Critical materials and The Netherlands – a view from the industrial-technological sector

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Cover image: An artist’s impression of a beryllium atom, a building block of one of the critical materials in this study

This research was conducted by a combined team of M2i (Derk Bol, Hans Christ) and TNO (Ton Bastein, Niels van Loon, Gerrit Oosterhuis). M2i was supported by the Faculty of Industrial Design Engineering at Delft University of Technology (Ivana Moerland under guidance of David Peck and Conny Bakker). This research formed the basis of the graduation project of Ivana Moerland. This report was originally published in February, 2012 and was titled ‘Kritische materialen en de Nederlandse technologische industrie’.

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Executive summary

Supply certainty of many metals and industrial minerals, crucial to modern society, is decreasing as a result of increasing demand combined with a range of geopolitical complications. In response to this issue, governments and industries all over the world are working, in different ways, on addressing this supply uncertainty. Europe is particularly affected by this issue, due to the fact it imports a significant amount of raw materials. The Netherlands is particularly affected by this situation. To provide some direction to member state governments and companies, The European Commission published a list of critical materials in 2010. Materials on this list were deemed essential to European industry and have a low supply certainty.

FME–CWM is an industry representative organisation for companies in the technological sector in The Netherlands. This sector is to a greater or lesser degree dependant on critical materials as defined by the EU. In order to develop a clear policy and provide support to its members, it is important that FME is aware of the current situation as a result of critical materials and the impact this situation can have on their member companies if supply uncertainty prevails. For this reason, FME commissioned this research project, which provides an insight into the role the critical materials play in the Dutch industrial-technological sector.

Thirty companies have participated in this research. They represent the cross section of the Dutch industrial-technological sector. A team, consisting of researchers from M2i, TNO and Delft University of Technology, visited all the companies and interviewed them about a range of different aspects regarding critical materials. The interview participants were mostly employees of either a procurement or R&D department. During the interviews the EU list of critical materials was used and additional space was left for the companies to indicate other materials that they consider as critical.

Conclusions

Following main conclusions can be drawn from the research:

− **Three quarter of the companies are more or less familiar with the term critical materials**
  Over three quarter of the companies are familiar with the term critical materials, however sometimes different names were used. A lot of the companies are directly confronted with critical materials through problems in the purchase of materials or parts. Nine out of thirty companies are following the developments around the critical materials closely, fifteen companies are less proactive, and six companies do not follow the development of the critical materials at all.

− **Critical materials play a role in the Dutch industrial-technological sector**
  Out of 35 different critical materials on the EU list; twelve were named as being used by the companies. Those most often named are Cobalt, Magnesium, Graphite and Tungsten (as alloying elements for steel manufacture) and Neodymium as an element used in permanent magnets. It is notable that only seven out of twelve named critical materials are seen to be critical by the participating companies. These are Cobalt, Germanium, Indium, Nioibium, Tantalum, Neodymium and Lanthanum. In addition companies named another fourteen materials which are critical to
their business, but are not named in the EU list. Most frequently named were Nickel, Chrome (both as a stainless steel alloy agent), Copper and special ingredients for plastics.

- Critical materials are often embedded in intermediate goods* and parts
  In only 7% of the cases, a critical material is purchased as a raw material. In 52% of the cases, the critical material was processed in metals or in intermediate goods and in the 36% of the cases critical materials were a part of bought-in components. This situation is indicative of the place of the Netherlands in the global supply chain. Dutch industry is mostly dependant on the import of pre-processed basic materials, intermediate goods and components. This however does not mean the Netherlands is any less sensitive to supply uncertainty in respect to critical materials.

- Critical materials problems are mostly supply chain based
  80% percent of participating companies have had difficulties with supply of the critical materials over the last five years. This concerns not only the materials on the EU list, but also other materials critical for a specific company. In most cases it appeared that the supply chain was sensitive to disruptions and there were not enough alternative (secondary sourcing) solutions available. This indicates, given the current critical materials situation, a new aspect that purchasing departments need to take into account. Developing alternative solutions such as redesigning the product and/or production process are employed by only a few companies. The R&D departments, in this respect, appear to be even less involved in issues around critical materials.

- Expectations over the next five years
  Twenty two of the companies (73%) expect that the role of the critical materials will grow. The most often named reasons are: expected growth in production, increasing sales of electric cars & e-bikes, and increases in high-tech electronics & electrical appliances production. The general expectation is that price increases of critical materials are to be expected.

- Threats and opportunities
  Sixteen companies (53%) do not expect to have problems with critical materials, due to good supply chain management and new (external) developments in recycling and production of critical materials. Six companies (20%) do, however, expect problems with critical materials in the coming five years. Reasons for this were either they cannot “enforce” supply stability (due to their size /power position) or because there is not enough capacity / resources in the companies for effective product innovation.
  Seven companies (23%) see only opportunities as a result of the increasing role of the critical materials. A better controlled supply chain can provide a competitive advantage. Critical materials are also perceived as a stimulus to a raised awareness of material application & use and to explore cradle-to-cradle design approaches.

* Intermediate goods = A particular material or item that is the final product of a distinct process that is then itself used as the input into the production process of some other product
Recommendations
The primary goal of this initial research is to evoke a discussion about critical materials and their role in Dutch industrial-technological sector. This discussion should involve all stakeholders: government, industry and scientific/research institutions. The researchers involved in this report would like to encourage this discussion with the following recommendations:

− **Develop and maintain an approach tailored to the Dutch list of critical materials**
  The EU list of critical materials covers only a part of materials critical to the Dutch industrial-technological sector. In order to develop a focussed policy concerning critical materials, a list based on the Dutch industrial-technological sector is required. In addition, a lot of companies want to follow the developments of critical materials in order to avoid problems or maximise opportunities. Having a detailed insight into raw materials critical to Dutch industrial-technological sector is advisable.

− **Make sure the supply chain of the Dutch industrial-technological sector is robust**
  One of the short term solutions to the problems with critical materials are improvements to the (often) vulnerable supply chains of Dutch companies. Charting various supply chains seems to deliver a significant advantage in this process. Adding to the robustness of the supply chain is avoidance of single sourcing as this is a weak spot in the supply chain.

− **Stimulate innovation in companies concerning alternatives**
  Adaptation of product design and utilisation of alternative materials is rarely seen as a response to the challenges of critical materials. In the long term, companies who embrace this approach will have a significant advantage. Stimulation of the innovation concerning utilisation of alternative materials can lead to changing a disadvantage (raw materials supply problems) in the Netherlands to an advantage.
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1 Critical materials

1.1 Global developments

A growing world population and increasing global prosperity has lead to increased pressure on natural resources: air, water, land, and energy & non-energy raw materials. The reduction in abundance of easier to win the energy raw materials, such as oil, gas and coal, is widely researched. Less well researched is the increasing demand for non-energy raw materials, present in the Earth’s crust in the form of ore and minerals, forming base materials for a large spectrum of metals and industrial minerals. Demand for these metals and industrial minerals are increasing due to the growing and increasingly prosperous world population. In addition, it is to be expected that the pressure on their price and availability will increase due to increases in their demand, partly driven by more recent products being introduced such as tablet devices, smart phones, plasma screens, LED-lighting, permanent magnets in hard disk drives, PC’s and wind turbines – to name but a few.

A complicating factor is that some metals and industrial minerals can only be economically mined at a limited number of places in the world. Countries as China, South Africa, Brazil, Kazakhstan and Australia have developed a powerful position in the respect of certain minerals and can use these as a strategic tool. An example of this can be seen when the Chinese temporary restricted the of export of Rare Earth metals to Japan in the spring of 2010\(^1\) and their consistent reduction of export quotas to the rest of the World is a matter of on-going diplomatic and trade agreement discussions.

