Climate Neutrality Foundation

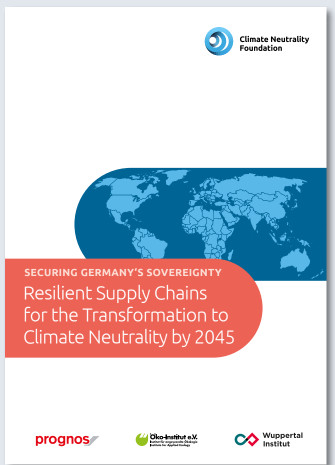
Factsheets

Resilient Supply Chains for the Transformation to Climate Neutrality by 2045

- **Key findings**
- **Overview of supply risks**
- **Critical raw materials**
- **Cross-sector strategies and measures**

Critical challenges and effective policy strategies for the following key transformation technologies:

- **Electromobility**
  Permanent magnets in electric motors / lithium-ion batteries
- **Photovoltaics**
  along the entire supply chain
- **Wind power**
  Permanent magnets in generators
- **Green steel**
  DRI plants
- **Green hydrogen**
  Electrolyzers



The factsheet edition is based on the following study: Prognos, Öko-Institut, Wuppertal Institut, 2023 Securing Germany's Sovereignty – Resilient supply chains for the transformation to climate neutrality by 2045, on behalf of the Climate Neutrality Foundation

More information and detailed data available online: www.stiftung-klima.de

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Study SECURING GERMANY'S SOVEREIGNTY

Resilient supply chains for the transformation to climate neutrality by 2045

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For the transformation to climate neutrality, the focus is on seven key technologies that provide particularly high CO_2 savings and have a strong demand ramp-up until 2030/2035, and for which there are already signs of supply bottlenecks: Photovoltaics, wind power (with permanent magnets), electromobility (with lithium-ion batteries and permanent magnets), electrolyzers for green hydrogen, heat pumps and DRI plants for the production of green steel.

This factsheet briefly highlights key findings on critical challenges and effective policy action strategies.

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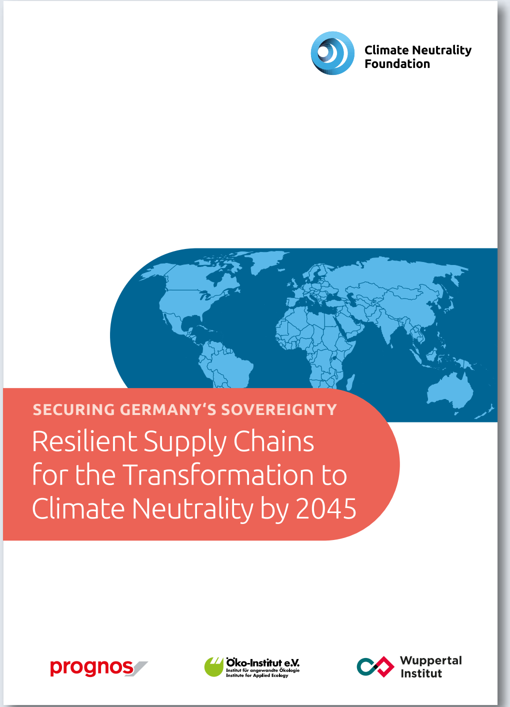

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Factsheet

Resilient supply chains for the transformation by 2045
Key findings

A supply chain is only as resilient as its weakest link

7 Key technologies

The following key industries play a strategic role in the transformation to climate neutrality:

- Photovoltaics
- Wind power
- Lithium-ion batteries for electromobility
- Permanent magnets for electromobility and wind power
- Electrolyzers
- Heat pumps
- Green steel plants (DRI shaft furnaces)

Consider the entire supply chain

A supply chain is only as resilient as its weakest link. Therefore, the entire supply chain — from raw materials, components and pre-products to the finished product — must be analyzed and checked for weak points and critical dependencies.

7 Very critical raw materials

- The key technologies include seven very critical raw materials, with a view to extraction and processing: ***Graphite, iridium, cobalt, lithium, manganese, light and heavy rare earths.***
- In addition, *nickel* and *polysilicon* should receive special attention as other medium critical (processed) raw materials.
- Criticality arises from both raw material extraction and processing.

Solutions

Production ramp-up in Europe

Increase resilience in the short term through targeted investment in domestic transformation industries and by locating particularly critical parts of supply chains in Germany and Europe. Particularly relevant:

- **PV industry:** especially ingots / wafers, solar glass, PV cells and modules.
- **Permanent magnets** and their precursors, especially for wind turbines and electromobility
- **Lithium-ion batteries** for electromobility: complete supply chain.
- Development of a lead market for **green steel**.

International diversification

- Building transformation-oriented partnerships will help reduce dependencies even in the short term.
- Supporting the development of deeper value chains instead of just supplying raw materials.
- The following countries outside the EU are of particular interest for **transformation partnerships**: *Australia, Brazil, Canada, Chile, Colombia, Ghana, Indonesia, Madagascar, Malawi, Mozambique, Namibia and South Africa.*

Recycling: Early-stage capacity building

- A significant contribution in the form of secondary raw materials from the circular economy is not expected until 2030/35.
- The path must already be paved today: Early capacity building in the recycling industry through design requirements, export restrictions on secondary raw materials, timely investment in recycling capacity, and building a supportive industrial ecosystem.

Raw material intensity and alternatives

- The reduction of raw material intensities and the development of alternative technology options is an important pillar of a resilience-oriented transformation policy.
- It is essential to develop a corresponding environment for innovation in Europe.

