German Environment Agency

1. November 2018

Substitution to reduce the criticality of raw materials in environmental technologies

Recommendation Paper: Conclusions drawn from a roadmapping project on substitution strategies for critical raw materials in environmental technologies

1 Background

The expansion and use of innovative environmental technologies are among the most important factors for improved resource efficiency, resource conservation and the transition to a green economy. Many environmental technologies rely on the use of specific raw materials for which there are already various supply risks. It is currently foreseeable that efficiency and recycling strategies will not be sufficient in themselves to markedly decrease the criticality of these materials, nor to ensure a far-reaching expansion of significant environmental technologies, not only in industrialised countries like Germany but also globally. Measures that support and facilitate substitution, i.e. the replacement of rare and strategic metals with raw materials that have lower environmental impacts, is the key in this respect.

1.1 The aim of the SubSKrit project

The research project *Substitution as a Strategy for Reducing the Criticality of Raw Materials for Environmental Technologies* (SubSKrit) was conducted by the Oeko-Institut and the Institute for Futures Studies and Technology Assessment on behalf of the German Environment Agency (UBA) within the scope of the Environmental Research Programme of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and ran from August 2014 until February 2018. **The project focused on the development of a roadmap for critical raw materials' substitution in environmental technologies.** This roadmap aims to show which substitution measures can substantially contribute to enabling a future expansion of environmental technologies – also against the background of rising supply risks for raw materials. It takes into account the long lead times, barriers and favourable factors influencing development from the research stage to market maturity and diffusion. The roadmap makes an important contribution to the implementation and further development of Germany's national raw materials strategy and resource efficiency programme (ProgRess) as well as to provide input for the national and international policy debate. To that end, key stakeholders and instruments – as well as relevant measures – were identified and external experts were involved in the project.

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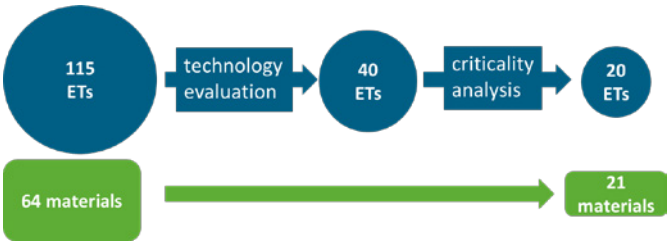
1.2 The project approach

- 115 environmental technologies were identified from recent studies and key policy documents and were subjected to a multi-stage selection process. As a result of this assessment, 40 environmental technologies (ET) were identified as significant and were therefore analysed in more detail.



- A scenario approach was used to determine the raw material requirements for a business-as-usual and a green economy scenario for the years 2025 and 2050. Out of a total of 64 raw materials investigated across the 40 selected environmental technologies, 38 will play a part in satisfying raw materials requirements.
- The criticality of the raw materials used in environmental technologies was ranked using a methodology comprising the three dimensions: supply risk, environmental implications, and strategic significance. In order to select 20 priority environmental technologies for screening of substitution options, the raw materials ranking was applied to the environmental technologies.
- Substitution options were identified and assessed for these 20 priority environmental technologies.
- With implementing the substitution options a substitution scenario shows the effects on criticality and the raw material demand for 21 relevant materials.
- The most promising and significant substitution options are discussed in a roadmap. The roadmap shows where action is needed, and what form it should take, in order to utilise the identified substitution potential.

The selected 20 priority environmental technologies*	
Electronics Lead-free solders Green data centres	**Storage technologies** Pedelec batteries Lithium-ion batteries for vehicles Stationary lithium-ion energy storage
Catalytic converter Automotive catalytic converter Industrial catalytic converter	**Solar technologies** Thin-film solar cells Concentrating solar power Tandem cells in concentrating PV
Permanent magnets Pedelec motors Hybrid motors Electric vehicle traction motor BEV / PHEV High performance permanent magnets industry Permanent magnet generators for wind turbines	**Other technologies** Combined cycle power plants RFID Chlor-alkali electrolysis with oxygen depolarised cathode White LED
Generators without permanent magnets Synchronous generators in wind turbines Asynchronous generators in wind turbines	

* In the box above 21 technologies are shown, as pedelec is one technology but has the battery and the motor in two different categories

2 Roadmap

Substitution options were identified for a number of key environmental technologies such as electric motors, solar energy, lighting and storage technologies. The roadmap shows where action is needed, and what form it should take in order to utilise the identified substitution potential. Reflecting this need for action, practical measures were identified in four areas: technological development, market launch, diffusion through awareness-raising and exchange, and legal/regulatory frameworks.

