

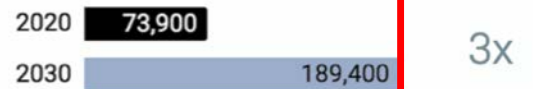
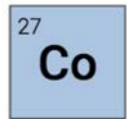
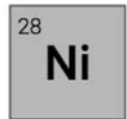
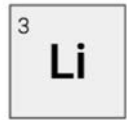
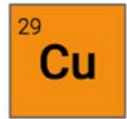


Untapping Critical Minerals Value from Mine Waste

Dr. Nadia Mykytczuk
CEO & President, MIRARCO

May 31, 2023

The Challenge of Meeting Critical Minerals Needs



Source: BloombergNEF RESEARCH INTERFACES



Enhance exploration
Develop deposits

Go deeper

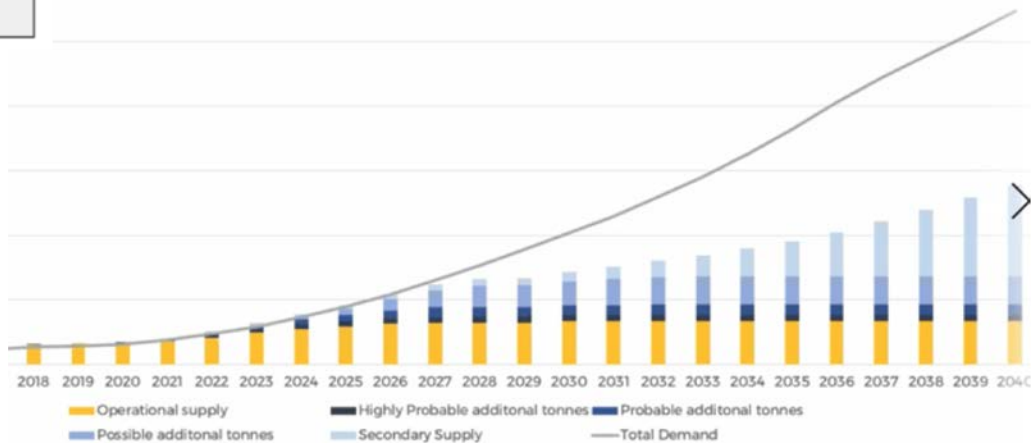
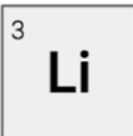


Improve processing

New green tech and innovation

Circular economy
Includes wastes





Tonnes

1,000,000

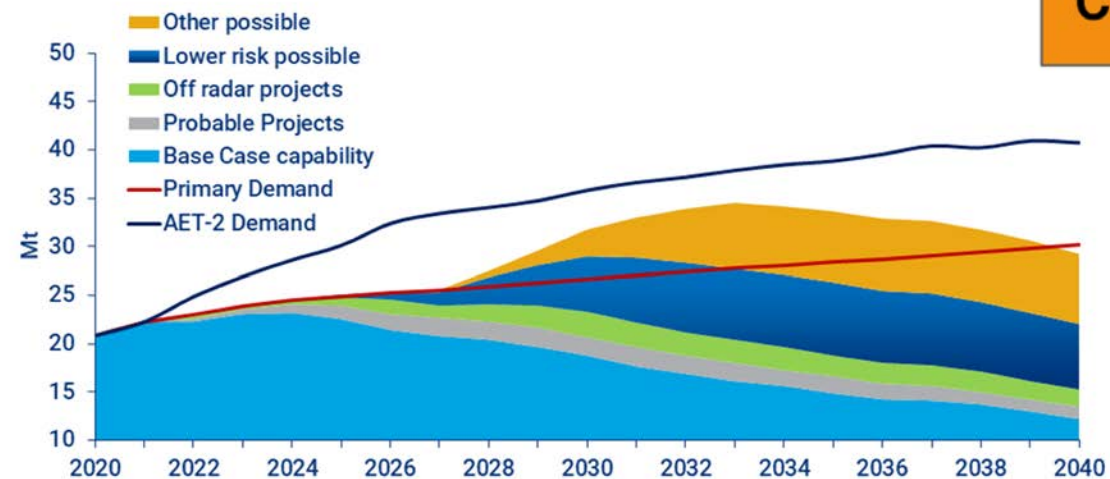
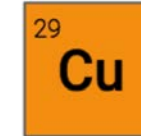
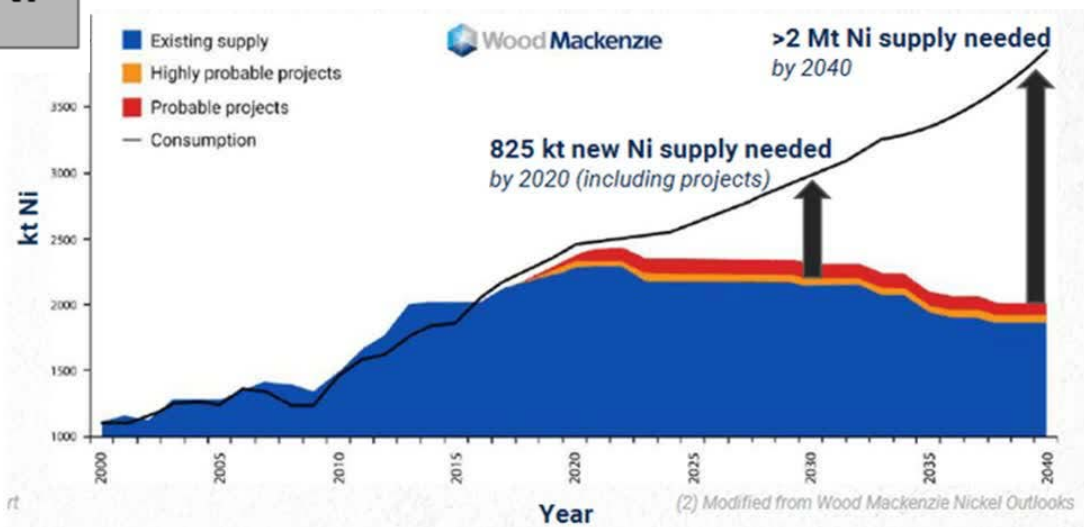
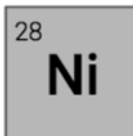
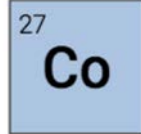
500,000

