Phytomining workshop introduction

2023.05.30

Dr. Philseok Kim (Program Director)

ARPA-E Phytomining Team

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(tech SETA)

Dr. Truong Nguyen
(tech SETA)

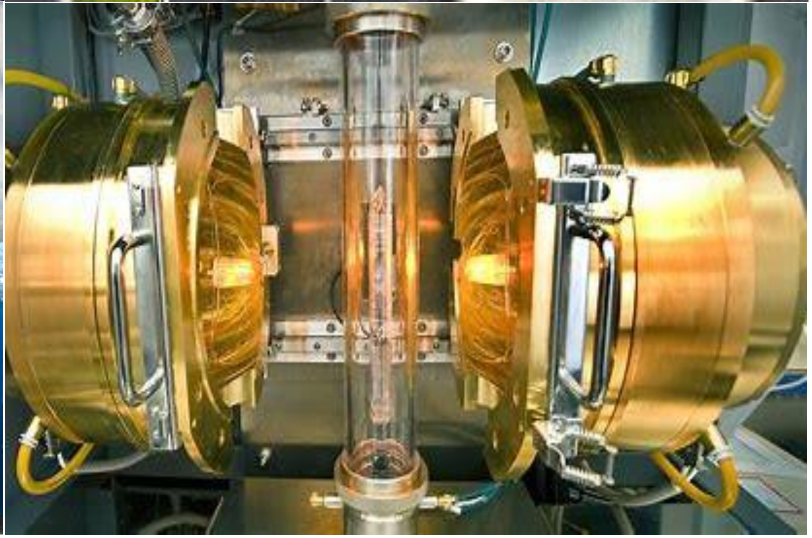
Dr. Elizabeth Troein
(former Fellow)

Dr. Daniel Garcia
(tech SETA)

Our future is powered by clean energy





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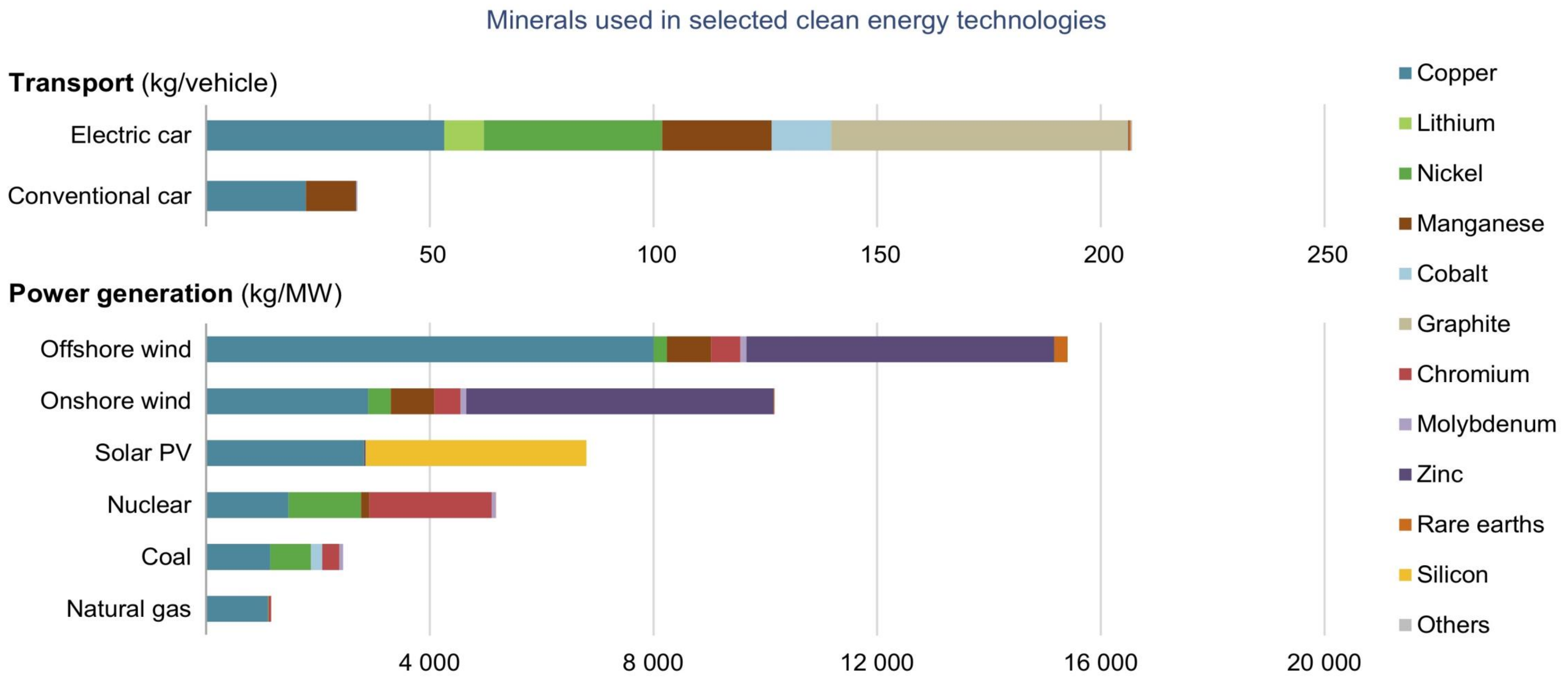
Clean energy minerals (CEMs) enable clean energy transition



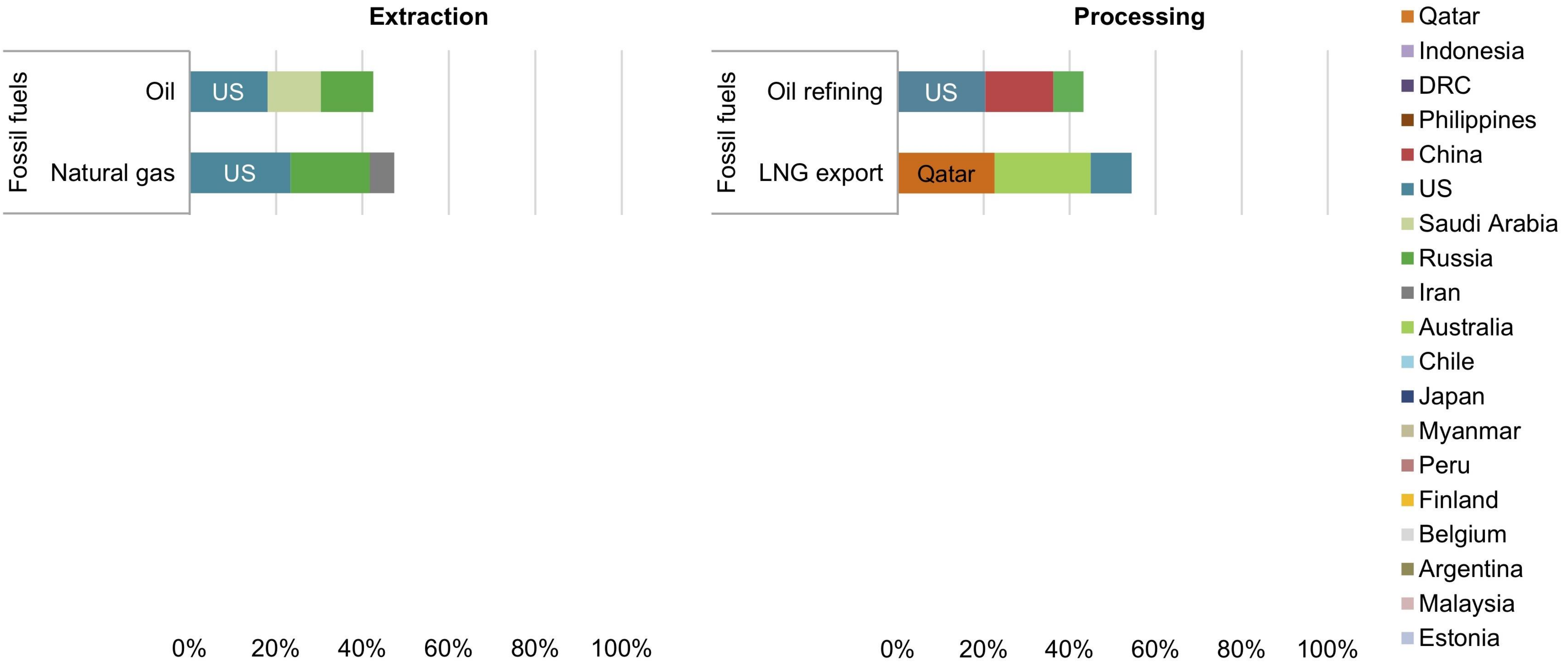
The Role of Critical Minerals in Clean Energy Transitions, IEA report (2021)

Notes: kg = kilogramme; MW = megawatt. The values for vehicles are for the entire vehicle including batteries, motors and glider. The intensities for an electric car are based on a 75 kWh NMC (nickel manganese cobalt) 622 cathode and graphite-based anode. The values for offshore wind and onshore wind are based on the direct-drive permanent magnet synchronous generator system (including array cables) and the doubly-fed induction generator system respectively. The values for coal and natural gas are based on ultra-supercritical plants and combined-cycle gas turbines. Actual consumption can vary by project depending on technology choice, project size and installation environment.

