Exploring Critical Materials using Ansys Granta EduPack Software

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Learning objectives and contents

Ansys software mentioned	• Ansys Granta EduPack™, a teaching software for materials education

Intended Learning Outcomes	
Knowledge and Understanding	Understanding of materials criticality concept and challenges with criticality assessment
Skills and Abilities	Ability to identify materials criticality and learn how to use EduPack to help analysing it
Values and Attitudes	Insights into materials-related risk

Contents:

- A brief history of critical raw materials
- Critical Raw Materials and their importance
- Criticality assessment
- Exploring material risk with Ansys Granta EduPack software
- CRM Example: Cobalt

The history of Critical Raw Materials (CRM)

- Post WW1 US passed the 1939 **Strategic and Critical Raw Materials Stockpiling Act**
- The Act established strategic materials supply reserves for the US common defence, industrial demands and military commitments.

The 1939 Act introduced three key initiatives to controlling Strategic material supplies:

- **Determine and develop domestic sources**
- **Devise new methods of recycling and reuse**
- **Develop substitutes for these materials**

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The years post WW2 in view of criticality

During **WW2** geopolitical resource management

1950s, growth limited by resource supply as new technologies need more materials

1960s, World economy grows placing strain on resources and environment

1970s, Growing world population, Oil/materials shortages, the notion of limits to growth.

1975-1980, Guidance released on managing resource supplies and CRMs but not looking at a wide range of materials.

1980-2000s Technological revolution, climate change & sustainability, a start of resource nationalism

btw ca. 2005 and 2015 an emergence of criticality assessment methodologies.

Modern age from ca 2006 trade/armed wars with strategies to secure economic power and strategic autonomy.

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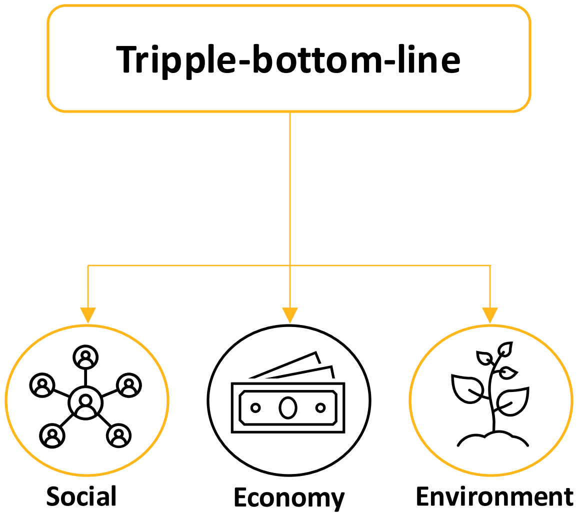
Challenges to today's society

Sustainability Framework in industrial context



UN: the way forward

Yet, we must ask **how** are these goals achieved?
In part, each goal can be achieved via technological solution.

Material flows in strategic technology

There are now many materials that are key to the deployment of technology that will help to solve these problems. These are often referred to as **technology materials**.

Each group of materials in the figure has an associated supply risk. We can see that some of these groups, notably the **Heavy Rare Earth Elements (HREEs)** and **Light Rare Earth Elements (LREEs)**, are high risk.

How do we **categorise** these materials and how can we **mitigate** these risks without sacrificing technological capability and efficiency?

LREE - La, Ce, Pr, Nd, Sm
HREE - Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Y