0

2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040

Total Demand
Secondary supply
Possible additional tonnes
Probable additional tonnes
Highly Probable additional tonnes
Operational supply

Source: Benchmark Minerals Cobalt Forecast



Source: Wood Mackenzie

Mine wastes still contain (low grade) metals



Waste Rock



Tailings



Slag



Seepage/
effluents

Addressing Mine Waste Liabilities

ENVIRONMENTAL IMPACTS

200 **ACTIVE**
MINES¹⁵

and approximately **10,000 abandoned mines**¹⁶ in Canada present the single largest source of waste produced by any natural resources industry

650.0
MILLION TONNES+

of mine waste are deposited by the Canadian mining industry yearly^{17,18}

20.0-200.0
TONNES OF SOLID
WASTE GENERATED

per tonne of metal extracted for most base metals¹⁹

FINANCIAL LIABILITIES

\$10.0 **BILLION**

^{*} In liability costs associated with ongoing treatment of mine wastes.

The Opportunity

FINANCIAL OPPORTUNITIES

**\$8.0-10.0
BILLION**

in nickel contained in mining
waste in the Sudbury region²⁴

\$2.0 BILLION+
mineral value in Alberta oil sands
tailings²⁷

\$10.0 BILLION

in estimated value stored in Canada's
gold mine waste²⁵

\$2.4 TRILLION

in copper contained in mine
waste globally²⁶

DEMAND FOR

BATTERIES

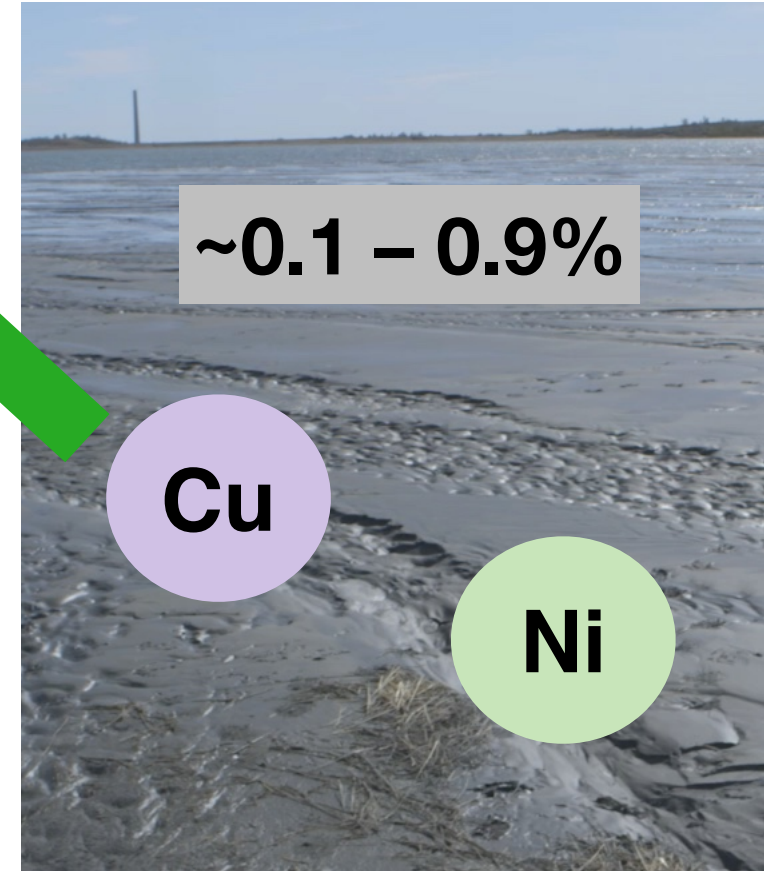
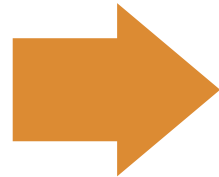
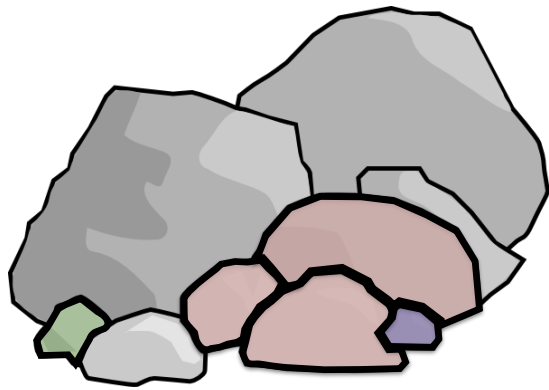
expected to triple the
available supply by 2030²⁸