Clean energy minerals (CEMs) are becoming 'new energy imports'

REDUCE IMPORTS

Share of top three producing countries in production of selected minerals and fossil fuels, 2019



The Role of Critical Minerals in Clean Energy Transitions, IEA report (2021)

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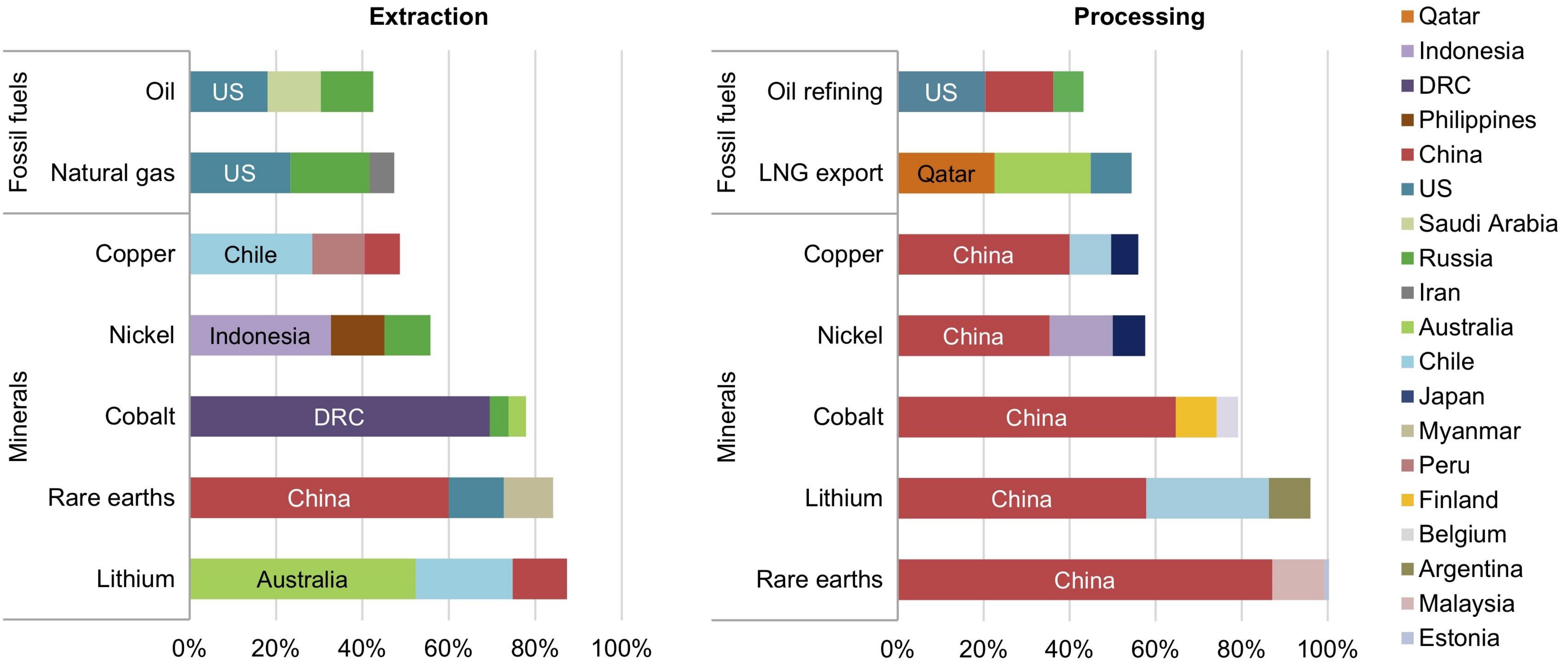

The Role of Critical Minerals in Clean Energy Transitions, IEA report (2021)

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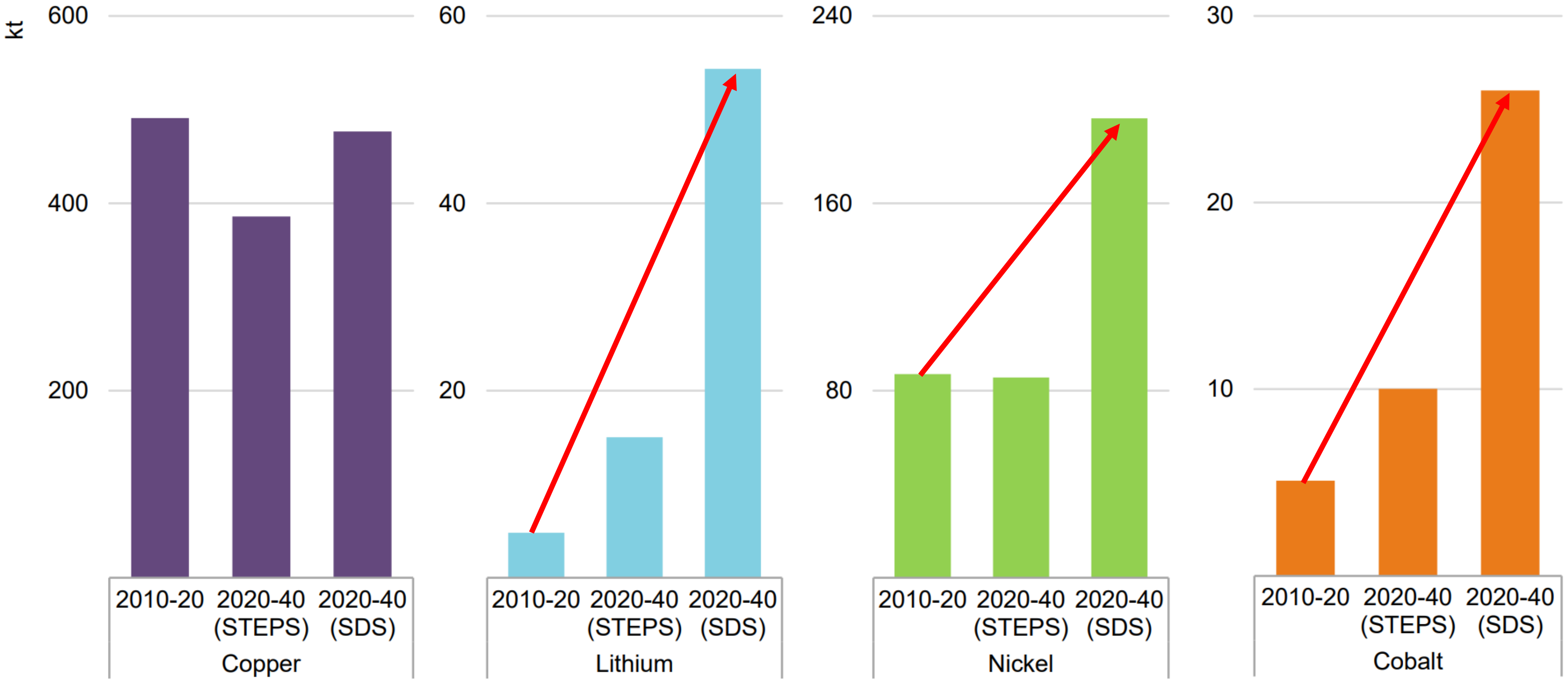
Limited CEM supplies means slow clean energy transition and slow economic growth in 2023+

In the SDS, the required level of supply growth for most minerals is well above the levels seen in the past decade

Annual average total demand growth for selected minerals by scenario



Notes: Total demand includes both demand from clean energy technologies and other consuming sectors. kt = thousand tonnes; STEPS = Stated Policies Scenario; SDS = Sustainable Development Scenario.

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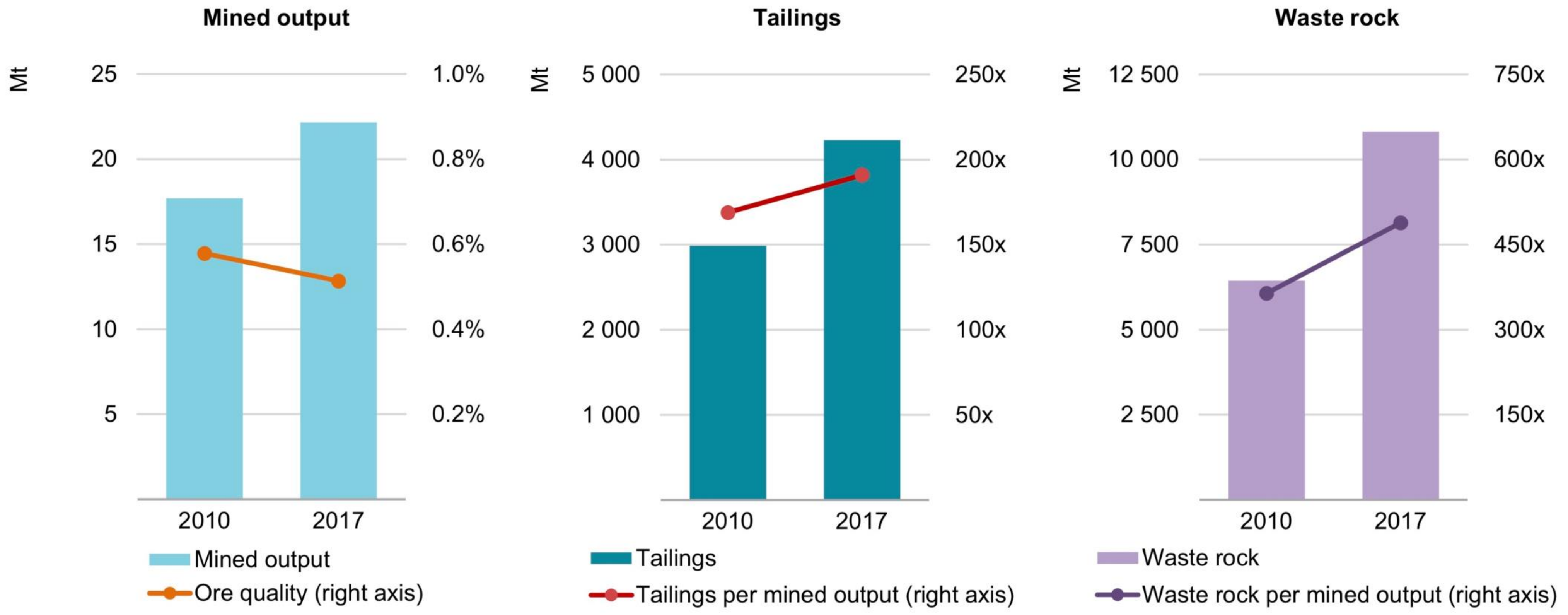
The Role of Critical Minerals in Clean Energy Transitions, IEA report (2021)

