



Critical materials for electrolyzers and supply chain dependencies for the EU

D. Blagoeva and S. Carrara

IRTC 2023, Lille, 15-17 February 2023

OUTLINE

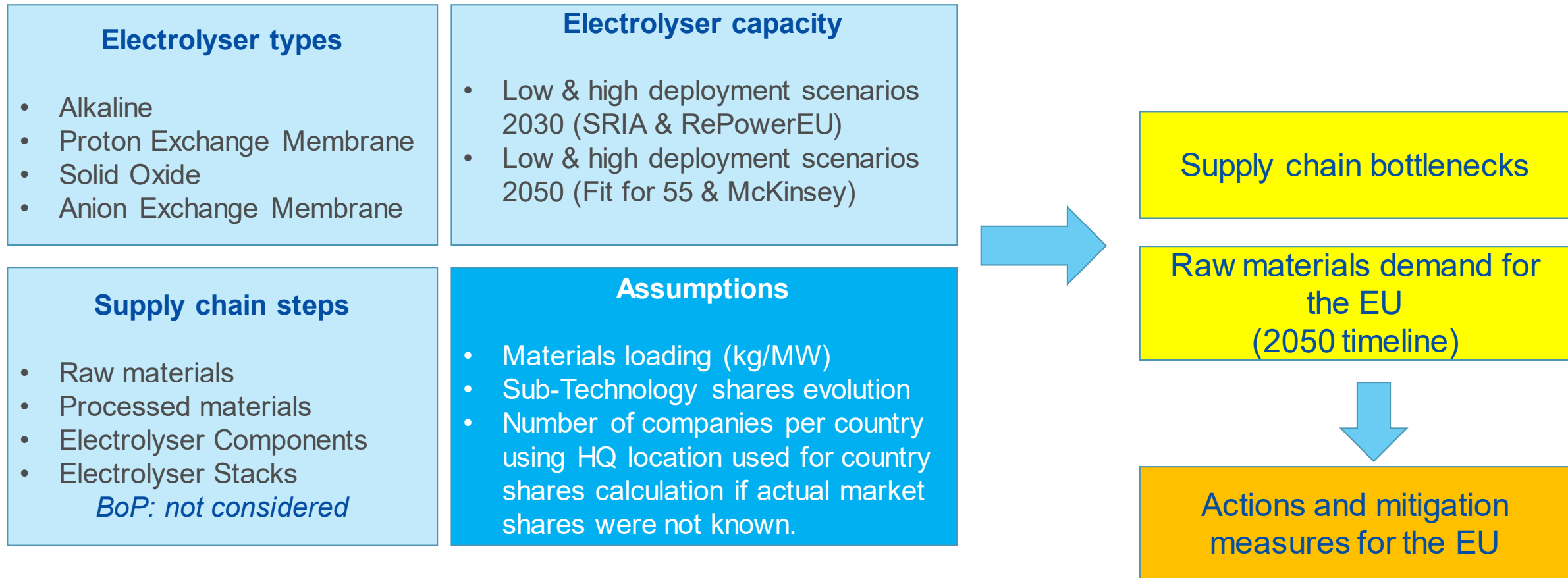
- Scope & Background
- Methodology
- Results
- Conclusions

SCOPE & BACKGROUND

- To identify **bottlenecks in the supply chain of electrolyzers** – from raw materials to stacks - that may hinder the deployment of this technology in the EU in order to meet the **RePowerEU targets**.
- Identify **actions and mitigation measures** to deal with potential bottlenecks!
- Work carried out by DG JRC in collaboration with DG GROW to **update and expand the 2020 foresight report**.



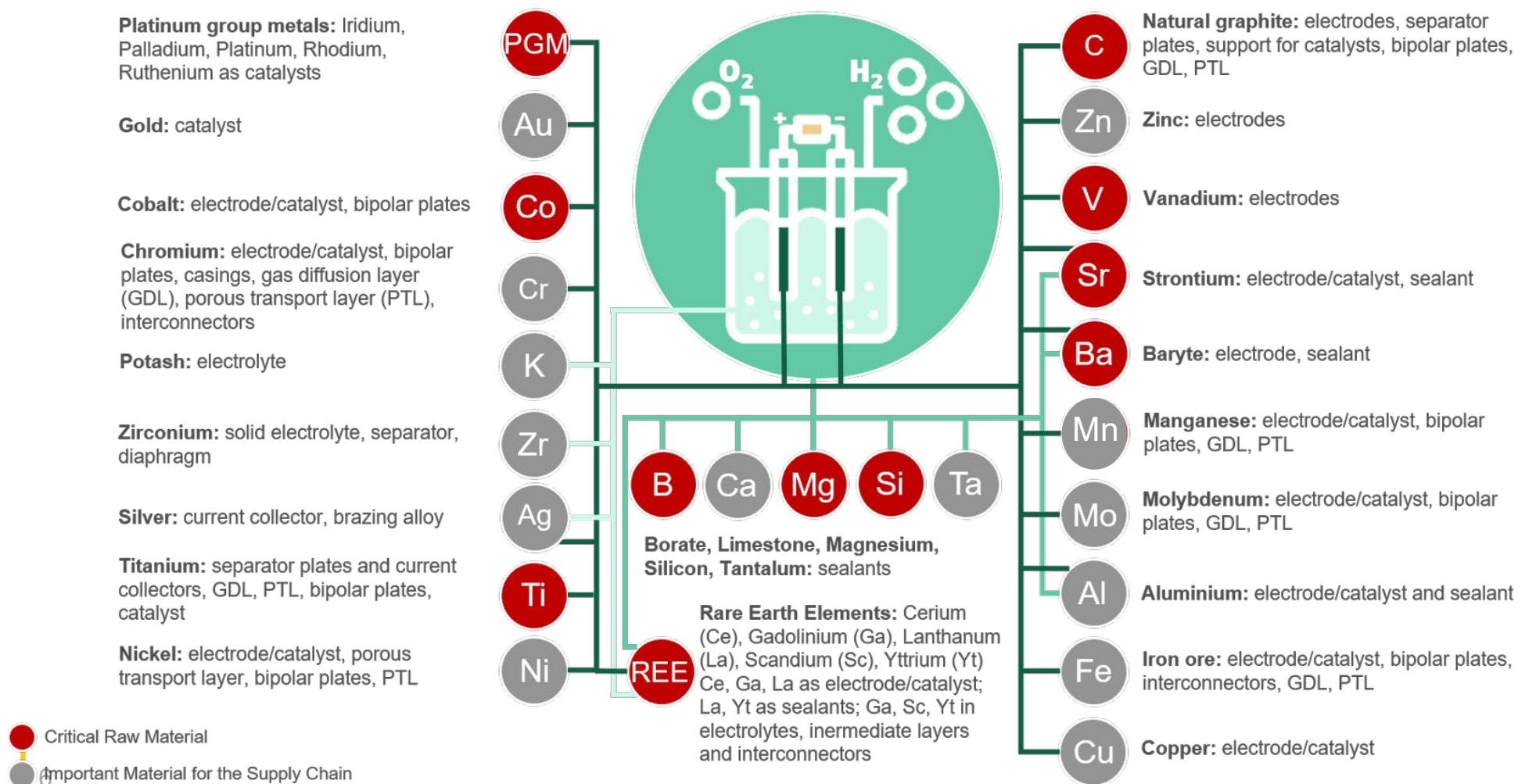
Methodology



RESULTS

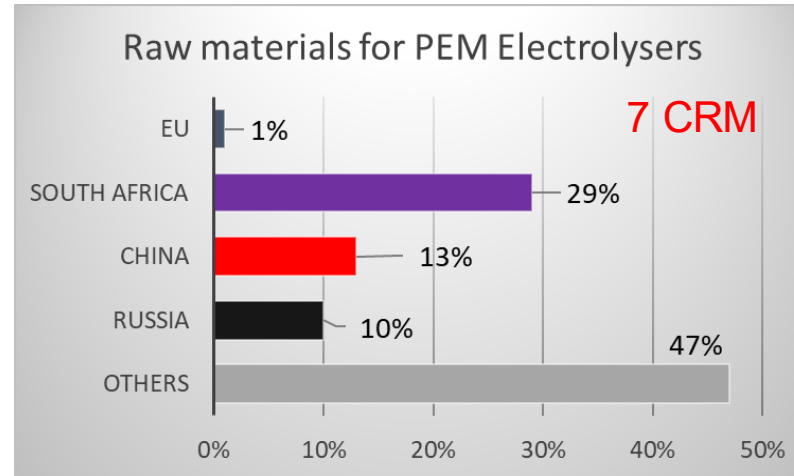
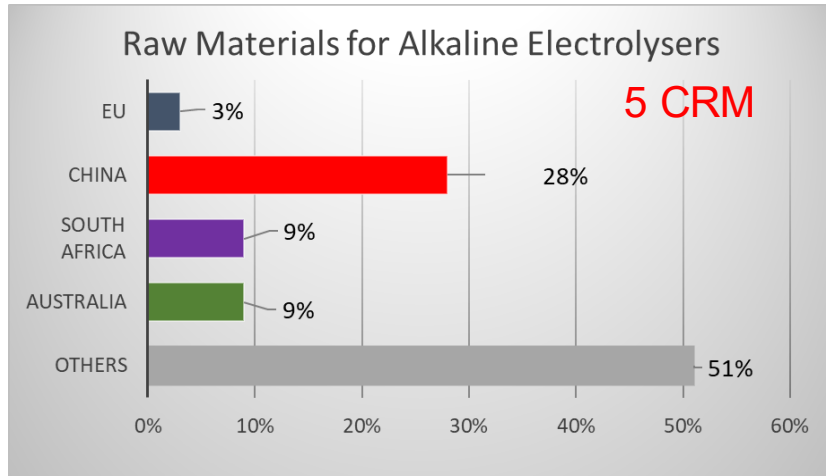
Raw materials used in Electrolysers

Around 40 raw materials identified for Alkaline, PEM, SO and AEM electrolysers.



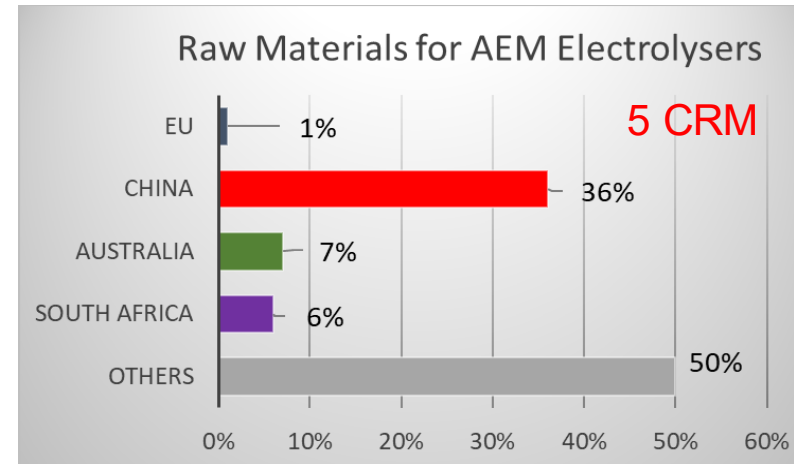
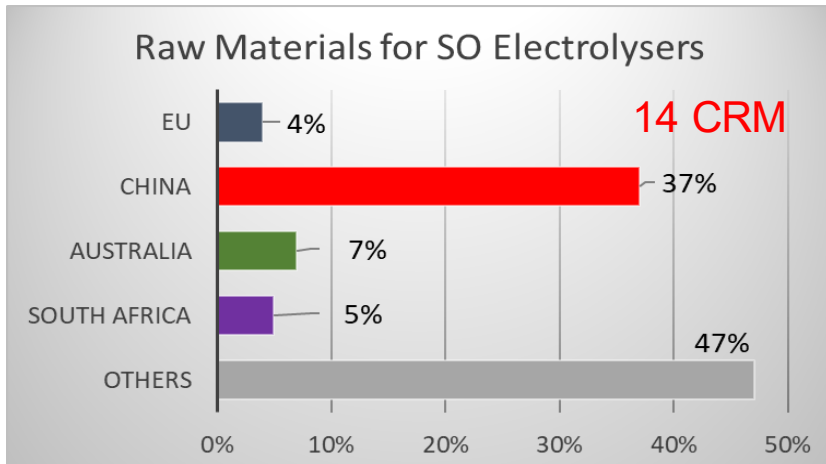
As in 2020
CRM list

Key suppliers of raw materials for Electrolysers



- China, South Africa, Australia – key suppliers of raw materials

- EU domestic production: 1 – 4 %

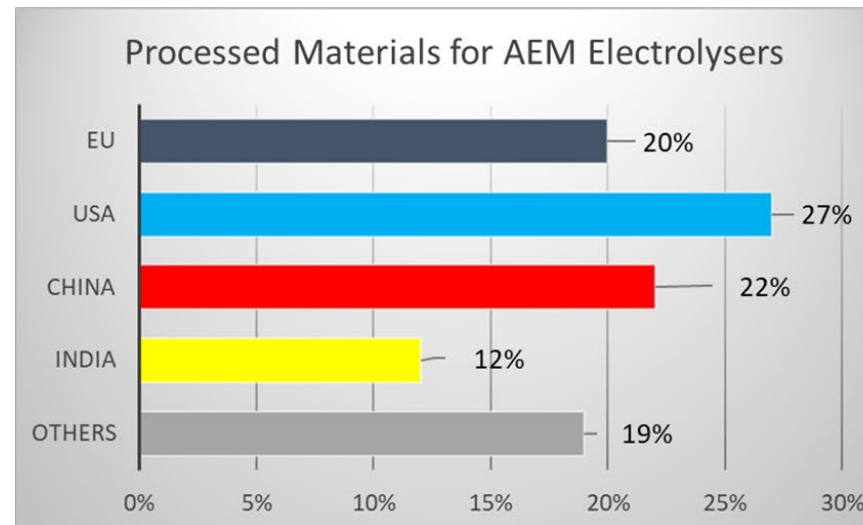
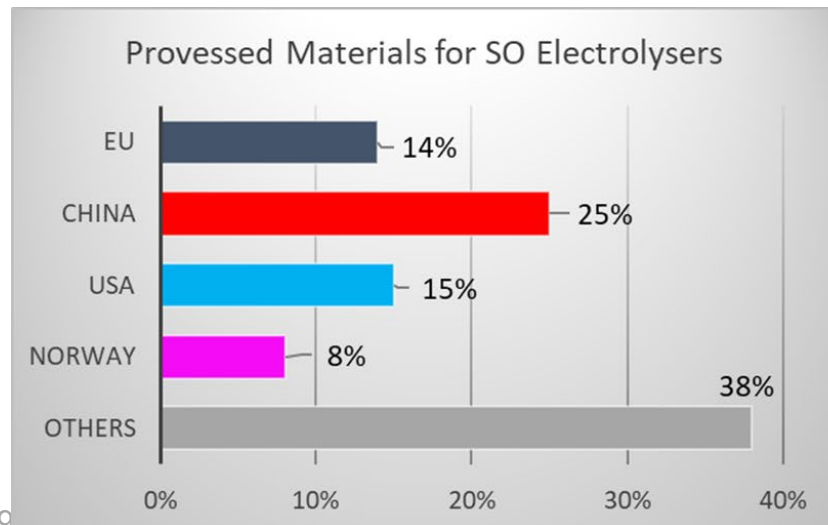
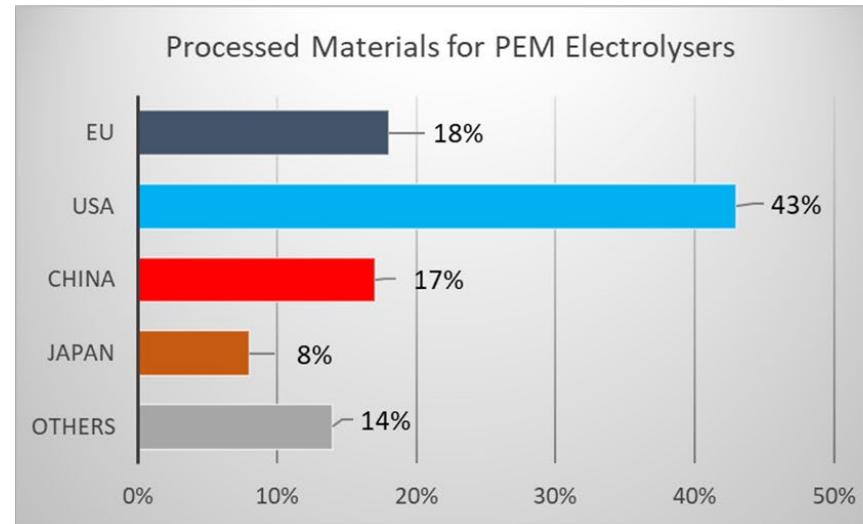
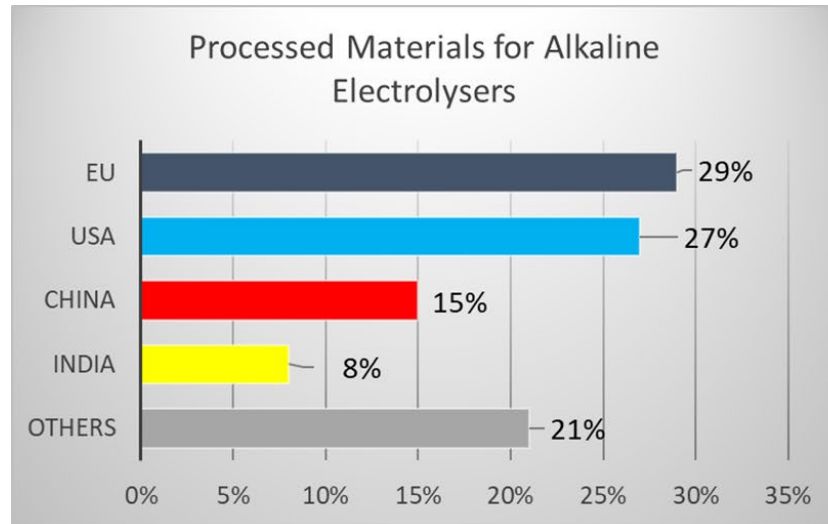