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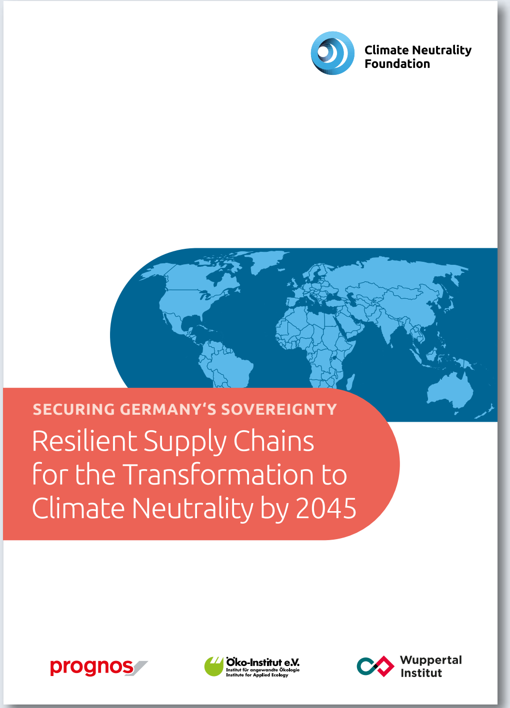

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Resilient supply chains for the transformation by 2045
Overview of supply risks

Initial situation

- **Seven key technologies** of central importance for the transformation to climate neutrality.
- Causes of supply shortages: Country concentration, short-term excess demand, and long-term shortages.
- Technologies with a strong **ramp-up to 2030/35** are in the focus here.
- The key technologies include **seven very critical raw materials**, with a view to extraction and processing: Graphite, iridium, cobalt, lithium, manganese, light and heavy rare earths. In addition, nickel and polysilicon should receive special attention as other medium critical (processed) raw materials.
- An analysis of the entire supply chain is required to assess resilience: Raw material extraction, processing, production of (sub)components and goods.

Criticality of strategic key technologies along the supply chain

	Raw material extraction	Raw material processing	(Sub)components	Goods
1. Photovoltaics		**Polysilicon:** China 79 %	**Ingots/wafers:** China 97 %	**Modules:** China 75 %
			Cells: China 85 %	
			Solar glass	
2. Wind power			Many components are sourced in China	Currently sufficient capacities in Europe, but declining competitiveness
3. Generators and motors (for wind power and electric mobility)	**Light rare earths:** China 58 %	**Light rare earths:** China 87 %	**Permanent magnets:** China 94 %	
	Heavy rare earths China / Myanmar: 100 %	**Heavy rare earths:** China 100 %		
4. Electric mobility Lithium-ion battery	**Lithium**	**Lithium**	**Cathode material:** China 71 %	**Battery cells**
	Cobalt: Congo 72 %	**Cobalt:** China 75 %		
	Manganese: South Africa 36 %	**Manganese:** China 95 %		
	Nickel: Indonesia 38 %	**Nickel:** China 55%		
	Graphite: China 73 %	**Graphite:** China 100 %	Anode material: China 91%	
5. Electrolyzers	**Iridium (PEMEL):** Production cannot be expanded. South Africa 85 %			
	Scandium (HTEL, only after 2030/35)			
6. Heat pumps			**Compressors** (partly with permanent magnets)	
7. Green steel	**Iron ores** in DRI quality			**Plant engineering** for direct reduction plants (DRI shaft furnace)

KEY ◎ Concentration and market power — Short/medium-term excess demand — ● Permanent shortage

Criticality: Very critical — Medium critical — Moderately critical

SOURCE Own representation NOTE Copper, titanium, gallium, germanium, yttrium and platinum: According to the investigations conducted in this study, these raw materials are strategically relevant for the transformation to climate neutrality to 2045, but not critical.

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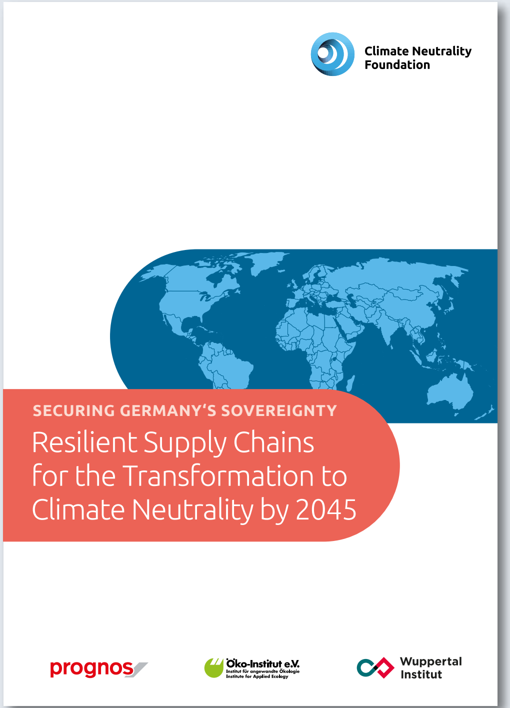

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Factsheet

Resilient supply chains for the transformation by 2045 Critical raw materials

Climate Neutrality Foundation

Initial situation

- For the transformation to climate neutrality, **seven key technologies** are of central importance.[1]
- In the key technologies needed for a successful transformation, seven **very critical raw materials** were identified with a view to **extraction and processing**: Graphite, iridium, cobalt, lithium, manganese, light and heavy rare earths. In addition, nickel and polysilicon should receive special attention as other medium critical (processed) raw materials.
- These relate in particular to electromobility, wind power and electrolyzers for the production of green hydrogen
- For details on raw materials as well as risk assessment of the subsequent stages of the supply chain, see factsheets on key technologies.[2]

Challenge: Electromobility Lithium-ion batteries[3]

	Lithium	Cobalt	Graphite	Manganese	Nickel
Extraction	Demand increases quickly	72 % Congo	73 % China (*for natural graphite*)	36 % South Africa	38 % Indonesia
Processing	73 % China	75 % China	100 % China	95 % China	55 % China
Solutions	- 30 % of European demand can be met through mine development (e.g. in Germany, Finland, France, Portugal) and the establishment of recycling facilities - Development of mines in Australia, Canada, Brazil, Ghana, etc. - Construction of lithium refineries in Germany, Poland, Finland	- Demand curbed by cobalt-free and low-cobalt lithium-ion batteries - Expansion of extraction in Europe (Finland) - Worldwide expansion of mines, e.g. in Australia	- Use of synthetic graphite - Diversification possible: Reserves distributed among various countries; increase in supply possible, e.g. in Brazil - Europe: Deposits in Norway and Sweden	- Demand curbed by manga-nese-free lithium-ion batteries (LFP) - Expansion of extraction in Europe (Finland) - Worldwide expansion of extraction	- Demand curbed by nickel-free lithium-ion batteries (LFP) - Expansion of extraction in Europe (Finland) - Worldwide expansion of extraction in countries such as Australia and Canada

Challenge: Electromobility and wind power Permanent magnets in electric motors / generators[4]