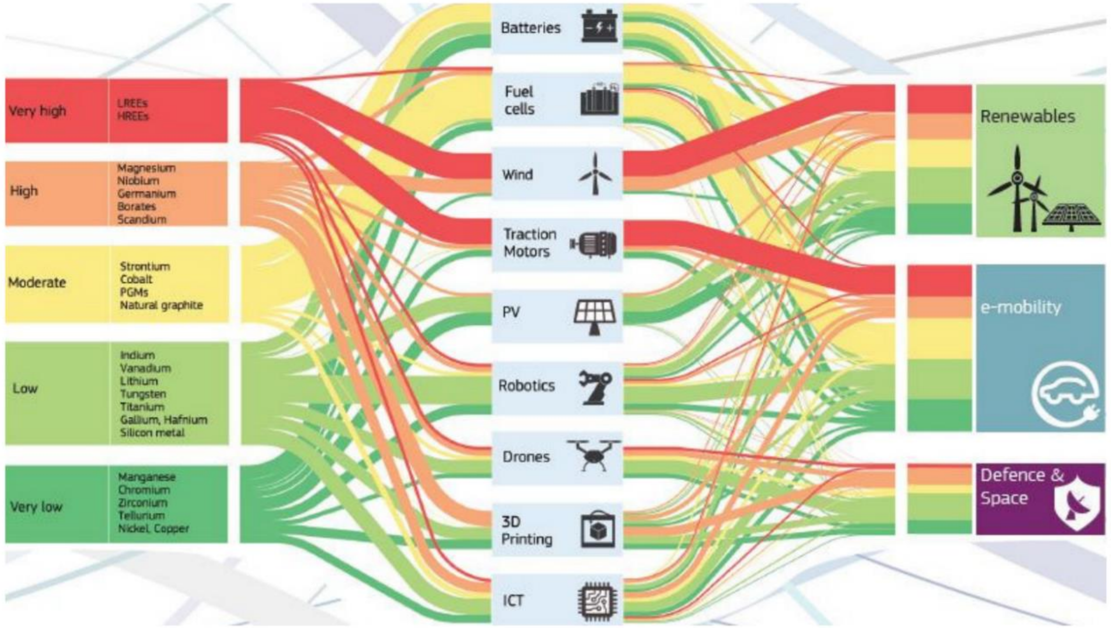


Fig 1 European Commission, Critical materials for strategic technologies and sectors in the EU – a foresight study 2020

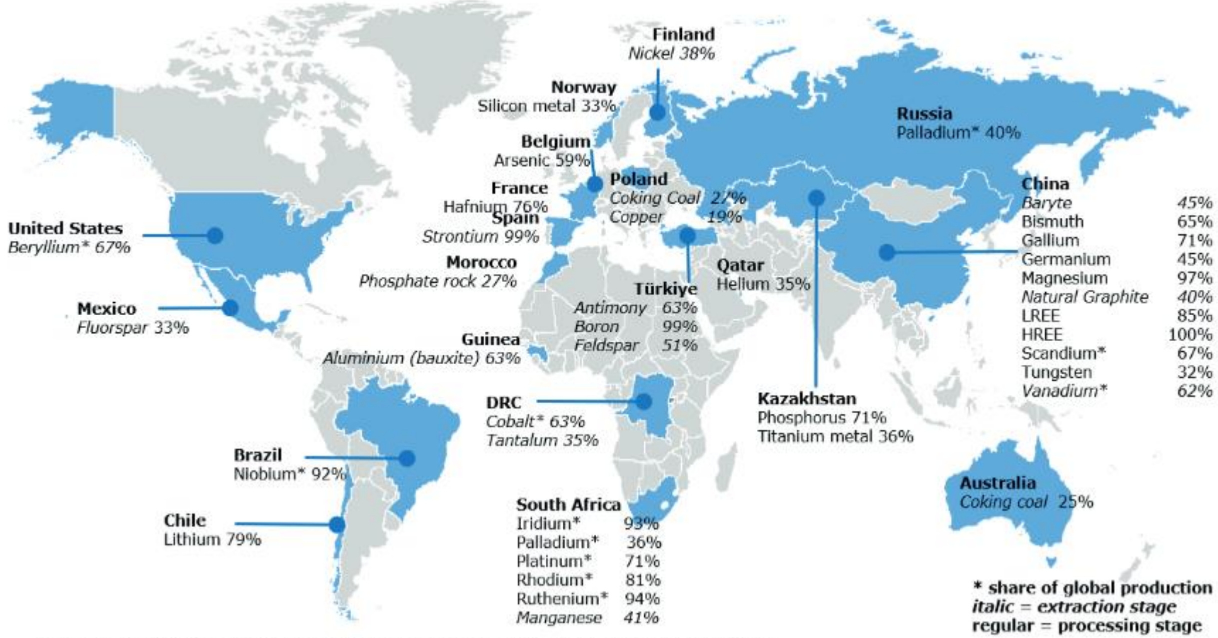
These are just a few examples of how these materials are used in technology. They are used much more extensively in practice.

