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Solutions for CRitical Raw materials - a European Expert Network

Primary Resource Supply in Europe

EU Raw Materials Week, 18-22 November Brussels

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Most CRM's are presented like this

- No active #### mining, beneficiation or metallurgy processes have been identified within the EU
- Although quite a few deposits have been in production at some time, most of them are currently considered as mined out, uneconomic, or just not explored at such detail that a feasibility study can be performed.
- Development of innovative technologies addressing exploration of CRM to discover new potential deposits on land and off shore.
- Adapting technology to work with
  - Economical constraints to allow for the exploitation of smaller and lower-grade deposits.
  - The treatment of primary mineral resources with increasing complexity
- To refine low grade ores and materials containing CRM while reducing energy consumption and environmental impact.

No technological barriers in most cases.
Available capital would fix all of these things.

Technology Minerals: Svecofennian Belt & Fennoscandian Shield

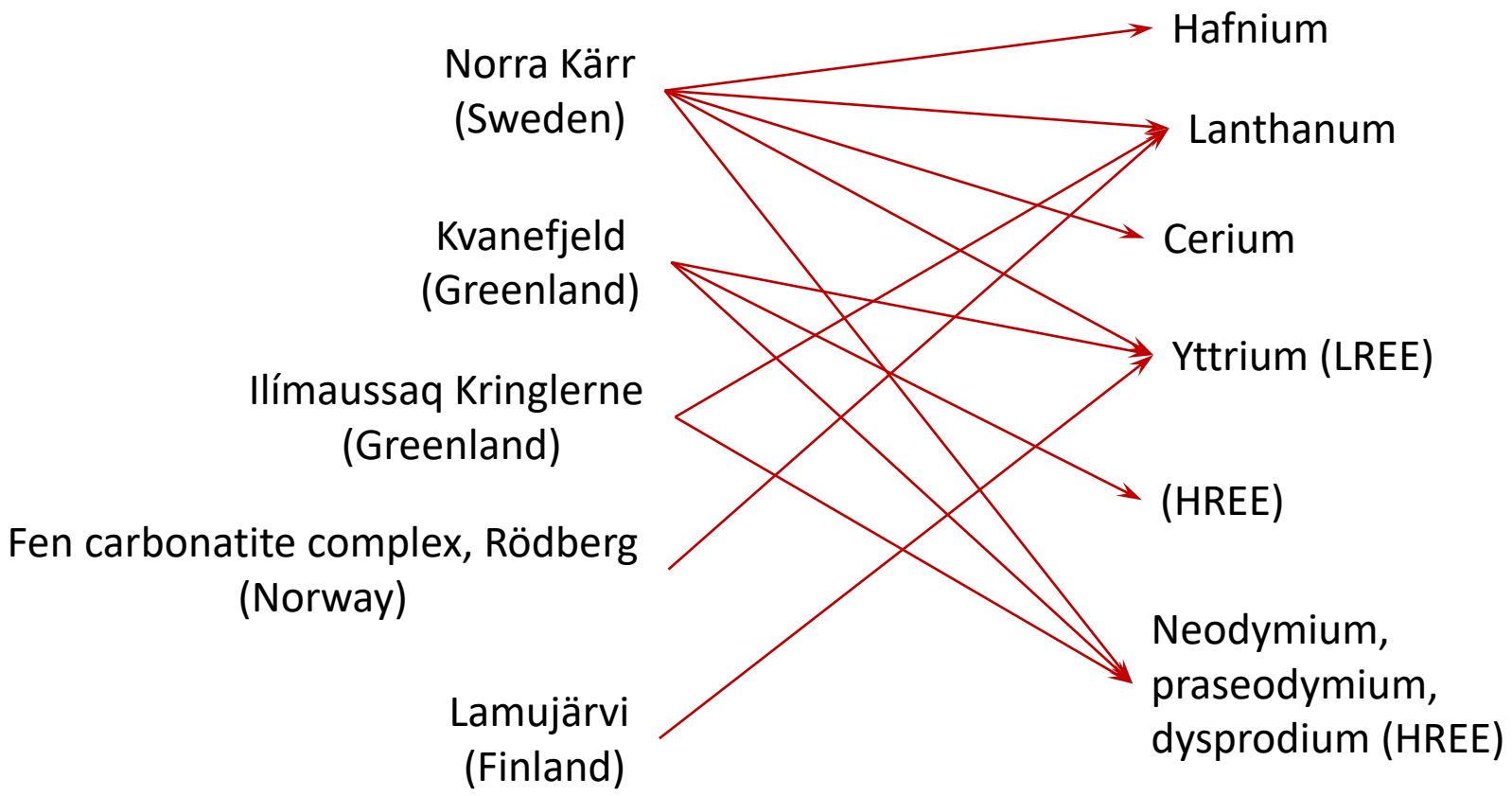
- The most well-known of the REE belts are of Precambrian to Palaeozoic age and occur in Greenland and the Fennoscandian Shield.

- Of particular importance for their REE potential are the Gardar Province of SW Greenland, the Svecofennian Belt and subsequent Mesoproterozoic rifts in Sweden.