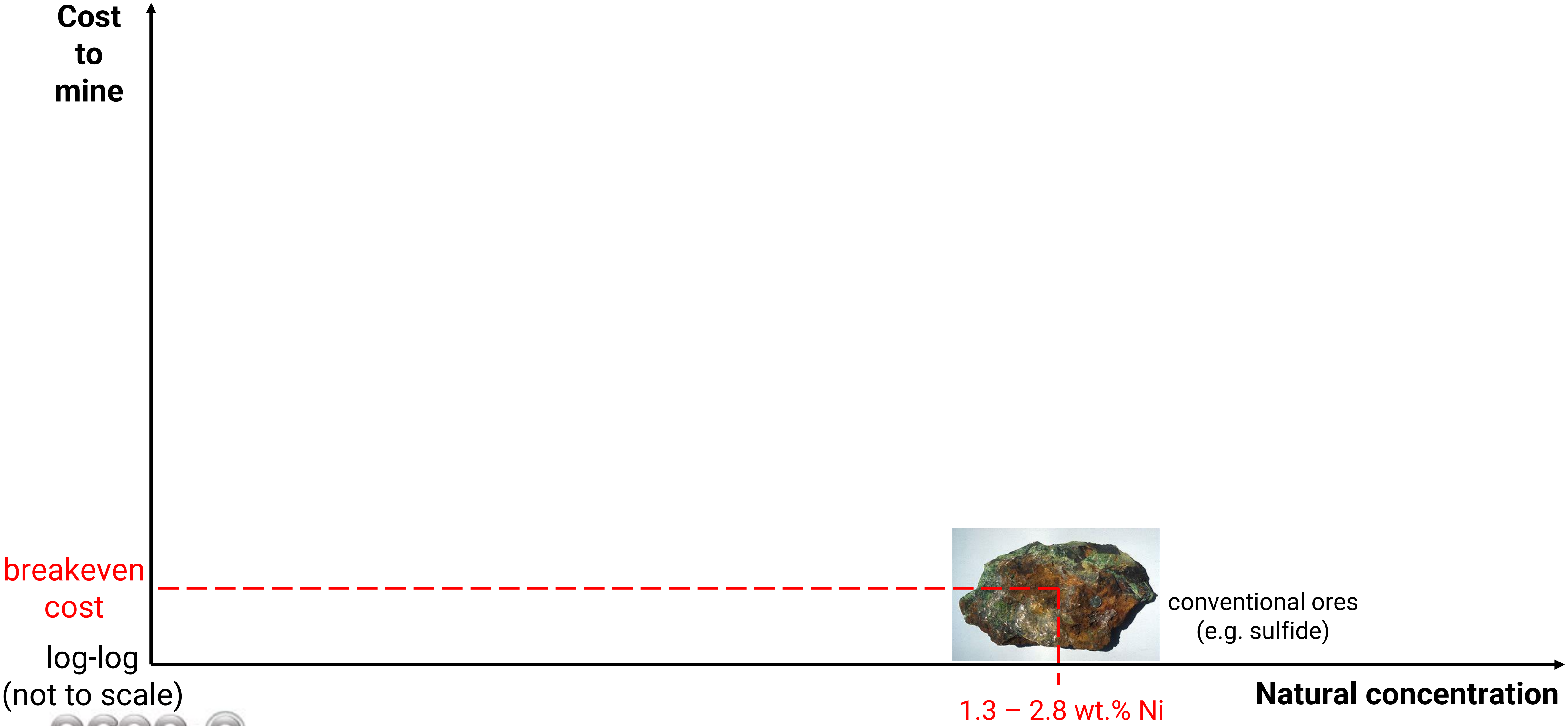
Increasingly dilute and wasteful mines necessitate alternative sources for metals and new mining technologies

- Can we disrupt the trend in naturally dilute metal mining (Ni, Co, REEs) and mine from generally regarded subeconomic for less money, less energy, lower emissions, and fewer wastes?



Source: IEA analysis based on data updated and expanded from Mudd and Jowitt (2016).

Alternative sources of critical minerals?



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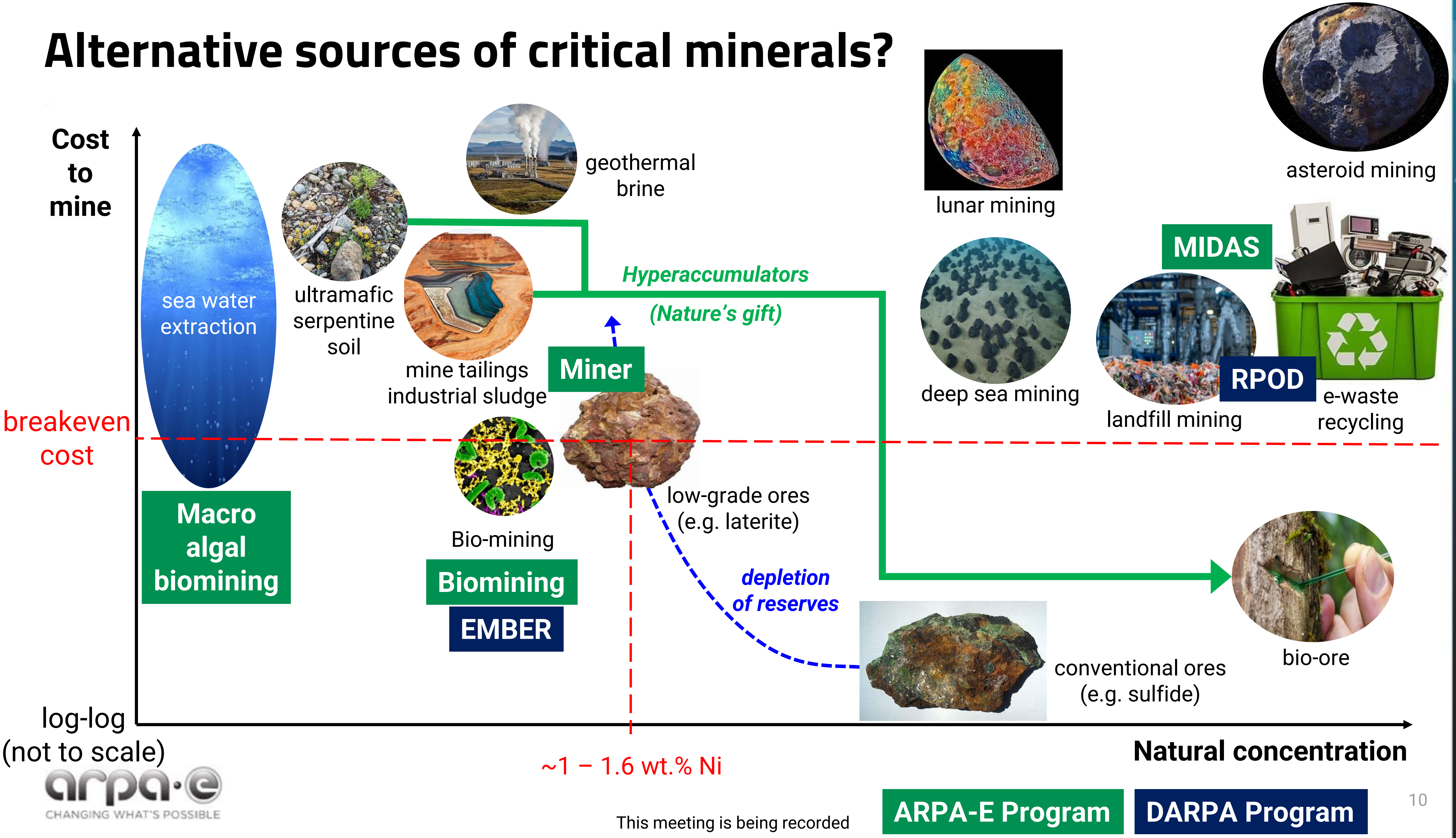
Alternative sources of critical minerals?



