Extracting Battery Minerals from Mine Waste

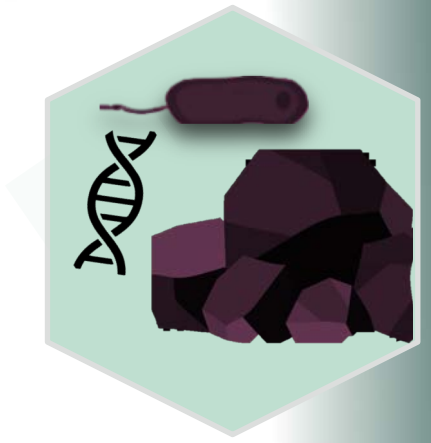
Dr. Nadia Mykytczuk, Interim CEO & President

May 26, 2022

Dr. Nadia Mykytczuk
Interim CEO/President MIRARCO
Interim Exec. Director Goodman School of Mines

mirarco
MINING INNOVATION

Mining Innovation, Rehabilitation, and Applied Research Corporation



Biomining
Bioremediation

Currently leading research in:

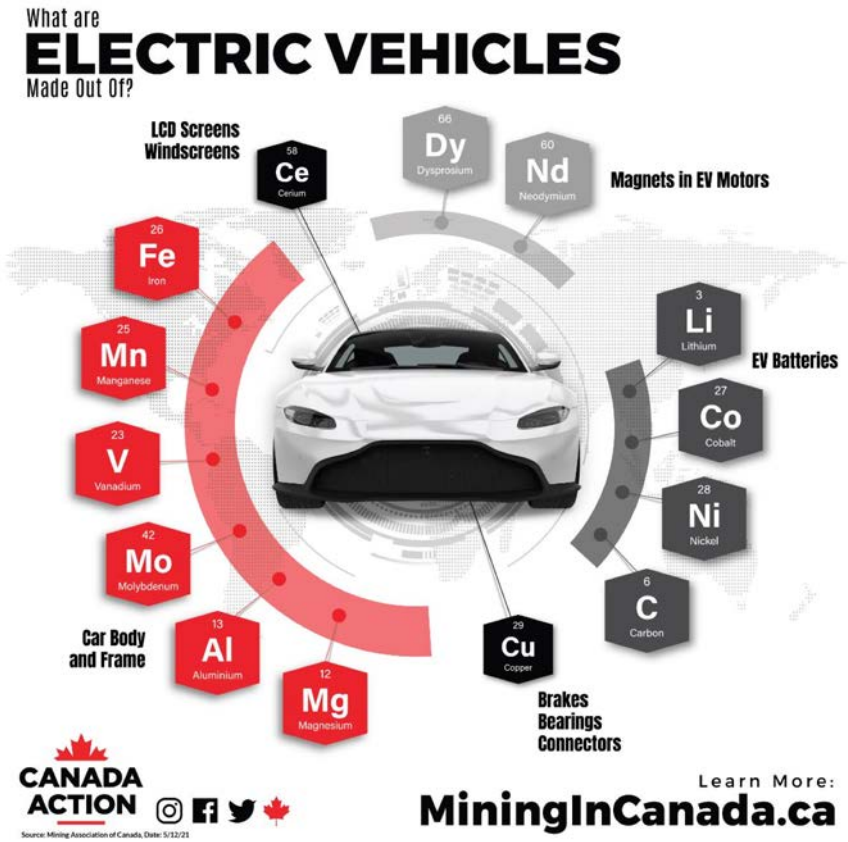
Safety

Rock Mechanics

Software

Energy

Key Canadian minerals for batteries and electric transportation