- Greenland, Sweden, Finland, Norway

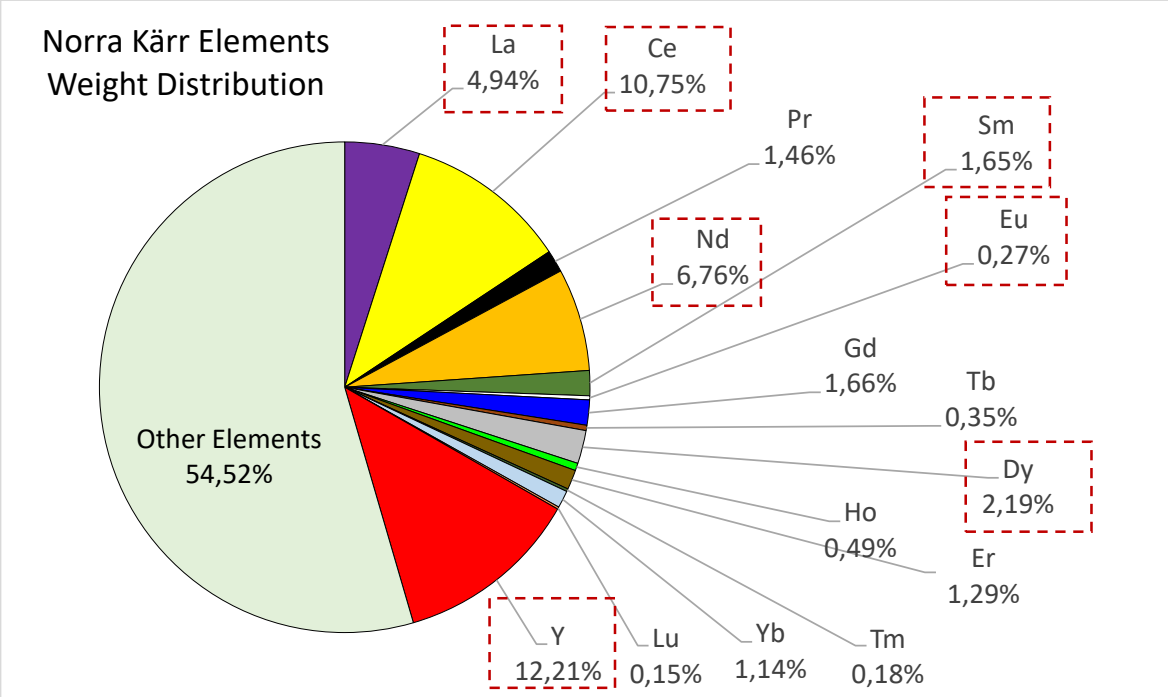
Explore and Develop

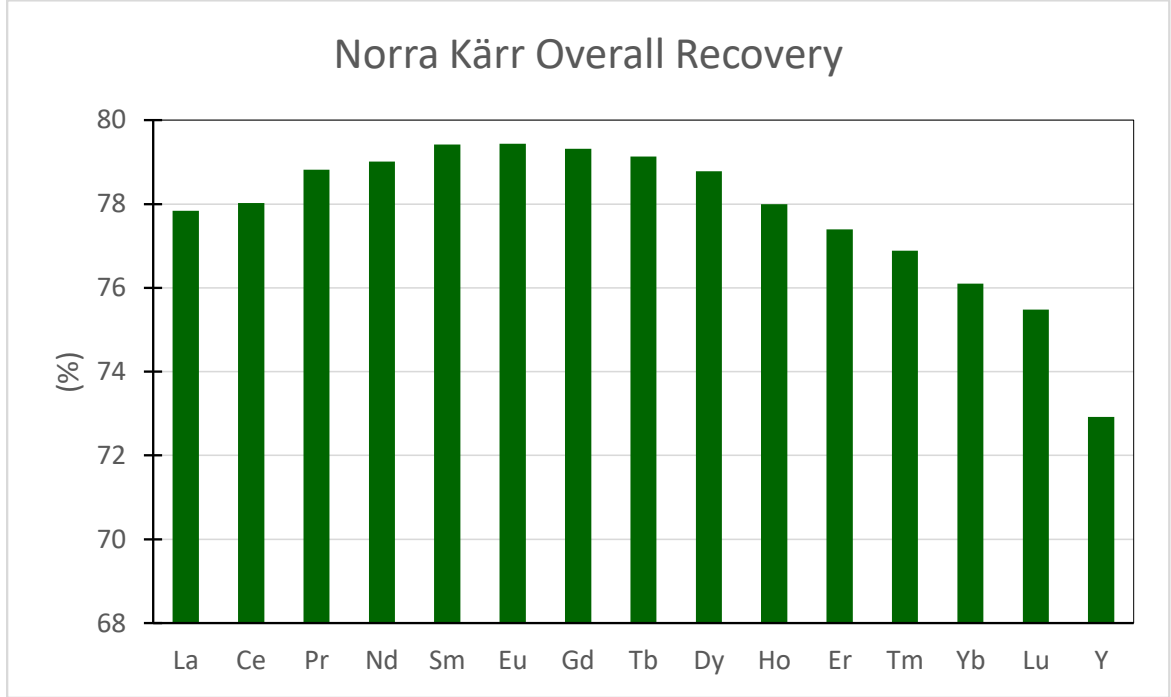
These 5 deposits should be developed



Norra Kärr (Sweden)

Why is this not already developed & producing?





