rare earth concentrate, 70% REO, from bastnasite GLO {} (2 kg because samarium has two kg of rare earth concentrate as input)	China 98%, 2% RoW	no info
Tin	Ecoinvent; Tin GLO {} market for Alloc Def	33% Europe, 67% RoW	100% prim

Equipment	Data source:	Geographical origin (indicative)	Mixed primary / secondary (indicative)
Titanium - dioxide from ilmenite	Ecoinvent; Ilmenite, 54% titanium dioxide GLO {} market for Alloc Def	Australia 36%, 8% Overall, 56% RoW	100% prim
Titanium - dioxide from rutile	Ecoinvent; Rutile, 95% titanium dioxide GLO {} market for Alloc Def	16% Australia, 59% Overall 25% RoW	100% prim
scheelite	Nuss & Eckelman 2014	no info	no info
Uranium	Uranium into yellowcake GLO {} market for Alloc Def	30% North America, 70% RoW	no info
Vanadium [proxy]	Proxy-based Nuss & Eckelman 2014; only raw material and energy consumption	no info	no info
Ytterbium [proxy]	Proxy: Ecoinvent's Rare earth concentrate, 70% REO, from bastnasite GLO {} (2 kg because samarium has two kg of rare earth concentrate as input)	China 98%, 2% ROW	no info
Yttrium [proxy]	Proxy: Ecoinvent's Rare earth concentrate, 70% REO, from bastnasite GLO {} (2 kg because samarium has two kg of rare earth concentrate as input)	China 98%, 2% ROW	no info
Zinc, Arkansas	Ecoinvent; Zinc GLO {} market for Alloc Def	1% Sweden, 94% in total and 5% RoW	no info
Zircon	Ecoinvent; Zircon, 50% zirconium GLO {} market for Alloc Def	39% Australia, 61% RoW	no info

Environmental effects

The environmental effects are shown in three graphs. One shows the Greenhouse Effect (CO₂ equivalents) of the materials analysed. All impact categories of the ReCiPe midpoint method are shown in weighted form (weighted using shadow prices). The third graph compares the weighted results of the midpoint method with the endpoint results. In all graphs, the Y axis is truncated, since gold and the platinum group metals have extremely high values when compared to other materials. All graphs should be interpreted with a margin of error of a factor of 2, given the uncertainty and generality of some data, as explained in section 0.

A varied picture emerges. There are a few extreme peaks: gold and the platinum group metals cause 5,000 to 30,000 kg CO₂ equivalents per kilogramme of material. All other materials cause 600 kg (silver) or less than 300 kg CO₂ equivalents per kilogramme, which is much less than these peaks. A major cause of the high scores for gold and the platinum group metals is the high monetary value

of these materials, which plays a role in the distribution of environmental effects across a number of co-products. The “conventional rare earth metals” (cerium to yttrium in the chart) all have relatively low CO₂ scores (3 to 40 kg CO₂ eq/kg).

The data offers some insight into which other environmental effects may play a role and how greenhouse gas effects (in the graph: “Climate Change”) relate to the other effects. In the case of the peaks (gold and the platinum group metals), the greenhouse gas effect seems to be a major factor, but this is only due to truncation of the Y axis; approximately 70-90% of the high scores for these materials is due to the formation of particulate matter (PM). PM (red on the chart) also plays a prominent role in the case of the other materials; there are only two materials for which PM causes less than half of the environmental effects (Uranium: ionising radiation, 59%, 29% PM; Strontium: water depletion 34%, PM 35%).

The comparison of both weighted totals (midpoints and endpoints) shows results that, by means of various weighting sets and approaches, result in a total score. Although the units differ (shadow prices are a different weighting factor to endpoints), the results show a surprising number of similarities; the same materials stand out (gold and the platinum group metals), and the results are of approximately the same order of magnitude. Both methods are thus useful in determining which materials have an extremely high or low environmental impact as a result of raw material extraction; the method used influences the details.

D Comparison with OECD CSR guidelines

The OECD guidelines are recommendations from the public domain aimed at multinational companies. At the time of writing, 33 national governments implement the directive. The OECD guidelines are consistent with what is considered to be standard CSR practice in the respective countries. It is important to realise that different interpretations of the CSR guidelines may be made at the detailed level for each country: cultural differences are unavoidable. Also, the principles of the OECD guidelines are not legally binding. The goal of the guidelines is to create a common framework of concepts and mutual understanding between the countries and companies involved.

Given the non-binding character of these guidelines, four essential qualitative points of departure must be observed in applying them. Firstly, economic activity should not cause any immediate negative impact on the indicators (“matters”) of the guidelines. Secondly, activities must not contribute significantly to existing effects. Thirdly, negative effects should not be attributed to other companies. Fourthly, suppliers, wherever they are situated in the world, are also encouraged to adopt the guidelines.

The guidelines are updated periodically via communication between National Contact Points. This occurs on the basis of case studies that may be raised by any legal entity (governments, companies, citizens).

A comparison of the indicators as presented in chapter 2 and the OECD guidelines is given in the following table.

Table: comparison of OECD CSR guidelines and indicators in study of Materials in the Dutch Economy

Chapter OECD guideline	(Potential) Relationship with materials in the Dutch Economy	(Partially) present in criticality matrices
Disclosure	Reliability and detail public data	No
Human Rights	Human Development Index	Yes
Employment and Industrial Relations	Economic importance in terms of added value	Yes (x-axis)
Environment	Environmental impacts	Yes
Corruption, bribery requests, and extortion	Human Development Index	Yes
Consumer interests	Price volatility final goods	No
Science and technology	Substitutability and recycling rates	Yes
Competition	World Governance Index	Yes
Taxation	World Governance Index	Yes

E Development of mining production

Data from the USGS Mineral Commodity Summaries allows the study of the progress of production. These developments point to increasing global population and purchasing power, but may also indicate changing applications for these materials. If use increases significantly faster than global GDP, then this certainly indicates that there are new applications that may lead to future scarcities.

The development of annual production between 2000 and 2012 is shown in Figure 52.

In the same period, global GDP increased by 93% (see Figure 51). Compared with the global increase in GDP, only eleven raw materials showed higher growth: cobalt, iron, limestone, gallium, lithium, manganese, niobium, feldspar, bauxite, germanium, and indium.

The growth in some of these materials (iron, bauxite, limestone, feldspar) is related to the enormous growth of major economies in recent decades and the associated construction of infrastructure. The growth in other materials appears to be related to the introduction of new technologies such as touch screens and flat panel displays (indium), glass fibre (germanium), lasers (gallium) electronics and ICs (germanium, gallium), solar cells (germanium, gallium), LED lighting (gallium, indium), energy storage and batteries (lithium and cobalt) and high-tech alloys for the automotive and oil industries (niobium, cobalt, manganese) etc.

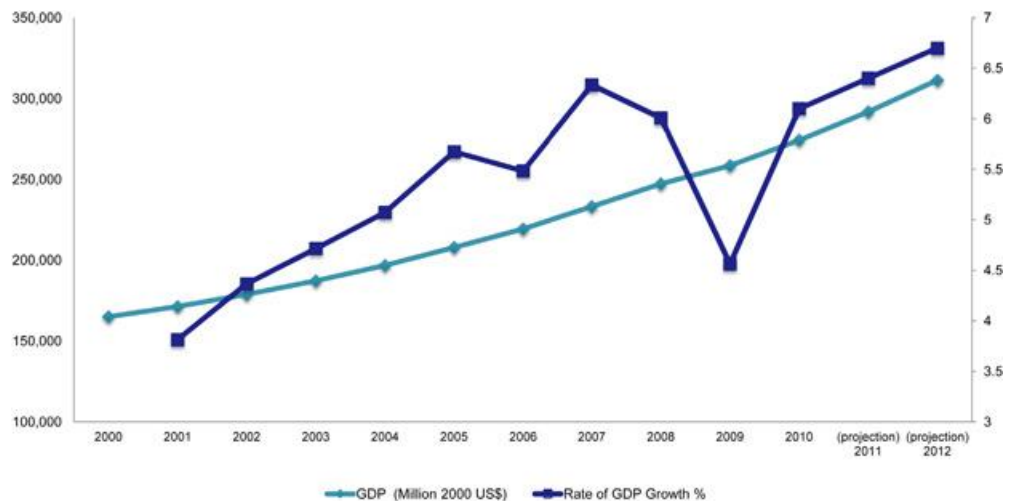


Figure 51 Global growth in GDP since 2000 (source: Global CCS Institute / World Bank)