CRM 2020 data used for calculations

Processed materials for Electrolysers

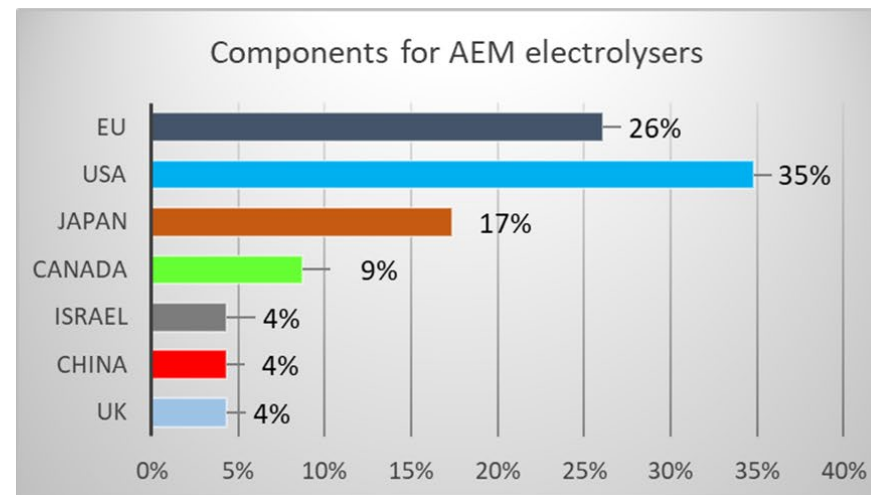
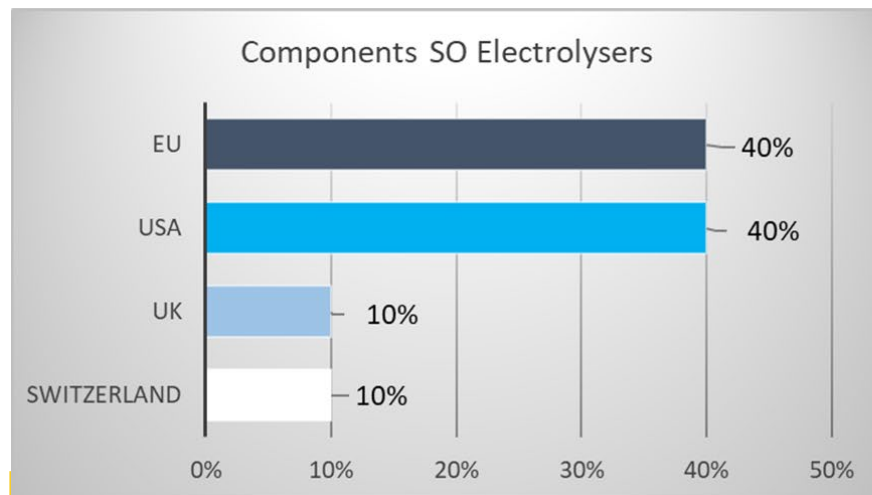
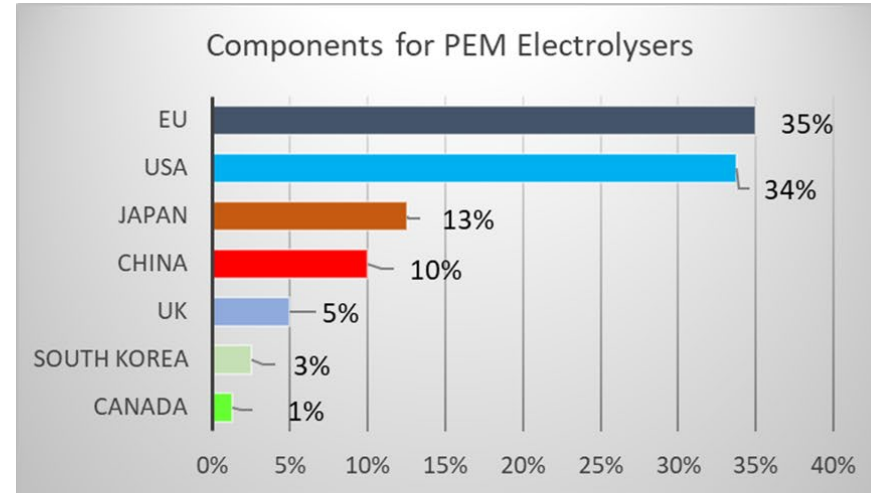
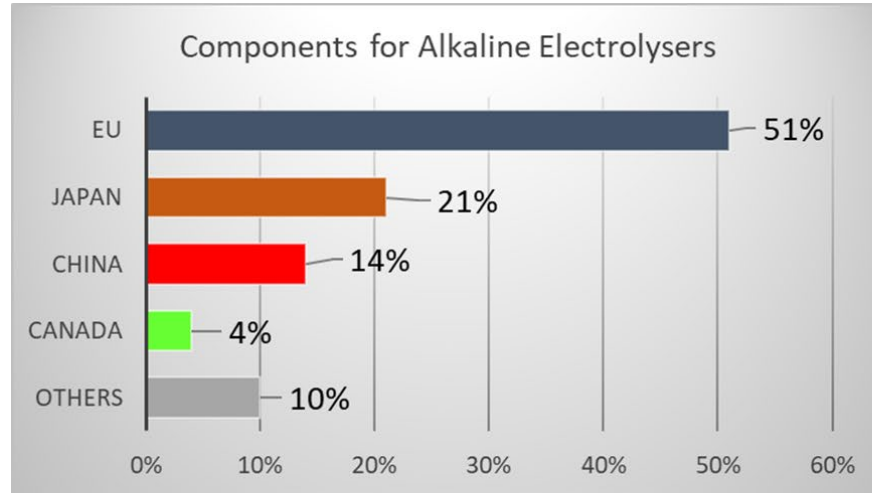
PM Alkaline Electrolysers	PM PEM Electrolysers	PM SO Electrolysers	PM AEM Electrolysers
Stainless steel	Perfluorosulfonic acid	Yttria Stabilised Zirconia	Styrene-ethylene-butylene-styrene copolymer
Zirconium oxide	Ruthenium oxide	High-temperature stainless steel	Polybenzimidazole
Ethylene Propylene Diene monomer	Stainless steel	Vermiculite	Carbon cloth/paper
Potassium hydroxide	Polytetrafluoroethylene	Yttria doped ceria	Graphene
Nickel-Molybdenum alloys	Synthetic graphite	Nickel oxide	Stainless steel
Nickel-Cobalt alloy	Graphite composites	Cerium Gadolinium oxide	Potassium hydroxide
Nickel-Iron alloys	Titanium alloys	Barium Yttrium Zirconate	Nickel-Cobalt alloys
Raney Nickel	Thermoplastics	Silver brazing alloy	Nickel-Iron alloys
Expanded Polytetrafluoroethylene	Carbon cloth/paper	Lanthanum Manganites	Raney Nickel
Polyethersulfone	Elastomers	Lanthanum Strontium Manganite	Nickel-Molybdenum alloys
Mild steel	Titanium foams	Aluminium oxide	Polytetrafluoroethylene
Polyetheretherketone	Titanium fiber felt		Polystyrene
Polyphenylene Sulfide	Iridium black		Polysulfone
Acrylonitrile butadiene styrene	Iridium oxide		Nickel foam
Aramid fibers	Rhodium oxide		Benzyltrimethylammonium hydroxide
Thermoplastics (sealants)	Carbon black		Polyphenylene (low density)
Nickel oxide	Platinum black		Nickel-Cromium alloys
	Platinum on carbon (Pt/C)		Nickel nanopowder
	Polyethersulfone		Nickel alloys (e.g. Ni-Al-Mo, Ni-Cu, Ni-Fe-Co alloys)

Key suppliers of processed materials for Electrolysers



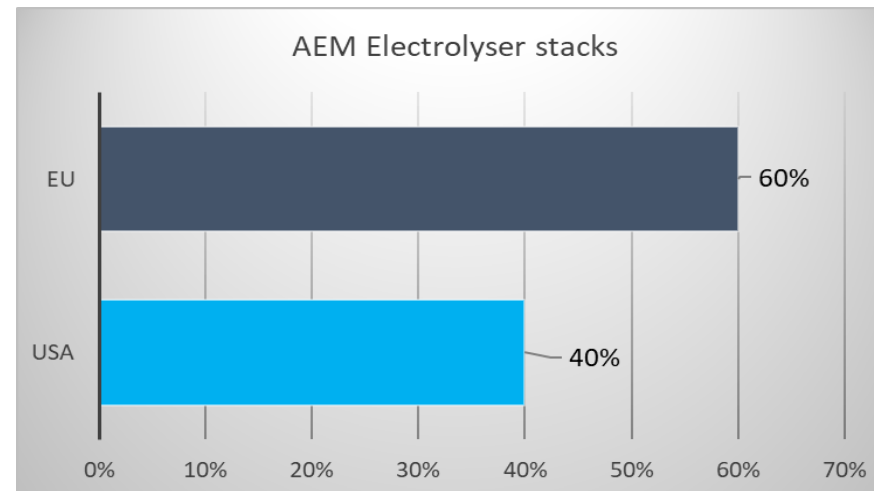
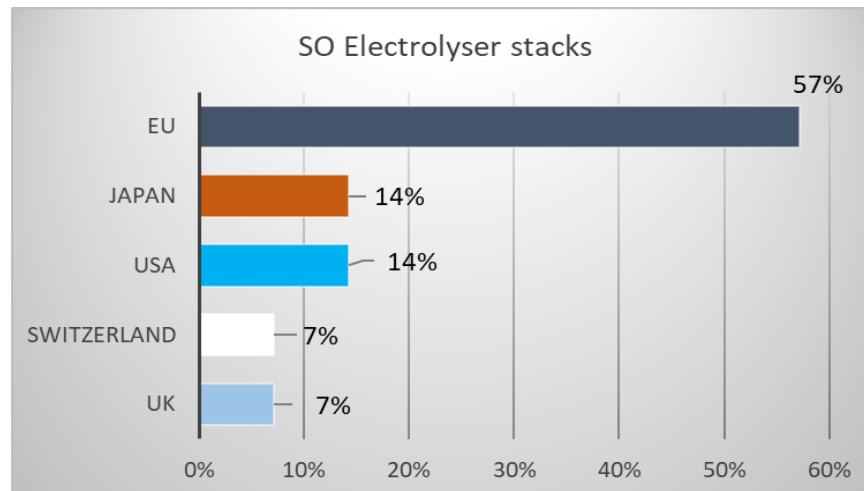
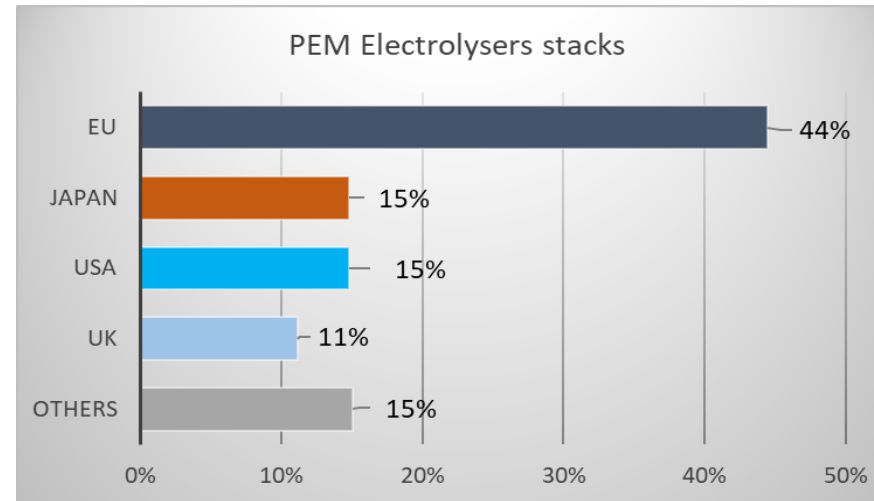
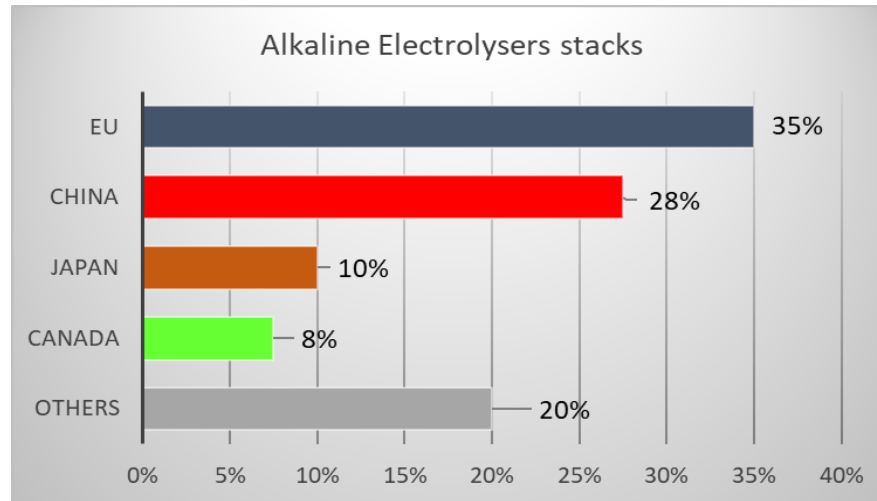
- EU, USA, China and India – key suppliers of processed materials
- EU is one of the major suppliers: **14 – 29 %**

Key suppliers of Electrolyser components



- EU, USA, Japan and China – key suppliers of components
- EU is one of the major suppliers: 26 – 51%

Key suppliers of Electrolyser stacks



- EU, Japan, China and USA – key suppliers of stacks
- EU is one of the major suppliers: 35 – 60%

EU materials demand evolution until 2050

Material	Scenario	2020 EU annual demand, tonnes	2030 EU annual demand, tonnes	2040 EU annual demand, tonnes	2050 EU annual demand, tonnes	Global annual supply, tonnes	2020 EU annual demand as % of the global supply	2030 EU annual demand as % of the global supply	2040 EU annual demand as % of the global supply	2050 EU annual demand as % of the global supply
Ir	Low demand	0.009	1.8	2.4	2.4	6	0.15%	30.00%	40.00%	40.00%
Ir	High demand	0.009	2.9	5.5	9.3	6	0.15%	48.33%	91.67%	155.00%
La	Low demand	0.001	3.8	31.4	96.7	35484	0.00%	0.01%	0.09%	0.27%
La	High demand	0.001	5.9	71.6	381.5	35484	0.00%	0.02%	0.20%	1.08%
Ru	Low demand	0.003	0.4	0.6	0.6	29	0.01%	1.51%	2.00%	1.95%
Ru	High demand	0.003	0.7	1.3	2.2	29	0.01%	2.37%	4.56%	7.69%
Rh	Low demand	0.003	0.4	0.6	0.6	23	0.01%	1.91%	2.52%	2.46%
Rh	High demand	0.003	0.7	1.3	2.2	23	0.01%	2.99%	5.75%	9.69%
Pd	Low demand	0.001	1.2	1.6	1.6	213	0.00%	0.56%	0.75%	0.75%
Pd	High demand	0.001	1.9	3.6	6.1	213	0.00%	0.89%	1.69%	2.86%
Pt	Low demand	0.007	1.8	2.4	2.4	183	0.00%	0.98%	1.31%	1.31%
Pt	High demand	0.007	2.9	5.5	9.3	183	0.00%	1.59%	3.01%	5.08%
Y	Low demand	0.0001	0.5	3.8	11.7	7997	0.00%	0.01%	0.05%	0.15%
Y	High demand	0.0001	0.7	8.7	46.3	7997	0.00%	0.01%	0.11%	0.58%
Zr	Low demand	0.5	419	736	1110	928830	0.00%	0.05%	0.08%	0.12%
Zr	High demand	0.5	657	1678	4378	928830	0.00%	0.07%	0.18%	0.47%
Ni	Low demand	4.1	3313	5691	8320	2143025	0.00%	0.15%	0.27%	0.39%
Ni	High demand	4.1	5197	12972	32815	2143025	0.00%	0.24%	0.61%	1.53%

Iridium from 2030 onwards can become bottleneck for the deployment of electrolyzers in the EU!

CONCLUSIONS

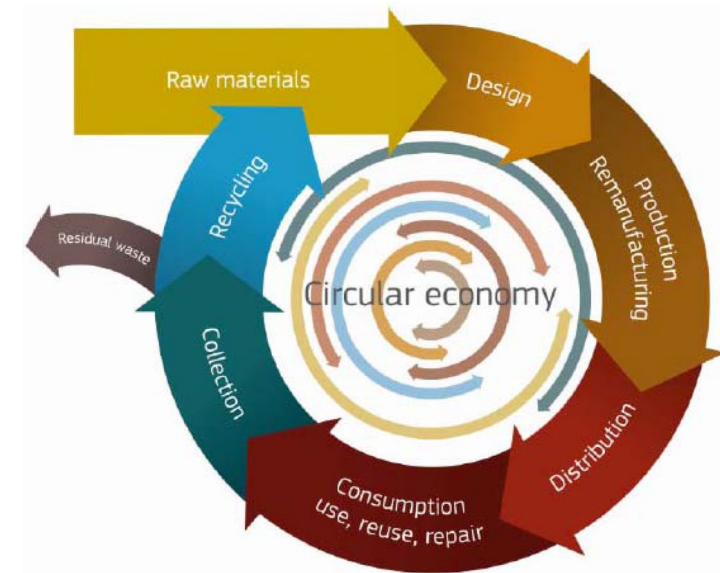
Conclusion (1)

- **EU is well positioned downstream in the supply chain**, being one of the major suppliers of processed materials, components and electrolyser stacks.
- The most **critical step in the supply chain is the Raw materials step**: the EU is producing **between 1% and 4% of the required raw materials**, where key suppliers are China, South Africa and Australia.
- **Iridium** could become bottleneck for the deployment of electrolyzers in the EU from 2030 onwards.
- Components and electrolyzers manufacturing: **EU is facing strong competition from China.**

Conclusions (2)

Actions and measures to decrease the primary demand

- **Supply diversification & Stockpiling** can be explored as option to alleviate future supply shortages for certain key materials.
- **Circularity**, including **Recycling, Re-use, Repair, Substitution, Materials Efficiency, Circular Design**.
- **R&D and innovation** along various circularity aspects, **from recycling to innovative design**, as well as improving the electrolyzers **performance** and **durability** (thus longer lifetime).
- Preserving the current **knowhow**.