Due to increasing demand and geopolitical complications, the supply certainty has decreased for a wide range of metals and industrial minerals crucial to society. In a reaction to this, governments and industries all over the world are working on attempts to reduce this supply uncertainty. Measures, both underway and proposed, can be classified into the following categories:

- Increasing the supply of critical materials (within a nation state or region - “own management”) by stimulating mining (deep sea as well as on land) and recycling
- Ensuring the availability by building up strategic stockpiles (policy in Japan and USA)
- Increase market supply and transparency by increasing free trade via the WTO. The EU\(^2\) is working on this closely with Japan and USA.
- Pushing back the utilisation of the critical materials by stimulation of resource efficiency and search for substitutes; there are some R&D programmes underway.

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\(^1\) In September 2010 China placed a temporary export blockade of Rare Earths to Japan, as a result of on-going dispute over the Senkaku islands. This dispute has had a large influence on the growth of Japanese investments in research on recycling and substitution of Rare Earth Metals.

\(^2\) On March 13, 2012 the EU registered a complaint with the WTO against the export restrictions by China concerning seventeen Rare Earth Metals. According to the EU these restrictions are against WTO rules concerning the free trade in raw materials. China in turn cites environmental protection concerns.
Various companies are also already responding. Different Japanese companies (Hitachi, Showa Denko) have recently decided to place their business expansions within China instead of Japan, in order to increase their supply certainty. Toyota (and Siemens) have invested in mining (of Rare Earths) to ensure their supply (vertical integration).

In a response to the worldwide concerns around raw materials, the EU started the Raw Materials Initiative (RMI) in 2008. In June 2010 a study group published a report as a part of the RMI, where a selection of fourteen material groups has been made based on analysis of supply uncertainty (combination of country risk and substitutability of the material) and economic importance to the EU. These materials, seen as critical, are Rare Earth Metals (a group of fourteen elements), Platinum Group Metals (PGM: Platinum, Palladium, Rhodium, Ruthenium, Osmium, iridium), Germanium, Magnesium, Antimony, Indium, Beryllium, Gallium, Cobalt, Tantalum, Fluorspar, Graphite, Tungsten and Niobium. The RMI-report proposes a greater focus on mining in the EU, for improving worldwide free trade and for stimulation of recycling and substitution of critical materials.

Figure 1 Analysis by the EU (RMI) of the most critical materials; the fourteen materials in the upper right quadrant are seen as the most critical. The 35 different materials shown are the starting point of this research.

1.2 Policy and research in the Netherlands

CBS-study

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In October 2010 the report Critical Materials in the Dutch Economy\textsuperscript{6} was published, where the CBS, based on concise analysis by TNO and CML, made the first initiative to quantify the importance of critical metals and industrial minerals for the Dutch economy. To do this the utilisation of critical materials in hundreds of product categories was estimated and the consequences of supply uncertainty for the Dutch economy were examined. Following product groups appeared to be particularly sensitive:

- Construction materials
- Basic metals
- Metal products
- Machinery en Equipment
- Office appliances, computers,
- Electrical appliances
- Medical, precision and optical appliances
- Cars and other vehicles
- Electricity and gas supply

This study gives a good first indication, but due to its general character it does not show the value of certain critical materials for any particular product. For example, the quantity of Indium in a product (such as plasma screen) can be very small, but the function of the product can depend greatly upon that material.

**Raw materials ‘note’**

In the light of international developments and as an answer to questions in the Dutch Parliament (Motion Orel-Nicolai, December 2010), the Dutch cabinet developed the Raw Materials ‘Note’ to the Dutch Parliament in the summer of 2011\textsuperscript{7}. In this document a wide array of government initiatives were announced:

- Increasing the supply by, amongst other things, promoting transparent and sustainable trading, stimulating recycling and research into the role of the Netherlands in deep sea mining activities
- Reducing the demand by increasing material efficiency
- Requesting, at an international level, for a shift of tax burden from personal employee income to the consumption of natural resources

The Raw Materials ‘Note’ concerns not only the international trading point of view of the Dutch government, but also the importance of the availability of raw materials for the Dutch industry:

> “It is determined that the Netherlands is an important transit country of not only biotic but also abiotic raw materials. Logistics, import and export are essential parts of the Dutch economy. A less open market for raw materials can therefore have direct consequences for the Dutch economy.”

\textsuperscript{6} Critical Materials in the Dutch Economy, Pascal van den Berg, Wilco de Jong, Luuk Schreven, CBS, October 2010

\textsuperscript{7} This document can be downloaded (Dutch only) at: http://www.rijksoverheid.nl/documenten-en-publicaties/rapporten/2011/07/15/grondstoffennotitie.html
“When it comes to abiotic raw materials for its own industry, the Netherlands is a particularly large importer of intermediate goods, and less of raw materials. In addition, our country has a relatively small but high-tech industry sector. A lot of big Dutch multinationals have relations with biotic and abiotic raw materials producers.”

The observation that Dutch industry is purchasing mostly intermediate goods can also be seen in the results of this research. The participating companies are a cross section of manufacturers and producers; not only were the companies who purchase raw materials interviewed, but also companies who have such materials in one form or another, often as a purchased intermediate goods or components.

The Raw Materials ‘Note’ states not only the risks, but also observes the opportunities for business:

“...there [are] next to the risks, also explicit opportunities. When access to the more scarce materials becomes more laborious, the importance of re-use and substitution increases. Innovation is the key word in this case. The Dutch economy is well established and able to realize opportunities and to turn increasing worldwide materials scarcity into a comparative advantage.”

“The Netherlands can become part of the international research top tier in the area of materials innovation, if the innovation agenda is more focussed on the matter. Material substitution and transition to a bio-based economy, within sustainability preconditions, also offer market and innovation opportunities.”

It is in this context that this research seeks to establish whether, in the view of the participating companies, the emerging materials situation offers any opportunities.

1.3 FME and the research: reason and approach

FME–CWM (FME) is an industry representative organisation for companies in the technological industry in The Netherlands, and it these companies which, in the above-mentioned CBS-study, is named as a potential “target” of critical materials. This sector can be vulnerable to supply uncertainties and volatile price changes. In order to provide clear policy advice and give focussed support to members, it is important for FME to be aware of the situation concerning critical materials and the impact they could have on their member companies.

Based on this need, FME developed with the research team the following questions:

- How familiar is the Dutch technological industry with the term ‘critical materials’?
- Which critical materials on the EU list are important for the Dutch technological industry? Are there any materials, not on this list, that are also seen as critical?
- What is the purpose and function of these critical materials?
- How vulnerable or dependant are the companies to these critical materials and in what way are the problems in this area handled?
- Do the critical materials offer opportunities?

The research aims to provide an initial investigation. Subsequent steps could focus on specific sectors of the Dutch technological industry, where the risks are either greater, or where there is a
large potential for economic growth. Due to research time pressures and limited resources, this research was conducted in the form of an exploration or a reconnaissance, where thirty companies were visited and people within the organisation were interviewed about critical materials.

Over 100+ companies were initially approached by FME with a request to participate in this research. They are all from the group of companies which had indicated interest during previous environment meetings and they are also members of the sector associations VNMI (Dutch metallurgical industry association), HTSP (High Tech Systems and Materials) and High Tech Systems, as well as the companies which participate in the ‘Sustainability Compass’ activity of the FME. During this selection no intentional targeting of companies who were known / suspected to use critical materials was done. Instead, as wide as possible spread of companies over various sectors and different places in the supply chain were chosen, in order to acquire a wide overview and to detect ‘hot spots’ where critical materials play a more important role.