The difference between ore and waste is the cost of extracting value

~1% Copper Sulfide

~25% Iron Sulfides

~1% Nickel Sulfide

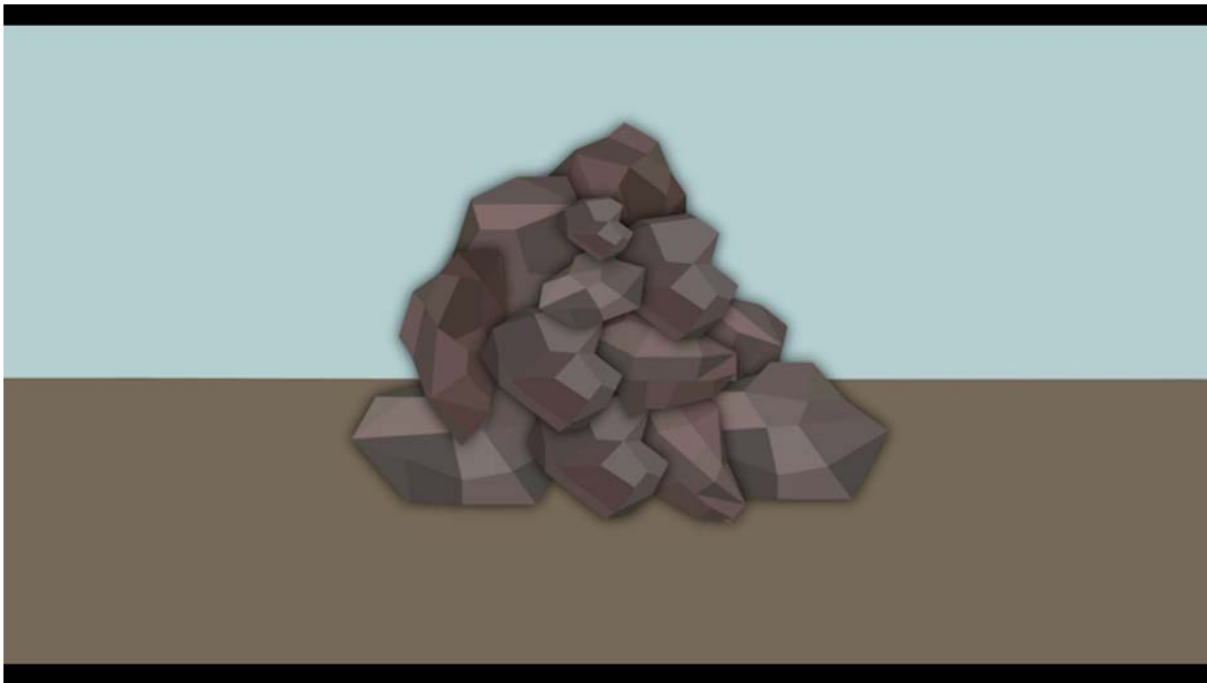


Mine waste streams still contain some valuable metals.

When is the extraction cost worth the effort of reprocessing these wastes to extract more value?

Harnessing Microbial Abilities to Extract Metals

Bioleaching/biomining: the controlled use of bacteria to extract metals from ores, concentrates, or wastes



Recover
more
minerals
for sale
\$

Render
wastes
less
reactive,
lower risk

Metals Amenable To Biomining

Most common (over last 40 years):

Au

Cu

U

High potential:

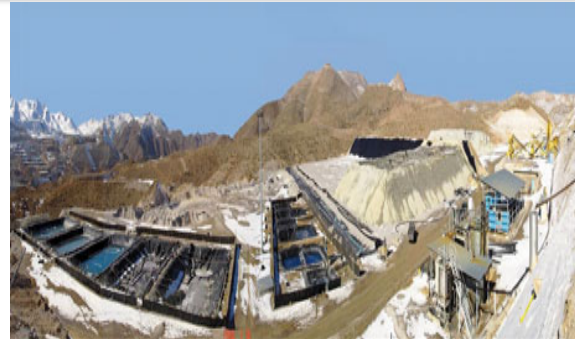
Co

Ni

Zn

Li

REEs



Cu

Teck's Quebrada Blanca mine in Chile

Au

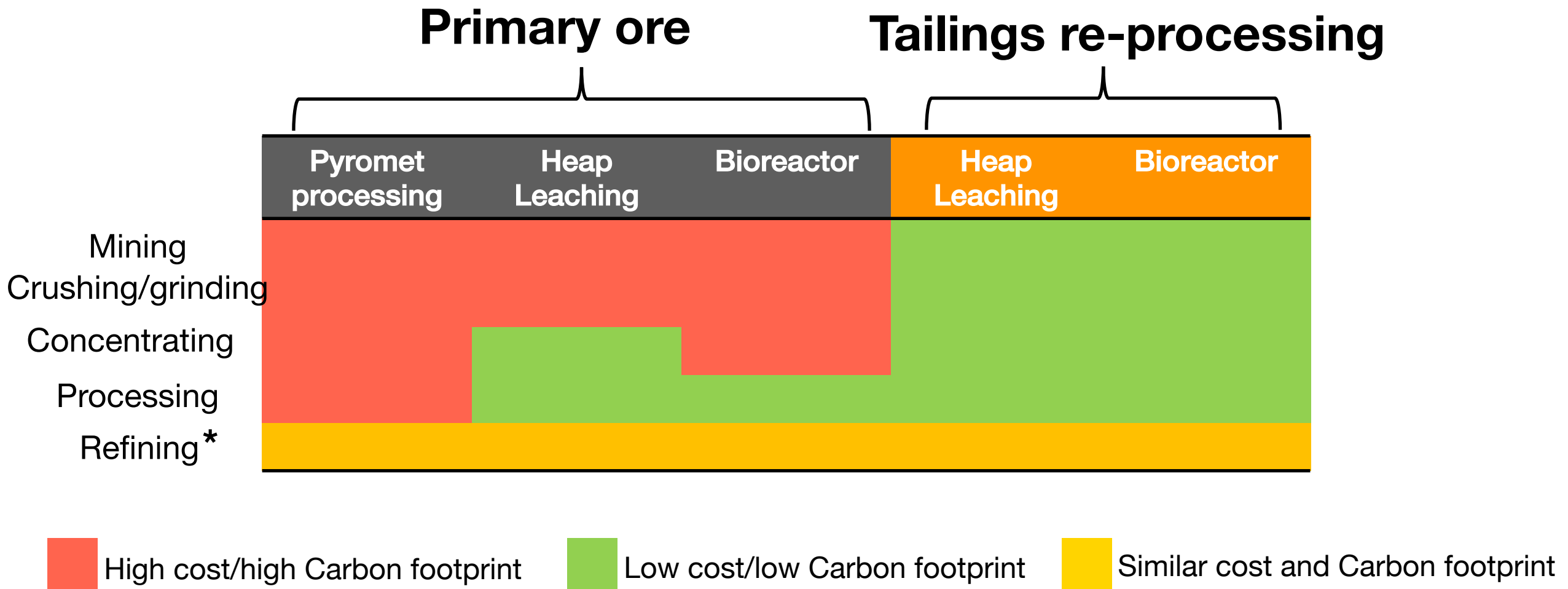
Refractory gold bioreactors, China



