EU Critical Raw Materials

Constanze VEEH

European Commission. Directorate-General for Internal Market, Industry, Entrepreneurship and SME's (DG GROW).

Unit I1 - «Energy intensive industries, Raw Materials and Hydrogen»

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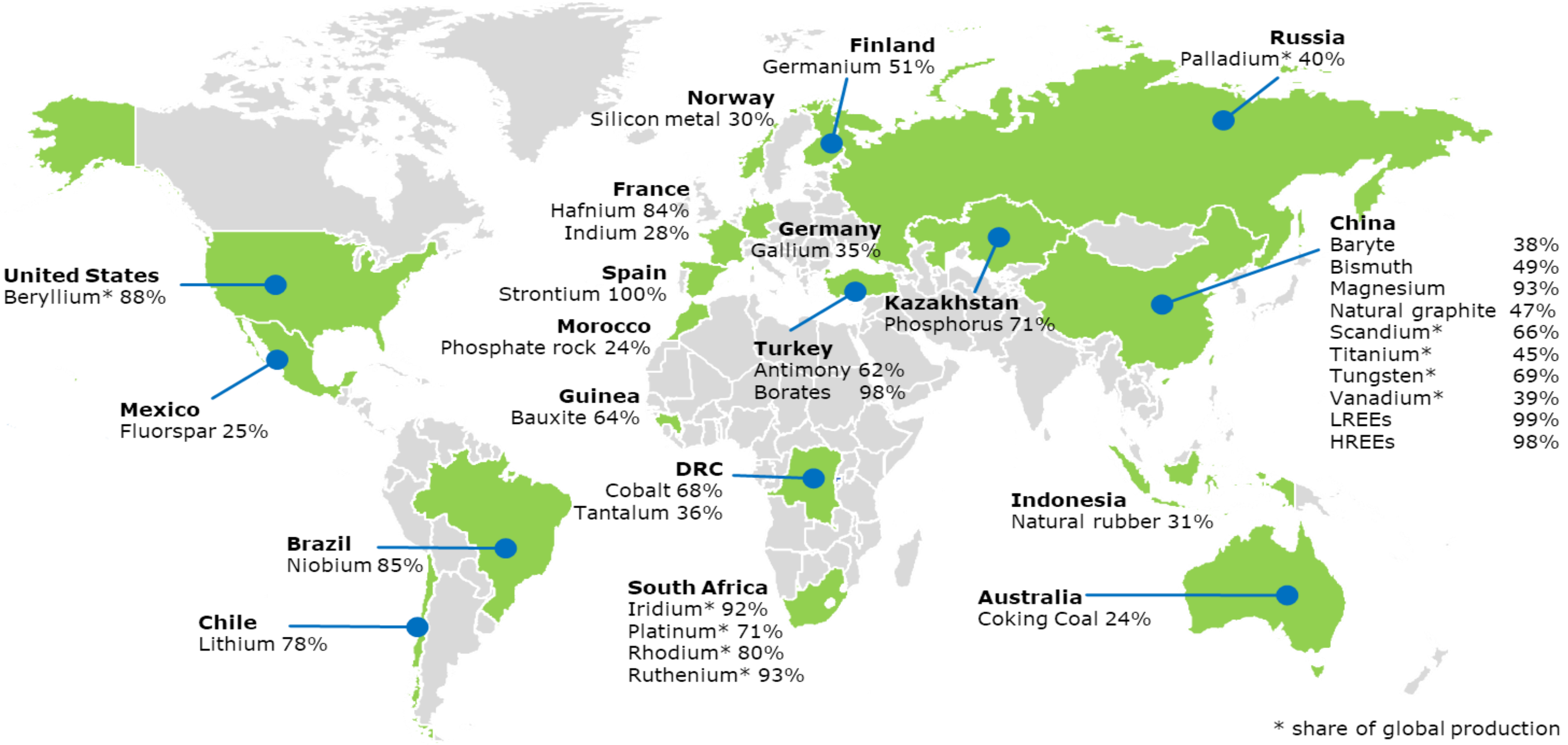
Raw Materials

EU CRM List 2020

2020 Critical Raw Materials		
Antimony	Germanium	Platinum Group Metals
Baryte	Hafnium	Phosphate rock
Bauxite	Heavy Rare Earth Elements	Phosphorus
Beryllium	Light Rare Earth Elements	Scandium
Bismuth	Indium	Silicon metal
Borate	Lithium	Strontium
Cobalt	Magnesium	Tantalum
Coking Coal	Natural Graphite	Titanium
Fluorspar	Natural Rubber	Tungsten
Gallium	Niobium	Vanadium

Structural dependencies in the EU supply of CRMs



Source: "European Commission, Study on the EU’s list of Critical Raw Materials – Final Report (2020)"

Materials assessed

Industrial and construction minerals	Aggregates, Baryte, Bentonite, Borates, Diatomite, Feldspar, Fluorspar, Gypsum, Kaolin clay, Limestone, Magnesite, Natural graphite, Perlite, Phosphate rock, Phosphorus, Potash, Silica sand, Sulphur, Talc
Iron and ferro-alloy metals	Chromium, Cobalt, Iron, Manganese, Molybdenum, Nickel, Niobium, Tantalum, Titanium, Tungsten, Vanadium
Precious metals	Gold, Silver and Platinum Group Metals (Iridium, Palladium, Platinum, Rhodium, Ruthenium)
Rare earths	Cerium, Dysprosium, Erbium, Europium, Gadolinium, Holmium, Lanthanum, Lutetium, Neodymium, Praseodymium, Samarium, Terbium, Thulium, Ytterbium, Yttrium + Scandium
Other non-ferrous metals	Aluminium, Antimony, Arsenic, Beryllium, Bismuth, Cadmium, Copper, Gallium, Germanium, Hafnium, Indium, Lead, Lithium, Magnesium, Rhenium, Selenium, Silicon metal, Strontium, Tellurium, Tin, Zinc, Zirconium
Bio and other materials	Natural cork, Natural Rubber, Natural Teak wood, Sapele wood, Coking coal, Hydrogen and Helium; Roundwood, Neon, Krypton, Xenon

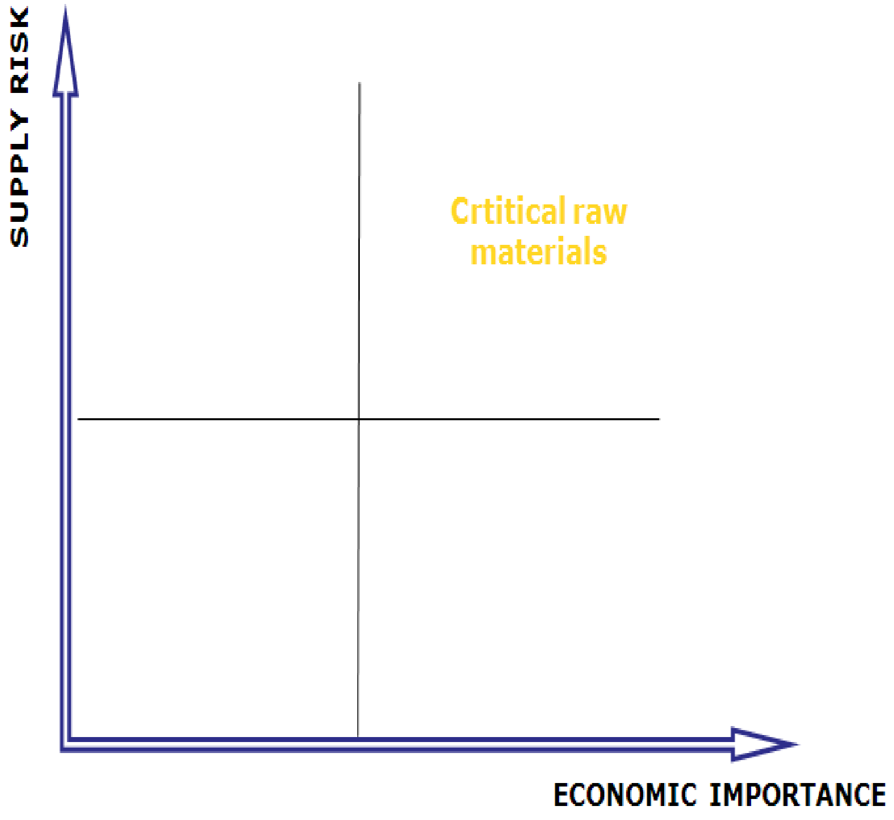
EU CRM methodology

Economic importance

- Importance of a raw material per economic sector & importance of the sector in the EU economy (value added)
- Substitution (technical and cost performance)

Supply risk

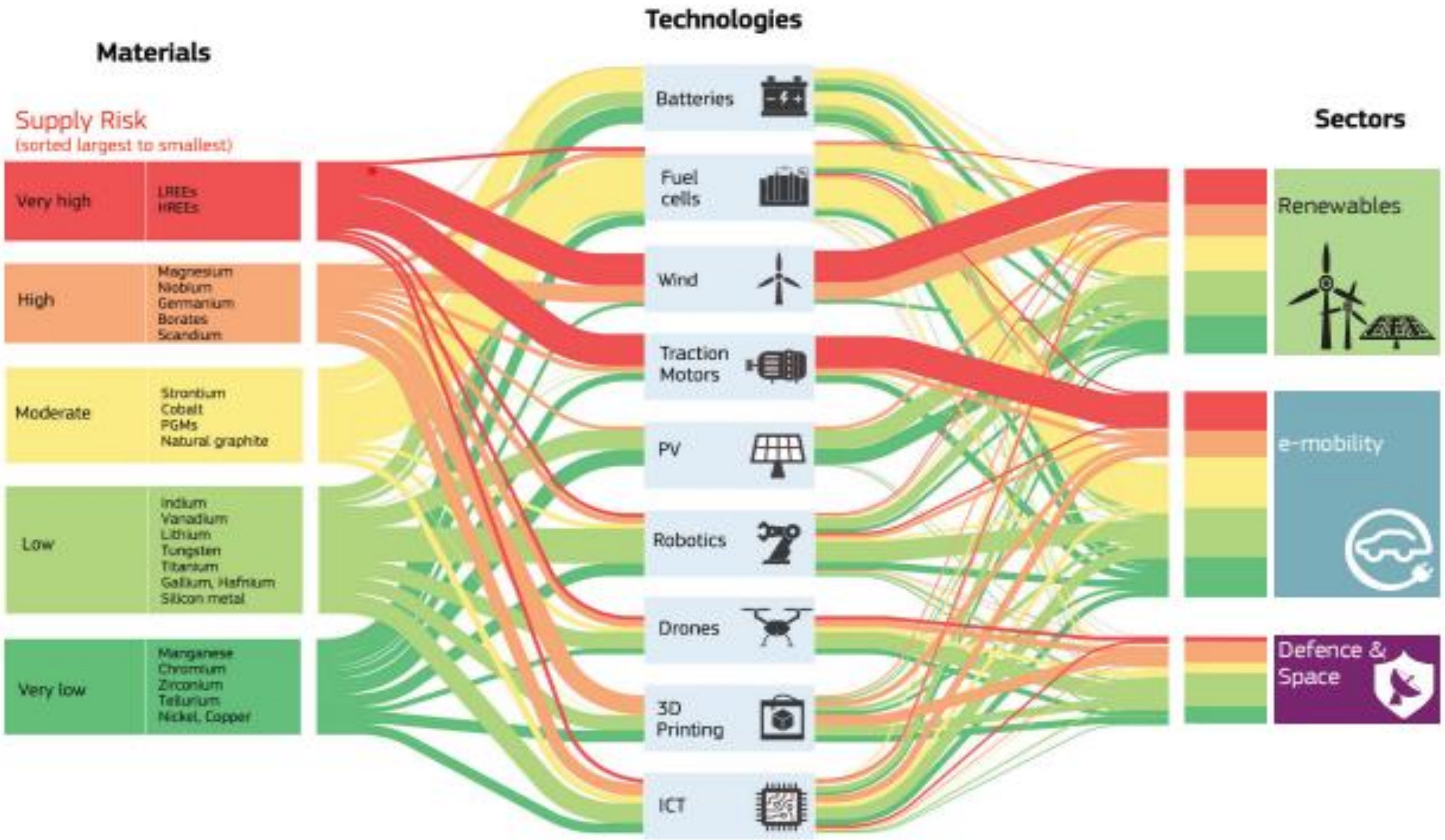
Global supply and EU sourcing (ores/refined materials)
Market concentration (HHI)
Governance performance (WGI)
Import reliance
Trade agreements and restrictions
End-of-Life Recycling Input Rate
Substitution (production, criticality, co/by-production)



European Commission

https://op.europa.eu/en/publication-detail/-/publication/2d43b7e2-66ac-11e7-b2f2-01aa75ed71a1

2020 Foresight study for strategic techs and sectors



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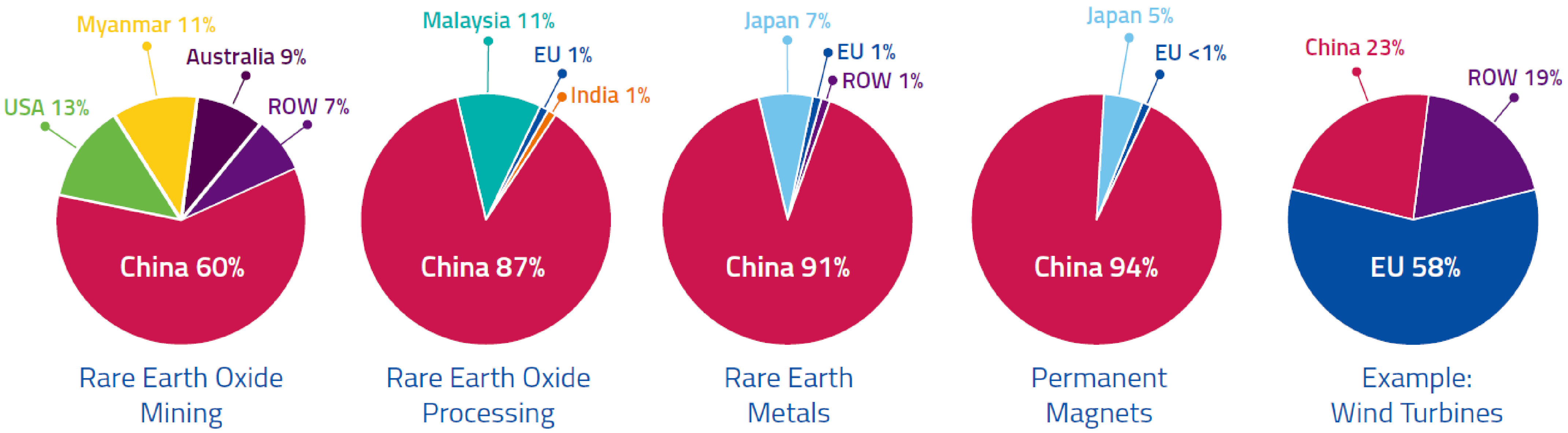
EU dependence ranges across the value chain

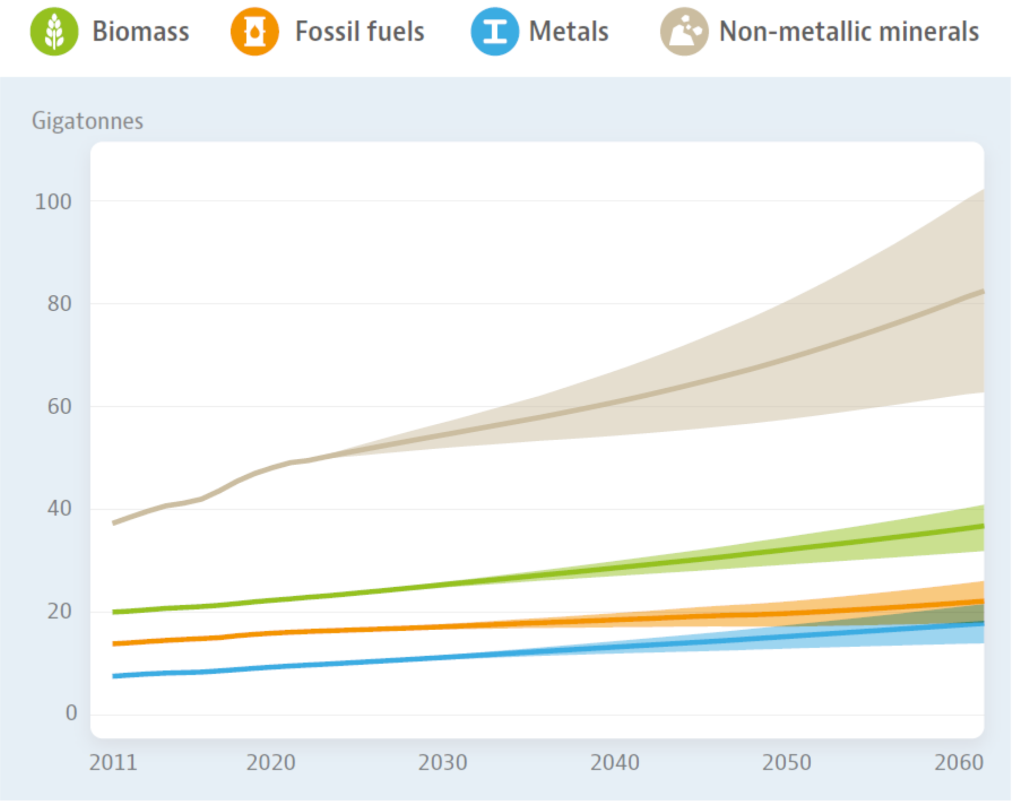


Chinese dominance along the Rare-Earths supply chain

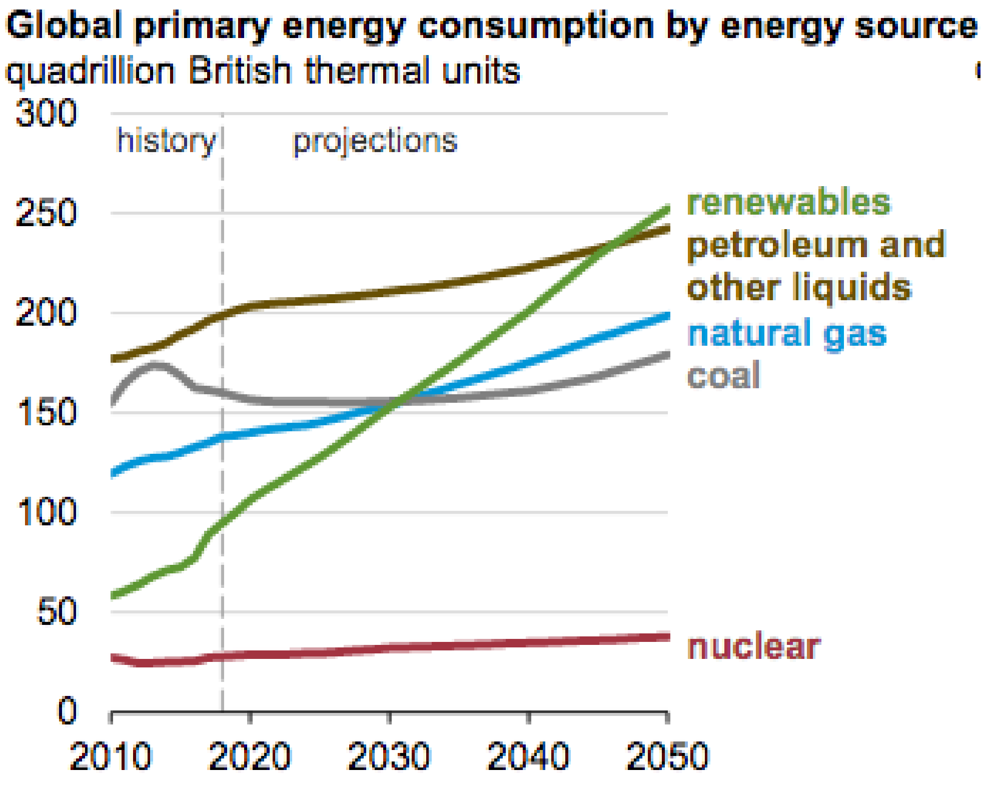
Source: ERMA, 2021 - Rare Earth Magnets and Motors: A European Call for Action

Global demand set to exceed global supply

Figure 6. **Growth in materials use depends on population and economic growth assumptions**



Source: OECD, Global Material Resources Outlook to 2060, 2019.



Source: Energy Information Administration, International Energy Outlook 2019.

Others are taking actions

Expanding its monopoly:
- controls 70% of Congo's cobalt;
- acquires stakes in AUS or USA companies

Developing refining capacity:
- controls 73% of global lithium cell manufacturing

Increasing its consumption:
- consumes 50-60% of world's metals
- plans additional 750 GW of wind and solar PV installed capacity by 2025

Restraining supply:
- All rare earths covered by 2022 export control list;
- 65 000 tonnes of rare earths exported in 2005 35 500 tonnes in 2020;

JOGMEC:
- monitoring
- stockpiling
- investing (Lynas rare earths refinery)
- supply contracts

Economic Security Promotion Act
- Ensuring Stable Supply of critical items

National Defence Stockpile

Defence Production Act
- 120 million USD to build rare earths refinery by Lynas

Section 232 investigations
- neodymium magnets,
- vanadium, titanium

Inflation Reduction Act

Critical minerals-related funding
- (Infrastructure Investment and Jobs Act)

Action Plan on Critical Raw Materials

1. European Raw Materials Alliance
2. Develop sustainable financing criteria for mining
3. Research and innovation on waste processing, advanced materials and substitution
4. Map the potential supply of secondary CRM from EU stocks and wastes
5. Identify priority mining and processing projects for critical raw materials in the EU
6. Develop expertise and skills
7. Deploy Earth observation programmes for exploration, operation and post-closure environmental management
8. Develop research and innovation projects on exploitation and processing of CRMs
9. Develop strategic international partnerships to secure CRMs supply
10. Promote responsible mining practices for CRMs

Horizon Europe Call – RESILIENT VALUE CHAINS 2023

Raw Materials for EU open strategic autonomy and successful transition to a climate-neutral and circular economy ~ 120MEUR for 2023

- Innovative technologies for sustainable and decarbonised **extraction** (RIA) (Lump sum)
- Technologies for **processing and refining** of critical raw materials (IA)
- **Recycling** technologies for critical raw materials from **EoL products** (IA)
- **Earth Observation** platform, products and services for raw materials (IA) (Lump sum)
- **Expert network** on Critical raw materials (CSA) (Lump sum)
- **Recyclability** and resource efficiency of **Rare Earth based magnets** (IA)

➢ Call HORIZON-CL4-2023-RESILIENCE-01 Deadline: 20 Apr 2023

➢ Call HORIZON-CL4-2023-RESILIENCE-01-TWO-STAGE Deadline: 7 Mar 2023 (1st stage), 5 Oct 2023 (2nd stage)

Critical Raw Materials Act

Key objective: secure EU supply of CRM

Signalling priority needs, incl. targeted RM

Strengthening monitoring and risk mitigation, incl. strategic stocks

Governance

Strengthening EU value chain, incl. strategic projects

Sustainability, incl. circularity

Pursuing supply diversification, research and innovation, skills

Time for action – the political mandate

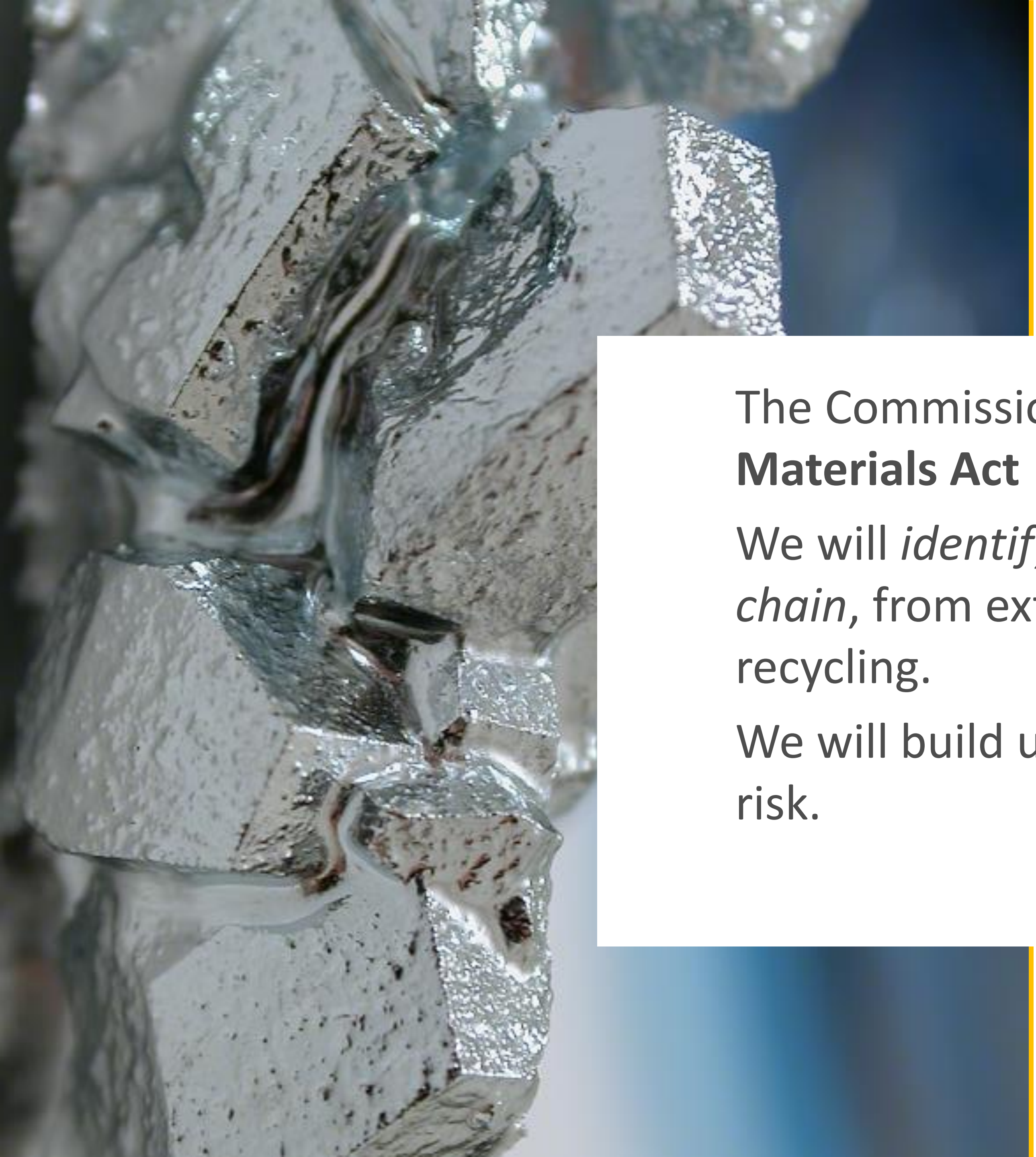
Heads of State/Government Versailles Declaration in March

Reducing our strategic dependencies - secure EU supply of Critical raw materials by means of

- strategic partnerships,
- exploring strategic stockpiling and
- promoting a circular economy and resource efficiency;

REPowerEU Plan and Conference on the Future of Europe in May/June

- Intensify the work on the supply of critical raw materials and prepare a legislative proposal.