Norra Kärr can deliver a secure long term source of heavy rare earth elements (“HREE”), zirconium, hafnium and niobium to European. Being one of only two NI43-101 REE resources on mainland Europe, the project was identified as potentially significant for European REE security (ERECON study)

M. Saxon, M. Leijd, K. Forrester, J. Berg, 2015. *Geology, mineralogy, and metallurgical processing of the Norra Kärr heavy REE deposit*. Sweden, Symposium on critical and strategic materials. British Columbia Geological Survey.

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Many EU deposits are considered not economic

- The are many deposits that are known and in various stages of mapping that contain useful CRM minerals in them
- There is no appetite to develop these deposits
  - Not considered economic
  - Minerals can just be bought from the international market, so ‘not my back yard’
- Borate
  - There is currently no production of borates within the EU
  - Borate deposits are known in southern and southwestern Europe, but there is no information available in the databases used in this study

Usually no technological barriers

Multiple deposits in EU are known but not quantified to reserve status

- Many known deposits across the EU
- Exploration is required to complete feasibility study on each and every one of these deposits

- Example: Beryllium
  - Primarily produced from two minerals: bertrandite and beryl
  - Known unexploited resources (tonnage data exists): Finland, France, Norway, Portugal.
  - Assumed unexploited resources only (no tonnage data): Denmark, Greenland, Germany, Sweden.

No technological barriers

Conduct exploration & develop prefeasibility level of readiness

Many deposits lack basic metallurgical studies

- Either not done well enough, or has not been done at all

- Example: Cerium

Scandium, Cobalt, PGM, Bismuth, Cerium

- Olserum deposit
  - There are no available published data concerning the metallurgical processing (leaching and REEs recovery) of Olserum concentrate after its flotation.
- Sokli deposit
  - There are no available data related with the metallurgical processing of Sokli ore. The optimization of the ore's beneficiation consists a required/preceded step.

Conduct geometallurgy & metallurgy studies to a prefeasibility level of readiness

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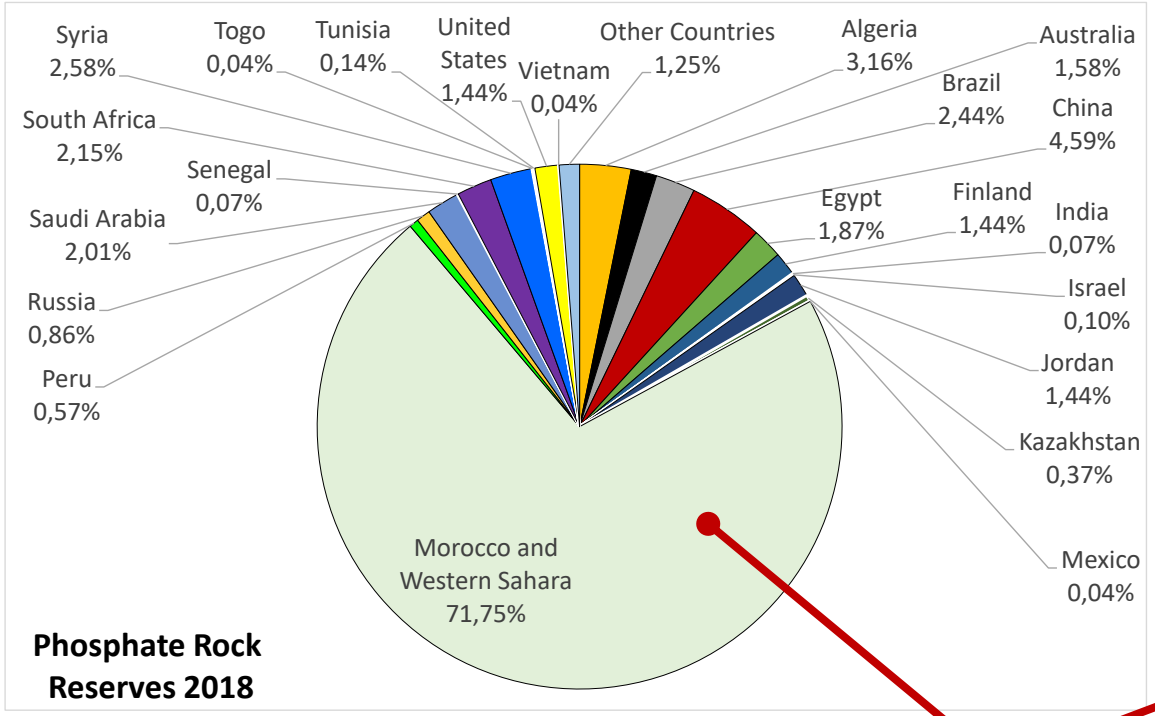
Phosphate rock

