Resilience of Critical Raw Materials (CRM) through Circularity

SA UrbanSymbiosis
Webinar May 9th 2025

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UrbanSymbiosis Seminar May 9th

Introduction Anna Aminoff, Hanken

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Agenda

Resilience of Critical Raw Materials (CRM)

- Introduction Circularity meets Resilience/ Associate Professor Anna Aminoff (Supply Chain Management and Social Responsibility at Hanken School of Economics)
- The role of circularity in security of supply/ Professor Györgyi Kovács (Supply Chain Management and Social Responsibility/ Hanken)
- Criticality and circularity – EU and company perspectives/ Senior Scientist Jyri Hanski (VTT Technical Research Centre of Finland Ltd)
- Sustainability perspectives of e-Micromobility/ Leading research scientist Jaana Sorvari (SYKE: Finnish Environment Institute)
- Future of sustainability/ Lead Michael Hanf (VTT)
- Concluding remarks: Resilience as driver for future / Research Manager Katri Valkokari (VTT)

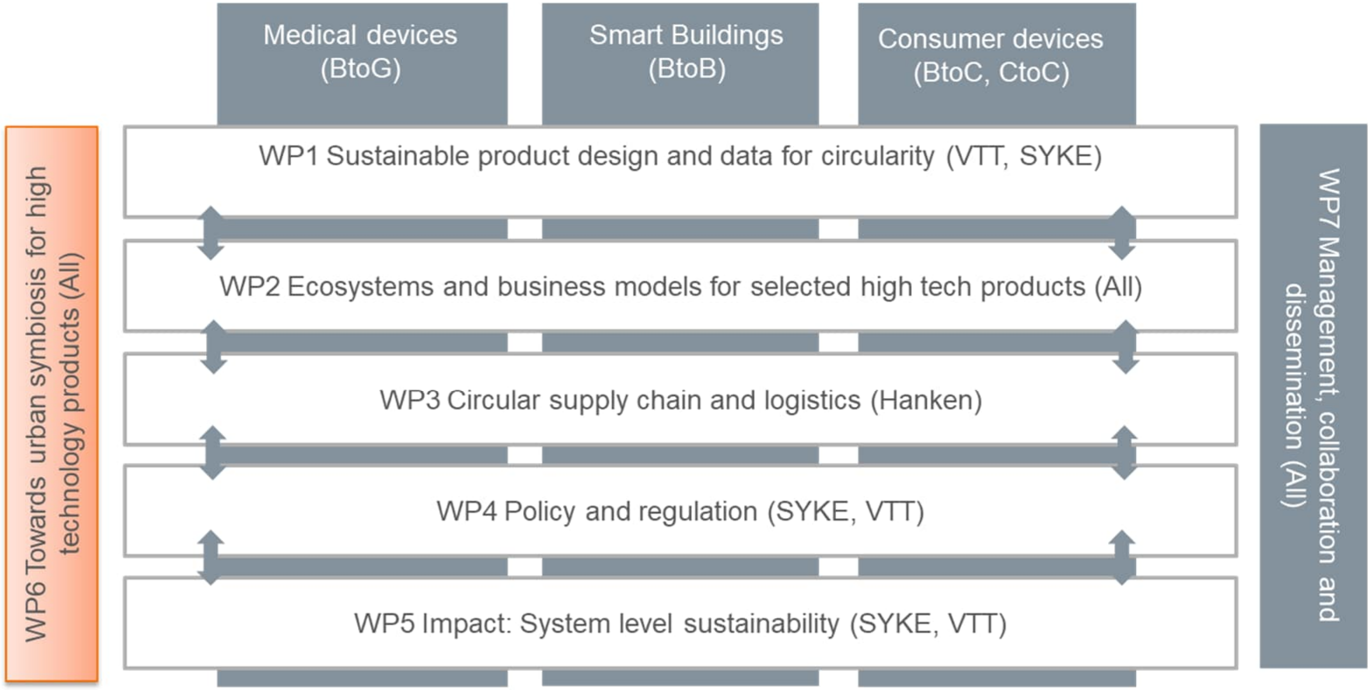
Creating sustainable pathways for cities by increasing the circularity of CRMs

To advance the urban symbiosis, we pose three main research questions:

1) What are the alternative value creation models, their implications for sustainability and security of supply for companies?

2) What are the mechanisms, means and policy intervention points available for cities to increase CRM efficiency and circularity?

3) What are the actions, following an urban symbiosis logic, that can enable cities to accelerate the sustainable and circular governance of CRMs?



https://www.urbansymbiosis.fi/

Main outcomes

- **Ecosystemic business models** for US: optimizing sustainability impact on selected high-tech products, value for stakeholders and competitiveness in global markets, and security of supply
- **Identification of circular supply chain configurations** to support US, contextual conditions under which proposed solutions are effective
- **Understanding of the role of cities** in US as a value creating actor in business ecosystems for promoting circular product design, novel business model innovation, logistics and supporting regulation
- **Pathways for CRM circularity**: synthesizing the business ecosystems, actor roles, value flows, city-level policy options and the sustainability impact

Critical raw materials

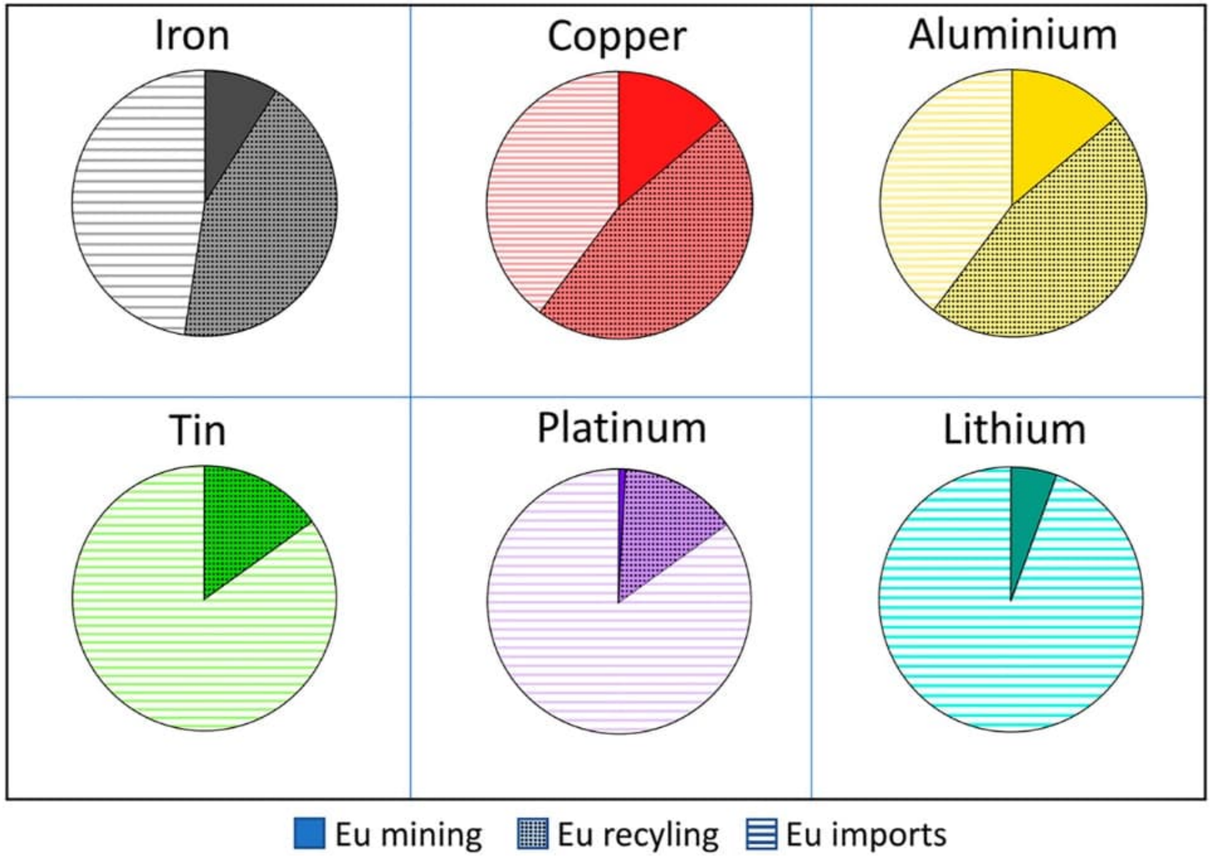
- Critical Raw Materials (CRMs) are defined as materials that are:
  - Economically important — essential for key sectors such as energy, defence, aerospace, digital technologies, and clean energy transitions (e.g., batteries, wind turbines, solar panels).
  - At high risk of supply disruption — due to limited global sources, geopolitical issues, trade dependencies, or lack of domestic production capacity.
  - The EU has identified 34 CRMs

- Strategic Raw Materials (SRMs) as a subset of CRMs that are crucial for green and digital transitions and defense technologies, and where supply risks are especially high.
- The EU has identified 16 SRMa

Circular resource strategies for CRMs

	Definition	Examples
Narrowing the loop	Reducing the amount of materials and energy used per product and limiting the number of products needed by increasing efficiency and exploring alternatives	**Miniaturization** of electronics to use less CRMs Substitution of CRMs with more abundant or recycled alternatives
Slowing the loop	Extending the lifespan and usage intensity of products and materials through strategies like reuse, repair, maintenance, and product-as-a-service models	**Refurbishment** of mobile phones Battery recelling/ refurbishment **Design for durability** in phones **Product-as-a-service** models (e.g., leasing instead of selling equipment) in medical imaging systems that use rare earths and beryllium, encouraging maintenance over disposal.
Closing the loop	Preventing leakage from the system, by reintroducing waste and used materials into production cycles via recycling, industrial symbiosis, and product take-back systems	Take-back-systems Material recovery Urban mining Industrial symbiosis

Enhancing Resilience of Critical Raw Materials through Circular Strategies



Troll, V. R., & Arndt, N. T. (2022). European Raw Materials Resilience—Turning a Blind Eye. *Earth Science, Systems and Society*, *2*. https://doi.org/10.3389/esss.2022.10058