One of the challenges was to decide how to inform the companies of the subject and context of the interviews without influencing the answers to be given. This is a common challenge in exploratory research. The strategy undertaken was to prepare those to be interviewed by sending a questionnaire (see appendix 1). There was no requirement for the companies to return the questionnaire, or even to complete it for the interview. The questionnaires did form the basis of the interviews and importantly allowed the respondent to prepare for the interview. The questionnaires were discussed during the interviews and supplemented where necessary. The interviews were audio digitally recorded to ensure all the details of the conversation could be considered during the subsequent analysis phase.

Confidentiality of the interviews as well as the acquired data were an important aspect of this research. In order to ensure the anonymity of the participating companies, the list of participants as well as any indication data is not included in this report, and will not be placed into the public domain.

The research interviews were conducted by joint team consisting of M2i (Derk Bol, Hans Christ) and TNO (Ton Bastein, Niels van Loon, Gerrit Oosterhuis). M2i was supported by the Faculty of Industrial Design Engineering of the Delft University of Technology (Ivana Moerland under the guidance and support of David Peck and Conny Bakker). Ivana Moerland collaborated with the research as part of her masters final graduation project. Her graduation report was published in February 2012, entitled ‘Critical Materials in The Netherlands’ and is available in the TU Delft library.

This research was commissioned by FME-CWM and was financially supported by AgentschapNL (a Dutch government agency, part of the ministry of economic affairs, agriculture and innovation).
2 A profile of the participating companies: the materials chain

2.1 Raw materials and the Dutch technological industry

The Netherlands imports a small amount of raw materials. Whilst there are some exceptions, in general, Dutch industrial production depends on the import of processed basic materials, intermediate goods and components\(^8\). This is linked to the role of the Netherlands in the international trading system and with the specialisation of the Netherlands in the business and financial services and wholesale activity, logistics and transport.

The so-called ‘Domestic Import’ data shows that raw materials do not play an important role in the Dutch economy. Domestic Import is the part of the import that is actually added to the Dutch economy for further production or consumption; anything that is being exported again is not a part of Domestic Import data. It consists of 9,3% raw materials, 61,7% intermediate goods and 29% end products. The boundary between raw materials and intermediate goods is not always easily established. For example, brass wire, which has undergone some processing, is said to be a intermediate good. On the other hand, copper bars are defined as ‘concentrated copper ore’ and are therefore seen as a raw material. This implies that the percentage of raw materials could even be less than 9,3%.

This could explain why the Dutch government and Dutch companies became aware of the situation somewhat later than for example Japan, and have therefore reacted later. High-tech production in Japan is much more dependent on import of the raw materials, including numerous critical materials.

The fact that most companies from the technological industry do not require raw materials directly for their production does not mean that the supply uncertainty of these raw materials is of no consequence. Raw materials are often processed in basic materials, intermediate goods, components and subassemblies, which in their turn are used in the production of end products.

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\(^8\) ‘Op weg naar een grondstoffenstrategie’, HCSS, TNO, CE Delft, June 2011. In this study, as a support to the raw materials strategy of the Rutte cabinet, import and export of raw materials, intermediate goods and end products of Copper, Indium and Neodymium are examined. There materials are barely imported as raw materials, but more often as part of intermediate goods and components.
2.2 The chain of materials

To get an insight into the role of the raw materials, intermediate goods and other phases in the product development chain, a chain of materials was developed for this research. In this chain, a breakdown into different types of companies was made, dependant on their place in the chain and the type of the product. Please note intermediate goods are termed ‘half products’ in the model shown in figure 2.

![Schematic of chain of materials](M2i, TNO).

The blue vertical arrows show that, for example, a producer of a subassembly can use components and basic metals as well as raw materials. An integrator can used unprocessed raw materials as well. But, in general, the further down the chain, the lesser the direct consumption of the pure raw materials and greater the consumption of the basic metals, intermediate goods, components and subassemblies.

In the following table six different types of companies in the chain of materials are explained. Due to the confidentiality restrictions, named examples are not based on the actual participating companies.
Table 1 description of the types of companies in the chain of materials

<table>
<thead>
<tr>
<th>Company type</th>
<th>Description</th>
<th>Product examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material producers</td>
<td>Processing raw materials into (engineered) metals, basic metals and half products</td>
<td>Copper (metal, bar, wire)</td>
</tr>
<tr>
<td>Component producers</td>
<td>Producing components (mostly B2B market), using (engineered) metals, basic metals and intermediate goods</td>
<td>Springs, LED’s</td>
</tr>
<tr>
<td>Sub-assemblers</td>
<td>Producing subassemblies: more complex assemblies, no end products</td>
<td>Braking system, lighting</td>
</tr>
<tr>
<td>Producers</td>
<td>Producing relatively simple products, with relatively simple supply chain</td>
<td>Domestic appliances, electric tools</td>
</tr>
<tr>
<td>Integrators</td>
<td>Producing complex products and equipment (OEM) with a complex supply chain</td>
<td>Medical equipment, production systems</td>
</tr>
<tr>
<td>Project producers</td>
<td>Development of processes and products based on customer specifications</td>
<td>Railway station smoking receptacle, chemical process systems</td>
</tr>
</tbody>
</table>
### 2.3 Product groups

A different classification of the companies was made according to the product groups as defined by CBS. Most important groups are shown below:

<table>
<thead>
<tr>
<th>Glass- &amp; construction materials</th>
<th>Glass sheets, stained glass, optical glass, glassware, stones, tiles, ceramics, sanitary fittings, plaster, lime, cement, concrete, tubes, natural stones, asphalt etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic metals</td>
<td>Non-alloyed and alloyed metals, (rolled) flat metal products, rolled wire, bars, metal profiles, metal rails, tubes, flanges, metal grains, drawn wire, metal powder etc.</td>
</tr>
<tr>
<td>Metal products</td>
<td>Parts of a bridge, construction parts, doors, windows, greenhouses, metal machine parts, gas bottles, capacitors, scissors, saws, tools, locks, knives, cutlery etc.</td>
</tr>
<tr>
<td>Machines and appliances</td>
<td>Engines, turbines, hydraulic/pneumatic systems, pumps, compressors, flaps, valves, tackle, cranes, lifts, air-conditioning appliances, purifying installations, agricultural appliances, metal processing equipment, groundwork equipment, industrial robots, domestic appliances etc.</td>
</tr>
<tr>
<td>Office appliances, computers</td>
<td>Photocopiers, printers, computer equipment and parts, projectors etc.</td>
</tr>
<tr>
<td>Electric appliances</td>
<td>Electric motors, generators, transformers, rectifiers, switches, conductors, wire, optical fibers, batteries, lamps, neon signs, electromagnet, permanent magnets, starting motors, insulators etc.</td>
</tr>
<tr>
<td>Audio, video and telecommunication</td>
<td>Integrated switches (chips), memories, capacitors, image enhancers, cathode ray tubes, diodes, telephones, digital cameras, video, radio and TV-equipment, recording equipment, projectors, loudspeakers, antennas etc.</td>
</tr>
<tr>
<td>Medical, precision and optical equipment</td>
<td>MRI-equipment, catheters, needles, etc. hospital equipment, prostheses, dentist equipment, digital cameras, film cameras and projection equipment, radar equipment, various test, measuring and calibration equipment, microscopes etc.</td>
</tr>
<tr>
<td>Automotive and transport vehicles</td>
<td>Cars, campers, heavy goods vehicles, articulated trailers, containers, crane vehicles, motorcycles, ships, aircraft, trains, bicycles and all supporting equipment</td>
</tr>
</tbody>
</table>
2.4 Profile of the participating companies

Thirty companies participated in the research\(^9\). In order to facilitate the interpretation of the research results, a profile of the participating companies is provided. This is done based on the most important materials used by the companies and the classification based on the chain of materials and product groups.