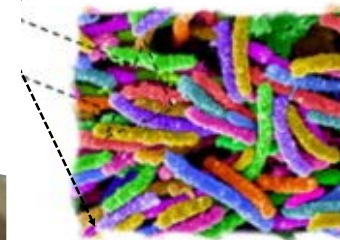
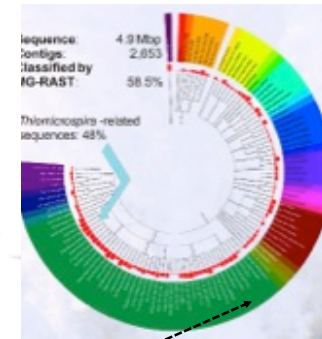
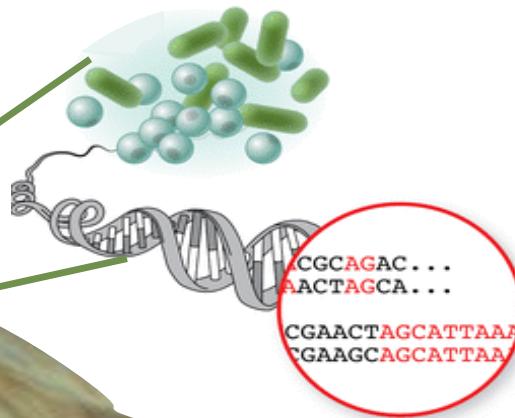
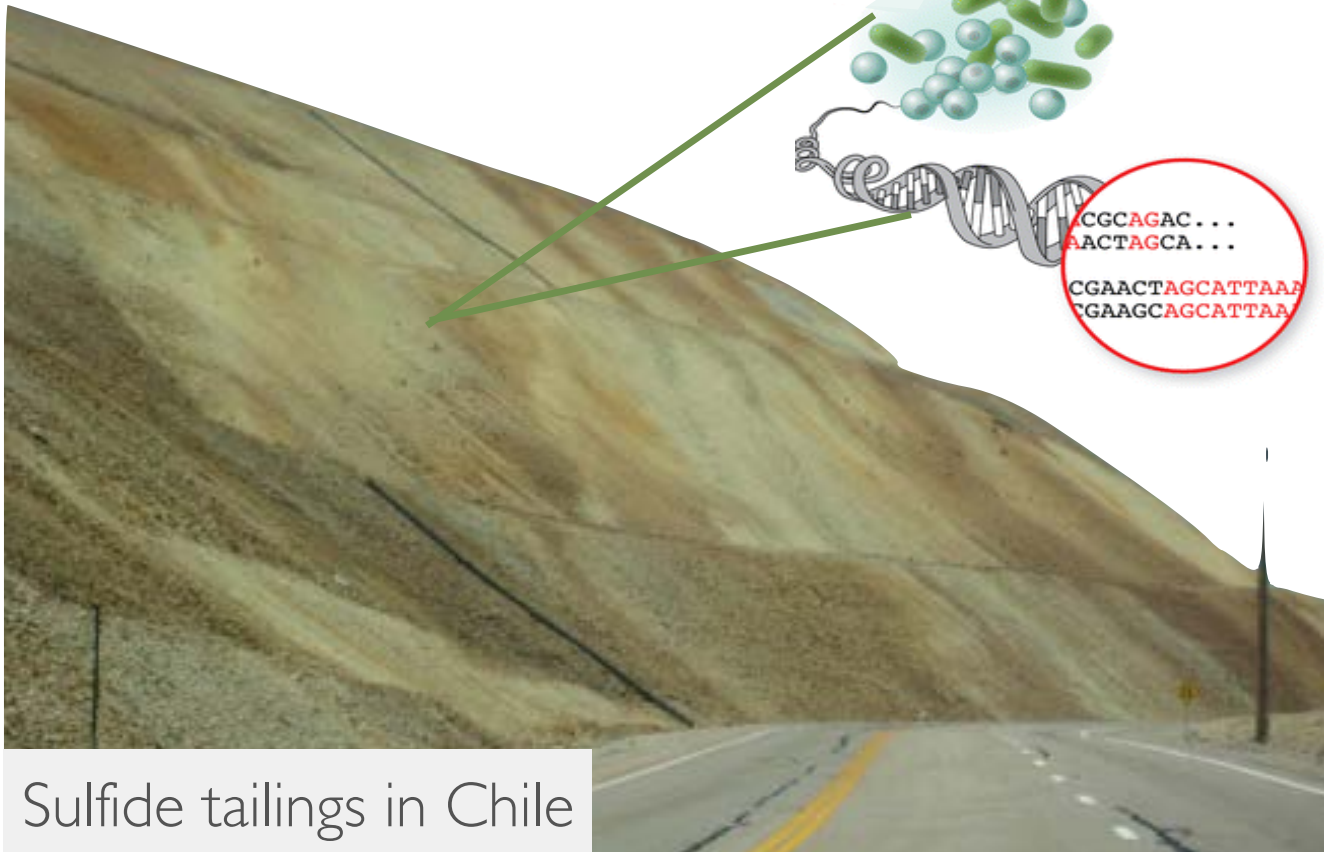
Ni