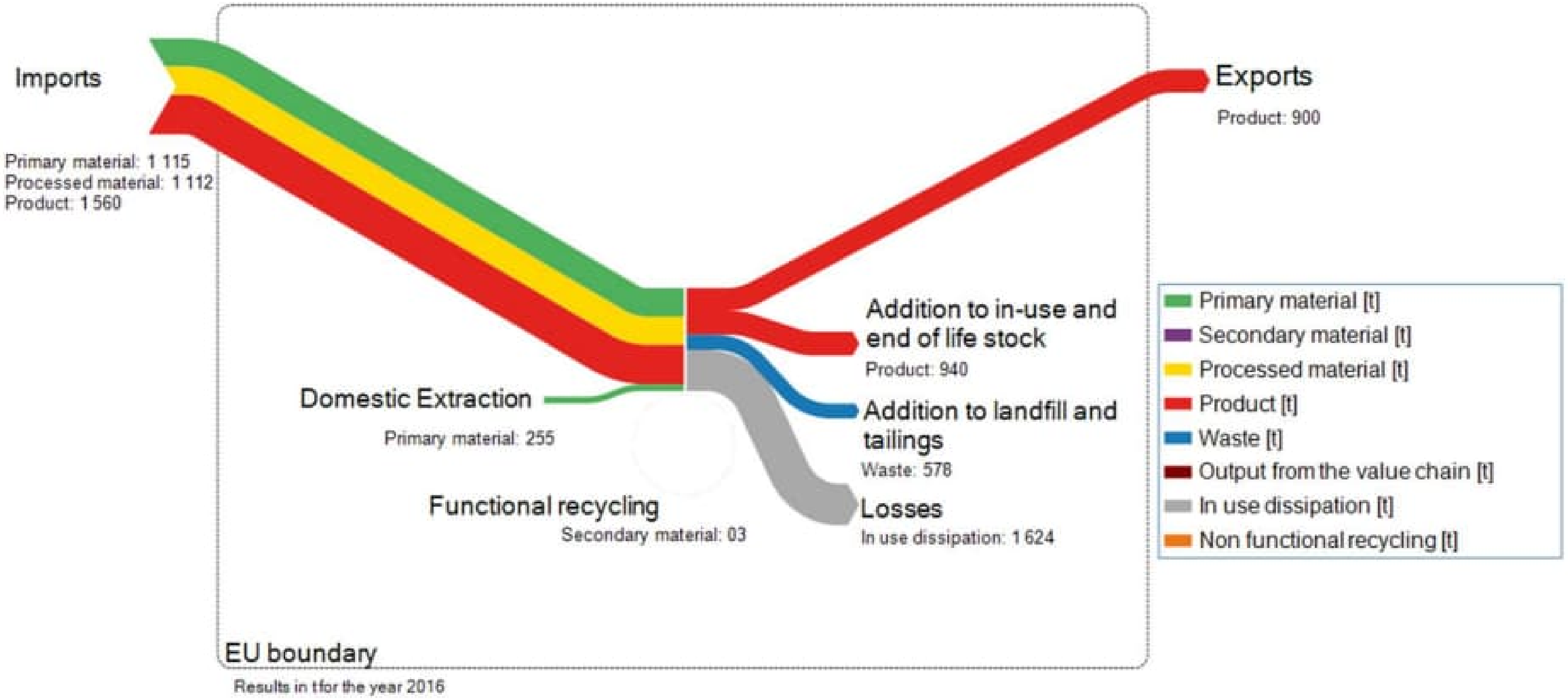


Figure 6. Simplified Sankey diagram of the flows of lithium in the EU (without the UK).

Matos et al., 2022

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THE ROLE OF CIRCULARITY IN SECURITY OF SUPPLY

Gyöngyi Kovács
Erkko Professor in Humanitarian Logistics, HUMLOG Institute
Dean of Research, Hanken School of Economics
2025-05-09

THE CONCEPT OF SECURITY OF SUPPLY (SoS)

Origins of the concept: energy security, defence security

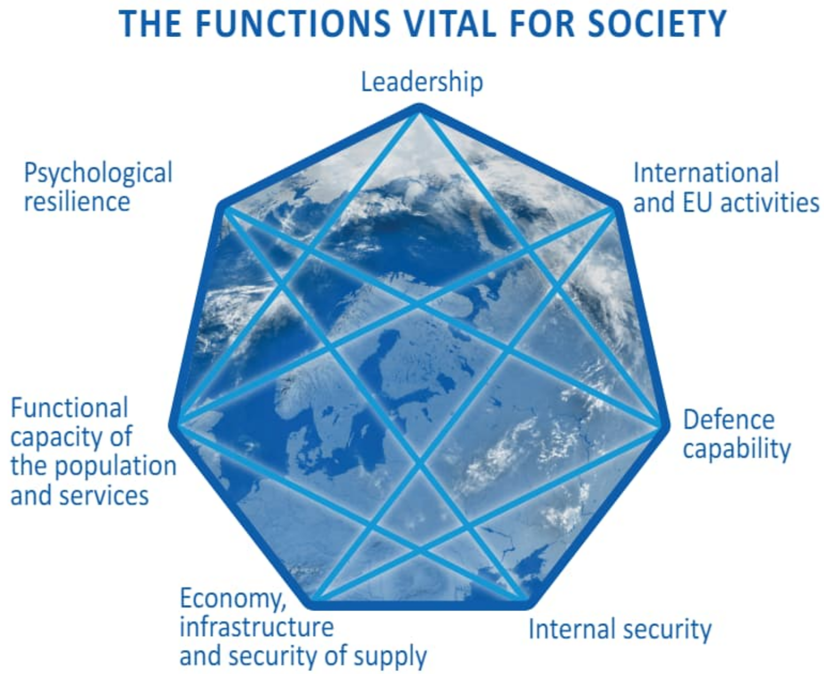
In Finland established as *huoltovarmuus / försörjningsberedskap* = security of supply

⇔ Taking a national security perspective

⇔ The backbone of comprehensive security

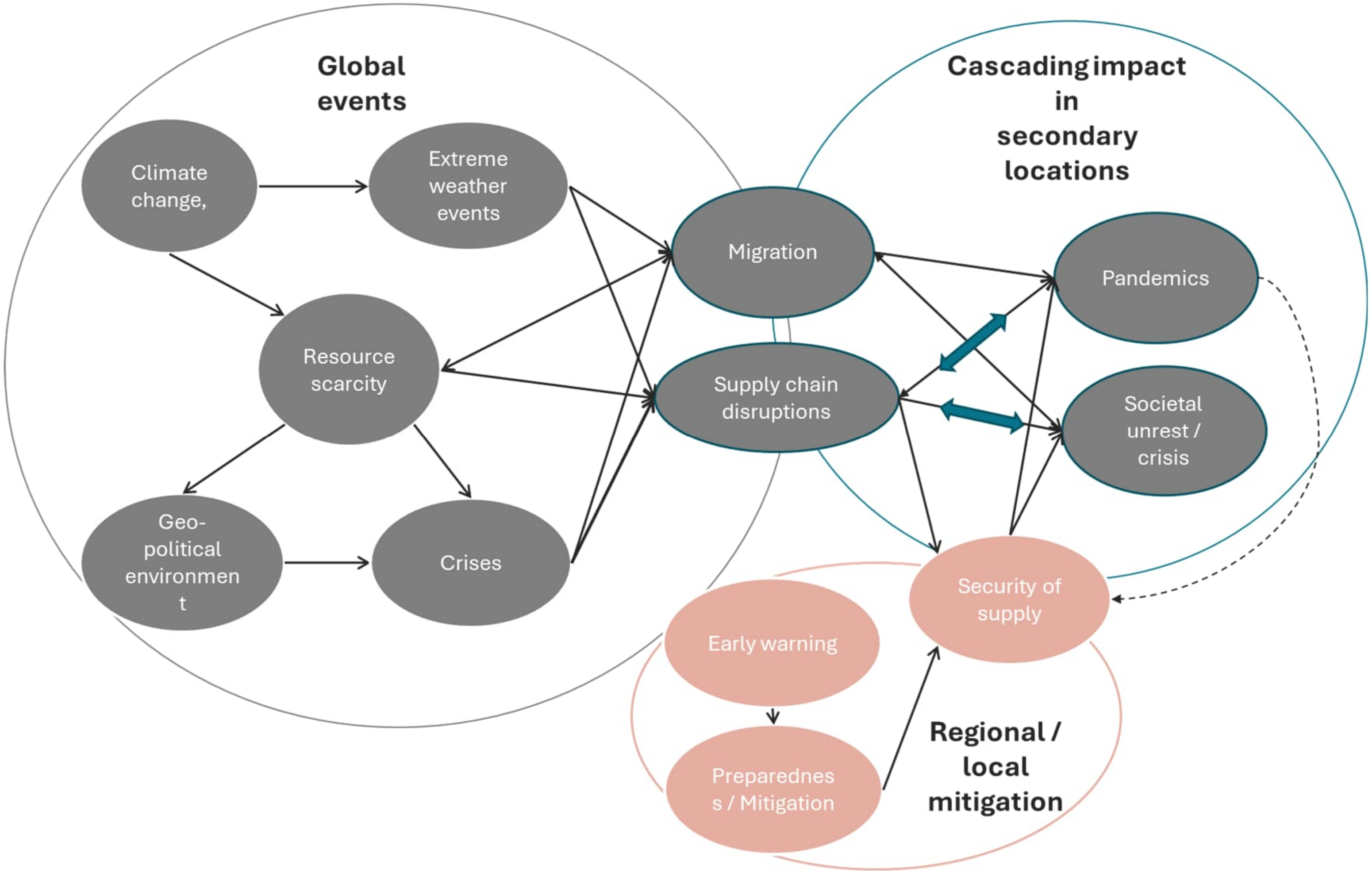
Definition of the National Emergency Supply Agency (NESA):

> *"**Security of supply** means preparation for potential crises and disruptions and continuity management by way of **safeguarding critical functions** so that society, the private sector and the population can continue to operate safely."*



Comprehensive security (Security Committee, 2024)

WE DON'T LIVE IN ISOLATION



Kovács (2022)

NATIONAL SoS

Autonomy / self-sufficiency
⇔ protectionism
⇔ backshoring, reshoring
⇔ safeguarding national production, national ownership of “essential” companies

Availability / preparedness
⇔ pre-positioning of essential materials & training across vital functions (pools)
⇔ production changeover capacity & capability

Overarching themes:
Control, national production vs import ⇔ linear supply chain view
Focus on specific scenarios (disasters, crises, conflicts)
Mitigating disruptions in global supply chains

RESHORING HAS ITS LIMITS

Not everything is available everywhere

- Reshoring final assembly does not take care of dependencies on (critical) raw materials
  (Remember the Finnish facemasks?)
- Not everything can be reshored
  (e.g. vaccine production)
- Geopolitical dependencies change over time
  ⇔ **friendshoring** / nearshoring**,** dual-multiple sourcing from different geographies, re-routing
  (*and yet we end up being dependent on the one common sub-supplier, e.g. Foxconn in Taiwan)*

Or is it?