**Most important materials used for production**

A first characteristic of the participating companies is that they use mostly metals and/or plastics materials for electronics for their products. This ‘metal-electro’ profile corresponds with the profile of the companies represented by FME.

**Classification of the companies according to the chain of materials and product groups**

In the following matrix the place of the participating companies in the chain of materials (see paragraph 2.2) is given and classified according to the product group as defined by CBS (see paragraph 2.3)

<table>
<thead>
<tr>
<th>Product group</th>
<th>Material producers</th>
<th>Component producers</th>
<th>Sub-assemblers</th>
<th>Producers</th>
<th>Integrators</th>
<th>Project-producers</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass &amp; construction materials</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Basic metals</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Metal products</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Appliances and equipment</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td></td>
<td>11</td>
</tr>
<tr>
<td>Office appliances and computers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Electric appliances</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Audio, video and telecommunication</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Medical, precision and optical equipment</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Auto’s and transport vehicles</td>
<td>2</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td><strong>3</strong></td>
<td><strong>9</strong></td>
<td><strong>5</strong></td>
<td><strong>3</strong></td>
<td><strong>8</strong></td>
<td><strong>2</strong></td>
<td><strong>30</strong></td>
</tr>
</tbody>
</table>

Due to the confidentiality, the names of the participating companies will not be made available.
Profile – chain of materials
All different types of organisations in the chain of materials are represented. The three material producers were well aware of the raw materials problems. What stands out is the large amount of the component producers and integrators. The component producers buy mostly basic materials and intermediate goods and are quite close to the raw materials supply and any possible bottlenecks. The integrators need mostly subassemblies and components for their production and are further away from the raw materials supply base.

Profile – product groups
None of the participating companies belongs to the Glass & Construction materials group. This corresponds with the ‘metal-electro’ profile of the FME-members. Product group Office appliances and computers is also not represented. This is a result of the definition of this group. The components of Office appliances and computers belong to the product groups’ electric appliances and Audio, video and telecommunication, which are represented by the participating companies. The product group Cars and transport vehicles are represented at different places in the chain of materials. This is reflective of the role the supply industry for automotive industry has in the Netherlands. The product group Appliances and equipment is most strongly represented eleven of the thirty companies. When choosing the classification of the companies, their products were taken into account; a lot of companies belong to this group. This description points out the utilisation of metals in many different processed forms and finishes. However, a lot of named products also contain parts such as batteries, electro motors and electronics, named in other product groups.

Cross links – chain of materials & product groups
Three of the material producers belong to the product group Basic metals. The fact that a component producer is also shown is because component-like products, such as metal rails and flanges, also belong in this group. In the definition of the companies in the chain of materials, these are included as component producers. The product group Appliances and equipment is represented in almost the whole chain of materials. Integrators are represented across three different product groups: Appliances and equipment (six), Medical, precision and optical equipment (one) and car’s and transport vehicles (one). The integrators are placed at the end of the chain of materials and deliver complex equipment with a broad spectrum of materials being used. Even though these companies are ‘far’ from the raw materials base, they are vulnerable to material supply problems due to the components included in their products. One of the integrators belongs to the product group Medical, precision and optical equipment and represents the high-tech industry in the Eindhoven region.

The participating companies and what they represent
Compared to the wide range of product assigned in CBS product group classifications (see section 2.3) it is clear that the thirty companies interviewed cannot not cover the wide range of technological products produced in the Netherlands. However, the companies that were approached and interviewed in this research are representative, to a certain level, of the technological industry,

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10 Glass producers use the critical materials Antimony and Cobalt for glass preparation and polishing
11 These examples are not based on the participating companies
as represented via FME. All companies have a clear metal- or electro- profile, as demonstrated in the classification according to the product groups. The temptation to approach only the big companies in Eindhoven and surrounding area (Medical, precision and optical equipment) was resisted. These companies are represented in the research as well, but the goal was to achieve as equal as possible spread across all product groups and chains of materials.
3 Critical materials: awareness, utilisation & problems

3.1 Awareness of critical materials

This study was initially intended to provide an insight into the utilisation of the critical materials as defined by the EU (see figure 1 paragraph 1.2), and the resulting problems companies may have experienced. The questions and discussions in the interviews have a somewhat broader basis and what was asked is: is the participant aware of the term ‘critical materials’ (outside of EU list) and how well are the developments in critical materials followed within the companies?

![Figure 3 How did you (your company) become aware of ‘critical materials’?](image)

Most of the participants appeared to be familiar with the concept of ‘critical materials’ (under various names) and were aware of the possible problems with the availability of those materials (see figure 3). Only seven participants had not come across the issue, five participants had heard about it from the media and suppliers, while eighteen participants had directly experienced problems, in one way or another (e.g. supply distortions, price increase or volatility).

Developments in the field of critical materials are, to a greater or lesser degree, followed by fifteen companies. A small number of the participants (six) do not follow developments whilst nine companies follow developments closely. The following of such developments is mainly conducted by the procurement department and sometimes by the R&D department or engineering departments in the companies.

It should be emphasized that when looking at the familiarity with critical materials and associated developments, the meaning of the term critical materials was taken in its broadest sense. Not only were the critical materials on the EU list taken into account, but also the materials defined as critical by the company. In the following paragraphs a clear distinction is made between critical materials on the EU list and those beyond the list.
### 3.2 Which critical materials are used from the EU list?

The following list shows the EU critical materials as defined at the time of the interviews. The list consists of eleven elements (from the main table), one composed material (Fluorspar), six Platinum Group Metals (PGM) and seventeen Rare Earth Metals (REM). This gives a total of 34 elements and one composed material.

<table>
<thead>
<tr>
<th>Element</th>
<th>PGM groep:</th>
<th>REM groep:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony (Sb)</td>
<td>Plutina (Pt)</td>
<td>Yttrium (Y)</td>
</tr>
<tr>
<td>Beryllium (Be)</td>
<td>Iridium (Ir)</td>
<td>Neodymium (Nd)</td>
</tr>
<tr>
<td>Kobalt (Co)</td>
<td>Osmium (Os)</td>
<td>Cerium (Ce)</td>
</tr>
<tr>
<td>Fluorspar</td>
<td>Palladium (Pd)</td>
<td>Lanthanum (La)</td>
</tr>
<tr>
<td>Gallium (Ga)</td>
<td>Ruthenium (Ru)</td>
<td>Scandium (Sc)</td>
</tr>
<tr>
<td>Germanium (Ge)</td>
<td>Rhodium (Rh)</td>
<td>Dysprosium (Dy)</td>
</tr>
<tr>
<td>Grafiet (C)</td>
<td></td>
<td>Samarium (Sm)</td>
</tr>
<tr>
<td>Indium (In)</td>
<td></td>
<td>Terbium (Tb)</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td></td>
<td>Praseodmium (Pr)</td>
</tr>
<tr>
<td>Niobium (Nb)</td>
<td></td>
<td>Promethium (Pm)</td>
</tr>
<tr>
<td>Tantale (Ta)</td>
<td></td>
<td>Europium (Eu)</td>
</tr>
<tr>
<td>Wolfram (W)</td>
<td></td>
<td>Gadolinium (Gd)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Holmium (Ho)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Erbium (Er)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thulium (Tm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ytterbium (Yb)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lutetium (Lu)</td>
</tr>
</tbody>
</table>

*Part of the questionnaire – the EU critical materials (note- Dutch spellings shown)*

The question - ‘Which of the 34 elements and one composed material are used in your products?’ is not an easy question to answer. One reason for this is because a lot of companies do not deal with raw materials, but in parts or intermediate goods, as shown in the classification of the companies in the chain of materials (paragraph 2.2). And if a company buys materials, they are in the form of processed materials, usually composed a number of elements.