Time for Action – CRM Act

“

The Commission will table a proposal on **Critical Raw Materials Act**

We will *identify strategic projects* all *along the supply chain*, from extraction to refining, from processing to recycling.

We will build up *strategic reserves* where supply is at risk.

Commission President’s State of the Union Speech on 14/9/2022

European Commission

Results of the public consultation

Call for evidence and open public consultation were open for 8 weeks (30/09 to 25/11)

Over 570 answers in total (310 on the call for evidence, 263 on the public consultation)

Main messages from stakeholders:

- Overall support for the initiative and agreement that the EU can do more at every stage of the **value chain** to boost its capacity, both for **primary and secondary** CRMs
- General shared understanding on the impediments to the EU CRM value chain development, such as length of **permitting** affecting projects' ability to find **financing** sources.
- A tailored response is key: problems and solutions are dependent on the material, on the value chain stage or on the Member State/local authorities. However, the overall policy responses find support, regarding **monitoring, permitting, strategic stocks, sustainability of raw materials, recycling**, etc.

CRM Act package

- **Communication on Critical Raw Materials**
- **Proposal for an Act on Critical Raw Materials and Impact Assessment**
- **Supporting documents**
  - Outcome of Technical assessment by DG GROW with external experts, and AhWG on Criticality, and validated at the Expert Workshops by SCRREEN2
  - Factsheets by DG GROW with SCRREEN2, and EC AhWG on Criticality. Inputs from the Expert Workshops by SCRREEN2.
  - Foresight study by DG GROW with DG JRC and SCRREEN2.

Later this year: Materials System Analysis on selected RM
by DG GROW and external contractor.

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Foresight on CRMs in technologies and sectors

Technologies in 2020
Drones
Robotics
Wind
Traction motors
Batteries
Fuel cells
Solar PV
3D printing
ICT

Additional Technologies
Electrolysers
Smartphones/tablets/laptops
Data storage & servers
Heat pumps
Data transmission networks
Rocket launchers & satellites
H_2-Direct Reduction of Iron

European Commission

Raw Materials Week

13-17 November 2023

Save the date!

10th Annual High Level Conference of the EIP on Raw Materials

6th EU Critical raw materials event

EU raw materials Partnership events

Future trends Innovation and skills for raw materials

UN Resources Management in Europe

…

https://www.eurawmaterialsweek.eu

European Commission

Nyrstar

Resources for a changing world

IRTC Lille - February 17th 2023
Criticality raw materials and energy transition

Xavier Constant
General Manager Nyrstar Auby, France

nyrstar

Agenda

- About Nyrstar
- The markets Nyrstar serves and the value chains we feed
- EU's critical minerals and metals autonomy
- What is needed to support Europe's strategic autonomy
- What Nyrstar can do to help secure output and how to get there

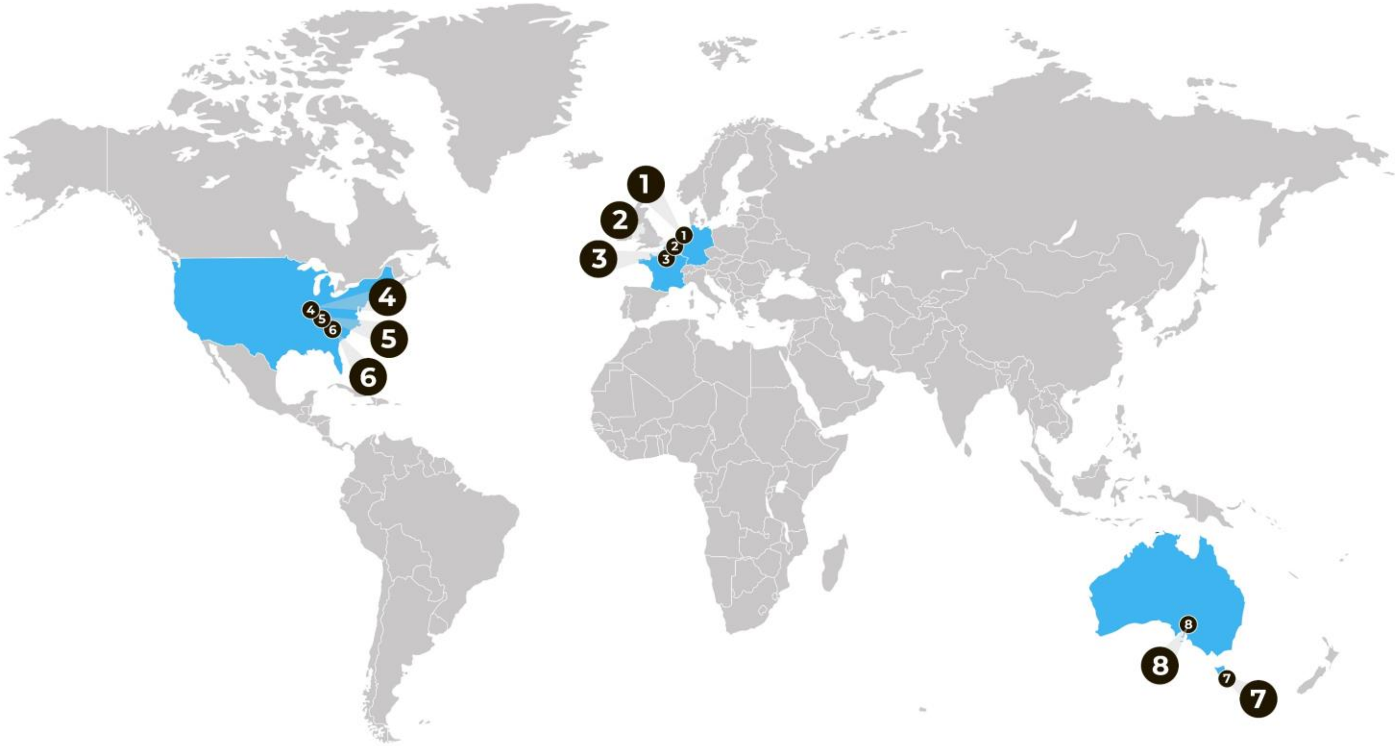
Co-funded by the European Union

About Nyrstar – global footprint

Nyrstar is an international producer of critical minerals and metals essential for a low carbon future.

With a market leading position in zinc and lead, Nyrstar has mining, smelting and other operations located in Europe, the U.S. and Australia and employs approximately 4,000 people. Its Corporate Office is based in Budel-Dorplein, the Netherlands.

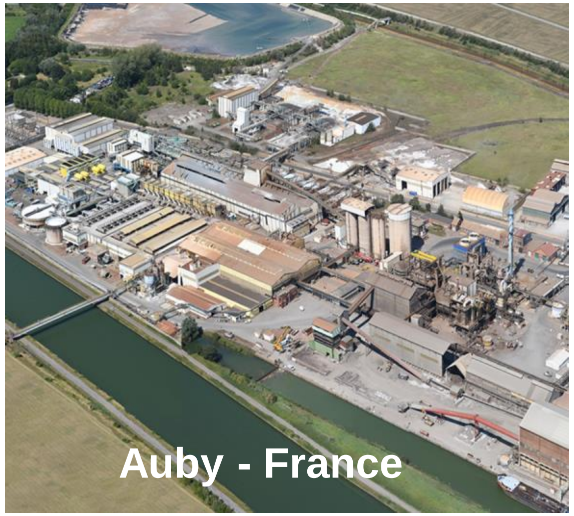
The company's operations are located close to key customers and major transport hubs to facilitate reliable and efficient delivery of raw materials and distribution of finished products.



MINING SMELTING HEADQUARTERS

1. **BUDEL** Smelter & Corporate Office, *The Netherlands*
2. **BALEN / PELT** Smelter & Oxide Washing Plant, *Belgium*
3. **AUBY** Smelter, *France*
4. **CLARKSVILLE** Smelter, *USA*
5. **EAST TENNESSEE** Mine Comlex, *USA*
6. **MID TENNESSEE** Mine Complex, *USA*
7. **HOBART** Smelter, *Australia*
8. **PORT PIRIE** Multi-metals Processing Facility, *Australia*

About Nyrstar – European footprint



About Nyrstar – committed to the green transition

- The zinc smelters Nyrstar operates in Europe are important links in the EU supply chain and are among the largest, most progressive, flexible and energy-efficient operations.
- Production process fully electrified.
- All Nyrstar European smelters are sourced with low-carbon energy and use up to 100% renewable energy.
- Generation of renewable energy on many of our EU sites.
- Ready for investing in the next step: Nyrstar's virtual battery… we'll come back to this later.

The markets we serve and the value chains we feed

Nyrstar boasts a rich history of metal processing. Our international presence and knowledge of the market combined with solid smelting and process technology experience enables us to mine, source, manufacture and sell the high quality products for which our customers worldwide know us. These include:

Zinc & zinc alloys

- Continuous galvanising zinc alloys
- Batch galvanising zinc alloys
- Zinc diecasting alloys
- Super Special High Grade (SHG) zinc

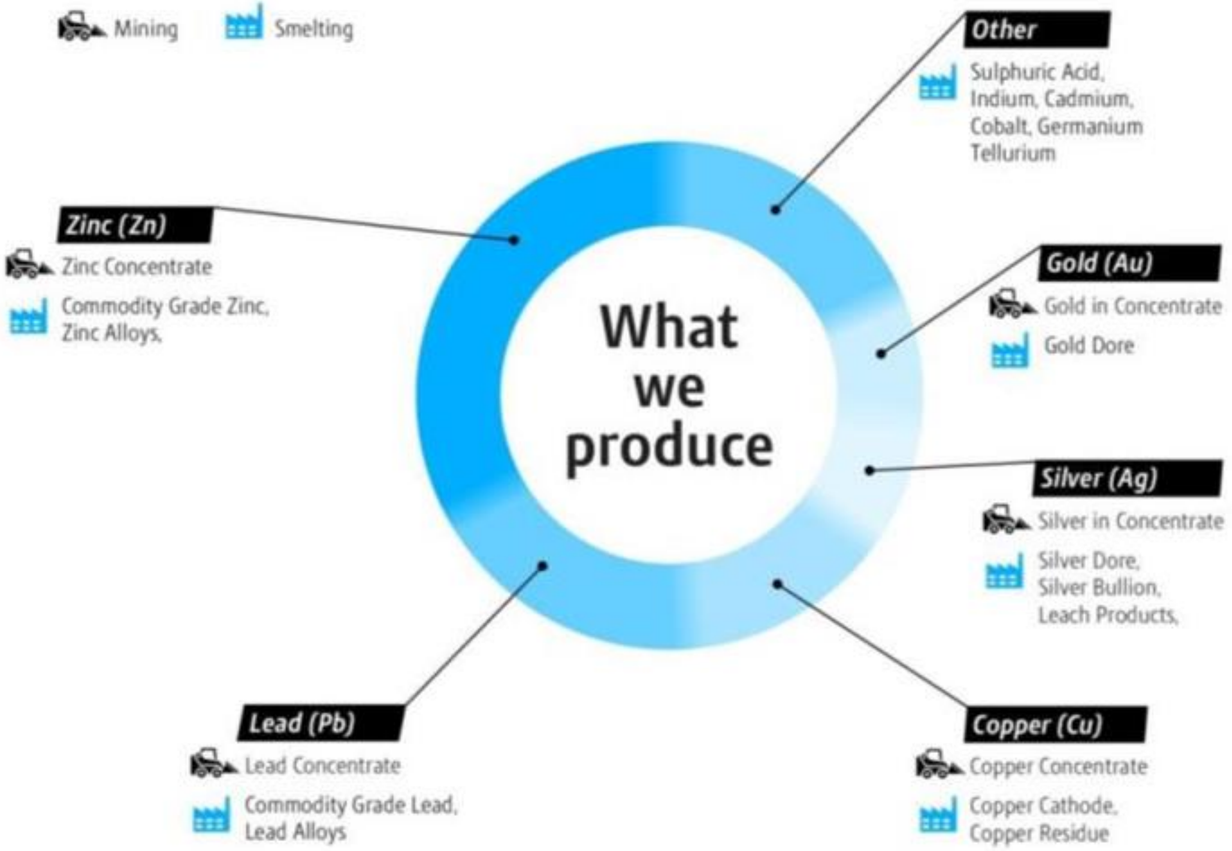
Lead & lead alloys

- BHAS lead
- Lead alloys

Other metals

Sulphuric Acid

Other products



EU's critical minerals and metals autonomy -> it starts with zinc (oxides).....

Nyrstar's zinc and lead smelters treat complex concentrates sourced from around the world and produce critical and strategic materials essential for the energy transition and critical to the electrification of industry.

Zinc is critical to the operation of low-carbon and strategic technologies. Extending the life of steel saves significantly on life-cycle CO_2 emissions, and it is an essential raw material in wind turbines, solar panels and electric vehicles.

Lead lead batteries for mobility and storage applications, submarine cables for wind turbines, coatings for solar panels, also needed in precious metals recycling.

EU's critical minerals and metals autonomy -> it starts with zinc (oxides).....

A number of other metals are recovered and refined in parallel with Nyrstar's zinc and lead production:

Indium is a critical raw material used in electronics (displays) and thin-film solar cells. >90% of the world's indium production is directly generated from the production of zinc.

Copper is essential for the electrification of Europe and used for all clean energy technologies.

Silver is essential in electronics and other technological applications such as photovoltaics and electric vehicles.

Cobalt is a critical raw material for battery cathodes, essential for revolution electric cars.

Manganese is used in steel production and is also an essential material for the cathode of lithium-ion batteries.

Sulphuric acid is used widely in nuclear power plants, the chemical industry, for the production of fertiliser and is an essential ingredient in the production of fibres, paints, rubber, plastics, steel and pharmaceuticals.

What is needed to support Europe's strategic autonomy

- European zinc and lead production is fully integrated with a very complex supply chain of a large number of non-ferrous metals. As soon as elements of this supply chain are no longer able to operate due to the current challenging economic conditions caused by the energy crisis, it will come to a halt.

- Without Nyrstar's products (or products generated by the supply chain Nyrstar is closely interlinked with), Europe runs an imminent risk of running out of materials essential for the production of:

  - galvanised steel,
  - chips and semiconductors,
  - high-performance solar energy panels for satellites
  - electric vehicles
  - a wide range of battery applications (e.g. for automotive, EV and energy storage)
  - critical products for the security of our region (such as infrared imaging systems, night vision goggles, radar, and telecom networks).

% metal required in 2050 for clean energy technologies vs. 2020 overall use (Global SDS ambitious climate scenario).** †

Lithium	2,109%	Silicon	62%
Dysprosium	433%	Terbium	62%
Cobalt	403%	Copper	51%
Tellurium	277%	Aluminium	43%
Scandium	204%	Tin	28%
Nickel	168%	Germanium	24%
Praseodymium	110%	Molybdenum	22%
Gallium	77%	Lead	22%
Neodymium	66%	Indium	17%
Platinum	64%	Zinc	14%
Iridium	63%	Silver	10%

From: 'Metals for Clean Energy' study, issued by KU Leuven in April 2022

- Metals will play a central role in successfully building Europe's clean technology value chains and meeting the EU's 2050 climate-neutrality goal.

What is needed to support Europe’s strategic autonomy

- Nyrstar supports the energy transition in every possible way:
  - fully electrified and flexible, running on green energy, zinc with lowest carbon footprint
  - strategic and critical minerals and metals essential for Europe's green transition
  - up to 30% of the feed is recycled zinc

- Still: energy costs of our European smelters have multiplied and there are significant differences between European countries in the support they provide to energy-intensive companies.

- Since Q4 2021, Europe has been a net importer of zinc due to a lack of level playing field.

- Europe's energy dependence leads to materials dependence.

- Medium- and long-term industrial policies are necessary. Industry relies on competitive energy prices to be able to resume / maintain full production of critical and strategic minerals and metals.

European zinc market balance (source: CRU and ILZSG)

		Consumption (kT)	Production (kT)	Available for export (kT)
2019	Q1	599	607	8
	Q2	592	616	24
	Q3	603	617	13
	Q4	579	615	36
2020	Q1	576	634	58
	Q2	511	609	98
	Q3	540	609	69
	Q4	549	618	69
2021	Q1	600	630	30
	Q2	611	625	14
	Q3	596	626	30
	Q4	592	585	(7)
2022	Q1	583	556	(27)
	Q2	580	569	(11)
	Q3	560	550	(11)

High energy prices in Europe are leading to closures and production cuts at European zinc producers.

What Nyrstar can do to help secure output and how to get there

Nyrstar is ready to take next steps to help the green transition even further by making maximum use of volatile renewable energy potential. How? By further:

- expanding on-site solar and wind power and battery-energy storage systems;

- increasing its flexible production process by investing in a virtual battery (135MW flexibility – 7000MWh storage) as you can see in this animation.

Conclusions

To fulfil our shared ambitions:

- A (medium-)long-term industrial perspective is necessary to keep industry in Europe and to have it contribute - in the most efficient way and with the least environmental impact - to the transition to a more sustainable society.

- A strong and sustainable European industrial policy is needed to help restore the level playing field between the global regions, as well as maximum implementation in the EU Member States so that a level playing field within Europe is established.

In our view this is essential to attract investments in the clean energy supply chain and to enable strategic companies to meet the current challenges and continue to develop.

Thank you for your attention.

Life Cycle Impact Assessment of Lithium mineral concentrates for the production of FEB applications

M.C.S. Ribeiro [1,2], A. Fiúza [1,2], M.L. Dinis [1,2], M.C. Vila [1,2] and A.C. Meira [2,3]

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[3] ISEP – School of Engineering, Polytechnic of Porto, Portugal

Introduction

Lepidolite Ore

This case study is part of a co-promotion project between the industry (proponent) and the academia whose main objectives is the sustainable production of Lithium mineral concentrates from the reserves of lepidolite ore that exist in concessions of the proponent, to be used on Ferroelectric Electrolyte Batteries (FEB) for electric vehicles.

It foresees the full recovery of the minerals in the ore (quartz, feldspar, and heavy metallic minerals), thus driving to a process that does not generate solid wastes (tailings). This way it becomes possible to attain the two main objectives of sustainable management of mineral resources: full utilization and absence of wastes.

The study is specifically focused on the LCIA of the production of Lithium hydroxide monohydrate ($LiOH.H_2O$), with battery grade (99%), using a 'cradle to gate' approach. The structure of the integrated production system comprises the following production stages: a) Mining, which leads to the extraction of the ore; b) Ore Processing, which leads to the production of mineral concentrates; c) Metallurgy, which leads to the production of marketable $LiOH.H_2O$ compound; and d) Distribution or outflow of the final product.

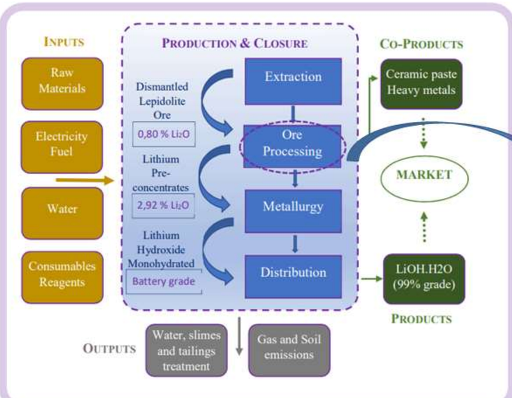
All relevant environmental, human health and socio-economic impacts of each production stage were considered and a contribution analysis was carried out allowing identifying the critical product cycle phases that can be further improved.

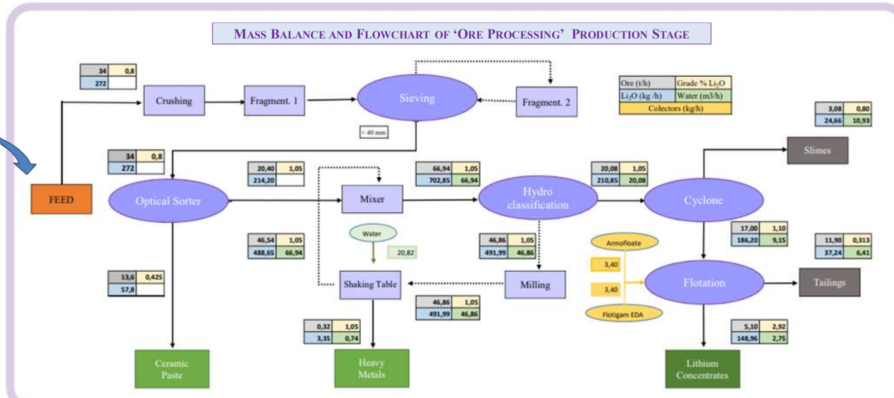
Goal and Scope

- **Overall Goal and Scope**: To evaluate the environmental load associated to the production of Lithium Hydroxide Monohydrate with battery grade, identifying the critical production stages that can be further improved. Specific goal of present study: Limited to 'Ore Processing' stage, identifying the critical production phases.
- **Functional Unit**: Elementary Lithium (ton/year). Functional unit of present study: Lithium Pre-concentrates (ton/year) with 2,92% concentration of Lithium Oxide (Li_2O).
- **Methodology**: 'Cradle to Gate' and 'Gate to Gate' approaches; ReCiPe 2016 v1.1 midpoint method, Hierachist perspective.
- **Data Sources**: Primary data from proponent and Secondary data from Ecoinvent and Industry Data 2.0 databases (Allocation at point of substitution model).
- **Software**: SimaPro, PRé Sustainability (9.40 version).
- **Assumptions**: Gonçalo Mine has reserves and capacity to provide 34 ton/h of lepidolite ore (0,8% Li_2O) during a lifetime of 15 years; Prospection works and using phase of Lithium compounds are not contemplated.

Gonçalo Mine (Mota Minerals concession), Guarda, Portugal
The European country with higher proven Lithium reserves.

System description and Boundaries



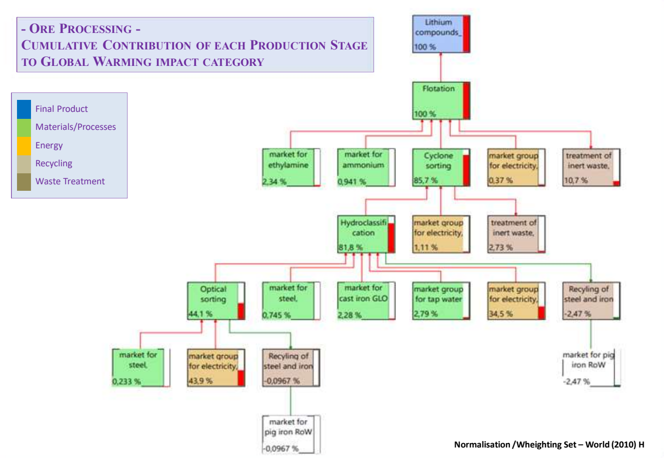


Partial Results

Ore Processing - Environmental Load per item / process consumption (%)

Impact Categories	Energy	Consumables Steel/Iron	Reagents Collectors	Water	Treatment Slimes/Tailings	Recycling Steel/Iron
Global Warming	**79,88**	3,26	3,28	2,79	13,43	-2,56
Stratospheric Ozone Depletion	**71,20**	1,91	1,60	4,60	21,70	-1,02
Ionizing Radiation	**90,90**	1,26	0,87	3,82	3,38	-0,26
Ozone Formation, Human Health	**56,60**	2,82	2,14	2,08	38,30	-1,94
Ozone Formation, Terrestrial Ecosyst.	**56,20**	2,89	2,26	2,09	38,60	-2,05
Fine Particles Matter Formation	**78,70**	3,52	1,69	2,72	15,10	-1,79
Terrestrial Acidification	**73,00**	2,87	2,77	2,63	20,40	-1,68
Freshwater Eutrophication	**90,20**	2,60	2,34	3,59	2,90	-1,78
Marine Eutrophication	**54,10**	1,93	40,30	3,05	2,09	-1,48
Terrestrial Ecotoxicity	**34,50**	31,27	3,49	3,62	28,80	-1,64
Freshwater Ecotoxicity	**74,40**	9,81	4,92	5,01	7,22	-1,39
Marine Ecotoxicity	**73,30**	10,46	4,72	5,00	7,96	-1,44
Human Carcinogenic Toxicity	26,00	**55,30**	1,36	10,40	7,91	-0,98
Human Non-Carcinogenic Toxicity	**82,70**	5,12	3,47	4,07	6,36	-1,67
Land Use	**54,90**	2,91	2,50	2,68	38,60	-1,54
Mineral Resource Scarcity	28,30	**108,70**	5,81	13,70	12,20	**-68,70**
Fossil Resource Scarcity	**64,80**	2,36	4,05	2,32	28,10	-1,57
Water Consumption	13,10	0,38	0,99	**76,70**	8,85	-0,03

- Ore Processing - Cumulative Contribution of each Production Stage to Global Warming impact category



Previous Conclusions

- '*Optical Sorting*' and '*Hydroclassification*' steps are the most critical phases of Ore Processing cycle production stage leading to the highest environmental loads in almost impact categories. This issue is associated to energy consumption relied to crushing/fragmentation and milling processes required to these steps.
- Consumables such as jaws for the primary and secondary crushers, balls for the mill and mill liners (made of chromium steel and cast iron), are instead the main responsible factors for the environmental loads associated to Human Carcinogenic Toxicity and Mineral Resources Scarcity, even considering the recycling of remaining material. These consumables are also linked to '*Optical Sorting*' and '*Hydroclassification*' steps.
- Slimes and tailing treatment, related to '*Cyclone Sorting*' and '*Flotation*' steps, also have slight to significant effects on overall environmental load.

CAVALI Project: Lithium Value Chain - Under P2020|COMPETE, financial support of Innovation National Agency, Portugal (POCI-01-0247-FEDER-047728)

The Geopolitical Supply Risk (GeoPolRisk) method for use in LCA and as comparative risk assessment

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Introduction

The geopolitical supply risk (GeoPolRisk) method evaluates resource criticality in Life Cycle Assessment, complementing other resource and environmental impact indicators. However, it is challenging to calculate characterization factors (CFs) for the midpoint (GeoPolRisk midpoint) indicator from the GeoPolRisk method. Therefore, a library based on python to operationalize the GeoPolRisk method is developed to facilitate the calculation of the CFs and showcase its application as a comparative risk assessment.