- Materials are already part of existing goods and services

SoS AND CRITICAL RAW MATERIALS

Supply

- Scarcity of critical raw materials overall
- Access to CRM in specific geographical regions
- Environmental implications of the extractive industries

...meeting demand

- Digitalisation and growing energy intensity
- Material needs for critical functions of society
- Securitisation of supply chains

⇔ Increased needs for critical raw materials

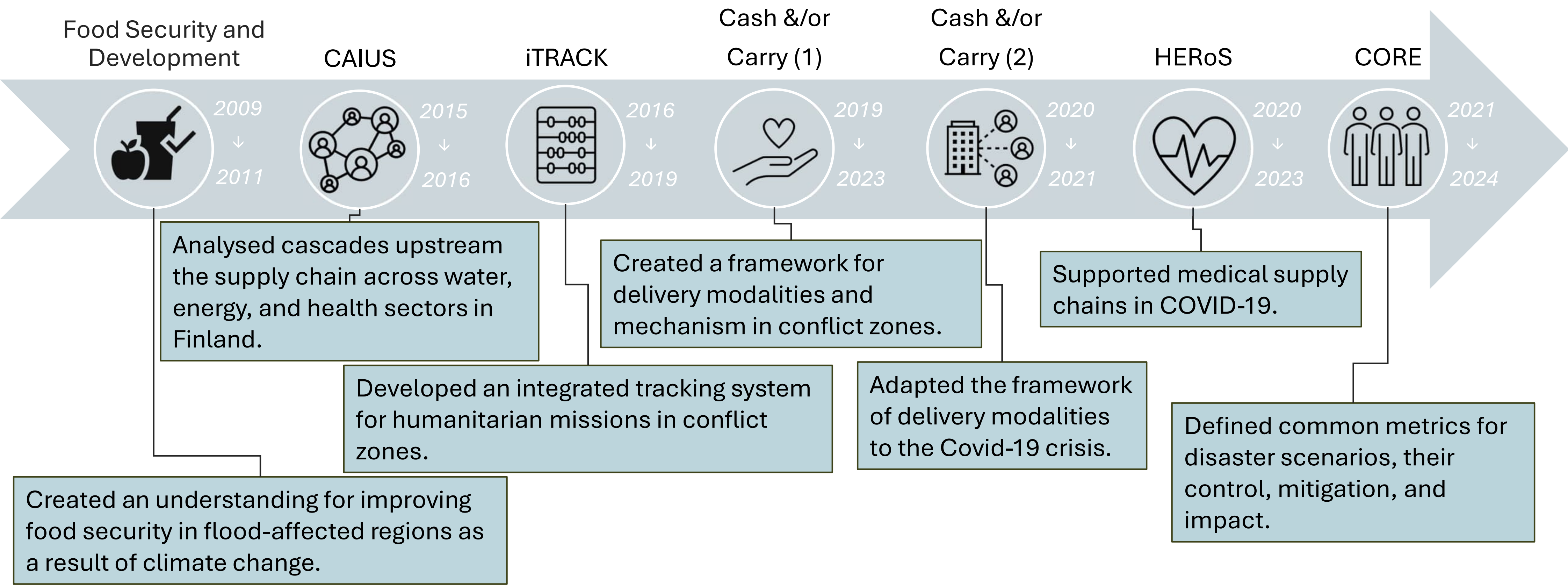
Options

Domestic extractive industries (mining and agriculture) + processing

Import from other countries

Circularity

SELECTED PAST PROJECTS WITH A SECURITY COMPONENT



LINKS AND RESEARCH THEMES

Emerging research themes in the area of resilience and security of supply:

- Breaking the silo, approach to resilience as **systems of systems** (beyond single company, sector or nation)
- Moving from engineering to **ecological approach to resilience** (adaptation to "new reality" instead of recreation of "old system")
- Incorporating the **natural environment in SoS**
- Using the **circular economy as means to access** raw materials
- Not leaving people behind, active inclusion of vulnerable groups and adaption to long-term trends (ageing, diversity)

As part of Hanken's profiling **COMPASS** (Comprehensive Security with Partnered Supply and Sustainability

)

Criticality and circularity – EU and company perspectives

Jyri Hanski and Seppo Lähdesmäki

Jyri Hanski

D.Sc. (industrial engineering), Senior Scientist at VTT

Research interest

- **Evaluation and development of industrial circular economy**
- **Criticality and critical raw materials**
- **Material flow analysis**
- **Sustainable asset management**

Motivation

US targets China's chip industry with new export controls

The measures are in line with US efforts to limit China's access to key technologies on national security grounds.

By Taejun Kang for RFA
2024.12.02

A Chinese flag is displayed next to a "Made in China" sign seen on a printed circuit board with semiconductor chips, in this illustration picture taken Feb. 17, 2023. (Illustration by Florence Lo/Reuters)

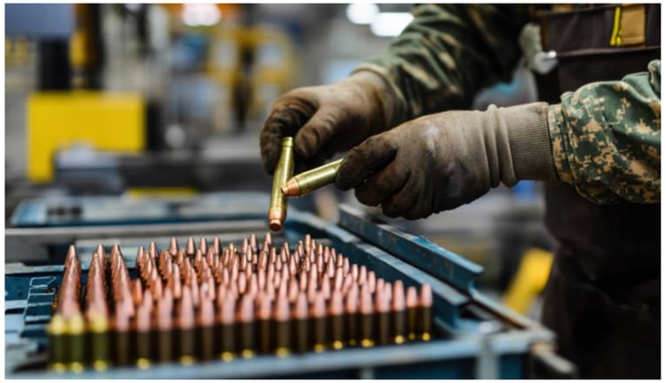
RESEARCH — JAN 30, 2025

China responds to US restrictions with export ban on select critical minerals

China has declared an export ban and imposed restrictions on several minerals and metals to the US. On Dec. 3, 2024, a day after the US expanded its technology restrictions on China, the latter government's Commerce Ministry said that exports of antimony, gallium, germanium and superhard materials to the US would cease. Additionally, graphite products destined for the US would come under stricter review regarding their intended end use.

Tungsten miner says clients in shock as China chokes supply

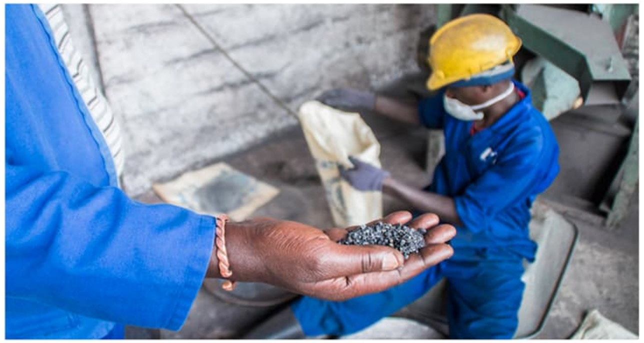
Bloomberg News | February 6, 2025 | 9:44 pm Battery Metals Intelligence China USA Specialty Minerals



Stock image.

China hits back at US tariffs with mineral export curbs

Cecilia Jamasmie | February 4, 2025 | 3:11 am Battery Metals Intelligence Markets News Asia Canada China USA Molybdenum Specialty Minerals



Washed tungsten, Rwanda. (*Image: Fairphone | Flickr.*) | *Under Creative Commons license. "Attribution-NonCommercial-ShareAlike CC BY-NC-SA."*

China deploys rare earths as weapon in trade war with Trump

Bloomberg News | April 7, 2025 | 6:22 am Critical Minerals China USA Rare Earth

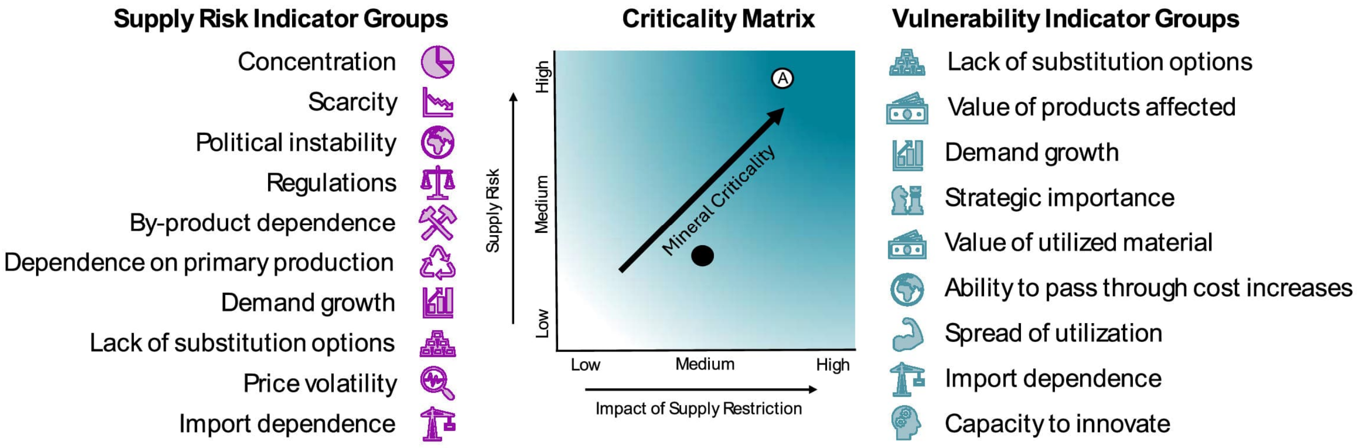
(Image: Pixabay)

Myanmar's tin-rich Wa State delays mining resumption meeting after earthquake

Reuters | April 3, 2025 | 8:43 am Asia Tin

Criticality and resilience

- **Resilience**: “ability of a system to return to its original state or a more favourable condition, after being disturbed” (Elleuch et al., 2016)
- **Critical materials**: “materials of high economic importance with high risk of supply disruption and lack of good substitutes” (European Commission, 2023).
  - Potential criticality dimensions: supply risk, vulnerability, substitutability, sustainability, resilience (Schriewers et al. 2020).
- **Criticality:**



Wietschel et al. 2025

Material criticality assessment

Schrijvers et al. 2020

- Military material stockpiles (20th century)
- Lack of local resources and Chinese export restrictions of REE 2007-2011 (20th to early 21st century)
- Starting systematic assessment of materials criticality 2008 onwards for
  - Product,
  - Technology,
  - Company,
  - Country or region,
  - and global level

EU Critical Raw Materials Act (CRMA)