The companies were asked to consider which elements can be found in their product range prior to the interview. In some cases, additional materials contained in products were agreed upon during the interviews, with the support of the interviewers. Due to the limited time for preparation and interviews, there was not an extensive overview of all elements used, but the following results provide a reasonable insight into which elements are used.
Out of the 34 critical elements and one critical composed material, as defined by the EU, twelve are utilised by the companies as part of their products (see figure 4). This does not mean that the companies directly experience these elements to be critical; this will be elaborated on in the following paragraphs.

Those materials named most often were Cobalt, Magnesium, Graphite, Tungsten (as an alloying element in steel) and Neodymium as an element in permanent magnets. In most cases the elements could be found in engineered basic metals, intermediate goods, or in the purchased components. Only Germanium, Magnesium, Graphite and Niobium were named as being utilised as a raw material. This is supported by the results shown in figure 5 where the division over this last category is shown.
On only nine occasions was a material utilised in the raw material state (including the extremely specific, high-tech utilisations, where materials are used in low volumes). Most critical materials reach the company as a part of a composed material, like a (steel)alloy, or within a purchased component, such as integrated circuits (IC’s) & magnets. This shows that these Dutch companies are not directly confronted with shifts on the materials market, but through their suppliers. Those suppliers play an important role in the awareness process. According to the companies, they also play an important role in finding solutions to the challenge.

An overview of EU-list critical materials and their utilisation by the participants can be found in the Appendix 2.

3.3 Which materials are seen as critical?

Materials from the EU-list

In the previous paragraph an overview was given of which critical elements from the EU-list are utilised by the companies. But which of those elements are actually seen as critical? Table 3a gives an overview.

Table 3a: materials from the EU-list of critical materials, seen as critical by the companies

<table>
<thead>
<tr>
<th>material</th>
<th>Number of times named</th>
<th>Utilisation form</th>
<th>Why is it seen as critical?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobalt (Co)</td>
<td>3</td>
<td>- Strong alloyed steel</td>
<td>- Strong price increase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Part of the ventilators</td>
<td>- Very long delivery time</td>
</tr>
<tr>
<td>Germanium (Ge)</td>
<td>2</td>
<td>- semiconductors</td>
<td>- delivery time problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Strong price increase</td>
</tr>
<tr>
<td>Indium (In)</td>
<td>2</td>
<td>- material for vacuum-sealers</td>
<td>- delivery time problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Strong price increase</td>
</tr>
<tr>
<td>Niobium (Nb)</td>
<td>1</td>
<td>- alloy element</td>
<td>- problems around conflict minerals (a)</td>
</tr>
<tr>
<td>Tantalum (Ta)</td>
<td>2</td>
<td>- specific IC’s and resistors</td>
<td>- shortage in IC production capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- protection material</td>
<td>- delivery time problems</td>
</tr>
<tr>
<td>Neodymium (Nd)</td>
<td>5</td>
<td>- permanent magnets</td>
<td>- suppliers did not keep up with fast growing demand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- passive components</td>
<td>- Strong price increase</td>
</tr>
<tr>
<td>Lanthanum (La)</td>
<td>1</td>
<td>- high K material for capacitors</td>
<td>Strong price increase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- doping agent</td>
<td></td>
</tr>
</tbody>
</table>

a. American law demands that the companies selling products in the USA can prove that the materials in those products are not originating from conflict areas; this is done to prevent the profit to be used for financing wars or by regimes violating human rights. It is known as ‘Congo Conflict Minerals Act’ and it is extended and included into the Dodd-Frank act, section 1502.

Other critical materials

During this research, room was left for the companies to indicate the materials they see as critical. To this end, a ‘other’ column was added in the questionnaire.
Table 3b on the following page provides an overview of the materials not included in the EU-list, but seen as critical by the participating companies. During the interviews, the ‘other’ column was frequently used.

Critical materials on the EU-list and those not on the EU-list
It can be seen that only a small part of the utilised materials from the EU list (seven out of twenty) is indicated to be critical by the participating companies (table 3a). In addition, seventeen materials which are not on the EU-list are seen as critical by the companies (table 3b). Does this suggest that the EU-list of the critical materials is wrong?

When the EU-list of critical materials was formulated, all factors which could contribute to the supply uncertainty (mining location, political views of the country of origin, conflict areas, and ecological problems in mining) were taken into account, including the importance of the materials for European industry. The companies in this research represent a cross section of the Dutch technological industry, not of European industry. Differences are possible. In addition, the limited number of companies participating in this research can be a cause of the deviations. But a more important reason is that the companies are interested in the direct adverse effects for their own production, like supply problems and unfavourable price developments of materials; they are less interested in geopolitical dimensions. In only one case (Niobium) was geopolitics named as a reason for the company to see a material as critical.

Considering the differences between the EU-list of critical materials and the materials seen as critical by the companies, it is interesting to consider adapting the list to include these Dutch industry responses.
<table>
<thead>
<tr>
<th>material</th>
<th>Number of times named</th>
<th>Utilisation form</th>
<th>Why is it seen as critical?</th>
</tr>
</thead>
</table>
| Various sorts of steel    | 4                     | -casing                                   | - strong price increase  
- required quantity increased (in most of the cases)  
- supply problems, because the acquisition is (maybe) too small (1)  
- shortage in specific sorts of steel |
| Nickel (Ni)               | 8                     | -in stainless steel objects (Ni and Cr are often used together and are not bought as raw material)  
- in Fe/Ni magnets | - as well the price the required quantity had increased (dependant on total production)  
- price increase cannot be passed on to the customer (1)  
- price of magnets strongly increased |
| Chrome (Cr)               | 5                     | -in stainless steel objects               | - strong price increase  
- supply problems |
| Lithium (Li)              | 1                     | -batteries                                 | - strong price increase and a strong increase in utilisation in recent past and the future |
| Molybdenum (Mo)           | 2                     | -lubricant ($\text{MoS}_2$)               | - temporarily no capacity, supply went to China |
| Aluminium (Al)            | 3                     | -(part of) fire retarder  
- Cast components | - fire retarder had a strong price increase |
| Strontium (Sr)            | 1                     | -metallurgic process agent                | - |
| Titanium (Ti)             | 1                     | -Whitener for plastics                    | - strong price increase |
| Zinc (Zn)                 | 3                     | -coating/galvanizing                      | - strong price volatility/price increase |
| Zircon (ZrSiO4)           | 1                     | -binding agent                            | - strong price increase |
| Copper (Cu) (brass)       | 5                     | -winding, wire  
- brass parts  
- heat conducting  
- non-magnetic vacuum sealer | - strong price increase and a strong increase in utilisation  
- capacity shortage supplier |
| Various plastics          | 4                     | -Hoses and pipes  
- softener  
- membrane material | - delivery problems, perhaps due to a too small acquisition  
- single source from factory with limited capacity, which had sold out to others  
- strong price volatility/price increase  
- Membrane material temporarily out of production due to 'Fukushima' |
| Silica (Si and Siliciumcarbide (SiC) and quartz) | 2 | -parts | - capacity shortage supplier (due to the financial crisis) |
| Materials for varnish     | 1                     | -varnish for metal finishing             | - materials for varnishes temporarily not available |
Eight companies have indicated to have had problems with one or more materials which are also on the EU-list. Sixteen companies have reported to have experienced supply problems with the materials seen as critical, but not included into EU-list.