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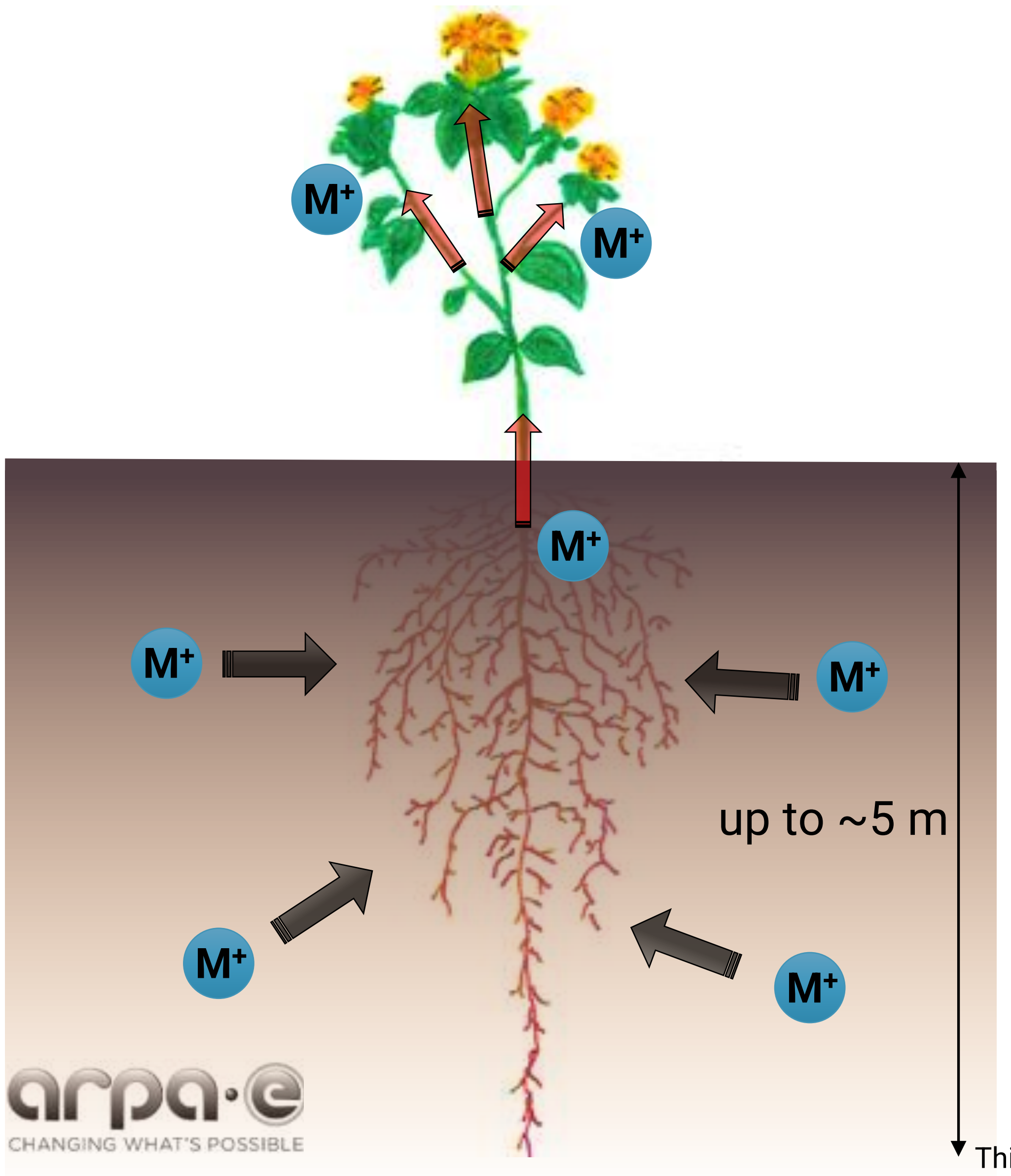
Phytomining – what does this workshop cover?



- A natural extension of botanical prospecting and the study of metal biochemistry and biogeography of metal hyperaccumulator plants
- Extraction from uneconomic resources
- **Exclusively utilizes hyperaccumulators**
- **Carried out on non-arable lands**
  - natural serpentine soil
  - anthropogenic waste lands
- **Includes downstream processes**
  - biomass processing
  - metal separation

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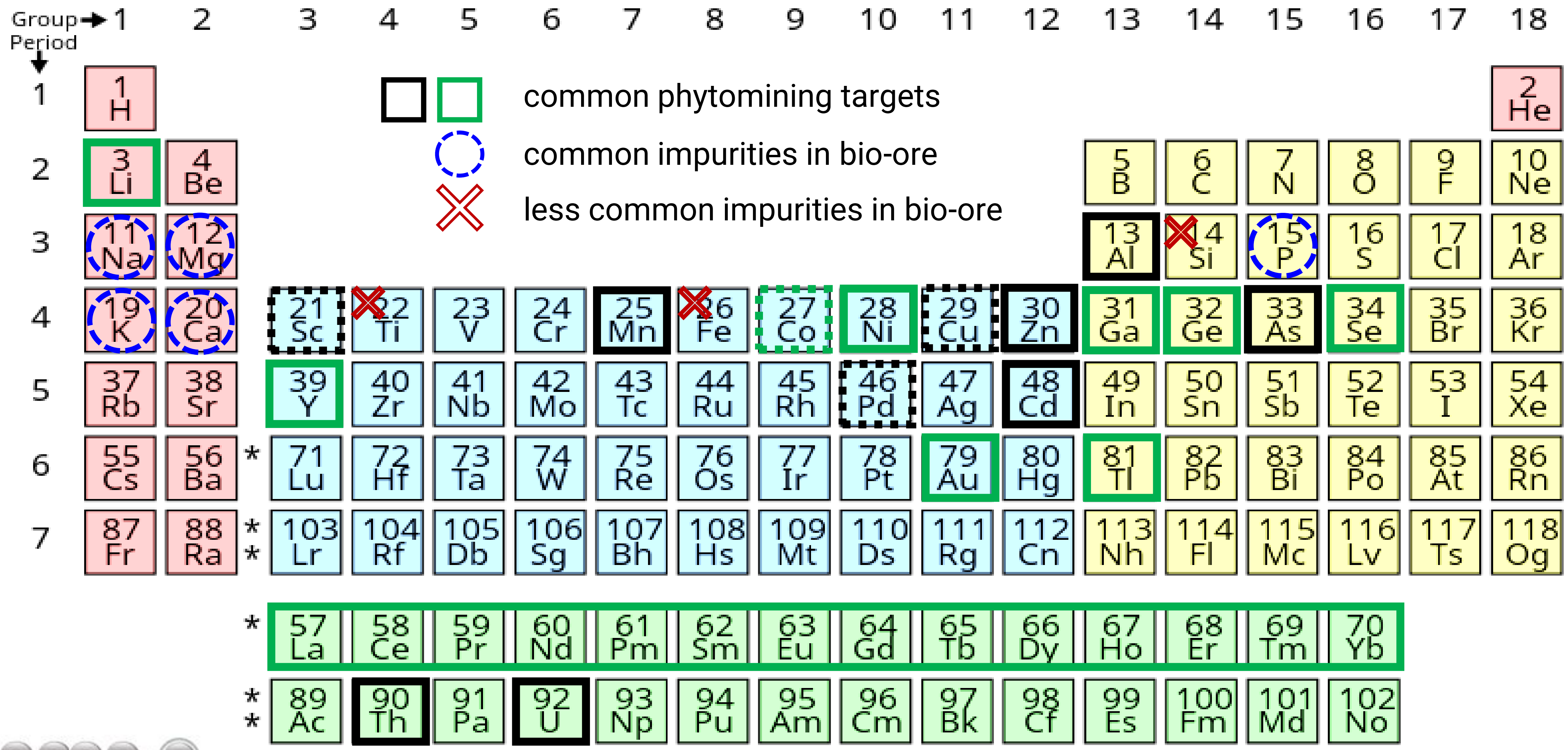
Periodic table of phytomining

Global Hyperaccumulator Database
http://hyperaccumulators.smi.uq.edu.au/collection/