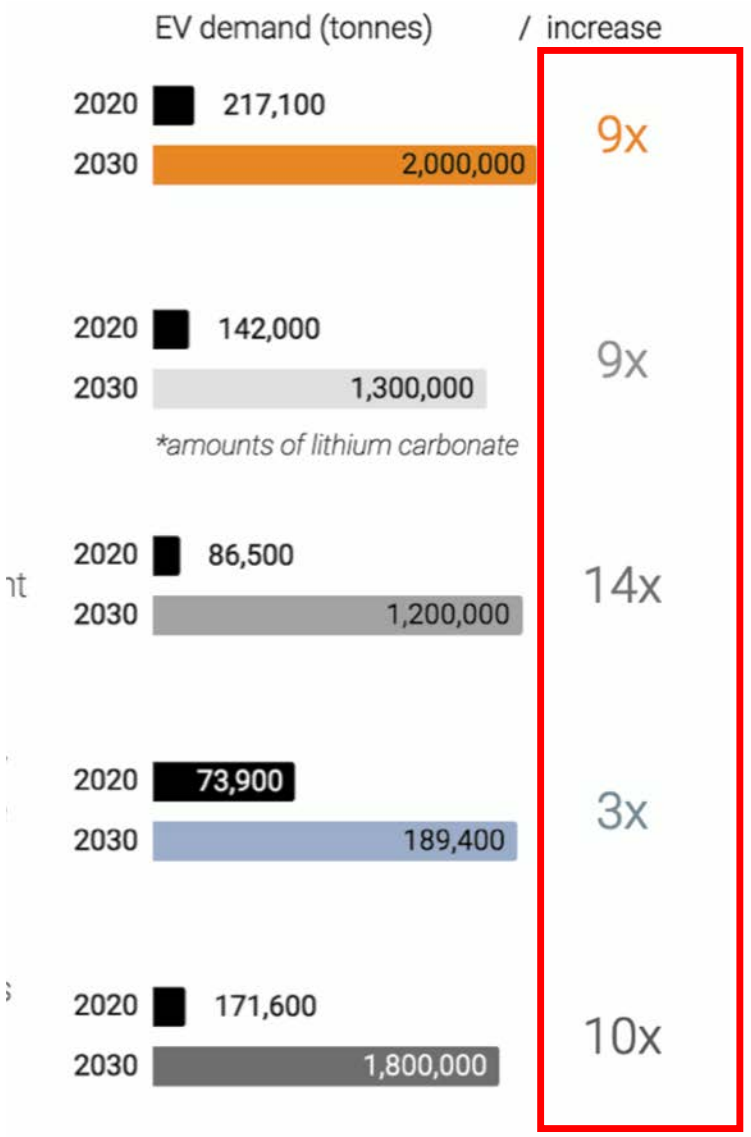
29 Cu

3 Li

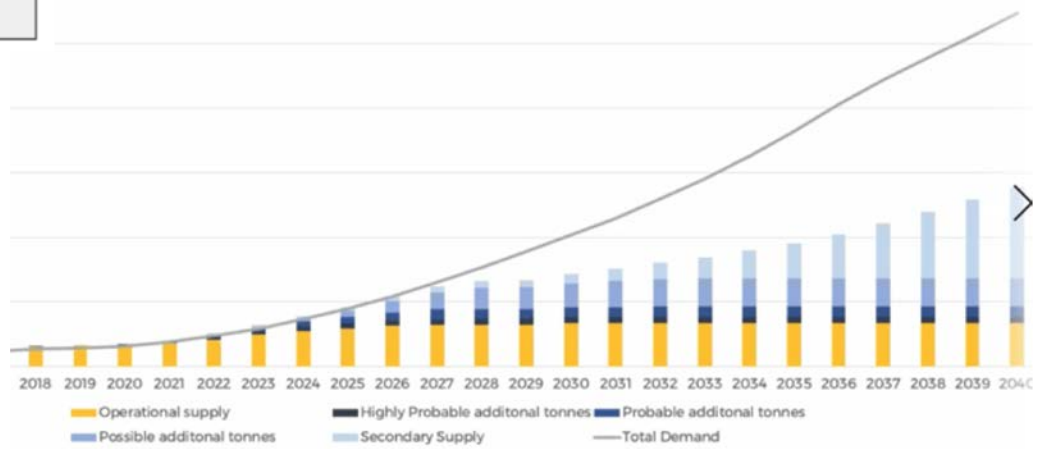
28 Ni

27 Co

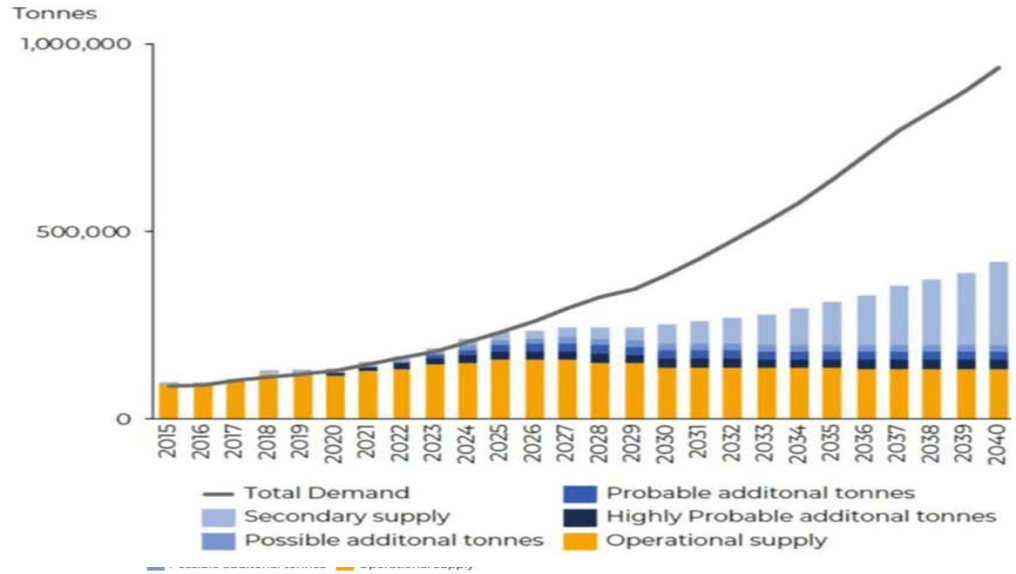
6 C



3
Li

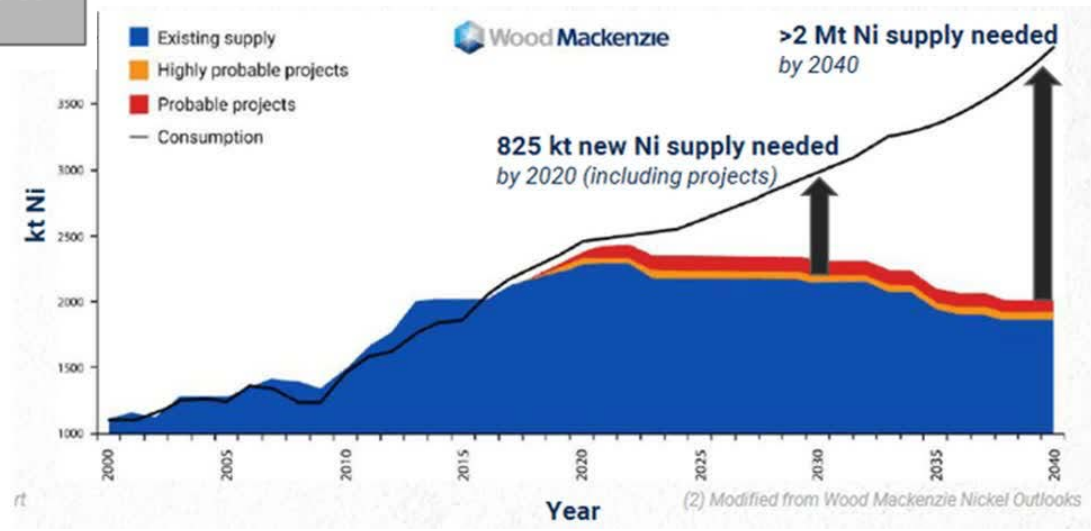


27
Co

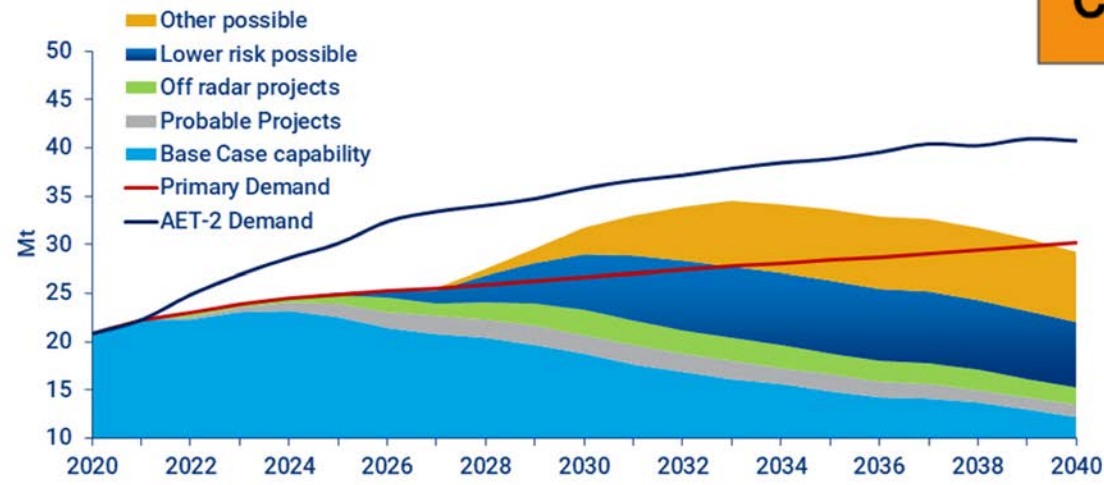


Source: Benchmark Minerals Cobalt Forecast

28
Ni



29
Cu



Source: Wood Mackenzie

Where will we find the missing supply?

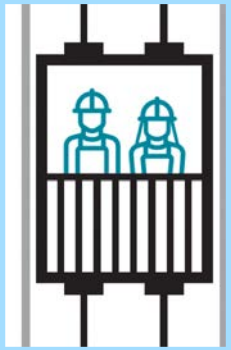
THE CANADIAN MINERALS AND METALS PLAN

Ontario's Critical Minerals Strategy
Unlocking potential to drive economic recovery and prosperity
2022-2027