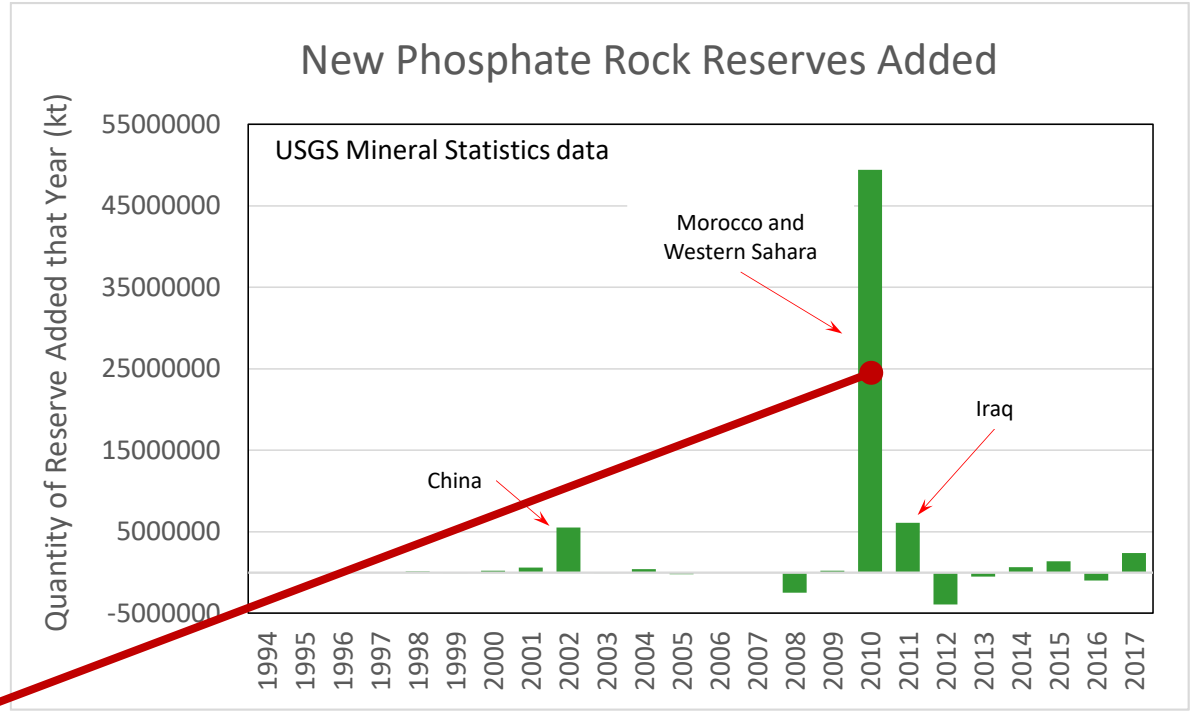
- The only currently operating phosphate rock mine and phosphorus production plant in the EU is in Siilinjärvi, eastern Finland
- There are lots of small scale deposits in EU
- Map them properly into reserves
- Develop each of them to pre-feasibility level of readiness

Most phosphate is in a centralized geographical supply

Production China dominated by 53%, Morocco 10%, U.S. 11%



Phosphate Rock Reserves 2018



Note: Iraq reserves not included in USGS data since 2015

USGS Mineral Statistics data

Reserve data a state secret. Not subject to external audit.

New discoveries have been few and small

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Land degradation and petrochemical fertilizer use in industrial agriculture

- Approx. 33% of the world's adequate or high-quality food-producing land in the past 40 years has been lost, related to use of petrochemical fertilizers
- At a rate that far outstrips the pace of natural processes to replace diminished soil erosion rates from ploughed fields average 10-100 times greater than natural rates of soil formation
  - With current arable land loss at a rate of 0.5% each year
  - 0.8 m^3 of soil sterilized for each bushel of wheat sent to market

Cameron, D., and Osborne, C. (2015): *Soil loss: an unfolding global disaster*, University of Sheffield's Grantham Centre for Sustainable Futures, presented at COP 21: UN climate change conference in Paris, published in News, Research, Policy by Grantham Centre for Sustainable Futures.

- Innovate a substitution as a raw input to make industrial agricultural fertilizer, or evolve food production so it does not need petrochemical products