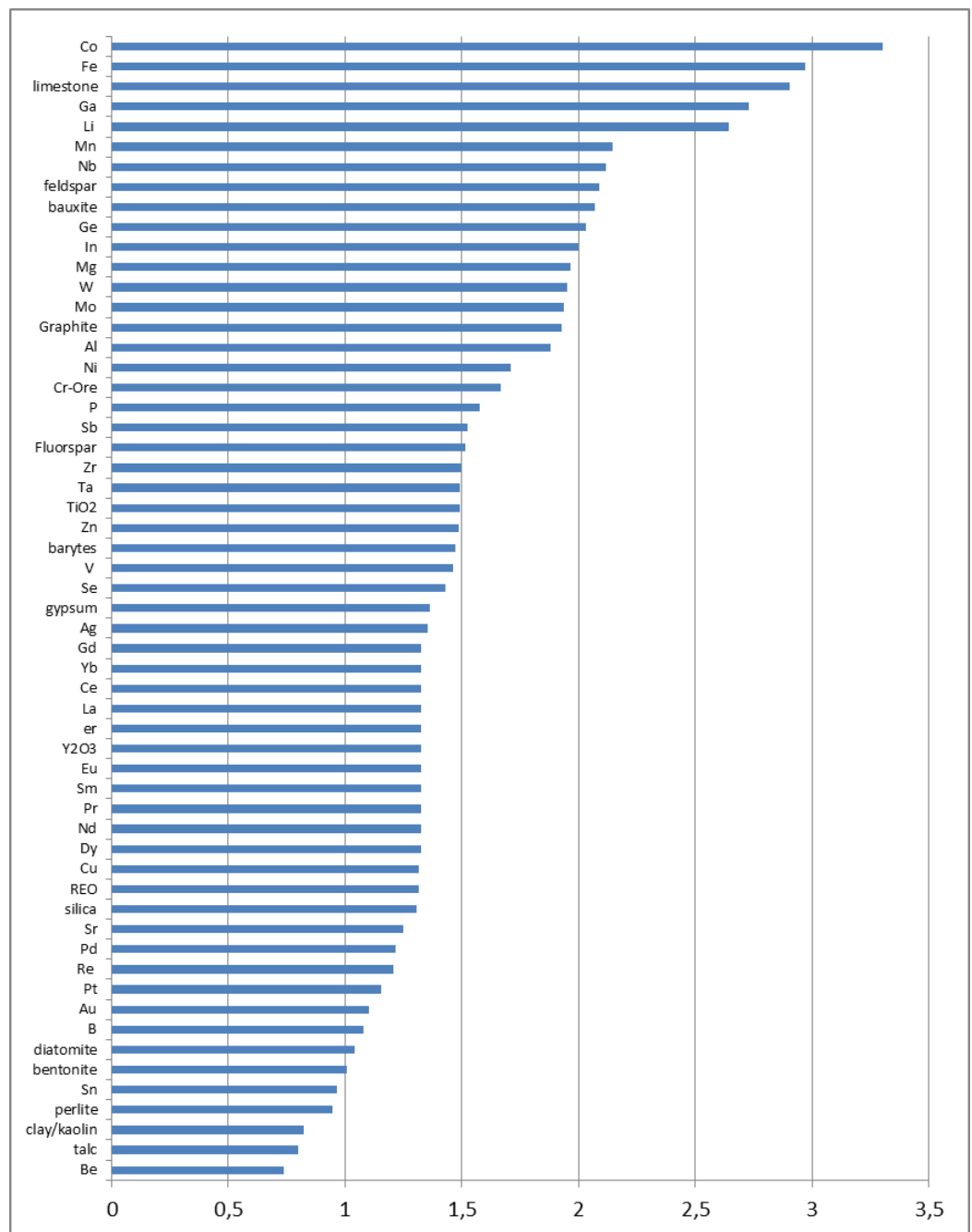


Figure 52 Development of annual production between 2000 and 2012 (> 1 means increase)

More needs to be looked at than just the development of production and the R/P ratio (in 2012), also the development of this ratio in recent years (see Figure 53) needs to be included. A decrease in the relative reserve in combination with an absolute low reserve can indicate higher risks regarding the security of supply. The data from the USGS Mineral Commodity Summaries shows that the commodities niobium, antimony, chromium, platinum, fluorspar, cobalt, tin, rare earths, tungsten and zinc, the R/P ratio has decreased by more than 10% between 2000 and 2012. The materials of antimony, zinc, tin, moreover combine a decrease in reserve valuation in an absolute sense, with a small reserve of less than 20 years.

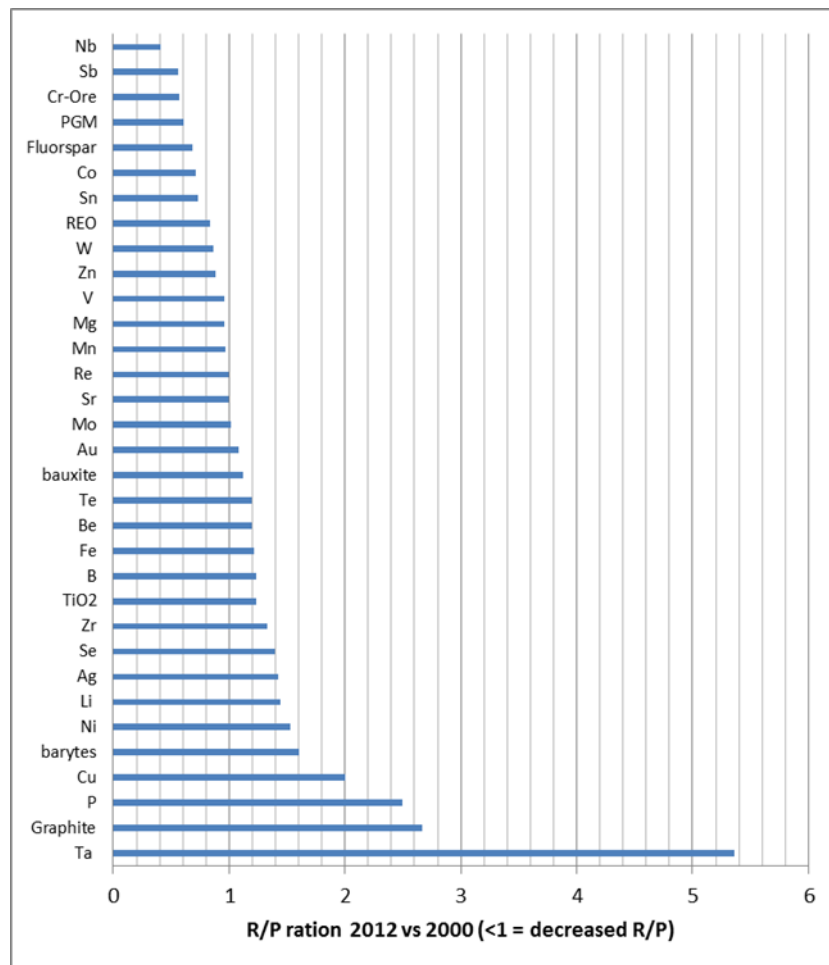


Figure 53 Change R/P ratio since 2000

F Concentration of production in source countries

Many minerals are only found (in economically viable quantities) in a limited number of countries. An overview of the geographical concentration of the raw materials considered here is given in Figure 54 by indicating the percentage supplied by the 3 largest producers (where data from the USGS Mineral Commodity Summaries is available) for each of the materials.

Detailed information about individual rare-earth metals and (aside from platinum and palladium) individual platinum group metals is not included here.

Except for gold, silver, tellurium, copper, and nickel, it emerges that more than 50% of the production of all other raw materials occurs in just 3 source countries.

China is clearly a dominant player. Other very dominant players (>80% of global production) are Brazil (for niobium, Nb) and the US (for beryllium, Be).