	Heavy rare earths (Dysprosium/terbium)	**Light rare earths:** (Neodymium/praesodymium)
Extraction	100 % China	58 % China
Processing	100 % China	87 % China
Solutions	- Mining and processing in Europe: Potential in Sweden, Estonia, Norway and France - Recycling growing strongly from 2035 due to returns of electric motors - Expansion of mining in traditional mining countries, such as Canada, Australia and the USA - Support for the development of mining and processing in Namibia, Malawi, Kenya	

Challenge: Green hydrogen PEM electrolyzers[5]

	Iridium
Extraction	No expansion of extraction likely

Solutions

- Further reduction of raw material intensity by 75% by 2040
- Short-term: Spark plug recycling
- Medium-term from 2035: Electrolyzer recycling
- Backup: Alkaline electrolyzers (without iridium)

KEY Criticality: Very critical, Medium critical, Moderately critical

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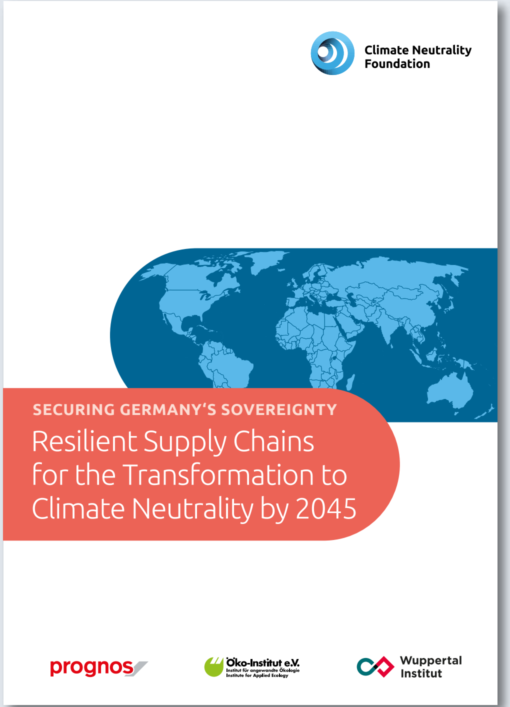

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COMMENTS:

1 **Key technologies**: For the transformation to climate neutrality, the focus is on seven key technologies that enable particularly high CO_2 savings, have a strong demand ramp-up until 2030/2035, and where supply bottlenecks are already emerging today. These include: Photovoltaics, wind power (including permanent magnets), electromobility (lithium-ion batteries, permanent magnets), electrolyzers for green hydrogen, heat pumps and DRI plants for the production of green steel.

2 To assess the criticality of technologies, the entire supply chain must be considered. Further information is available in the **factsheets on individual key technologies**.

3 **Lithium-ion batteries:** will remain the dominant battery technology for the electromobility sector in the medium term. They are characterized by a particularly high power density and range.

4 **Permanent magnets made of rare earths** (neodymium-iron-boron magnets) have become a central component of generators and electric motors. Almost 100 % of electric passenger cars, electric trucks and offshore wind turbines use these permanent magnets. Compared to electric magnets, they have a high power density and are installed wherever space and weight are a limiting factor.

5 **PEM electrolyzers**: Two processes for the production of green hydrogen are ready for the market today: Alkaline electrolysis and PEM electrolysis. PEM electrolyzers are particularly suitable for power systems with a high proportion of volatile power generation because they can be operated very flexibly and are very efficient. The market share will therefore increase sharply in the future.

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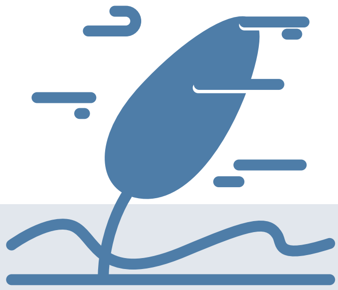
Resilient supply chains for the transformation by 2045

Cross-sector strategies and measures



"In addition to companies, policymakers in particular have an essential responsibility to define the supportive framework for accelerating the development of the industries of the future and resilient supply chains for the key technologies of transformation and thus future prosperity."

Comprehensive Resilience Monitoring

- Establish and institutionally embed resilience monitoring across the supply chain.
- Regular analysis of raw material availability and supply relationships with critical dependencies along strategically relevant supply chains.
- Examine design options for embedding at national and European level.

Stable domestic markets

- Create stable domestic markets for transformative key technologies by ensuring stable regulatory measures (regulatory law, CO_2-Pricing) and infrastructure development.
- Reliable funding instruments in Germany and the EU to support green lead markets with forward-looking skilled labor and the development or continuation of clear export strategies
- Accelerated planning and approval procedures and reduction of inefficient bureaucracy.

Purchasing pools and bundling of supply contracts

- Enabling purchasing pools for strategic raw materials and goods.
- Bundling and securing of supply and purchase contracts by the public sector.
- Review and possible reform of antitrust laws to strengthen resilient supply chains.

Resilient content requirements

- Setting resilience regulations with standards, for example on environmental and social compatibility criteria for funding measures and with regard to the import of goods.
- Examination of options for implementation, for example through bonuses in tenders or feed-in tariffs (along the lines of the staggered model of the Inflation Reduction Act) or also as a qualitative criterion in corresponding tenders.
- Integration into the development or updating of export strategies for transformation technologies.

Domestic business location policy

- Strong representation of domestic business location policy in the area of strategic raw materials and goods Compensatory measures to establish a level playing field with subsidized competitors outside Europe, with investment support (CAPEX) and temporary operating cost subsidies (OPEX).
- Eligibility for funding for the establishment of a business location should be based not only on regional criteria, but also and in particular on resilience factors.
- Extraction of critical raw materials within the EU must be prioritized.

Transformation Partnerships

- Expand and strengthen transformation partnerships.
- Establish transformative industry partnerships as a pillar of the resilience and diversification strategy — strengthen economic cooperation beyond existing raw materials and technology partnerships.
- Strengthen value creation in partner countries and participation in supply chains, especially in countries of the Global South. Intensified cooperation in education and research projects.

Capacity building in the recycling industry

- Early capacity building in the recycling industry through design requirements, export restrictions on secondary raw materials (such as of valuable black mass from battery recycling) and precursors, as well as robust implementation of the EU Battery Regulation and the Critical Raw Materials Act of the EU.
- Establish long-term recycling strategies, support programs for R&D and infrastructure development.
- Robust and timely national implementation of the EU's Critical Raw Materials Act with a view to material-specific end-of-life recycling quotas as well as through Recycled Content requirements.