The GeoPolRisk Method

The GeoPolRisk method is an import-based indicator to integrate the criticality of raw materials into the area of protection natural resources, proposed by (Sonnemann et al., 2015). It is designed to evaluate the supply risk of importing a resource from a trade (country, trade block, region, group of countries, or company/organization) perspective during a specific period. The method provides two values;

A. The GeoPolRisk score, a non dimensional value representing the share of imports of a resource at risk.
B. The CFs for the GeoPolRisk midpoint indicator.

$$\text{GPRS} = \left(HHI_A * \left[\sum_i \frac{g_i * f_{Aic}}{p_{Ac} + F_{Ac}} \right] \right)^2 * \bar{p}$$

- Import share of the analysed country weighted with the political instability indicator of the exporter of the resource.
- Production concentration of the resource evaluated using normalized Herfindahl-Hirschman Index
- Yearly average market price of the resource.

Integration into LCA

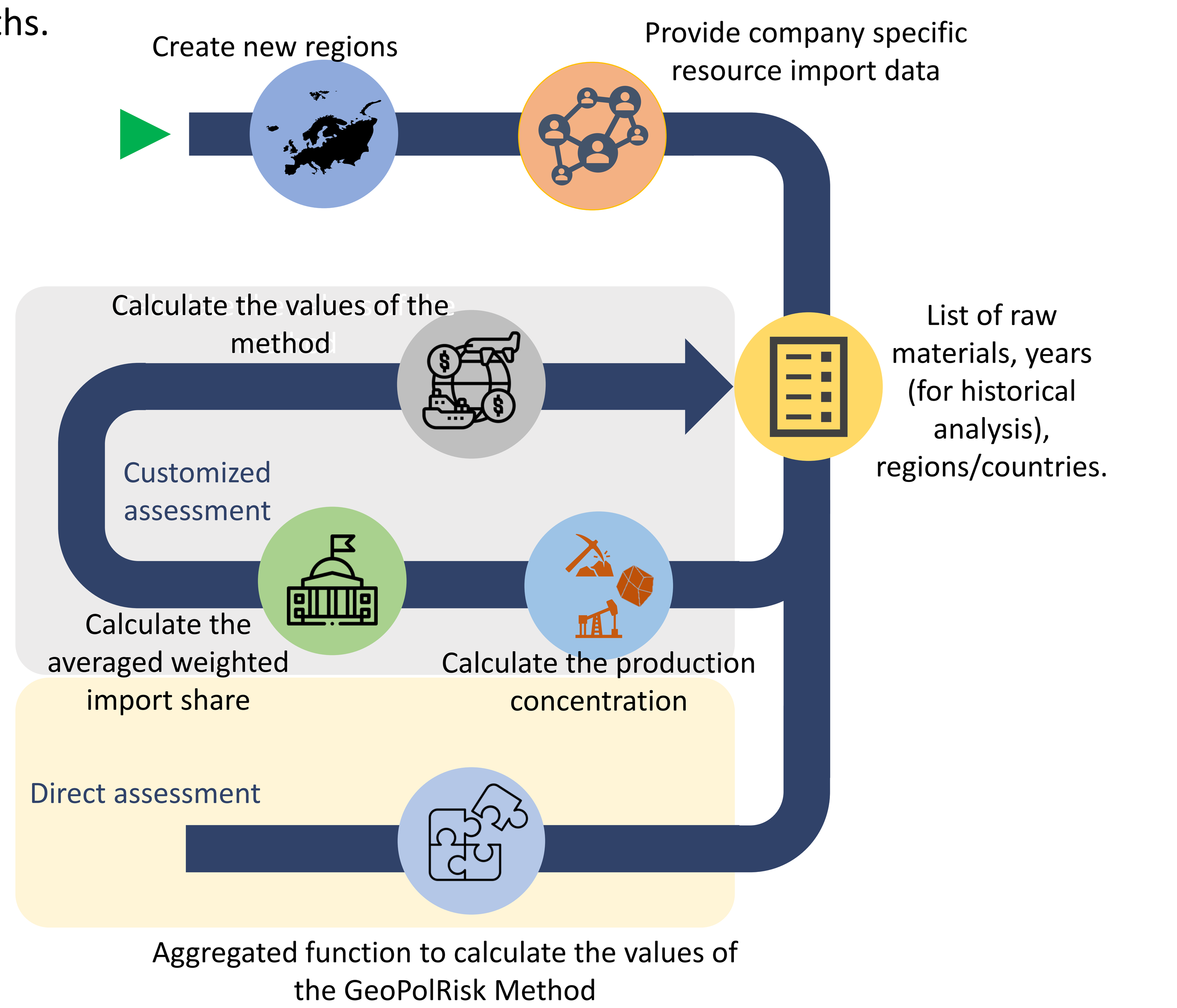
★ The GeoPolRisk midpoint indicator provides a potential economic damage due to sourcing of a raw material.
★ The CFs for the "flows" in LCA are dependent on the perspective of assessment.
★ The CFs for 6 countries (the US, the EU, Japan, Canada, Australia and South Korea) are available for assessment in a nation's perspective.
★ "Direct assessment" path can be used to a calculate CFs for other countries or regions.
★ For a company's perspective assessment, provide the specific trade data and follow the "direct assessment" path to calculate CFs specific for the company.

Comparative risk assessment

★ The GeoPolRisk score is a product of the Herfindahl Hirschman index and the averaged weighted import share of a raw material.
★ The score is mass independent and represents relative supply risk of importing raw materials.
★ Software can integrate this library if it supports python and take benefit of the individual functions to extract and analyse information on the go.
★ A company with a specific import mix can use this score to compare the supply risk of raw material to that of a country's import mix.

GeoPolRisk Calculation Library

The calculation library allows users to customize the assessment by creating new economic regions, providing company specific resource import data, analyzing the components of the GeoPolRisk method to highlight the hotspots. A user can opt to use the library following two paths.



The two paths to use the calculation library for calculating the values of the GeoPolRisk Method

GeoPolRisk Online Tool

The GeoPolRisk online tool is graphical user interface built on the framework of the calculation library.

SCAN ME

Accessibility

Version 2.0
Github Repo:
https://github.com/akoyamp/geopolrisk-py

*This study will be available as a scientific article with the title "Introducing a python-based library to operationalize the Geopolitical Supply Risk Potential Indicator for use in life cycle assessment and comparative risk assessment".

Perspectives

There is an ongoing development in the library to improve memory consumption and decrease the time required for each function. The database is updated to the year 2020 for 30 resources. A significant on-going development is automating the collection of data from publicly available databases. A framework is being developed to crawl through the websites to collect relevant information and use artificial intelligence to verify and extract the data.

Assessment of Medium-Term Supply Disruption Impacts of the Swiss Mobility Sector within Life Cycle Sustainability Assessment

Empa
Materials Science and Technology

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Introduction & Objectives

The expected rapid implementation of electric vehicles (EVs) in Switzerland in the coming decades will lead to an increasing dependency of the country on high-tech products such as lithium-ion batteries and critical raw materials and thus higher risk of supply disruption. It is therefore important to identify mobility scenarios with the lowest supply risks as well as the biggest supply bottlenecks (i.e. highest supply disruption impacts along the supply chain).

To identify such impacts, we use our recently developed SPOTTER approach, which, in contrast to existing approaches, allows for assessing supply disruption impacts along the full supply chain in the medium-term (i.e. 5-15 years) within Life Cycle Sustainability Assessment [1]. This poster provides an overview of different Swiss mobility scenarios and represents the methodology as well as first results of our study.

Materials and Methods

In view of an increased electrification of the mobility sector as well as potential changes in the demography and consumer behavior in Switzerland, the share of vehicle technologies on the market and the vehicle fleet is likely to change in the country. The four scenarios presented in Table 1 describe the development of the fleet of battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), hybrid electric vehicles (HEVs) and internal combustion engine vehicles (ICEVs).

Assessing the supply disruption impacts along the supply chains related to these four scenarios involves an analysis of several inventory flows. In order to reduce the data collection and computation efforts, we have developed a five-step screening procedure that allows to identify the most influential inventory flows for the impact assessment (Figure 1). Within the first three steps of this procedure, the types of materials/products to be analyzed are identified.

Considering the identified material/product types, the inventory analysis is performed. First, the country-specific flows of final products are defined based on country-specific production data and by selecting the flows that respect the rule described in the fourth step of Figure 1.

After the definition of the final product flows, the flows of materials and intermediate products are defined step-by-step upstream the supply chain. Thereby, global average weight ratios and the country-specific production amounts of the individual materials/products are used and the flows are selected that are below the thresholds described within the fifth step of the screening procedure in Figure 1.

Table 1: Description of scenarios for the Swiss mobility sector until the year 2040. The basis (i.e. situation in the year 2021) is defined by a population of ~8.67 Mio people, a vehicle-per-capita ratio of ~0.54 and the following shares of passenger vehicle types: ~13% BEV, ~9% PHEV, ~23% HEV and ~55% ICEV.

Technology type / **Demography & vehicle amount**	*Experts "Auto Recycling Schweiz"[2]* • ~97% of BEV in 2040 • face out of HEV in 2027 • face out of PHEV in 2036 • ~3% of ICEV in 2040	*McKinsey & Company and Bloomberg[3, 4]* • ~67% of BEV in 2040 • ~11% of HEV in 2040 • ~5% of PHEV in 2040 • ~17% of ICEV in 2040
Demographic increase of ~16% and vehicle-per-capita increase of ~4% until 2040	**Scenario 1: "Fast electromobility transition & Increasing vehicle fleet"**	**Scenario 3: "Slow electromobility transition & Increasing vehicle fleet"**
Demographic increase of ~9% and vehicle-per-capita decrease of ~17% until 2040	**Scenario 2: "Fast electromobility transition & Decreasing vehicle fleet"**	**Scenario 4: "Slow electromobility transition & Decreasing vehicle fleet"**

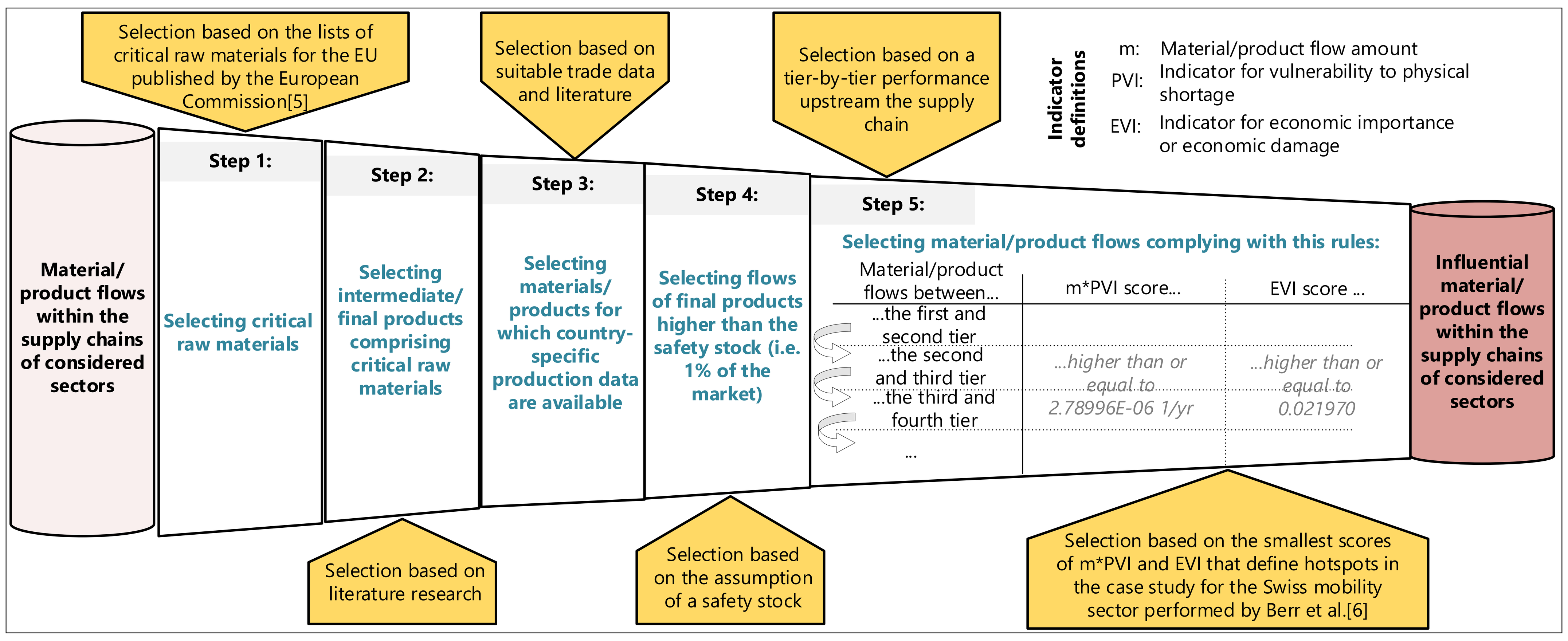

Figure 1: Screening procedure for material/product flows most influential for the supply disruption impact assessment

Results

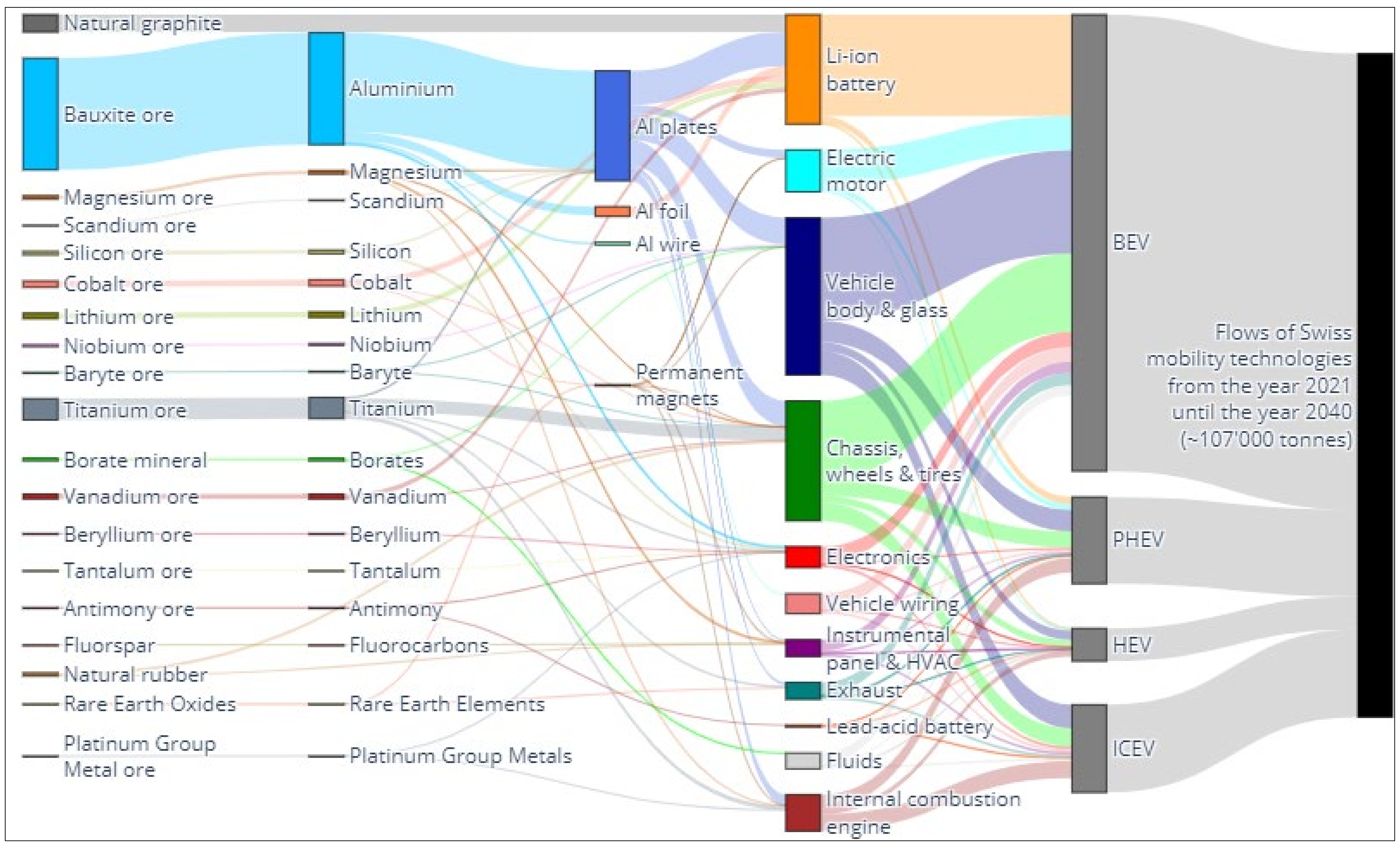

Figure 2: Material/product flows related to Scenario 1 described in Table 1. A decrease in the cobalt and lithium contents of the lithium-ion traction batteries over time that is estimated based on information from [7] is considered.

Conclusions & Outlook

- Four different Swiss mobility scenarios have been defined considering fast and slow electric mobility transitions and in- and decreasing vehicle fleets.
- Figure 2 shows that relatively large amounts of li-ion batteries and electric motors and relatively low amounts of internal combustion engines and lead-acid batteries are used when considering a fast electromobility transition.
- Furthermore, Figure 2 highlights that technologies used in the Swiss mobility sector consume until 2040 a variety of raw materials that are evaluated as "critical" by the European Commission[5] (i.e. 19 different raw materials). Bauxite, titanium and natural graphite are thereby used in the largest amounts.
- In a next step, material/product flows related to the other scenarios will be quantified as shown in Figure 2 and country-specific flows will be determined following the fourth and fifth step of the procedure described in Figure 1.
- Considering these country-specific flows, supply disruption impacts for each scenario will be assessed and compared by using the equations described in the SPOTTER approach[1].
- Within this assessment, impacts of cost variability and limited availability due to demand growth, co-product dependency, primary raw material reliance and depletion of ultimate resources will be evaluated.

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73 NRP Sustainable Economy National Research Programme
FNSNF Swiss National Science Foundation

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The Role of Data Synthesis for Critical Raw Materials

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OFFIS Institute for Information Technology

1. Background and Problem Statement

The cost of energy has become significant within production costs and there are supply disruption risks, which result in the urgent need of monitoring and, if possible, optimizing of energy and resource consumption in the manufacturing sector. Additionally, current goals such as circular economy and zero-emissions, require that the used resources have traceability. This can only be achieved with data sharing between the different actors in the supply chain. However, there are not enough sustainability and critical raw material traceability models from the manufacturing sector, which come from measured data because companies are not willing to share their production data, since it contains sensitive information.

The Sustainable Manufacturing Systems group investigates the potential of data synthesis for the following challenges in the industrial sector:

C1. Lack of resource data for their traceability between the different actors of the supply chain.

C2. Reluctance of companies to share production data, due to the risk of leakage of sensitive information.

3. Privacy-Preserving Data Sharing

- There are many approaches to achieve privacy-preserving data sharing.
- Differential privacy [2] is the leading standard for data privacy guarantee.
- In our proposed methodology, privacy is evaluated using the differential privacy standard.

4. Potential for Critical Raw Materials and Sustainability

- We propose the use of a Digital Twin [3, 4], as shown in figure 2.
- In the pre-processing level, deep generative models are used to perform data synthesis on the original data. The analysis is done with artificial data, which is private according to the company's privacy budget and useful for the models (the structure and distribution of the original database are respected).
- This addresses both challenges C1 and C2, because artificial data and the models developed in the analytics level of the Digital Twin can be shared with the different actors of the supply chain and enable the traceability of the resources, within them Critical Raw Materials, without risking sensitive information from the companies.

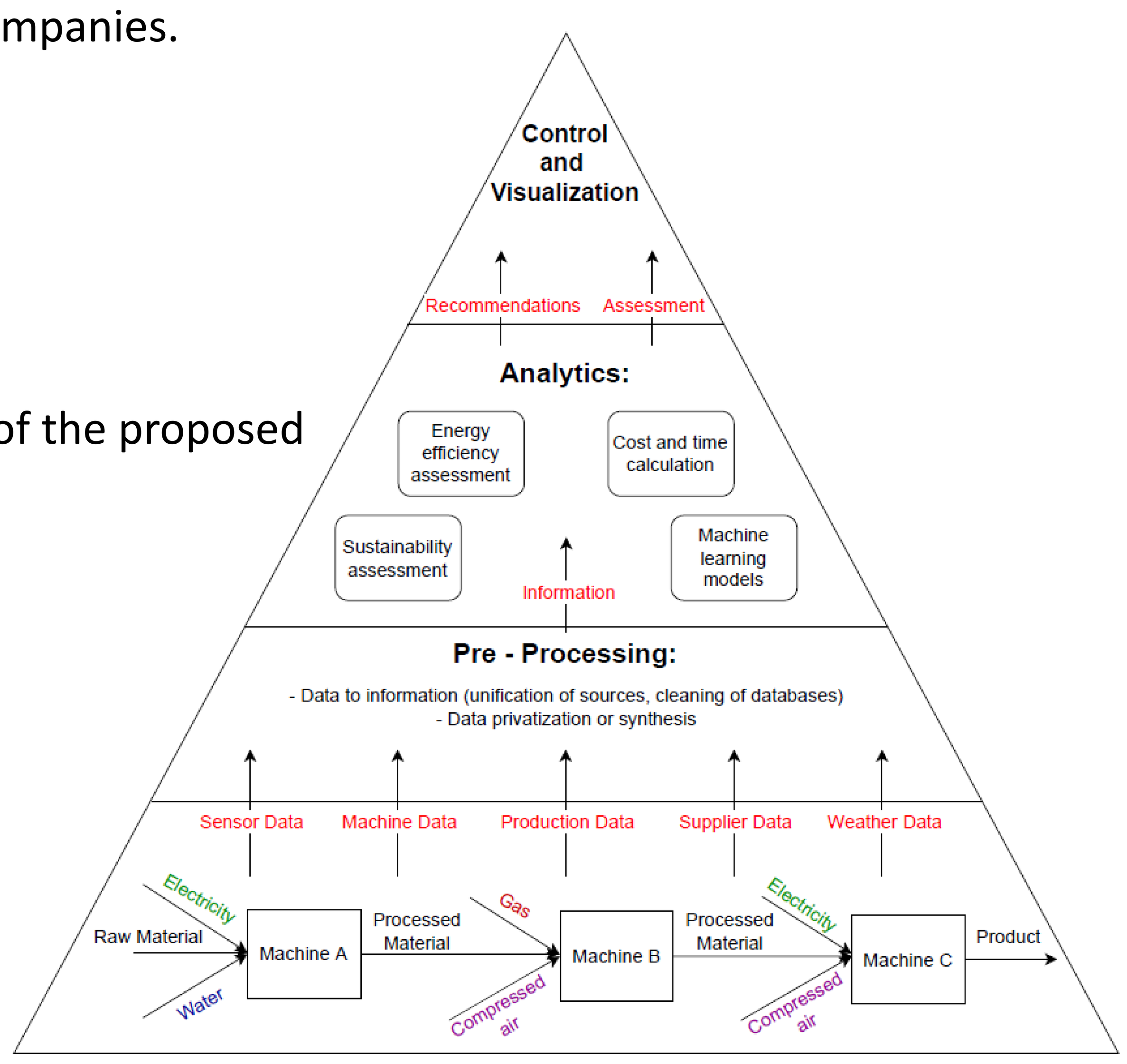


Fig. 2. Architecture of the proposed Digital Twin

2. What is Data Synthesis?

- Data synthesis is the process through which artificial data is generated from a data source, with the purpose of having a data set with the same structure and distribution but that does not reveal private information.
- Artificial data is used in research and to share information between different entities. It had been mainly used for health data applications.
- The main methods used currently for data synthesis are shown in figure 1. Our research focuses on the approaches inside the red box, which are based on artificial intelligence.

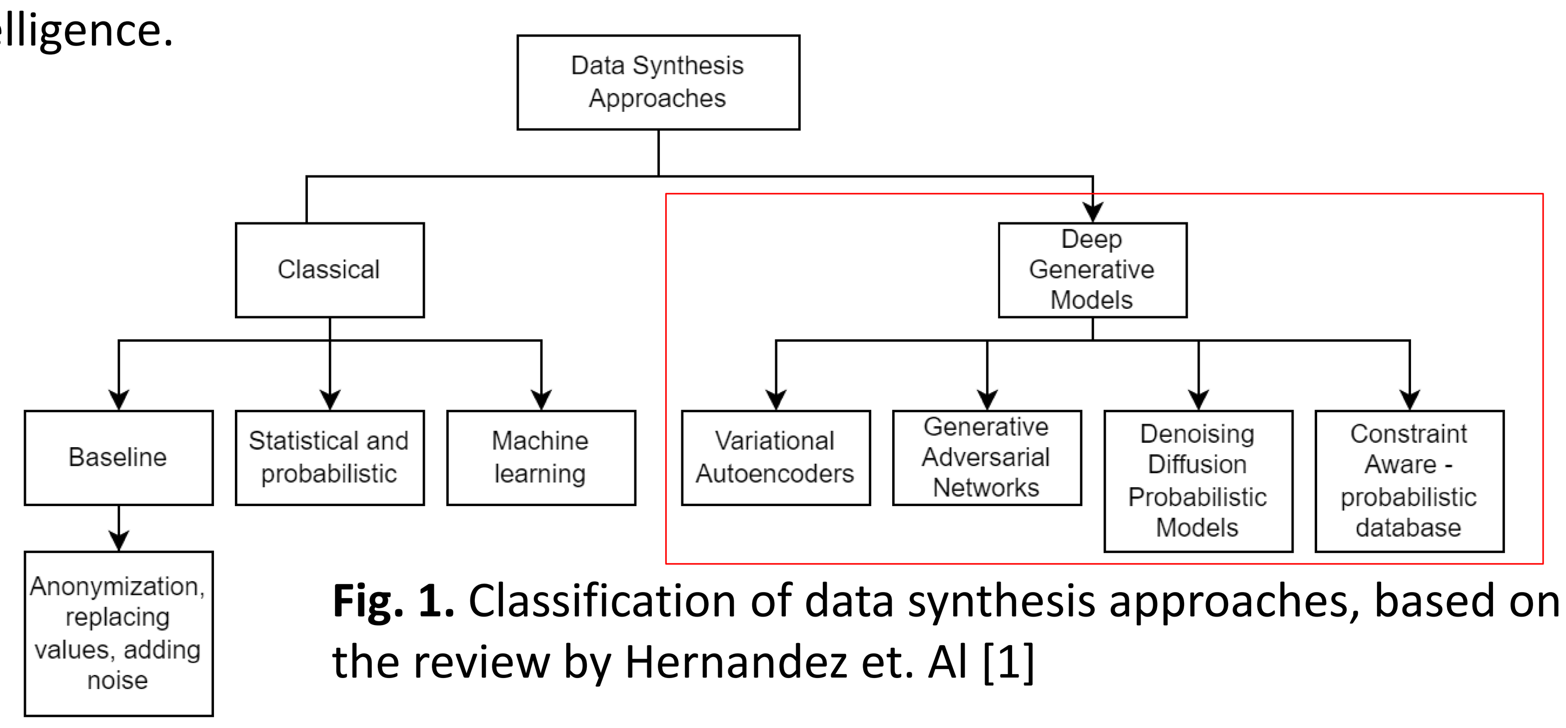


Fig. 1. Classification of data synthesis approaches, based on the review by Hernandez et. Al [1]

5. Case Studies – Work in Progress

- Two industry partners in northern Germany: one in the airplane industry and one in the trailer truck production. 2022.