Materials in the Dutch economy

- A vulnerability analysis -

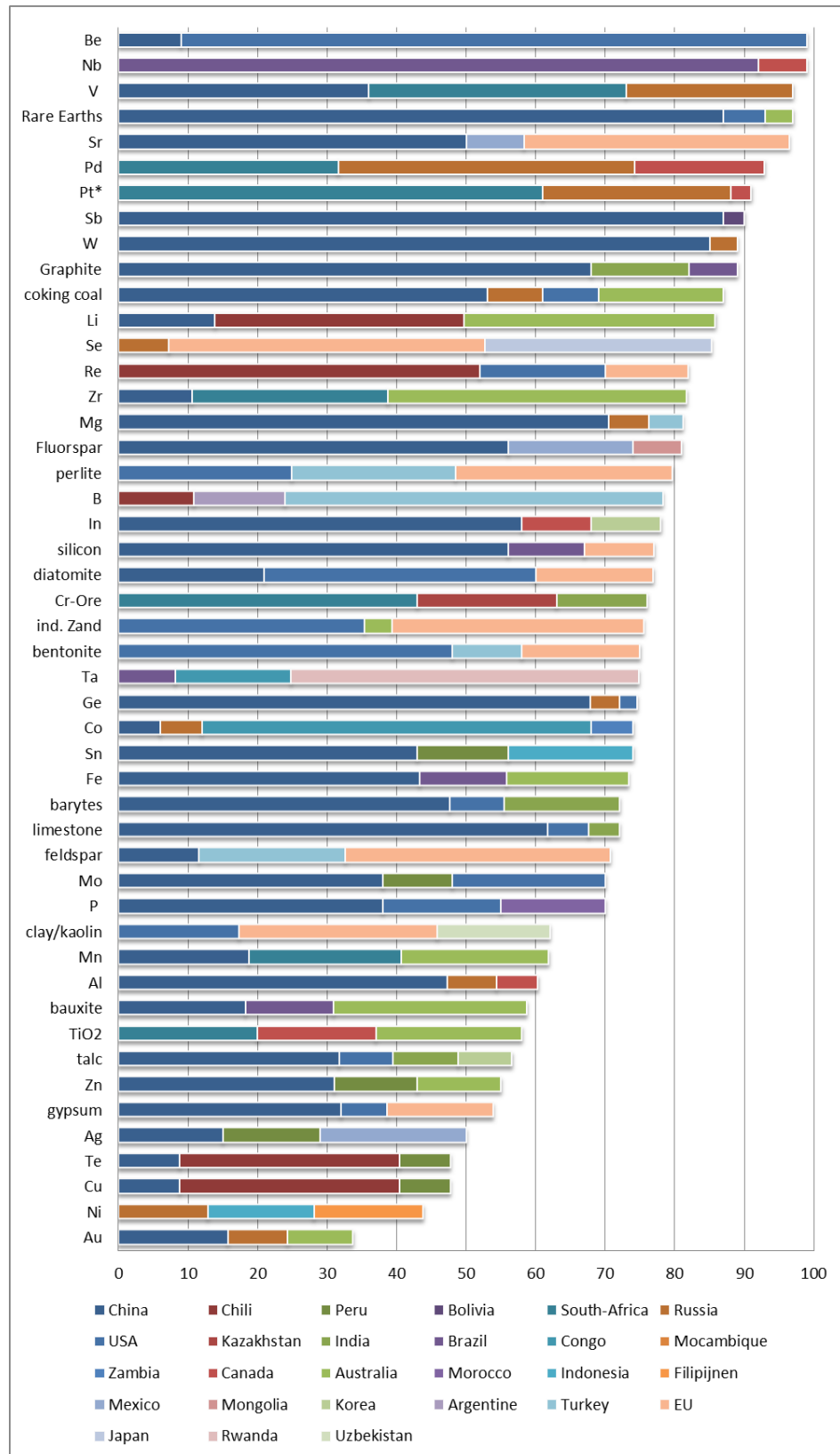


Figure 54 Top three raw material producing countries

China's position as the world's largest producer of minerals deserves special attention. The China's share in the production of the materials seen here is given in Figure 55. This shows that for twelve commodities China is accountable for more than 50% of the total world production.

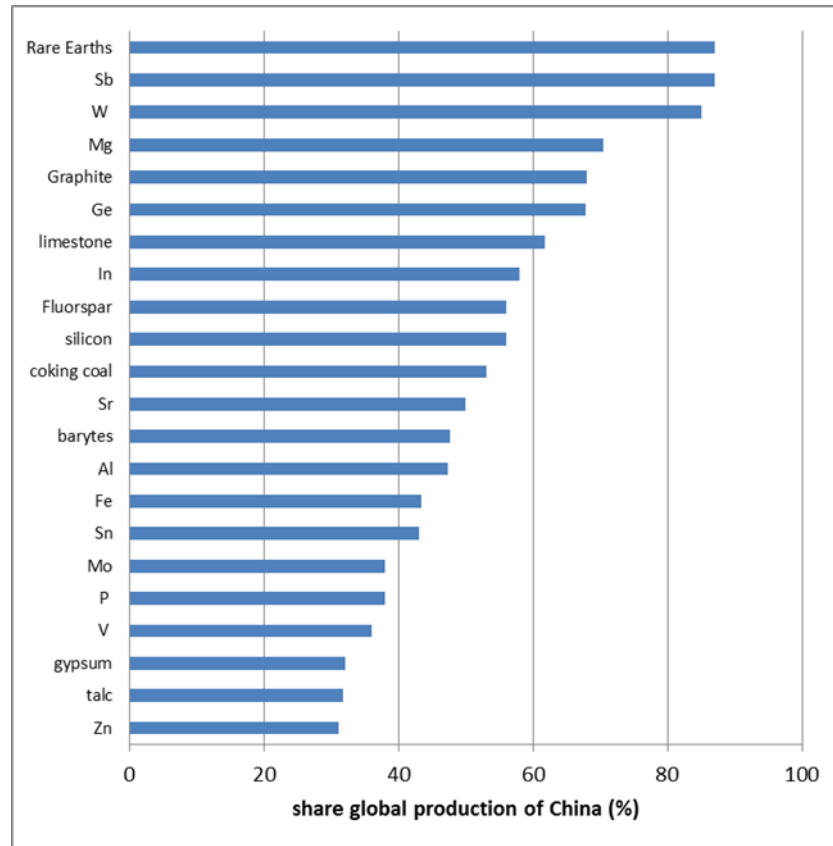


Figure 55 China's share in world production of specified commodities

G International development of databases

Yale (United States), Department of Industrial Ecology. This department, under the leadership of T. Graedel, is a world leader in the field of raw material dependence. The research department has a database containing details of the entire value chain of several hundred products in a dataset. In 2012, the database contained seven critical materials, 49 countries and 200,000 product groups. A single value chain contains thousands of elements, each representing a specific company with an associated product. CML maintains good contacts with this department and can play a connecting role in a research agenda.

NIMS (Japan), Department of Materials Science. This department, under the leadership of K. Halada, is another world leader, this time specifically with regard to linking raw materials and products. The database contains almost all of the specific metals that are used in the economy and many thousands of product groups. The accuracy of this data is higher than the matrix that forms the heart of this study. In partnerships initiated by the EU, the use of this data has already been discussed and is thus a real possibility.

GRANTA (UK), Department of Product Design Technology. This company has been a leading player in product design consultancy for many years. Their track record has enabled them to build a database that shows composition data for products in great detail. The precise scope of the database is not clear, but an indication may be taken from the scope ofecoinvent. This equates to more than 30,000 product groups, 70 materials and numerous environmental effects. In addition, specific design details of materials and product groups are mapped (including a distribution of typical lifespan).

Chalmers (Sweden), Department of Urban Studies. Under the leadership of L. Rosado, a database has been constructed of approximately 15,000 product groups and dozens of raw materials. Although the level of detail with respect to raw materials is less than in the matrix, this database includes detailed information on geographic origin and destination, as well as use aspects. The database will form an important element of European research into the Urban Mine in the EU. For this reason, collaboration with this party within the framework of future situations is not only possible, but also expressly desired.

H Consultation of Member States on the Circular Economy

Consultation of Member States on the Circular Economy

The Commission will put forward a new initiative on the circular economy by the end of 2015. This initiative will comprise a revised proposal on waste, as well as an action plan addressing the circular economy throughout the value chain.

Public consultations on the review of EU waste targets and on the sustainability of the food system took place in 2013. A public consultation is ongoing until 20 August 2015 to cover other issues relating to the transition to a circular economy, including how to address the different parts of the economic cycle (e.g. production and consumption phases) as well as enabling framework conditions, such as innovation and investments. A separate consultation on waste market distortions is also ongoing until 4 September.

Member States are encouraged to participate to the ongoing public consultations in order to share their views regarding measures that could be taken at EU level to promote the circular economy. However, given the specific experience that many Member States have in implementing measures on their national territories, or encountering barriers to the circular economy, as well as their technical expertise regarding waste management, the Commission would like to specifically consult Member States on the questions set out below.

In light of the cross-cutting nature of the issues at stake, Member States are encouraged to develop their answers through an inclusive and coordinated approach, involving various departments and in particular those in charge of environmental and economic affairs.

Contributions should be sent before 10 September to ENV-GROW-CIRCULAR-ECONOMY@ec.europa.eu

Part 1 – Circular economy measures

- **Have you encountered specific barriers in your country to the establishment of a more circular economy? Can you describe these main barriers?**

The Netherlands welcomes the opportunity to play a supportive role for the Commission in its work on developing its circular economy proposal. Before the summer we published the non-papers ‘Further proposals for a new Circular Economy Package’ and ‘NL suggestions for the Commission’s revision of the Waste package - the concept of ‘waste’ and in the enclosed paper – “Reduction of food waste” (see attachments 1-4). Although this third consultation serves to support the Commission’s thinking on the new circular economy package, the Netherlands reserves the right to reconsider its position once the Commission’s new proposal is published, thereby taking into account the accompanying Impact Assessment and possible assessments at national level.