2.1 Technological development

Research and development are required primarily in respect of those substitution options for which a relatively small market share is projected to 2025. Here, a number of disadvantages and obstacles have to be overcome for utilisation of this substitution potential. In many instances, it will be necessary to resolve ongoing technical challenges (lower power density, higher costs) for substitution to become competitive. Further research is therefore required to improve efficiency. Moreover, laboratory efficiency must be achieved in commercial systems as well. For example the substitution option for white LEDs: With white organic light emitting diodes (wOLEDs), it is important to improve their physical and technical properties in the short to medium term. At present, their lifespan is still too short for practical use and they are less energy-efficient than white LEDs. Further research and development are required in order to make inexpensive wOLEDs ready for use in products aimed at the consumer market.

2.2 Market launch

Many substitution options are already at a very advanced stage of development but are only found in niche markets. This applies, for example, to substitutes for white LEDs, low voltage motors with high-performance permanent magnets in industrial applications, and hybrid and electric traction motors. Here, the main priority is to expedite market launch and diffusion. With regard to white LEDs, conversion of lighting technology will have fairly major implications for value chains. Furthermore, the use of area (instead of point) light sources can cause problems in terms of compatibility with lighting systems in the existing building stock. In order to bring these products to market, entirely new lighting concepts for both indoor and outdoor areas will have to be developed. With regard to diffusion, production costs will have to be reduced for some substitution options. Support is required, for example, in order to scale up demonstration and pilot systems to commercial production and to reduce costs. Support could also be provided for process development, gathering of experience and economies of scale in manufacturing.

2.3 Diffusion through awareness-raising and exchange

In many cases, utilisation of substitution options can be supported with awareness-raising and exchange. With electric traction motors, for example, various technological options, such as asynchronous motors and synchronous motors with reduced rare earth content, are already available in some battery electric vehicles now on the market. Further diffusion should be supported with awareness-raising and confidence-building measures. With asynchronous motors, it is mainly the motor manufacturers themselves who have an interest in establishing their product in the market. Nevertheless, efforts should also be made by the German Government and ministries (e.g. BMU, BMWi), networks and associations (e.g. VDMA, VDA, ZVEI, VDI ZRE) and the EU (e.g. Joint Research Centre, EU Framework Programme for Research and Innovation/Horizon 2020) to develop information offers on the substitution of the asynchronous motor for the synchronous motor. With permanent magnets, too, further diffusion is required, which should be supported by broad-scale awareness-raising, starting right away.

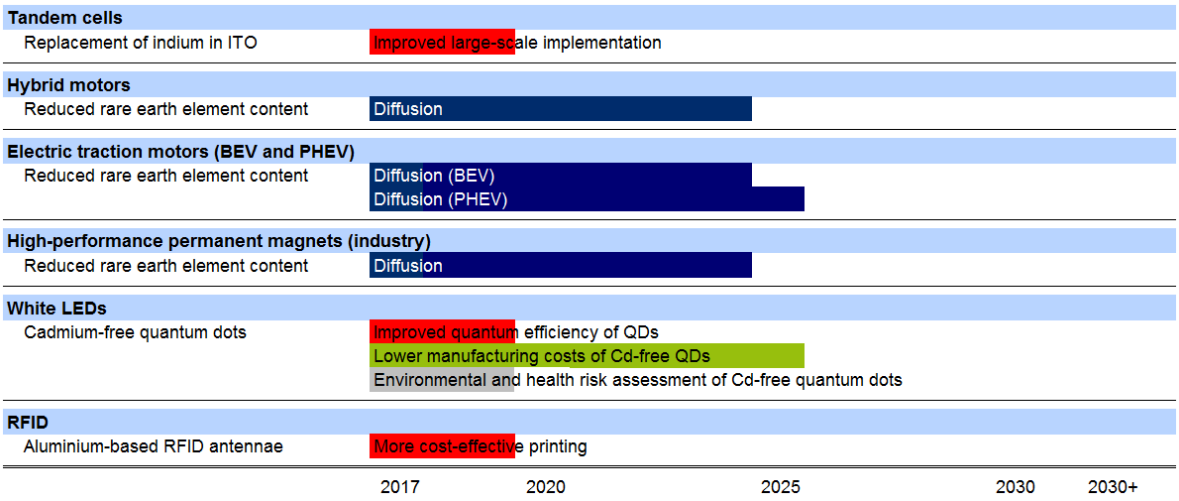
2.4 Legal/regulatory frameworks

In addition to technological development, market launch and diffusion through awareness-raising and exchange, legal and regulatory measures have a significant role to play (e.g. in relation to wOLEDs). Innovation should be accompanied by studies on the environmental and health impacts of cadmium-free quantum dots, with a particular focus on the manufacturing of quantum dots and the safe disposal/recycling of the lighting products. In addition, the utilisation of substitution potential should be supported through standardisation to ensure compatibility of wOLED lighting products, including appropriate measurement and quality standards.