Keep in touch



EU Science Hub: ec.europa.eu/jrc



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EU Science, Research and Innovation



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Thank you



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Exploring different electric vehicle and battery scenarios on critical raw material demand in the UK

Friday 17th February

Sophie Kempston

Institute for Global Sustainable Development, University of Warwick, UK



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Science

Ban on new petrol and diesel cars in UK from 2030 under PM's green plan

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UK to slash emissions by 68% by 2030, as part of Paris Agreement NDC

The UK Government will aim to reduce emissions by 68% by 2030, as part of a domestic action plan that will deliver the nation's contribution towards the Paris Agreement and limiting global temperature increases to well below 2C and build towards net-zero by 2050.

Foreword

In this report, the Committee on Climate Change recommends a new emissions target for the UK: net-zero greenhouse gases by 2050.



HM Government

TOGETHER
FOR OUR
PLANET



Net Zero Strategy: Build Back Greener

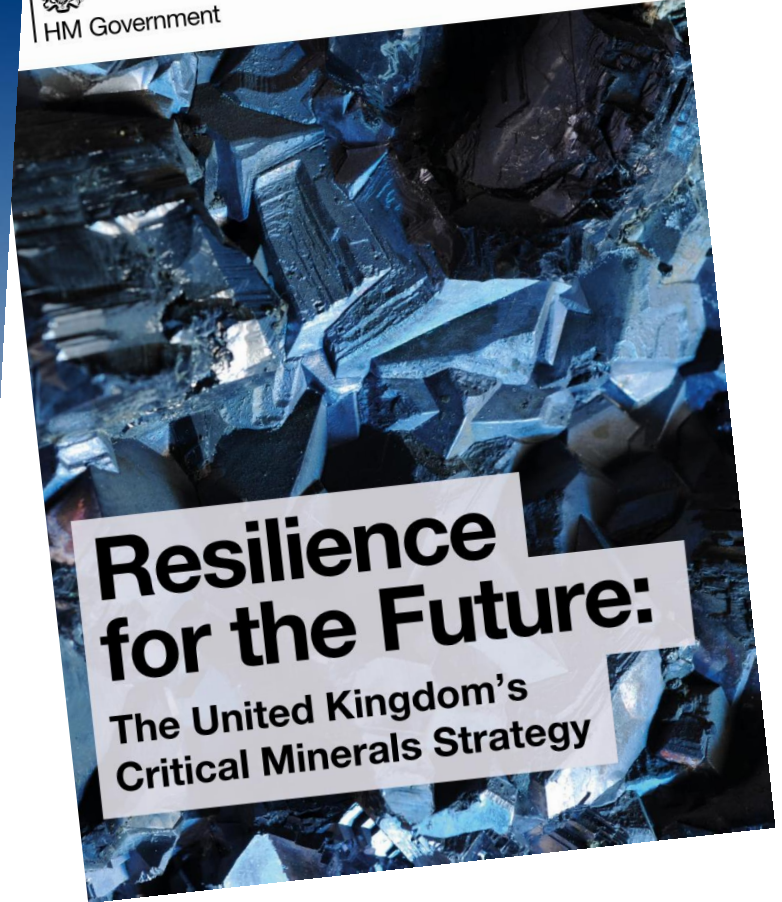
October 2021



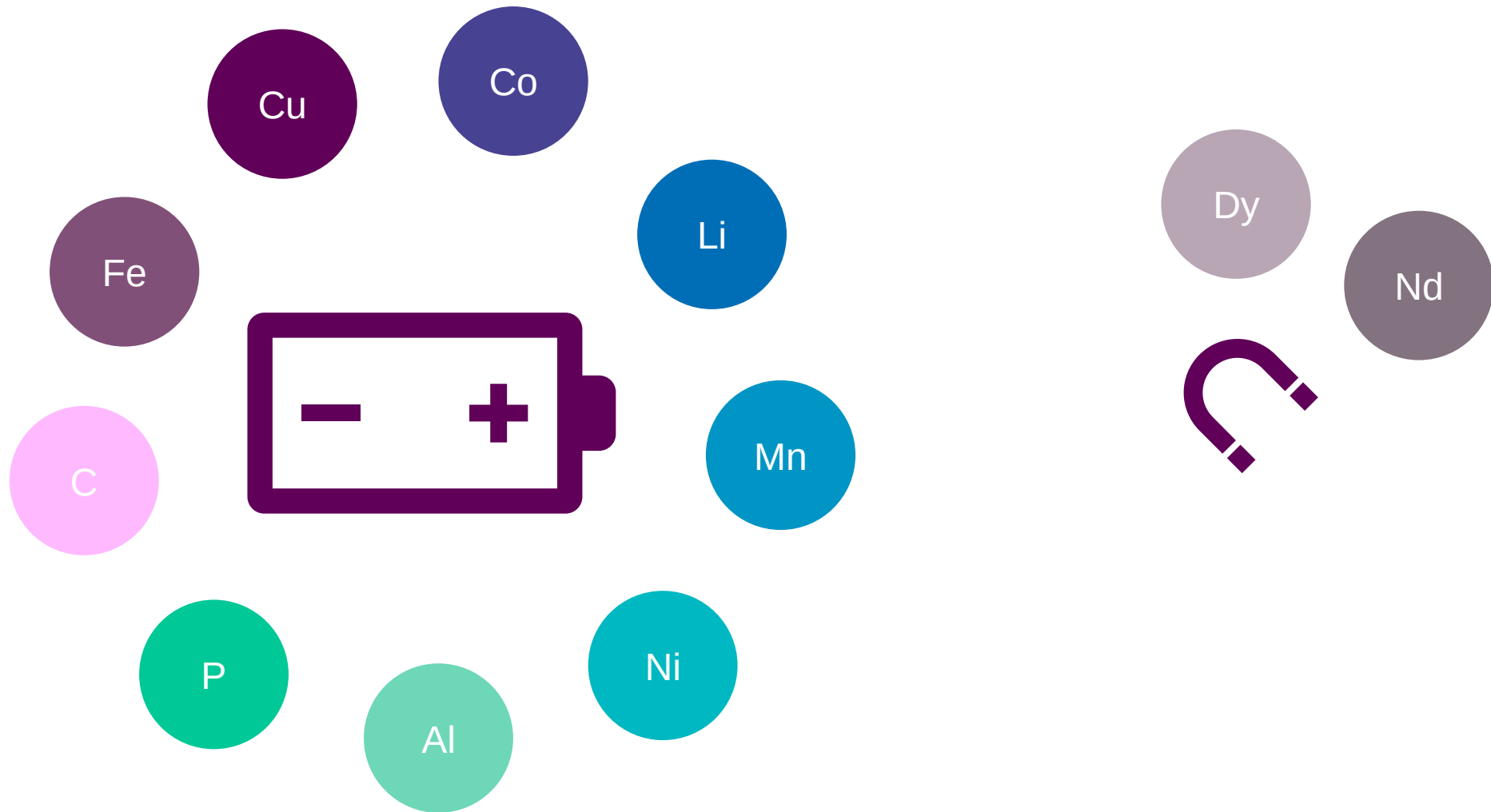
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Resilience for the Future:

The United Kingdom's
Critical Minerals Strategy

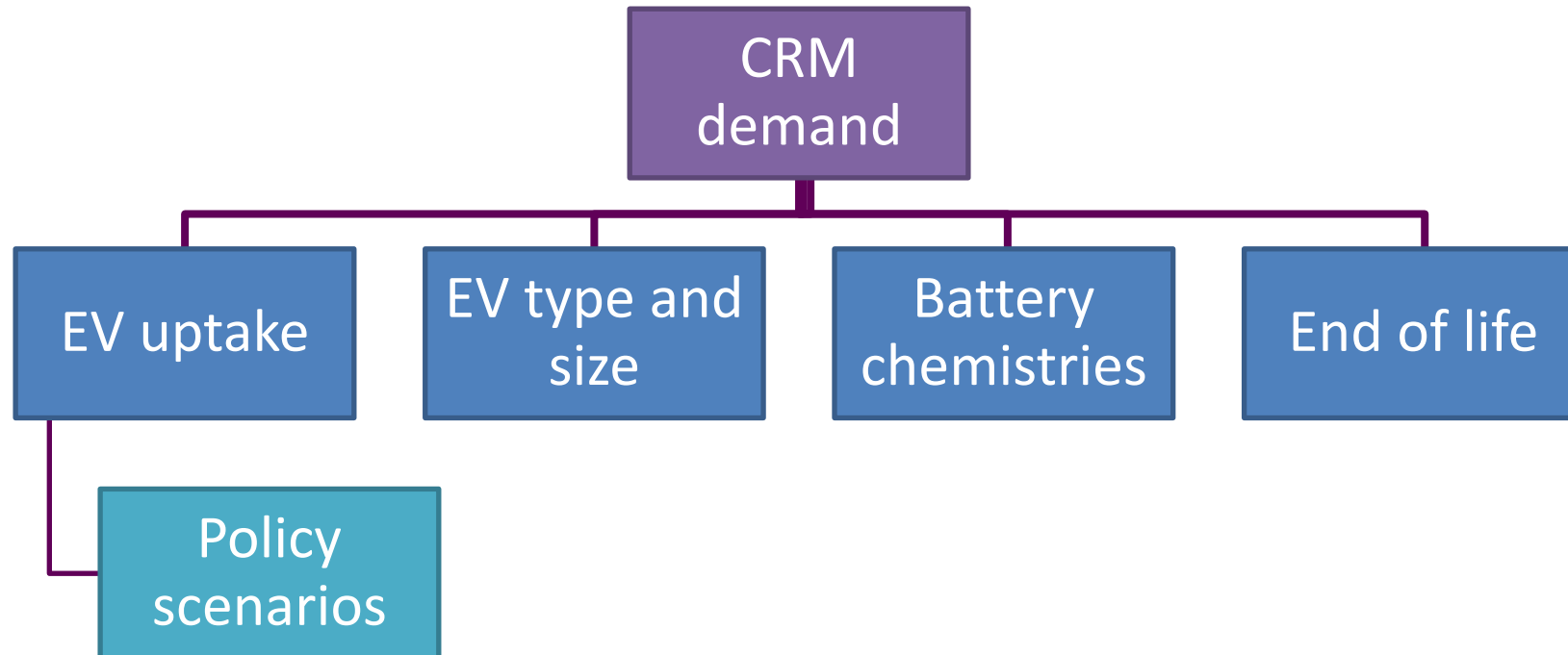


Key materials



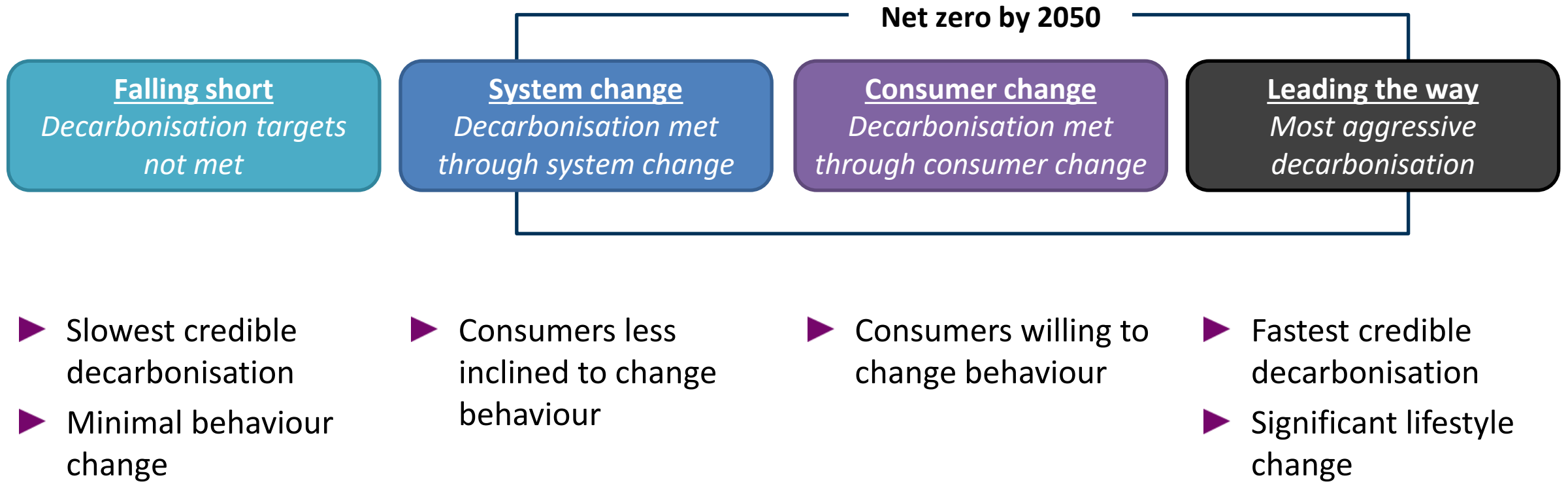
Research problem

- **Objective:** to produce estimates for critical raw material demand from increased EV uptake in the UK until 2050
- **Problem:** uncertainty about what the future looks like



Model structure

Layer 1: EV market



Model structure

Layer 1: EV market

Falling short

Decarbonisation targets not met

System change

Decarbonisation met through system change

Consumer change

Decarbonisation met through consumer change

Leading the way

Most aggressive decarbonisation

Layer 2: LIB market

BAU (high NMC)

Current battery trends continue

High LFP

LFP becomes a leading chemistry

High manganese

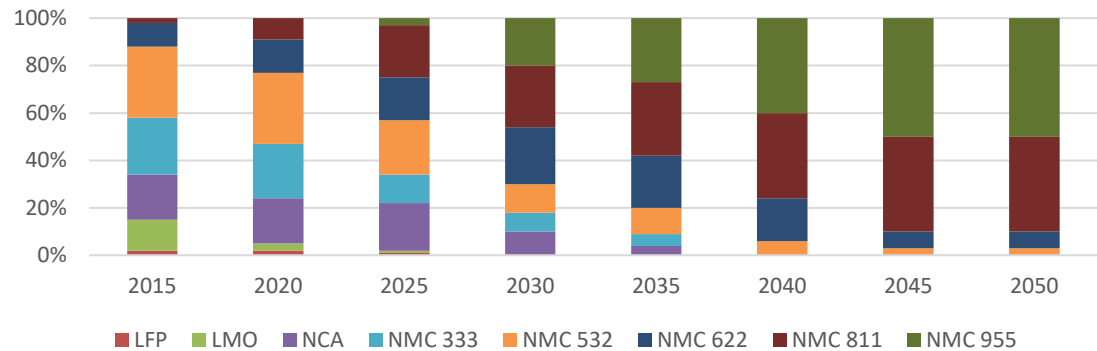
LMO becomes a more prominent chemistry

New tech

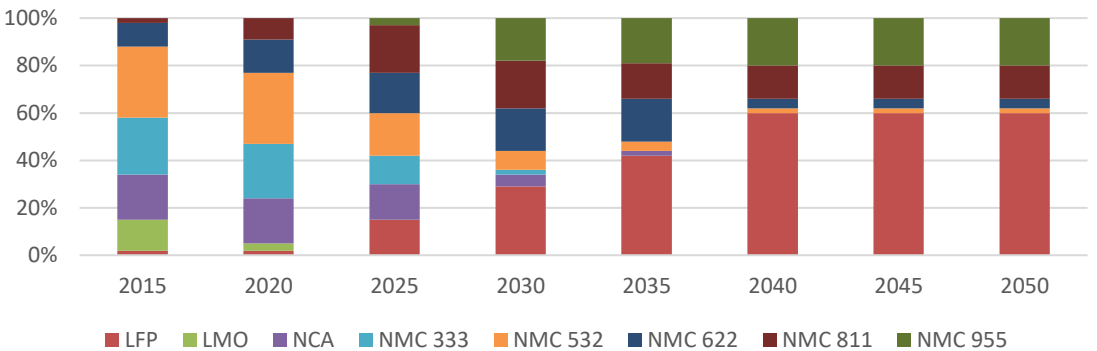
Solid-state batteries start to dominate

Battery market shares

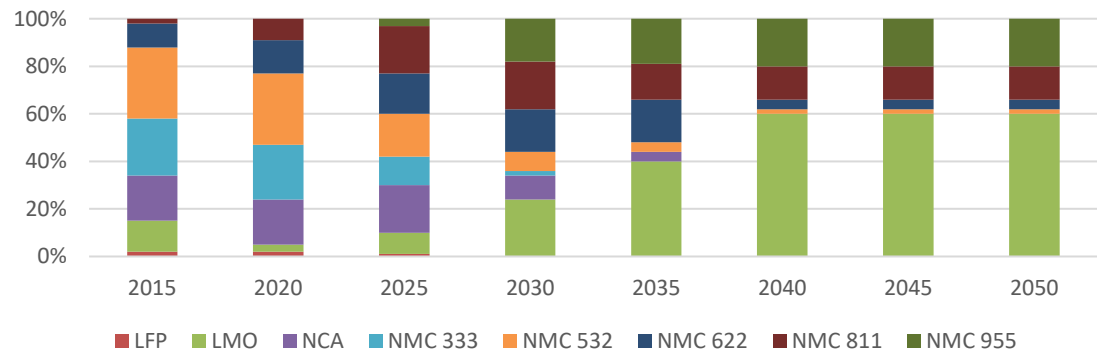
Battery market shares, NMC scenario



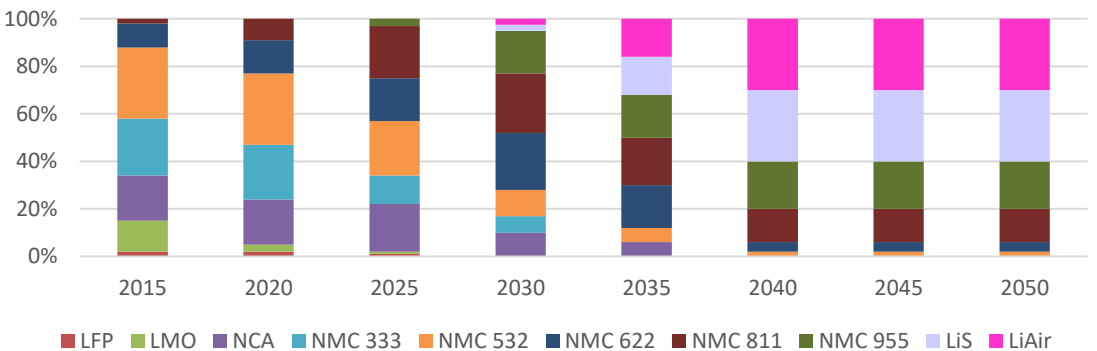
Battery market share, LFP scenario



Battery market share, LMO scenario



Battery market share, new tech scenario



Model structure

Layer 1: EV market

Falling short

Decarbonisation targets not met

System change

Decarbonisation met through system change

Consumer change

Decarbonisation met through consumer change

Leading the way

Most aggressive decarbonisation

Layer 2: LIB market

BAU (high NMC)