Global Supply of EU Critical Minerals

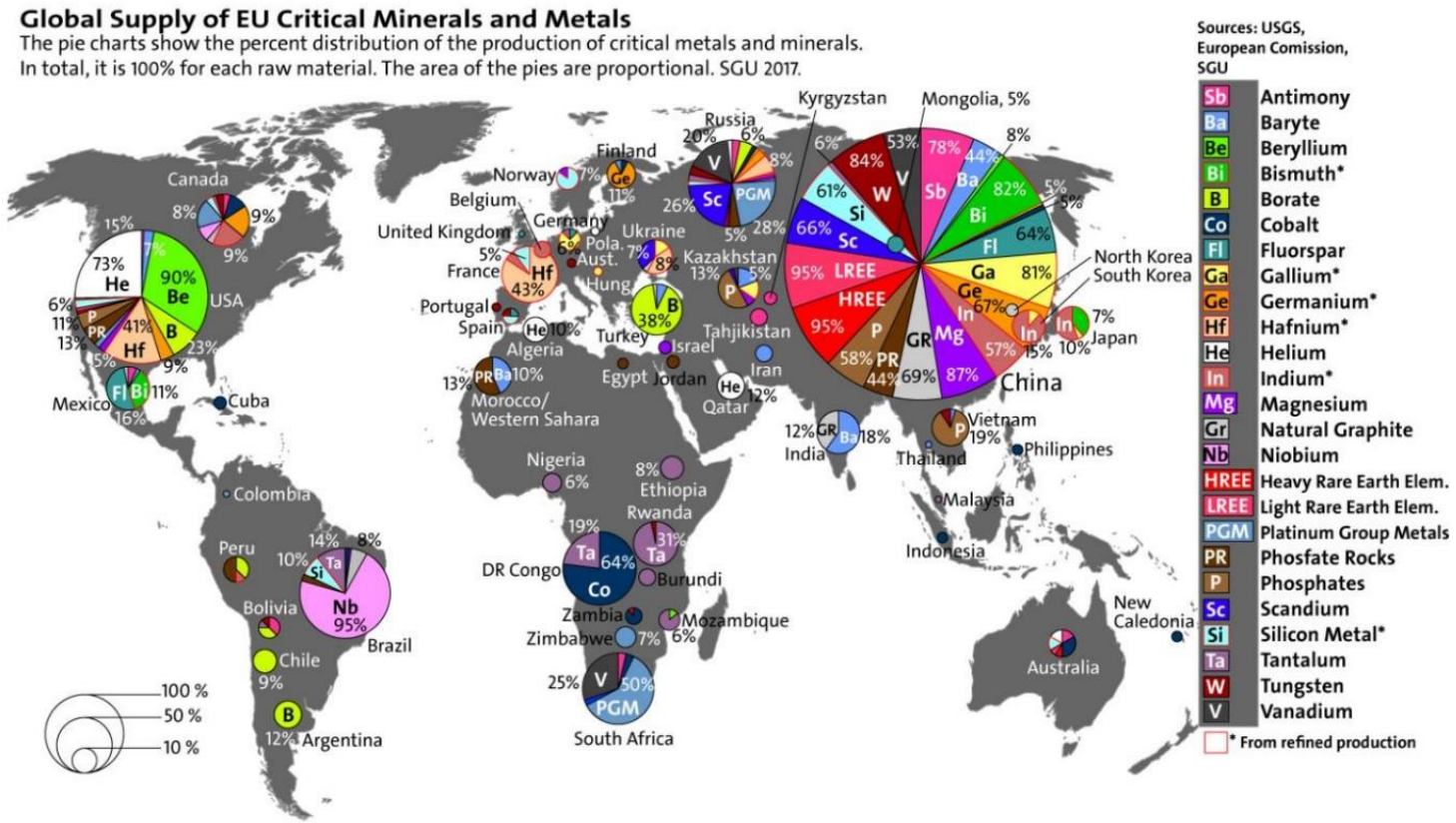

Figure 1 Global supply of EU Critical Minerals and Metals. Source: SGU

China now dominates mining, refining, smelting, manufacture and recycling

Current state of play in Chinese plan:
Made in China 2025

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The two paradigms in the ‘developed’ world…

1. All products manufactured should be 100% sourced from socially ethical and environmentally sustainable sources.

This is usually much more expensive and is often not as strong in performance.

Political strategic development

2. The most economically lowest cost products should dominate the market.

When it comes down to spending their own money, consumers usually pick this option.

Economic market reality outcome

Social belief is out of phase with market reality within the same demographics

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China is industrially dominant because…

- Environmental restrictions are much more lax
- Social acceptance of industrial operations less relevant

- Chinese operating costs are lower, at a rate not legal in Europe

- PRC government strategic planning backed by serious capital and corporate cooperation (start in approx. 2000)
- China first industrial ecosystem is fully developed and effectively optimized to support Chinese businesses
  - Chinese objective = be the worlds biggest and only industrial superpower

Technology breakthrough (that we keep)

Change business model behind mining

Develop a European equivalent, fit for purpose to be <u>domestically resilient</u>

A series of interlocking industrial ecosystems that serve an EU strategic purpose

If we continue to use commodity price as a metric, we may as well concede the market to China