Fig. 3. Characterization of manufacturing process and structure of the data.

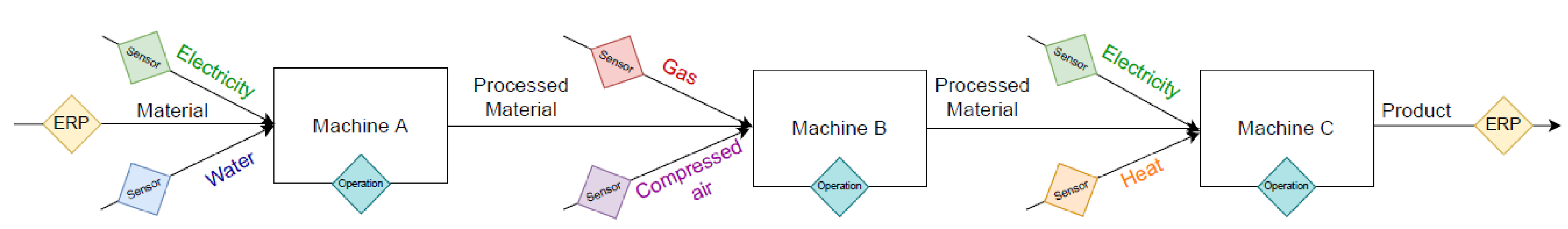


Fig. 4. Retrofitting, installation of sensors and data collection from the different data sources (sensors, machines, production, supplier, weather). Preparation of databases.

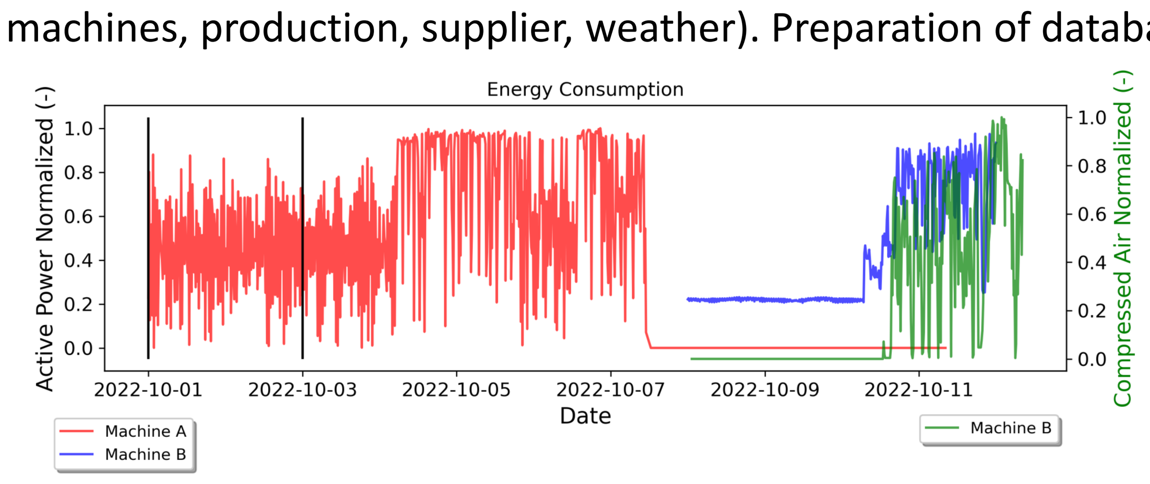
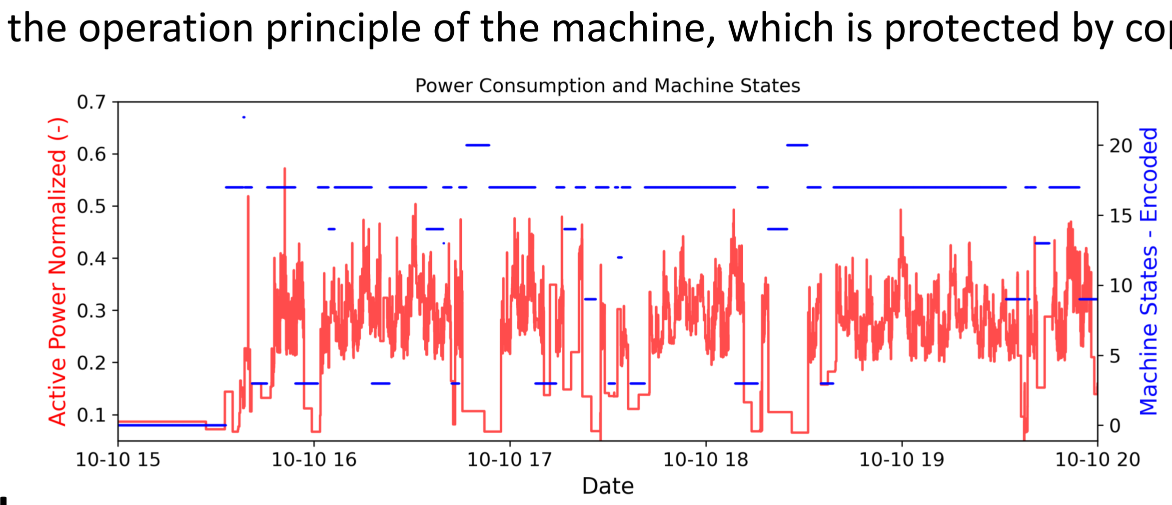


Fig. 5. Data pre-processing: simple example where the categorical data "states of the machine" is encoded using an Ordinal Encoder and numerical data is normalized. The output data does not reveal the operation principle of the machine, which is protected by copyright.



- **Future work:**
  - Further characterize the structure and define all the possible constraints present in manufacturing data.
  - Implement and evaluate the more complex approaches for data synthesis and privacy-preserving data sharing to improve the output data.

Project Websites:

Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages

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Lehrstuhl Ökologische ÖRT Ressourcentechnologie

UNIVERSITÄT BAYREUTH

Techno-economic-environmental categorization of critical raw materials recycling processes

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Motivation

Secondary raw materials play an important role in easing the supply of critical raw materials. Various recycling processes exist, and others are under development. However, the full potential of secondary critical raw material production has yet to be realized due to the lack of appropriate categorization and the missing identification of interconnections between different recycling pathways. In the following, we provide an overview of recycling processes and propose a categorization scheme based on technological, environmental, and economic evaluation criteria.

Research questions

1. How should categories for secondary raw materials be selected?
2. How can system boundaries of processes within the circular economy be defined uniformly?
3. How can technical, techno-economic and techno-ecological systematic interrelations be identified?

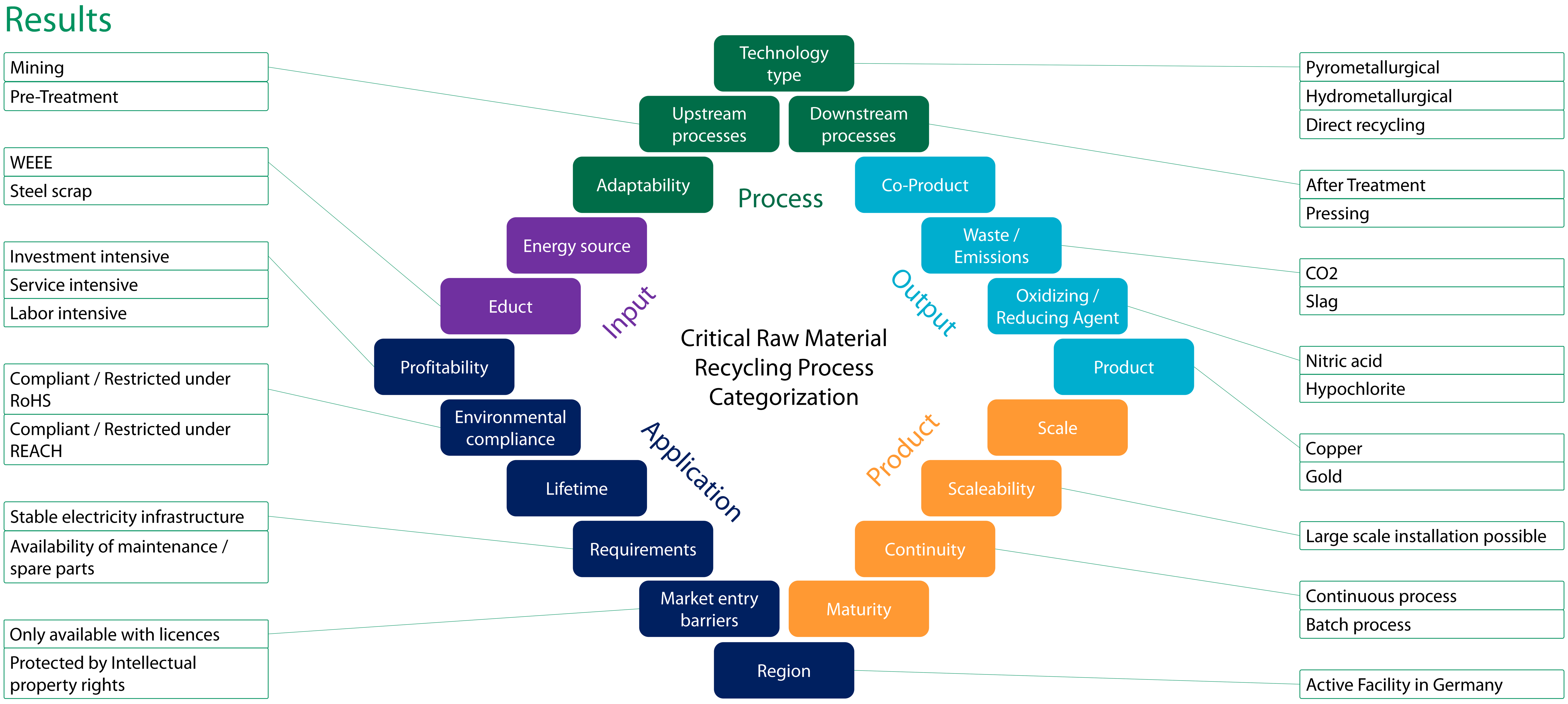
Instructions

Mark most important category (for academia)

Mark most important category (for industry)

Leave a comment, suggestion or note

Results



Conclusion

A comprehensive framework or approach for evaluating the criticality of secondary production and identifying dependencies between individual secondary raw materials and their processes is currently lacking. With this overview, we aim to initiate a more in-depth discussion on secondary critical raw material supply pathways and the constraints and criticalities associated with them. The findings will be valuable for materials scientists, engineers, businesses, and policymakers as they work to develop more recyclable materials and strategies for critical raw materials.

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The University of Manchester

Authors: Raphael Ricardo Zepon Tarpani; Akilu Yunusa-Kaltungo; Meini Su; Patrick Manu; Clara Cheung; Michael Watson; Paul Ladislaus; Alejandro Gallego-Schmid.

Evaluating the climate change impact of cement enhanced by graphene

Introduction

Ordinary Portland Cement (OPC)

- The construction sector is responsible for about 23% of global CO_2 emissions, and cement production for about 7%[1].
- The impact of the construction sector must be mitigated.
- We have estimated the environmental impacts of OPC production (**Figure 1**).

Graphene (Gr)

- Graphene has been shown to improve OPC's mechanical properties.
- There has been limited work on the life cycle impacts of Gr-enhanced cement[2,3].
- We have estimated the environmental impacts of Gr production (**Figure 2**).
- **We evaluated the environmental impacts of adding Gr to OPC.**

Figure 1 The OPC facility. Materials and energy are sourced from regional suppliers or local quarry.

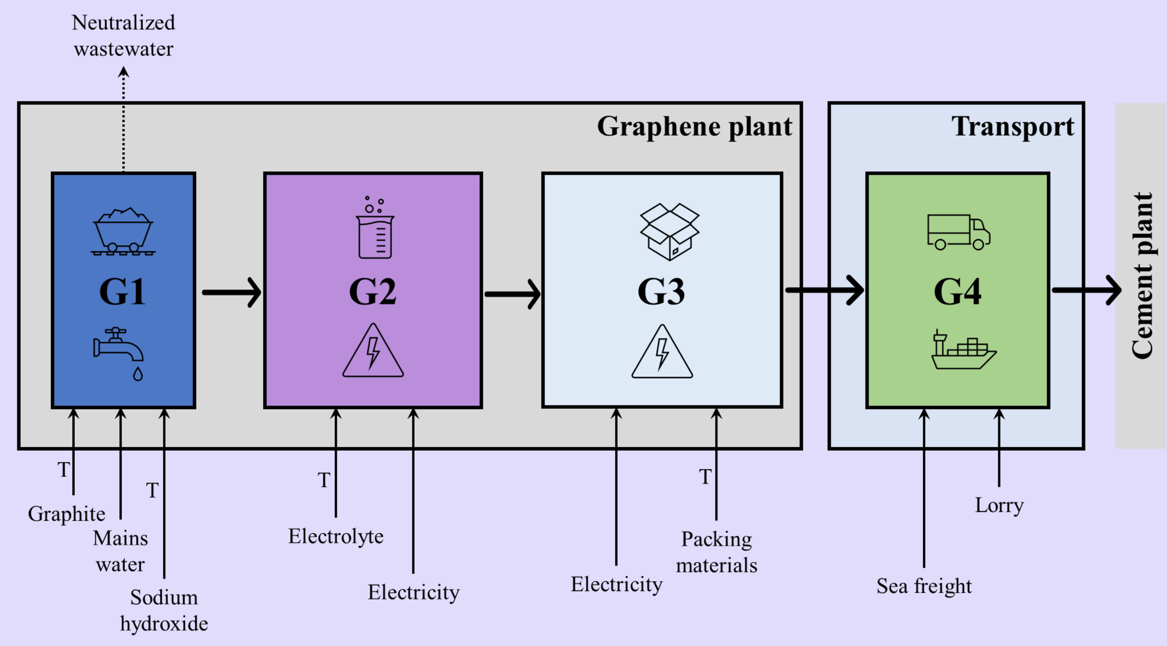

Figure 2 Life cycle stages of Gr production.

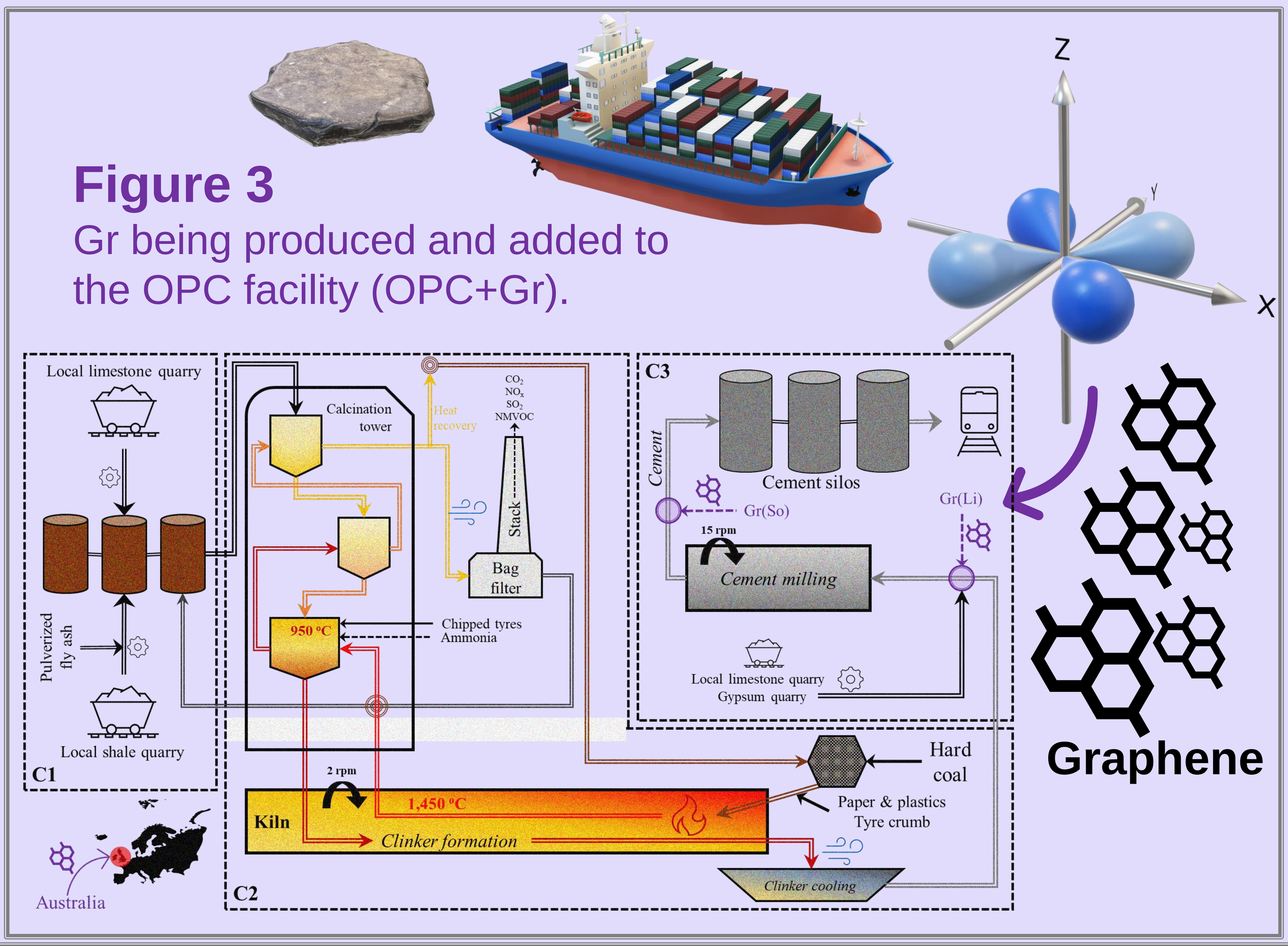

Figure 3 Gr being produced and added to the OPC facility (OPC+Gr).

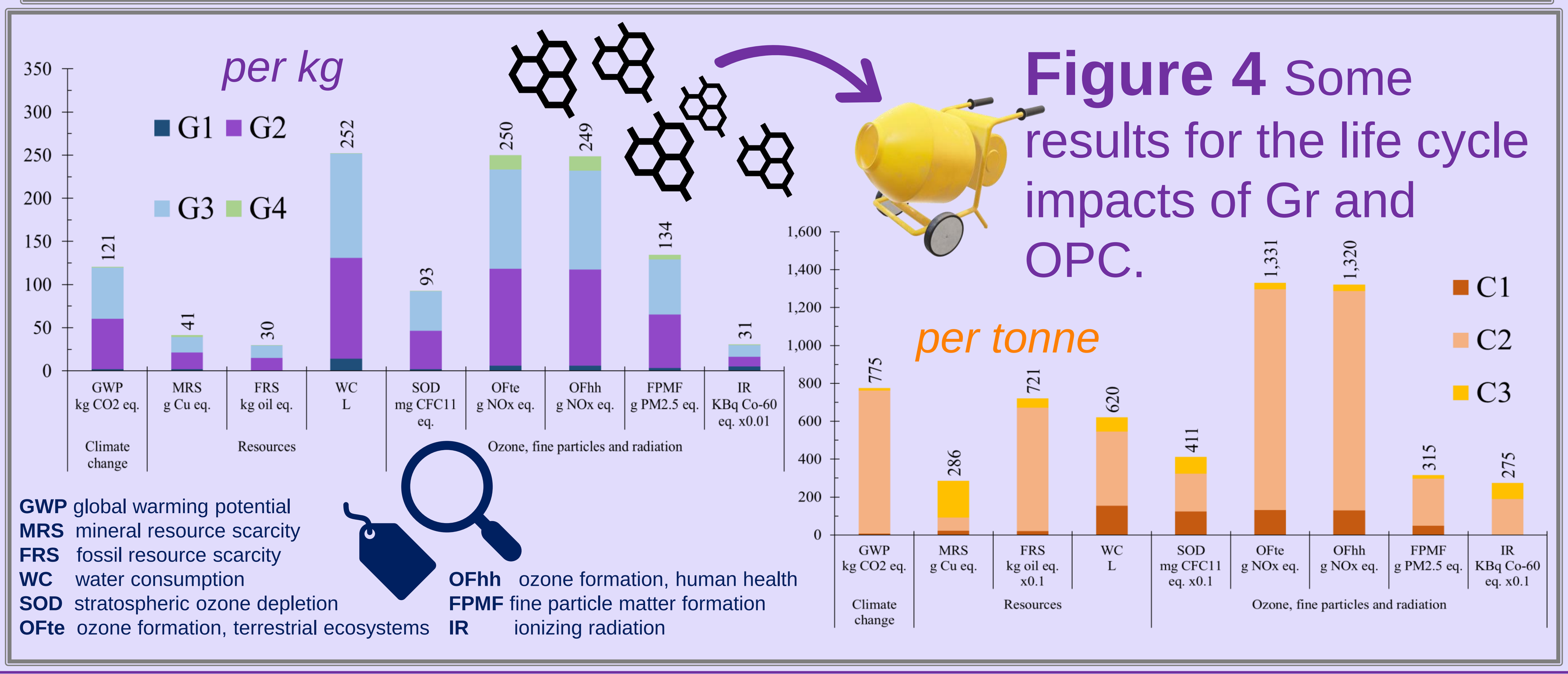

Figure 4 Some results for the life cycle impacts of Gr and OPC.

Methodology

Life cycle assessment (LCA)

- OPC and Gr assessed, using reliable primary data.
- Modelled with Simapro software and Ecoinvent v3.8. database.
- The goal was to understand the life cycle impacts of OPC and Gr, plus of **Gr-enhanced OPC (OPC+Gr)** (**Figure 3**).

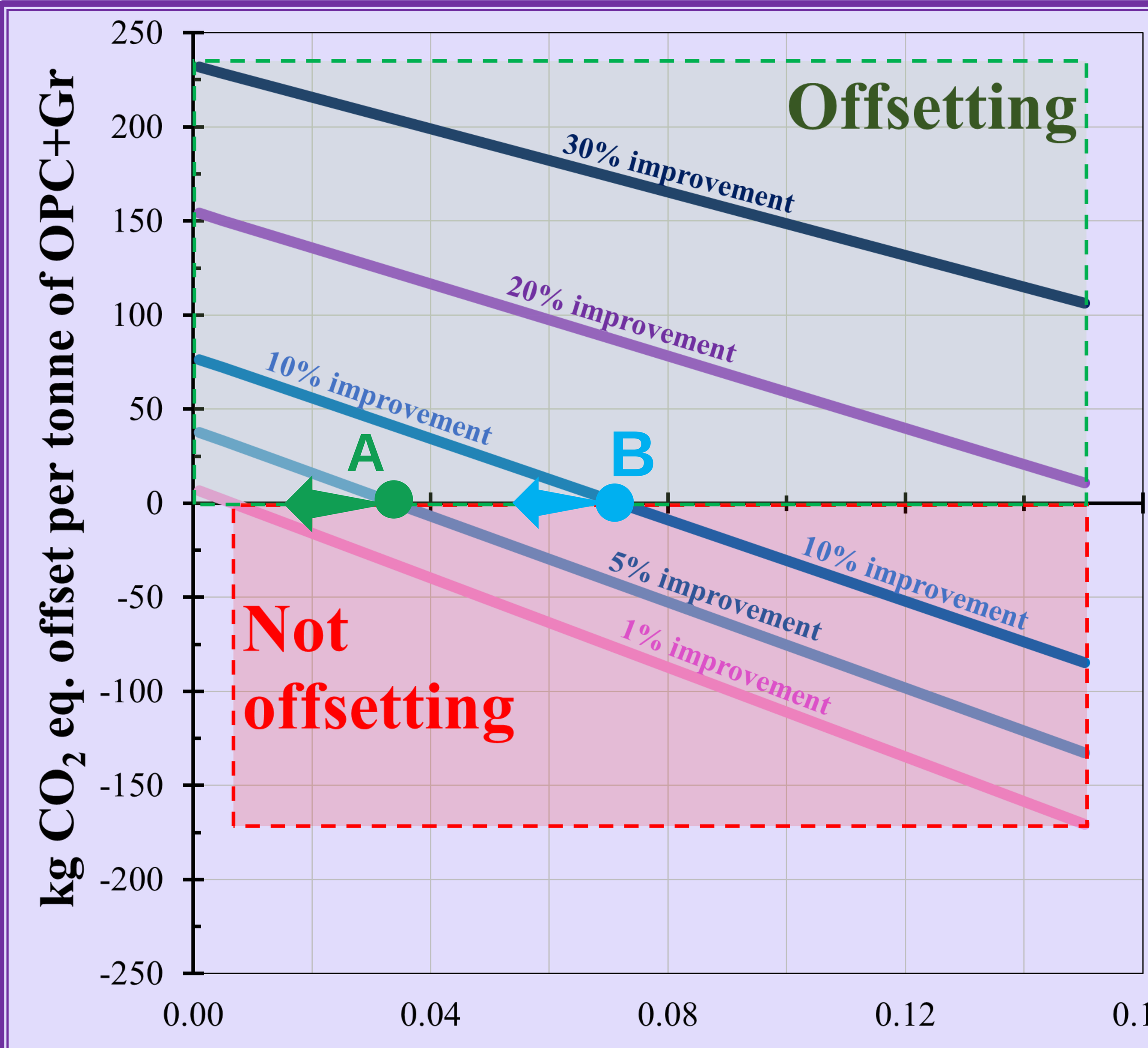

Figure 5 Results for the offset of CO_2 eq. per tonne of OPC+Gr produced according to different amounts of Gr added and estimated improvement in OPC's strength.

Results

- Climate change potential (GWP) of OPC 775 kg CO_2 eq. / tonne produced; and of Gr 121 kg CO_2 eq. / kg produced (**Figure 4**).
- We have shown that **Gr can reduce the embodied carbon of OPC** (**Figure 5**) **for loads < 350 g / tonne for 5% strength improvement (A), or loads < 720 g / tonne for 10% strength improvement (B)** for example.