In our earlier consultations we made the remark that there is a strong connection the Bioeconomy strategy and a Circular Economy – package and that this connection must be made on a European policy level. In this consultation we speak about a circular economy when we think of a circular and biobased economy.

To capture the opportunities within Europe as described for instance in the report ‘Growth Within: a circular economy vision for a competitive Europe’¹, a different speed’ resource approach for Europe needs to be designed to meet member states were they are. In this consultation we are envisioning such an approach.

In The Netherlands we distinguish three levels in the transition towards a circular economy (linear economy, linear economy with feedback, circular economy). Each level builds on the previous one and has its own strengths and weaknesses (linear: upscaling/resource intense, linear with feedback: mitigation/a-symmetric power relations, circular: multiple value creation/unpredictability). Each level has four transition phases (development, start-up, acceleration, stabilisation) and has its own corresponding policy tools and government roles and requires a different set of instruments.

Evolving from a linear economy, to a linear economy with feedback, we are now on the onset of a transition to a circular economy.

A circular economy, other than linear economy (with feedback) can be characterised by the following developments:

- Sustainability as the preconditional mind-set (inclusive system-thinking to progress Sustainable Development Goals).
- Ambitious coalitions with hybrid governance structures, through which public, private and societal partners create new business (eco)systems².
- The number and distribution of materials **locally and globally** will increase substantially by turning ‘waste’ into new inputs, and by using biobased materials.
- Downward and increasingly upward cascading of materials to dramatically increase society's resource effectivity.
- The emergence of global-local industrial production networks, linking resource niches and markets across the globe through ICT. These networks will disrupt

¹ : See <http://www.ellenmacarthurfoundation.org/news/latest-research-reveals-more-growth-jobs-and-competitiveness-with-a-circular-economy>

² Wikipedia: “An economic community supported by a foundation of interacting organizations and individuals—the organisms of the business world. The economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders. Over time, they [coevolve](#) their capabilities and roles, and tend to align themselves with the directions set by one or more central companies. Those companies holding leadership roles may change over time, but the function of ecosystem leader is valued by the community because it enables members to move toward shared visions to align their investments, and to find mutually supportive roles.”¹

current supply chains with its ‘step-by-step complexity’ (from raw material to semi- to final product/service), by skipping multiple steps of supply chains as well as integrating multiple steps of multiple supply chains simultaneously (‘non-linear complexity’). In the latter also consumers become producers (‘prosumers’).

- The inclusion of biodiversity & ecosystem services (‘natural capital’) as preconditions for a sustained supply of raw materials entering the economy. Even though in the beginning of the transition this may require a sustainable mix of fossil based and biobased resources together with the decarbonization of energy supply.

With these characteristic of circular economy in mind the following policies at the national / EU level need to be reviewed:

- **Innovation:**
 - A multitude of material-, production- and process and social innovations are needed to create consciously guided, crosssectoral system innovation. To achieve this, larger and smaller strategic public-private partnerships, including large as well as small and medium sized frontrunner enterprises, are needed.
 - Active support by governments to implement results of innovation policy can be frustrated by own institutional frameworks (f.e. procurement, state aid rules, rigid standard setting).
- **Competition:** Governments facilitate and participate in ambitious coalitions with private and societal partners and deliberately accelerate certain aspects of the transition towards a circular economy. To do so governments may find themselves violating the European competition framework in looking for a preferential treatment of circular and biobased cases as being unequal cases in relation to a linear, unsustainable economy.
- **Trade:**
 - Sustainability will become an increasingly important theme within conflict resolution mechanisms (f.e. discussions around TTIP).
 - As international transport of ‘waste’ and renewable resources will increase (f.e. North Sea Resource Roundabout), current regulatory arrangements potentially hamper the occurrence of new markets.
 - Upscale markets for repairing, restore, refurbishing, reusing products and materials within Europe with supportive recycling- and retrieving infrastructure cannot as yet compete with the low prices of ‘virgin’ products and materials and resource hunger of industrialising countries (f.e. case of Thermphos versus possible European exploitation of Tasman rare earths mine).
- **Public risk management:** A primary role of government is to protect public interests such as health, safety and environment. Consciously transitioning towards a circular economy raises the question how governments can protect public interests in a circular

economy (i.e. with new inspection and detection methods using innovative ICT and data mining applications for efficient and selective intervention).

European countries can be distinguished on basis of their individual state-of-play in the transition from a linear to a circular economy. Based on the above described characteristics and consequences for policy, some of the key barriers for the successful transition towards a circular economy are described below. First some general notions, second the barriers are ordered by the tree levels of transition.

General pre-conditions:

- *Adaptive and flexible policymaking during the transition is needed:* Within Europe, differences in the level and maturity of the transition towards a circular economy exist. Current EU policy tools are not integrated from a ‘different speed’ resource approach. This makes it hard to work on systems innovations throughout Europe, which require long term visioning and active involvement from multiple stakeholders. This hampers the transition to a circular economy, or at least the speeding-up of such transition.
- *Integrated and cohesive knowledge infrastructure is needed:* The field of resource policy on national and European level is still fragmented into different domains (resilience of eco-systems and functions, resource dependency, resource efficiency, circular economy, biobased economy) with their ‘own’ departments, own networks, perspectives, methods and policy instruments. To create a ‘different speed’ resource approach, conceptual and measurement integration is necessary to take precise and effective measures.
- *Re-activating solidified intelligence within ‘stranded’ assets:* At every phase so called ‘stranded’ assets can emerge because of shifts in the techno-economic infrastructure. Engineering ingenuity is needed to transform these assets into building blocks of the next phase. Without transition focused (private-public) programs to transform them, the creative destruction of markets will be fought off by the potential ‘losers’ by protecting their vested interests through governmental and political channels. These dynamics considerably slow down the speed of the transition towards a circular economy.

Key-barriers in linear economy without feedback:

- *System-thinking is lacking* ("no chains, only links"): Production and consumption patterns are based on optimizing and maximizing within their own domains, inhibiting the formation of supply chains and creates a 'take-make-waste' mind-set leading to negative effects.
- *Environmental ‘hygiene’ through elimination not transformation:* The need to abate unwanted by- and rest materials (f.e. health and land availability issues), combined with an efficiency mind-set, created waste incinerations aimed at eliminating materials without consciously engineered industrial symbiosis (f.e. energy- and material recovery).
- *No real EU internal waste market:* Because of the slow pace of implementation of the waste acquis and the differences between member states in the use of waste

definitions, detection and inspection methods and customs routines a real EU waste market isn't realised yet. This means 'economies of scale' within the EU are dampened and deters large investors.

- *Ignoring the importance of maintaining natural capital.* While effectively priority is given to handling abiotic resources that have entered the economy (recycling, waste), little attention is being paid to the need to preserve and sustainably use ecosystem services and safeguard valuable biotic resources, notably fertile soils, climate regulation & resilience, pollination and pest control.

Key-barriers in linear economy with feedback:

- *Global producers, national consumers.* Global dispersment of the different steps of supply chains, makes downward cascading challenging as multiple (national) borders are crossed. As downward cascading implies the re-use of materials, trust is the crucial ingredient to compensate for the powerful loss-averse inclination in people."Moreover, products and processes have as yet not been designed to enable full recovery of the materials used without loss of material integrity. The (cultural) status of the secondary resources (used goods, residues, waste) burdens the retrieved or recycled products with a negative image (perceived image of being polluted). Cultural boundaries become a pre-condition to create business models in which cascading principles are used. Therefore most "chain" approaches stay within national borders and represent one or just a few steps of a supply chain to achieve tangible results.
- *Integrating 'external' costs favours agent-based approaches:* Policies and methods focussing on 'negative effects' (f.e. LCA) and increasingly 'positive effects' (f.e. Social Return On Investment) of organisations, emphasize agent-based approaches. As with most phase 2 approaches, the systemic nature of the business activities generating these effects is considered pre-given and only the effects upon the rest of the system are under consideration. This generates (unintended) systemic inertia, which system based approaches try to overcome by designing mutually enforcing actor repertoires from a system's point of view.
- *Consumer creates biggest negative impact:* Growing corporate product responsibility helps to impose connections between links in the supply chains (system-responsibility) and brings down negative external effects considerably. In member states well advanced into phase 2 the consumer-phase continues to be one of the most environmentally burdensome link in the cycle.