Critical Raw Materials

There is an inherent **risk** to the **supply** of any material. In order to be able to continue developing and deploying key technologies it is vital to mitigate or avoid this.

Countries and other entities began creating lists of materials that had a high associated **supply risk** and were also of high **economic importance**.

Groups of materials of particularly high economic importance and supply risk are referred to **as Critical Raw Materials** (**CRMs**). Different countries have different lists of CRMs depending on access to domestic supply, geopolitics and economic strength nationally. Such lists are reviewed every 3-4 years.



Source: "European Commission, Study on the Critical Raw Materials for the EU 2023– Final Report"

"Strategic Raw materials" and "Critical Raw materials" are sometimes used interchangeably. Often, however, "strategic" refers more to military purposes or how relevant they are for "strategic technologies". Copper and Nickel do not meet the CRM thresholds but are on the CRM list as Strategic Raw Materials (European Critical Raw Materials Act 2023).

Criticality broader view

- The **scope for criticality assessment** can be different, be that at a level of economy, sector, technology, company, product. For an individual company in the EU the whole list of critical raw materials might not be applicable.

- The **level of criticality** depends on the **probability** of the **supply disruption and vulnerability to supply disruption (or economic importance)**, which can be influenced by **geopolitical, geological, economic, technical, social and environmental factors**.

Example of Rare Earth Elements (REE) strategy in Japan

- Resource **shortages** in 1980.
- **Nationalise** resource reserves.
- Relied heavily on China for REEs.
- In 1983 **stockpiled** 7 key resources.
- 2010 **Chinese REE embargo** on Japan and an increase in export tax and VAT.

Developed production processes that **decrease the use of CRMs**.

Invested in R&D to explore substitutions for CRMs particularly REEs

Domestic ocean supply exploration.

Signed a progressive **deal with EU to share a joint CRM strategy** (2023).

Increased **reuse** and **recycling** of CRMs.

- **Reliance** on Chinese REEs exports fell from 85% (2009) to 58% in 2018.
- By 2025 it is on track to **reduce** its single country **import reliance** for materials to 50%. As well as increasing its self-sufficiency in meeting Cobalt demand to 50%.

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Result of CRM control to the Triple-bottom-line

Japan

Tripple-bottom-line

Economy

- **Diversified** resource supply reduces risk of material shortages. e.g. Japanese supply REEs from Australian mine - Lynas Rare Earth.
- **Innovative technology** with less CRMs can increase competitiveness
- Lessened **reliance** on **single exporters** stabilises industrial economies as commodity volatility and production bottlenecks (a result of supply shortage) are reduced.

Social

- Exploration of new technologies domestically helps engagement of **local communities**.
- Mining conditions in another industrialized country, such as Australia are under scrutiny of international and local regulations - an impact on **workers** can be better controlled.

Environment

- More stable supply of technology materials (CRMs) in Japan means less risk of disruption for production of **sustainable/green technologies.**
- Seabed mining is in exploratory stage, while an idea of bringing more reliable domestic supply is a very attractive one, can cause **environmental disruption.**
- Recycling and reuse reduces strain on **environment**.

Assessing criticality

- Criticality assessments are developed to raise awareness of CRMs and carried out by governments, companies and even individuals.
- If a company uses its own criticality assessment, each company-specific mitigation steps influences the individual criticality score; if it e.g. uses a national list as a reference, this is not necessarily the case.
- The EU evaluates the criticality of a material by aggregating into single values of supply risk and the economic importance. A threshold is then defined for both axes. If a material is found to be above both thresholds – it is considered critical.