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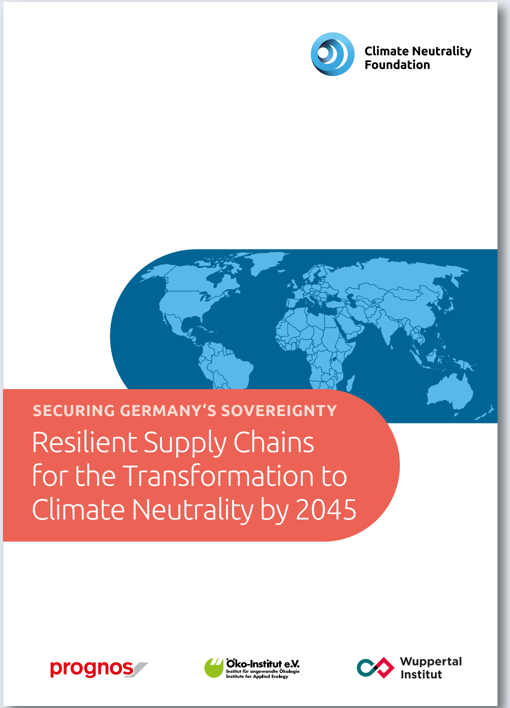

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Factsheet

Resilient supply chains in electromobility
Lithium-ion batteries[1]

Initial situation

- Lithium-ion batteries will remain the **dominant battery technology**.
- Alternative technologies (sodium-ion batteries[2]) initially only for niche markets.
- Critical raw materials: **Lithium, cobalt, graphite, manganese and nickel**.
- Critical components: **Anode and cathode material**.
- Many announcements on the construction of battery cells. Few projects with upstream supply chain.

Challenge: Market concentrations along the supply chain

Top1 country: Market share in terms of production (2022)

Raw material production[2]:	Raw material processing	Components	Goods
Lithium 52 % Australia	Lithium 73 % China	Cathode Material 71 % China	Battery Cells 77 % China
Cobalt 72 % Congo	Cobalt 75 % China	Anode Material 91 % China	
Graphite 73 % China	Graphite 100 % China		
Manganese 36 % South Africa	Manganese 95 % China		
Nickel 38 % Indonesia	Nickel 55 % China		

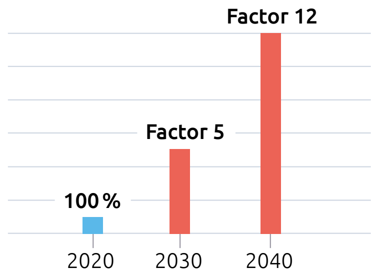
- Criticality due to high concentration in China of up to up to 100 % – especially in downstream stages of the supply chain.

KEY
Criticality: Very critical Medium critical Moderately critical

Challenge: Lithium bottleneck

Increase in demand compared to current production

- Criticality due to the very rapid ramp-up in demand by 2030.
- Rapidly expand extraction worldwide to meet demand.[3]



Solutions see also factsheet on cross-sector strategies and actions

Production ramp-up in Europe

- Establish and institutionally embed *resilience monitoring* across the entire supply chain.
- Establish domestic sales markets. European potentials available:
  - *Lithium production:* Germany, Finland, France, Portugal. 30 % of the demand in Europe could be met
  - First projects for *Lithium refineries* in Germany, Finland, Poland in planning and construction phase.
  - *Cathode material:* First projects under construction and operation in Finland, Germany, Poland.
  - *Anode material*: Capacities planned in Sweden.
  - *Battery cells:* 100 % of the demand in Europe in 2030 could be met.
- Drive extraction of critical raw materials within the EU.
- *Resilience requirements:* environmental and social compatibility criteria for support measures, as well as for importing goods.

Diversification

- Build and strengthen **transformative industry partnerships** with countries such as *Australia, Brazil, Canada, Chile, Colombia, Ghana and Namibia.*
- Strengthen value creation in partner countries and participation in supply chains, especially in countries of the Global South. Intensified cooperation in education and research projects.

Recycling

- Potential: 10 % of domestic lithium demand from recycling possible by 2035 (cobalt 25 %).
- Robust and timely national implementation of the EU Battery Regulation and the EU's Critical Raw Materials Act.

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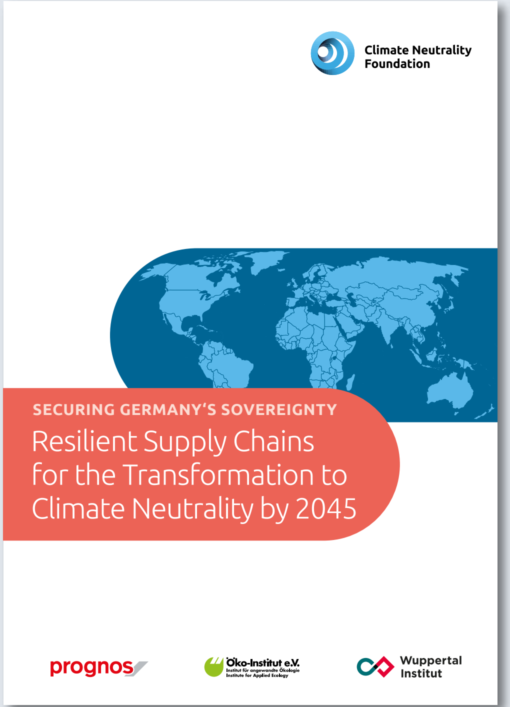

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COMMENTS:

1 Further information on electromobility in the **factsheet: Electromobility - Permanent magnets in electric motors**.

2 **Sodium-ion batteries** have a low energy density and thus a shorter range. The advantage is the lower cost: today already 40 % lower than lithium-ion batteries. The batteries are thus particularly suitable for urban traffic or for the markets in India, South America and Africa.

3 **Lithium demand scenarios**: Source: Sustainable Development Scenario (IEA 2022), expected demand around 400 kt in 2030. Eight to ten years are needed for mine development. The mines that are potentially available in 2030 would need to be developed today. The German Mineral Resources Agency DERA (2022) currently expects global mine production to range from 220 to 360 kt. Cf. www.deutsche-rohstoffagentur.de/ENRA/EN/Downloads/vortrag-lithium-schmidt-22.pdf?__blob=publicationFile&v=2

4 **Lithium**: Domestic extraction and recycling could cover 30 % of demand in Europe. Source: German Mineral Resources Agency (DERA 2022): Battery Raw Materials Outlook for Demand and Supply in Europe. 3rd Future Battery Forum, Nov 3 - 4, 2022.