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Innovate UK Project No: 10019613
High-Performance Graphene Enhanced Cement: A Revolutionary Innovation in Low Carbon Manufacturing Process (GR-LCM)

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BREEDON · MORGAN SINDALL GROUP · FIRSTGRAPHENE World leading materials technology | ASX:FGR

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Does criticality lead to more recycling?
The case of rare earth magnets

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SUSMAGPRO
SUSTAINABLE RECOVERY, REPROCESSING AND REUSE OF RARE-EARTH MAGNETS IN THE CIRCULAR ECONOMY

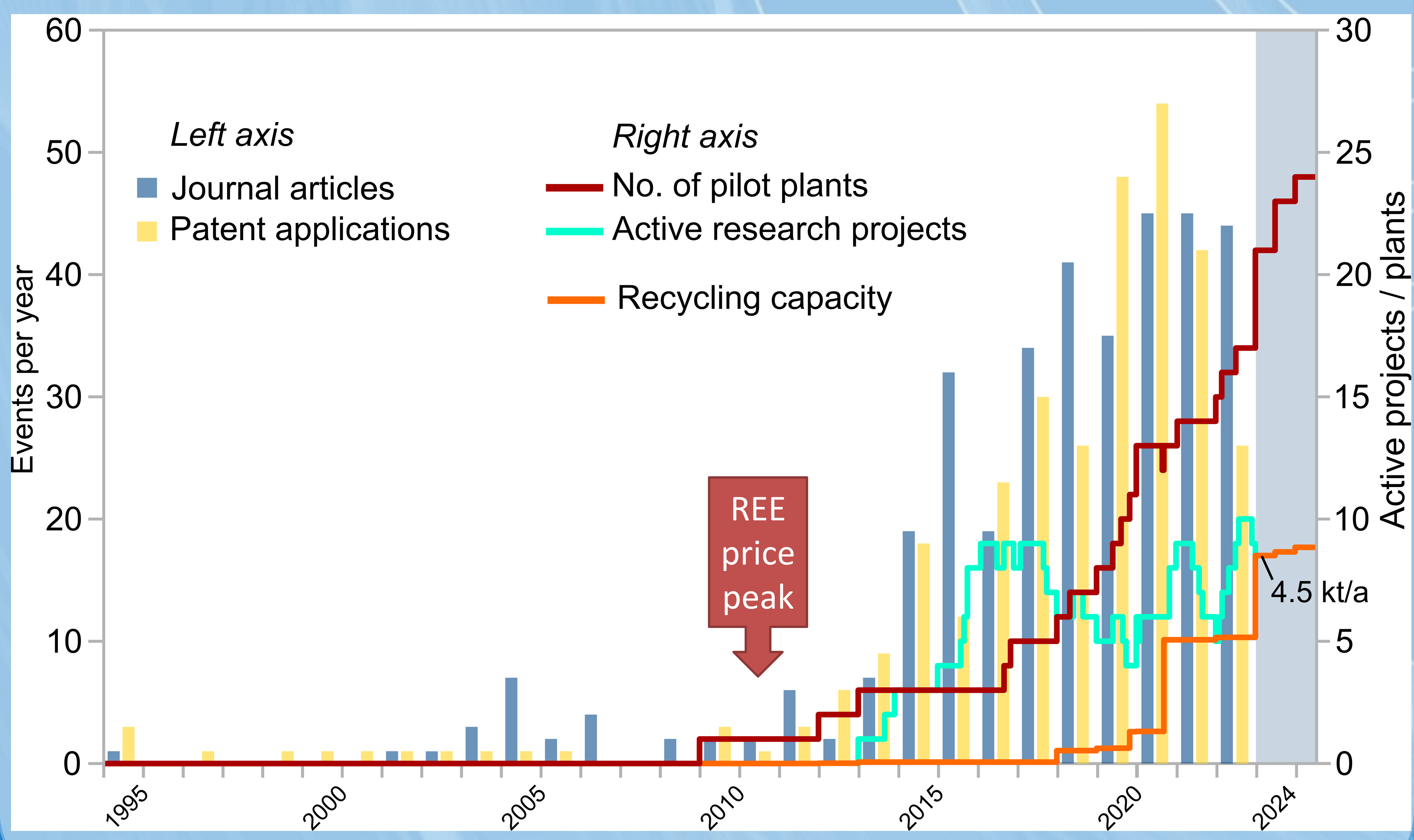
CML

Introduction

NdFeB magnets are used in energy-efficient electric motors, pumps, loudspeakers and wind turbines. The supply of NdFeB is critical due to the centralized production, which can be reduced by recycling. We investigated the magnet recycling system, its development, strengths and weaknesses.

- ❖ Gather important events in the research and development (R&D) of recycling, using Patentscope, Web of Science, and general search engines.
- ❖ Application of recyclability framework [1] to the case of EV motors.

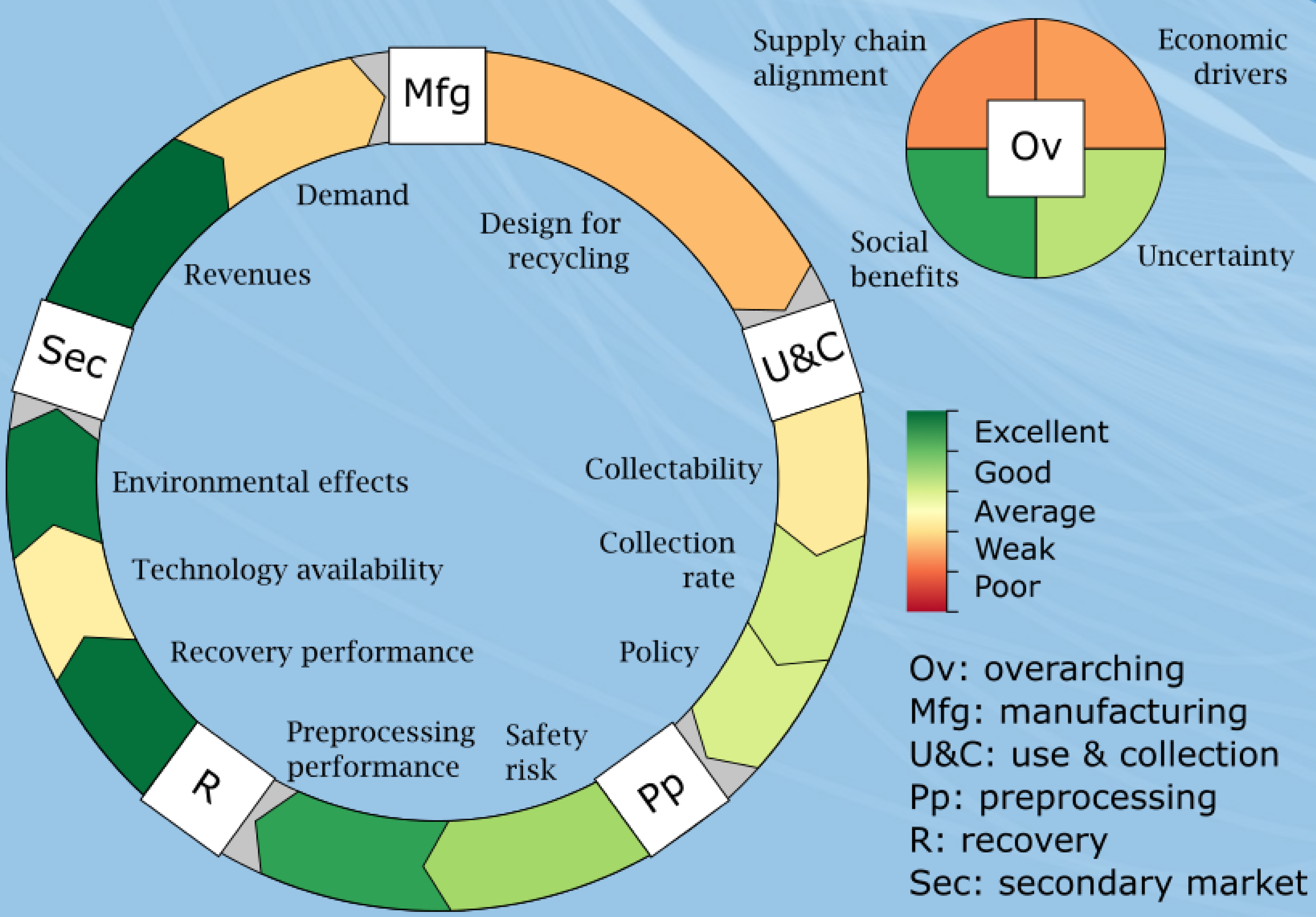
Increasing recycling R&D activity



Barriers and drivers in the magnet recycling chain

The recyclability of materials depends on the product properties and on organizational structures [1]. For EV motor magnets, we find [2]:

- ❖ Lower environmental impacts and safety hazards than for primary production
- ❖ Significant revenues from (co)recovered metals: NdFeB plus cleaner Fe, Al, Cu
- ❖ Challenges in collection and waste exports
- ❖ Currently small waste flow
- ❖ Motor design is not optimal for recovering magnets and the variety of designs is large



Discussion

Recycling does not necessarily lead to lower criticality [3]. In the case of NdFeB magnets:

- ❖ Dependence on metallurgical expertise remains.
- ❖ Status quo if existing manufacturers start recycling.
- ❖ Diversification due to multiple emerging recyclers.
- ❖ Due to demand growth, recycling is only a partial solution.

Conclusion & Outlook

Disruption of rare earth supply coincides with increasing R&D activities in NdFeB recycling.

Recycling of NdFeB magnets is technically possible, but it takes time to develop an aligned recycling system.

The number and capacity of announced recycling plants is increasing.

Recycling can be supported by design for recycling, regulation of waste treatment, and larger future waste flows (for economies of scale).

More research needed to map magnet recycling business in Asia.

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SUSMAGPRO
SUSTAINABLE RECOVERY, REPROCESSING AND REUSE OF RARE-EARTH MAGNETS IN THE CIRCULAR ECONOMY

COORDINATOR: Pforzheim University (Germany), Prof. Carlo Burkhardt

CONTACT: https://www.susmagpro.eu/contact

Universiteit Leiden Science

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European Commission

Titanium metal circularity in the EU

Status quo and future potential

Brian Baldassarre[a], Alejandro Buesa[a], Paola Albizzati[a], Malgorzata Jakimow[a], Luis Tercero[b], Denis Stijepic[b]
[a] European Commission, Joint Research Centre
[b] Fraunhofer ISI

Background

Titanium metal (Ti) is used in strategic applications, yet it is sourced from third countries. Circular economy strategies can play a fundamental role for the EU's strategic autonomy.

- Ti is used in strategic applications, aerospace and defence systems.
- In the EU, Ti is entirely imported from few countries; the war in Ukraine has exacerbated supply disruption concerns.
- Circular economy strategies (i.e., reducing, reusing, recycling) can play a fundamental role in ensuring reliable supply.

Objective

Assess current circularity and potential in the Ti supply chain, focusing on civil aviation and defence.

Results *[This work is currently ongoing, results are preliminary]*

- Detailed Ti supply chain including linear and circular processes from extraction and processing, to manufacturing, use and end-of-life.
- A seletion of specific drivers and barriers within the supply chain for increasing circularity in the EU.
- A quantitative estimation of Ti scrap trade flows, functional to develop future circularity scenarios assessed in terms of their economic and environmental impacts.

Method

Literature reviews; Stakeholder consultations; Database modelling.

- Literature review to gain a preliminary understanding of the supply chain structure, material flows and stakeholders.
- Qualitative insights collected by consulting key stakeholders across the supply chain (*processed into a list of barriers/ drivers to circularity)*
- Quantitative data on Ti scrap collected from different geographical/sectorial databases. (*translated into circularity scenarios which feed into economic and environmental models)*

Overview of the methodological approach and its stages.

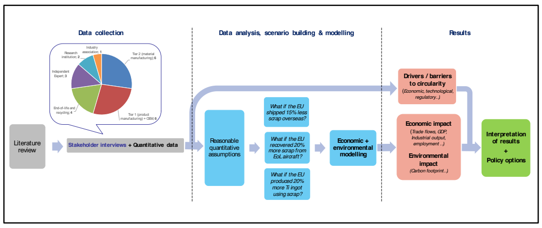
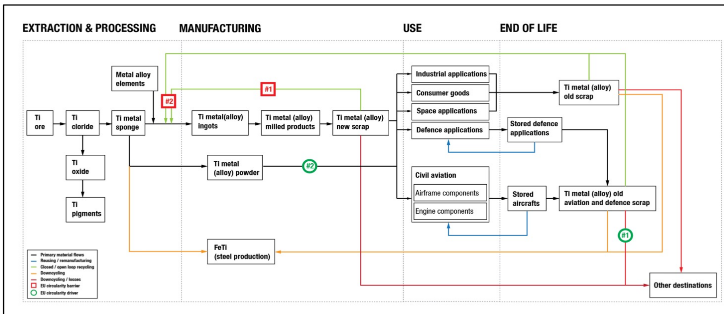
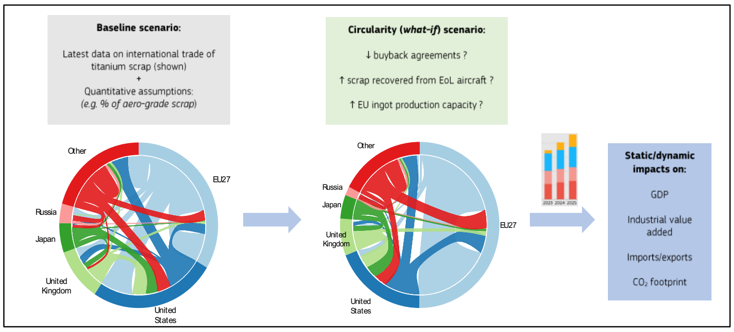


Diagram of the Ti supply chain, showing circularity drivers (green)/barriers (red) at the stage where they occur.



	Type	Brief description
EU circularity barrier #1	*Economic*	As per the commercial agreements between Tier 2 companies from overseas supplying wrought titanium metal products to EU Tier 1 companies and OEMs, the latter are required to **send back the scrap generated** in the manufacturing process
EU circularity barrier #2	*Technical*	Ensuring quality and safety standards of recycled titanium metal scrap for aviation and defence applications requires an **additional processing step before ingot remelting**, with a technology not yet widely deployed in the EU
EU circularity driver #1	*Economic*	Opportunity to **recover more titanium metal embedded in the frame of aircraft** that reach end-of-life in the EU, which is currently mixed with aluminium and downcycled because extraction is not yet cost-effective
EU circularity driver #2	*Technical*	Emerging **additive manufacturing** technologies might allow to reduce up to 90% of titanium metal needed in the manufacturing of aircraft components in the EU

Example of scenario analysis and modelling based on cross-country flows of titanium scrap .



Expected outcomes and future work

- Exhaustive list of cultural, regulatory, economic, and technical barriers related to enhancing titanium metal circularity in the EU.
- Detailed picture of the origin and destination of secondary (pre-consumer and post-consumer) material flows, along with sectorial insights and firm-level interactions.
- Impacts of greater circularity on the Ti supply chain.
- Research on macro-level international relations and dynamics to identify targeted and preventive policy actions to ensure security of supply.

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Joint Research Centre

Solving for India's Critical Mineral Challenge through Battery Materials Innovation

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Introduction

- CEEW estimates suggest that between FY22 and FY30, India's cumulative demand for energy storage at 903 GWh
- India's USD 2.3 billion production linked incentive (PLI) scheme for advanced chemistry batteries of 2022 – 50 GWh annual battery cell manufacturing capacity in India by 2025 creating demand for cathode active materials (CAM) – 1000 to 2000 t/GWh – and anode active materials (AAM) – ~1000 t/GWh
- Localisation of significant CAM and AAM production due to indigenisation requirements would result in demand for battery minerals which aren't mined in India at sufficient scale

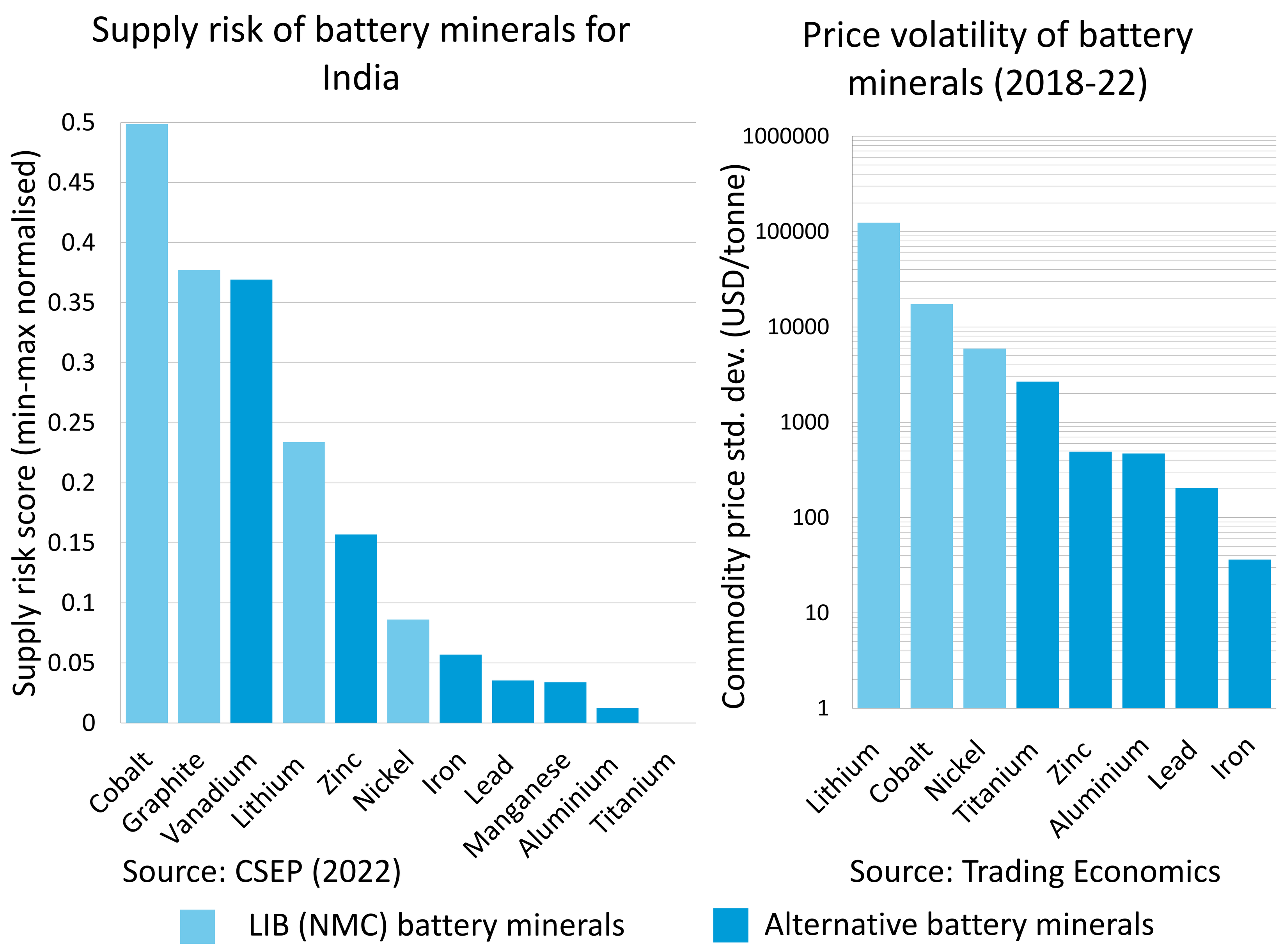
Research question: "How can India identify, develop and scale low critical mineral (CM) battery chemistries?"

Methods

- Battery supply risk calculated using methodology developed by Greenwood, Wentker, and Leker (2021) using a stoichiometric risk and maximum risk approach based on mineral supply risk scores developed by Chadha and Sivamani (2022)
- Key battery chemistries identified based on Future of Energy Storage report by MIT (2022)
- Mineral price analysis data from Trading Economics website
- Analysis of patent trends using WIPO Patentscope filtered by "English Title" and "Applicant Nationality" fields
- Analysis of Indian battery materials research funding using Department of Science and Technology (DST) Clean Energy Materials Initiative (CEMI) project data

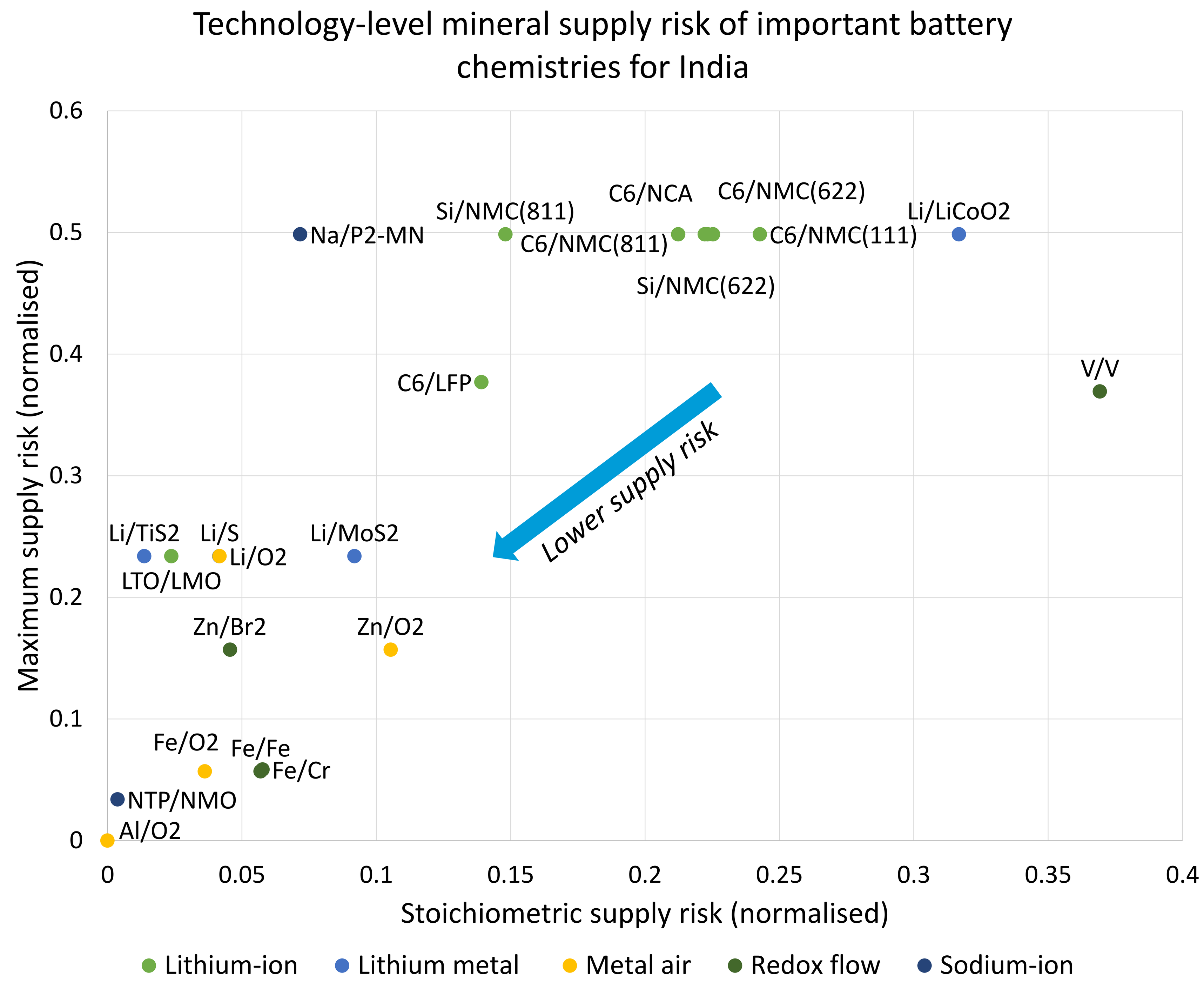
High supply risk for current battery minerals (LIBs)

Current LIBs, especially NMC and NCA, make use of minerals at high supply risk (considered critical minerals) and high price volatility



Need a criticality framework to guide innovation

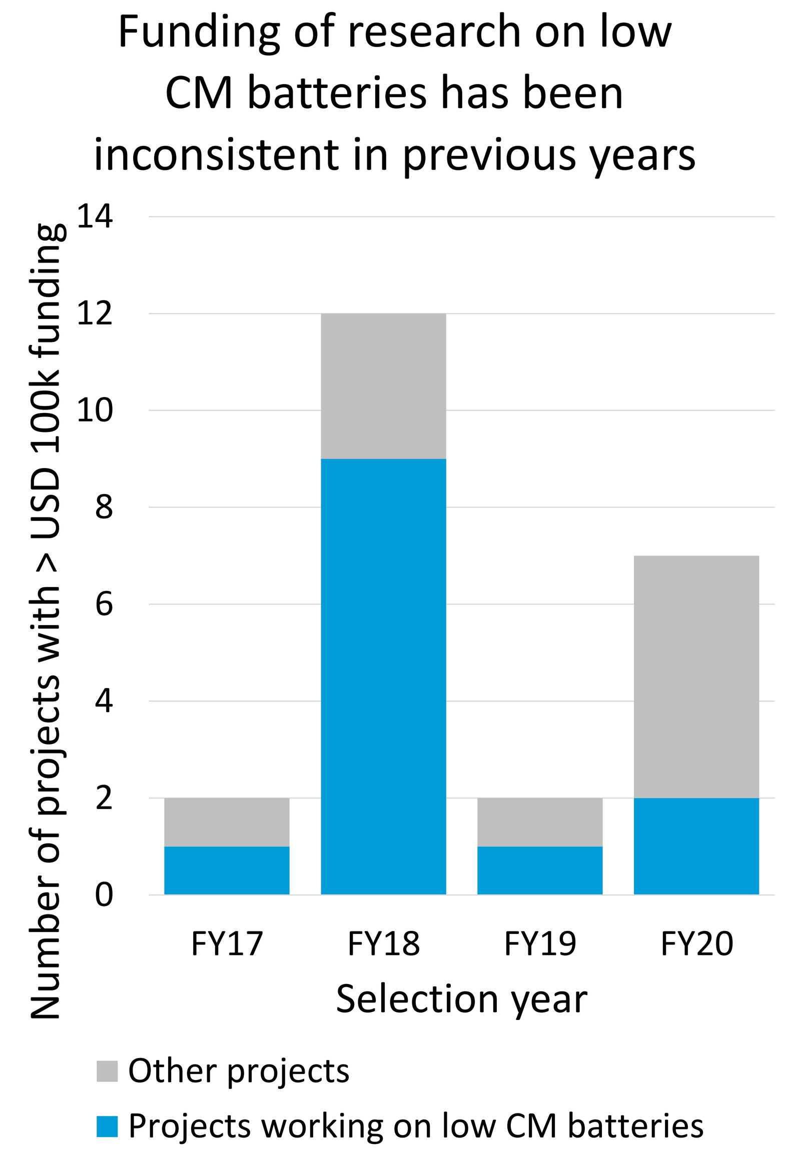
- Policy objectives should increase focus on critical minerals – lack of an objective assessment framework based on supply risks
- We evaluated each anode/cathode couple on the highest individual supply risk amongst all contained minerals (maximum supply risk) as well as a weighted combined supply risk for all contained minerals (stoichiometric supply risk) to identify
- Supply risk evaluates import dependence, exporter governance and concentration scores, substitutability and recyclability
- Assessment must be ongoing – constant changes in mining capacities, domestic production, trade, governance indicators