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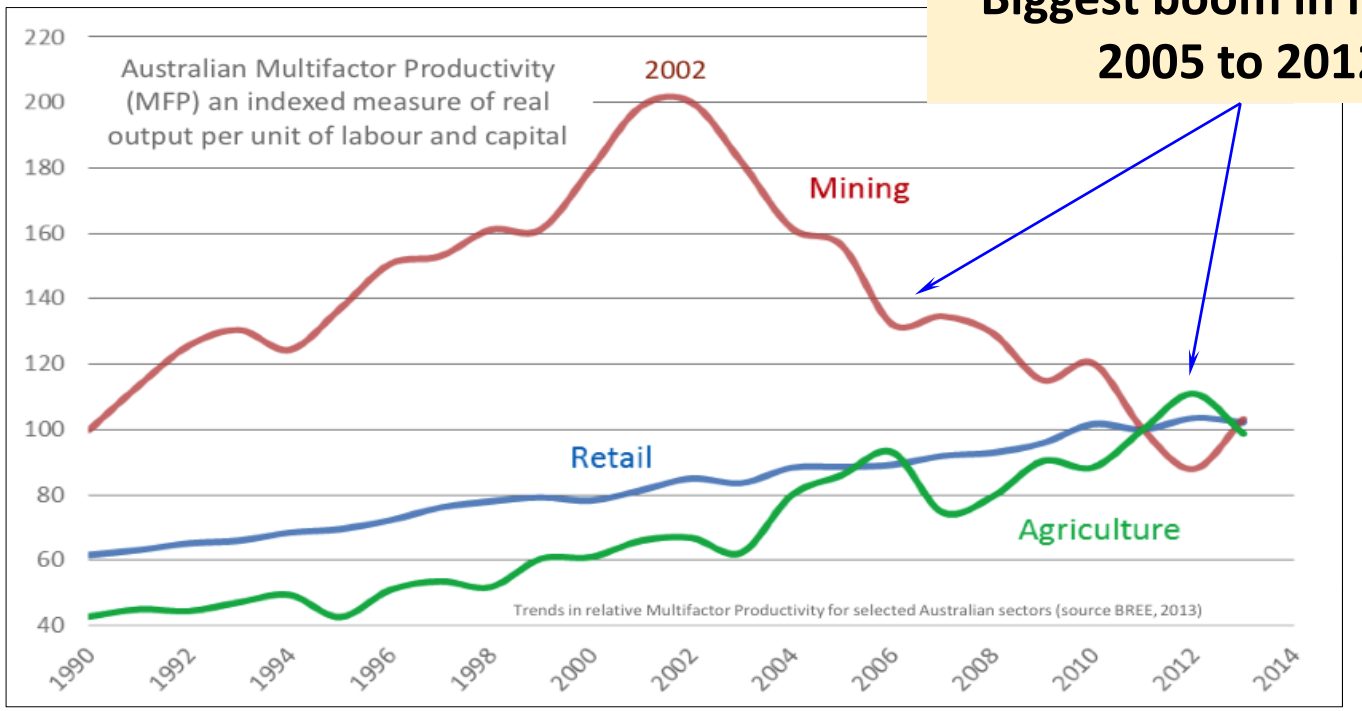
The international mining industry is evolving to a new business model

The efficiency in which capital, labour, materials, services, and energy are utilised to generate a unit of product



Biggest boom in history 2005 to 2012

53% Decrease in Multifactor Productivity 2001 to 2012

Between 2001 and 2012, approx. twice the physical work done and capital is needed to produce the same unit of metal

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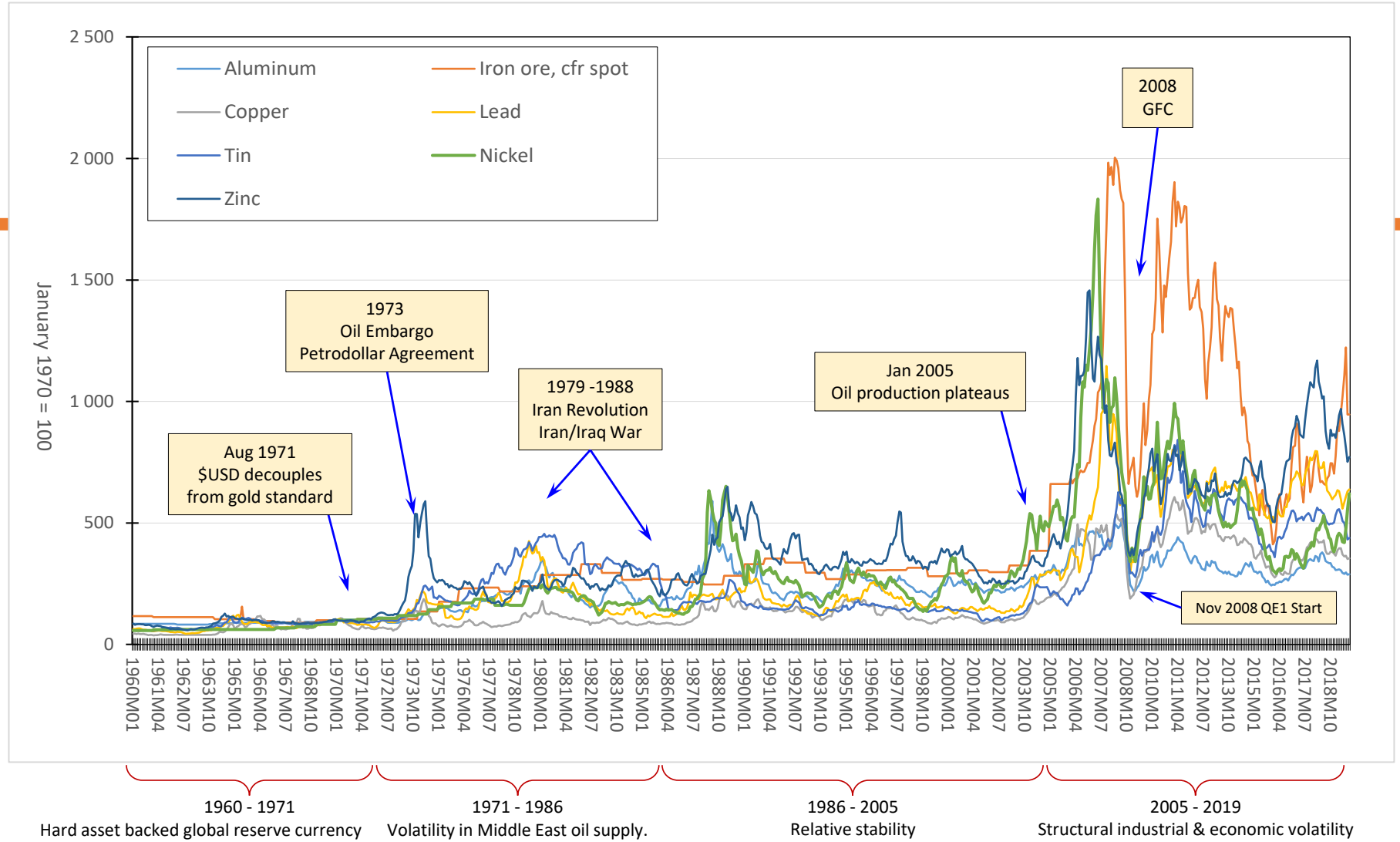