Current battery trends continue

High LFP

LFP becomes a leading chemistry

High manganese

LMO becomes a more prominent chemistry

New tech

Solid-state batteries start to dominate

Layer 3: End-of-Life

Minimum

Min. requirements from legislation

High recycling

100% recycling, no reuse

Mixed

Mixed recycling and reuse

High reuse

No recycling, 100% reuse

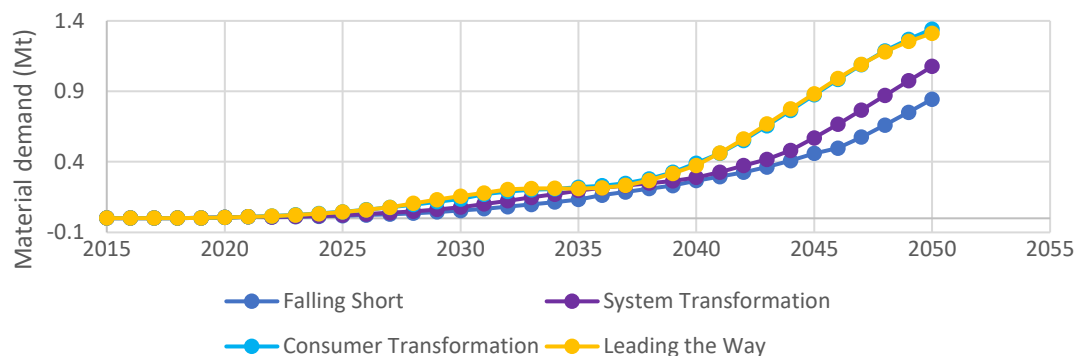


Results

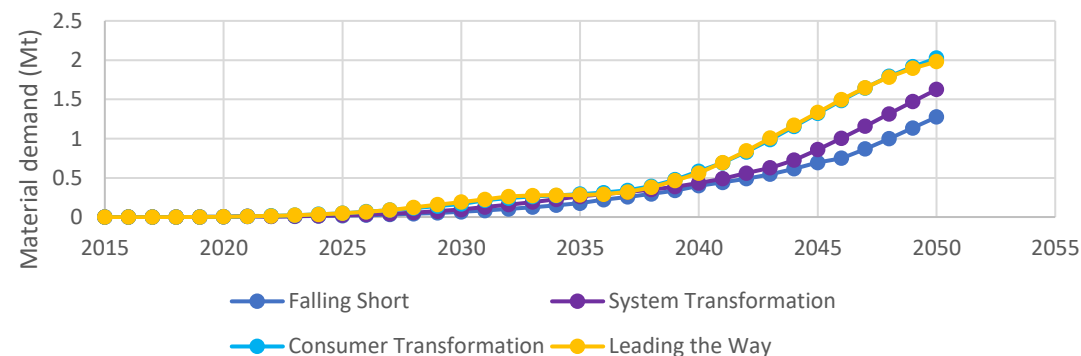
Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
125,058	125,487	124,000	105,450	85,000	125,058	125,487	124,000	105,450	85,000
154,568	56,845	110,000	150,000	35,000	83,000	95,054	97,511	99,011	99,216
101,090	101,684	101,962	124,500	125,000	154,000	95,000	154,200	110,000	89,000
50,000	68,700								

Demand varies widely across scenarios, but patterns stay broadly the same

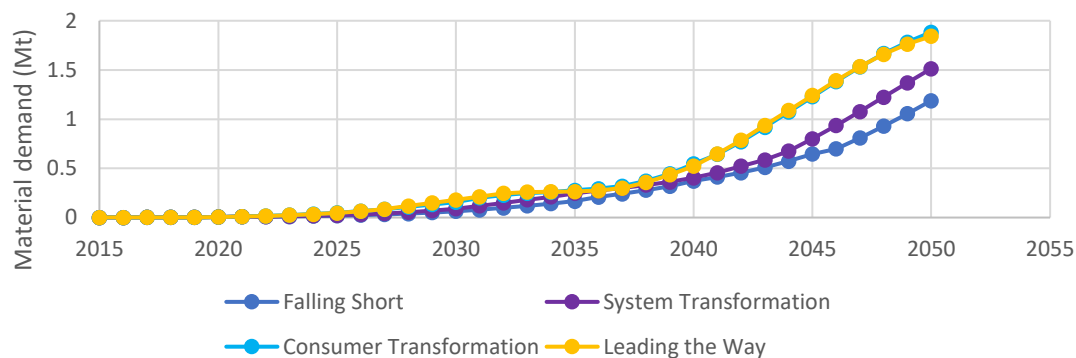
Copper demand, NMC scenarios



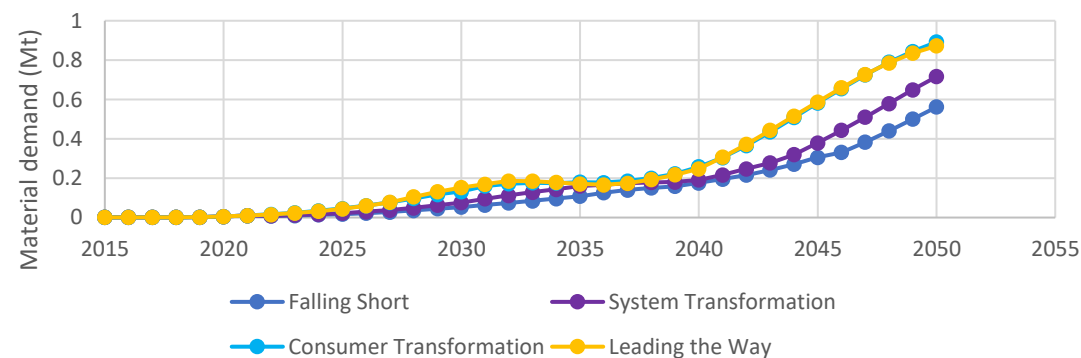
Copper demand, LFP scenarios



Copper demand, LMO scenarios



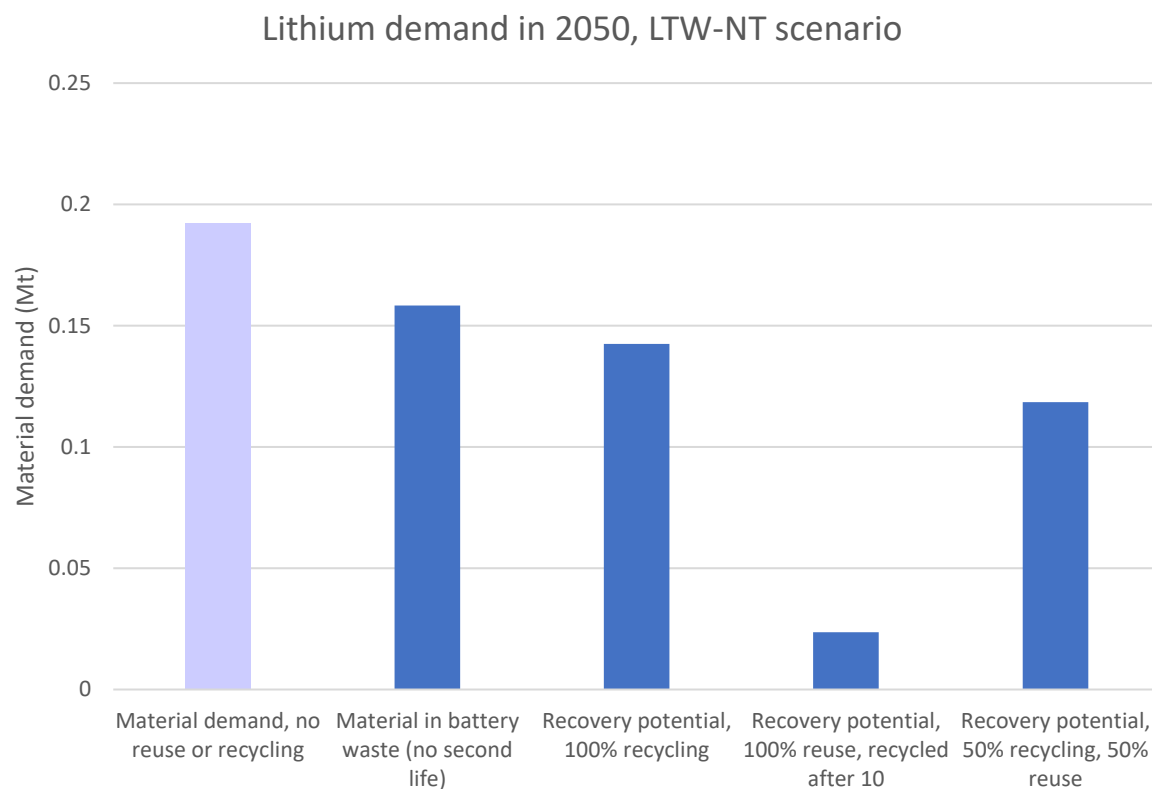
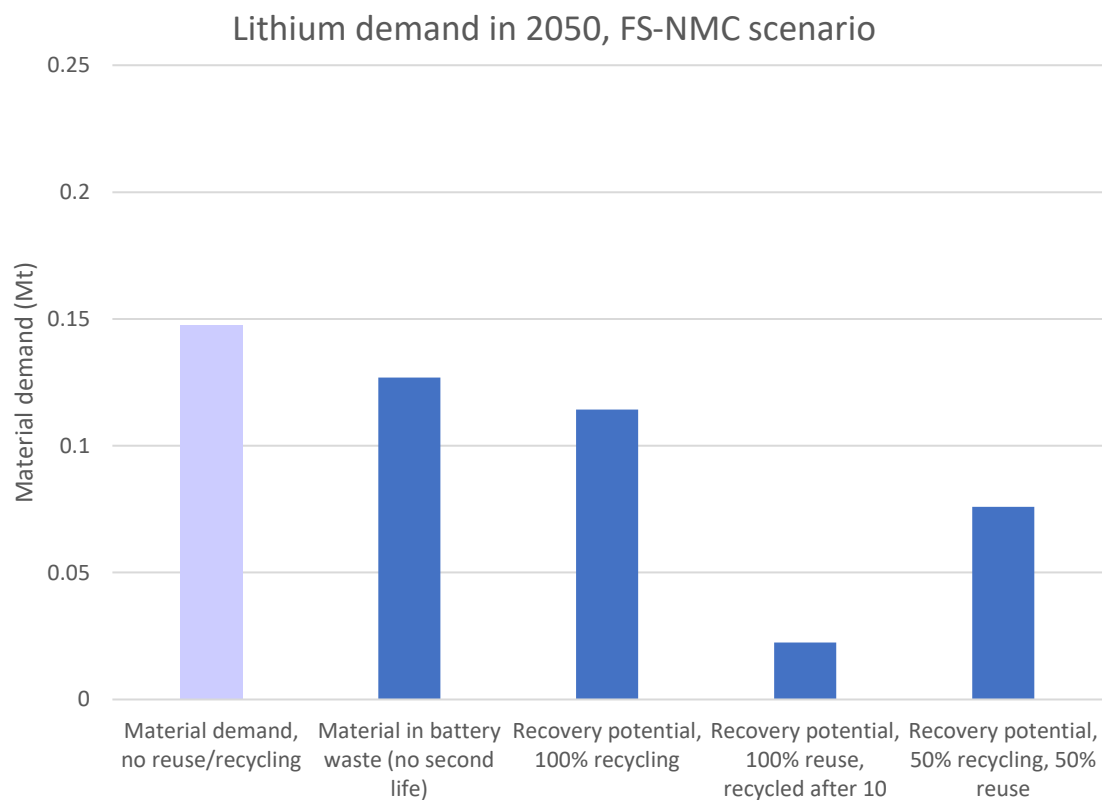
Copper demand, New tech scenarios



Certain critical minerals are sensitive to changes in battery chemistries and EV uptake scenarios

- ▶ LMO scenario increases manganese demand **over 10x** from baseline
- ▶ LFP scenario increases phosphorus demand by **0.5 Mt** in 2050
- ▶ Neodymium demand in 2050 could be **8.5x** global annual production

Reuse results in more primary material demand in all scenarios, but recycling quantities are still a way off



Implications

- ▶ **Clear trade-offs** between different sectors and actions:
 - Reuse vs recycling
 - Material circularity vs circular economy
 - Academia vs industry
- ▶ Consumer demand seems to **drive increased material demand** (due to increased numbers of BEVs)
- ▶ Need to account for **various future scenarios** when setting strategic objectives

Moving forward: putting these numbers into context

- ▶ What impact will this increase in demand have on sustainability?
- ▶ What is important for sustainability in this sector?
- ▶ How do we measure this sustainability?



If you have expertise in the lithium-ion battery supply chain in any of these categories, please get in touch!



Thank you!



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The great transitions

The need for linking natural resources, population, energy, commodities, services, economy, governance and society

Harald Sverdrup,

System Dynamics Group, Gameschool, Norwegian Inland University, Hamar, Norway

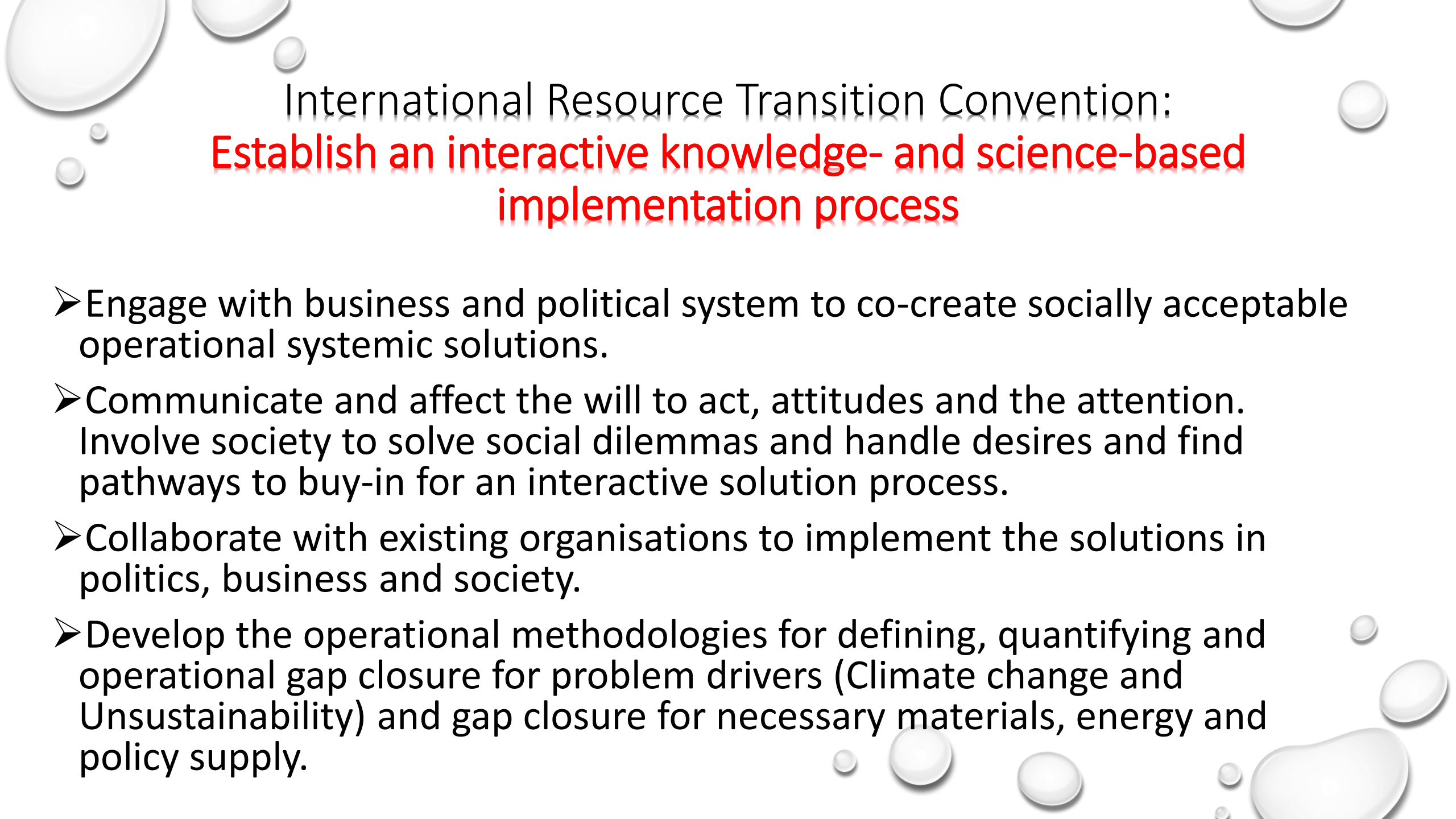
Earlier: Industrial Engineering, University of Iceland

On the greatest of challenges

1. The problem
 1. All fossil resources have an end date. The ends are all coming to you
2. The challenges are all connected and linked
 1. Transit from finite-fossil-energy to renewable
 2. Have sufficient materials for all technology
 3. Make the whole system work in society
3. Go towards solutions
 1. Develop sustainable energy systems
 2. Go towards metals and materials conservation and circularity
 3. Resources are real money; Finite resources are finite money

The three survival transitions required and their context

1. An energy transition
2. A resource transition
3. A social transition
 1. Interactive adaptive learning process
 2. Stay within the frames of democracy
 3. Social cooperation, unification of agendas and broad commitment
 4. A systemic approach to change
 5. Sustainable pathway to goals



International Resource Transition Convention: **Establish an interactive knowledge- and science-based implementation process**

- Engage with business and political system to co-create socially acceptable operational systemic solutions.
- Communicate and affect the will to act, attitudes and the attention. Involve society to solve social dilemmas and handle desires and find pathways to buy-in for an interactive solution process.
- Collaborate with existing organisations to implement the solutions in politics, business and society.
- Develop the operational methodologies for defining, quantifying and operational gap closure for problem drivers (Climate change and Unsustainability) and gap closure for necessary materials, energy and policy supply.