5 **Battery cells**: Currently planning for 50 sites for potential battery production of 850 to 1,300 GWh per year. Projected demand 1,000 GWh per year.

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Factsheet

Resilient supply chains in electromobility
Permanent magnets[1]

Initial situation

- Almost 100 % of all electric passenger cars and electric trucks today use rare earth permanent magnets in their motors.[2]
- Alternative technologies only in development or with clear disadvantages.[3]
- Critical raw materials: **Light and heavy rare earths**.[4]
- High criticality in processing, components and production of permanent magnets

Challenge: Market concentrations along the supply chain

Top 3 countries: Market share in terms of production (2022)

	Raw material extraction	Raw material processing		Components	Goods
	Mixtures of rare earths[3]	Light rare earth oxides	Heavy rare earth oxides	Rare earth metals	Permanent magnets
1.	58 % China	87 % China	100 % China	91 % China	94 % China
2.	14 % USA	11 % Malaysia	-	7 % Japan	5 % Japan
3.	12 % Myanmar	1 % India	-	1 % Rest of the world	1 % Germany
Europe	-	1 %	-	1 %	1 %

- Rare earth extraction (total) in various countries.
- Extraction of heavy rare earths currently exclusively in southern China (very critical).[3]
- China has quasi-monopoly in beneficiation and magnet production.
  Current production of permanent magnets in Europe is carried out by only one company.

KEY Criticality: Very critical Medium critical Moderately critical

Solutions see also factsheet on cross-sector strategies and actions

Production ramp-up in Europe

- Establish domestic sales markets. 20 % European production along the entire supply chain possible by 2030:
  - *Raw material extraction:* Sweden, Norway
  - *Raw material processing:* Rare earth oxides: Norway, Estonia, France
  - *Components:* Rare earth metals: Estonia, Great Britain
  - *Goods:* Permanent magnets: Germany, Estonia
- Strict resilience requirements for funding measures.
- Support R&D to develop powerful magnet-less electric motors.

Diversification

- Build and strengthen **transformative industrial partnerships** with countries such as *Australia, Kenya, Colombia, Malawi, Namibia and the USA.*
- Strengthen value creation in partner countries and participation in supply chains, especially in countries of the Global South. Intensified cooperation in education and research projects.

Recycling

- Robust and timely national implementation of the reformed EU End-of-Life Vehicles Directive (EU ELV Directive) on the removal and dismantling of electric motors.
- Robust and timely national implementation of the EU's Critical Raw Materials Act with a view to material-specific end-of-life recycling rates as well as through recycled content.

Climate Neutrality Foundation

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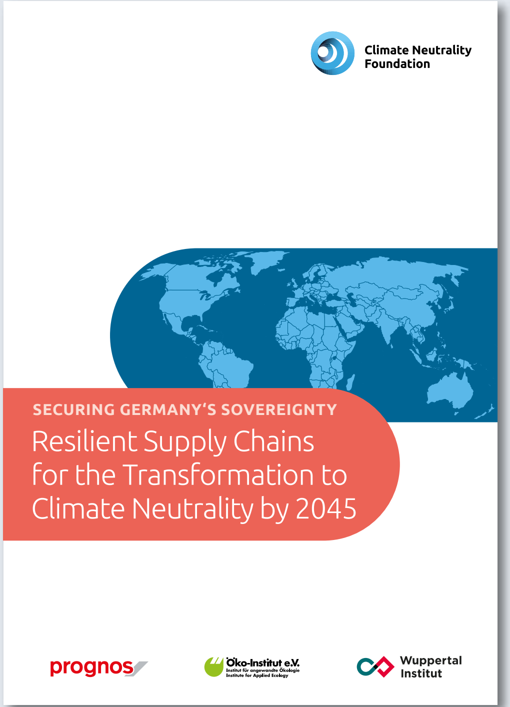

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Condensed Study

Long version

COMMENTS:

1 Permanent magnets in the electric motor. Further information on electromobility in the factsheet: **Electromobility – lithium-ion batteries.**

2 Permanent magnets are also installed in 95 % of offshore wind turbines (see **factsheet: Wind power**)

3 **Alternative permanent magnets:** At the latest after the great rare earth crisis in 2012, alternatives to permanent magnets made of rare earths were researched and further developed (iron nitride, ferrites, samarium cobalt). So far, no alternative is foreseeable that can provide similarly high energy densities as the neodymium-iron-boron magnets.

4 **Rareearths**: include 17 metals, 4 of which are relevant for permanent magnets: Neodymium and praseodymium (light rare earths) and dysprosium and terbium (heavy rare earths).

5 **Rareearths**: occur in mixtures. Composition differs depending on the mine. Statistical data here refers to the entire group of rare earths. No separate data is available for the relevant four metals. However, extraction of heavy rare earths currently only in southern China and Myanmar (very high criticality). Heavy rare earths are used to prevent the magnets from becoming permanently demagnetized at high temperatures.

6 Cf. *European Raw Materials Alliance (ERMA, 2021)*: Rare Earth Magnets and Motors: A European Call for Action.

7 Advantages of recycling: Rare earths account for 30 % by weight in magnets, only 1 % in natural deposits (complex separation of unwanted elements necessary here).

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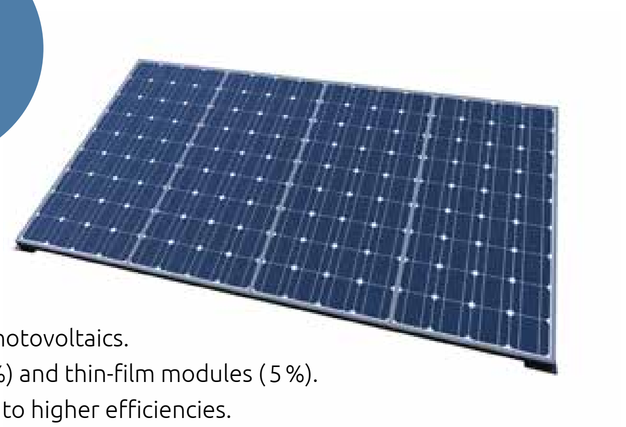
Factsheet

Climate Neutrality Foundation

Resilient supply chains for photovoltaic systems



Initial situation

- Photovoltaics is one of the cheapest CO_2-free power generation technologies. Around 65 % of the power plant capacity added worldwide today is based on photovoltaics.
- Two technologies: Modules made from **wafer-based silicon** (market share: 95 %) and thin-film modules (5 %).
- **Wafer-based cells** will continue to **dominate the market in the long term** due to higher efficiencies.