Key-barriers in circular economy:

- *Uneven playing field for cross-sectoral innovations (including service business models which aim to replace products):* The sourcing of the needed biomass and a-biotic (meta)materials as well as the application of the generated multipurpose products will be mostly cross-sectoral and cover several sectors at the same time. This creates repeated sectoral 'border' problems caused by sector specific risk analysis (f.e. health, environmental, financial), administrative requirements (f.e. accounting rules, intellectual property), existing normalisation and certification schemes and risk-averse attitudes within government and companies. This leads to unnecessary

administrative burdens and creates an uneven playing field for cross-sectoral innovations.

- *A genuine upward cascading policy ladder in combination with circular design of products and processes is lacking:* The systemic characteristic of supply chains to create step-by-step complexity with large inputs of energy and materials is not sustainable taking into account current ecological stresses and continuing growth of a more wealthy and demanding world population. A higher-order economic functioning able to restore ecosystems, aimed at creating abundance (f.e. energy-positive, CO₂ as resource, harnessing quantum potentials, open source approaches) and driven by creativity and sustainability is needed. A linear economy (with feedback) stimulates an increasing variety of new material sources distributed throughout the economy. A circular economy can be kick-started by cascading ‘waste’ upwards to transform it in new multipurpose products and therefore skipping multiple steps of current supply chains³. Upwards cascading implies creating new higher order functionalities using biomass and a-biotic (meta)materials. However, current waste legislation is based on the downward cascading of materials and reused ‘waste’ within sectoral boundaries. This is operationalised by using the ladders of Lansink, Moerman or the more recently proposed ‘circularity ladder’. These ladders are aimed at making current (techno-economic) practices "less bad" but do not transform the way we produce and consume products. ‘Upward’ cascading currently means climbing back up the ladders of Lansink or Moerman (implying that the ‘highest’ level of upward cascading is ‘prevention’ and not creating a proposition with very high functionality) or creating a ladder based on multiple-added value for people, planet and profit (dependent on healthy markets and influenced by market policy interventions). A real upward cascading ladder⁴ needs to be created to stimulate new ways of production as described above. At the moment we know some examples of upward cascading. It is possible that upward cascading is not possible in all fields or we may not know them yet with the knowledge of today.
- *Production and utility sites no longer form a solid basis for containment of public risk:* As production facilities drastically scale down in size, (industrial) sampling methods and publicly accessible laboratories become more widely available and ideas become the most constraining form of capital, the number of small scale entrepreneurs working across the globe will explode. Where current practices of containing public risk (f.e. through licensing, certification and normalisation processes, risk-based

³ For instance, livestock manure and sewage sludge are rich resources for nutrients. Already, technologies have been developed to effectively extract specific nutrients and to produce high quality fertilizers, which can compete with industrial fertilizers. Further innovations lead to use of these nutrients in substrates for insects and algae, which in turn present sustainable opportunities for our food and feed production. Creating end-of-livestock manure- criteria for fertilizer materials in the Regulation (EC) nr. 2003/2003 or Directive nr. 91/676/EEC, will enable further innovation and trade in high value products made from animal manure.

⁴ : Creating a upward cascading ladder means combining a) real world examples within business and science, and b) knowledge related to complexity as found in nature to provide a system level approach needed to think through policy actions. Promising concepts to operationalise an upward cascading ladder are (eco)exergy (amount of working energy of a ‘system’) and other methods from information theory to calculate the level of information being stored and processed.

inspection) are based on a known number of production and utility sites which constitute ‘legal entities’, an unknown and fast growing number of producers and ‘prosumers’ less ground-based and ‘legally unknown’ will emerge and engage in ‘down and uploading’ of new materials, products and ideas on the internet. As (a)biotic materials from numerous sources can be turned into products around the globe, enforcing sectoral norms which control public risks will become very challenging.

- **What are the most successful measures taken in your country, at national, regional, or local level to facilitate the transition to a circular economy? (These can include legislative initiatives, financial instruments such as taxation, support programmes, awareness campaigns, public procurement, etc.). Are there any particular lessons learned from these measures, and could they in your view be usefully replicated in other countries or regions?**

Linear economy without feedback:

A very effective measure to start the transition towards a circular economy is the introduction of landfill restrictions for waste streams for which better alternatives exist. In the Netherlands a ban on land filling of domestic waste was already set in the year 1993 and its introduction, in combination with minimum standards for waste streams, can still be seen as the corner stone for the success of the Dutch waste policies in the years that followed, resulting in recycling/reuse percentages of 80% averaged over all waste streams.

Linear economy with feedback:

Not a measure, but an attitude has been very important in NL: cooperation. This cooperation can be formalized in different ways. Core of these cooperation is the good use of the competences of the parties involved, bringing expected and unexpected parties together, and creation of commitment. Formalisation can be a good way to create agreement on the objectives, results and actions to be taken. Examples include flexible forms of Extended Producer Responsibility for separate waste collection schemes and mandatory sectoral recycling targets.

In the Netherlands the Green Deal approach has proven to be a very useful instrument to promote front-runners and to encourage multi-stakeholder alliances that are aimed at economic growth and at improving the environment. We have good experiences with public-private partnerships. In the Netherlands the so called ‘Green Deal approach’ has proven to be a very useful instrument to promote front-runners and to encourage multi-stakeholder alliances that are aimed at economic growth and at improving the environment.

Within the Dutch Industrial and Innovation Policy (‘Topsectorenbeleid’) a lot of innovation aimed at retrieving valuable resources from ‘waste’ (f.e. in agrofood industry) or re-use of by-products (f.i. chemical process industry) is financed.

Examples of successful cooperation in NL are:

- Covenant on the improvement of recycling: more and better. Partners are waste and recycling branches, covering a big part of the companies active in the field of waste management, recycling and production of secondary materials. Also the local governments responsible for separate waste collection are partners in the covenant. Most important benefit of the covenant is that companies and government work together on projects that aim for the improvement of recycling. The projects are part of a joint working program that is renewed every year.
- Close cooperation with municipalities on the transition to a circular economy for waste flows that are collected by these governments, municipal waste. In this cooperation a framework is agreed upon for the approach and a 10-year working program is started. Target is to minimize the residual waste fraction per capita from 242 kg in 2013 to 100 kg in 2020 with a further reduction the following 5 years. A joint program committee has been formed, financed by central government to improve waste separation, to prevent waste and to optimize material chains together with other chain partners.
- Chemical industry companies working together while connecting steps in their production processes and making these more sustainable by improved process technology.
- Specific chain agreements:
 - Plastics, with over 70 partners focusing on improving innovation and reduce negative impact of plastics.
 - In 2011 the 'Phosphorus Value Chain Agreement' was signed in the Netherlands. More than 20 companies, knowledge institutes, NGO's and the government agreed to create a sustainable market for recycled phosphorus within 2 years. This by turning the phosphorus problem into an opportunity: recovering and recycling phosphorus from waste streams and livestock manure to create new markets and solve water quality problems.
 - Packaging agreement between companies, local government and central government to finance and improve prevention and recycling of packaging waste, and to reduce litter. This is a 10 year agreement that focuses on good cooperation between the partners, improving innovation while gradually closing the circle for packaging material. Starting in 2013 there has been an increase in plastic recycling, a sustainable packaging institute is started that works on prevention with a yearly roadmap, beverage cartons collection is started for a 3 year period (2015-2017) and in 2016 a 2 year pilot for a refund system for small drinking bottles and cans is started nationwide.

Another example is our national program Smart Regulation for Green Growth, a government initiative that aims to remove the barriers to investment, that innovative entrepreneurs perceive from legislation and regulations. This multidisciplinary taskforce takes a bottom-up approach, collecting signals coming from companies and trying to find solutions in regulatory flexibility.

Besides this attitude, the process of making a program that links several aspects of the transition to a circular economy and the implementation of actions is necessary to make clear the direction you want to go to. This resulted in the program From waste to resources, which got a parliament wide support.

Within the program (and also before) a promising and successful instrument is the chain approach, projects on a material/product chain with the following steps taken:

- In cooperation with stakeholders make a joint vision.
- get agreement on the actions of each party to be taken.
- set up a governance.
- implementation of actions.

An example of coalition forming is the Realise Acceleration of Circular Economy coalition, a coalition between NGO's and government, implementing projects like on acceleration as on circular design⁵, enlarging high value reuse, attacking obstacles for circular economy, communication, and accelerate introduction of circular principles in product chains.