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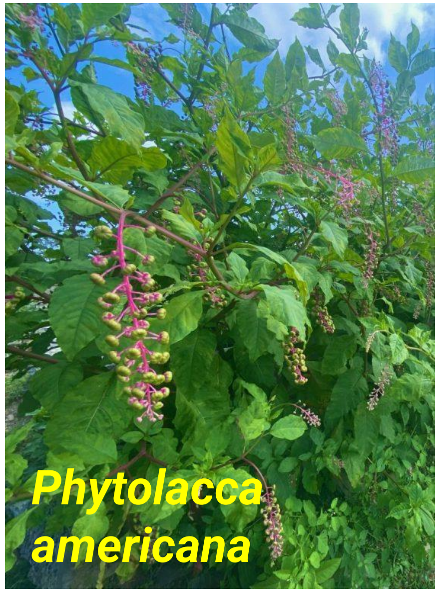
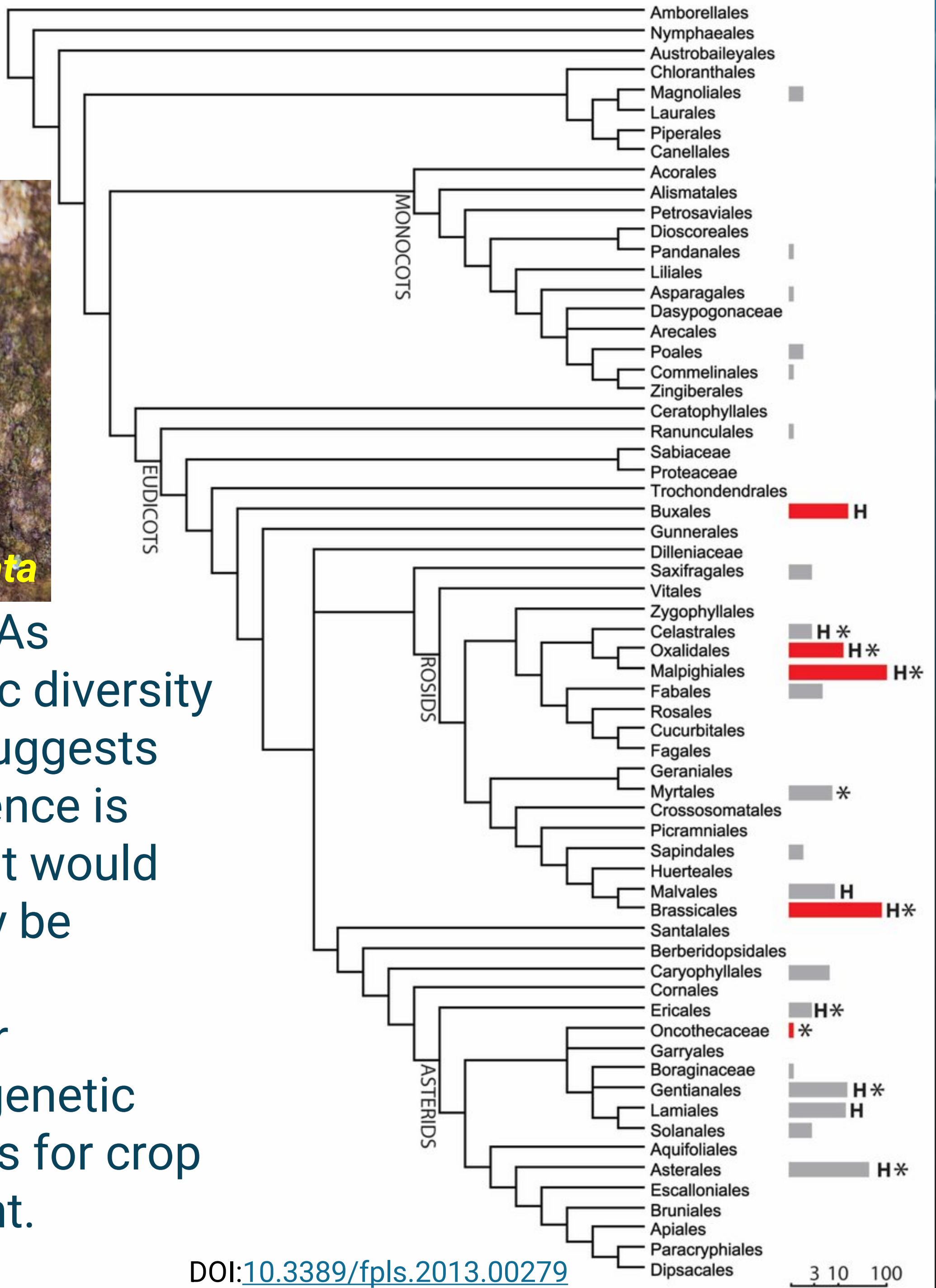
High diversity of hyperaccumulators (HAs) provides a host of options



- +700 ID'd HAs
- Phylogenetic diversity of Ni HAs suggests that occurrence is beyond what would theoretically be expected.
- Potential for leveraging genetic mechanisms for crop development.



DOI:10.3389/fpls.2013.00279

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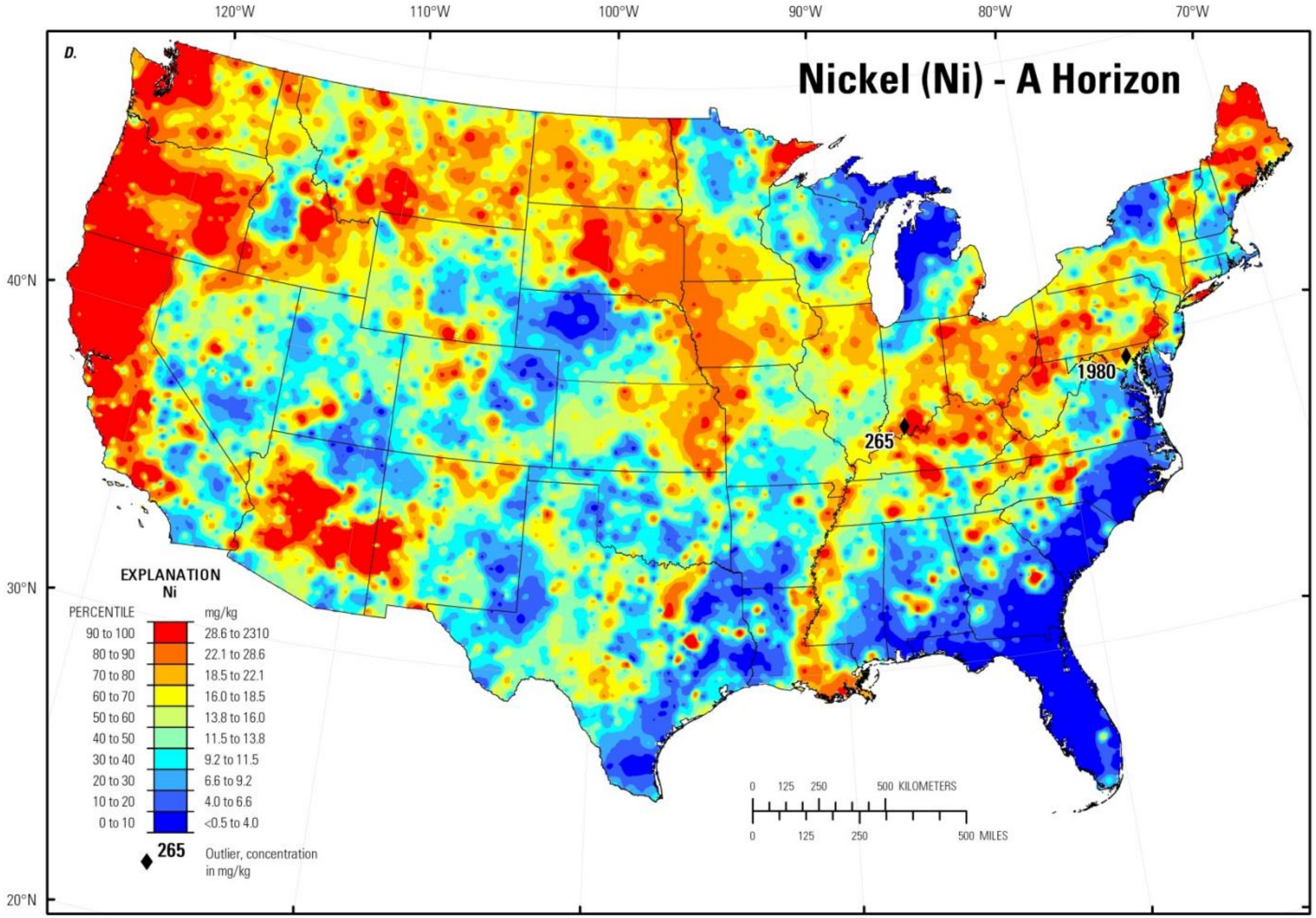
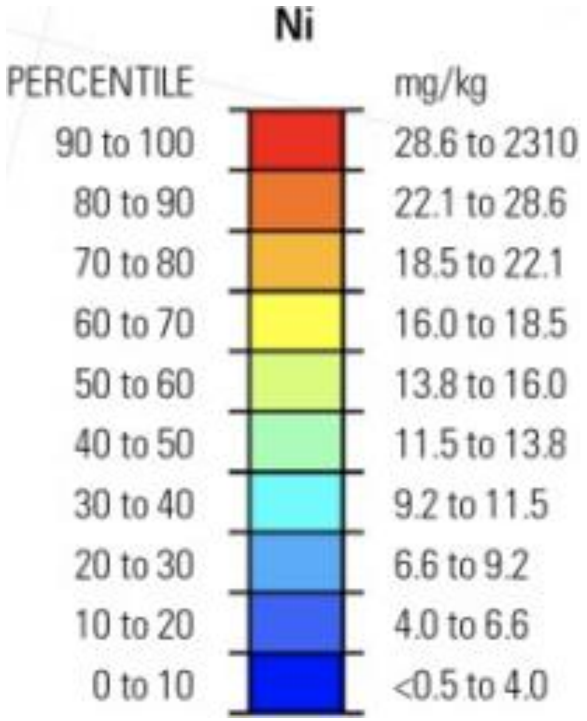
Nickel in US surface soil