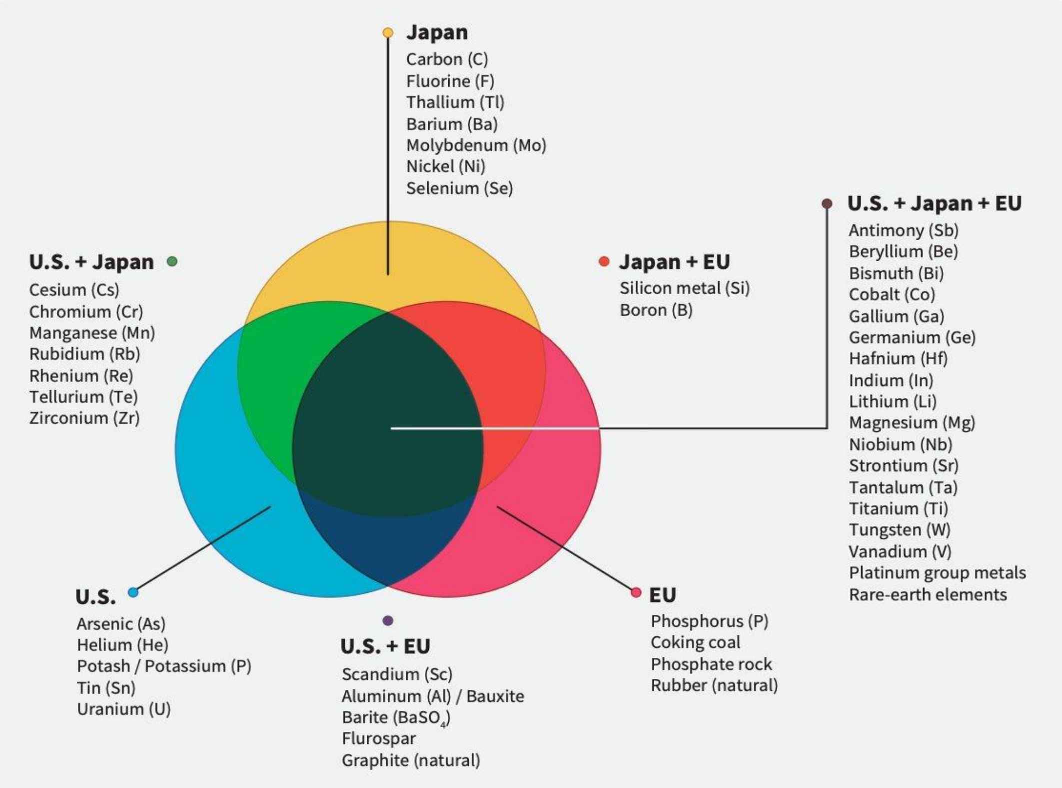
Supply risk categories in Raw Material Supply Risk Assessments
- more information in Helbig C. et al (2021, 3)

Challenges with criticality assessment

"Raw material criticality is the field of study that evaluates the economic and technical dependency on a certain material, as well as the probability of supply disruptions, for a defined stakeholder group within a certain time frame". (Schrijvers et al, 2020, 2).

Issues with criticality evaluation:

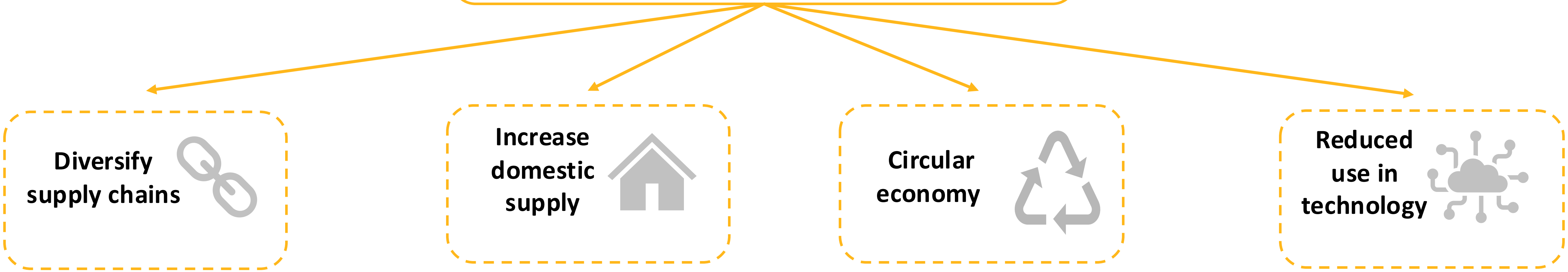
- Differences in goals and scope, leading to different priorities and indicators, not always transparent enough and limited by availability of quality data, yet also reflect individual cases.
- Comprehensive review of criticality assessment methods is provided here: (Schrijvers et al, 2020)