Terrafame heap leach, Finland

Green advantages of biomining



Genomics tools helping to move bioleaching from niche to robust technology

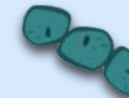


High resolution community diversity and functional profile

Optimizing the bioleaching process



- assess diversity



- capitalize abilities of microorganisms



- keep your "catalyst" happy and active



Developing and scaling-up bioleaching technology

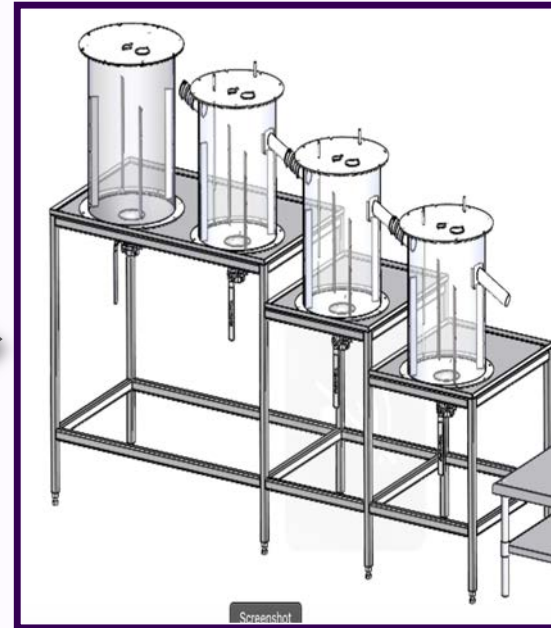
1. Bench-scale



2. Bench-scale



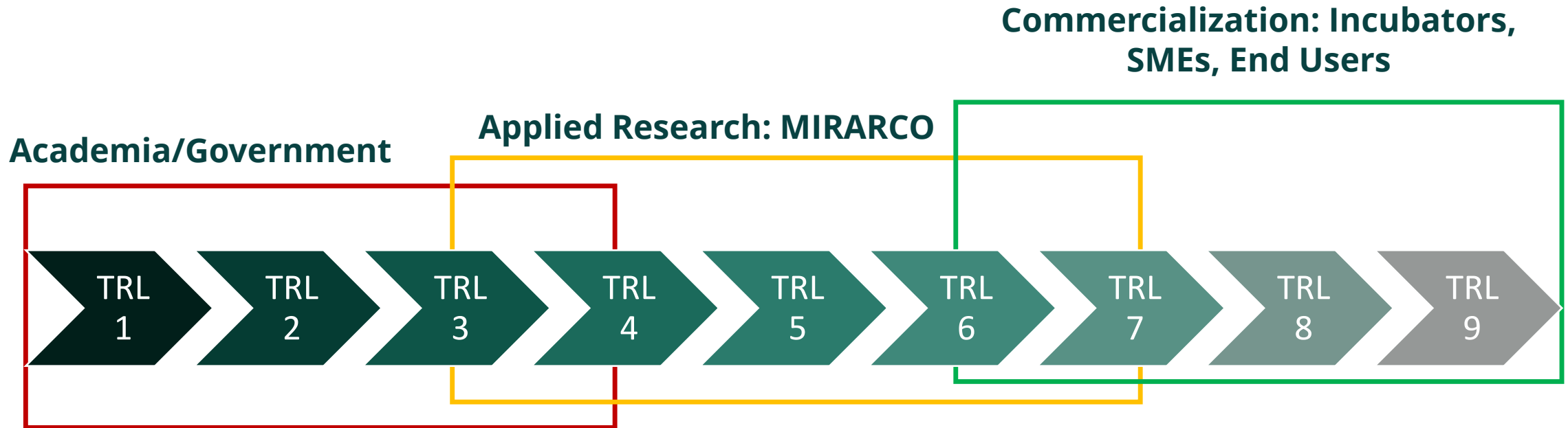
3. Pilot



4. Demonstration



How do we accelerate (bio)technologies up the chain?



The Centre for Mine Waste Biotechnology



Biomining



Bioreactors



Soil/phyto remediation



Treatment wetlands

Completed feasibility study and business case April 2022
Started implementation and capital campaign Nov 2022- present



Applied Research: MIRARCO

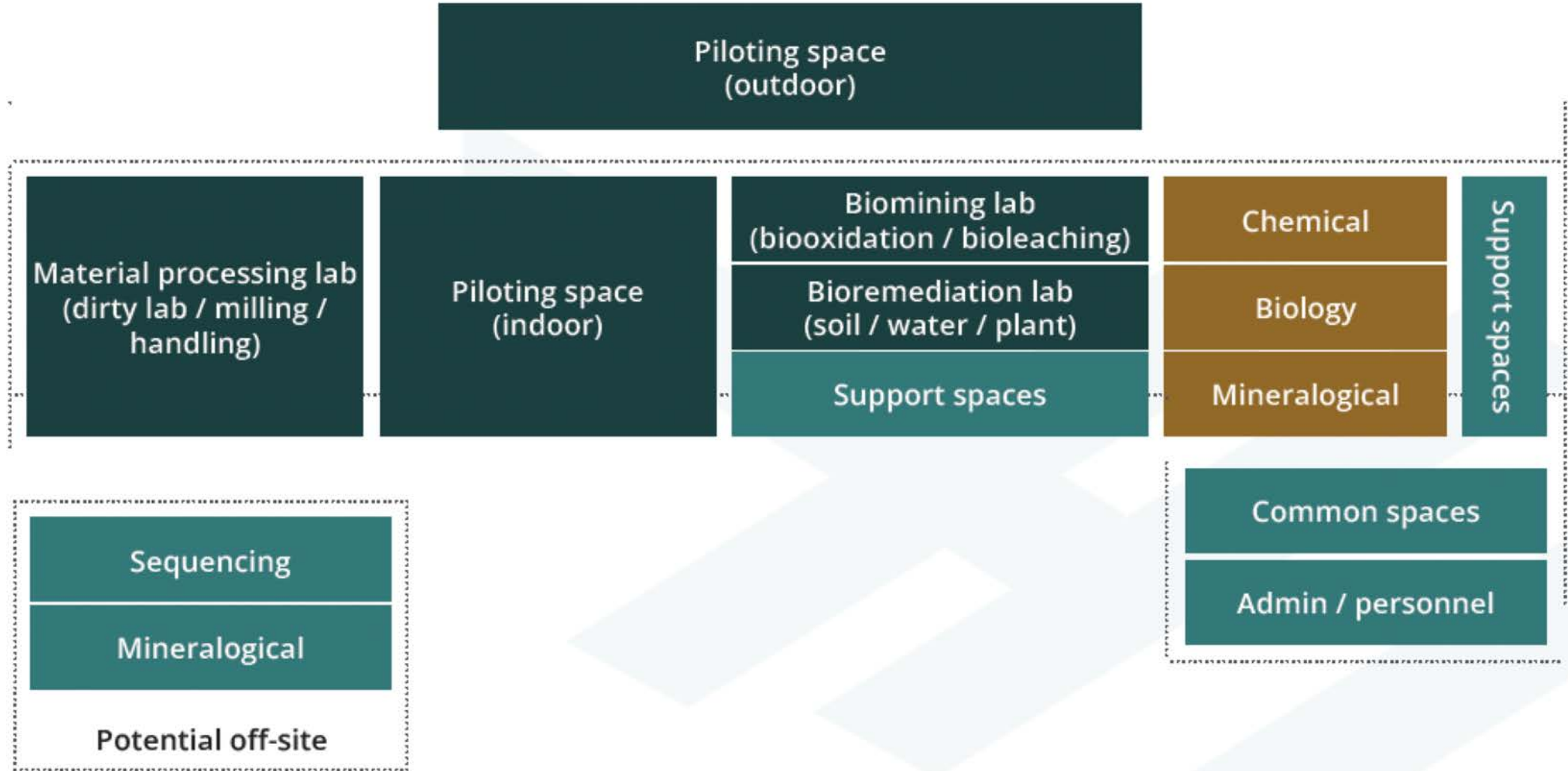
The Centre

Filling a Gap

The Centre will accelerate mining innovation through research commercialization, collaboration and education.