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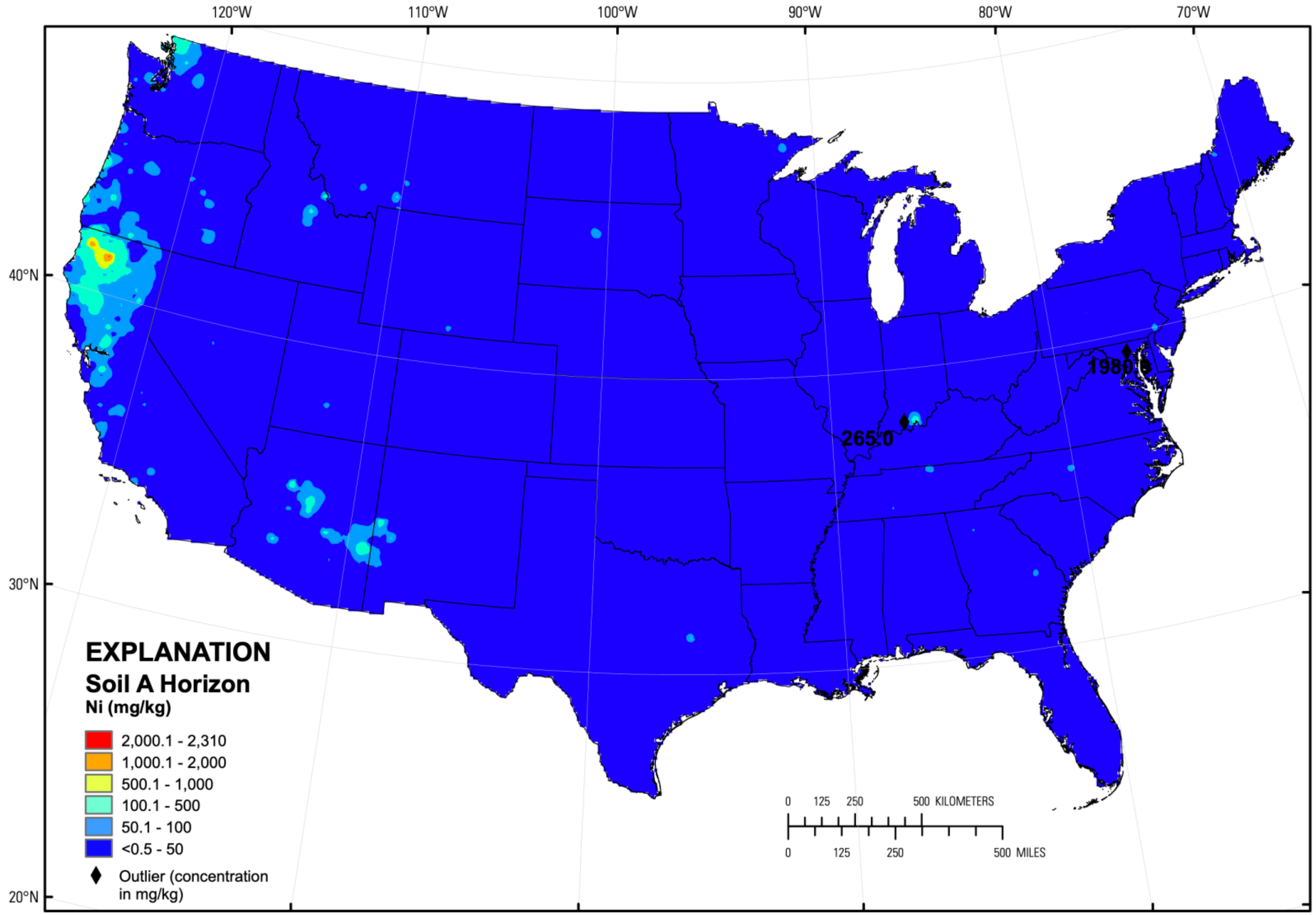

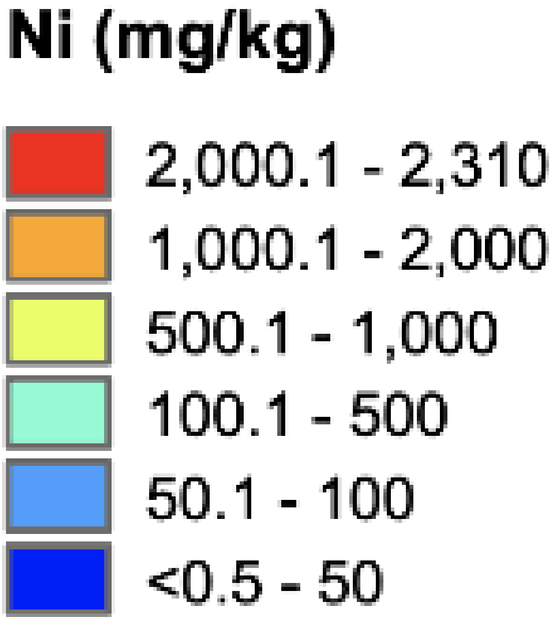

>90% of potential lands for Ni phytomining are infertile, non-arable

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Opportunistic surface REE deposits in the US

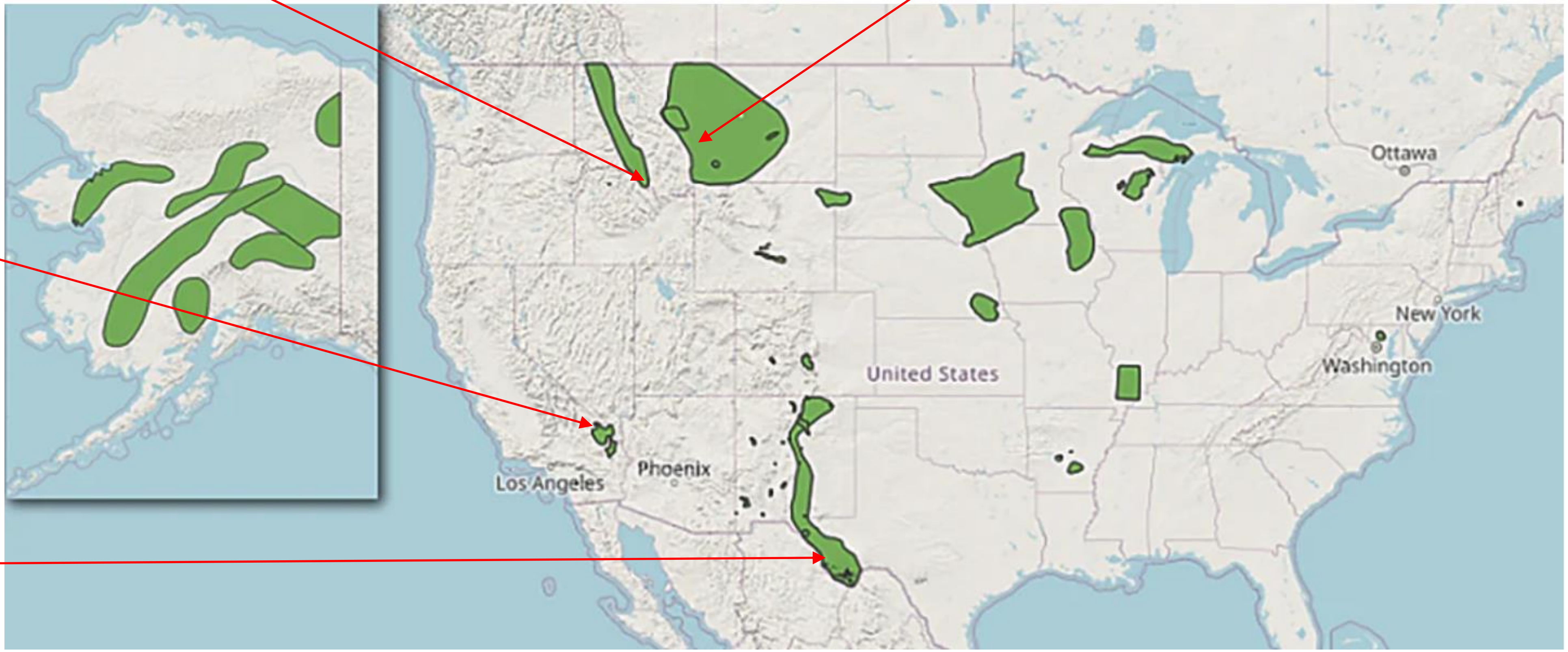
Diamond Creek, ID
~1% - >4% TREO

REE minerals: monazite, xenotime
Ore minerals: fluorite, hematite, thorite

Sheep Creek, MT
new USGS survey planned
low radioactives

Mountain Pass, CA
18.4 MT carbonatite
ore reserves
grading 7.98% REO
cut-off at 5%