Comparison of CRM lists for the US, EU and Japan
- more information in (Nakano J., 2021).

Methods of mitigating criticality

There are multiple methods of reducing our reliance on CRMs. It should be noted though that at times, CRMs **have to be used** as there are **no alternatives**.



Evaluating criticality with Ansys Granta EduPack software data

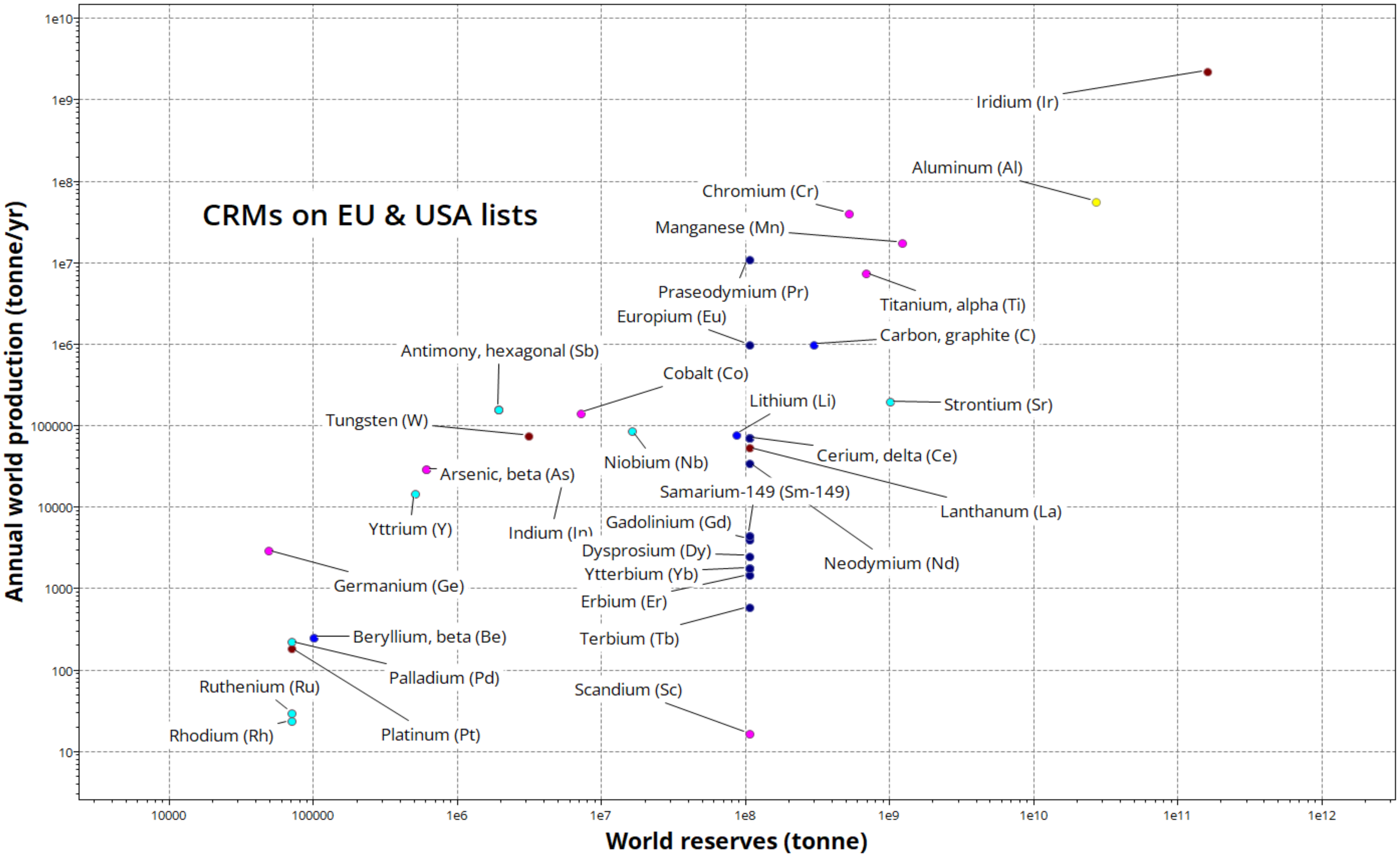
- Can check to see if an element is on either the **EU or US** critical raw material list in the **Element record**.