The three survival transitions required and their context

1. An energy transition
2. A resource transition
3. A social transition
 1. Interactive adaptive learning process
 2. Stay within the frames of democracy
 3. Social cooperation, unification of agendas and broad commitment
 4. A systemic approach to change
 5. Sustainable pathway to goals

The four point challenge

1. Develop an operational plan for a resource transition, (1) Nationally, (2) in Europe and (3) Global linking, to make the energy transition and resource transition required to stop climate change and avoid resource supply discontinuity
2. Create an implementation process that provides the necessary science basis, an operational plan for GAP CLOSURE, the required communication effort, gain public attention and adequate political input
3. Stay within social sustainability limitations on change, while being economically viable and physically sustainable, and link energy, resources and society in one systemic approach
4. Make it happen from local to global, and make the approach to goals must be quantitatively verifiable: Build a supporting and guiding organization

Possible deliverables

1. Interactive and adaptive solution development process
 - Technical and scientific
 - Social and political
2. A process to change wills and attitude at some levels
3. Clear advice for policy and legislative changes required
4. Roadmap for operational implementation
 - Participation of governance, public agencies and NGOs
 - Participation of business and industry
 - Operational scientific support center, coordination and data base center (UN/ECE-LRTAP model)
 - A roadmap for unifying the agendas

Overall actions plan 2022-2030

- **Initiate movement (2022-2024)**

- Steering Committee has endorsed a Transition Program
- Find the initiating funding
- National Task Forces in 2-4 friendly nations with a similar or aligned philosophy on resource efficiency and climate change (Netherlands, France, Germany, Sweden).

- **Establish International Resource Transition Convention (IRTC) & Supporting organisation (2022)**

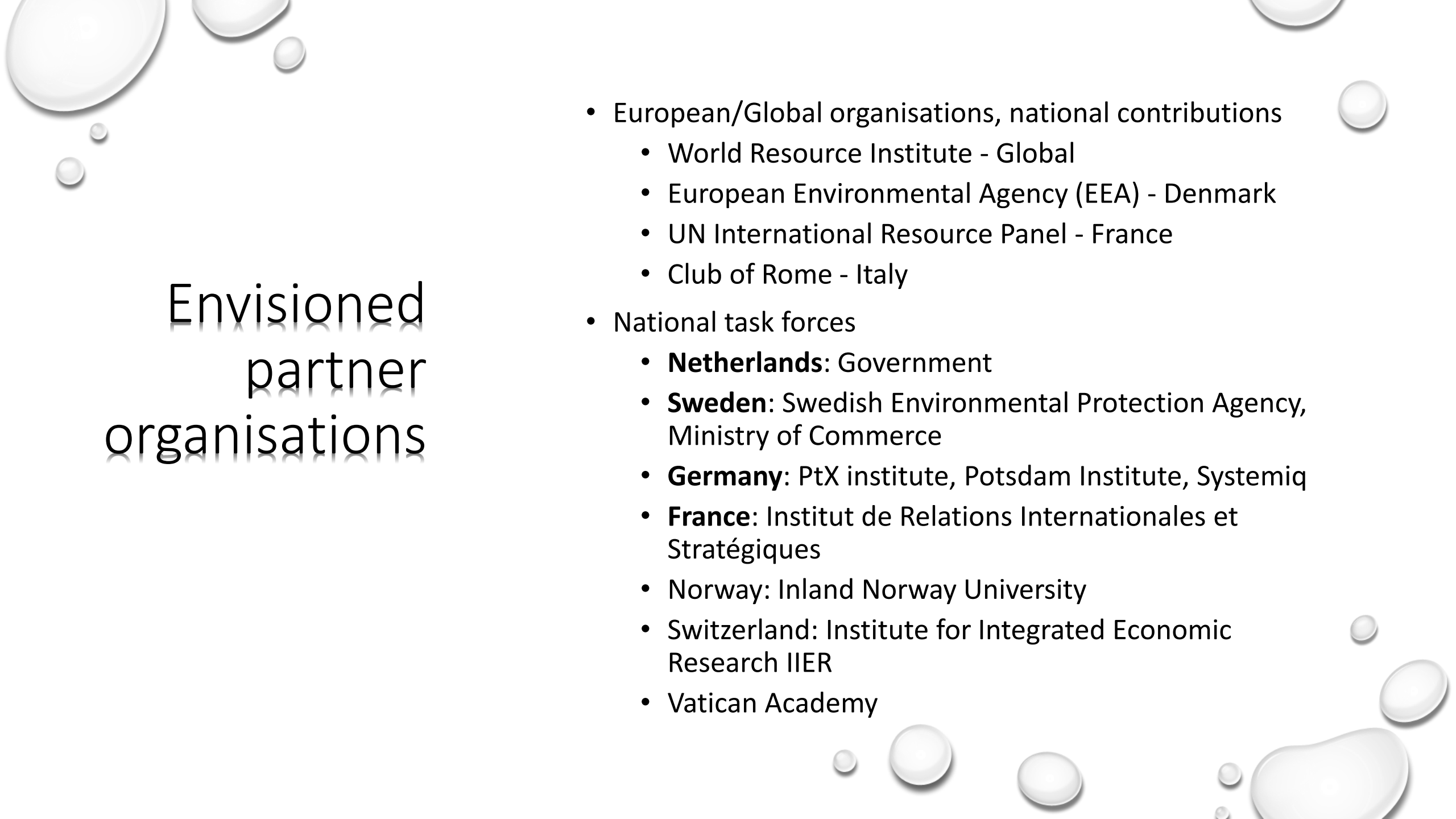
- National Modelling teams -> Combined European Modelling Taskforce
- Find national state funding
- Communication and Coordination Centre for Europe -> International coordination strategy
- Taskforce on Gap Closure -> Gap-Mapping Guidance Handbook

- **Gap Closure 2023-2028**

- Secure governmental endorsement and funding support
- Conduct Gap-Analysis & integrated policy assessment
- Make proposals for gap-closure and policy optimisation
- Generate awareness and buy-in in business, politics and society; nominate political champions
- Implementation of Resource & Climate Treaties and new/revised policies

- **Go Global (2026-2030)**

- Global Resource & Climate Treaty, policies including a Global Resources Bank
- Transit to a United Nations endorsed global convention (UN-IRTC)



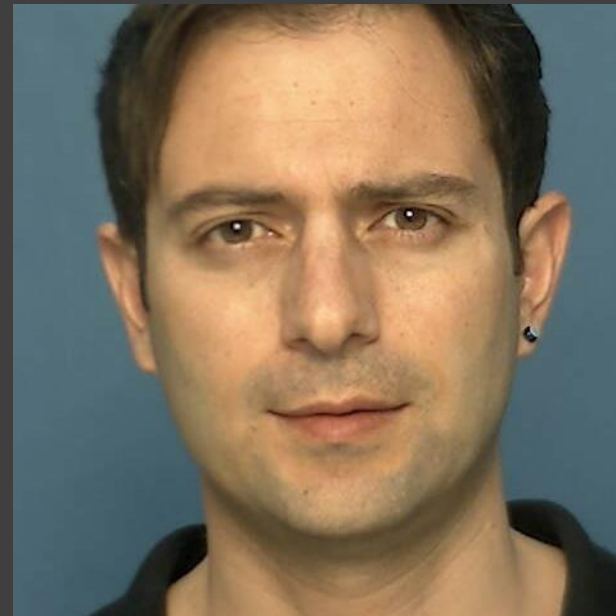
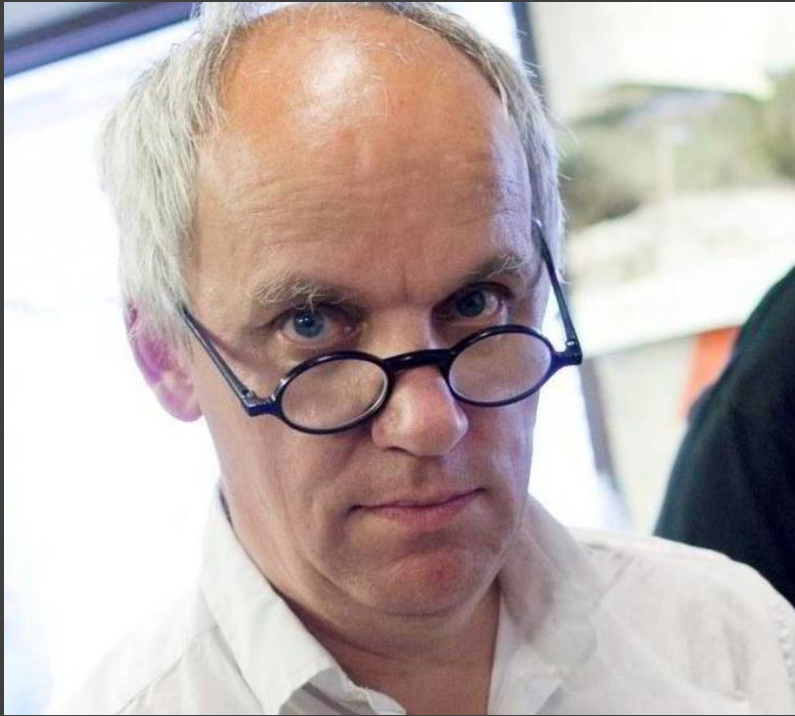
Envisioned partner organisations

- European/Global organisations, national contributions
 - World Resource Institute - Global
 - European Environmental Agency (EEA) - Denmark
 - UN International Resource Panel - France
 - Club of Rome - Italy
- National task forces
 - **Netherlands:** Government
 - **Sweden:** Swedish Environmental Protection Agency, Ministry of Commerce
 - **Germany:** PtX institute, Potsdam Institute, Systemiq
 - **France:** Institut de Relations Internationales et Stratégiques
 - Norway: Inland Norway University
 - Switzerland: Institute for Integrated Economic Research IIER
 - Vatican Academy

The pioneering work: Wold3>WORLD7 evolution history; Think systems, think new, think resources

- 1961-1971; **World1-World2**; Forrester team (1961-1971), MIT; Industrial dynamics, urban dynamics, world dynamics, the first pioneering basic concept for how a World model is put together. The model was very simplified and aggregated to a high level because of computational constraints of the computers available at the time (Forrester 1961, 1969, 1971).
- 1971-2004; **World3**; The Meadows team (1972-2004), MIT; World dynamics and limits to growth. The model was more elaborate than World2, better parameterized and described in “Limits to growth” and “Dynamics of Growth in a Final World” (Meadows et al., 1972, 1974). The model had significant simplifications because of computational constraints of the computers available at the time.



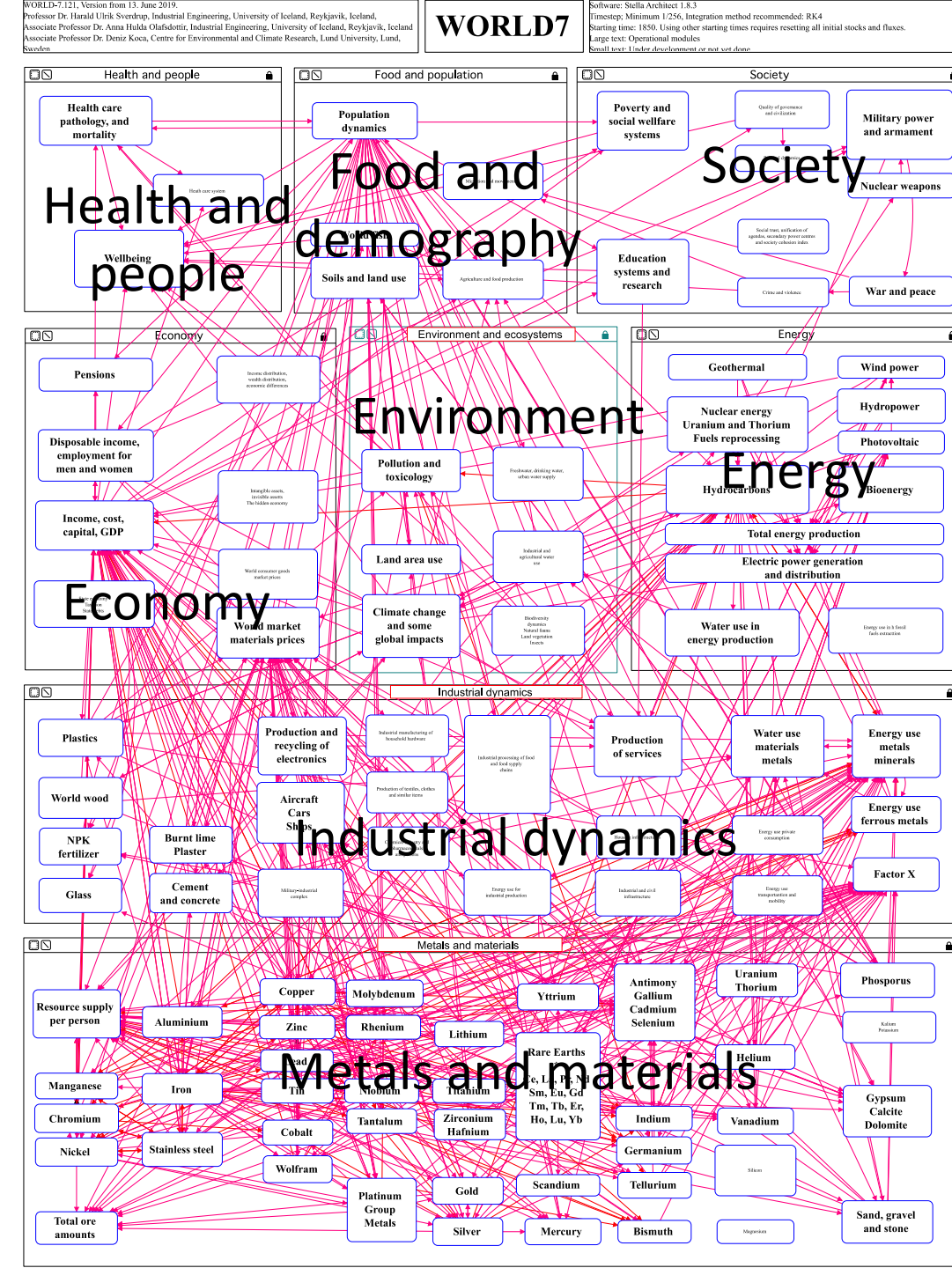


WORLD7 evolution history; To reach high; Stand on the shoulders of others

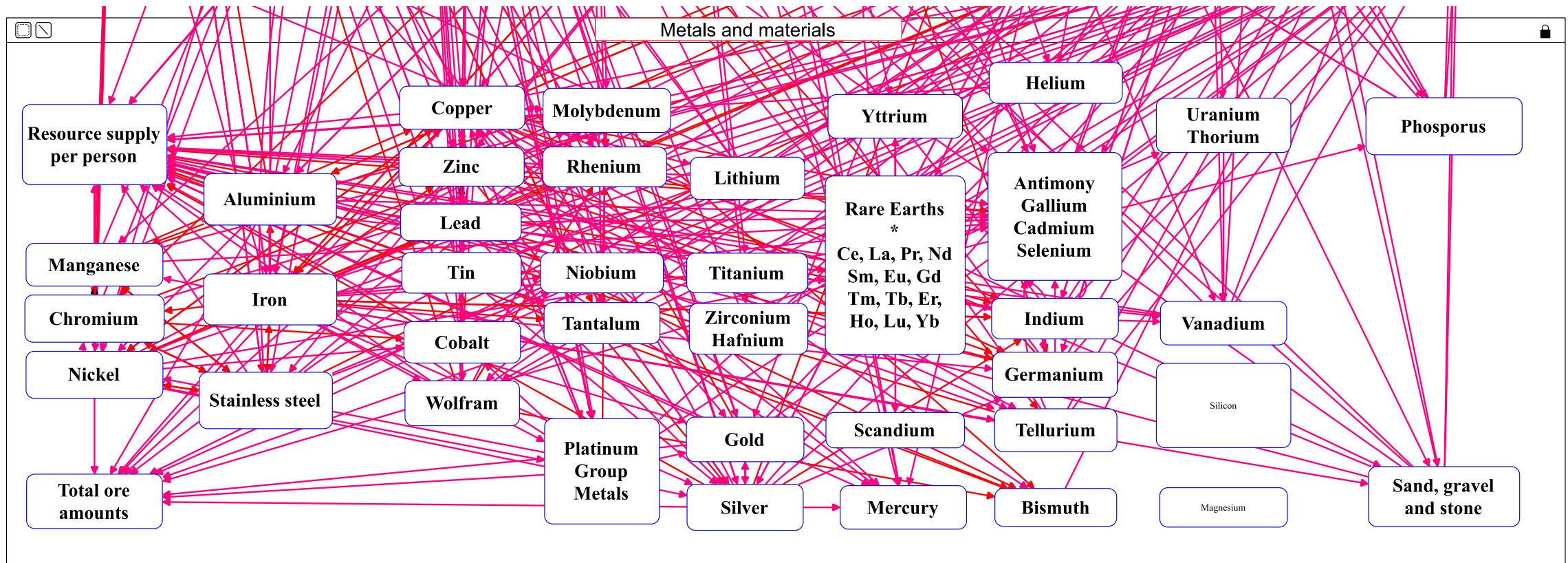
- 2011-2012; **WORLD4**, Sverdrup 2013-2015, **WORLD5** Sverdrup 2015-2019; **WORLD6**; Sverdrup and Koca, 2015-2016, University of Lund and Sverdrup and Olafsdottir, 2016-present, University of Iceland . WORLD6 has reality-based market mechanisms and simulates commodity and resource price dynamics internally. handles the global economic and financial development, and captures economic cycles of growth and decline. The modules are linked and resource and policy aspects can be addressed. The model is developed in the STELLA System Dynamics software. WORLD6 has no parts included from the earlier models.
- 2019-present: **WORLD7**. global integrated Assessment model (IAM). Harald Sverdrup and Anna Olafsdottir: Reorganization of the whole model stucture. Completion of the resource parts. Emphasis on whole system cross-linked feedbacks. Inclusion of social modules, development of a full biophysical economic model.