Circular economy

In this stage the circular economy is still a pioneering effort. In the area of technological and organisational innovation which exceeds sectoral approaches, for instance, livestock manure and sewage sludge are rich resources for nutrients. Already, technologies have been developed to effectively extract rare metals and to produce high quality biobased fertilizers, which can compete with industrial (fossil based) fertilizers. Further innovations lead to use of these nutrients in substrates for insects and algae, which in turn present sustainable opportunities for our food and feed production. Some further examples in The Netherlands exist in the forms of R&D⁶, smart industry applications such as the 3/4 D printing with living materials and in the field of biobased economy with examples such as artificial photosynthesis and 'waste' wood pyrolysis. New technologies (including artificial photosynthesis) are worked out (on the level of fundamental research) to valorise CO₂ for energy storage and chemical building blocks and to decarbonize energy supplies by electrification of the chemical industry.

⁵ TU-Delft: "The term "circular economy" denotes an industrial system that is, by design and intention, restorative, using resources either in a bio-cycle or in a techno-cycle – with all technical resources designed for multiple use cycles, at high quality. It is considered as a more sustainable alternative to the current "linear economy" and has recently gained the attention of governments, NGO's, researchers and increasingly, large companies. Powered by renewable energy, a circular economy can be fully sustainable from an ecological perspective. From the viewpoint of business, it also holds promise, as value is maintained for longer and a zero-growth scenario is avoided. However, unlocking this potential requires shifts in business models, changes in supply chain management, and new notions of ownership. Also, to fit a circular economy, products require redesign (e.g. to be more easily upgradable) and additional systemic components (e.g. take-back services) – which in turn raises the question how consumers perceive and appreciate the new value proposition.

⁶: For example 'Chemistry and physics: Fundamental for our future. Vision paper 2025', <http://www.nwo.nl/en/news-and-events/news/2013/cw/vision-document-chemistry-and-physics-in-2025-presented.html>

- **Based on your national experience, what would be the three most important measures to be adopted at EU level in order to promote the circular economy? Please be specific**

Frontrunner Policy Framework at the European level should be introduced, adaptable to the state-of-play in individual European countries (from linear to circular), creating room for cross-sectoral innovation ecosystems and best-performing approaches. This means a ‘different speed’ resource approach which can be established within different EU programs (f.e. Cohesion Funds) and directives (f.e. Ecodesign) to create stepping stones for accelerated system innovations and exploit ‘systemic comparative advantages’ within Europe.

General pre-conditions for a ‘different speed’ resource approach are:

- *Innovation enabling policies and legislation:* To provide more opportunities for accelerated growth of new business models and markets, policies and legislation can be more innovation friendly through 1) goal oriented regulation with technology neutrality, 2) ‘right to challenge’ norms if equal results by different means can be accomplished, 3) inclusion of experiment provisions, 4) introducing the ‘innovation principle’ when creating new policies.
- *Room within competition framework:* Cooperation between organizations and competition can be in conflict. This could hamper promising and desirable initiatives. The Netherlands therefore invites the Commission to initiate a discussion on the merits of allowing broad-based cooperation within the EU framework on competition in favour of circular business cases and sustainability in general.
- *Active involvement civil servants:* As we have learned from the Green Deal approach, the active involvement from civil servants is an important part of acceleration the transition towards a circular economy. Participation is necessary to understand and nudge dynamics within and between sectors. Such an approach at the EU-level would be most welcome, for instance in the form of EU Innovation Deals.
- *Integrated and cohesive resource knowledge infrastructure:* To actively make use of the response-adaptive nature of a circular economy (arising from its characteristics described at the top), resource related vulnerabilities within ecosystems and industries have to be transparent and transformed by (circular) practices into innovation opportunities. To achieve this the following items need to be integrated:
 - up-to-date and precise information about the resilience of ecosystems and functions and (a)biotic resource needs of industries.
 - Benchmark suitable performance information about the amount of ecosystem services provided by nature and the resource efficiency and effectivity of industries.

- Identification (real life/modelling) of feedback practices and innovative circular solutions to turn resource vulnerabilities into innovation opportunities.
- In order to exploit the potential of a circular economy to address the challenges, the Netherlands invites the Commission to develop state of the art European intelligence on resources by integrating available data and knowledge of the domains mentioned.
- *Governance, indicators and intelligence*: A successful transition towards a circular economy will be the cumulative result of ongoing initiatives of society as whole, including all levels governments, civil society and business. Its progress will benefit from appropriate governance requirements that assess the contribution of existing and future policies and monitor the progress in the EU as a whole, in terms of quantitative and qualitative objectives and dashboard of indicators. Such a governance system should be integrated with a sophisticated EU intelligence infrastructure that allows full exploitation of a circular economy to address the challenges of resource security and play an important part in strengthening the EU's competitive position. Such an infrastructure should integrate available data and knowledge on resource security, resource efficiency, possibilities for feedbacks, biobased economy, and natural capital.

Linear economy without feedback:

- *Laggards*: gradually implemented landfill ban and implement waste acquis.
- *Followers*: Criteria for energy recovery combined with support for industrial symbiotic waste incineration. To ensure enough scale, the accompanying obligation could be to set up bilateral cooperation with laggards for technical transfer and the creation of business ventures. Furthermore international standardisation of environmental- and waste legislations helps to capture 'economies of scale'.
- *Frontrunners*: Innovation funds turning landfills into urban mines. To ensure enough scale the accompanying obligation could be to set up bilateral cooperation with followers for technical transfer and the creation of business ventures. Information and advice networks for and by frontrunner partners.

Linear economy with feedback:

- *Laggards*: Toprunner approach within Ecodesign (extended to all products), letting the speed of the markets raise *base line* quality standards.
Followers: The aim is to create more biobased and circular products, stimulated with a Toprunner approach of the Ecodesign aiming for a 'race to the top'. This means introducing dynamic standards, both by setting progressively changing minimum performance standards, as well as by setting standards for preferred high achievers.

A specific topic that should be addressed within in the bioeconomy strategy and the circular economy package is food waste and losses. From a perspective of circular (bio) economy it is important that resources from the food supply chain,

which do not reach the consumers in the first processing of food are not considered as waste in relation to the Waste Framework Directive. Reason for this is that they can still be efficiently used in animal feed, composting or the creation of biobased materials or energy, provided there is no risk for human or animal health or the environment. The new circular economy package and the bioeconomy strategy could address the reduction of food waste by reaching a consensus that the principal objective must be to prevent the creation of 'secondary resources' (food losses and waste) from the food supply chain, and making as much use as possible of the unavoidable secondary resources in the food supply chain. A framework could be created to ensure that all EU Member States can map the mass balance of all flows in the food supply chain in a uniform manner. The FUSIONS 'Food Waste Quantification' document could provide a basis for this, in which is explained how the various elements of this mass balance can be filled in uniformly throughout Europe (<http://www.eu-fusions.org/index.php/publications>)⁷.

- *Frontrunners: Frontrunners:* Installing a EU platform helping companies to overcome regulatory obstacle (f.e. providing assistance with 'right to challenge' of consolidated norms).

A necessary precondition is to understand the legal status of the secondary resources: Are these resources product or waste? In legal terms waste - as described in the European Waste Framework Directive - is any substance or object which the holder discards, intends or is required to discard. Remarkably the Waste Framework Directive does not hold a definition of the word 'to discard'. As a consequence the distinction between product and waste remains highly unpredictable. Within a circular economy with activities as reuse, repair and refurbishment, the status of a material or product should be clear and in line with the ambition of resource efficiency and environmental protection. Especially the lack of a definition of the key element in the definition of waste - the word 'to discard' - leads to a situation where there is no legal certainty for investments in circular economy initiatives, and where there is no level playing field between Member States. Therefore, The Netherlands sees great value in further clarification of the term 'to discard', and proposes a definition which exempts cases that fulfil

⁷: See <http://www.eu-fusions.org/index.php/publications>. The FUSIONS project also published a report "Review of EU legislation and policies with implications on food waste"(15 June 2015), in order to examine opportunities for the reduction of food waste (see previous URL). Within the scope of the circular economy package this could be further examined leading to concrete suggestions of amending EU legislations if this contributes to the reduction of food waste, of course without compromising on food safety and animal health. In this regard the Netherlands would point at the appeal of the Agricultural Council in May 2014 to extent the list of products, which have a long shelf life and retain their quality for a very long time, that could be exempted from the requirement for a 'best before' date on the label (extension of Annex X of EU Regulation 1169/2011).

the conditions to protect human health and the environment and to improve the efficient use of resources (in line with the aim of the Waste Framework Directive)⁸. Also, a narrow definition of secondary resources in legal frameworks like “secondary resources are waste materials” should be avoided (see the introduction of chapter 5 of the second consultation).

Other appropriate policy measures are stimulating and facilitating (downward)cascading of products and materials as indicated in our submitted ‘Public consultation on the Circular Economy’ (see attachment 3).