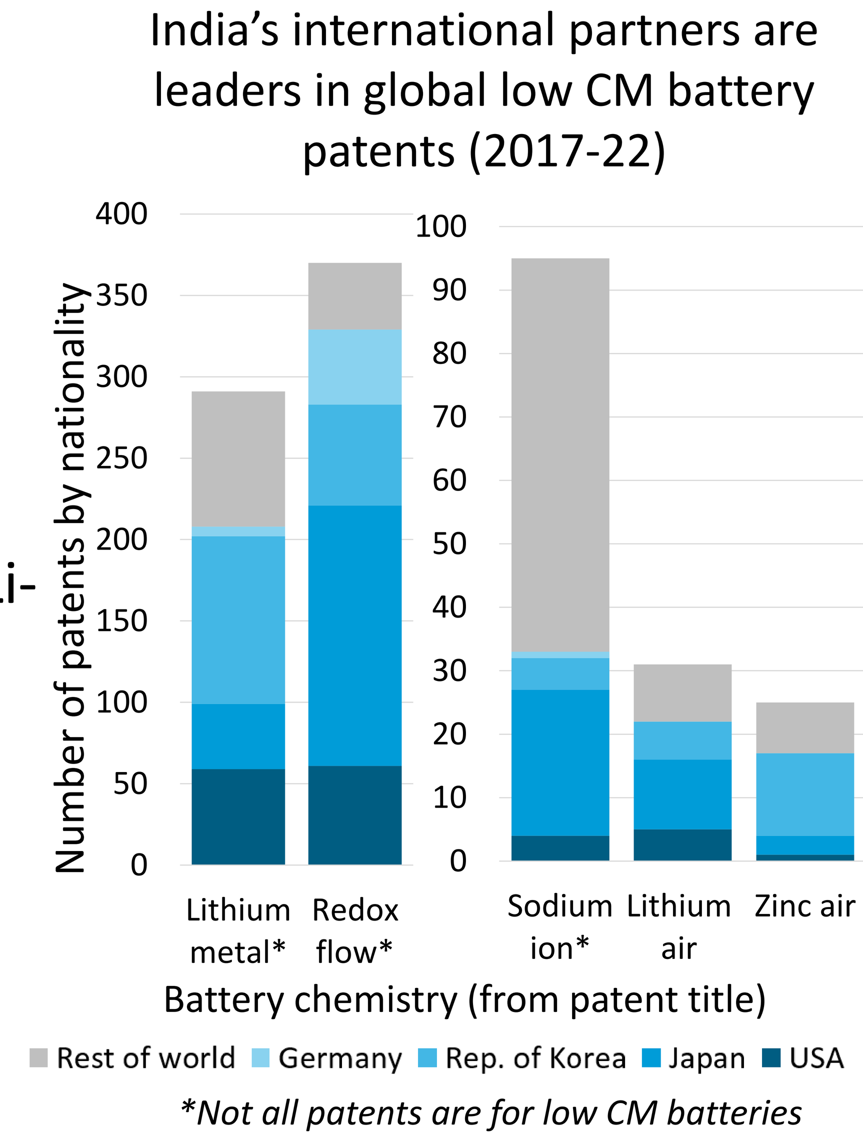


A roadmap to foster low CM battery technologies

Supporting indigenous innovation in low critical mineral (CM) battery chemistries:

- 13 projects with some low CM battery focus, and overall grant greater than USD 100k, were selected for funding by DST CEMI between 2016 to 2020
- The latest Advanced Materials and Energy Storage Technology (AMEST) programme is focused on cost, performance and safety; it should include a criticality framework as an additional selection criteria
- Indian R&D policy must address the gap between basic research and patents
- Indian academic and research institutions can partner with Japan, US, Germany, SK under Mission Innovation, Supply Chain Resilience Initiative and EU-India Trade and Technology Council
- Dedicated focus on identified low CM battery technologies (Li-based/alternative chemistries)
- India's planned manufacturing incentive schemes should include a criticality framework as an added criteria for selection or additional funding of technologies





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Department of Informatics

SUSTAINABILITY LAB

Critical raw materials depletion in LCA – a case of laptop recycling and component reuse

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ABSTRACT

Life cycle assessment (LCA) is a well-known methodology for assessing environmental impacts of products and services. Several studies have estimated impacts from treatment of waste electric and electronic equipment (WEEE), but few of them include impacts from critical raw materials depletion.
In this study, the current state of the art LCA methodology for assessing the impacts from depletion of critical raw materials is evaluated. The current system for laptop recycling is compared with a scenario of increased components reuse and a scenario where the laptop is stored in the consumer's drawer.

Two different life cycle impact assessment (LCIA) methods were tested. The case study has revealed limitations in data availability when it comes to critical raw materials content in electronic products.

The two LCIA methods show similar results for the case study. Reuse of components is a promising solution when it comes to depletion of critical raw materials due to limitations in the current recycling system. Storing laptops in the drawer after use is the least beneficial option.

Methodology

Life Cycle Analysis (LCA)

- SimaPro software with ecoinvent database data was applied

Case Study

- Use of digital product i.e., laptop computer by an employee
- Laptop computer was disassembled, and materials and weight of main components were identified

Goal and Scope

- The study aims at investigating the available life cycle impact assessment methods addressing critical materials depletion and the effect of repair and reuse, with the purpose of contributing with discussions regarding their applicability and lucidity when communicating to decision makers.

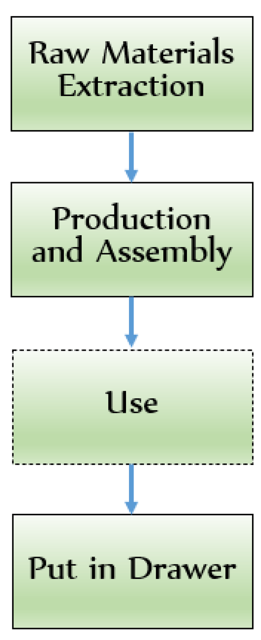
Functional Unit

- Use of laptop computer by one employee during six years

Considered Scenario & Descriptions

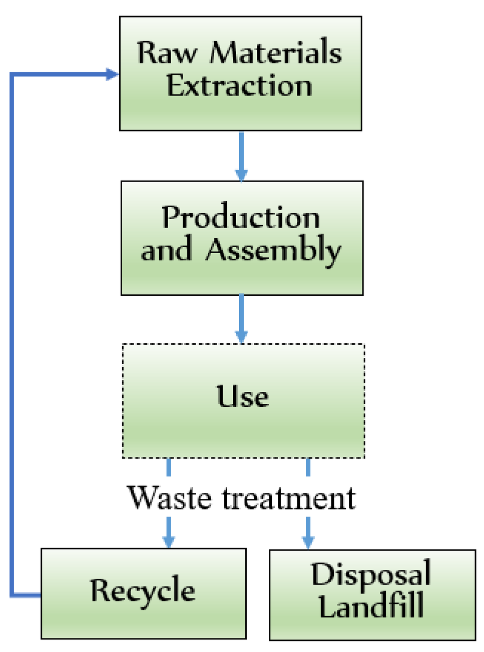
Laptop life cycle flow chart

Drawer Scenario



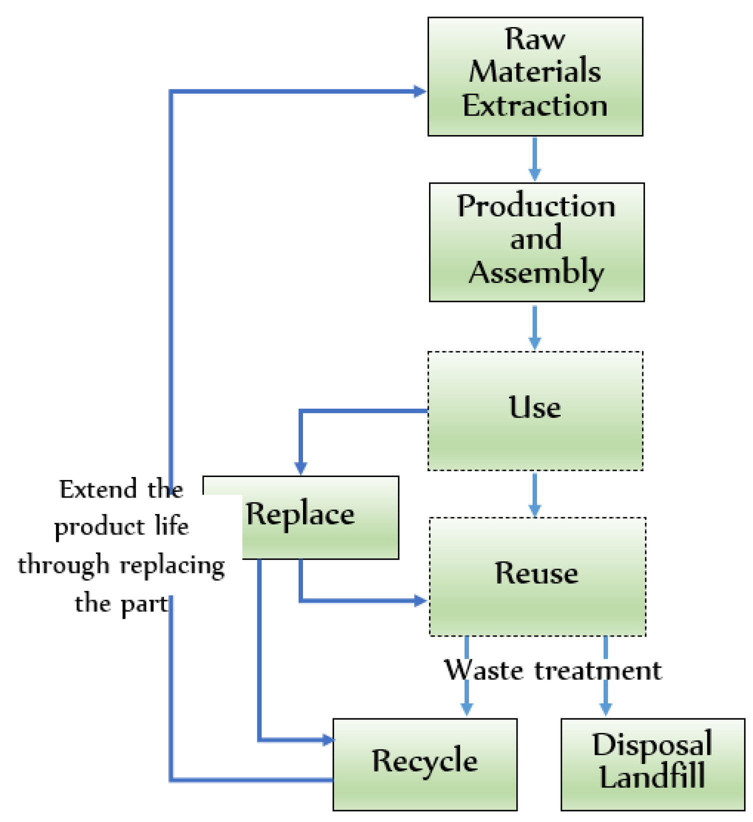
- After the first use life, the laptop is kept in drawer.
- 2 laptops were needed

Recycle Scenario



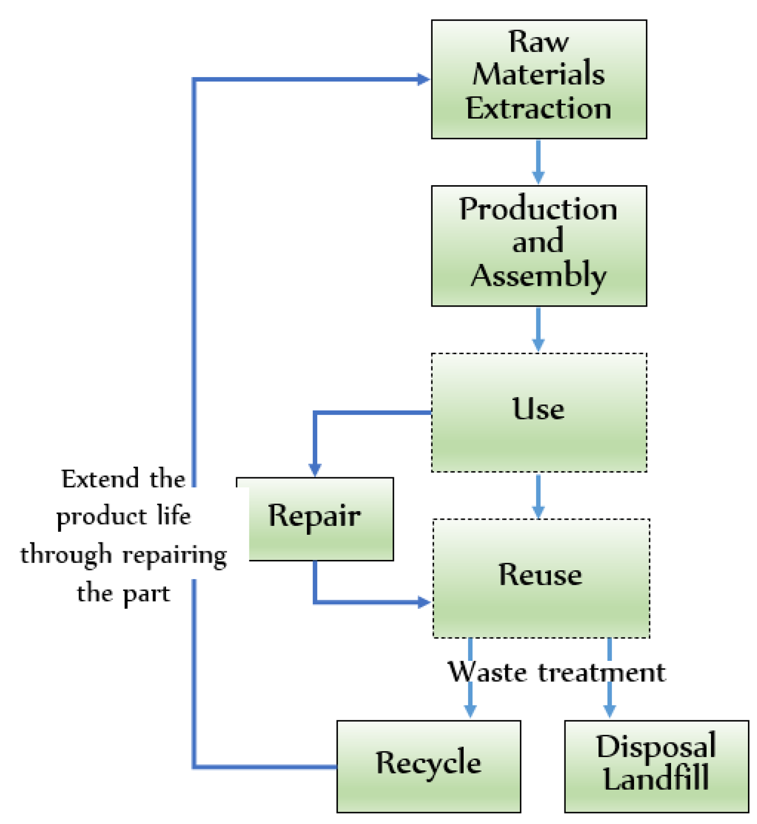
- At the end of use life phase, proper waste treatment is conducted.
- 2 laptops were needed

Replace Scenario



- After the first use life, a component, i.e. battery is replaced to be reused for the next 3 years
- 1 laptop and 1 battery to replace the old ones were needed

Repair Scenario



- After the first use life, a component i.e. battery is repaired to be used for the next 3 years
- 1 laptop was needed and a repair activities

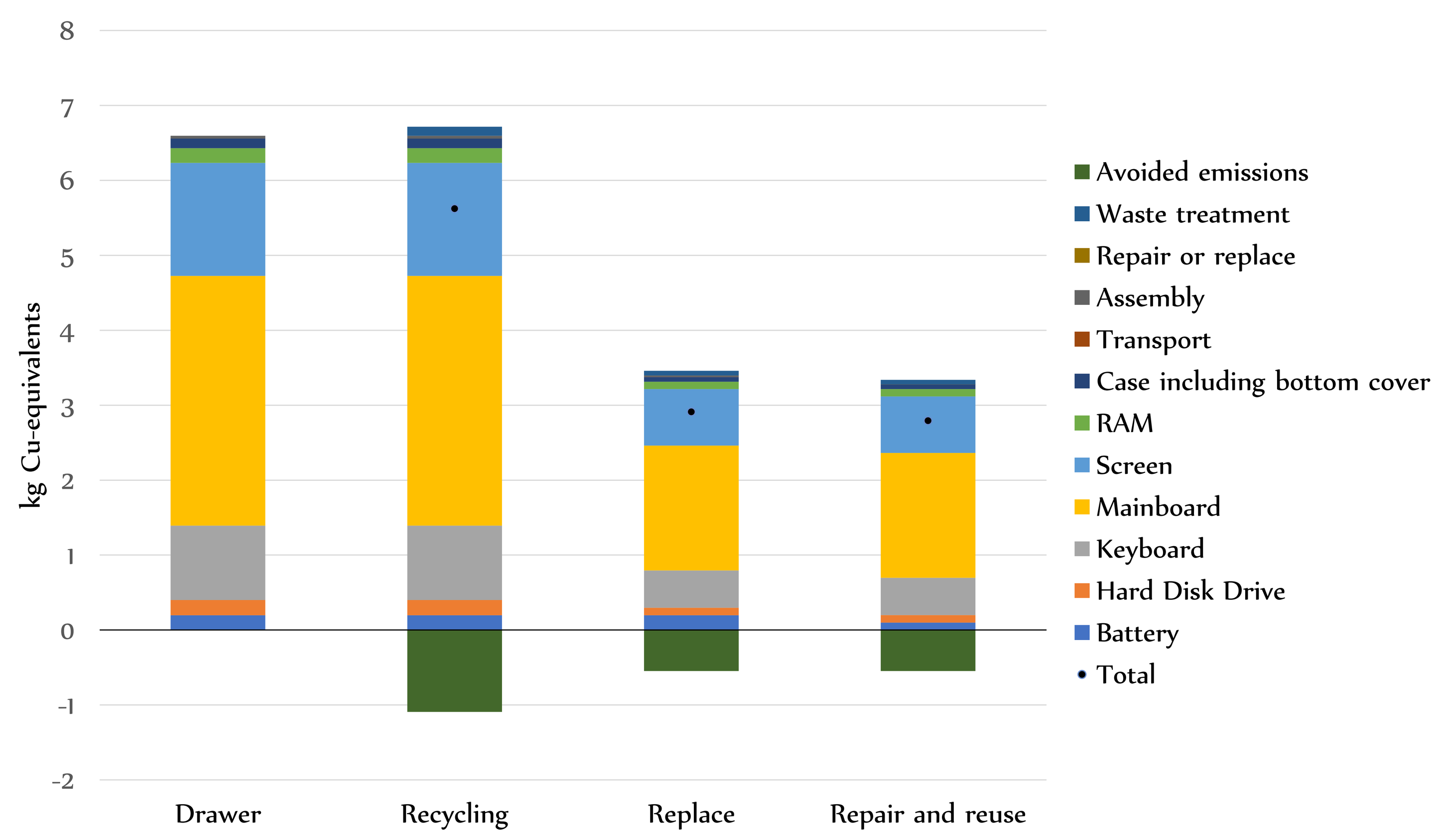
❖ Average service life of a laptop was assumend to be 3 years for all scenarios

Enviromental impact assessment methods Investigated

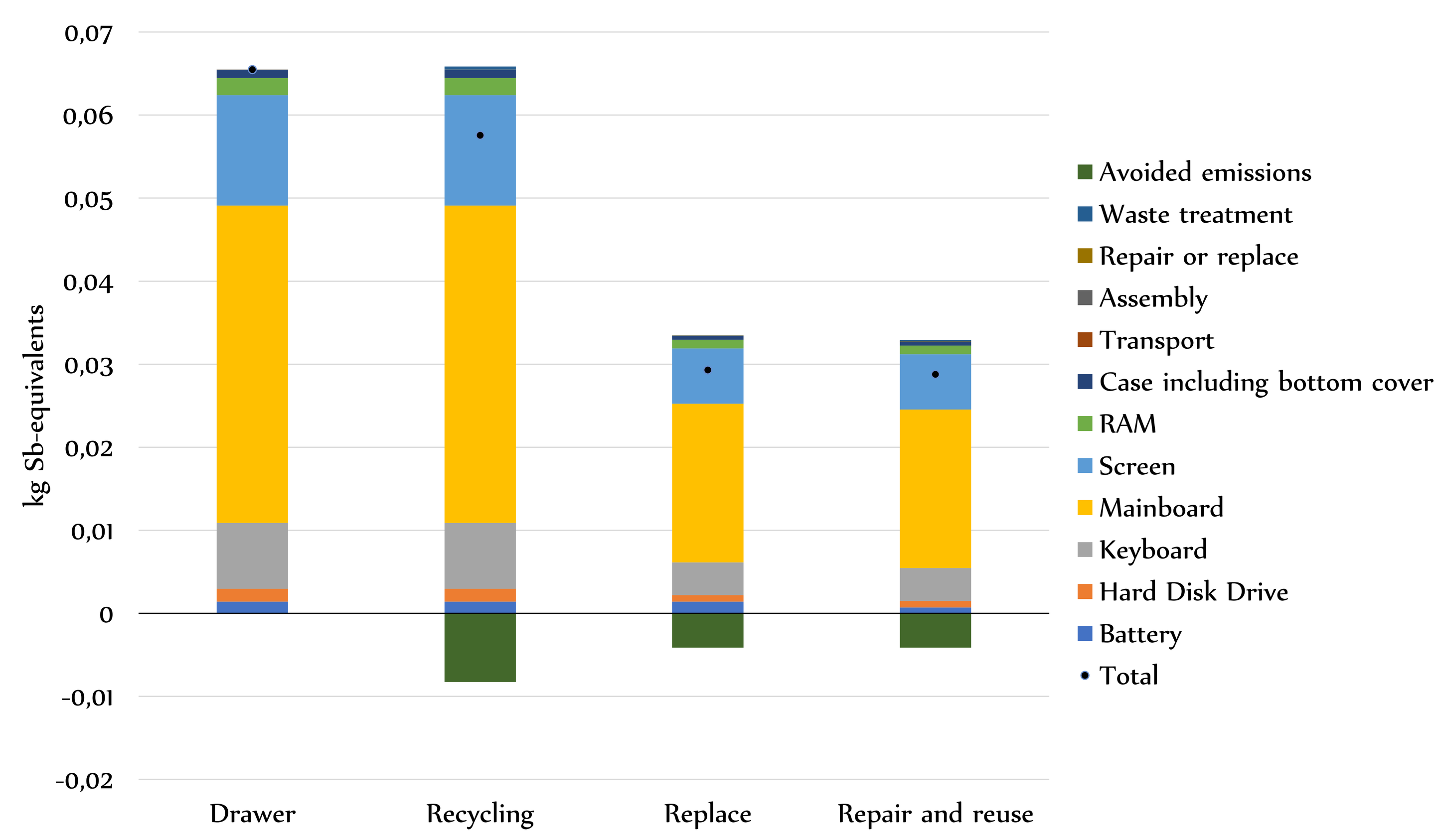
Method	Unit	Basis for characterization factors (CF)	Reference
Mineral resource scarcity in ReCiPe method	Kg Cu-equivalents	Surplus ore potential	Huijbrechts et al., 2017 Vieira et al., 2016
Resource, minerals and metals use in Environmental Footprint method (EF-method)	Kg Sb-equivalents	Abiotic depletion potential (ADP) ultimate reserve	Van Oers et al., 2002 as implemented in CML (2016)

Results

Mineral resource scarcity in ReCiPe 2016 Midpoint (H) Method



EF - Method



Conclusions

- The ReCiPe and EF method show similar results
- The largest impacts are from the mainboard and is mostly caused by gold consumption
- The repair and reuse scenarios have the lowest impacts, while the drawer scenario has the highest impact
- Finding data for material use in laptop components is challenging, and datasets are outdated

A method proposal to assess ligno-cellulosic resources criticality at the firm level (LignoCrit)

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INTRODUCTION

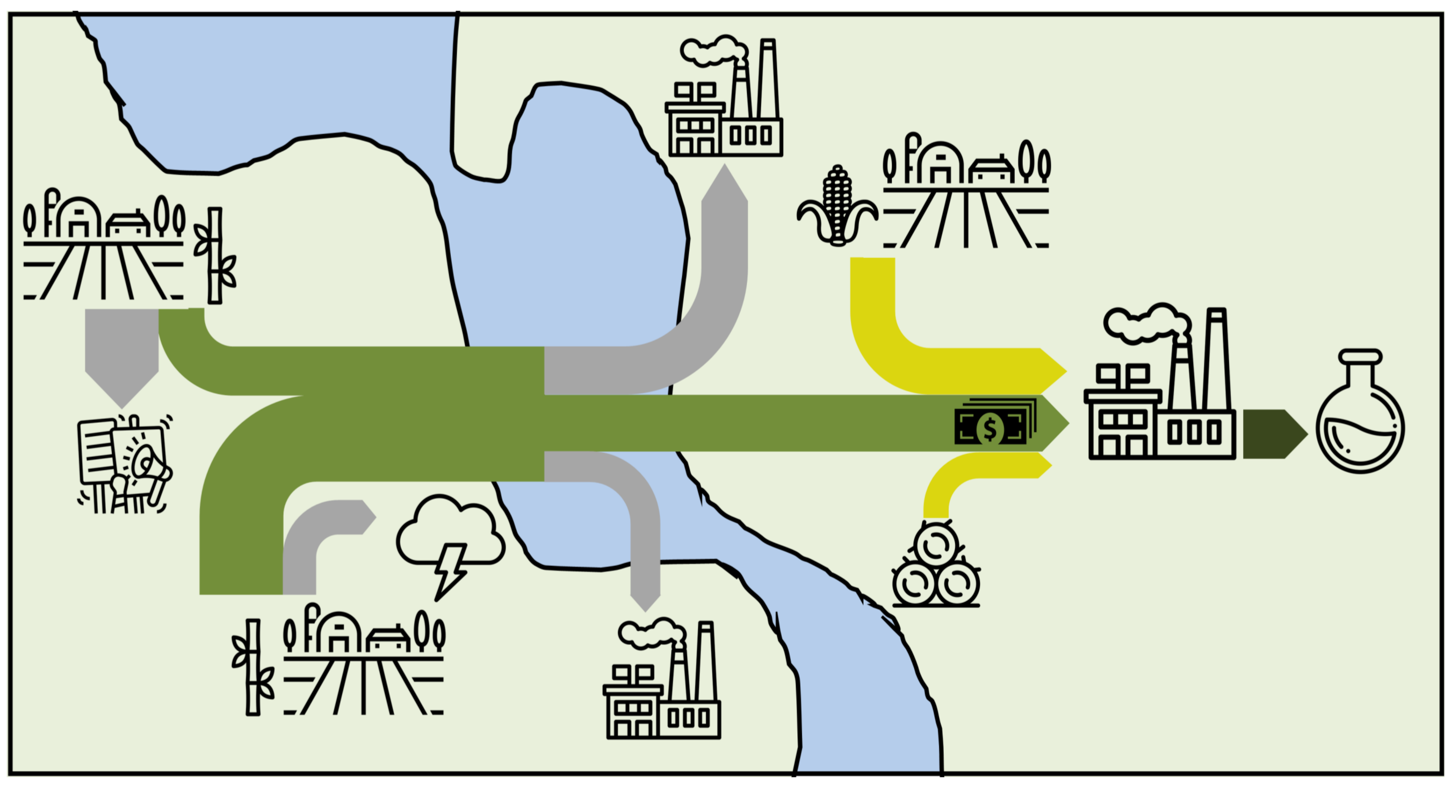
CONTEXT (1)

Bioeconomy and Green Chemistry are developing and increase demand on ligno-cellulosic resources while their access is constrained by physical, economic and societal events:

→ Need to **secure and maintain access to ligno-cellulosic ersources**

→ Anticipating **potential supply risks** and **mitigating their effects**

to ensure the stability and sustainability of the firms.



STATE OF THE ART (2)

$$Criticality = f(SR, VSD, EI)\ [1]$$

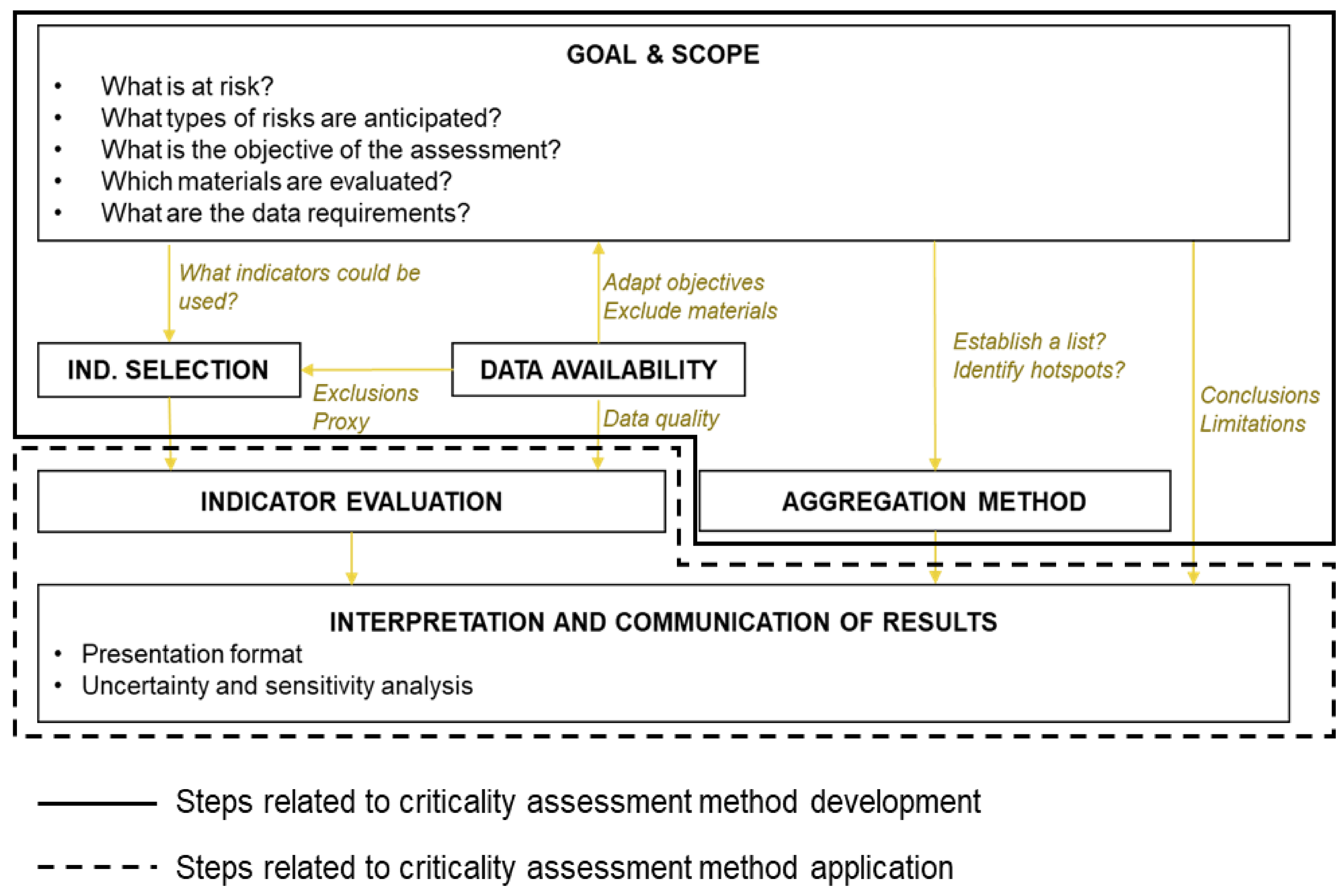
Where:

- SR = Supply Risk,
- VSD = Vulnerability to Supply Disruptions,
- EI = Environmental Implications

OBJECTIVES (3)

Developing a criticality assessment method based on the **IRTC framework** [2] to :

- Identify **potential critical ligno-cellulosic resources** and their substitutes for their operations based on [3,4]
- **Understand the potential risks and their origins** as a way to anticipate ligno-cellulosic resources supply disruptions
- **Limit their effects** on the value-chains.