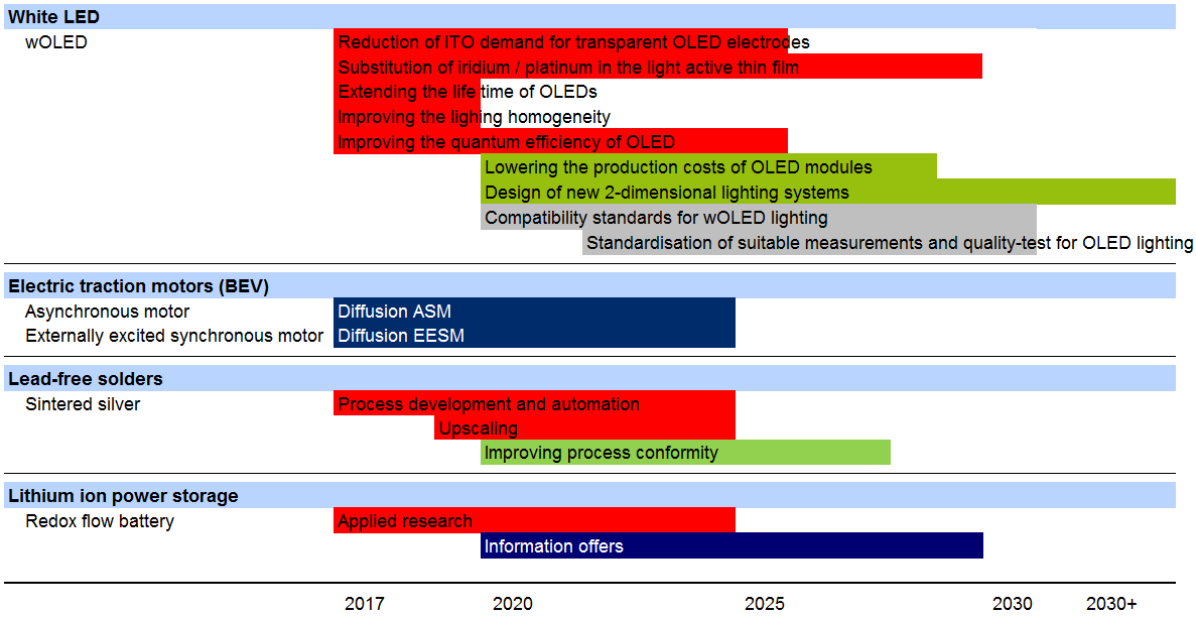
2.5 Roadmap at a glance

The following tables show the environmental technologies, substitution options and adequate measures whose projected market share in 2025 exceeds 15% (priority 1) and those with a projected share of 5-15 % (priority 2).

Priority 1: Environmental technologies and their substitution options



Priority 2: Environmental technologies and their substitution options



3 Conclusion and Recommendations

- More intensive moves towards material efficiency and substitution should be initiated before raw materials become scarce and critical. Systematic screening and early review of criticality are essential.
- A forward-looking approach in practical action is vital. This can be achieved through regular monitoring. Environmental technologies and raw materials should be assessed for criticality and substitution options every four years.
- The substitution options with high market potential should be analysed in more depth to exploit the potential.
- Targeted efforts are required in the innovation system from policy-makers for the utilisation of the identified substitution potential through research, innovation and diffusion funding. Key players are research institutes, e.g. Fraunhofer, industrial collective research (AiF), as well as European universities, major research centres, like European Innovation Partnership (EIP), EIT Raw Materials, Joint Research Centre (JRC), industry and associations.
- The roadmap can only be implemented through concerted action by manufacturers, consumers, policy-makers and the scientific community due to the vast resources required for the implementation of the broad spectrum of measures.
- There is scope to provide support for substitution research by opening up the German Government's Resource Efficiency Award to include substitution or by launching a separate BMBF Substitution Research Programme, focusing on lighting, solar and storage technologies, as part of the resource efficiency funding programmes. In Europe the support for substitution research could be strengthened by e.g. the European research framework programmes (e.g. Horizon 2020), the knowledge and Innovation Communities (KIC) of eit (European institute of innovation and technology) and the Raw Material Information System (RMIS of the EC).

Synopsis

A far-sighted approach should be adopted towards the issue of critical raw materials substitution in order to minimise the impacts of scarcity on the economy and in particular on the implementation of environmental technologies which are indispensable to achieve the sustainable development goals. As the raw materials markets are extremely volatile and the extraction of some raw materials is limited to a small number of countries, price shocks with dramatic short-term impacts may occur more frequently in future. It is vital, therefore, to establish continuous monitoring of environmental technologies which make use of potentially critical raw materials and to introduce regular reviews of substitution options for these technologies.

The project report and the working papers of SubSKrit are available online: https://www.umweltbundesamt.de/publikationen/substitution-als-strategie-minderung-rohstoffkritikalitaet.

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