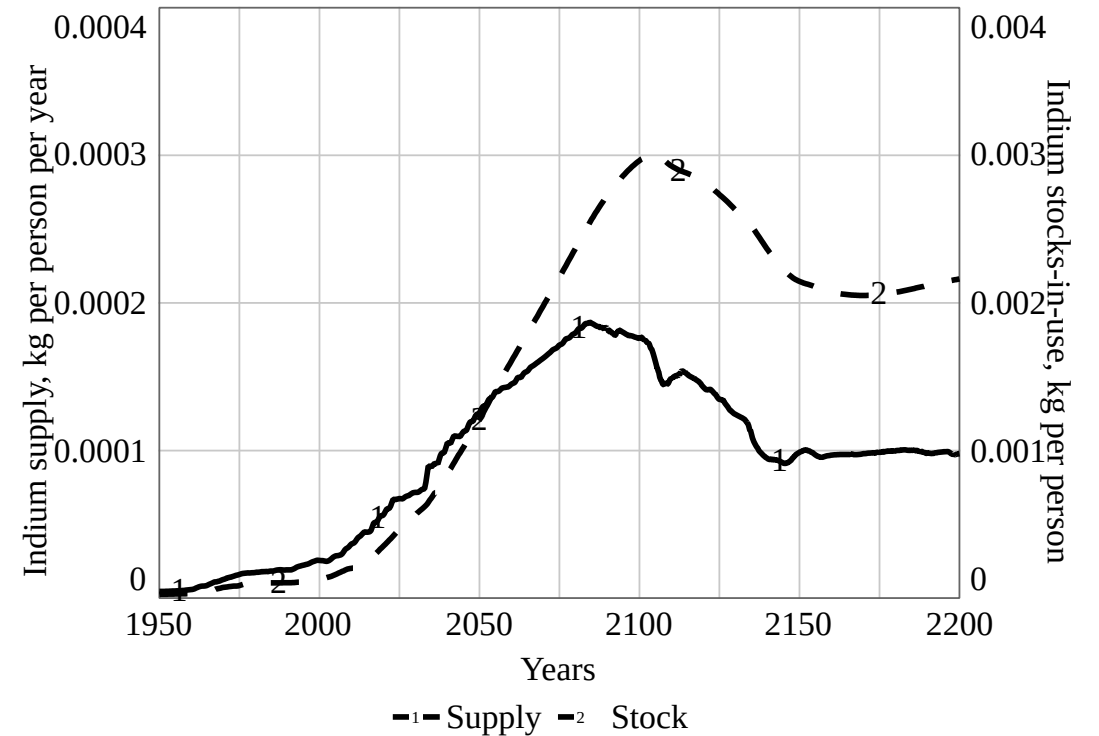
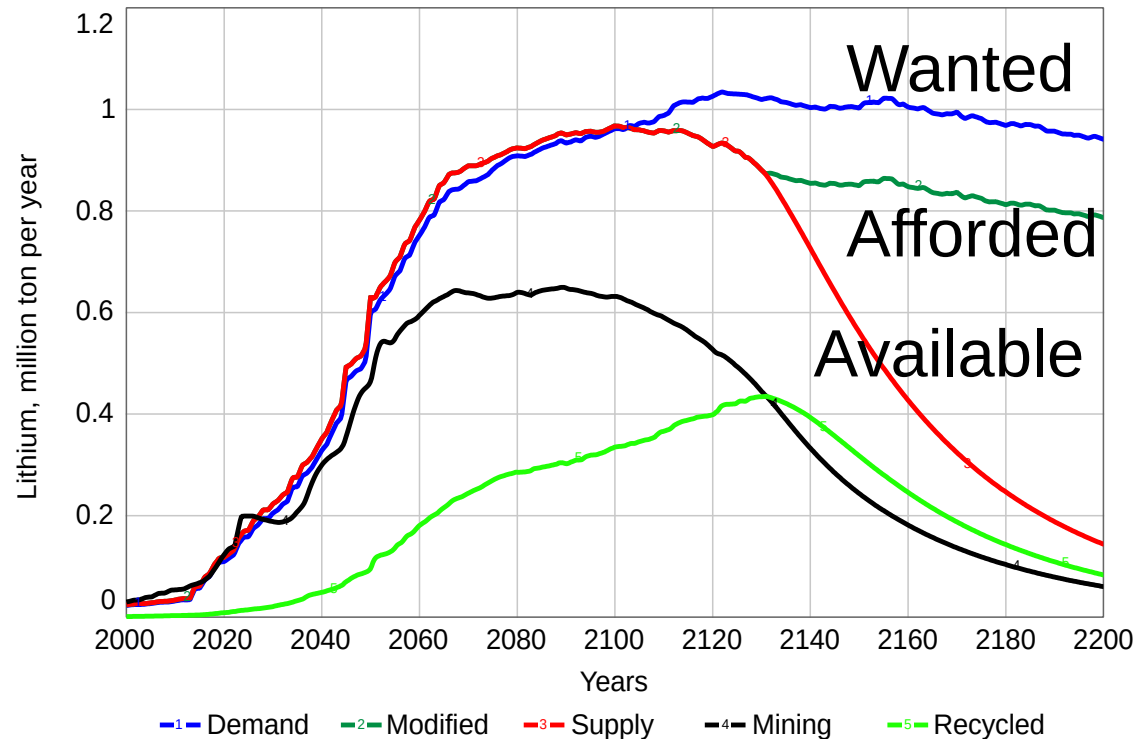
WORLD7 Integrated Assessment Model



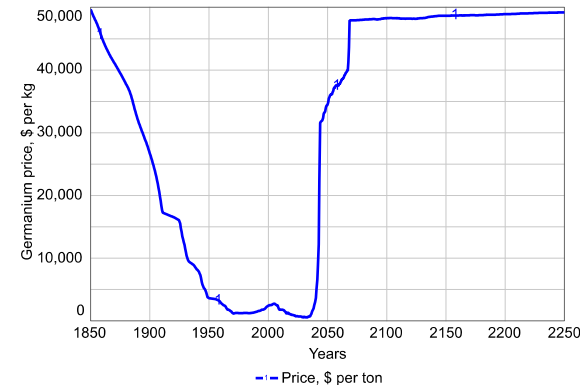
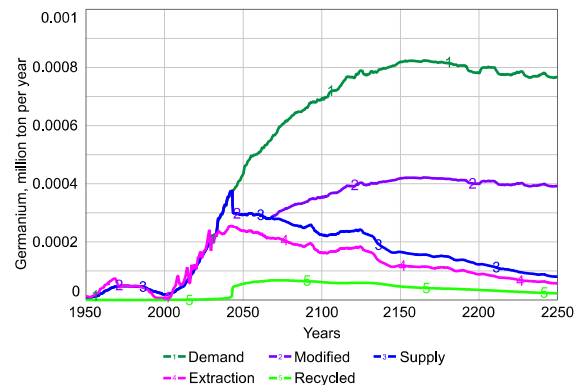
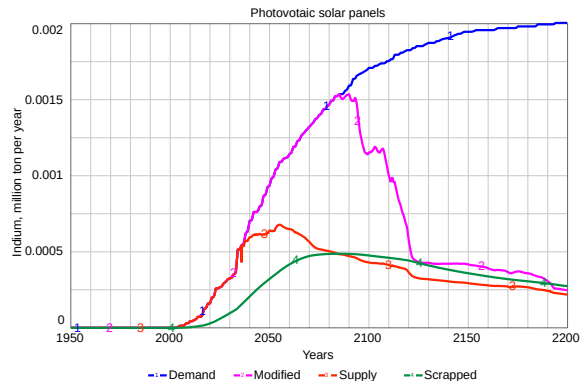
Natural resources, metals and materials



Reading the WORLD7 simulation diagrams for Lithium and indium, understanding «scarcity»



Resource scarcity may limit photovoltaics, a necessity to combine technologies using: Indium, Germanium, Gallium, Cadmium-Tellurium, Silver



Fossil fuels: oil, gas, coal, peat, uranium, thorium, geothermal, many biofuels;

Technology-based energy harvest: photovoltaic, wind;

Renewable energy: hydropower, geothermal, forest-based biofuels

1. Source of energy is unsustainable and resource stocks are declining
2. Resources used in extraction are sustainable

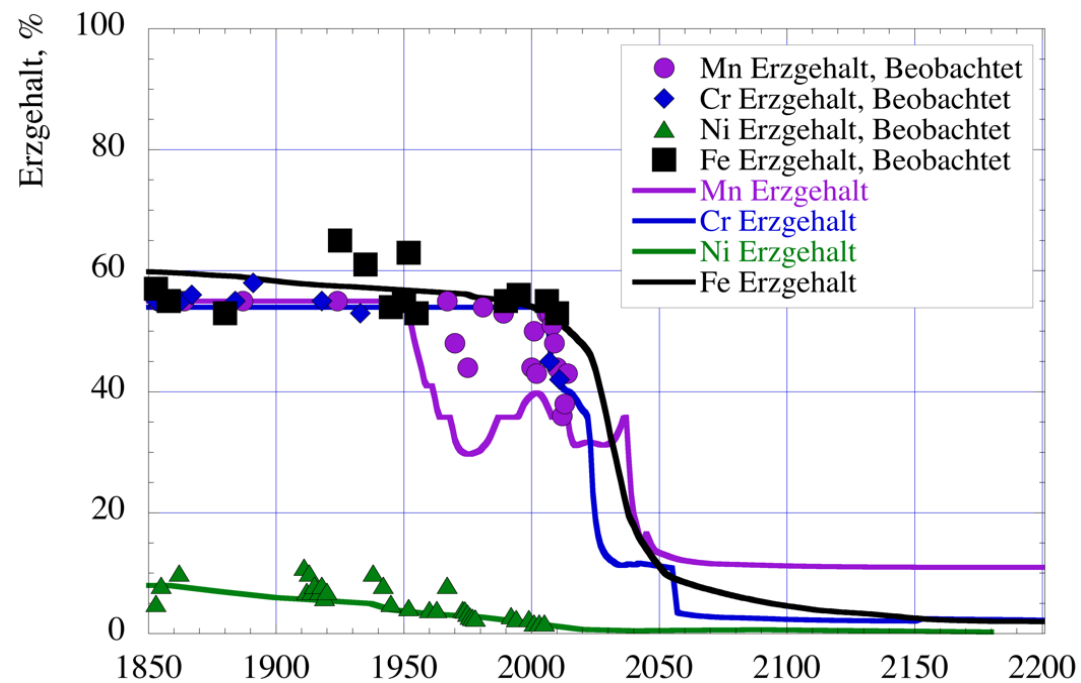
1. Source of energy is sustainable
2. Resources used for extraction are partly unsustainable

1. Source of energy is sustainable
2. Resources used for extraction is sustainable
3. Conditioned on sustainable extraction levels

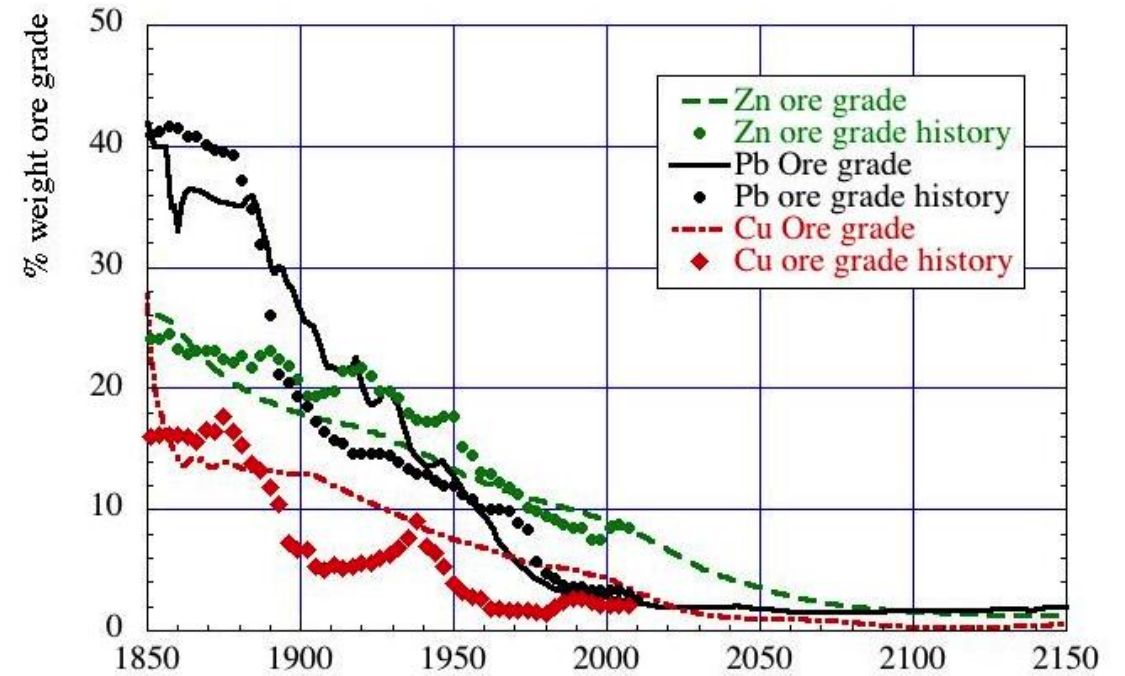
Based on WORLD7 model simulations, new technologies have huge challenges

Metal	Scarcity risk status in year			Policy recommendation
	2100	2200	2400	
Antimony	Enough	Enough	Enough	Business-as-usual
Cadmium	Enough	Enough	Enough	Phase out when possible
Bismuth	Enough	Scarce	Scarce	Improve recycling, make product recyclable
Germanium	Enough	Scarce	Scarce	Improve recycling, make product recyclable
Gallium	Enough	Scarce	Exhausted	Improve recycling, conservation, deposit system
Selenium Indium	Scarce	Scarce	Exhausted	Improve production, improve recycling, conservation, deposit system, make products recyclable
Vanadium	Enough	Scarce	Exhausted	Improve recycling, make products recyclable
Tellurium	Enough	Enough	Scarce	Improve recycling, make products recyclable
Silver	Scarce	Scarce	Exhausted	Limit losses, increase recycling, deposit system
Cobalt	Scarce	Scarce	Exhausted	Limit losses, demand recycling, deposit system
Lithium	Enough	Scarce	Exhausted	Limit losses, demand recycling, deposit system

Resource quality is consistently declining for important energy, materials and metal resources

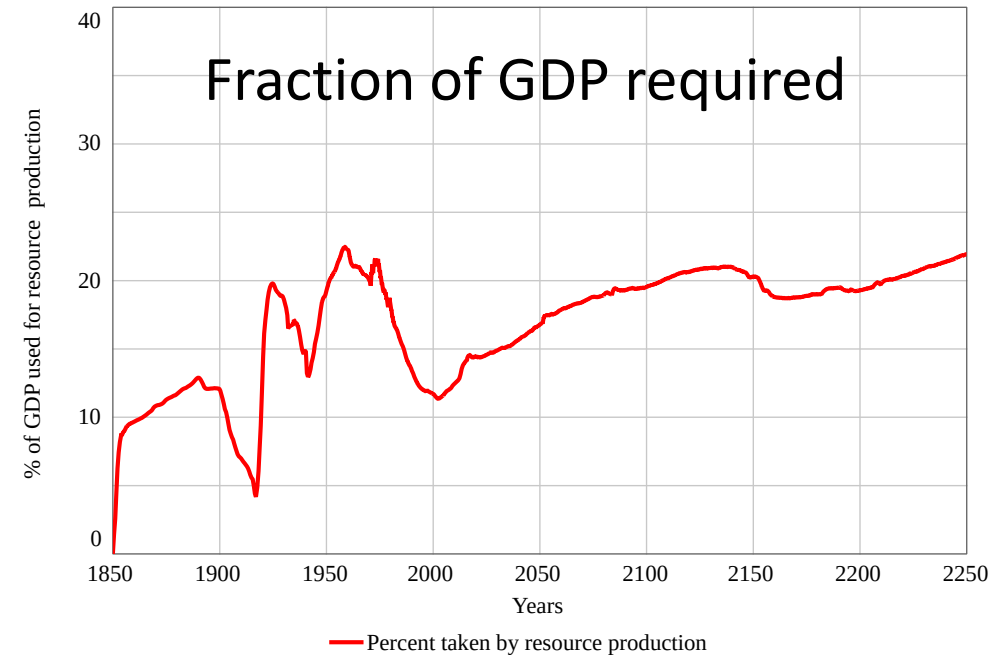
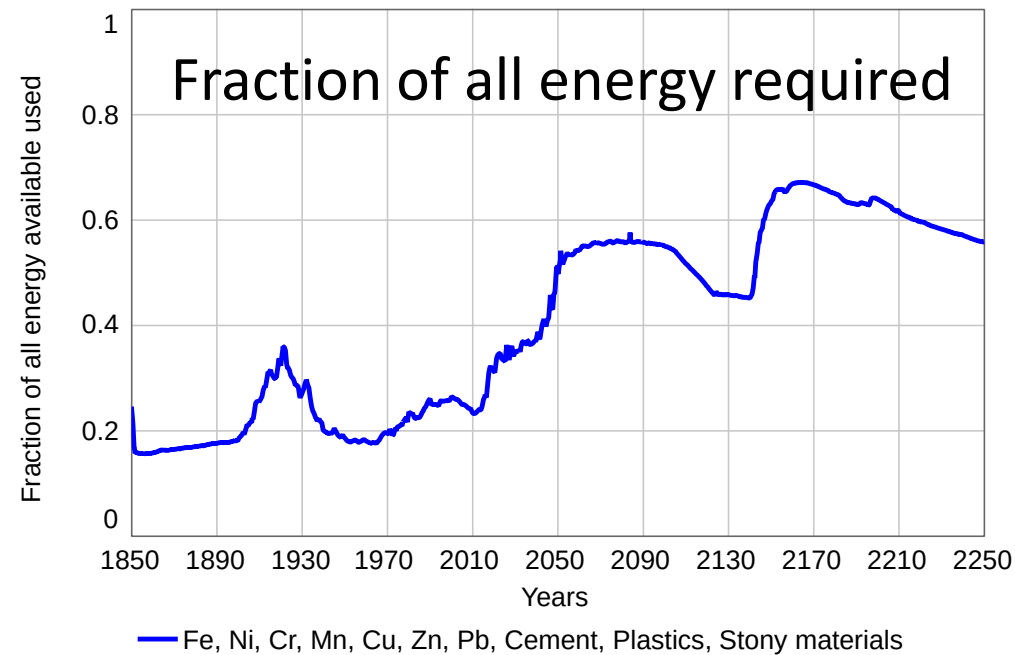