Trans-Pecos, TX
Round Top, TX
rhyolites



US total REE reserve: 2,300,000 Mt (~1% of world)
$2.5T worldwide market by 2030

2022 US production: 43,000 Mt
2022 US imports: 11,000 Mt

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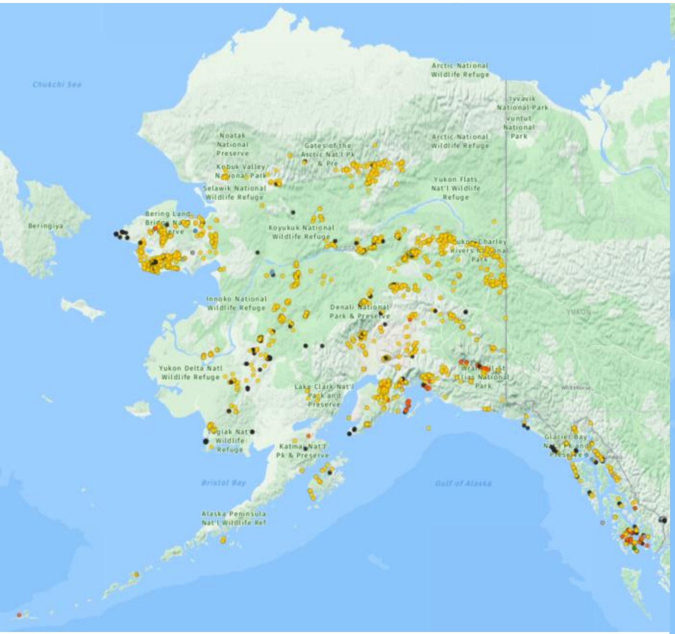
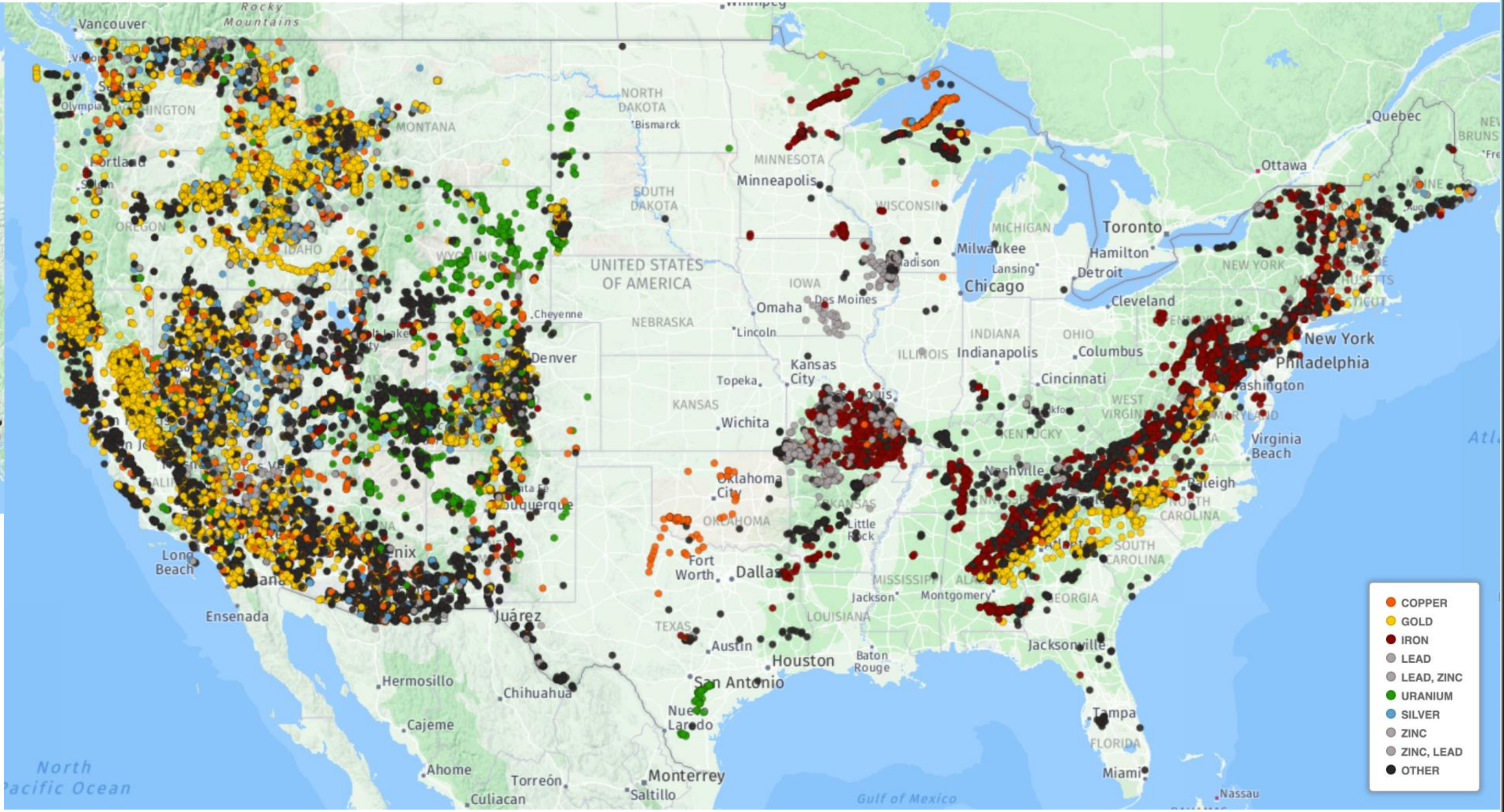
This meeting is being recorded https://mrdata.usgs.gov/ree/map-us.html

Abandoned mines in the U.S. – anthropogenic source of CEMs





https://davidmanthos.carto.com/viz/9e48164c-45da-11e5-bcf9-0e0c41326911/public_map

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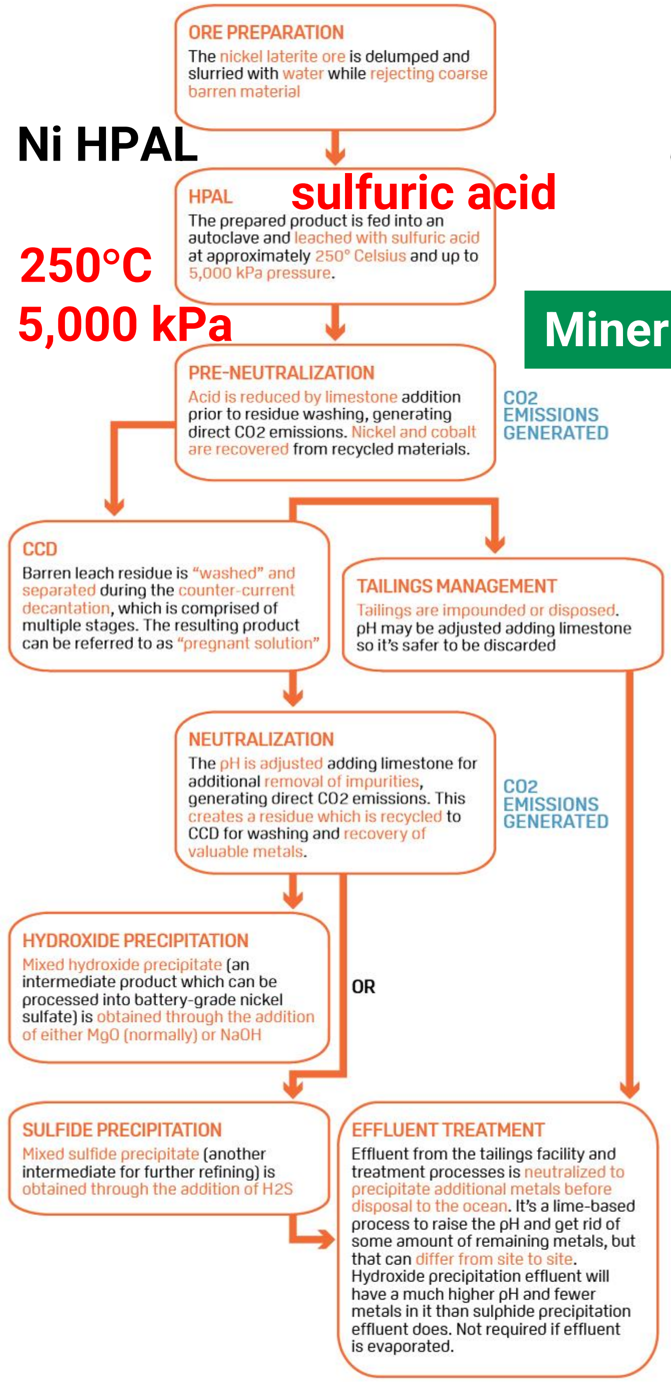
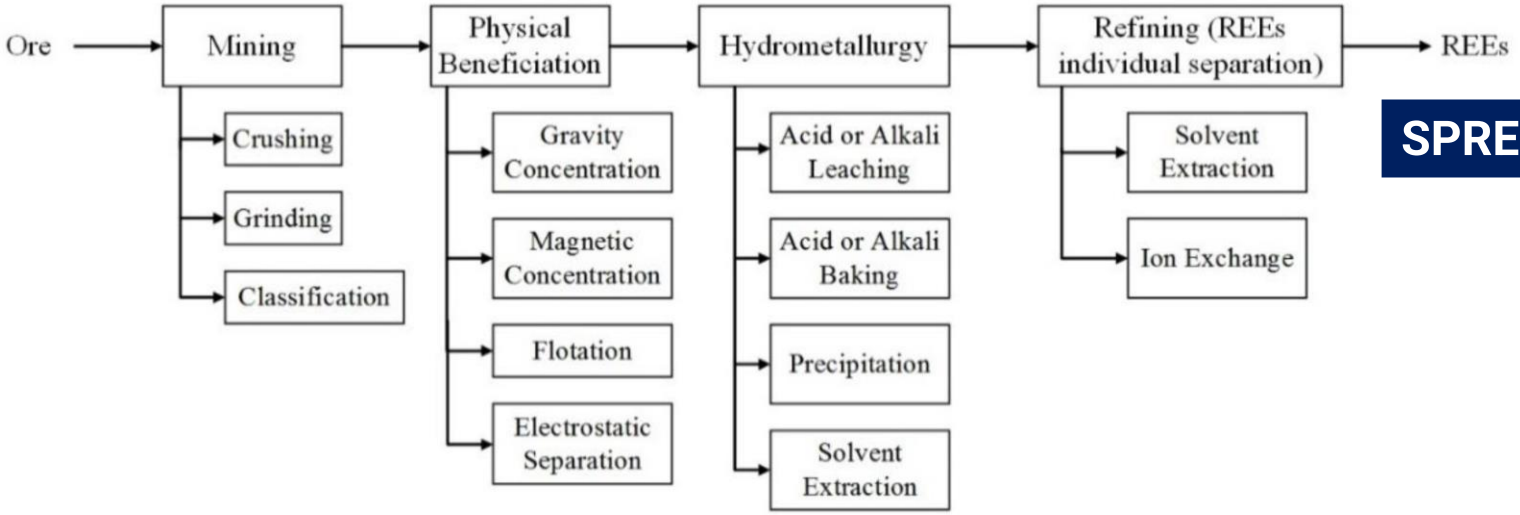
Nascent space requires R&D for optimizing biomass processing and metal separation

SIMPLIFIED HPAL PROCESSING FLOWSHEET



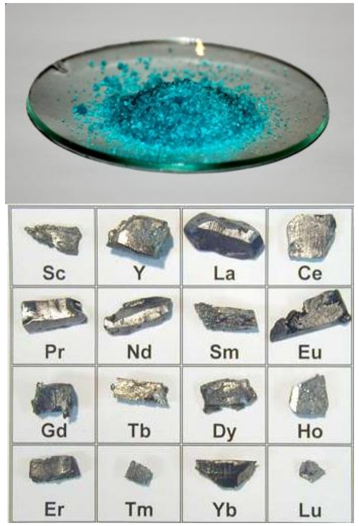
Source: S&P Global Platts, Trytten Consulting Services, Clean Teq

Miner



SPREE

Can hyperaccumulators be engineered to be our chemist?