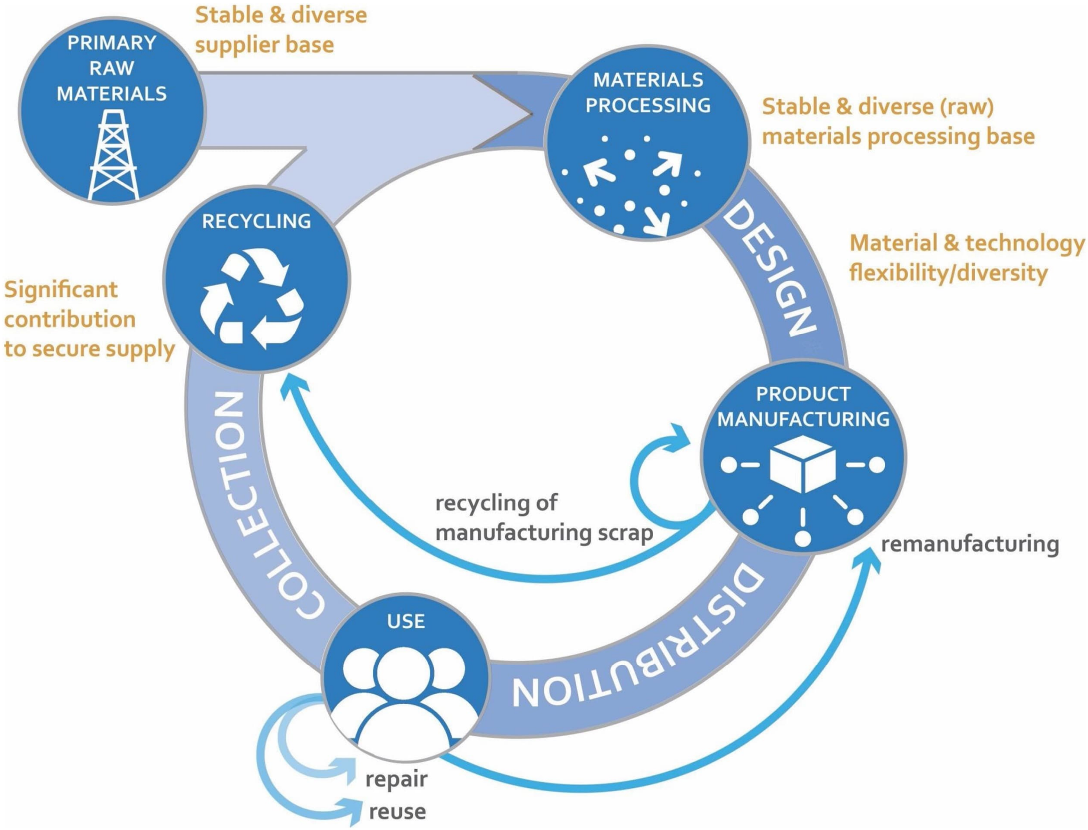
EU CRMA 2024

- ”ensure EU access to a secure and sustainable supply of critical raw materials”
  - List of critical raw materials
  - Benchmark for EU’s capabilities by 2030 for extraction (10% annual consumption), processing (40%), recycling (25%) and dependence on a single third country (max 65%)
  - Creating resilient supply chains by strategic projects, monitoring and stress-testing, coordination of strategic stocks and risk-preparedness of companies
  - Diversifying imports by trade agreements and partnerships
- Are we reaching these benchmarks?

Circular economy – an answer for increasing critical materials resilience?

Tercero-Espinoza et al. 2020

- Greater circularity leads to lower criticality
  - Decoupling supply from primary resources →self-sufficiency
  - Reducing material demand through circular strategies (not just recycling)
  - Design for circularity, substituting CRMs in design
- But,
  - CRMs typically in small volumes in EoL products
  - Technical, economic, environmental and safety challenges in CRM recovery



What can companies do to increase their supply chain resilience? Role of circularity?

Supply risk

Material and component supplier concentration
Import reliance
Concentration and scarcity of resource
Political stability of supplier countries
Circularity strategies: availability of substitutes and secondary production
...

Economic importance

Strategic stockpiles
Ability to pass-through cost increase (also price sensitivity)
Revenue impacted
Procurement strategy
Consumption volume
Diversification
...

Resilience

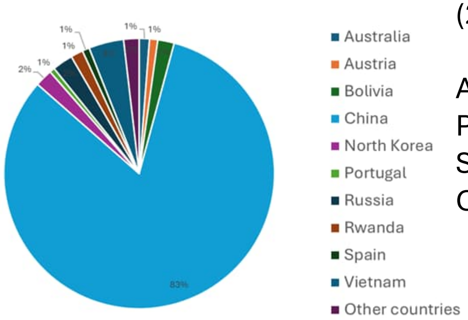
Material efficiency
Substitutability
Recyclability
Innovation potential
Backup supplier
...

Case Tungsten

Supply risk / likelihood of disruption

Extraction

Mine production (2024). USGS



EU suppliers (2016-2020)

Austria 35%
Portugal 23%
Spain 21%
Other 21%

Import reliance: 21%.

Companionality: 5%

Dependence on primary production: 42%

EU share: 3% of global production.

EU consumption: 2,622 tonnes average 2016-2020.

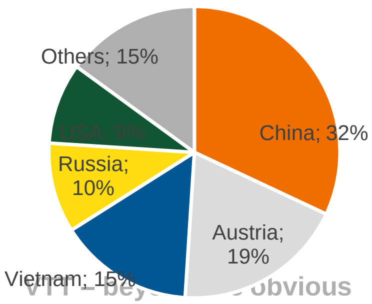
Global mine production: 81,000 tonnes in 2024

Processing

Tungsten processing (2018-2022)

China 86%
United States 4%
Russia 3%
Vietnam 3%
Austria 2%
Japan 2%

EU suppliers (2016-2020)



Import reliance: 80%.

EU share: 11.8% of global production.

EU consumption: 10,481 tonnes average 2016-2020.

WGI of main EU suppliers: -1.13, -0.51, -0.04, 0.03 and 0.73

Economic importance / effect of disruption

EU demand: 2,622 / 10,481 tonnes

Economic size of sectors: highest score on all materials on economic importance in CRM assessment (2023)

Strategic importance: Mill, cutting and mining tools, alloys e.g., for aeronautics, space, defense, electrical technology

Ability to pass through cost increase: global competition high

Strategic stockpiles: not known

Resilience / recovery from disruption

Substitutability: substitutes available for many uses but with lower performance.

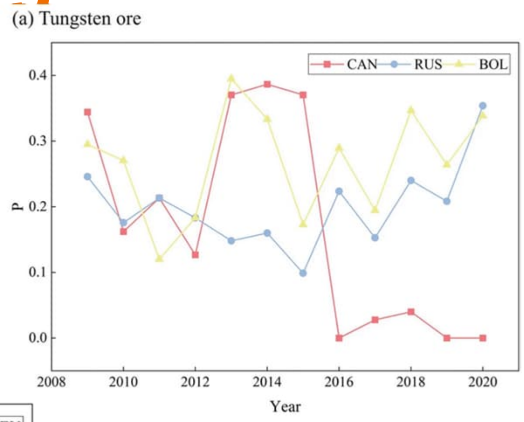
Backup supplier: Reactivation of capacities. Secondary resources: recycling of tungsten metal and reprocessing of tungsten tailings

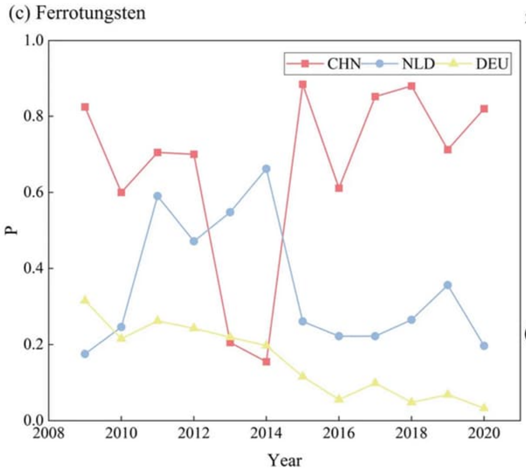
Buildup of EU primary production: Considerable reserves in the EU Spain, Portugal, Austria. Portugal and Austria existing tungsten mining

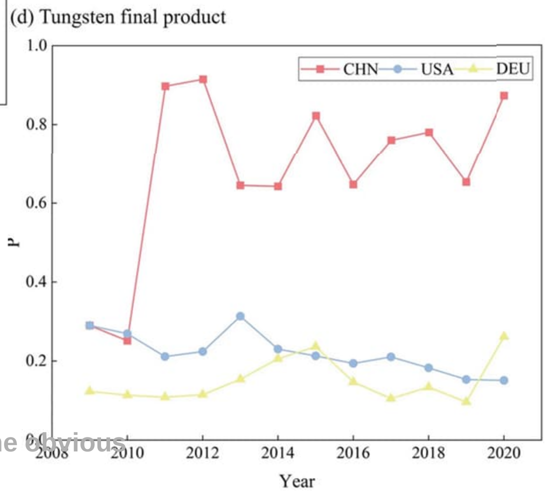
Circular economy incl. Recycling: high EoL-RIR in EU 42%