Challenge: Market concentrations along the supply chain

Top3 regions and Europe: Global market share in terms of production (2022)[1]

	Raw material processing	Subcomponents		Components	
	Polysilicon	Ingots, wafers	Solar cell, *Solar glass*[2]	PV module	Inverters
1.	79 % China	97 % China	85 % China	75 % China	73 % China
2.	**8 %** Germany	**2.5 %** Asia-Pacific	**12 %** Asia-Pacific	**15 %** Asia-Pacific	**16 %** Europe
3.	**6 %** Asia-Pacific	**0.5 %** Europe	**1.2 %** India	**3.1 %** India	**12 %** Rest of the world
Europe	**8 %** (21 GW)	**0.5 %** (<2 GW)	**0.6 %** (>2 GW, *3-4 GW*)	**2.8 %** (<10 GW)	**16 %**

Dominance of China along entire supply chain. Strong expansion in China continues.

KEY Criticality: Very critical, Medium critical, Moderately critical

Solutions

see also factsheet on cross-sector strategies and actions

Production ramp-up in Europe

- Build domestic sales markets through resilience requirements and CAPEX/OPEX extraction: 40 % domestic production possible by 2030, many projects in planning, but realization uncertain. Correct political framework in Germany imperative:
- Include tender segment in current EEG amendment for PV modules with domestic value-added content.
- In this tender segment, incentives for European manufacturing should be provided through bonuses.
- Reduced-interest loans from KfW for resilience installations in the small-axis segment. Resilience bonuses on electricity produced should also be considered here.
- Establish and institutionally embed resilience monitoring across the supply chain.

Recycling

- Design requirements for components, export restrictions on secondary raw materials and precursors, and robust implementation of the EU's Critical Raw Materials Act.
- Recycling of polysilicon and solar glass are already in the development phase. Further R&D funding programs to recycle individual components and increase the efficiency of recycled cells.

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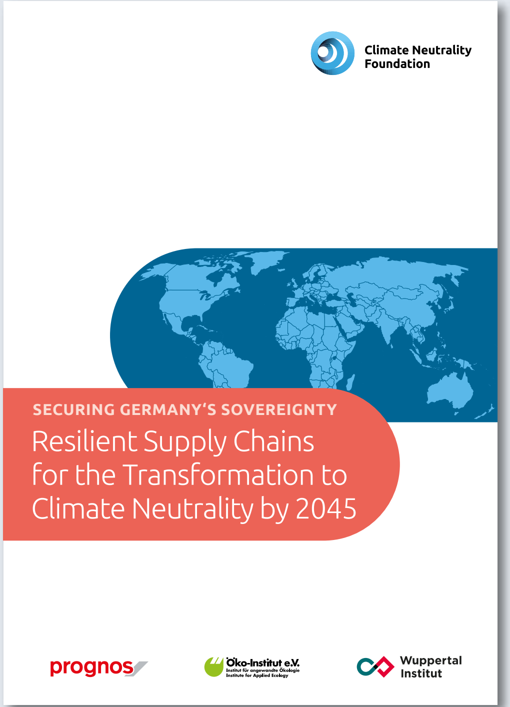

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Condensed Study

Long version

COMMENTS:

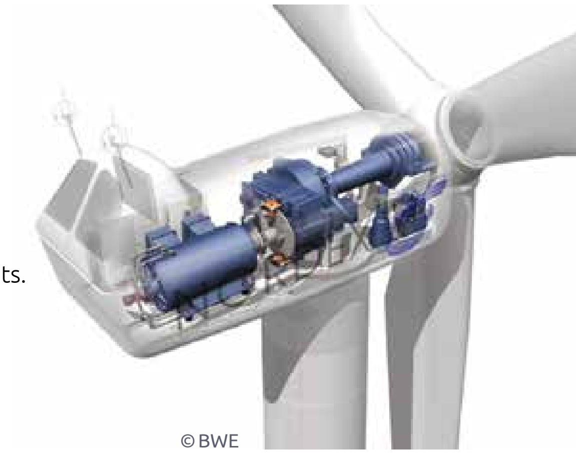
1 Sources: IEA, Statista. Raw material extraction of quartz sand is not critical and has therefore not been listed.

2 **Solar glass:** No comprehensive data available on this. Market shares expected to be similar to other components due to high transport weight. Germany's share of the world market below 0.5 %.

Factsheet

Climate Neutrality Foundation

Resilient supply chains for wind turbines
Permanent magnets



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Initial situation

- Wind turbines are complex systems consisting of thousands of individual components.
- **Very critical: High-efficiency permanent magnets in the generator.**[1]
- Almost **100 % of offshore wind turbines** today have highly efficient permanent magnets made of rare earths in the generator. Share for **onshore wind at 20 %**.
- These contain **light and heavy rare earths.**[2]
- Previously strong domestic manufacturing industry, but declining competitiveness.

Challenges: Market concentrations along the supply chain

Top 3 countries: Global market share in terms of production (2022)

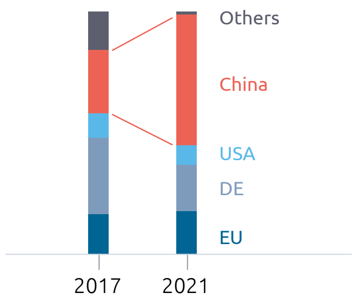
	Raw material extraction	Raw material processing		Components	Goods
	Mixtures of rare earths[3]	Light rare earth oxides	Heavy rare earth oxides	Rare earth metals	Permanent magnets
1.	58 % China	87 % China	100 % China	91 % China	94 % China
2.	14 % USA	11 % Malasia	–	7 % Japan	5 % Japan
3.	12 % Myanmar	1 % India	-	1 % Rest of the world	1 % Germany

- Rare earth extraction (total) in various countries.
- Extraction of heavy rare earths currently exclusively in southern China.[3]
- China has quasi-monopoly in beneficiation and magnet production.