Figure 6 Number of companies which have had problems with critical materials
3.4 Critical materials and the supply chain

In the previous paragraph all materials seen as critical by the participating companies were summarised. It is clear that criticality of a material means the following:

− The material is essential for production and is difficult to replace
− There are problems with on-time delivery or there is a chance these problems might occur
− Prices increases or fluctuations / volatility

According to the companies, the materials are difficult to replace. Therefore it is vital to them to secure the price and supply of those materials. This means that the critical materials become a responsibility of the procurement departments. The tables 3a and 3b show that they have had problems with supply and prices over the last five years.

In general the price increase is seen as less of a problem than not being able to get a material on time. Three companies have, however, explicitly reported sharply increased prices as a reason for additional concern.

It transpired that 24 of the participating companies have experienced problems with supply of critical materials over the last five years. This includes not only the materials on the EU-list, but also the materials seen as critical by the companies, as shown in figure 6.

From the description of the supply problems in tables 3a and 3b it appears that in many cases the supply chain is sensitive to distortions and that there are too few alternatives (secondary sourcing) to be found.

The fact that the high number of materials (steel, plastics, lubricants etc.) seen as critical, suggests that supply chains are not robust. It was frequently noted that one factory having problems in the Far East can lead to a production interruption. The strong growth of China and other Asian economies have created, for them, an significant buying power, introducing the risk that – even in an apparent absence of scarcity – companies can be left empty handed. Therefore, it is to be recommended that the whole supply chain is charted, possible vulnerabilities are discovered and mitigation measures are taken before a supply interruption takes place.

Problems with critical materials are mainly seen as problems with a supply chain and as such are the responsibility of the procurement departments. Procurement departments seem to have gained an additional problem dimension with the arrival of the critical materials phenomenon. Developments in product design and product process happens in a relatively small part of the companies. The R&D departments are often not really included in dealing with critical materials.
4 Critical materials: problem approach

4.1 Various actions

A company naturally takes action when problems with the supply or price of critical materials are encountered. How have the companies in this research approached those problems?

Out of thirty participating companies, 24 have taken action in the last five years. Most companies took more than one action; two companies which have had no problems, have taken precautionary measures. This provides the following overview:

![Figure 7 actions taken by the companies]

The actions can be divided into actions focussed at suppliers (red), own stock management (blue) and product adjustments (green).

Three-quarter of the actions are focussed at ensuring the supply by the suppliers or by own stock management. Less than a quarter of the actions are focussed at adaptation of own product or process. This division is understandable, considering the fact that the problems with supply have arisen unexpectedly. Forming stockpiles or making new agreements with suppliers are appropriate for a speedy response, whilst searching for substitutes or adapting the production process to a more efficient one requires considerable of research and development.

Being able to undertake product or process adaptation depends on the place of the company in the chain and the role the R&D department has in the company. Buyers of components or subassemblies have less influence on radical adaptation of material contents of own products. Companies with active R&D departments are more inclined – as a part of continuous product development – towards substitution or other product or process adaptation.
In section 2.4 companies were classified according to the chain of materials (six types of producers) and product groups (six product groups). The number of participating companies is too small to be able to state any statistically significant results per place in the chain or product group. However, from the results of the interviews some correlations can be derived.

**Relationship with position in the chain of materials**

The awareness concerning critical materials is highest with the material producers (well aware) and lowest at product producers (average to low awareness). The awareness is equally divided over the rest of the companies in the chain, varying form low to well aware.

The place in the chain of materials appears not to determine the extent to which critical materials play a role in the business. This seems surprising at first: material producers are expected to be more dependent on the (possibly critical) materials than the companies further down the chain. An aspect that plays a role here is the fact that for a lot of companies they not only purchase sub-assemblies or components but also purchase one or more raw materials. But also the companies who are not purchasing the raw materials directly can be kept up to date through their suppliers when purchasing components such as IC’s and permanent magnets.

It is not surprising that the degree of awareness in the companies is closely related to the earlier experience of problems with critical materials.

**4.2 Does the place in the chain of materials matter?**

It is interesting to observe if there is a relationship between critical materials awareness, type of materials, management role and problem approach – and the type of the product and place the companies have in the chain. Can ‘hot spots’ be pointed out where critical materials play an important role?

In section 2.4 companies were classified according to the chain of materials (six types of producers) and product groups (six product groups). The number of participating companies is too small to be able to state any statistically significant results per place in the chain or product group. However, from the results of the interviews some correlations can be derived.
Relation with product groups
As well as the product groups, the list of critical materials are broadly defined. Possibly, as a result this broad definition, it is not possible to distinguish one product group or one product where more critical or less critical materials are used. Whether a company has problems with critical materials also seems not to be dependant on a particular product group.

If one looks closely at critical materials from the EU-list, three types of products catch the eye: magnets (in electrical motors and other applications), electronics and some alloy elements for metals (in most cases: steel). When these are part of products in companies, the named materials from the EU-list are known in the company and are defined as critical and in those cases actions or precautions have been taken to ensure the supply.

4.3 Awareness and risk management

Awareness
Awareness covers not only the term ‘being aware of’ but also the term ‘being familiar with’. Being only aware of critical materials means that the companies have read about it or have heard about it, but it does not mean they are doing anything. Because the questionnaire, with some additional information, was sent to the companies prior to the interviews, it is possible that this research has, to some extent, influenced awareness.

Being familiar with critical materials is a more active form of knowledge. All companies in this research which are familiar with critical materials have had problems with these materials in the past. As discussed previously, the familiarity with critical materials is greatest with material producers (well) and lowest at project producers (low to average). All other companies in the chain show the same variation in familiarity with the critical materials (low to well).

Risk management
Do critical materials problems lead to the development and introduction of risk management activity? Section 4.1 describes actions taken in response to problems with critical materials. Does this lead to an active policy concerning critical materials and corresponding risk management activity?
It is illustrative to classify the participating companies in a risk management – problem matrix, as shown above. The quadrants can be classified as follows:

- Quadrant I. Three companies which have had no problems, have no risk management concerning critical materials. Even so there were two companies who have taken actions concerning multi-sourcing.
- Quadrant II. Three companies have decided, even before the problems with critical materials arise, to proactively include this into their risk management activity.
- Quadrant III. Seven companies indicated they conduct no risk management activity, even after having problems. Some of those companies are taking actions to prevent this from happening in the future; these actions are not considered to be risk management activities.
- Quadrant IV. It is clear that risk management activity that includes critical materials is conducted mostly in the companies (seventeen) which have had problems with critical materials.

The actions that are being taken, being either a part of risk management or not, are quite diverse. Deploying normal business responses to ensuring supply is the most likely action: multi-sourcing, LTA (long term agreement) and forecasting. Following that comes holding additional stock and lastly substitution.
5 The next five years

It is interesting to reflect on how the situation, with regards to critical materials, may develop over the next five years. What changes do the companies expect over this period? Is the role of critical materials going to grow or diminish? What developments will cause this? And do the companies see opportunities?