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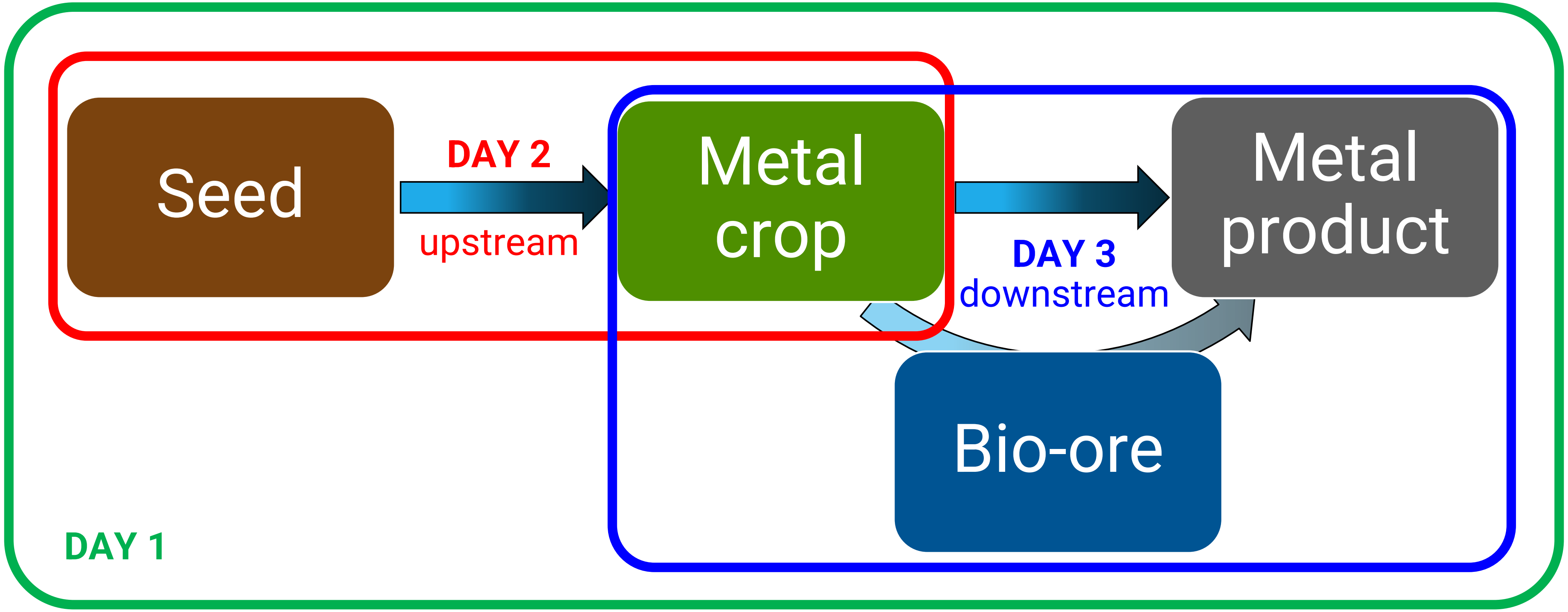
3 Day-Virtual Workshop & Breakout Discussions

- DAY 1 (5/30): Phytomining, General Topic
- DAY 2 (6/01): Hyperaccumulators – Agronomy, Biology, and Soil Science
- DAY 3 (6/14): Biomass processing & Metal extraction/separation



Invited speakers

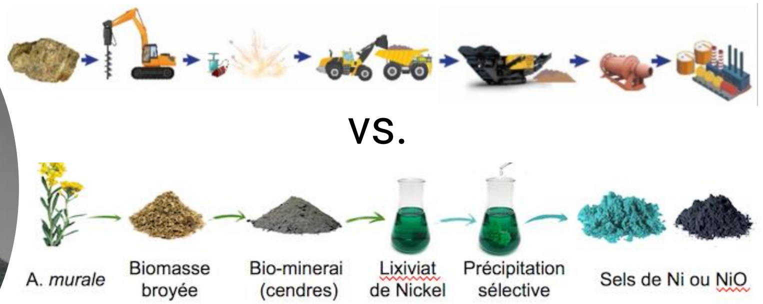
DAY 1

Dr. Rufus Chaney (ret. USDA)

Cited by		VIEW ALL
	All	Since 2018
Citations	42860	10414
h-index	110	52
i10-index	336	192

History of U.S. Phytomining

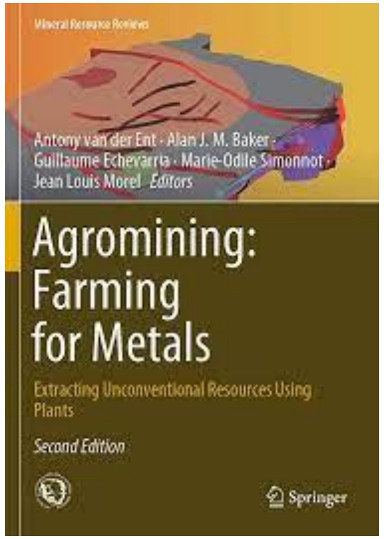
Prof. Victor Vasquez (Univ. Nevada, Reno)



TEA/LCA

Dr. Antony van der Ent (Econick/Botanickel)

Hyperacummulators Agromining in Europe



DAY 2

Prof. Marie-Odile Simonnot (Univ. Lorraine, Nancy)

Metal separations

DAY 3

Workshop guidelines and rules

- **Ask** many questions after speaker presentations (enter questions in the chat)
- **Engage** actively during B/O sessions (your opinions matter!)
- **Network** with the participants and look for potential partners
- **Request** follow up meetings with ARPA-E (phil.kim@hq.doe.gov)

- ARPA-E is NOT looking for reaching a consensus during the workshop
- ARPA-E wants to gather inputs and opinions from all of you

You may not cross the boundaries set by the laws of physics!

However, erase the 'box' around your usual thinking!

Have fun!

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DAY 1 Breakout Session

Please be back by 2:45 pm ET

- **If you haven't registered, please register now**
- **WebEx link:** https://doe.webex.com/weblink/register/r873475edc505c2deeeab02ddcfcd21e4

- Email to request registration for **Day 2 and 3 Breakouts**: Kalena.Stovall@hq.doe.gov

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https://arpa-e.energy.gov

AGENDA - DAY 1 (MAY 30TH)

Time (EST)	Description
1:00 – 1:10 PM	**ARPA-E Introduction** *Dr. Evelyn Wang, ARPA-E Director*
1:10 – 1:25 PM	**Workshop Goals, US critical mineral supply chain issues, Phytomining as an alternative solution** *Dr. Philseok Kim, ARPA-E Program Director*
1:25 – 2:15 PM	**Invited Talk: The history of phytoremediation and phytomining in the U.S.** *Dr. Rufus Chaney (retired, former USDA)*
2:15 – 2:30 PM	**Invited Talk: TEA and LCA considerations for phytomining in the U.S.** *Professor Victor Vasquez (University of Nevada, Reno)*
2:30 – 2:40 PM	**Break; Transition to Breakout 1**
2:40 – 4:00 PM	**Breakout 1: Phytomining in the US (General Topic)**
4:00 – 4:05 PM	**Next Steps** *Dr. Philseok Kim, ARPA-E Program Director*

AGENDA - DAY 2 (JUNE 1st)

Time (EST)	Description
1:00 – 1:15 PM	**Readout from Breakout 1** *Dr. Philseok Kim, ARPA-E Program Director*
1:15 – 1:50 PM	**Invited Talk: Agromining – A European Perspective** *Dr. Antony van der Ent (Econick and Botanickel)*
1:50 – 2:50 PM	**Breakout 2a: Hyperaccumulators – Agronomy, Biology, Soil Science (from seed to metal crops)**
2:50 – 3:00 PM	**Break**
3: 00 – 4:00 PM	**Breakout 2b: Hyperaccumulators – Agronomy, Biology, Soil Science (continued)**

AGENDA - DAY 3 (JUNE 14th)

Time (EST)	Description
1:00 – 1:15 PM	**Readout from Breakout 2** *Dr. Philseok Kim, ARPA-E Program Director*
1:15 – 1:50 PM	**Invited Talk: Separation of nickel and rare earth elements from hyperaccumulators** *Professor Marie-Odile Simonnot (University of Lorraine, Nancy, France)*
1:50 – 2:50 PM	**Breakout 3: Biomass Processing, Metal Extraction & Separation (from metal crop to high-value metal products)**
2:50 – 3:00 PM	**Break**
3:00 – 4:00 PM	**Breakout 3: Biomass Processing, Extraction & Separation (from metal crop to high-value metal products) (continued)**
4:00 – 4:05 PM	**Next Steps** *Dr. Philseok Kim, ARPA-E Program Director*