METHOD PROPOSAL

GOAL AND SCOPE DEFINITION (1)

What is at risk?

Continuity in supply-chain operations.

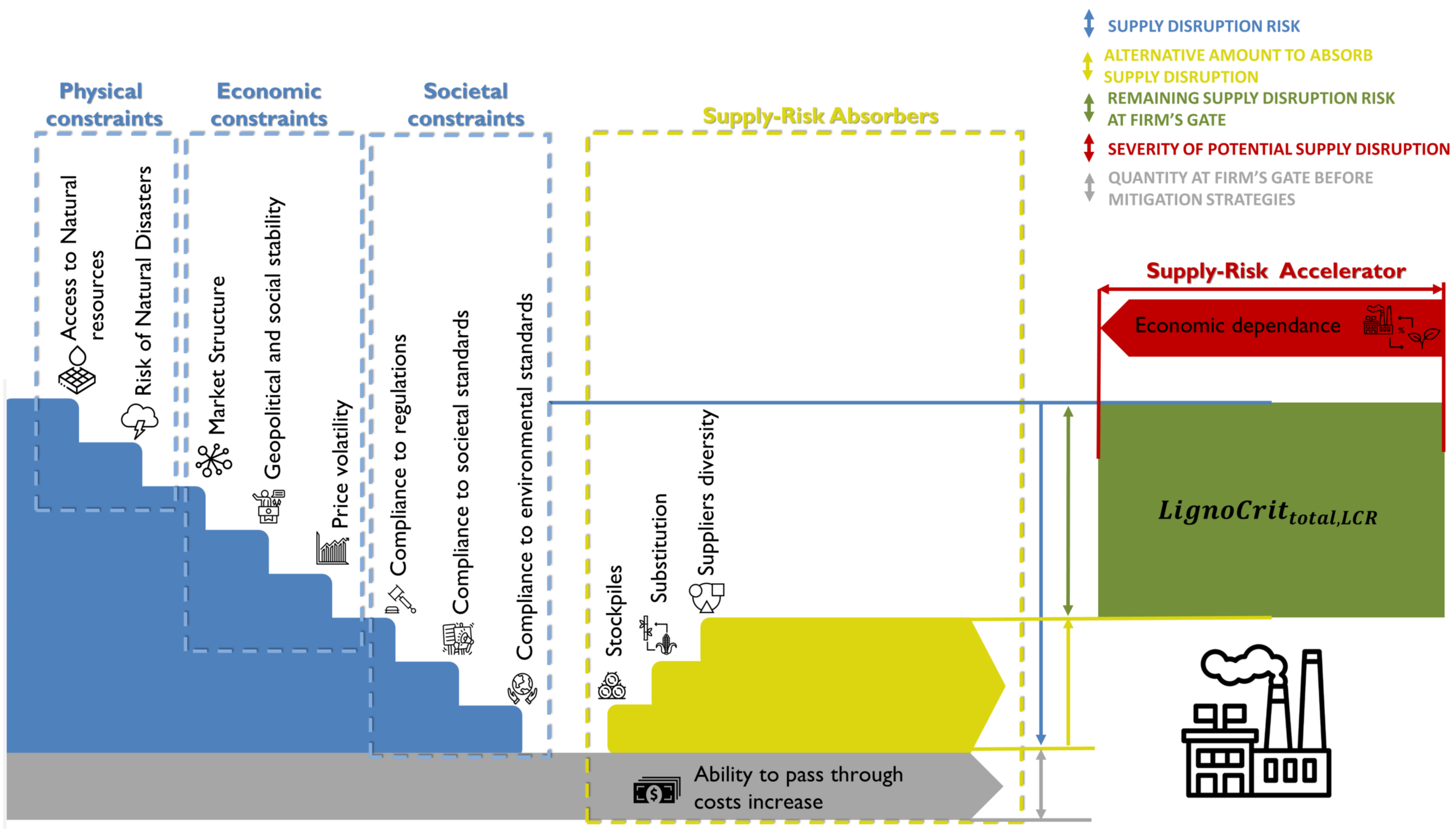
What types of risks are anticipated?

Supply risk (SR) and firm's strategic decisions and characteristics to mitigate anticipated risks.

What is the objective and which materials are evaluated?

Identify and quantify the determinants of ligno-cellulosic resources' criticality to guide feedstock selection and help firms understand and anticipate the associated risks.

INDICATORS SELECTION (2)



INDICATORS EVALUATION (3)

Characterization:

Estimation or calculation thanks to different datasets, tools and publications.

Normalization and Weighting :

Distance-to-target approach [3] and Equal Weighting:

$$LignoCrit_{LCR,SR_i} = RF_{LCR} \cdot \left(\frac{I_{i,LCR}}{T_{i,LCR}}\right)^2$$

$$LignoCrit_{LCR,SR_{c_j}} = \frac{\sum_{i=1}^{n} LignoCrit_{LCR,SR_i}}{n}$$

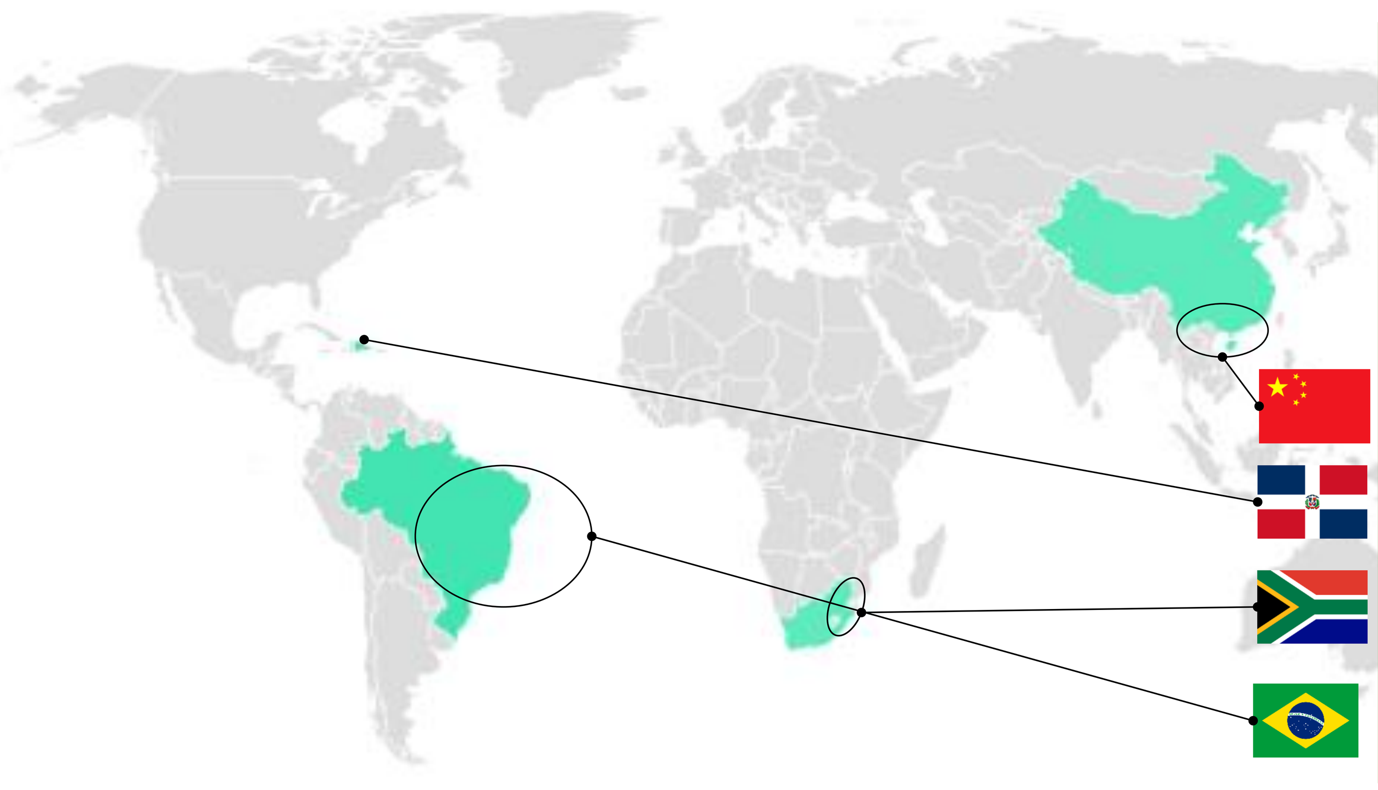
$$LignoCrit_{LCR,SR} = \sum_{j=1}^{n} LignoCrit_{LCR,SR_{c_j}}$$

$$LignoCrit_{LCR} = LignoCrit_{LCR,SR} \times ED_{LCR}$$

Where:

- ED_{LCR}: Firm's economic dependence to resource LCR
- $I_{i,LCR}$: Value of the indicator i for resource LCR
- $LignoCrit_{LCR,SR_i}$: Supply risk for the indicator i for the resource LCR
- $LignoCrit_{LCR,SR_{c_j}}$: Average supply-risk in category j
- $LignoCrit_{LCR,SR}$: Supply disruption risk for resource LCR
- $LignoCrit_{LCR}$ = Criticality score for resource LCR from region R at the firm's gate
- RF_{LCR}: Reference flow for the resource LCR
- $T_{i,LCR}$: Target value of indicator i for resource LCR

APPLICATION (fictive case)



	SUPPLY-RISK	Physical constraints	Economic constraints	Societal constraints
China	0,77	0,32	0,40	0,04
Dominican Republic	0,69	0,28	0,40	0,01
South Africa	0,79	0,30	0,44	0,04
Brazil	0,65	0,25	0,40	0,01

Application to Bagasse from Brazil, China, Dominican Republic, and South Africa:

NB: Absorbers and accelerators are considered equal for all supplier countries (excluded from assessment))

PERSPECTIVES

→ Practitioners survey to build a relevant aggregation method

→ Definition of an AoP to build feedback-loops and/or impact-pathways

→ Supply-risk database development for several resources from different countries.

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Assessment of contextualized phosphorus recycling and its criticality

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Why phosphorus recycling?

Phosphorus (P) is an **essential element for crop nutrition**. It plays a crucial role in global food security.

Phosphate rock: main source of phosphorus

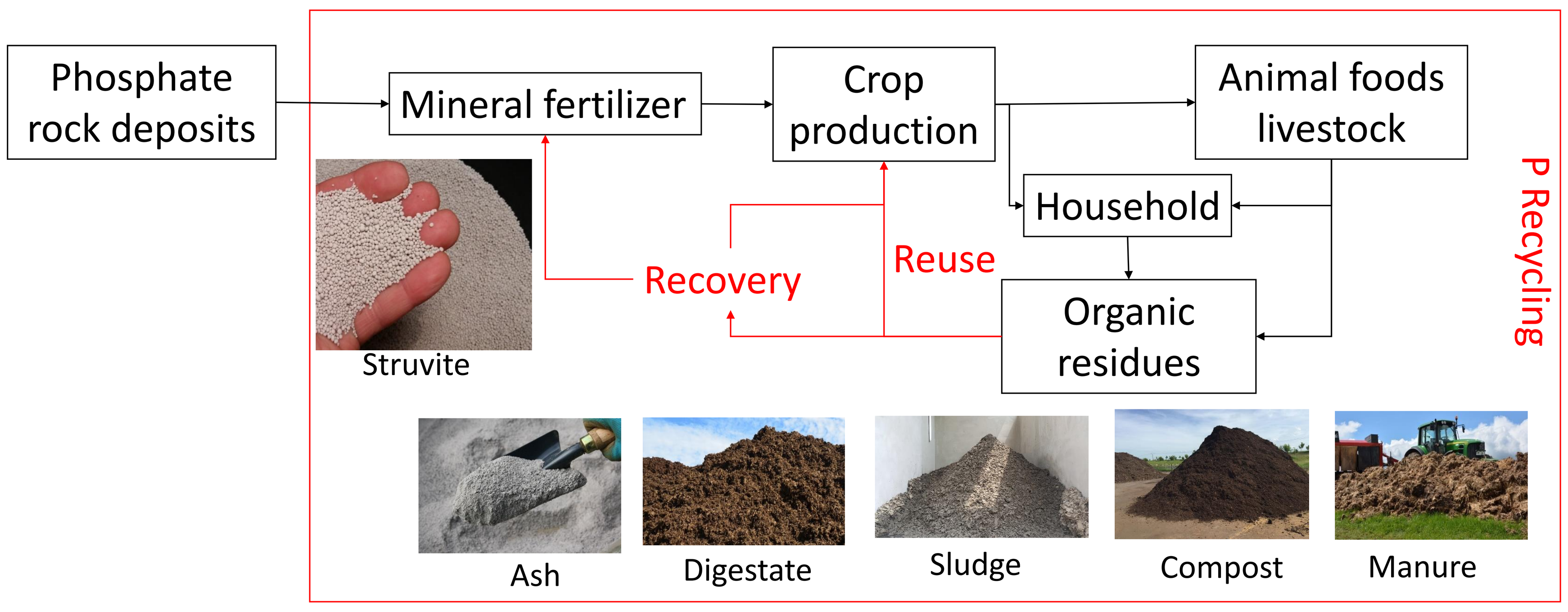
- ► Critical raw material for European Union's (EU) economy
- ► Non renewable and exhaustible resource
- ► Long time scale for the exploration of new deposits
- ► Uneven distribution of global reserves

- ► Mostly used for phosphate mineral fertilizer manufacturing (86% in EU)
- ► P as element cannot be substituted in crop fertilizing
- ► Finland is the only European country producer of phosphate rock (16% of EU supplier)
- ► High EU dependency on third party countries

In the agricultural sector, providing **P from recycling** sources is currently the only way to **mitigate phosphate rock criticality**

Main issues for phosphorus recycling

Phosphorus recycling refers to the **reuse** in agriculture of collected (i.e. organic effluent) or **recovered** phosphorus (i.e. struvite) which is contained in organic residues (OR) as digestate, manure, sludge…



- ► P content varies according to OR types, treatment processes
- ► OR diversity is a function of the economic activities present at the spatial scale
- ► OR reuse in agriculture is presided over by regulations
- ► Farmers may not use P recycled depending the characteristics of OR (price, agronomic value, location,…)

=> P recycling depends on the **geographical scale studied** and its **context** (regulatory, social, economic, agronomic,...).

The context and geographical scale are not taken into account in the evaluation of the recycling rate indicators used in the raw material criticality assessment (as EOL-RR, EOL-RIR,….)

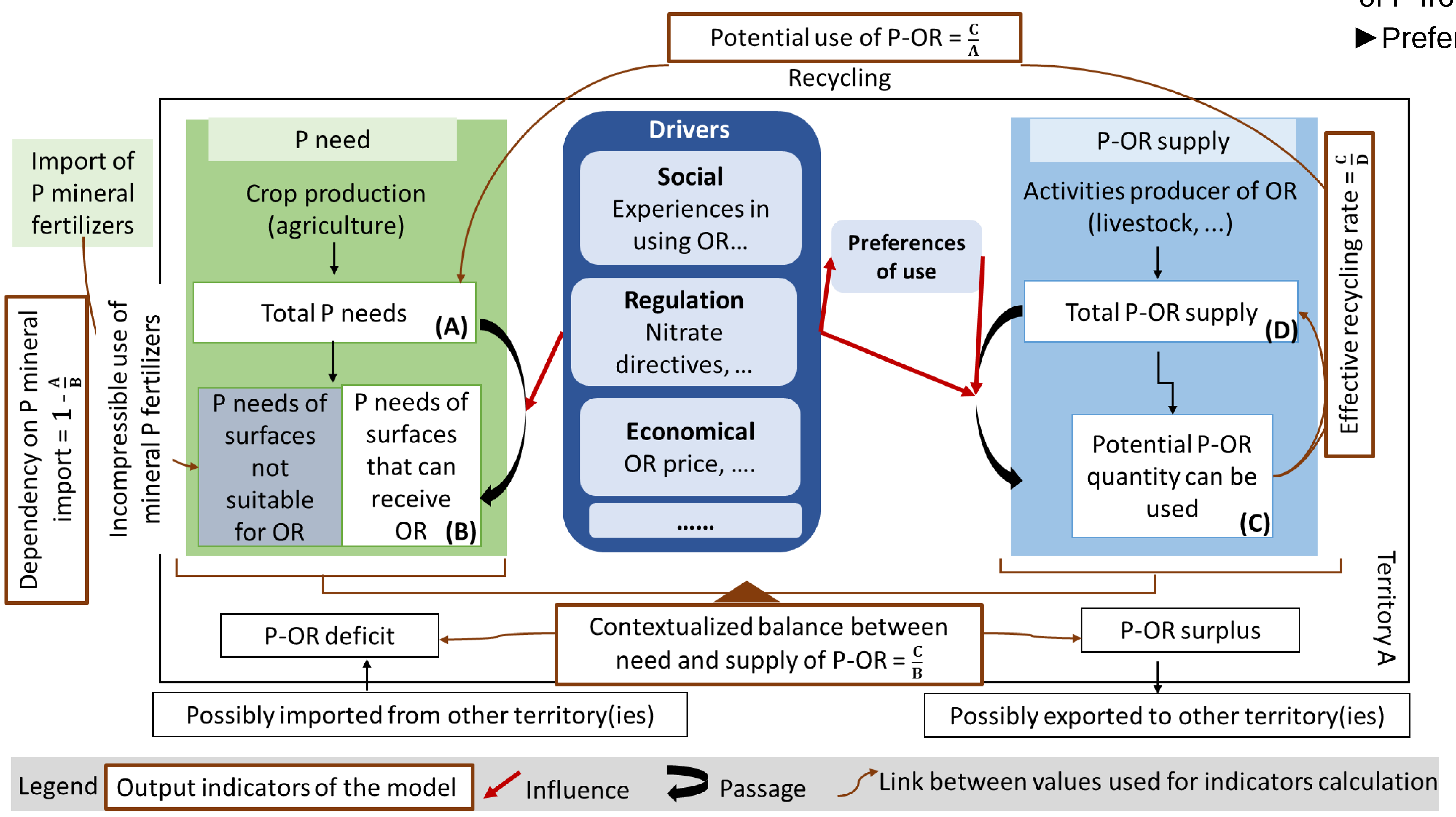
There is a need to **contextualize P recycling** at the **local scale**

Conceptual model for contextualized phosphorus recycling

The conceptual model aims to put P recycling back into its context to assess the **maximum recoverable and recyclable potential** of phosphorus from organic residues deposits in the studied territory.

To build the model, four set of parameters are identified

- ► P-OR supply
- ► P needs
- ► Drivers, i.e. any factors that can influence the use of P from OR by farmers
- ► Preferences of use by farmers



Studied territories in France

Conclusion

The proposed model will help to provide **an effective recycling rate consistent with local context** (fertilizer regulation, water framework directive, farmers preferences, agronomy context…). This promotes a **better integration of the characteristics of phosphorus recycling into criticality assessment**.

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IRTC 2023

Decoupling Economic Growth and Zero Pollution Through Industrial Waste Recycling

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Motivation

SUSTAINABLE DEVELOPMENT GOALS

Synopsis

The correlation between EKC and recycling potential indicated a downward trend showing China is moving toward decoupling. By expanding holistic utilization, the Chinese vision for 2030 advocates for decoupling economic growth and zero pollution (Circular Economy). Most cities should develop a centralized industrial solid waste management system to combat the inevitable reduction in decoupling efficiency.

Methodology

- The EKC hypothesis and decoupling analysis are both effective methods for studying sustainability evaluation.
- To our knowledge, China has never done national-level research examining the industrial waste generation inside the EKC framework.
- We shall address this lacuna in the existing literature.

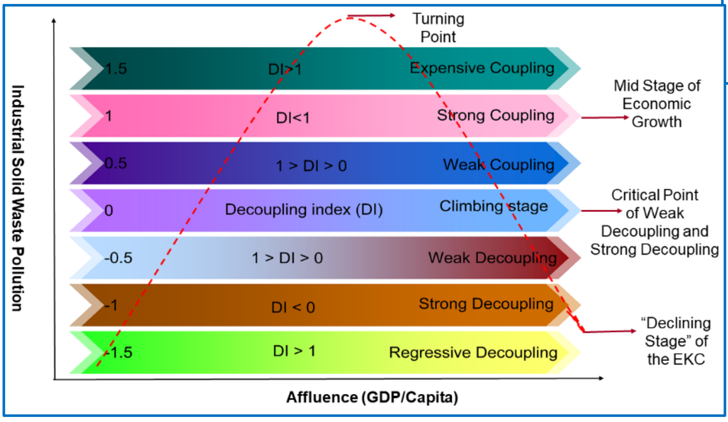

Figure 1: *The pattern of decoupling between industrial waste emissions and GDPPC(US$)*

Results

- Panel data from East Asian nations (such as China) can be utilized to evaluate the generalizability of the results.
- Again, governments should establish Environmental, Social, and Corporate Governance to find efficient, cost-effective, and investment-worthy waste utilization sources.
- Along with technological advancements, this will cut waste emissions and stimulate economic growth.
- This approach has increased industrial resource efficiency, resulting in a 50% reduction in industrial energy intensity throughout the 1990s.

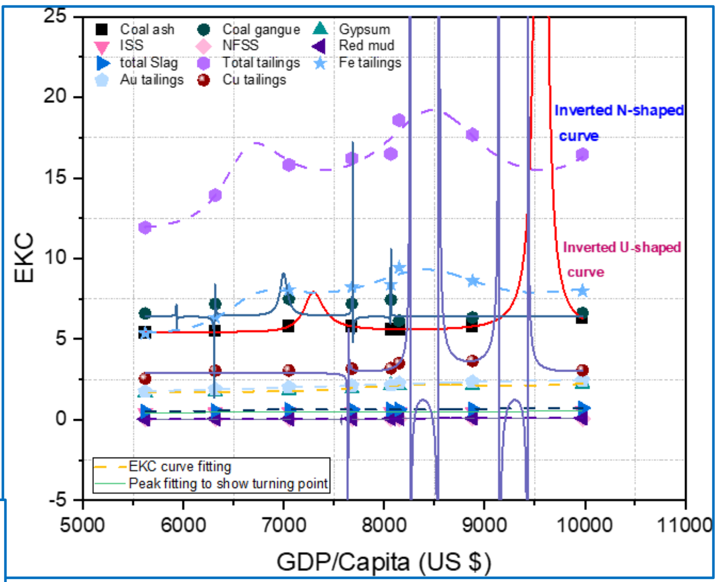

Figure 2: *Environmental Kuznets Curve (EKC) and decoupling index of industrial waste emissions and GDPPC (US$)*

Conclusion

- Global attention has shifted substantially from natural mining to urban mining as a result of escalating resource shortages and environmental damage.
- This study's industrial waste EKC calculations could influence Government Industrial Waste Management Policies.
- Thus, this Decoupling diagram can help create an industrial waste management finance system.
- The Funding Scheme would charge industrial waste management and pay funds to qualified recyclers.

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Direct Critical Metal Footprint of the UK Households

Xiaocheng Hu, Xiaoyu Yan

Introduction

- Critical metals (CMs), such as cobalt, indium, lithium, palladium, tantalum, and rare earth elements (REEs), suffer from significant global supply risks due to their vulnerabilities to economic shocks.
- In the absence of a closed-loop recycling system, most metal-rich electrical and electronic equipment (EEE) would end up in landfill or waste incineration plants, causing significant environmental impacts as more energy and materials are needed for manufacturing new EEE.
- Waste EEE (WEEE) usually contain a significantly higher concentration of metals (including both common metals and CMs) than naturally occurring ores, offering a great opportunity for sustainable sourcing.
- UK is one of the largest WEEE producers in the world, generating 23.9 kg per capita annually.
- In this study, we quantify the annual direct critical metal footprint (CMF) of UK households during 2011 and 2020, defined as the amounts of CMs contained in the EEE products purchased, owned, and disposed of by UK households.