![Figure 9: the role of the critical materials over the next five years]

Changing role of critical materials

As can be seen in figure 9 the majority of companies (22) expect the role of the critical materials to increase over the next five years. Of these companies, sixteen believe that this increasing role will not give rise to any problems, because they also expect mining and recycling to increase correspondingly.

Six out of those 22 companies do not rule out problems over the next five years. The sources of possible problems were stated as:

- Being a small player means having a weaker ‘buying power’
- Companies operating in a ‘conservative marketplace’ have less room for alternative designs and material use strategies
- The strength of the company is in the design of the overall product and not in the aspects presented by critical materials issues; this has insufficient ‘innovation power’.

Three companies expect that the role of the critical materials will diminish due to the either decreasing demand or alternatives (substitute materials).

Reasons for an increasing role of critical materials

Companies gave the following reasons:

- Expected production increases of the company (2)
- Increasing importance of precision motors, where (Neodymium-containing) permanent magnets are present (3)
- Increasing use of electric mobility (and therefore increasing the need for batteries and electric motors containing Neodymium)
- Increased utilisation of high-tech electronics in domestic appliances and process equipment. (3)
- Emission requirements, where amongst other materials plastics have to be used and where motors with more electronics have to be developed\(^\text{12}\).

### Solutions to increase supply certainty

Companies named the following solutions

- Develop a more robust logistics approach, like multi-sourcing or better agreements with suppliers, for example by outsourcing supply of critical materials to a specialised procurement organisation
- Develop more efficient management of raw materials in production processes, as well as recycling of waste materials
- Seek and utilise alternative materials and adapt product design

In addition to the above, thirteen companies see opportunities through timely reaction as materials become more critical. In comparison six companies still see the issue mainly as an external threat and eight companies are undecided.

### Opportunities and critical materials

Seven out of the thirty companies also see opportunities as a result of the increasing role of critical materials:

- Through the development of more robust product designs and having an improved supply chain, a competitive advantage can be created (2)
- Discussions concerning critical materials is a stimulus towards a more aware and smarter utilisation of materials and cradle-to-cradle design (4)
- One producer of material sees increasing market opportunities and price developments for some of the critical materials

### Summary

Most companies expect the role of critical materials to grow, but also believe that the problems will be prevented by the discovery of new virgin sources or alternatives (substitute materials). A minority expect problems over the next five years, whilst a few also sees opportunities.

\(^{12}\) For example: new rules for more economical electro-motors require the addition of Electronics (EC technology), which would generate new demand for IC-components
Appendices

Appendix 1: The Questionnaire

The research was an interview, based on a questionnaire (in Dutch), sent to the participant prior to the interview. The interviews were conducted by two different teams of interviewers. The teams met to discuss the approach to ensure the research was conducted in the same way, to produce a comparable data set. The interviews were also audio-recorded for further analysis at a later stage.

The questions (translated into English) in the questionnaire are shown on the following pages:
Critical materials in The Netherlands
- A response from industry -

Questionnaire

Dear Sir/Madam,

Firstly, thank you for agreeing to participate in this important research.

This questionnaire forms a key part of the ‘Critical materials in the Netherlands’ project, which has been ordered by the technological sector industry representative body, FME-CWM. The project is led by TNO and M2i, in cooperation with the Delft University of Technology (TU Delft). With this research we will gain a better insight into the reaction of Dutch companies to the phenomenon of material criticality.

Critical materials are materials which are important or even essential for your products, are likely to experience price fluctuations and supply insecurity. This phenomenon has also been called material scarcity.

The following pages contain the questionnaire, which will serve as basis for the follow-up interviews.

The questionnaire is divided into five main themes:

1. Knowledge of the term "critical materials" in the company
2. The role of the critical materials in the company
3. Risk management and critical materials
4. Business and critical materials
5. Support concerning critical materials

A core theme in the research is the focus around a chosen product / product group from your company. This product is selected by you, in consultation with the researchers, during a telephone conversation prior to the follow-up interview.

In order to help make the follow-up interview more effective, we would ask you to go through the questionnaire beforehand and to gather the necessary information as required. ‘Explanation’ boxes are provided below some questions in order to allow for expansion or additional comments.

If the materials critical for your company are not named in the questionnaire, please raise this during the interview.

Finally, once again, we would like to thank you for your cooperation.

The FME/M2i/TNO/TU-Delft team.
1 Familiarity with the term “critical materials” in the company

1.1 How did your company become aware of the problems concerning critical materials (material scarcity)?

Which terms are used in your company to describe the problem? (More than one answers possible)

- Material scarcity
- Material deficit
- Critical materials
- Critique materials
- Supply insecurity
- Other term, namely: ____________________________
- This is not talked about
- I do not know/have no opinion

1.2 Indicate factors, which in your opinion, have directly or indirectly caused material criticality. Rank the factor from 1 to 7, where 1 is the most probable cause and 7 is the least probable cause.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Factor</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>_____</td>
<td>Economical factors</td>
<td>More demand than supply</td>
</tr>
<tr>
<td>_____</td>
<td>Geopolitical factors</td>
<td>Limitation by export quota of producing countries</td>
</tr>
<tr>
<td>_____</td>
<td>Suppliers</td>
<td>Suppliers monopoly on certain materials</td>
</tr>
<tr>
<td>_____</td>
<td>Mining &amp; processing</td>
<td>Not enough new capacity</td>
</tr>
<tr>
<td>_____</td>
<td>Product design</td>
<td>Products are not design for reuse and recycling</td>
</tr>
<tr>
<td>_____</td>
<td>Material sciences</td>
<td>Not enough research on alternative materials</td>
</tr>
<tr>
<td>_____</td>
<td>Recycling</td>
<td>Not enough recycling of critical materials</td>
</tr>
<tr>
<td>_____</td>
<td>Other, namely:</td>
<td></td>
</tr>
</tbody>
</table>

1.3 Indicate on the scale given below how well, developments in the field of material criticality are followed within your company.

Not at all | Very closely

1.4 How (and by whom) are the developments followed within your company?

1.5 Can you name the measurements your company has taken as reaction on issues caused by critical materials?
1.6 Are you familiar with the strategy of your competitors concerning critical materials?

1.7 If yes, does that influence decision making in your company?

2 Role of critical materials in the company

This part of the questionnaire – with exception of first question - concerns role of critical materials in an on forehand chosen product.

2.1 Can you name all of the critical materials contained in all products throughout entire product range of your company?

☐ Yes
☐ No
☐ Partially

2.2 Which element(s) from tables hereunder are used in the chosen product/product group? (Multiple answers possible)

<table>
<thead>
<tr>
<th>Element:</th>
<th>PGM group:</th>
<th>REM group:</th>
<th>Other:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony (Sb)</td>
<td>Platinum (Pt)</td>
<td>Yttrium (Y)</td>
<td></td>
</tr>
<tr>
<td>Beryllium (Be)</td>
<td>Iridium (Ir)</td>
<td>Neodymium (Nd)</td>
<td></td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>Osmium (Os)</td>
<td>Cerium (Ce)</td>
<td></td>
</tr>
<tr>
<td>Fluorspar</td>
<td>Palladium (Pd)</td>
<td>Lanthanum (La)</td>
<td></td>
</tr>
<tr>
<td>Gallium (Ga)</td>
<td>Ruthenium (Ru)</td>
<td>Scandium (Sc)</td>
<td></td>
</tr>
<tr>
<td>Germanium (Ge)</td>
<td>Rhodium (Rh)</td>
<td>Dysprosium (Dy)</td>
<td></td>
</tr>
<tr>
<td>Graphite (C)</td>
<td></td>
<td>Samarium (Sm)</td>
<td></td>
</tr>
<tr>
<td>Indium (In)</td>
<td></td>
<td>Terbium (Tb)</td>
<td></td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td></td>
<td>Praseodymium (Pr)</td>
<td></td>
</tr>
<tr>
<td>Niobium (Nb)</td>
<td></td>
<td>Promethium (Pm)</td>
<td></td>
</tr>
<tr>
<td>Tantalum (Ta)</td>
<td></td>
<td>Europium (Eu)</td>
<td></td>
</tr>
<tr>
<td>Tungsten (W)</td>
<td></td>
<td>Gadolinium (Gd)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Holmium (Ho)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Erbium (Er)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thulium (Tm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ytterbium (Yb)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lutetium (Lu)</td>
<td></td>
</tr>
</tbody>
</table>
2.3 In the last question you have ticked several critical elements used in the product. Could you, per element, state in which material it is used and who are the suppliers?