Case Tungsten: value chain resilience

Zheng et al. 2025



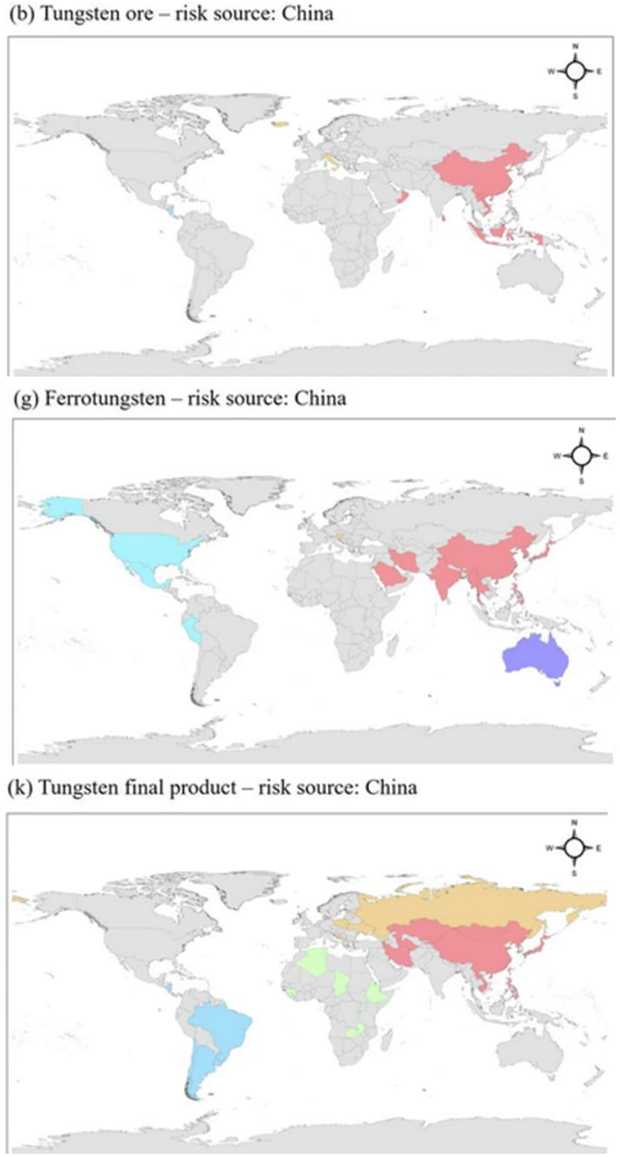




Mining

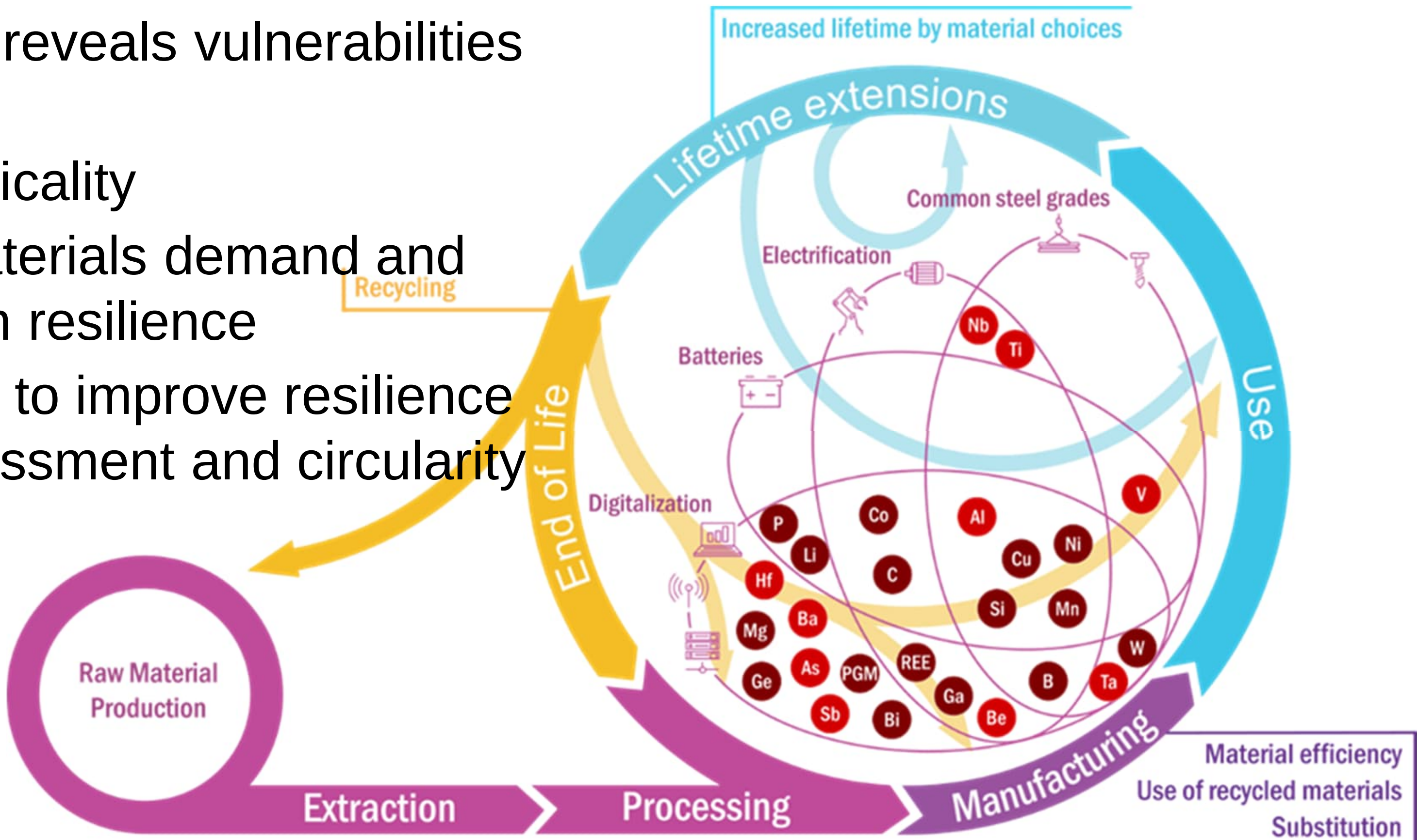
Processed materials

Tungsten products



Key messages

- Criticality assessment reveals vulnerabilities in supply chains
- Circularity reduces criticality
- Circularity reduces materials demand and increases supply chain resilience
- We help organizations to improve resilience through criticality assessment and circularity



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UrbanSymbiosis WP5

Sustainability perspectives of e-micro-mobility

Jaana Sorvari, Susanna Horn, Marko Tainio

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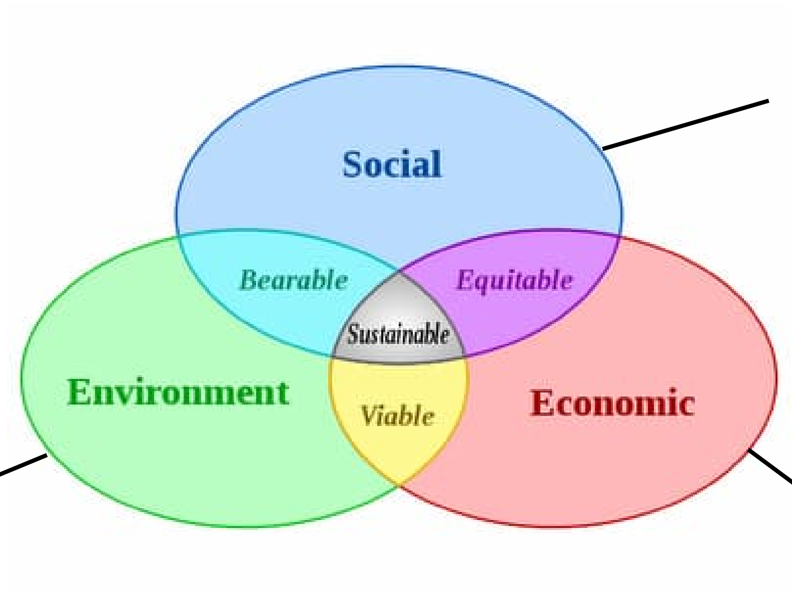
Sustainability elements in e-micro-mobility



Well-being
- human health
- other, e.g. employment, safety, equality, fairness, prospects for education and recreation, etc.

Global
- climate impact
Regional/local
- water, air and soil contamination
- depletion of natural resources

Security of supply, fair competition, profits, value retention, investment viability etc.

Motivation for the study, 1/2

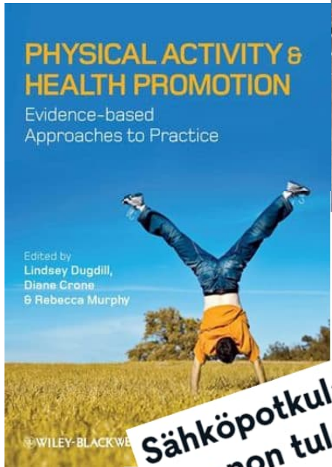
Vast number of SEPARATE e-micro-mobility studies on

- environmental impact, focus on climate impact during use phase
- **traffic accidents** and their implications for human health and mortality
- fire incidences related to Li batteries

Also

- positive health impact of physical activity

BUT no studies (?) that…



Sähköpotkulaudan akku räjähti ja sytytti asunnon tuleen – asukas pelastettiin, kissalle lisähappea

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Motivation for the study 2/2

…

- integrate the different aspects

  → **sustainability**
- consider specifically **CRM**s as one of the key sustainability elements

→→

need for a more **holistic perspective** considering the current, multiple key driving policies

  - climate change, natural resources: CRMs, zero pollution: human health, sustainable and smart mobility strategy (e.g. vision zero)

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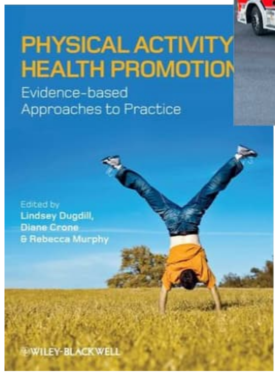
What we know based on previous studies ? (literature survey)

- Environmental impact
  - Compared to traditional motorized transport, e-micro-mobility has a positive effect on regarding mitigation of climate impact – the effect is case-specific
  - Climate impact is considered the most important
  - Negative impacts arise mainly from the extraction of raw materials

- Security of supply (CRMs)
  - Varies depending on the raw material
- Accidents
  - Increased tendency in case of e-scooters, even mortality
  - Very case-dependent (e.g. infrastructure, human behavior & driving habits…)



- Physical activity
  - Positive effect on health status, prolonged life expectancy

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Starting point

- no own experimental data → need to rely on literature data
- unavailability of literature data → not possible to consider all potential sustainability aspects
    - social aspects (due to extraction of resources, in particular), including occupational health
    - other environmental impact than climate impact, i.e. regional/local impact
    - economic impact
    - indirect impact to human health (arising from environmental pollution)
    - impact on ecosystem services