The mining industry changed in 2005

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Create more favourable business conditions

- Allow it to be more feasible to industrially process and refine in Europe
- Or, technologically evolve the process path where it becomes more EU friendly
- This would change the business model for many existing potential mines
    - Example Natural Graphite

Develop full vertical value chains so they can survive

- Most mining start-ups have to operate on their own.
  - They usually come up against Chinese competition, who are backed by the PRC government and a fully vertically integrated value chain.

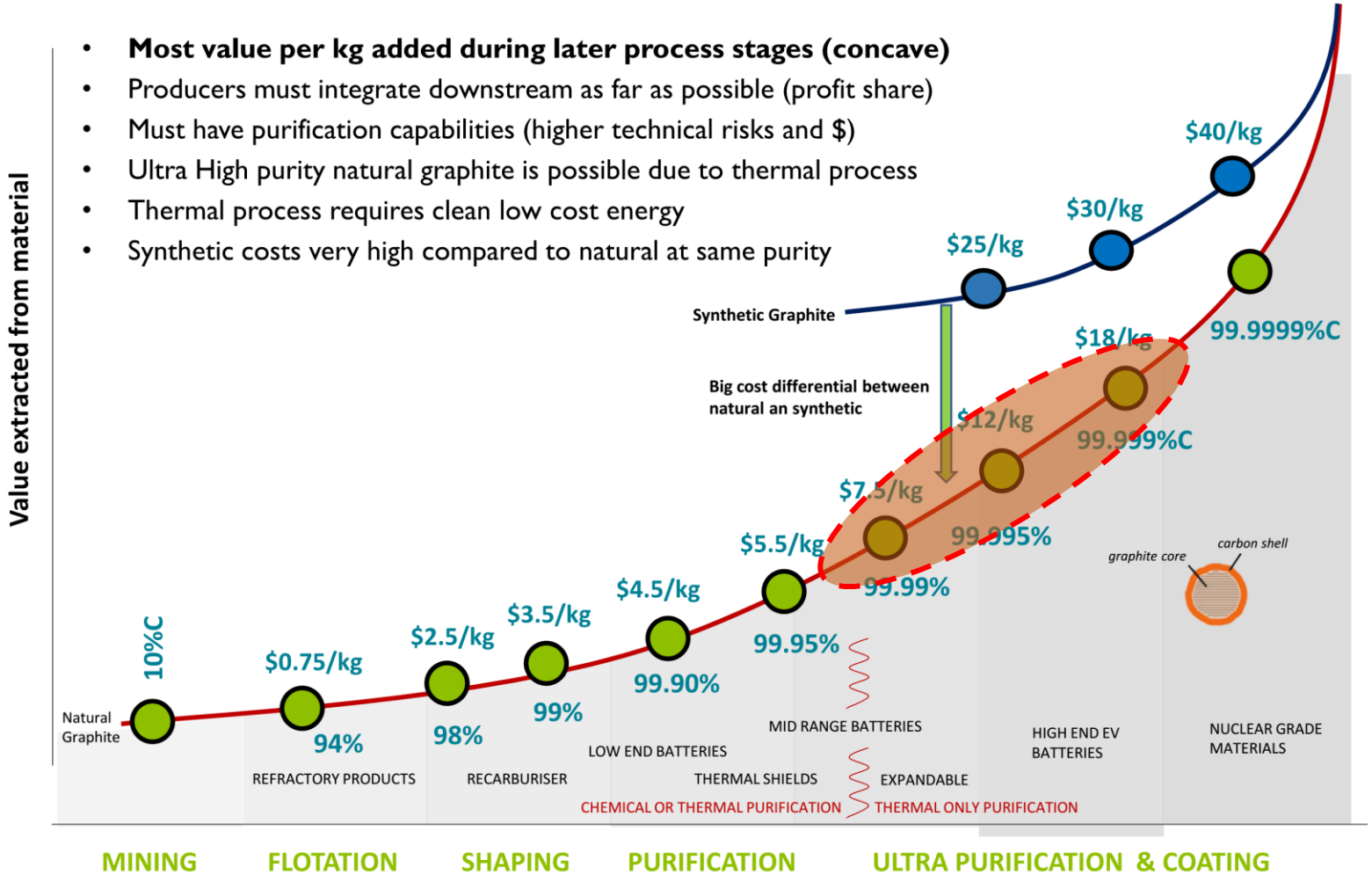
- Develop an industrial ecosystem around one end of the value chain
  - Battery minerals to battery chemicals - Finland
  - The German, South Korean and Japanese major car manufacturers have all been advised to create vertical supply chains they control directly
  - This incudes purchase and development of mines to supply the minerals & metals they need