Enhance exploration

Develop deposits

Go deeper

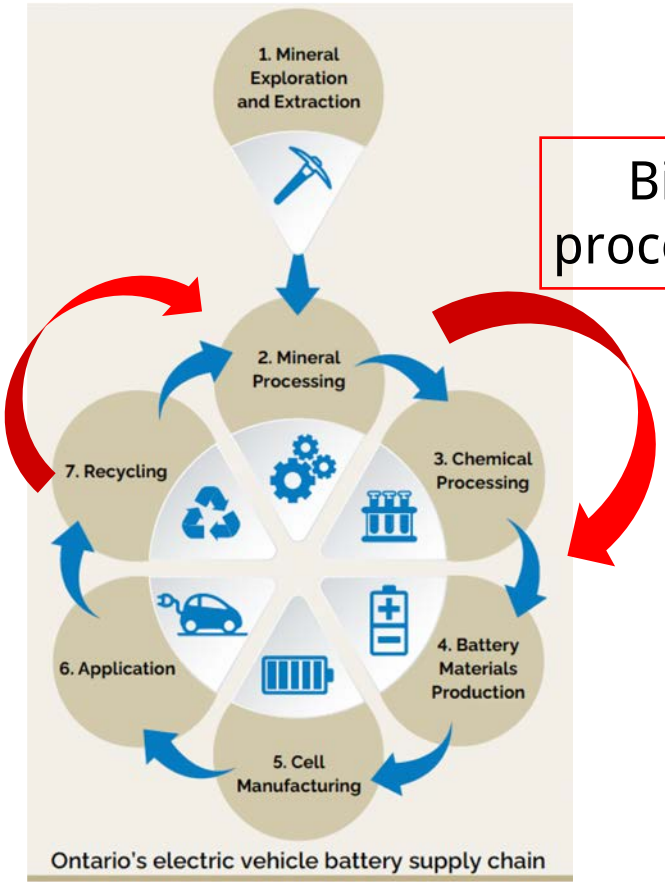


Improve processing

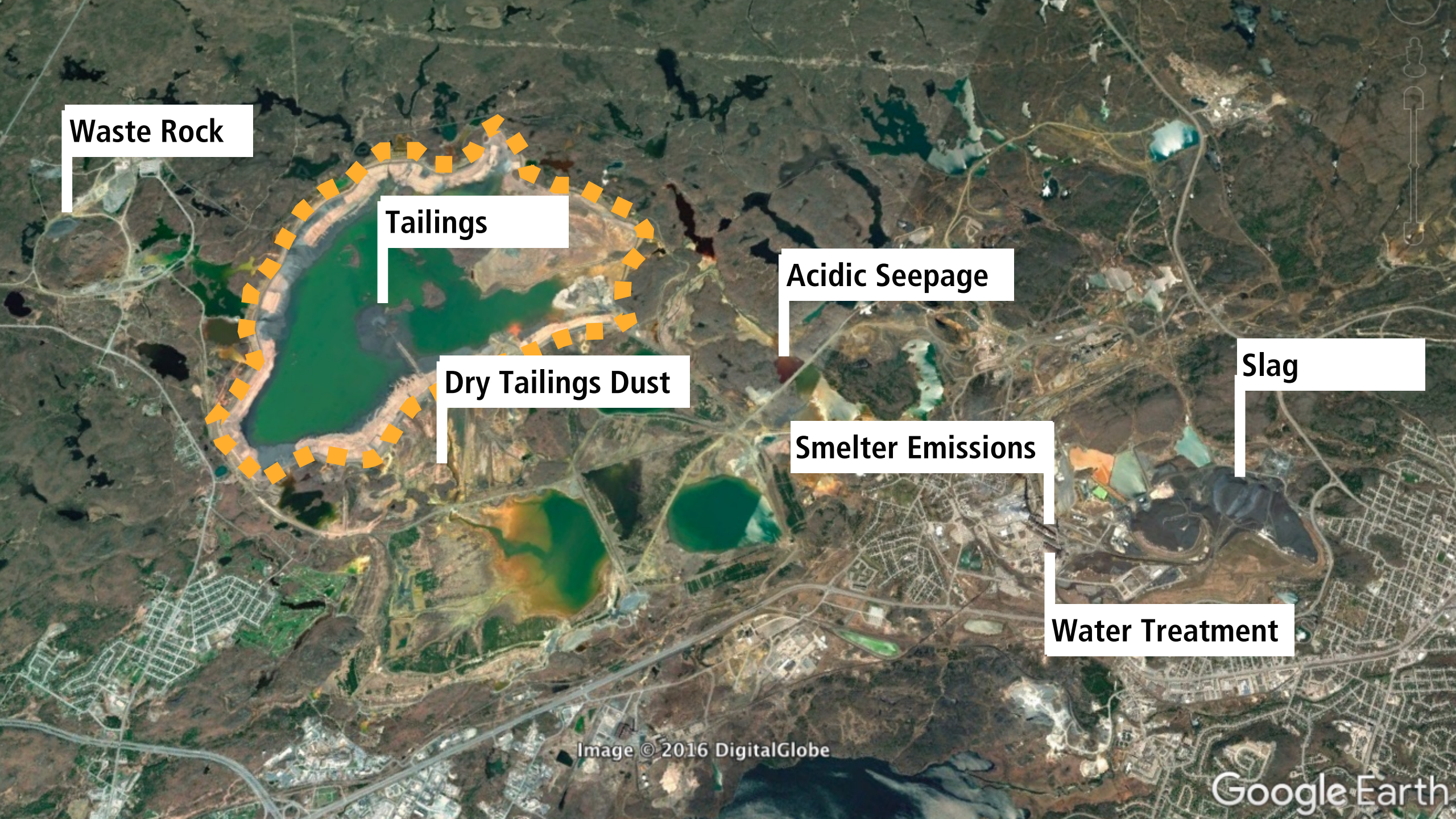
New green tech and innovation

Circular economy
Includes wastes

NRCan: Pan-Canadian "Mining value from Waste"



Bio-processing


Waste Rock
Tailings
Dry Tailings Dust
Acidic Seepage
Smelter Emissions
Slag
Water Treatment
Image © 2016 DigitalGlobe
Google Earth

ENVIRONMENTAL IMPACTS

200 **ACTIVE MINES**[15]

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 metals [19]

70.0%

OF CANADIAN MINES

report a substantial environmental risk [20]

FINANCIAL LIABILITIES

$10.0

BILLION

in liability costs associated with ongoing treatment of mine wastes [21]