Based on the experiences, the Netherlands further proposes to address green procurement (circular, biobased and energy efficient) in the forthcoming CE-action plan in the following way:

- Integrate green procurement in the existing green public procurement program.
- Support pilots for green procurement, by funding, guidelines and tools.
- Share best practices about green procurement and new business models.
- Focus on learning and development for Europe (frontrunners, followers and laggards), not only on quick results for frontrunners.
- Choose for the pragmatic approach: learning by doing. Analyse pilots and experiments to support the systematic and academic approach, not the other way around.
- Support countries with tools and training to make steps forward with green procurement.
- Develop a system to support different phases of green procurement policy development within the EU.
- Integrate green in the criteria documents for SPP for relevant product groups according to the latest market developments.
- Include social/ethical aspects in green public procurement.
- Demanding procurement contractors to come forward with the most sustainable solutions, not only for the short term, but also for the period characterized by maintenance (for instance energy-efficiency) and finally end-of life (for instants re-use).

Circular (bio)economy:

- *Only a frontrunners oriented policy framework:*
 - The circular economy and sustainability initiatives may require organizations to work together to have the desired cross-sectoral and cross-resources effects. Therefore we propose a EU Circular Economy Challenge as described below.
-
- *Scope:*

⁸ : Further elaboration of this suggestions can be found in the non-paper – “NL suggestions for the Commission’s revision of the Waste package - the concept of ‘waste’” (see attachment 2).

- EU societal resource challenges, touching 1 billion people worldwide, should be central. For example ‘sustainable nutrition’, ‘nature-industry symbiosis’, ‘living within known planetary boundaries’.
- Base-line: The solutions have to create 1st, 2nd and 3rd order positive external effects (f.e. less use, positive rebound-effect, self-perpetuation of business model).
- Create a call with no budget attached to ask member states what the biggest transitions are the EU has to go through, what kind of networks are needed and what roles the different partners within those networks need to play. In this way relevant actors become known.
- *Thresholds:*
 - Coalitions of companies, governments, knowledge centres, societal parties AND groups of willing consumers are mandatory. For governments this means setting up transition teams or scouting team to actively participate in tackling the EU resource challenge.
 - Global consortia have to be able to join.
 - Parties should be committed to high levels of transparency.
 - The selected coalition(s) agree through sustainable procurement to buy the developed solutions themselves.
- *Legal framework:*
 - Experimental zone with a sunset-clause of 4 years, in which sectoral norms can be temporarily suspended after an integrated risk assessment (“yes, if”).
 - Mutual recognition between participating member states in case higher standards being met concerning public risks. An example is the North Sea Roundabout.
 - Automatic recognition within participating member states of the developed solutions if accomplished scrutiny standards are the same of higher within a country. This speeds up market-entry of the developed solutions. Lessons can be learned from regional interstate cooperation (e.g. art 11 of [Regulation \(EU\) no. 1143/2014 on invasive alien species](#)).
 - High level steering from the European Commission
- *Integrated risk assessment:*
 - The necessary cross-sectoral risk analysis will be conducted by the European Commission and will form a learning project within the Better Regulation initiative. The costs for the cross-sectoral risk analysis can be (partly) deducted from the designated budget. An example is the Dutch law ‘Wind energy at sea’.
 - Within the project, new detection and screening methods should be developed if non-existent, turned into monitoring protocols implementable for small entrepreneurs and made public. The EU recognition of monitoring organisations (e.g. art 8 of [Regulation \(EU\) no. 995/2010](#) (Timber regulation))

can be inspirational on how to organize the recognition of the monitoring protocols.

- Through the program Green Public Procurement the conducted cross-sectoral risk-analysis will be made publicly available and suitable for governments to integrate in their procurement procedures.
- *Policy development:*

World class knowledge centres create an upward cascading policy ladder and deduce important knowledge questions which could be taken up by Horizon 2020. An illustrative opportunity in this regard can be found within the development towards a sustainable agriculture is the possibility of upward cycling of fertilizer products from waste of livestock manure. This possibility is currently lacking in European regulation. A framework to make this possible could be created in the Nitrate Directive, Waste, Fertilizer and Animal by-product regulation.
- Learning journey on what a cross-sectoral certification scheme could look like based on the practices of the participating frontrunners.
- Transferring the lessons-learned and developed solution into directives such as Ecodesign (article 15, lid 6), adding them to the BREV's potential technology list, informing the course of the Eco-innovation program, identifying chances within the Cohesion funds etc.
- Promoting transparency and accountability of land use programmes and areas, to provide assurance to landowners, investors, businesses and others, that will drive a best practice approach, will encourage businesses to become involved, and that will help to attract new and additional funding for sustainable land use. The Netherlands, to this end, supports the development and implementation of the Verified Conservation Areas Register (VCA, see <http://v-c-a.org/>) that registers both protected and productive areas for which ecological ambitions have been formulated.
- Collecting ideas for innovative consumer responsibility schemes by means of competitions to learn how consumers becoming 'prosumers' can be part of systemic solutions.

Part 2 – Waste

- **Definition of municipal waste**

Since the beginning of the 1990s Eurostat has been collecting annual data from MS on the generation and treatment of municipal solid waste on the basis of a questionnaire developed by the OECD and Eurostat. Member States report annually to Eurostat on MSW generated and on the type of treatment applied. Clear guidance is provided by Eurostat on how to report MSW generated and treatment.

In order to ensure a better harmonization of the calculation method and its alignment to the OECD/Eurostat approach, the Commission proposed in its previous legislative proposal to include in the Waste Framework Directive a definition of ‘municipal waste’ aligned with the existing OECD/Eurostat definition and covering "household waste and other waste from retail, trade, small businesses, office buildings and institutions similar in nature and composition".

Based on the input and reactions from both stakeholders and the Member States delegations during Council discussions the following questions have arisen:

- Should the definition remain neutral as to who is responsible for collection/management of the targeted waste stream (e.g. municipalities or private actors)?
- To what extent should the definition include waste from retail, trade, small businesses, office buildings and institutions that is similar in nature and composition to household waste? Would a quantitative criterion be useful?
- Is there a need to establish a clearer link between the OECD/Eurostat definition and the list of waste codes as specified in Commission Regulation (EU) 849/2010?

- **What are your views on these issues?**

First of all it is important that the definition remains neutral as to who is responsible for the collection of the waste. Member States’ data must be comparable.

In the Netherlands we focus on Municipal Waste from Households with an ambitious target of 75% waste separation (at source or after collection) in 2020. In order to reach this goal it is also important to focus on material chains such as biowaste, plastics and paper. An advantage of the approach of focusing on specific material chains is that all parties in the value chain are stimulated to establish a common approach for the entire chain, including the waste phase. In our view there is no specific need for a clearer link with Commission Regulation (EU) 849/2010.

- **Do you have any additional technical suggestions to improve the definition proposed by the Commission in 2014?**

The Netherlands prefers a definition for Household waste instead of Municipal waste.

A suggestion is to focus also on the quantity of waste that cannot be recycled after separation (residual waste). This seems only to make sense if you can use a kg/person target for Household waste. If this target is used for a broader waste stream from both households and retail and small businesses, it is not comparable (and representative) anymore, since it depends on the specific municipality and its economy if it has more or less retail and small businesses in relation to the amount of inhabitants.

Therefore, a kg/inhabitant target seems only to make sense if used for Household waste. An advantage of this approach is that you focus on one of the main purposes of waste policies, to improve resource efficiency. Having high recycling rates is positive, but does not guarantee that a Member State has little residual waste and focuses on prevention. On the other hand, having lower recycling rates does not necessarily mean that a Member State is incinerating more waste, than a member state with higher recycling rates. E.g. when 30% of 300kg is recycled it results in 210 kg residual waste which exits the value chain and is (ideally) incinerated with energy recovery. When 50% of 700kg is recycled, the result is an amount of 350kg residual waste that exits the value chain.

The overall goal is to minimize the amount of material that 'leaves' the economy. Therefore we also should focus on the amount of residual waste. This amount has to be reduced, which can only be achieved by increasing both prevention and recycling. A kg/habitant target (like 100 kg residual household waste) is suggested as an approach to focus on both prevention and recycling.

- **Calculation method**

According to existing rules, the amount of recycled waste -to be reported with a view of compliance with the targets for municipal and packaging waste is defined as the "input into a final recycling process" (WFD) or an 'effective' recycling process (Packaging and Packaging Waste Directive - PPWD). Member States may also report as "recycled" what is separately collected (in the case of the WFD) or the output from the sorting plants (in the case of both the WFD and the PPWD) as long as there are no "significant losses".