Critical materials information	
In EU Critical list?	✓
In US Critical list?	✓

- Can also see if **more than 5%** of a material contains **critical elements** in the **Material record**.

Critical materials risk	
Contains >5wt% critical elements?	Yes

Analyzing CRMs data with Ansys Granta EduPack Software



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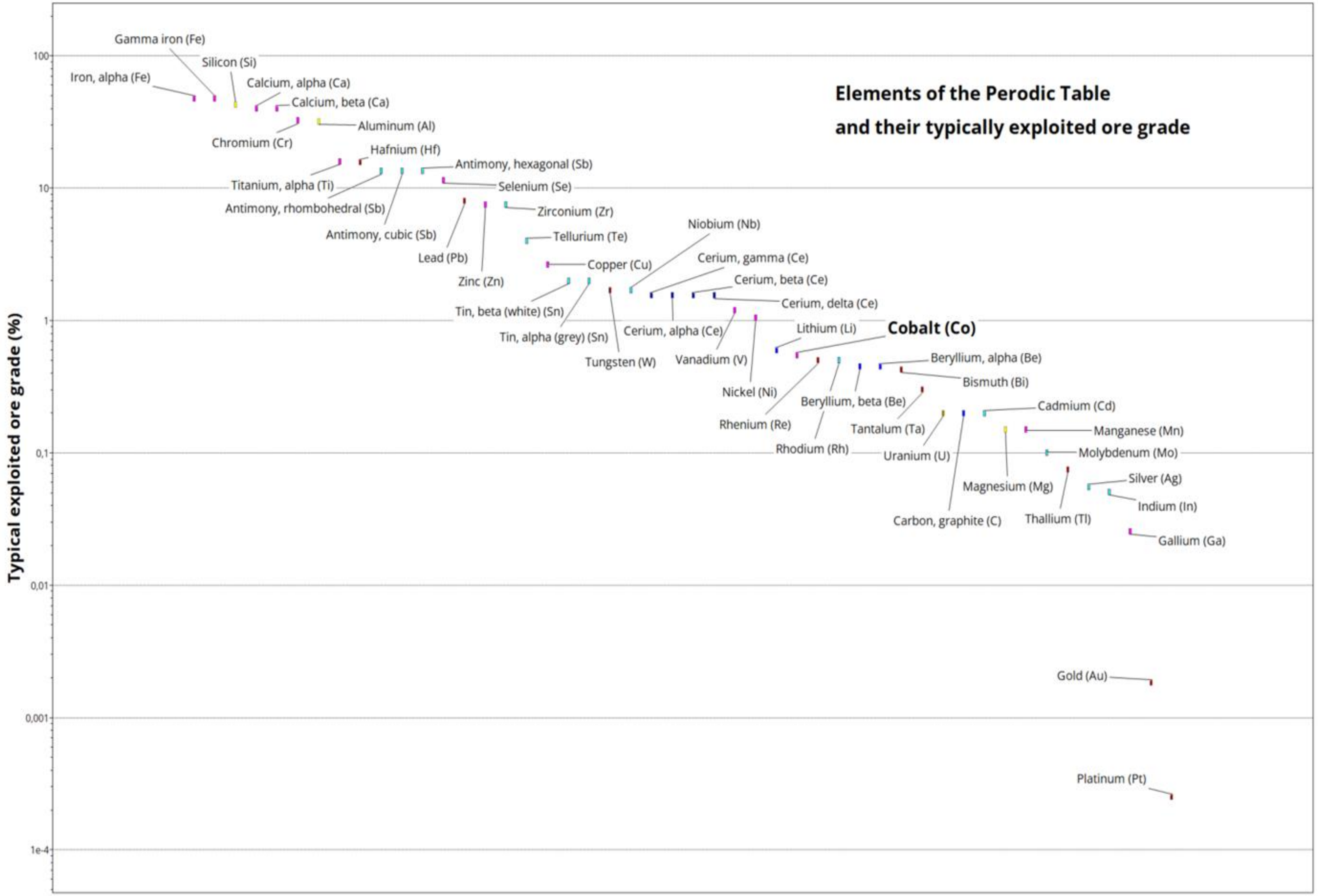
Ore grades & Elements in Ansys Granta EduPack software