$5.7

BILLION+

in unsecured government liability costs associated with contaminated mine sites in Canada [22]

$1.8

BILLION+

in government liability costs associated with Ontario's contaminated mine sites [23]

Tailings: Liability or opportunity?

FINANCIAL OPPORTUNITIES

$8.0-10.0 BILLION
in nickel contained in mining waste in the Sudbury region [24]

$10.0 BILLION
in estimated value stored in Canada's gold mine waste [25]

$2.4 TRILLION
in copper contained in mine waste globally [26]

$2.0 BILLION+
mineral value in Alberta oil sands tailings [27]

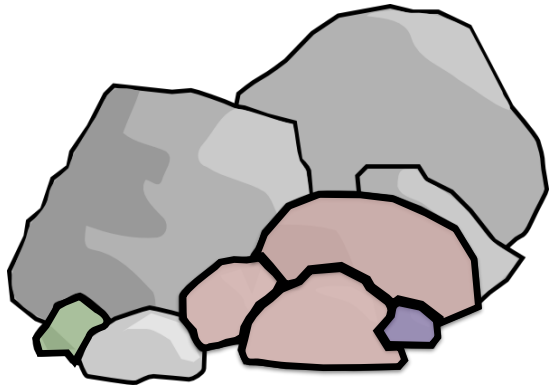
DEMAND FOR
BATTERIES
expected to triple the available supply by 2030 [28]