KEY Criticality: Very critical, Medium critical, Moderately critical

Market concentrations in the construction of Wind Turbines

Market share by country (2022)



China's market share in the construction of wind turbines has increased significantly.

Solutions see also factsheet on cross-sector strategies and actions

Production ramp-up in Europe

- Establish domestic sales markets. 20 % European production along the entire supply chain possible by 2030:
  - *Raw material extraction:* Sweden, Norway
  - *Raw material processing:* Rare earth oxides: Norway, Estonia, France
  - *Components:* Rare earth metals: Estonia, Great Britain
  - *Goods:* Permanent magnets: Germany, Estonia
- Strict resilience requirements for funding measures.
- Support R&D to develop powerful magnet-less electric motors.

Diversification

- Build and strengthen **transformative industrial partnerships** with countries such as *Australia, Kenya, Colombia, Malawi, Namibia and the USA.*
- Strengthening value creation in partner countries and participation in supply chains, especially in countries of the Global South. Intensified cooperation in educational and research projects.

Recycling

- Robust and timely national implementation of the reformed EU End-of-Life Vehicles Directive (EU ELV Directive) on the removal and dismantling of electric motors.
- Robust and timely national implementation of the EU's Critical Raw Materials Act with a view to material-specific end-of-life recycling rates as well as through recycled content.

Maintain production of wind turbines in Europe

- Ensure continued production, safeguard capacity expansions.
- Resilient content requirements

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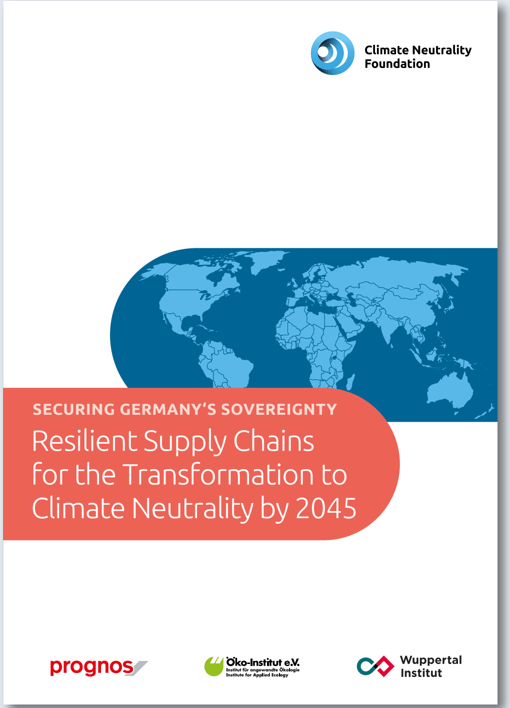

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COMMENTS:

1 Permanent magnets are also used in 95 % of electric passenger cars and 100 % of electric trucks (see **factsheet on electromobility**).

2 **Rareearths**: include 17 metals, 4 of which are relevant for permanent magnets: Neodymium and praseodymium (light rare earths) and dysprosium and terbium (heavy rare earths).

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5 Benefits of recycling: Rare earths account for 30 % by weight in magnets, only 1 % in natural deposits (complex separation of unwanted elements necessary here).

Factsheet

Resilient supply chains for Green Steel
DRI plants

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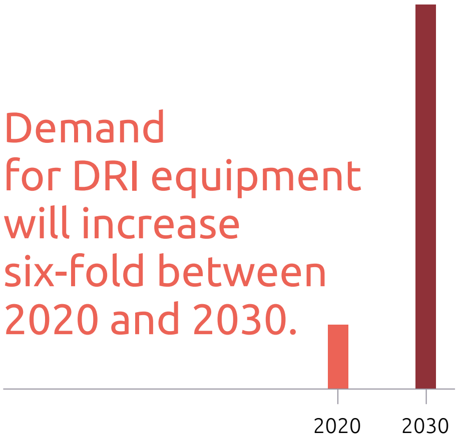
Initial situation

- To produce CO_2-free, green primary steel, iron ore pellets are reduced in **direct reduction plants (DRI plants)** with the help of hydrogen and then converted into crude steel in converters or electric arc furnaces.
- Deadline for **converting blast furnaces to DRI plants** and electric melting units: for 40 % of the plants by 2029 and for the remaining 60 % by 2035. Replacement time depends on the end of the furnace journey.
- In Germany, capacities of 15 million tons per year are planned **by 2030**. This corresponds to **six large-scale plants** in the world-scale format.

Challenge: Strongly increasing demand for DRI plants with bottlenecks in plant construction

- Criticality due to the very rapid ramp-up in demand through 2030.
- DRI technology has been in use since the 1970s — using natural gas as a reducing agent. A new feature is the use of hydrogen instead of natural gas.
- There are only two technology providers in the world that can build these plants: Midrex and Tenova. Tenova builds the plants itself, Midrex commissions licensees with plant construction.
- Estimated potential new construction capacity per year: 8 to 10 tons per year.
- 100 % use of hydrogen has so far only been proven in practice by Tenova.

Demand for DRI equipment will increase six-fold between 2020 and 2030.



Status and potential

- Replacement of all German blast furnaces by 2035 — own DRI plants as a hedge against supply bottlenecks and to increase resilience.
- Today, the only DRI facility located in Europe is operated in Hamburg. Two projects are currently being planned in Sweden.

Solutions

see also factsheet on cross-sector strategies and actions

Production ramp-up in Europe

- *Securing investments* through *financial extraction* in addition to theCarbon Boundary Adjustment Scheme (CBAM) and support for the ramp-up of a lead market for green steel.
- Import of green direct reduced iron (or in briquetted form as HBI – hot briquetted iron) from future HBI hubs, e.g. in the Middle East and Australia.
- Credit protection. Support to establish supplier relationships, firm purchase agreements for green DRI.
- Building and strengthening transformative industry partnerships. Strengthen value creation in partner countries and participation in supply chains, especially in countries of the Global South.
- Intensified cooperation in education and research projects.

Diversification

- Credit protection
- Support to establish supplier relationships, firm purchase agreements for green DRI.
- Help build liquid world markets for DRI trade.

Recycling

- Share of recycled steel today at around 40 percent. Expansion to 60 percent by 2045 is possible.
- Better segregation of waste and pre-sorting of scrap to prevent down-cycling.