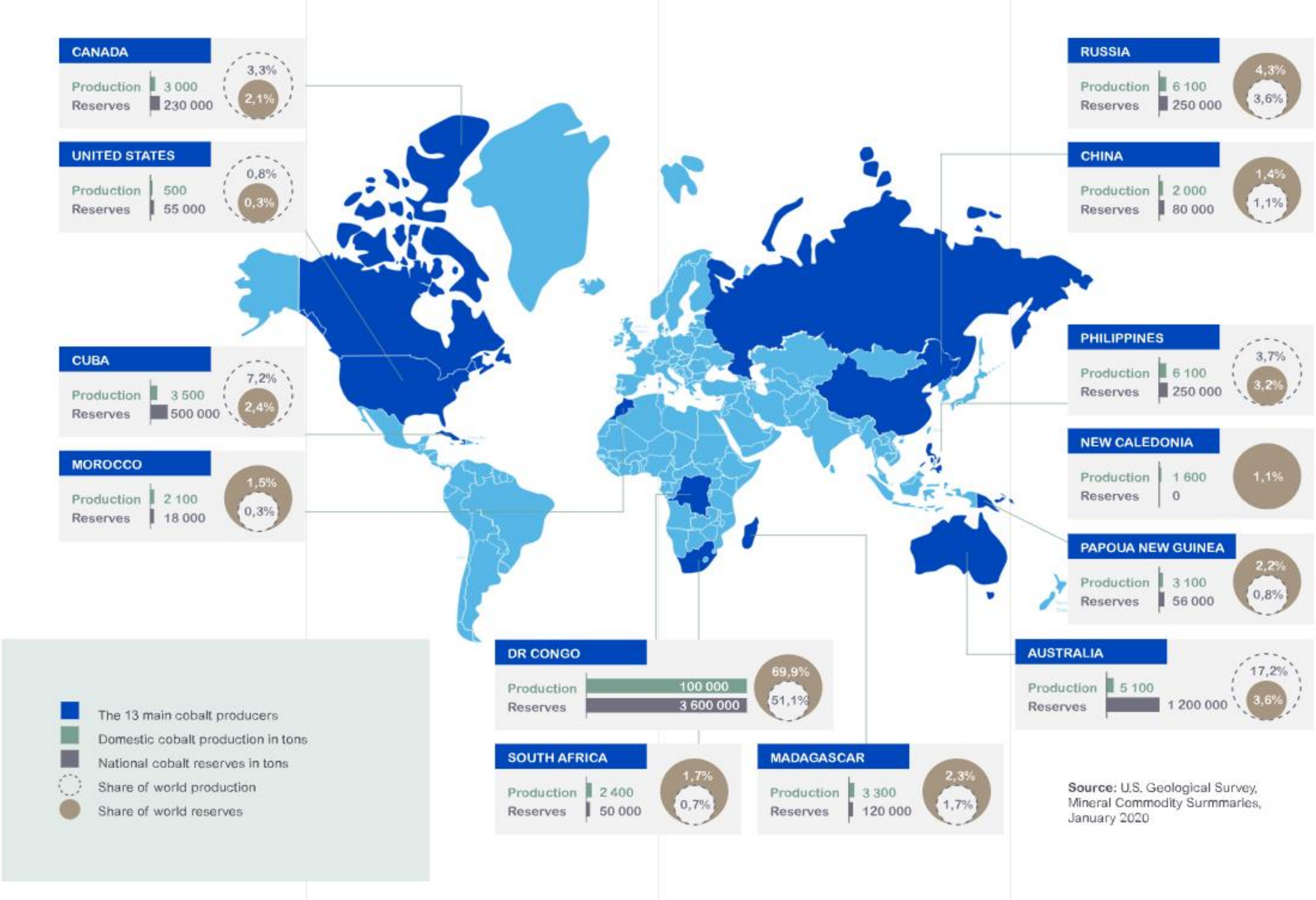
The many uses of Cobalt

27 **Co**
Cobalt

- Used in **medicine** due to their high **biocompatibility**, high **corrosion** and wear **resistance**.
- Used in **Superalloys** in aviation given its high temperature strength
- Cobalt-based cathode technology important for **electric transport/renewable energy storage**
- Can be turned into a blue colour for **pigments** and **inks**.
- **Electroplating** as it is hard and resistant to oxidation.
- Also used as a **catalyst** in the photochemical and plastic industries.
- **Electrical components** in circuits and semi-conductors.
- Component **of vitamin B12**
- Can be magnetised, when alloyed with Al or Ni makes **powerful magnets**
- Extensively used as a component of the **cathode** in batteries.

https://www.omlus.com/wp-content/uploads/2017/12/Cobalt-Institute-60-yrs-1024x561.png - a modified figure from this source

World Cobalt production and reserves in 2019



https://www.cobaltinstitute.org/about-cobalt/cobalt-life-cycle/

The problems with Cobalt

Cobalt has a wide range of applications and is used **extensively** in **sustainable** technologies. **Demand** has significantly **increased** year-on-year.

The **DR Congo** has more Cobalt deposits than every other nation combined.
Co mines in the DRC are mostly owned **by foreign companies**; China dominates refining (2/3 of world production).

The DR Congo relies heavily on 'artisanal' mining. This essentially refers to:

- **Child Labor**
- **Slave Labor**
- **Extremely low salary**
- **Use of hands or pickaxe and shovel**
- **No safety equipment**

Cobalt is a **gamma emitter** and is therefore, radioactive. Complications of unsafe extraction conditions have been shown to include:

- **Cancer**
- **Thyroid issues**
- **Vomiting and heart complications**
- **Asma and pneumonia**