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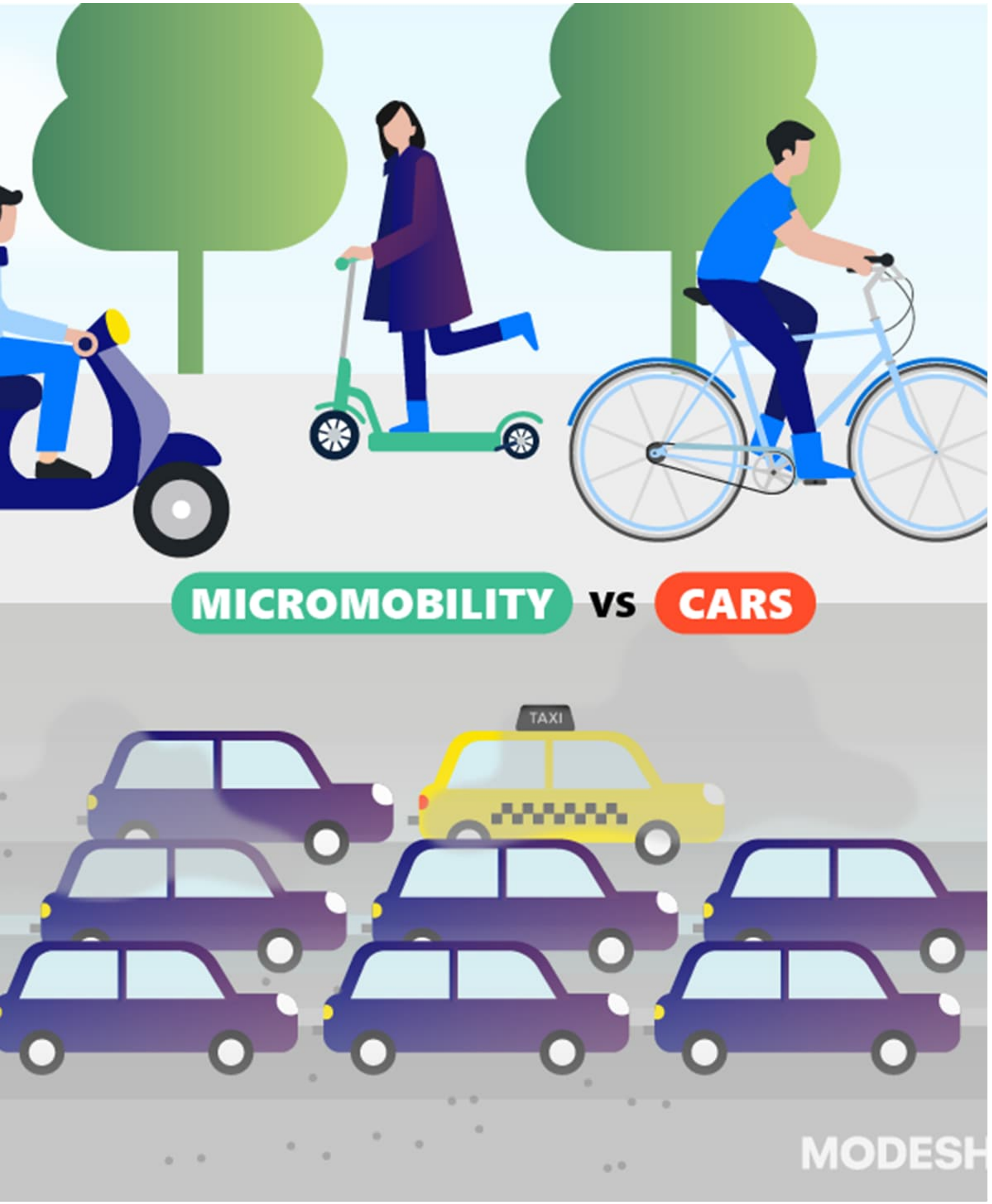

Chosen modes of travel to compare

- e-scooter
- e-bike
- walking
- combustion engine car (petrol)

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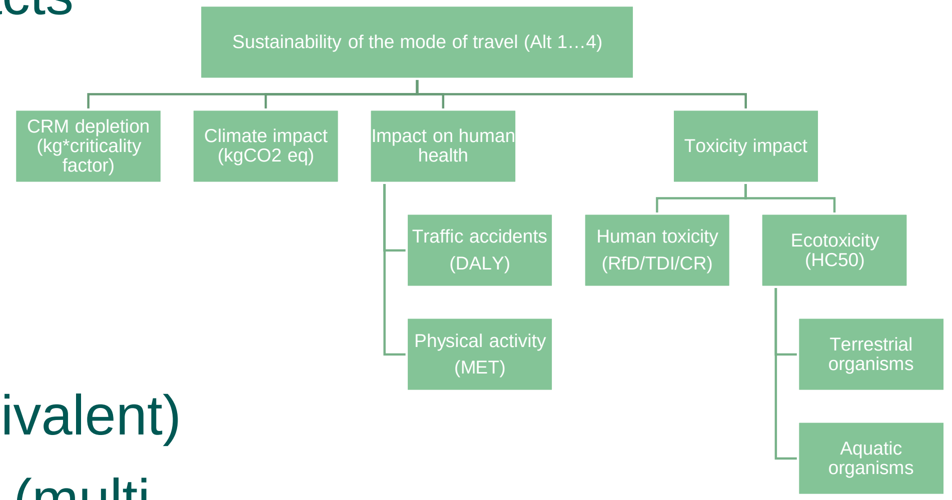
Study methods

- Climate impact: LCA, incl. substitution impacts
- Use of CRM: weighted intensity (= amount & criticality)
- Adverse health impact: DALY (disability adjusted life years
- Positive health impact: MET (metabolic equivalent)
- “Sustainability”: integration based on MAVT (multi-attribute value theory) = calculation of a preference score
- Uncertainties: analysis (qualitat + Monte Carlo?)
- Effect of criteria weighting: simple sensitivity analysis



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Study methods: DALY and MET

- DALY (= YLL* + YLD**): statistics (e.g. GBD, national incidence data, MMfE), literature + Burden Calculator (?)
- MET: Compendium + conversion

Table X. MET (metabolic equivalent) values for the studied transport modes (Source: 2024 Adult Compendium of Physical Activities, https://pacompendium.com/).

Means of transport	MET	Basis
E-scooter	2,5/2.8	corresponds standing / motor scooter or motorcycle riding
E-bike	4.0-6.8[a]	
Car	2.0	driving an automobile or a light truck
Walking	3.5	corresponds walking for transportation 2.8-3.2 mph; range 2.3-8.5 speed varying from <2 mph to 5.5 mph, firm surface, no carrying load

*time lost through premature death

**time lived in states of less than optimal health (= disability)

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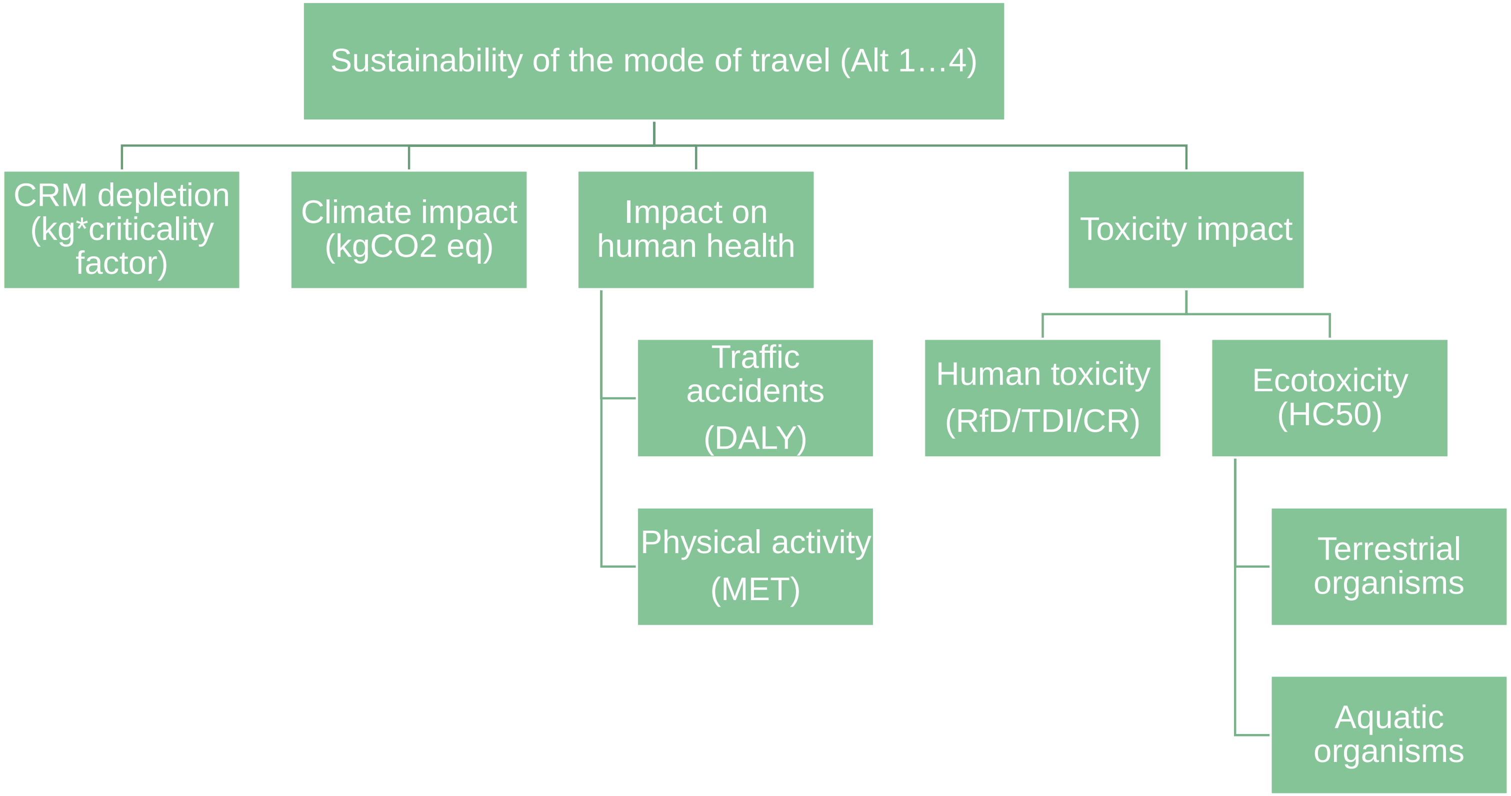
Study methods: Integration, MAVT



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Analysis of the results and discussion

- Major results and their usability
- Uncertainties
  - Uncertainties related to input data
  - Specific method-related data gaps
  - Effect of substitution
- Impact of product ownership
- Wider adoptability of the results
  - Finland vs. other countries, e.g. climate conditions (annual operating time, availability of renting services, infrastructure, population density, number of means of transport, driving habits, use patterns…)
- Other sustainability factors and needs for further studies
- Trends (i.a. restrictions → accidents)

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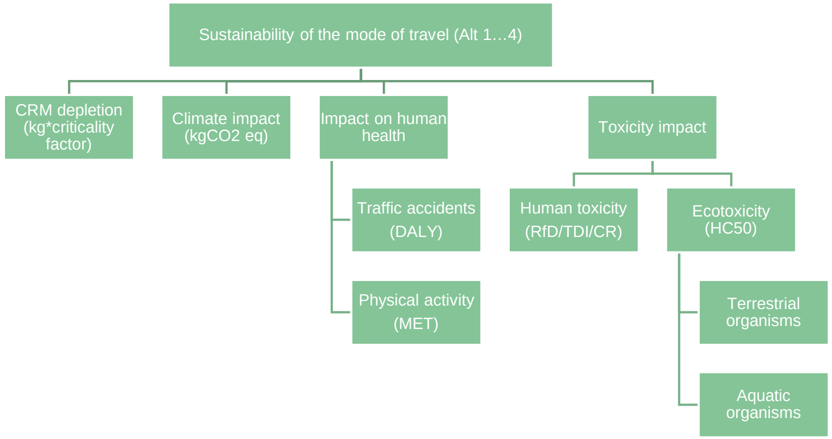
Open questions

To include or not:

- role of different actors

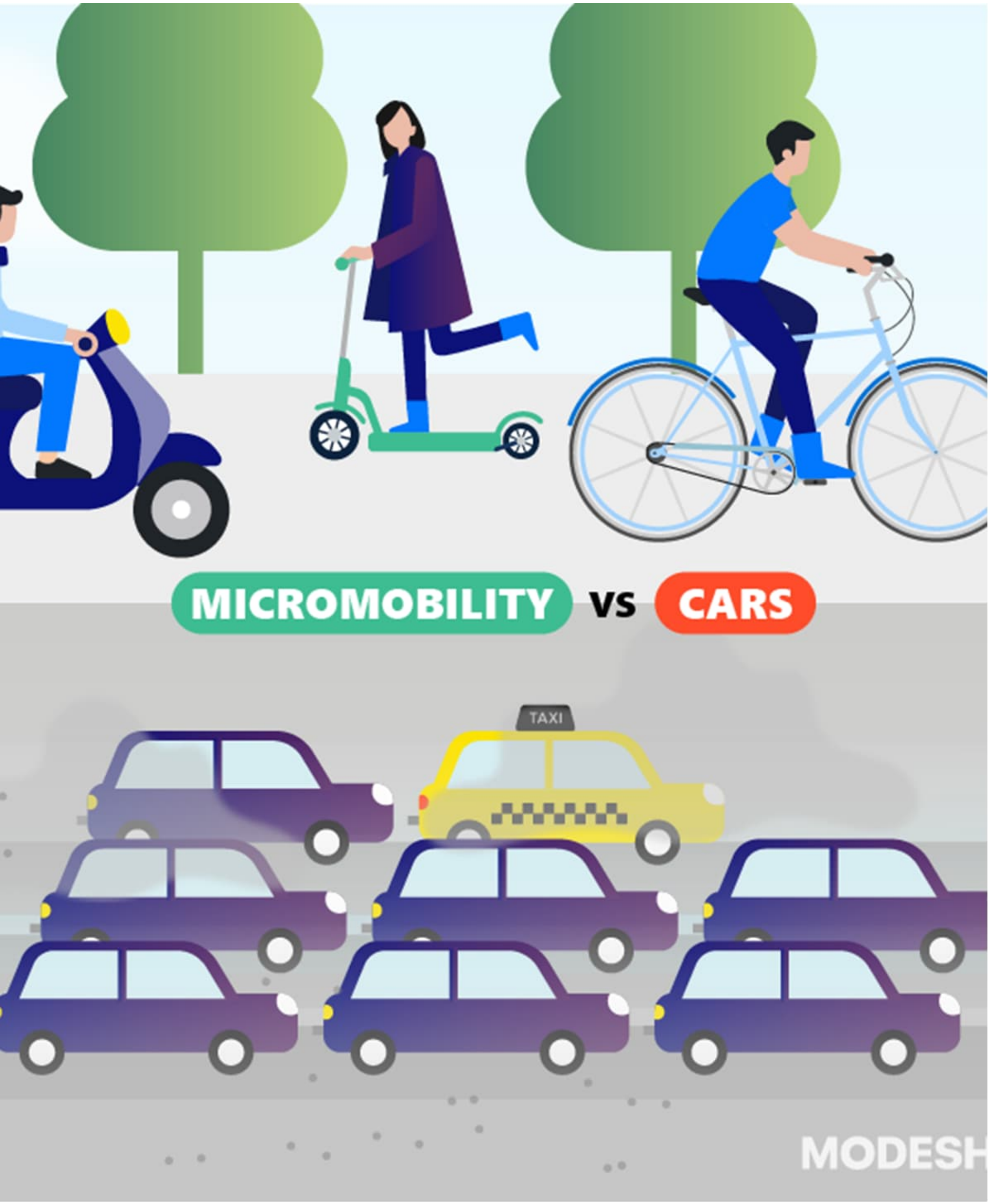
Toxicity impact assessment: Pb vs. Li battery

- equivalent to simple hazard assessment based on toxicity benchmarks (E.g. SSbD procedure, 1st stage)
- challenges: potentially non-comparable benchmarks consideration of chemical speciation: "realistic worst case" (covering all life cycle stages ?) ?



DALYs

- Database or If based on database or calculation tool? If database, how to make comparable with LCA assumptions and impacts ?
    - LCA scale (= city): e.g. serious car related accidents happen outside cities and e-scooters' (also e-bikes'?) within city,



Any questions /comments ?

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Suomen ympäristökeskus
Finlands miljöcentral
Finnish Environment Institute

The future of sustainability

Michael Hanf, Lead, Sustainable Business

Shortly about myself:
Michael Hanf

- Born and raised in Aachen, Germany
- Living in Finland since April 2004
- Two sons, two cats, one dog

1994-2000

Master of Science in Business Administration

2000-2017

Worked 16 years in Management & Strategy Consulting

2017-2023

Established and ran my own strategy consulting business

2023-

Lead, Sustainable Business

The Future of Sustainability

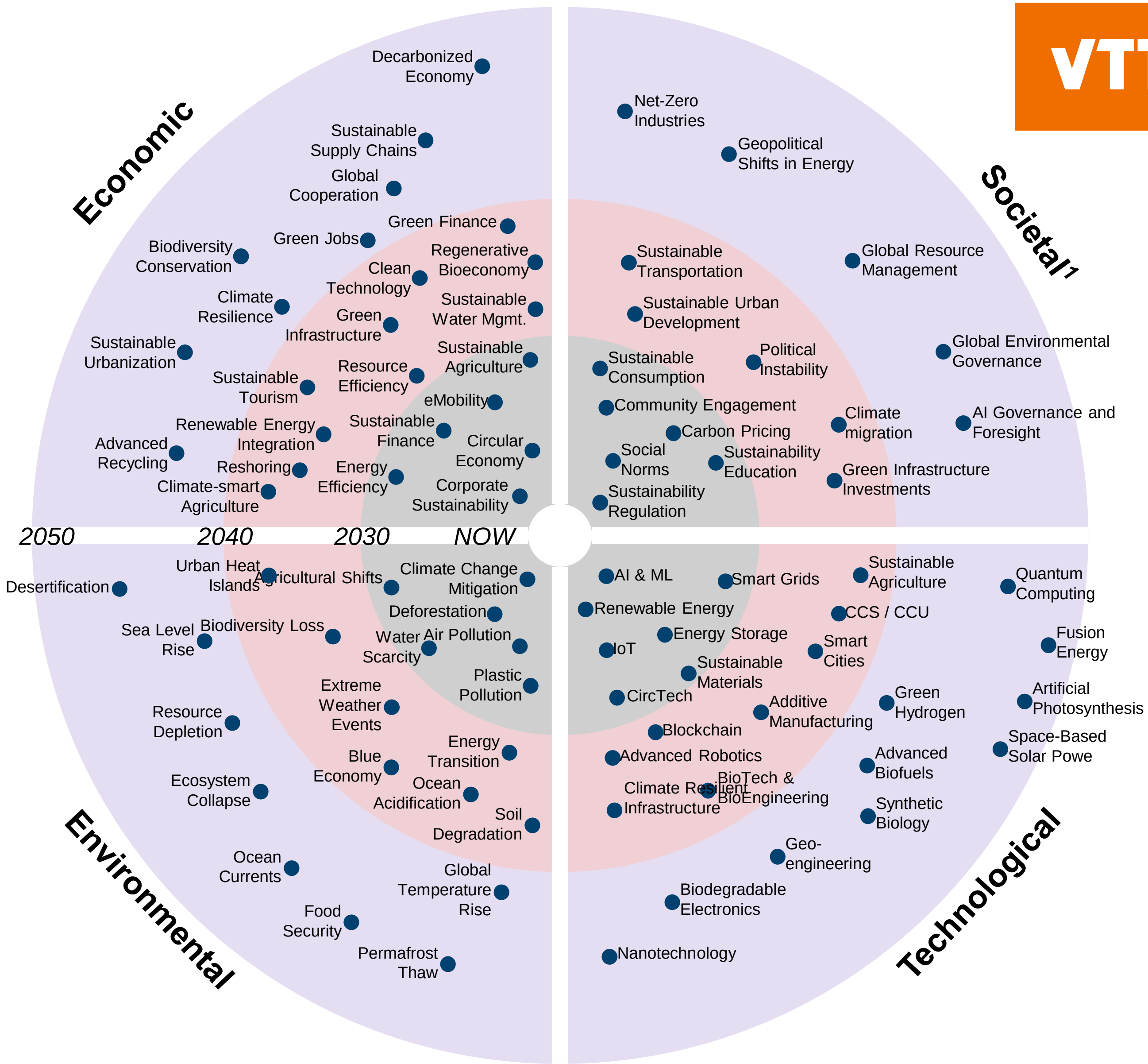
The perfect storm

The convergence of global sustainability trends amplifies complexity, forcing companies to make difficult decisions about prioritization.

- Intensifying Environmental Challenges
- Growing Social Tensions
- Rapid Technological Advancements
- Shifting Regulatory Landscapes
- Evolving Consumer Expectations


VTT
The Future
Short foresight window
Focus on existing business
Narrow field of view on relevance
Emphasis on resilience and survival
Valid but reactive strategy

Future of sustainability study



1) Societal dimension includes political, social and regulatory trends.