Iron, Manganese, Chromium, Nickel



Copper, Zinc, Lead

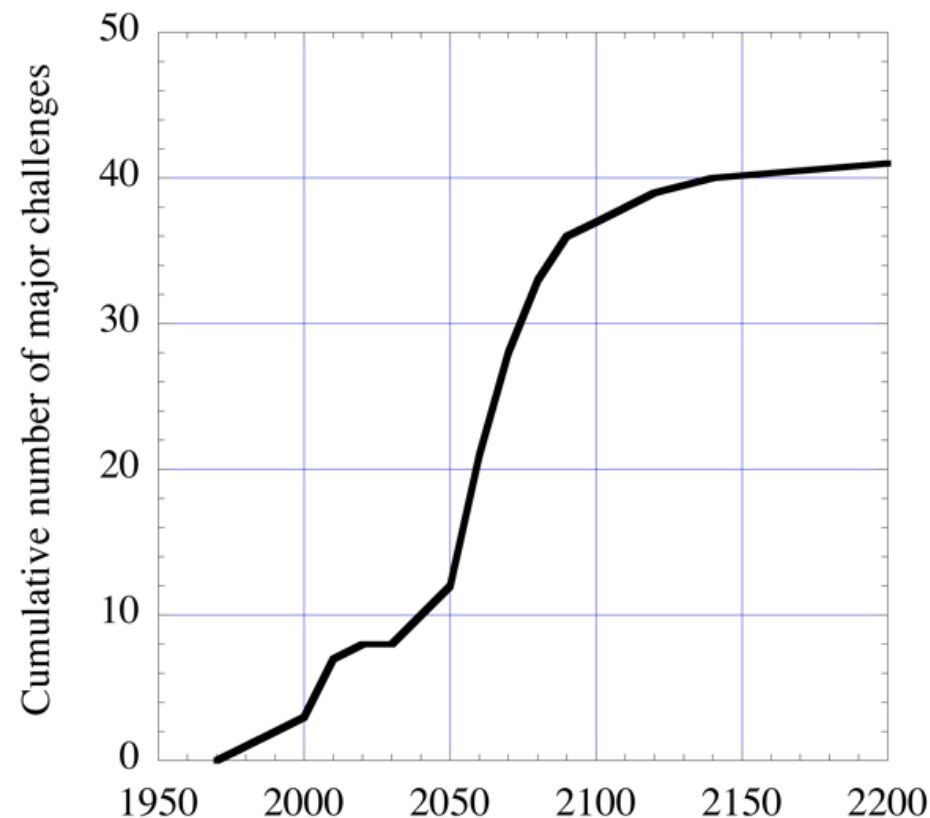
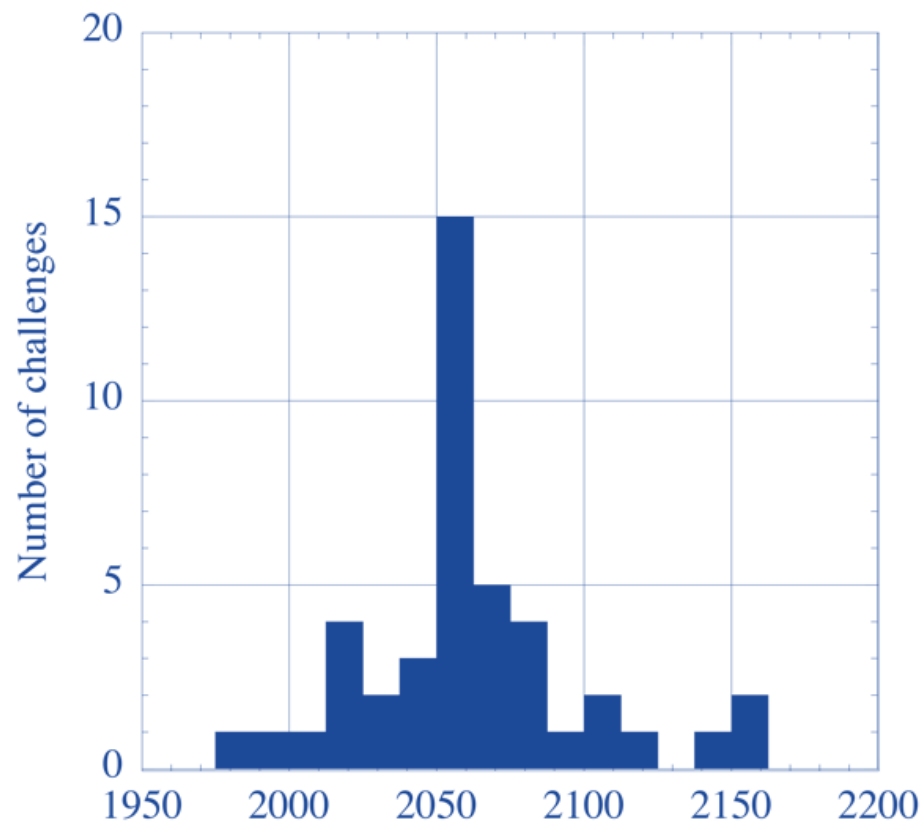
As resource quality decline, cost and effort go up
in order to maintain supply



When Do resource extraction, production and supply reach maximum?

Metal	Extraction peak year	Supply peak year	Recycling degree (%)	Metal	Extraction peak year	Supply peak year	Recycling degree (%)
Oil	2012	2014	0	Titanium	2038	2060	40
Gas	2016	2016	0	Tellurium	1984	2060	0
Coal	2020	2018	0	Phosphorus	2035	2060	16-25
Cadmium	2010	2020	80	Palladium	2042	2065	60
Gold	2016	2036	85-90	Aluminium	2030	2070	75
Cobalt	2026	2040	40	Iron	2052	2072	60
Gallium	2026	2042	5-15	Stainless steel	2052	2070	65
Silver	2038	2045	70	Manganese	2053	2072	45
Selenium	2042	2050	0-5	Tantalum	2035	2078	60
Cut stone	2040	2050	20	Molybdenum	2038	2080	40
Lead	2041	2051	65	Rhenium	2042	2080	40
Niobium	2045	2052	60	Uranium	2035	2080	50
Tin	2046	2055	40	Zinc	2046	2090	20
Antimony	2048	2056	5-15	Chromium	2051	2110	22
Indium	2042	2055	20-40	Copper	2044	2120	60
Rhodium	2034	2058	60	Lithium	2060	2142	10-20
Germanium	2042	2058	20-30	Sand	2075	2150	30
Bismuth	2044	2059	5-15	Gravel	2130	2150	20
Nickel	2028	2060	50-60	Rare Earths	2045	2280	15
Platinum	2036	2060	70	Thorium	2090	2400	90

Challenges pile up under business-as-usual towards 2040 - 2070



Conclusions: There is not much time left!

- We need to act before resource limitations reduce our possibilities and when we still have the minimum required capital available
- Big change takes time, and we need to act at once; how we use the next 3 decades will be critical
- Do not squander the time we have left bickering



孫子兵法



Several operations theatres to win:

- Science arena
- Attention arena
- Policy arena



Alvaro J. Hahn Menacho :: PhD Candidate :: Technology Assessment :: Paul Scherrer Institut

Material scarcity and the energy transition: An integrated LCA-IAM perspective

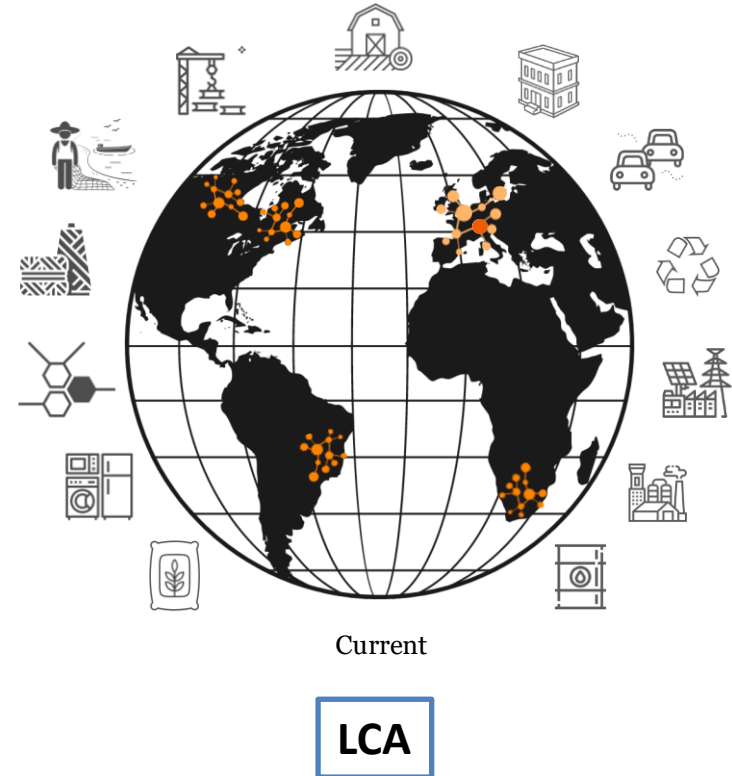
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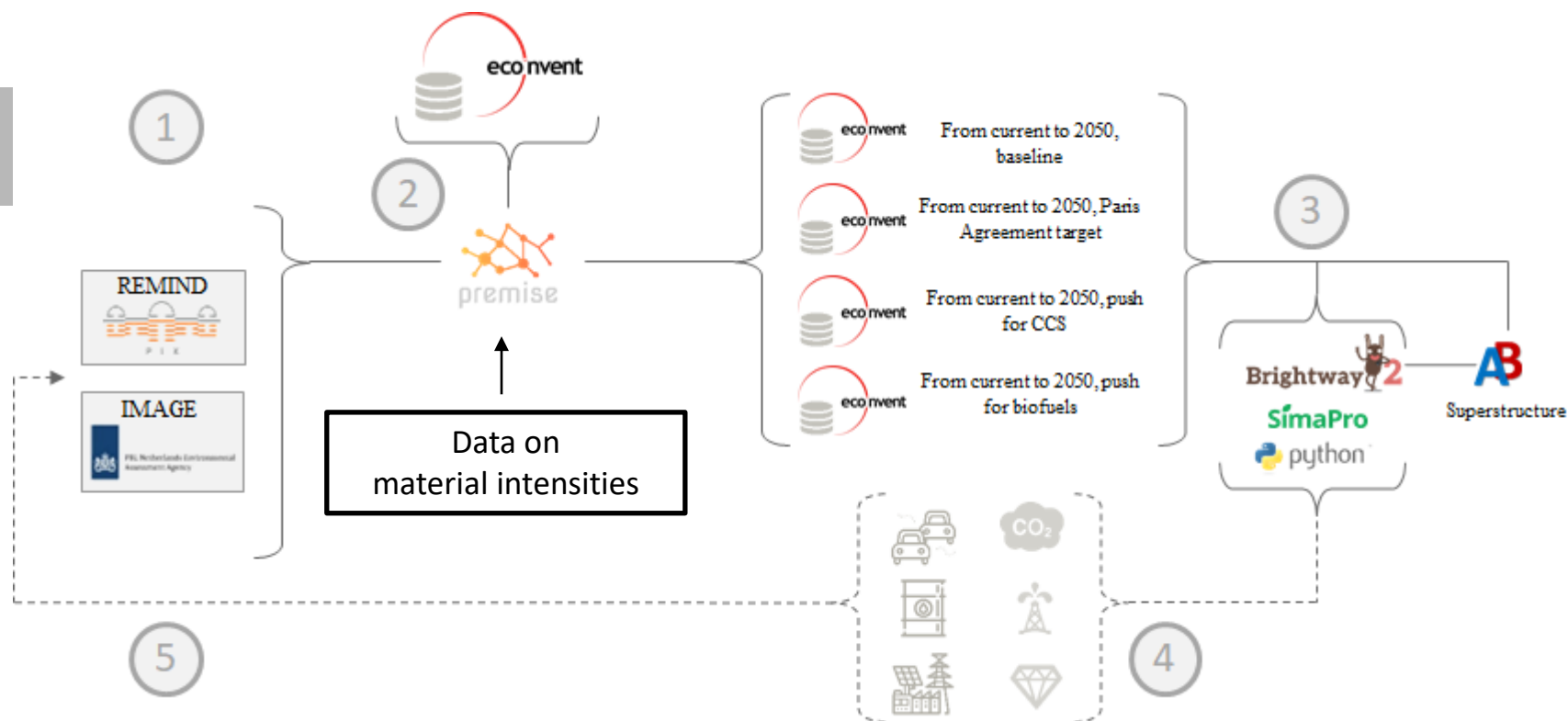
Research Question



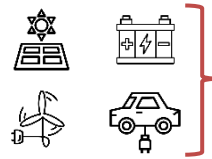
How will **future scenarios** impact the evolving **global demand for metals** in the **electricity** and **transportation** sectors over the next decades?



Method

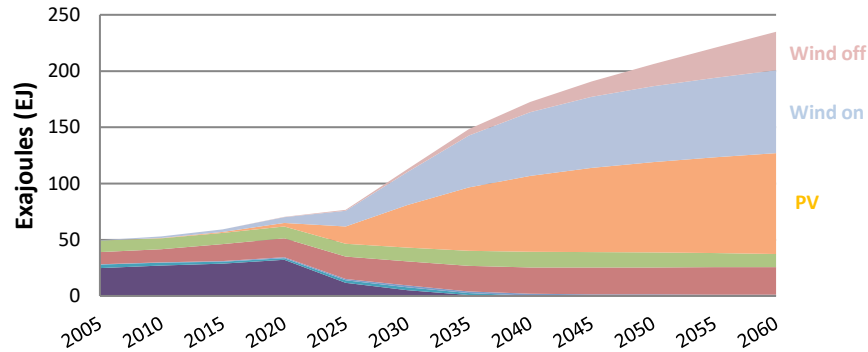
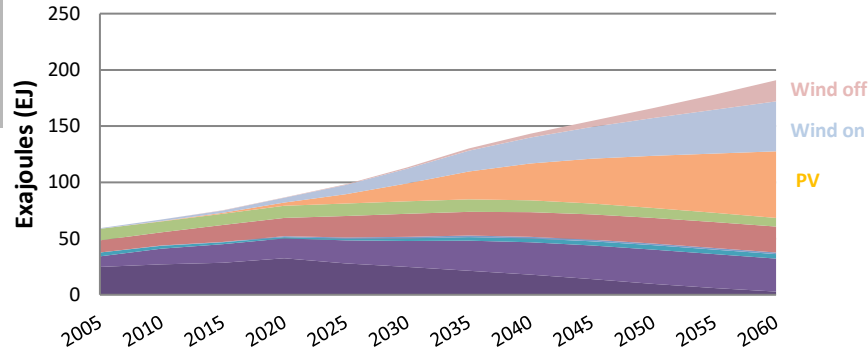


100

Non-CO₂ emissions

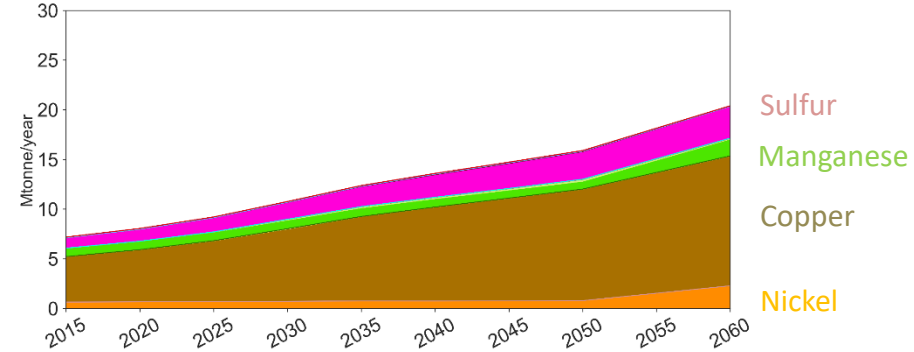
Material demand projections - Electricity