- **Damage to water supply and ecology**

The breakdown

Issues:

- Cobalt is a technology material, and it is therefore of **economic importance. Demand** has greatly increased.
- Extraction grade material is sourced mainly from the DR Congo. The human rights abuses and poor governance in the DR Congo creates a **supply risk and lead to negative social consequences**.

- It is important to note that here the supply risk is **not** a result of the limited reserves, but rather the risk of reliance on a country with **poor governance** and working conditions.
- This creates **reputational risk** for companies, supplying materials from this region, affecting their brand value.

Mitigation:

- Technologies that are **less reliant** on Cobalt could be developed, e.g. **substitution**.
- **Diversification of supply chain and increase of its transparency, potentially via certification** route.
- **Exploration of domestic supply.**
- Increase **reuse** (and recycling) and promote material **circularity,** decreasing demand of primary production.
- **Opportunities for social investments to combat** negative social consequences.

Summary

- Groups of materials of particularly high economic importance and supply risk are referred to **as Critical Raw Materials** (**CRMs**).
- Different countries have different **lists of CRMs** depending on access to domestic supply, geopolitics and economic strength nationally.
- There are **different methods for criticality assessment**, varied in goals and scopes, using different indicators.
- The Granta EduPack software can help **in visualising data on elements and CRMs**, helping with presenting a bigger picture.
- Example of **Cobalt** shows high importance of CRMs and complex challenges in many cases.

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References

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