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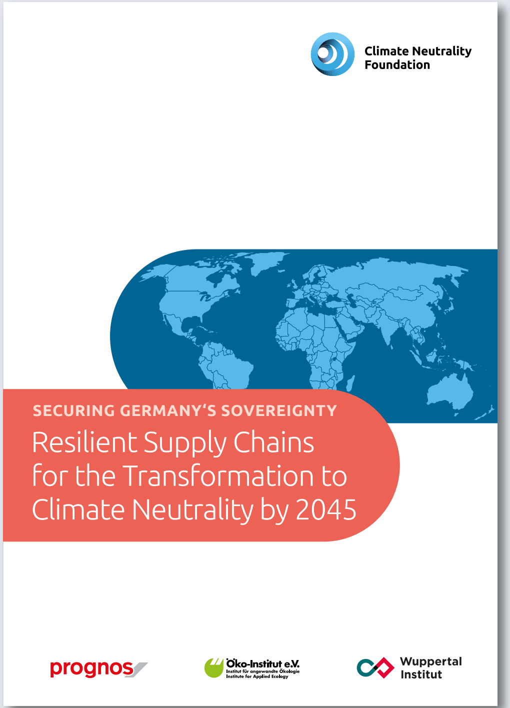

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Climate Neutrality Foundation

Resilient supply chains for Green Hydrogen Electrolyzers

© HTEC SYSTEMS GmbH

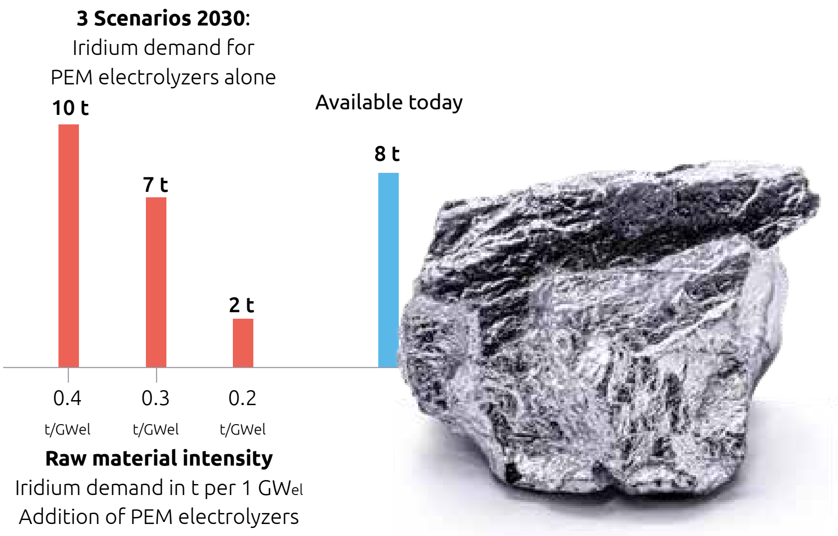
Initial situation

- Two processes for the production of green hydrogen are ready for the market today: Alkaline electrolysis (AEL) and PEM electrolysis.
- AEL (market share: 70 %), comparatively inflexible and lower efficiency, but no critical raw materials or components.
- **PEM electrolyzers** (market share): **high flexibility, very efficient**, market share will increase strongly. **Critical raw materials: Iridium**
- Technologies in the development stage: High temperature electrolyzer, AEM electrolyzer.

Challenges: Demand for iridium is increasing

Global demand in 2030 depending on raw material intensity (Assumption: addition of 24 GW of electrolyzer capacity worldwide)

- IEA 2022: 2030 could see 60 GW_{el} of electrolyzers getting built.
- Assuming 40 % of which are PEM: **24 GW_{el} PEM electrolyzers**
- Iridium required for this **depends on raw material intensity**.



Iridium extraction not expected to expand

- Very **rare metal**.
- Only 8 tons produced worldwide
- 85 % of entire production is in South Africa
- Third most expensive metal in the world
- Extraction is completely dependent on platinum extraction (minor metal)
- 40 % of platinum is used for catalytic converters for cars: **Declining demand for primary platinum**: due to electromobility and large recycling potential from old car catalytic converters.
- **Platinum and thus iridium extraction will** probably **not be expanded** – could even be reduced.

Solutions see also factsheet on cross-sector strategies and actions

Reduction in material intensity

- Reduction of raw material intensity by 75 % from 0.4 t/GW_{el} today to 0.1 t/ GWel possible by 2040.
- R&D to reduce the thickness of the material layers – e.g. through innovative automated processes (vapor deposition of nanolayers and combination with less expensive substrate materials).
- Develop domestic sales markets and infrastructure for green hydrogen (stable regulatory framework, reliable funding instruments, accelerated planning and approval procedures.)

Alternative technologies

- Use of iridium-free alkaline electrolyzers (AEL) in conjunction with batteries to compensate for lower flexibility, taking into account higher power consumption by batteries and lower efficiency of AEL.

Recycling

- Establish long-term recycling strategies, support programs for R&D and build infra-structure for iridium recycling.
- Consider recyclability in the development of electrolysis plants.

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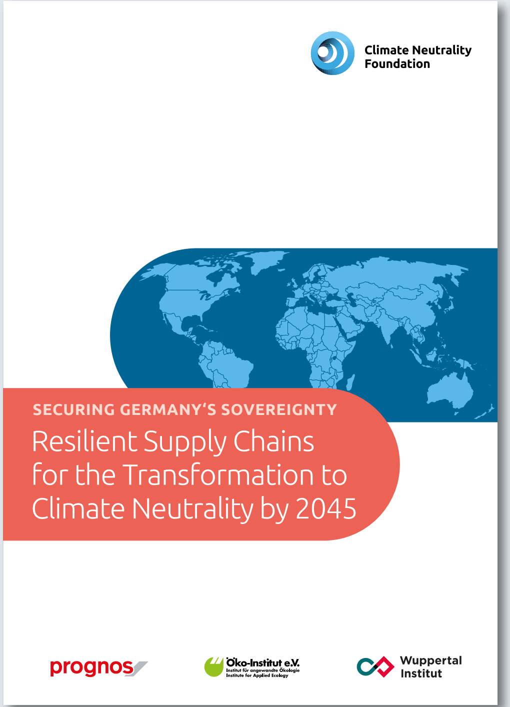

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