Scale-up from Bench-to-pilot	The Centre will shepherd technology development from bench-to-pilot with infrastructure, equipment, and cross-sector expertise. It will process a large volume of mine waste materials on-site and in-situ.
Commercialization, De-risking, Adoption & Implementation	The Centre will demonstrate ROI of biomining, develop linkages with regulators to support regulatory evolution, and provide pathways to industry adoption, ranging from TRLs 6-9.
Education & Training	The Centre will support a major talent pipeline to produce HQP in mining biotechnology, attracting top international students, researchers and companies into the Ontario economy.

Centre Facilities



Facility plan anticipates 45,000 sqft of industrial, lab, and office spaces



THE CENTRE FOR MINE WASTE BIOTECHNOLOGY

FEASIBILITY STUDY AND BUSINESS CASE

May 2022

Next Steps



Financial positioning is strong

The Centre offers a powerful return on investment

The initiative responds to an identified gap in the mining innovation ecosystem

The Centre has a unique value proposition / key differentiator

The Centre aligns with government and industry priorities

**INVESTMENT:
\$21 M
For 45,000 sq ft.
build of
facility and
infrastructure**



Capital Funding Requests Underway: \$21.0M



Feasibility and Financial Model

The Centre will offer a variety of services and programs, each generating a source of revenue:



But the need to
accelerate
innovations for
critical minerals is
urgent

so we advance the
science NOW



NOHFC Industrial Research Chair in Biomining and Bioremediation



Chair sponsors



An Agency
the Govern
of Ontario



CAMBRIAN
COLLEGE

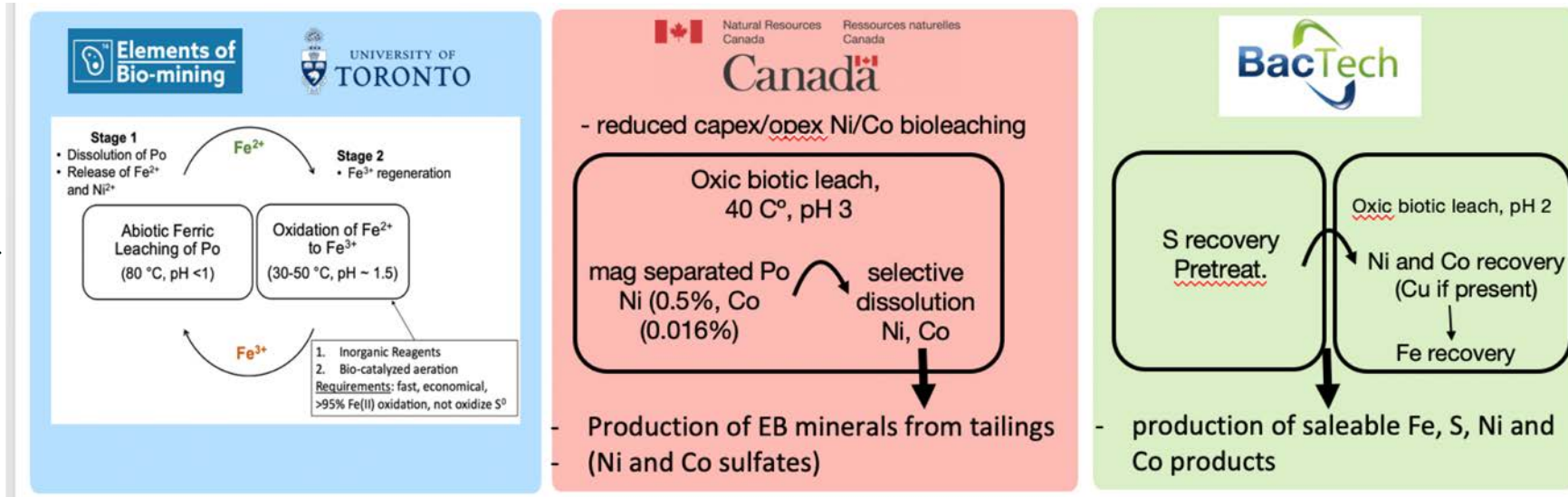
Partners



Teck

Recovery of Ni Co from Sudbury pyrrhotite tailings

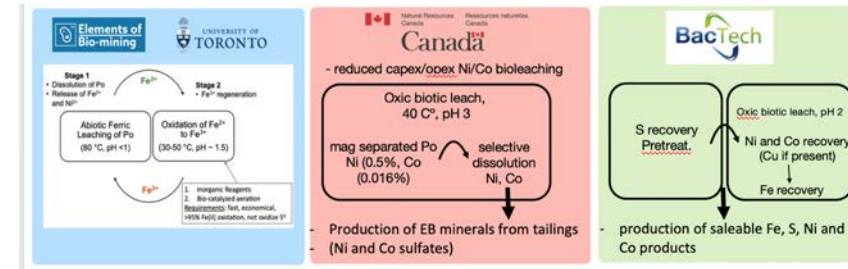
1. Comparing different bioleaching processes





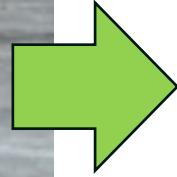
Recovery of **Ni** **Co** from Sudbury pyrrhotite tailings