Megatrends shaping the future of sustainability

Decarbonization of the Global Economy

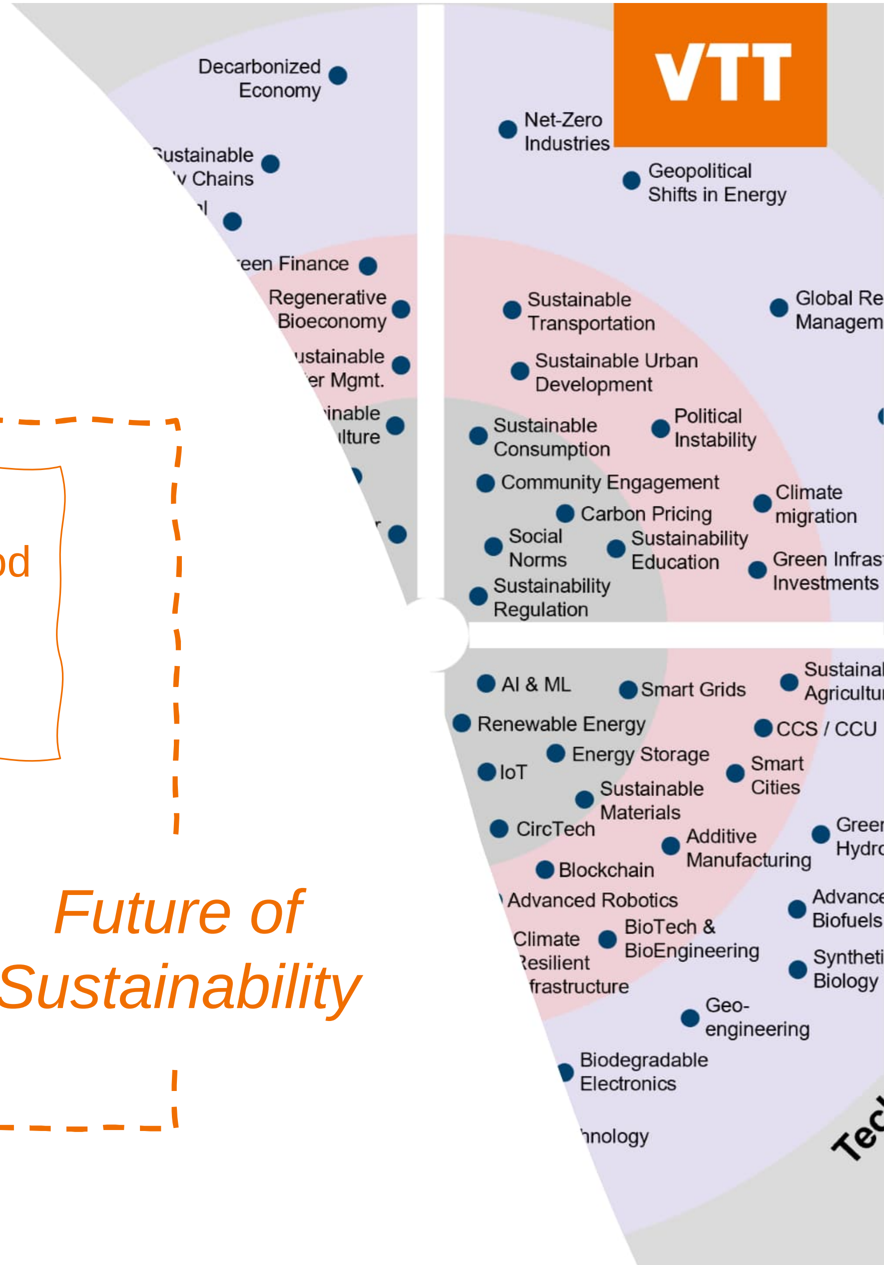
The Rise of Circular Economies

Sustainable Food Systems and Consumption

Sustainable Urbanization and Resilient Infrastructure

Emergence of a Sustainability-Centric Economic Model

Future of Sustainability



Megatrends shaping the future of sustainability

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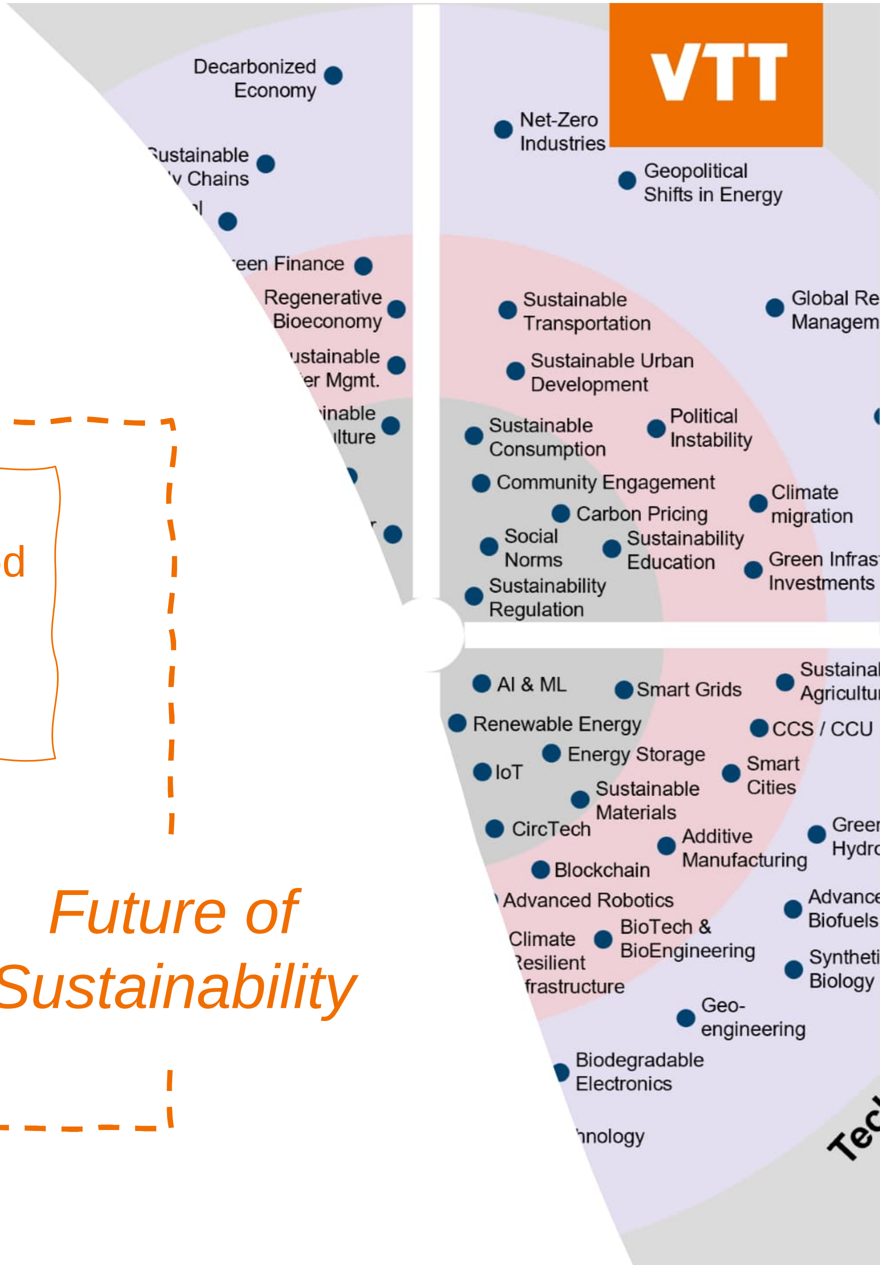

beyond the obvious

Thank you!

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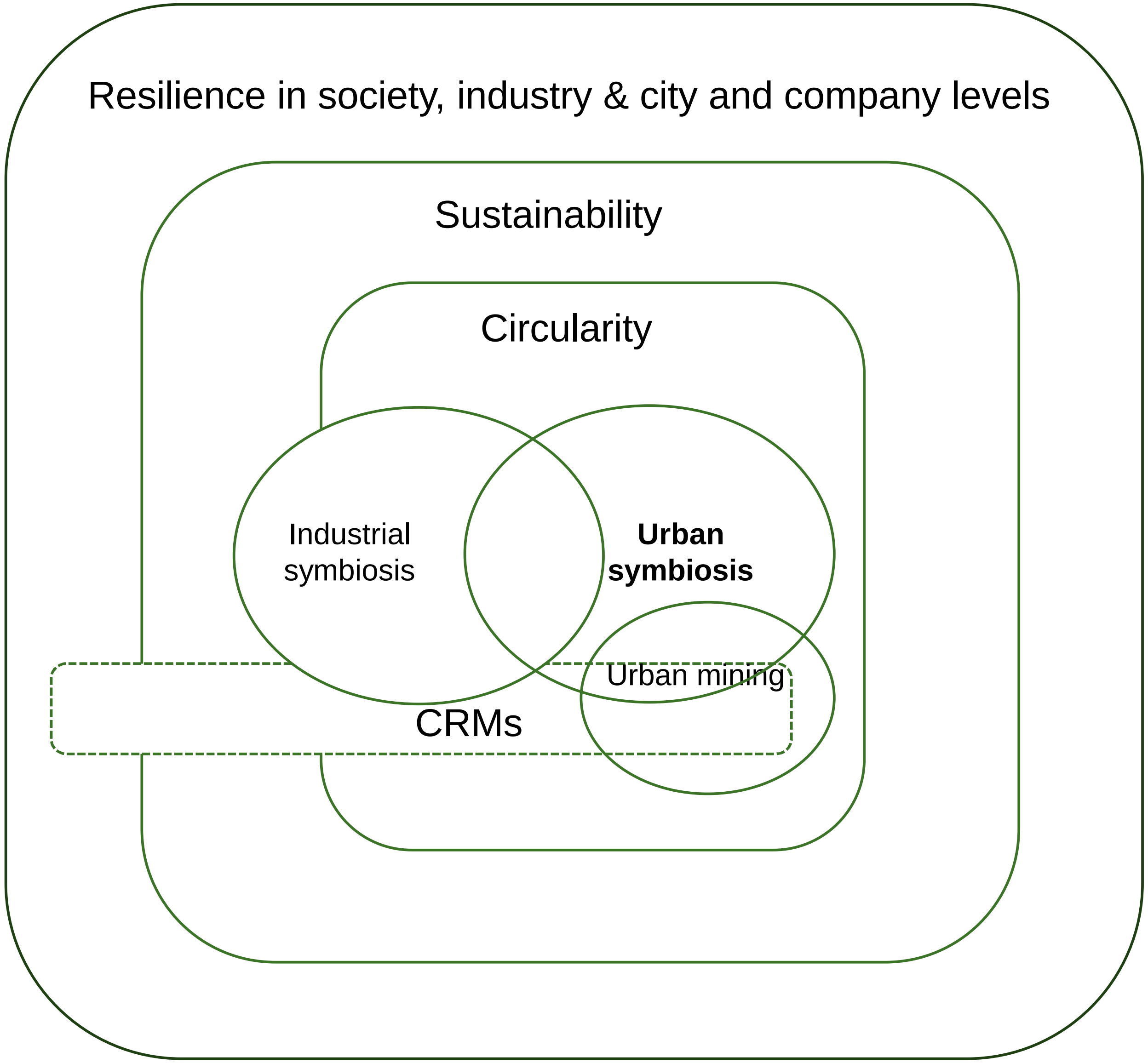
Concluding remarks: Resilience as driver for future

Katri Valkokari, VTT

Urban symbiosis of CRMs in the city context

Urban symbiosis emphasizes the disruptive value-adding collaborative models, the resource dependencies between businesses, organizations, and consumers within cities.

The urban symbiosis approach starts with understanding the metabolism of CRMs and the shared value between actors involved in their governance (public, private and consumers) in three levels.



Elements for building resilience of critical raw materials(CRM)

STRATEGIES AND POLICIES FOR SECURITY OF SUPPLY

LOCALIZATION AND COLLABORATION FOR SYMBIOSIS

ADAPTION TO UNCERTAIN ENVIRONMENTS