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1. For more information on the recovery of raw materials, see: EC Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (2018). Raw materials scoreboard 2018

European innovation partnership on raw materials. DOI: 10.2873/08258: https://publications.europa.eu/en/publication-detail/-/publication/117c8d9b-e3d3-11e8-b690-01aa75ed71a1

2. The EC has created a list of critical raw materials for the EU, which is regularly reviewed and updated: http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en

3. The EC is funding several projects addressing both the substitution of indium (e.g. on Transparent Conductive Oxides applications) or its sustainable production via innovative extraction, processing and recycling technologies. These research and innovation programmes include H2020 projects – such as INREP and INFINITY – both of which focus on substitution of indium. Relevant LIFE projects include LIFE RECUMETAL, PHOTOLIFE and LIFE-PHOSTER.

Science for Environment Policy

Closing the loop on critical materials for renewable energy tech: 10 key factors

A new study lists 10 factors to help create a closed-loop supply chain for critical materials. However, interviews with key actors in supply chains for photovoltaic (PV) panels and wind turbines suggest that manufacturers and recyclers hold different perspectives on these factors. The research highlights the importance of cooperation between supply-chain actors, as well as investment in technologies and infrastructure for closed-loop supply chains.

Green energy technologies are vital in building a sustainable, low-carbon society, but depend on critical raw materials. These are economically valuable, hard-to-substitute materials with an unreliable supply, usually because they are imported from a small number of countries — some of which are politically unstable. These risky supply chains create an uncertain environment for industry.

In a closed-loop supply chain, products, or the materials within them, are returned to manufacturers for re-use. As well as helping secure materials in the long term, closed-loop supply chains can also bring major environmental benefits by avoiding the negative impacts of mining, extracting, and processing raw materials — such as air pollution and greenhouse gas emissions. However, previous research has suggested that many manufacturers do not consider closed-loop supply chains to be feasible.

EC Horizon 2020 projects, such as CloseWEEE (Integrated solutions for pre-processing electronic equipment, closing the loop of post-consumer high-grade plastics, and advanced recovery of critical raw materials antimony and graphite) and SecREEts (Secure European Critical Rare Earth Elements) are working on the recovery of valuable raw materials from primary and secondary sources[1].

This study explored the factors that could encourage closed-loop supply chains, focusing on the PV and wind turbine industries. These two sectors are responsible for the greatest use of critical raw materials in green energy technologies. PV uses indium and gallium (both categorised as critical raw materials for the EU[2,3]), among others, for instance, and wind turbines use rare earth elements, including neodymium and dysprosium.

By analysing existing studies on the topic, the researchers drew up a list of 10 factors that influence the implementation of closed-loop supply chains for critical materials:

1. **Technical feasibility of recycling**. This depends on the design of the product — for example, whether it is easy to disassemble, or how the materials are mixed together.
2. **Availability of items for recycling**. This refers to the amount, quality, and location of returned products, and partly depends upon consumer and business behaviour.
3. **Market for recycled materials**. This is generally driven by the market price of materials.
4. **Economic feasibility**. This is the overall balance of costs and benefits in a closed-loop system. Costs may include investments in product design, or the costs of recycling processes.
5. **Competition**. A competitive environment will affect product recovery. In-house recycling, for example, can benefit manufacturers by keeping materials away from competitors.
6. **Information exchange and supply chain transparency**. This concerns sharing information on products and materials both along and between supply chains.

Continued on next page.

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Closing the loop on critical materials for renewable energy tech: 10 key factors *(continued)*

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7. **Engagement of supply chain actors**. This refers to cooperation between supply chain actors as well as competitors.
8. **Established industrial infrastructure**. This refers to the facilities, capacity, and technology for collecting and processing products and materials.
9. **Legislation**. This includes recycling targets and manufacturer requirements on product take-back, for example[4]. It is increasingly recognised that legislation needs to be directed towards all participants in the supply chain, not just manufacturers and recyclers.
10. **Public engagement**. The public's awareness of recycling's benefits, and their willingness to return products and protect the environment, will all affect the closed-loop supply chain.

The researchers then interviewed representatives from 10 leading EU-based companies in the PV and wind turbine supply chains for their thoughts on closed-loop strategies for critical raw materials. Four of the companies were manufacturers, and six were 'reverse supply-chain operators', i.e. those involved in collecting end-of-life products and recycling. While this is, therefore, a small-scale study, the in-depth results provide insights for policymakers and practitioners involved in implementing closed-loop supply chains.

All 10 of the influencing factors were mentioned to some degree by the interviewees (who had not been shown the researchers' list to avoid bias). The most commonly mentioned factor was *Technical feasibility of recycling*. One of the main barriers to recycling cited by reverse supply-chain operators was the complexity of product design, specifically the small concentrations and complex mixtures of materials. Manufacturers, on the other hand, saw the current lack of suitable recycling technologies as a barrier to recycling. They believed 70-90% of the materials in their products to be recyclable.

The two other main factors for interviewees were *Availability of items for recycling* and *Economic feasibility*. Insufficient collection systems for end-of-life products, plus a lack of business incentives for manufacturers to engage in material recovery, were among reasons given for non-involvement in closed-loop supply chains.

While the interviewees typically discussed the influencing factors in terms of barriers, the researchers suggest that such 'bottleneck conditions' could serve as guidelines for actions which enable closed loops. The study also suggests that aligning the views of different supply chain actors could help promote closed-loop supply chains through greater collaboration. Harmonising legislation at the international level could also support closed loops, given that materials flow across national boundaries.

4. The Directive 2012/19/EU on waste electrical and electronic equipment (WEEE), Annex V, sets out specific recycling and recovery targets for different categories of WEEE, including photovoltaic panels. These targets increase over time. The WEEE Directive also provides for producers of electrical and electronic equipment - including producers of PV panels - to set up take-back systems allowing consumers to return the waste electrical and electronic equipment. According to the Directive, producers are obliged to cover the costs for the collection, treatment, recovery and environmentally-sound management of the waste from their products.