Natural Graphite

- The global demand of graphite is increasing, leading to the necessity to exploit lower grade resources.
- Economic deposits all over Europe
- High technology applications (battery anodes) clients in China only
- The challenge is to produce graphite pure enough for the battery industry or the nuclear industry

Natural Graphite - Market

All graphite battery anodes are manufactured in China



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Technology evolution (has to be implemented)

Not viable in Europe

Natural Graphite

Development of this concept could change the business model for mineral deposits.

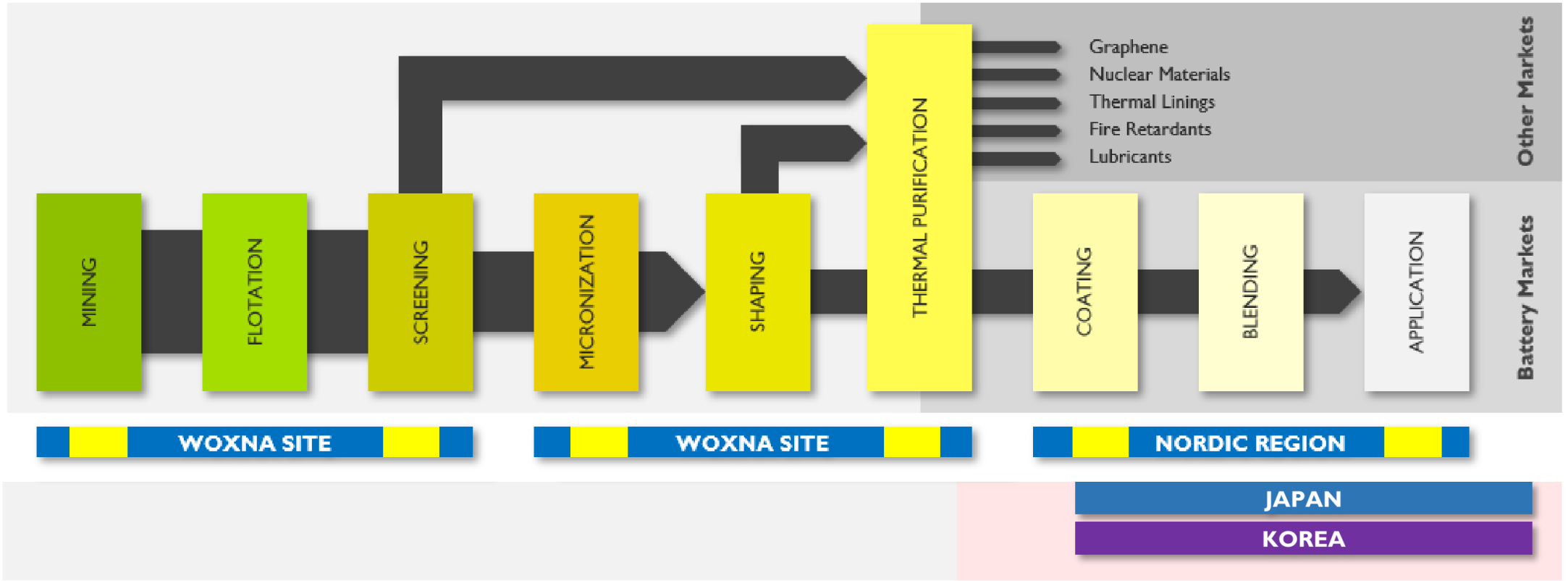
Woxna, Beowulf & Talga graphite deposits all would become viable

CHEMICAL PURIFICATION

- Embedded technology, lower risk
- Predictable costs based on other sites
- Lower energy demand
- Product is more familiar to customers
- Continuous feed
- Potentially cheaper (highly site dependant)
- Potentially lower capital cost

- Substantial water effluent
- No ability to modify products
- Higher permitting hurdles due to chemical handling and emissions
- Larger operating footprint
- OHS issues from materials handling
- Chemical treatment causes graphite swelling – greater need for coating
- New waste streams require capital to manage
- Head to head with Chinese product

Natrual Graphite – change the business model



This could trigger the viability of a battery giga factory

Tasks to be done

Conventional tasks

- Develop known deposits with completed feasibility studies
- Conduct exploration programs in areas with known areas of mineralization
  - Develop deposits into quantified reserves
- Conduct geometallurgical and metallurgical studies on all deposits of interest to the level of prefeasibility level of readiness.

Unconventional tasks

- Change the business model of mining
- Change access of capital to start operations
- Develop vertical supply chains around multiple strategic industrial ecosystems
  - Linked to EU controlled mining operations

Thank you!

Get in touch for more information!

All of the reports produced in the project will be available for download on the SCRREEN website.

Project coordinator: Stephane Bourg, CEA
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