1. Comparing different bioleaching processes



2. Pilot testing for optimal process(es) or combination





Recovery of **Ni** **Co** from Sudbury pyrrhotite tailings

2. Pilot testing for optimal process(es) or combination



3. Recovery of high and lesser value elements

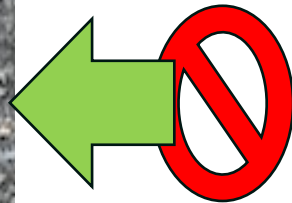


Recovery for battery feedstock



Recovery to reduce reactivity

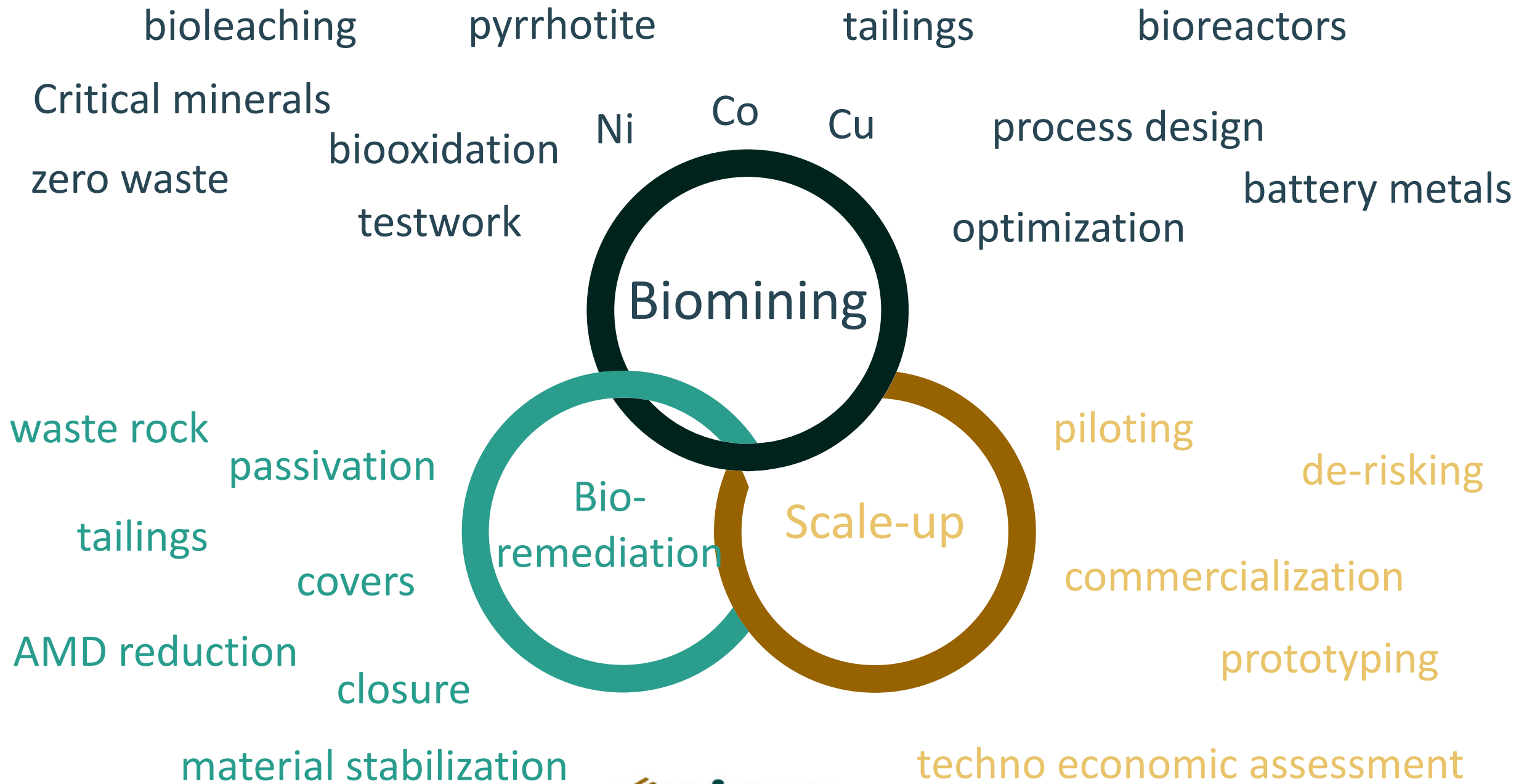
4. Re-purpose residues = zero waste approach



Leach residue



Usable/stable materials



Supporting Ontario/Canada's Critical Minerals Strategy

The Centre's biotechnologies will support in **advancing Ontario and Canada's position as a global leader in critical mineral supply chain** through the following:



Supporting
Ontario Critical
Minerals
Strategy



Addressing
mining
industry
challenges



Creating
jobs for the
province



On-the-job
opportunities
to address
gap in skills



Attracting
students,
researchers,
and additional
mining industry



Growth of new
companies in
the mining
supply chain

Thank you



“ To meet critical metal demands of tomorrow, the Canadian mineral resource sector must look beyond traditional practices, and invest in innovative and sustainable technologies and expertise



Questions?

Dr. Nadia Mykytczuk (MIRARCO)

nmykytczuk@mirarco.org

(705) 675-1151 x 5110