Electricity generation scenario

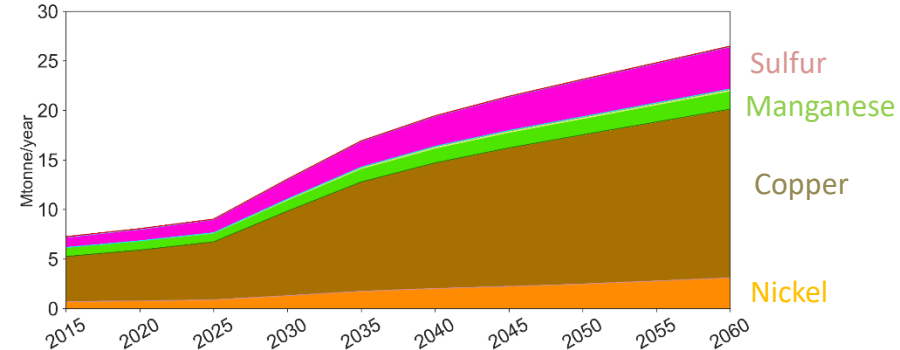


Material demand

Demand from electricity sector - REMIND Base scenario



Demand from electricity sector - REMIND 1.5°C scenario

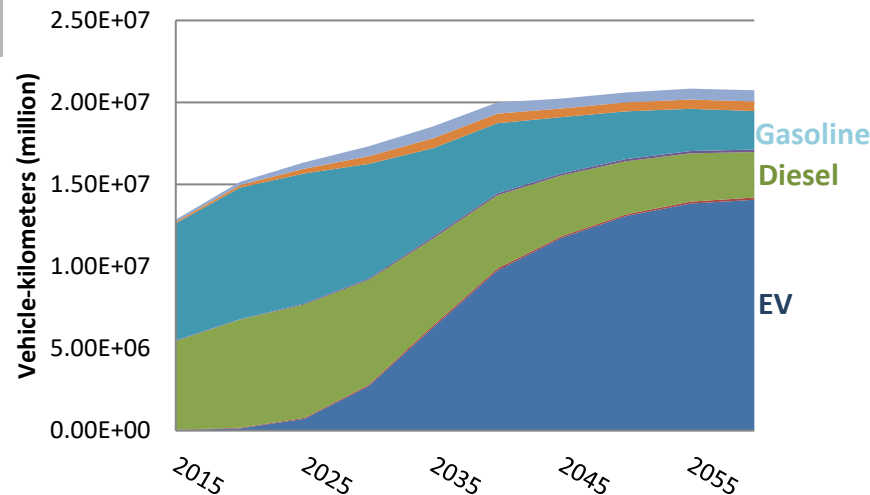


Coal PC
Gas CC
Gas CHP
Gas CC CCS
Geothermal
Hydro
Nuclear
Solar PV Centralized
Wind Onshore
Wind Offshore

Nickel
Cobalt
Copper
Cadmium
Gadolinium
Gallium
Germanium
Indium
Lithium
Manganese
Potassium
Scandium
Selenium
Silver
Strontium
Sulfur
Tellurium
Vanadium
Zirconium
Cerium
Neodymium
Dysprosium
Lanthanum
Yttrium
Platinum
Iridium

Material demand projections - Transport

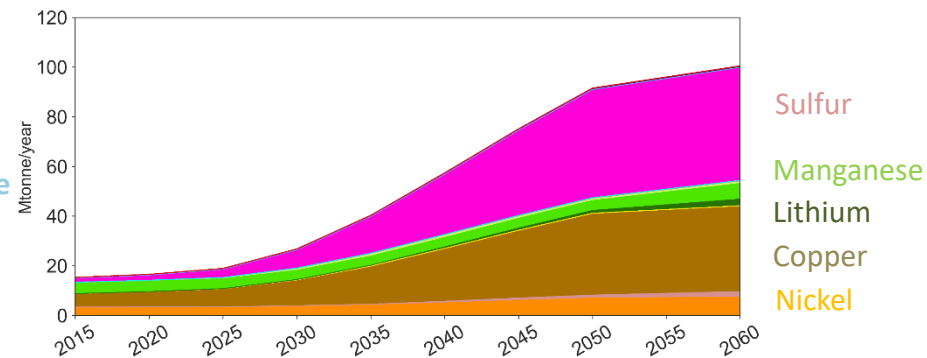
Transport demand scenario



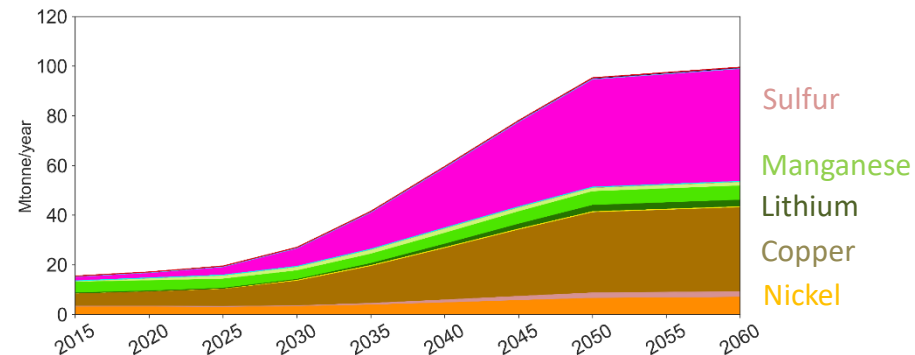
- Battery EV
- Internal combustion - Diesel
- Internal combustion - Gasoline
- Hybrid - Gasoline
- Fuel cell EV
- Internal combustion - Gas
- Hybrid - Diesel

Material demand

Demand from transport sector - REMIND Base scenario



Demand from transport sector - REMIND 1.5°C scenario



- | | | | | | | |
|-----------|--------------|-------------|-------------|-------------|--------------|------------|
| ■ Nickel | ■ Gadolinium | ■ Lithium | ■ Selenium | ■ Tellurium | ■ Cerium | ■ Yttrium |
| ■ Cobalt | ■ Gallium | ■ Manganese | ■ Silver | ■ Vanadium | ■ Neodymium | ■ Platinum |
| ■ Copper | ■ Germanium | ■ Potassium | ■ Strontium | ■ Zirconium | ■ Dysprosium | ■ Iridium |
| ■ Cadmium | ■ Indium | ■ Scandium | ■ Sulfur | ■ Lanthanum | | |

- IAM scenarios can be limited in scope: very few information on metals, chemicals, etc.
- Difficult to systematically assess the spread of a technology
- Inadequate geographical resolution

Next steps

- Enrich the current metals database with factors for other technologies and sectors
- Model not only total demand, but demand from primary and secondary sources
- Add missing inventories related to specialty metals mining
- Evaluate the scarcity of each metal
- Evaluate the total environmental impacts of this supply (e.g. global warming, water use)
 - **Identify material related temporal and geographical bottlenecks associated with energy transition scenarios**
 - **Identify environmental burden shifts between environmental categories and regions**

Wir schaffen Wissen – heute für morgen

Technology Assessment Group

<https://www.psi.ch/en/ta>

Questions?

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Project funded by



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs
Education and Research EAER
State Secretariat for Education,
Research and Innovation SERI



Horizon 2020
European Union Funding
for Research & Innovation





IRTC CONFERENCE 2023

A low carbon hydrogen economy in the UK: decarbonisation driving long-term PGM demand growth

Francesca Price



UK Critical Minerals
Intelligence Centre



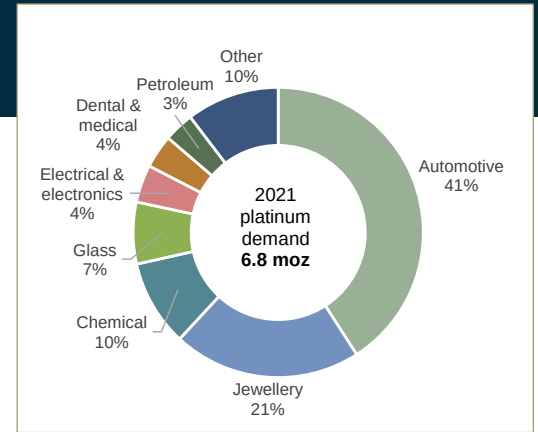
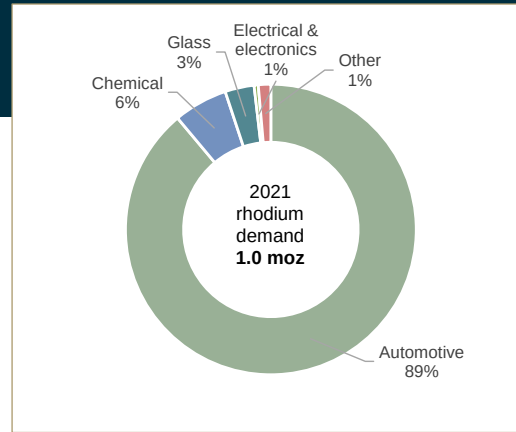
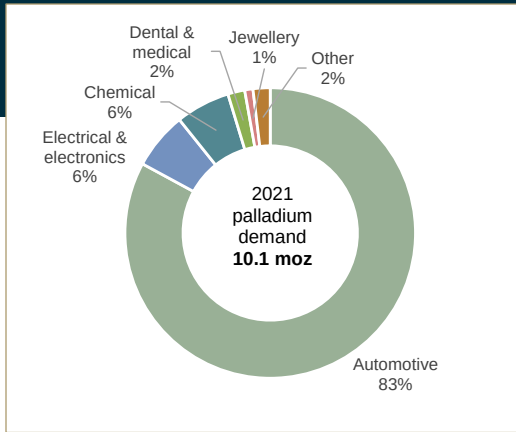
British
Geological
Survey

Change ahead?

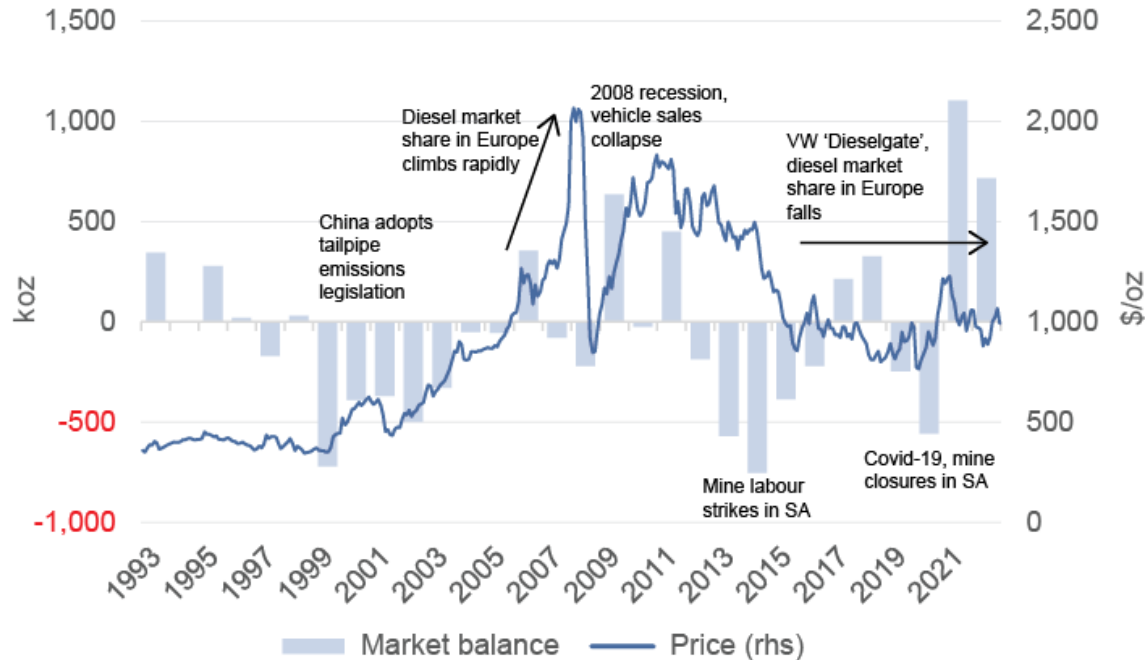
- We are facing huge challenges to the way in which we produce and use raw materials given the current economic and political climate
- Both threats and opportunities have emerged
- The global energy transition will drive major shifts in PGM markets
- Traditional end uses such as autocatalysts will decline over the longer term
- Demand for the hydrogen economy, other clean energy and sustainability applications to increase



Autocatalyst demand dominates Pd & Rh, less so Pt



Declining auto demand has kept prices suppressed

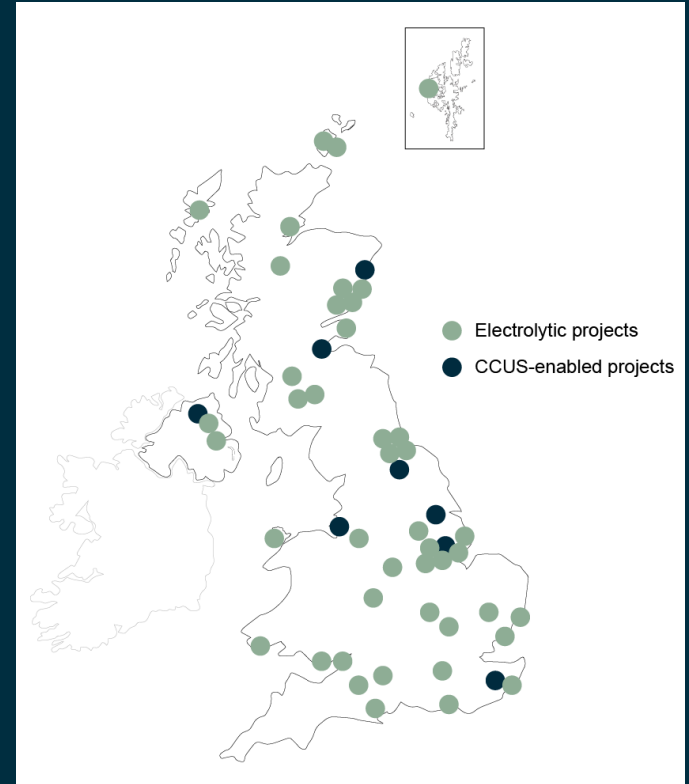


The hydrogen economy has shifted platinum's fate, with added challenges for minor metals

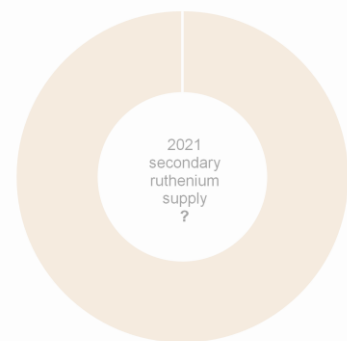
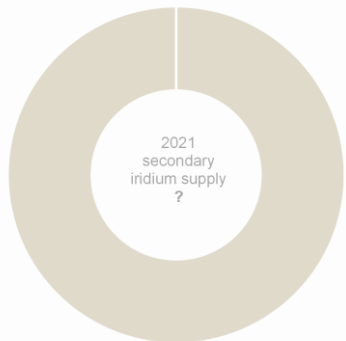
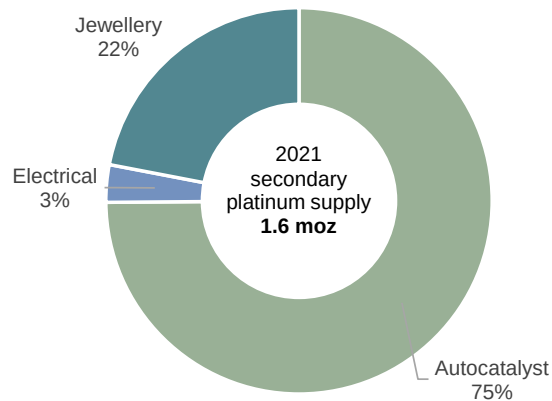
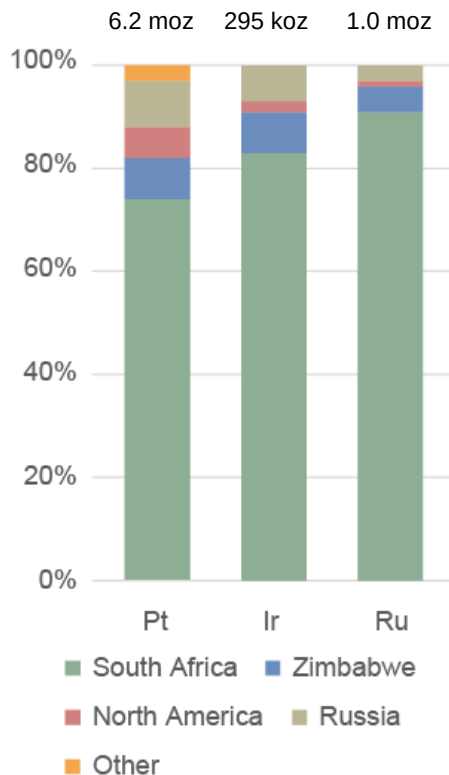
- Platinum and iridium play an essential role in the production of green hydrogen in PEM electrolyzers
- Platinum also used in PEM fuel cells, alongside ruthenium in small quantities to remove CO
- Hydrogen Council estimates PEM electrolyser capacity would need to increase to around 80-100 GW by 2030 to make sufficient progress towards net zero targets
- Assuming a 40% PEM market share and at current loadings, this equates to 225-300 koz Pt and 500-700 koz Ir by the end of the decade
- A meaningful demand opportunity for Pt, a supply challenge for Ir

A green hydrogen economy in the UK

- UK Hydrogen Strategy – 10GW of low carbon hydrogen production capacity by 2030, with at least half from electrolytic hydrogen
- However, UK project pipeline is currently around 20GW
- PEM expected to take a larger share of UK market
- Wide demand opportunity depending on ‘top down’ or ‘bottom up’ approach



South Africa: supplying hydrogen's future



By-product supplies are price inelastic

- In most geological deposits of PGMs, platinum is the primary commodity
- By-products (including Pd and Rh) historically contributed only a small fraction to producers' revenues
- The usual market mechanisms of supply and demand do not apply
- Platinum has determined the structure of PGM mines
- Significant capacity has been mothballed since 2008



A coordinated effort from producers and end-users will support hydrogen's growth

- Significant mothballed capacity that can be restarted with low capital requirements and short lead times
- Producers working to balance their metal portfolios with this emerging demand sector – in their interest for long-term profitability
- Platinum and iridium challenging to substitute entirely, but reducing loadings will be a key enabler for PEM becoming cost competitive with other electrolyser technologies
- Scope to reduce ruthenium content with 'greening' of hydrogen (fewer impurities)

Concluding remarks

Automotive demand to decrease

driven by uptake of EVs and the global transition to a net-zero economy

Green opportunities

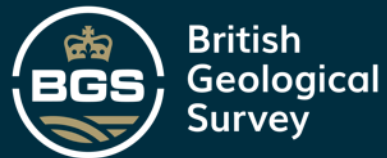
will drive PGM demand over the coming decades, with strong growth from green hydrogen production via electrolysis

Technological innovation

will reduce material intensity via familiar methods, while producers explore ways to maximise supply of critical metals

Working together

to ensure future PGM demand ratios are aligned with supply, helping reduce price volatility and provide reassurance to adopters of PGMs in the long term



THANK YOU

 [British Geological Survey](#)

 [UK Critical Minerals Intelligence Centre](#)