Methodology

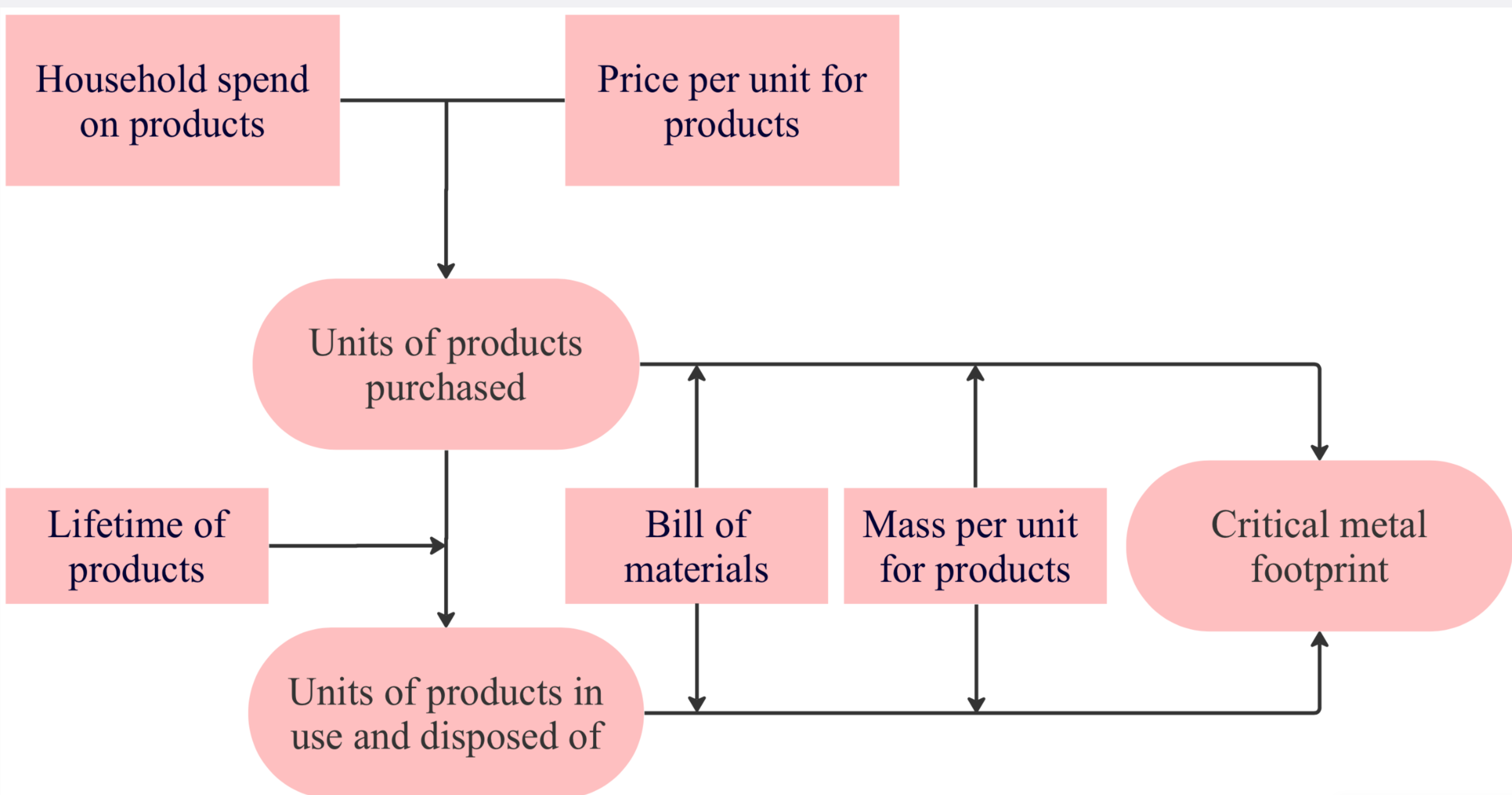

Fig. 1 | **An overview of the methodology**, with rectangles showing the input parameters and ovals showing the outputs.

- Family Spending in the UK and Consumer Price Inflation Item Indices and Price Quotes (both published by the Office for National Statistics) are used as the main data for household spending and price per product.
- The lifetime of each EEE is assumed to follow a Weibull distribution.
- Bill of materials (BOM) data are primarily extracted from the Ecoinvent life-cycle inventory database (version 3.8).
- The average mass of each EEE is collected from online sources including Amazon, Argos, and Reuse Network.

Botton line: Our analysis provides new insights for researchers, governments, industries, and the general public to understand the importance of CMs as well as the potential environmental benefits and economic opportunities in making these high value CMs more circular.

Results

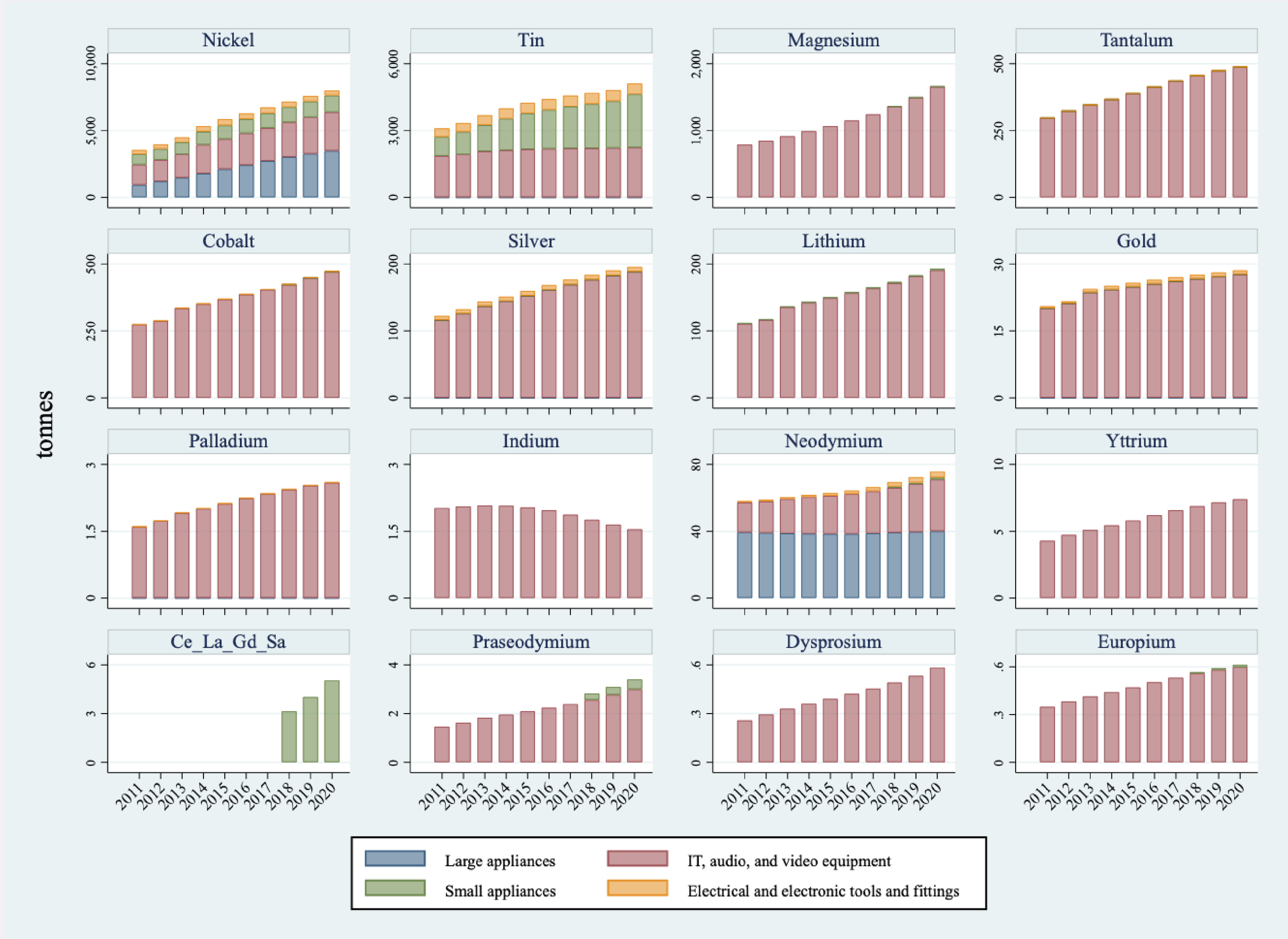

Fig. 2 | **CMF of WEEE disposed of by UK households between 2011 and 2020.** Ce_La_Gd_Sa is the sum of cerium, lanthanum, gadolinium, and samarium. Note the different scales of the y axes.

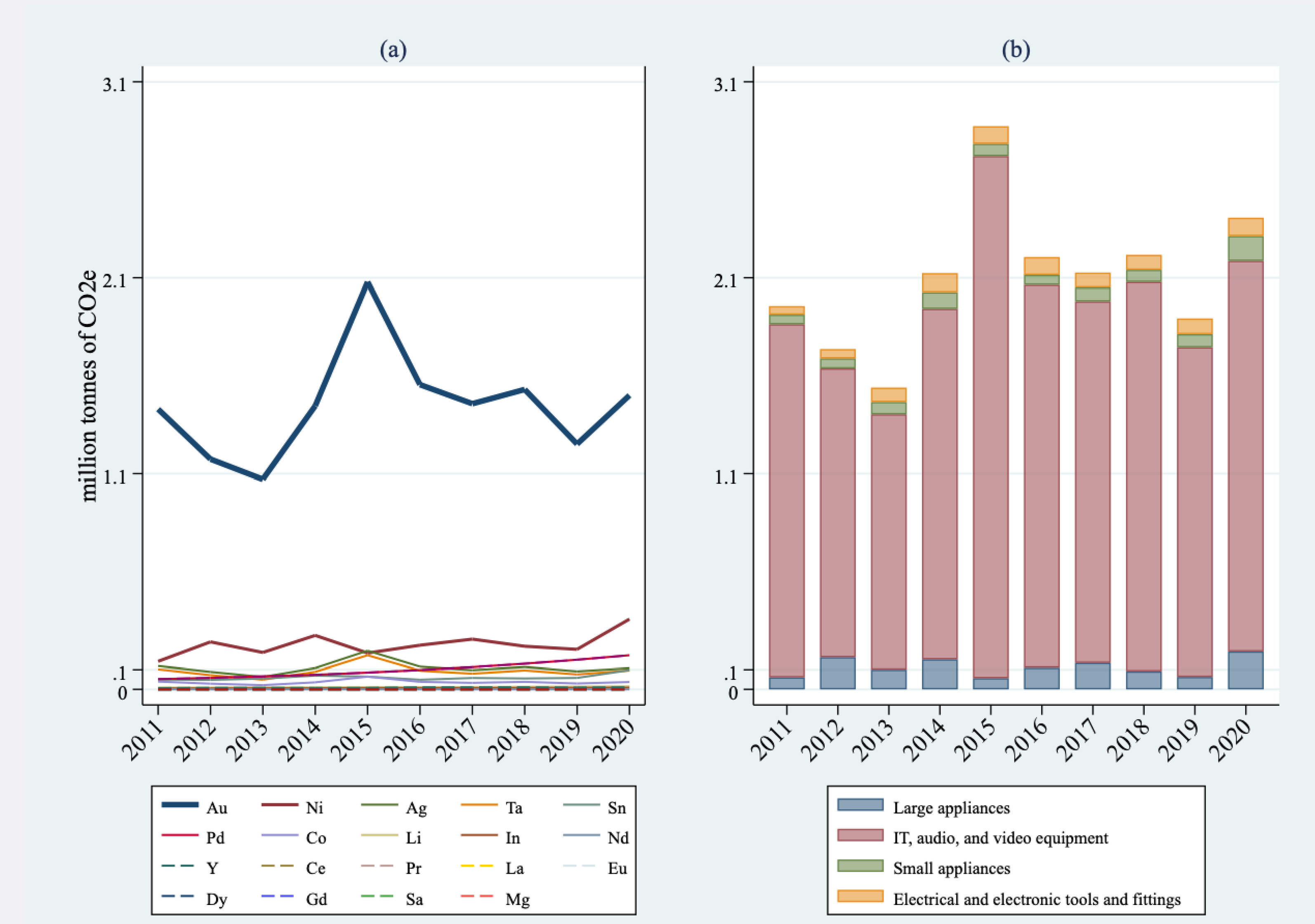

Fig. 3 | **The global warming impact of CMs contained in purchased EEE by (a) metal and (b) EEE** - the share of each EEE group in each year.

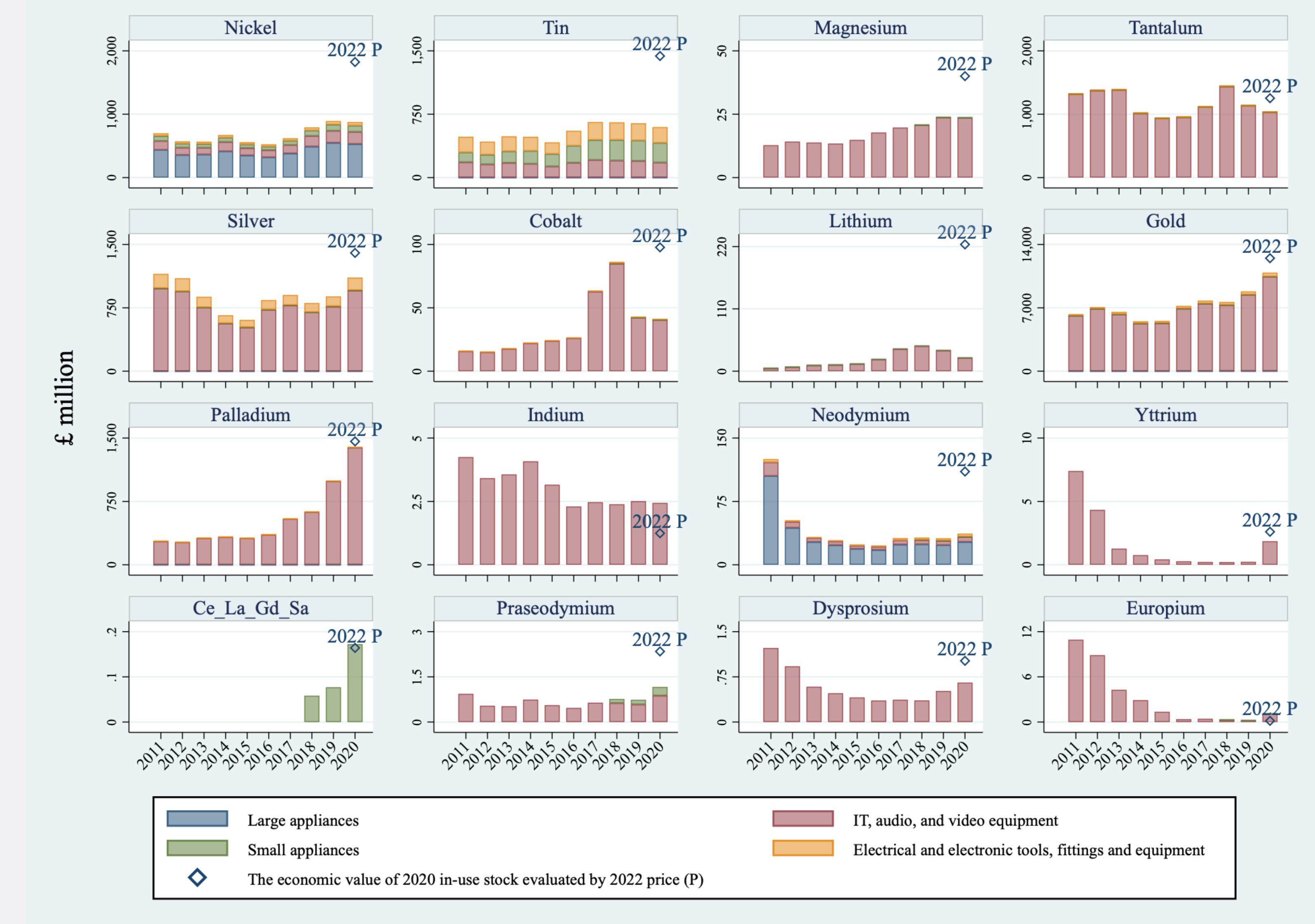

Fig. 4 | **Economic value of individual CMs contained in UK household WEEE by different EEE groups.** Note that the 2020 CMF is estimated by the price of each CM in the first quarter of 2022. Bar charts present the share of each EEE group in each year.

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NICER PROGRAMME

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UK Research and Innovation

From the stock of Lithium batteries at the end of their life : direct recycling of active materials for reuse in batterie design

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Why recycling battery-active materials?

- Battery market development
- Demand increasing of
  - Battery active materials (NMC, LCO, LFP, …)
  - Raw materials (i.e. metallic salts)

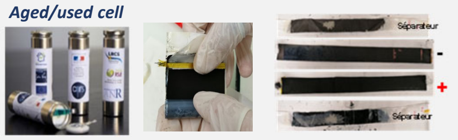
➢ ***Raw materials***
Declining availability, increasing of their costs
➢ ***Batteries at end of life***
Increasing of stock
Environment impact

Need for recycling
Transitions metal base-materials
Direct recycling process without destroying
Life Cycle Analysis

1. From batteries at end of life to spent materials

Spent materials

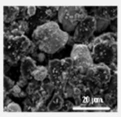
Aged/used cell



Cell opening, solvent cleaning

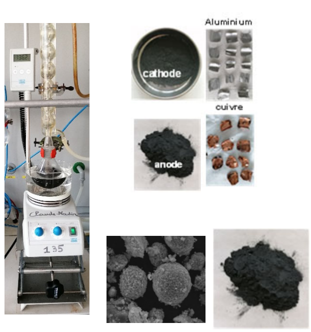
Black Mass (BM) (industrial origin)

***Successive* sieving**



Component separation

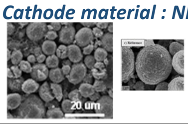
Solvent process

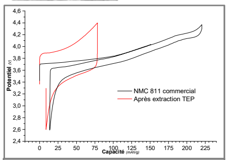


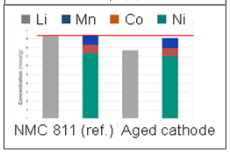
NMC 811 , Graphite

Diagnostics

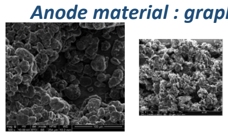
Cathode material : NMC 811

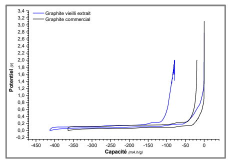






Anode material : graphite





✓ **Preserved structure**
✗ **Preserved but degraded morphology**
✗ **Lack of lithium element**
✗ **Degraded electrochemical capacity**

3. Which environmental impact : Impact life cycle analysis

From scientific datas to modelisation

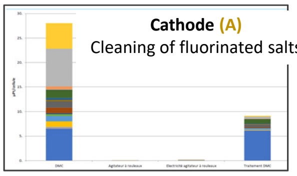
« to recycle a 40 g-18650 type cell by direct recycling »

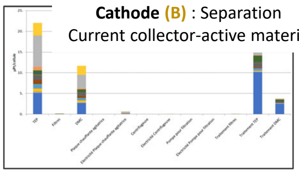
Tools :
- -EF 3.0 method
- -Software : Sima Pro 9.3.0.3
- -Database : EcoInvent 3.8
- -Cut-Off method

Indicators and methods in line with the recommendations of the European community

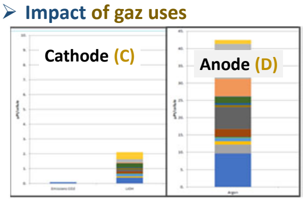
Two strongest impacts

➢ **Impact of solvent uses**



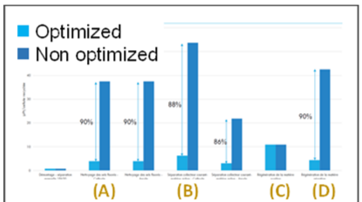


➢ **Impact of gaz uses**



How to reduce these impacts ?

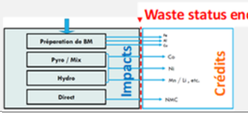
Large scale modeling
Consumables : closed loop / 10 uses

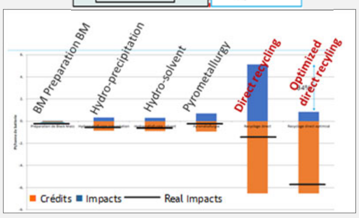


approx. 80-90% gain when optimized

Benefice of direct recycling

Credits > Impacts





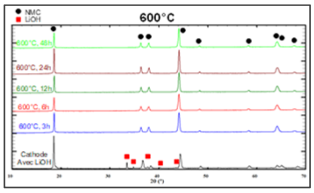
Credits > Impacts
➔ **Bénéfices for direct recycling**

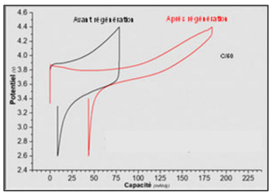
2. Direct regeneration

- ***Relithiation of cathode materials :*** Thermal treatments with lithium precursor

NMC 811 from 18650 spent cell

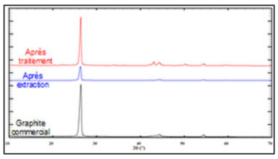
under air 600°C – 3h

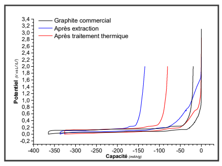




- ***Regeneration of graphite anode materials :*** Thermal treatments

From Black Mass after separation





Under Ar/H_2
600°C - 12h ou 24h

towards
- **recovered structures**
- **an improved electrochemistry**

4. Conclusions

❑ Direct recycling of battery active materials : demonstrated at lab. scale from 18650 unit cell and industrial black mass using thermal treatment under air and Argon

❑ Impact Life Cycle Analysis :
- Strong impacts related to solvent and gazes uses
- direct recycling direct recycling can be promising improving for example the uses of consumables (to reduce the loop, to increase the number of uses

❑ Encourage "process and life cycle analysis" links

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Status of Lithium-Ion Battery Recycling

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Abstract

Sustainable electric mobility is only possible if the traction batteries are recycled in a closed loop. To achieve recovery rates of over 90 %, it is necessary to recover materials from the batteries that have not been considered so far. Two of these materials are the organic solvents of the electrolyte and the graphite of the anode. In this contribution we consider possible processes, and associated difficulties, for the recovery of these materials.

State-of-the-Art Large Scale Recycling

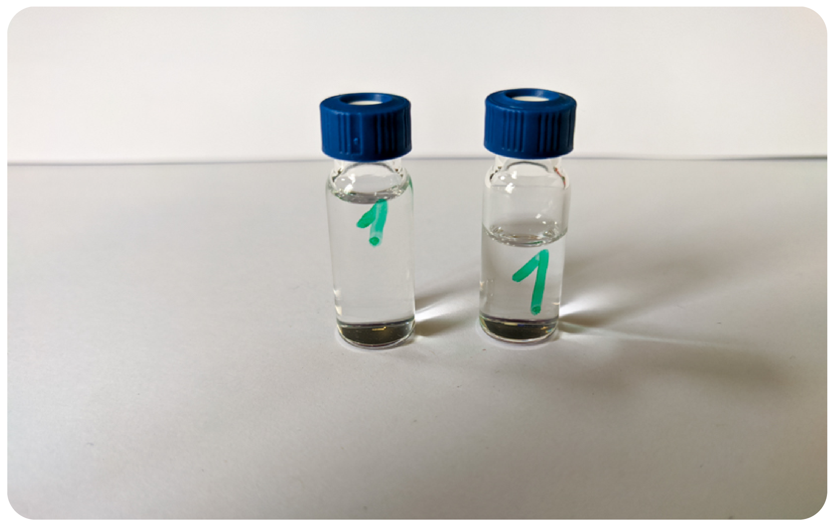
Till today, the biggest scale lithium-ion battery recycling plants are based on pyrometallurgical and hydrometallurgical processes. This is highly scalable, but materials like the solvents from the electrolyte or the graphite from the anode are not or only with high impurities recovered on a material basis. Thus, a lot of research effort is invested to develop new processes and improve existing ones.

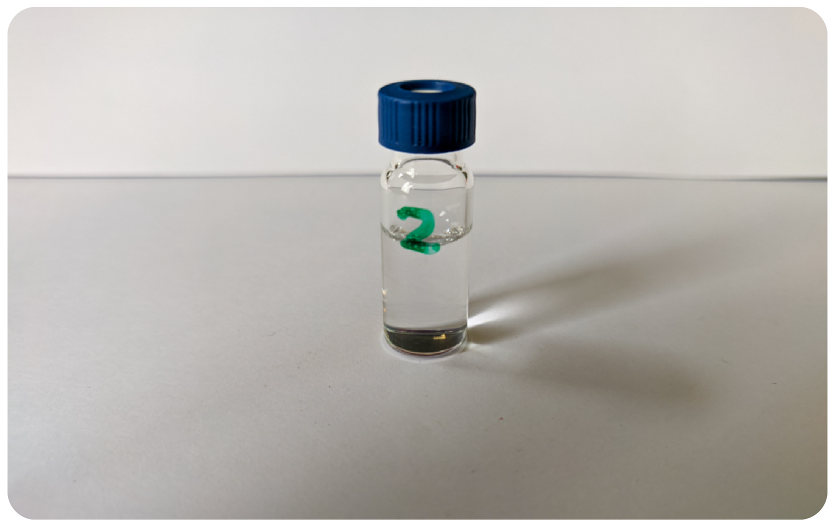
Most research focus is on using mechanical separation techniques instead of smelting the cells in a reactor. The LithoRec process from Germany successfully addressed the steps mechanical comminution and separation. However, there are still open questions about the recovery of the electrolyte and graphite.

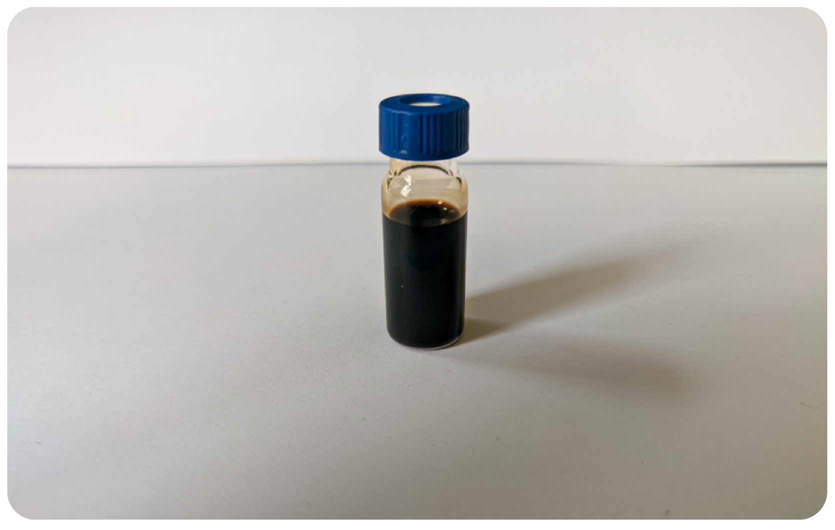
Librec Project

In this Innosuisse project (Swiss research funding agency) the Bern University of Applied Sciences and Librec AG are developing a recycling process for EV batteries located in Switzerland. The process is based on the research project LithoRec from Germany. We aim to improve the process in following areas:

- Optimized deep discharge
- Partially automated disassembly of EV packs to modules
- Recovery of the electrolyte solvents
- Recovery of graphite before the hydrometallurgical step







Recovery of the Electrolyte Solvents

The electrolyte solvents are recovered after thermal drying. The resulting condensate is contaminated with decomposition products formed during battery use and during thermal drying.

To purify the solvents, a vacuum distillation was performed. The feed is shown in the top left picture. After the distillation, we have the two fractions 1 (top right) and 2 (bottom left). The remaining liquid is the sump (bottom right).

GC analysis showed that unwanted compounds, including fluoride, accumulate in fraction 1 and in the sump. Fraction 2 only consists of clean electrolyte solvents.

Recovery of Graphite

During the pyrometallurgical step, graphite is reduced to CO_2 or used as reducing agent. In hydrometallurgical processes, graphite is either reduced to CO_2 in the pretreatment step, or remains as solid residue after filtration. The novel methods aim to mechanically separate the graphite from the metal oxides before this step. The challenge lies in engineering a process with high enough selectivity.

Three possible graphite recovery methods are investigated: flotation, magnetic separation and centrifugation. Flotation and the Falcon centrifuge show promising results and are investigated further.

The pictures on the right show the laboratory-scale Falcon centrifuge and the resulting separated black mass.

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Closed-loop Battery Recycling

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Innosuisse – Schweizerische Agentur für Innovationsförderung