<table>
<thead>
<tr>
<th>Element</th>
<th>Material/Component</th>
<th>Function of the element(s)</th>
<th>Suppliers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

2.4 In the table hereunder, state three materials critical for your company and indicate on scale 1 to 5 if the price of the materials has in- or decreased over last 5 years.
   1 = heavy increase, 2 = increase, 3 = stable, 4 = decrease, 5 = heavy decrease

<table>
<thead>
<tr>
<th>Material</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.5 In the table hereunder, indicate on scale 1 to 5 if the quantities required by your companies have in- or decreased over last 5 years. Use the same materials as in previous question.  
1 = heavy increase, 2 = increase, 3 = stable, 4 = decrease, 5 = heavy decrease

<table>
<thead>
<tr>
<th>Material</th>
<th>Required quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.6 Previous questions concern role of critical materials in your current products. Do you expect the role of critical materials to decrease or to increase, due to new product developments?

Could you name any examples?
2.7 Did your company experience issues with supply of critical materials over the last 5 years?

☐ No
☐ Yes

If yes, what has caused those problems, in your opinion?

If yes, which critical materials were affected?

If yes, what was the reaction of your company?
3 Risk-management and critical materials

3.1 Do critical materials play a role in the risk management of the company?

☐ Yes, this is an active part of the management
☐ No, not at this moment, but there are plans to include it in the near future
☐ No, critical materials are not involved in risk management of the company

3.2 Which (material specific) measurements are/will be taken to deal with material criticality?
   (Multiple answers possible)

☐ Substitution of critical materials by other, less critical materials
☐ Efficient use of critical materials in products and production
☐ Spreading of risk by choosing multiple suppliers from different countries
☐ Stock piling of critical materials
☐ Else, namely: __________________________________________________________
☐ I do not know / not applicable

3.3 If, for example, one or more of critical materials named by you in question 2.2 is in three months suddenly not available any more, which steps could your company take right now in order to avoid possible problems?
3.4 Which change does your company expect within 3-5 years concerning critical materials?

☐ Critical materials are a much bigger problem and limit the production of certain components and or products.

☐ Critical materials are a much bigger problem, but due to the timely reaction of the company we can deal with possible limitations.

☐ Critical materials are not a problem anymore, due to the discovery of new material sources

☐ Critical materials have never been a problem.
4  **Business and critical materials**

4.1 Does the company see any potential in the critical materials?

- Yes, there are already developments in the company.
- Yes, there are plans, but no concrete developments yet
- No, this phenomenon is actually a threat for the company
- I do not know / have no opinion on this matter

5  **Support concerning critical materials**

5.1 In the list hereunder several possibilities are stated which could provide support to the company in limiting the risk the critical materials are posing. Which ones would your companies like to use? (Multiple answers possible)

- Regular meetings with updates on the latest developments concerning this phenomenon
- Swift expert check-ups of the company to determine the risk the critical materials are posing
- Hiring experts on a long term to gain advice on strategy (consultants)
- Insight in quantities of critical materials in all products and components of the company
- Personnel training to increase knowledge in this field
- Else, namely: ____________________________________________________________
- None of the above
Appendix 2: EU-list critical materials used by the companies

Table 4 materials from the EU-list of critical materials used by the participating companies

<table>
<thead>
<tr>
<th>EU critical material</th>
<th>Utilisation in companies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of times named</td>
</tr>
<tr>
<td>Antimony (Sb)</td>
<td>5</td>
</tr>
<tr>
<td>Beryllium (Be)</td>
<td>4</td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>14</td>
</tr>
<tr>
<td>Gallium (Ga)</td>
<td>4</td>
</tr>
<tr>
<td>Germanium (Ge)</td>
<td>6</td>
</tr>
<tr>
<td>Graphite (C)</td>
<td>15</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>EU critical material</th>
<th>Utilisation in companies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raw material</strong></td>
<td><strong>Number of times named</strong></td>
</tr>
<tr>
<td><strong>Magnesium (Mg)</strong></td>
<td>12</td>
</tr>
</tbody>
</table>
| - Dependency on China (>90%)  
- Recycling limited | | material (1) | casting (1) | | |
| | | engineered material (8) | alternative fire retarder (1) | | |
| | | - fireproof ovens (1) | - de-sulphurisation (1) | | |
| **Indium (In)** | 5 | raw material (1) | displays (3) | ++ | ++ |
| - Strong increase of high-tech application (LED, PV)  
- By-product Zinc mining  
- Recycling is not starting  
- Dependency on China | | material (1) | vacuum seals (1) | | |
| | | - component (3) | - in semi conductors (1) | | |
| **Niobium (Nb)** | 7 | raw material (2) | steel alloys | | |
| - Dependency on Brazil (>90%)  
- Recycling and substitution not very likely | | engineered material (5) | | | |
| **Tantalum (Ta)** | 6 | material (2) | capacitors (3) | | |
| - Dependency on Congo  
- Limited recycling and substitution possibilities | | component (3) | X-ray protection (1) | | |
| **Tungsten (W)** | 13 | engineered material (12) | hard steel (tools) (11) | + | |
| - Dependency on China (also for foreign production)  
- Substitution limited (worse performance) | | component (1) | welding material (1) | | |
| | | | - laser (1) | | |
| **Platinum* (Pt)** | 6 | material (2) | catalyst (2) | + | 0 |
| - Very limited stocks  
- Partially no recycling due to dissipative employment  
- Dependency on South-Africa | | component (4) | sensors/thermocouple (2) | | |
<p>| | | | - passive electronic components (1) | | |
| <em><em>Palladium</em> (Pd)</em>* | 6 | material (3) | chip capacitors (3) | | |
| - See Platinum | | component (3) | plastic coating (1) | | |
| | | | - catalyst (1) | | |
| <em><em>Rhodium</em> (Rh)</em>* | 2 | material | catalyst | | |
| - See Platinum | | component | - thermo couple | | |
| <strong>Yttrium</strong> (Y) | 4 | material (2) | - in LED (‘phosphors) (2) | | |
| - See Neodymium | | component (2) | - dopant golden wire (1) | | |
| <em><em>Neodymium</em> (Nd)</em>* | 11 | material (2) | permanent magnets (linear, step) | ++ | ++ |</p>
<table>
<thead>
<tr>
<th>EU critical material</th>
<th>Utilisation in companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material</td>
<td>Number of times named</td>
</tr>
<tr>
<td>(Nd)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerium** (Ce)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Lanthanum** (La)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Scandium** (Sc)</td>
<td>1</td>
</tr>
<tr>
<td>Samarium** (Sm)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Explanation**
- Changes in price in the last five years: 0 (no change), + (increased), ++ (strong increase to doubled)