In the Commission's view, these rules need to be further clarified in order to ensure a more uniform implementation and comparability across the EU, while avoiding potential misinterpretation, or abuses (e.g. waste that is landfilled or incinerated being reported as recycled).

In this context, the Commission would like to enquire with the Member States on the following:

- **At what stage in the waste management process do you measure quantities to be reported as recycled / prepared for re-use? Does this measurement point vary**

depending on the waste fraction or material stream? If the measurement takes place before waste reaches the final recycler, how do you ensure that "significant losses" do not occur after measurement?

Input in the recycling process defines the quantity of recycled material despite possible losses in the process to a final secondary resource. Because "significant losses" has not been specified, it is not taken into account.

- **What is the approximate share of municipal and packaging waste generated in your country sent to a final recycler located in another MS? What is the approximate share sent to a final recycler located in another MS outside the EU?**

Unknown.

- **In your view, what would be the most appropriate single point of measurement to obtain reliable and comparable data while limiting administrative burden (e.g. output of first sorting operation, output of last sorting operation, input to the final recycler, etc.)? Please motivate your choice.**

At this moment it is, due to the current monitoring, hard to define exactly which share of waste streams can be recycled. The exact amount of losses in the waste management process are unknown. It seems that while setting targets in the past, the idea was that waste streams can be recycled for 100%. But the amount that can be recycled using the best available technologies at the moment is unknown and certainly not 100% for all waste streams.

So, first of all, an assessment is needed to define a baseline for the recycling rates of the different waste streams in the EU at the moment, to know the share of the waste that is used as recycled material in products.

Besides that it is important to know which improvements in waste management can be achieved in the near future to improve the recycling rate.

In the end, when choosing a method, it is important that it is a very clear and practical method.

- **Incentivising re-use**

Some Member States as well as some stakeholders called for concrete actions to incentivise/reward Member States' efforts on re-use. While a specific target for re-use would be difficult to set at this stage due to unavailability of data and methodological gaps, alternative ways of incentivising/rewarding re-use might be considered as long as reliable data is available.

- **Would you agree that additional actions are needed to favour re-use? If yes, what actions do you see as most appropriate at EU level?**

- Re-use should not be discouraged due to the ambition to recycle products that could be re-used. Being the second step of the waste hierarchy, re-use should be facilitated as much as possible. As an example we would like to mention second life electric vehicle batteries. Directive 2006/66/EC on batteries describes that waste batteries have to be recycled. But this directive should, in line with the waste hierarchy, first allow and point at preparation for re-use of batteries that have become waste.

Innovative technology enables the re-use of car-batteries that are no longer suitable for their original purpose for other purposes (temporary storage of excess renewable energy). Thus the batteries have a 'second life use' before being recycled. However, since re-use does not contribute directly to the realization of the recycling targets, and because of the requirement set in Directive 2006/66/EC on batteries, the original producer is not stimulated to put the batteries on the market for re-use.

- Another issue that has been raised before in this consultation which also touches the problem described above has to do with the question if such a battery when it comes at the end of its lifecycle as battery for use in an electric car, is then discarded, or not? Even when it's certain that this battery will be re-used for storage of energy in stationary storage applications?

The Waste Framework Directive and present case-law do not provide for the ultimate test. Following the Arco-judgment we can say with certainty that the fact that the battery is still valuable, does not mean that this battery is excluded from the concept of waste. But when this battery is given a second life, does this mean that this battery has been discarded, or not?

Normally a used battery should be tested, cleaned and maybe repaired or reassembled before re-use. Do we automatically have to qualify these actions as 'preparing for re-use' as defined in the Waste Framework Directive? When this is true, these actions would then qualify as waste recovery actions.

One of the basics of waste law is that waste can cease to be waste after a complete recovery operation. The question now is: when a used car battery is tested and reassembled, is this battery then end of waste, thus no longer waste? Is the integration of this battery in a stationary storage system then re-use of a non-waste second life battery? Again: following the more common sense approach of the European Court of Justice and the Dutch council of state we believe that these types of circular economy initiatives could be stimulated without need to apply the requirements of the European Waste Shipment Regulation. In other words: what would be the environmental need to consider this second life battery as waste? The Waste Framework Directive itself however offers only little guidance how these initiatives should be tested in case by case situations.

So, the lack of a definition, especially the lack of a definition of the key element in the definition of waste - the word 'to discard' – makes it difficult to make a distinction

between waste or product (non-waste). By defining 'discard' as explained in the added non-paper, reuse could be stimulated.

In all, the EU waste policy should encourage the possibility to re-use goods once they have become waste. Legal clarity will ensure that reusable products, characterized as waste, are not viewed as taken off the market just because of their legal status.

- Another example are wood pallets and their re-use instead of recycling. We might focus too much on recycling and the recycling goals instead of taking into account and recognize re-use which is on a higher level of the waste hierarchy.
- At this moment Extended Producer Responsibility (EPR) rarely supports preparation for re-use where you would expect that it should do if we look to the overall goal of EPR.

Additional instruments can be developed with which producers can analyze whether there is business in remanufacturing, refurbishment and reuse of their products. For example a methodology for measuring preparation for re-use could be developed in combination with separate quantitative targets for preparation for re-use away from recycling and increasing the diversion of re-usable products from the waste stream. Furthermore could be looked into the possibility to use EPR schemes for safeguarding the potential re-use of products in their entire logistic chain.

- **What would be the key waste streams for which it would make sense to incentive re-use? Are national data available on these streams? If yes, please provide recent statistics on the re-use streams in your Member State.**

No key waste streams, in practice most on vehicles (and parts), medical equipment and copying equipment.

- **In your view, should re-use streams for which reliable data is available be accounted for and rewarded under the existing recycling and preparation for re-use targets?**

Should be accounted for but not together with recycling. Re-use has to be accounted separately since it is on a higher level of the waste hierarchy.

- **Minimum requirements on Extended Producer Responsibility (EPR)**

In the withdrawn proposal, the Commission also proposed to include a new annex (Annex 7) with a list of minimum mandatory requirements on EPR. The aim of this proposal was to improve the cost efficiency and transparency of EPR systems which currently differ significantly across the EU. However, some Member States and stakeholders expressed concerns as to the level of detail of these requirements and the need to adapt existing schemes.

- **Based on your national experience, what are the key conditions to improve the cost efficiency and functioning of the EPR schemes?**

Key condition for improvement of EPR is transparency which can be stimulated by competition between the schemes. More transparency should lead to improved schemes where real individual costs can be allocated to specific producers and their own products and could be linked to the design of products. In that way there will also be a financial incentive for reuse and high quality recycling.

And in order to create a level playing field and transparency, and a minimum level of recycling (high standard), recyclers (waste management operators) have to be certified (e.g. Weelabex for E-Waste). Besides that, recyclers are, if certified, allowed to operate independent from a scheme to create competition. This structure is a good example for other EPR schemes. This certification can also be reviewed when high value recycling is possible.

Another possibility is to prescribe the use of recycled materials in the products. This prescription should not cannibalize the reuse of products .

- **Do you see the need for a differentiated approach depending on the waste stream concerned?**

Yes, depending on value of the waste. General principles can be the same, but specific measures have to be differentiated. Recyclers should be allowed to collect waste themselves, in order to make a profit. All within the frames of an obliged minimum standard for recycling and registration of the volumes involved.

Furthermore EPR could be more than a waste collection scheme. It can be a major instrument in supporting implementation of the waste hierarchy. To ensure this, the Netherlands suggests the Commission to further develop EPR taking in account the whole circle including waste prevention, reuse and recycling, thereby taking into consideration possible market effects and costs of implementation. This could integrate circular design principles to facilitate new business models, minimize the environmental footprint of products, minimize the waste residue and optimize waste treatment. To this extent, further development of EPR would be more appropriate in the context of a renewed European Product Policy instead of within the Waste Framework Directive.

Attachment 1: Further proposals for a new circular economy package

Attachment 2: NL suggestions for the Commission's revision of the Waste package - the concept of 'waste'

Attachment 3: NL response to Consultation 2 on Waste Markets

Attachment 4: Reduction of Food Waste – Dutch position paper

Attachment 5: FUSIONS 'Food Waste Quantification' document

The FUSIONS project just published a report "Review of EU legislation and policies with implications on food waste"(15 June 2015), in order to examine opportunities for the reduction of food waste (enclosed). Within the scope of the circular economy package this could be further examined leading to concrete suggestions of amending EU legislations if this contributes to the reduction of food waste, of course without compromising on food safety and animal health. In this regard the Netherlands would point at the appeal of the Agricultural Council in May 2014 to extent the list of products, which have a long shelf life and retain their quality for a very long time, that could be exempted from the requirement for a 'best before' date on the label (extension of Annex X of EU Regulation 1169/2011).