TUM Mission Network
Circular Economy
CirculaTUM

Circular Recovery of Critical Raw Materials for the Energy Transition

Alisa Dachi & Tim Büthe

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Motivation

Climate change is threatening the foundations of life on earth. It urgently requires transitioning from carbon-based to sustainable sources of energy. The energy transition, however, presents us with new challenges: Ensuring a stable supply of energy from naturally fluctuating green (solar, wind, etc.) and blue (rivers, ocean currents, etc.) sources, requires storing and transporting unprecedented amounts of energy.

Yet, all current technologies for storing energy – and many technologies for generating energy from sustainable sources – require the use of particular metals and other specialized materials. These "critical raw materials" for the energy transition are non-energy raw materials for which there are few or no substitutes. Yet, they are necessary for building or operating key components of the energy transition, such as wind turbines, solar panels and electric vehicle batteries (see also Figure 1).

As a consequence, the global demand for these critical raw materials (CRMs) is expected to grow explosively, far beyond the amounts that can be readily extracted from known sites. Their extraction lacks sustainability in other ways, too: It has substantial negative environmental and health externalities – and for many CRMs is possible only from source countries that are politically unstable and prone to (accidental and deliberate) supply chain interruptions. And EU countries are particularly strongly at risk of such interruptions, since they are highly dependent on importing critical raw materials – often from a limited number of countries: China provides 98% of the rare earths, Turkey 98% of the borate, and South Africa 71% of the platinum used in the EU.

Addressing climate change through the energy transition thus also requires shifting to a circular economy for critical raw materials. Circular recovery of CRMs with (more) local repair, recovery and re-use allows for their extended availability and eases our dependency on global supply chains that are susceptible to massive political risks.

For most critical raw materials, however, greater circular recovery will not arise without public policies that create incentives or legal or regulatory mandates. This project examines how and why democratic signatories of the Paris Agreement in Europe and the Americas differ in their public policies for circular recovery of critical raw materials.

SRMs	Li-ion batteries	Wind turbines	Solar PV	Electrolysers	Fuel cells	Traction motors	H2-DRI	Heat pumps	Data transmission networks	Data storage and servers	Smartphones, tablets, laptops
Aluminium/ bauxite	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Bismuth									✓	✓	✓
Boron		✓	✓	✓	✓	✓		✓	✓	✓	✓
Cobalt	✓			✓	✓				✓		✓
Copper	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Gallium			✓						✓	✓	✓
Germanium			✓						✓	✓	✓
Lithium	✓								✓		✓
Magnesium				✓						✓	✓
Manganese	✓	✓		✓	✓		✓	✓	✓	✓	✓
Natural graphite	✓			✓	✓		✓		✓		✓
Nickel	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
PGM				✓	✓				✓	✓	✓
HREEs		✓		✓	✓	✓		✓	✓	✓	✓
LREEs		✓		✓	✓	✓		✓	✓	✓	✓
Silicon metal		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Titanium metal											✓
Tungsten				✓							✓

Figure 1
Select Critical Raw Materials Required for the Production/Operation of Various Strategic Goods
Source: Righetti & Rizos, *Reducing Supply Risks* (CEPS 2024:4)

Project Partners (Internal)

Chair for International Relations (Prof. Dr. Tim Büthe)
Munich School of Politics & Public Policy @ TUM-SOT &
TUM School of Management
Technical University of Munich
ir-chair@hfp.tum.de

Research Question

We ask, first, descriptively: To what extent and how does the policy support for CRM circular recovery vary across advanced democracies that have in principle committed to the energy transition and a pro-sustainability agenda? Second, we ask analytically: What explains the variation in CRM circular recovery-boosting policies?

Approach

To address the first question, we map the cross-national variation in laws, regulations, and public policies governing the circular recovery of critical raw materials, building a dataset that captures multiple dimensions of CRM circular recovery policies of 46 countries, focused on the collection of e-waste and end-of-product-life photovoltaics and batteries, as well as the recycling of those products for circular recovery of the critical raw materials used in those products.

To answer the second question, we examine several possible drivers of those policies theoretically, then conduct what to the best of our knowledge is the first broadly cross-national statistical analysis of these policy differences to advance our understanding of how the politics of the circular economy and the political geography of critical materials interact.

Preliminary Findings

We show that almost all countries in Europe and the Americas have some CRM circular recovery policies. At the same time, even across the OECD, and certainly across the full dataset, governments differ greatly in the extent and the specifics of their circular economy initiatives for energy transition CRMs.

Statistical findings are very preliminary, given that we are still building the dataset, but with this caveat we find: CRM circular recovery policies are still something of a luxury product: countries with higher GDP per capita tend to have more ambitious policies. Countries with a proven commitment to the energy transition also show a greater commitment to CRM recovery through more ambitious policies – as do countries with higher state capacity, suggesting that such policies are not just declamatory politics. Finally, EU institutionalized commitment matters: member states have more ambitious CRM recovery policies, even beyond what is covered by EU mandates.