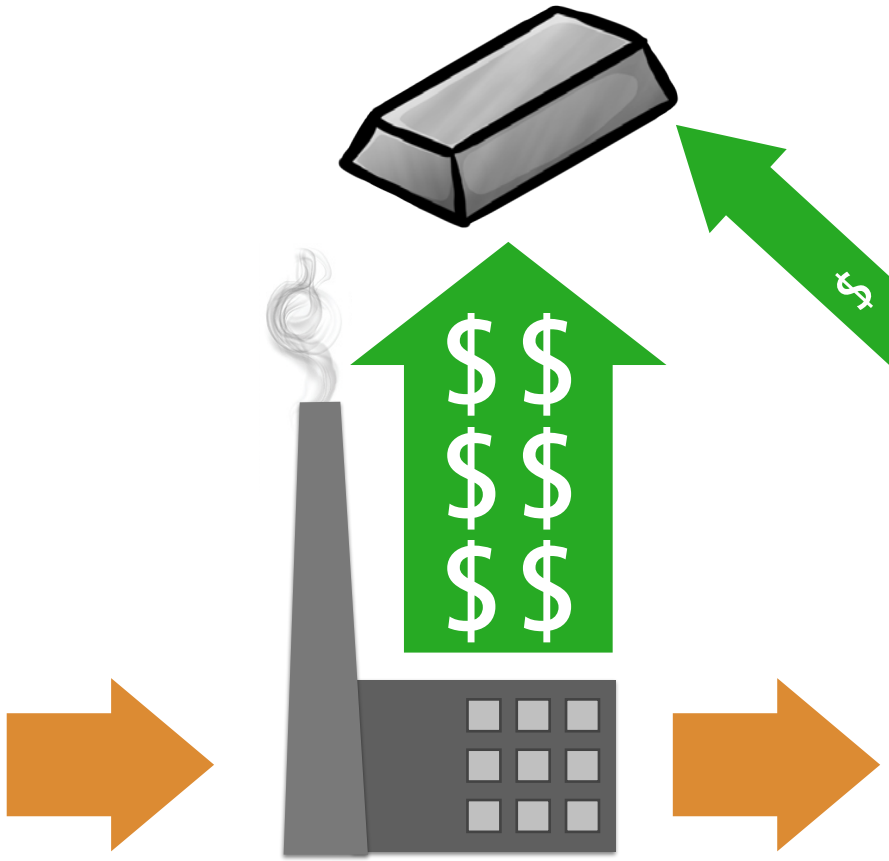
The difference between ore and waste is the cost of extracting value

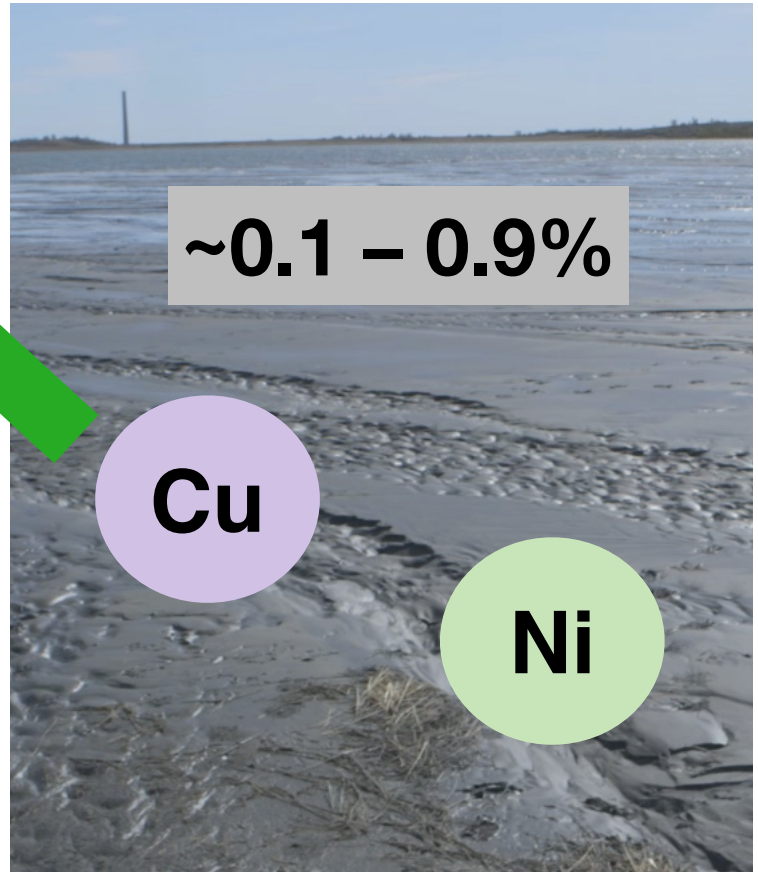
~1% Copper Sulfide

~25% Iron Sulfides

~1% Nickel Sulfide



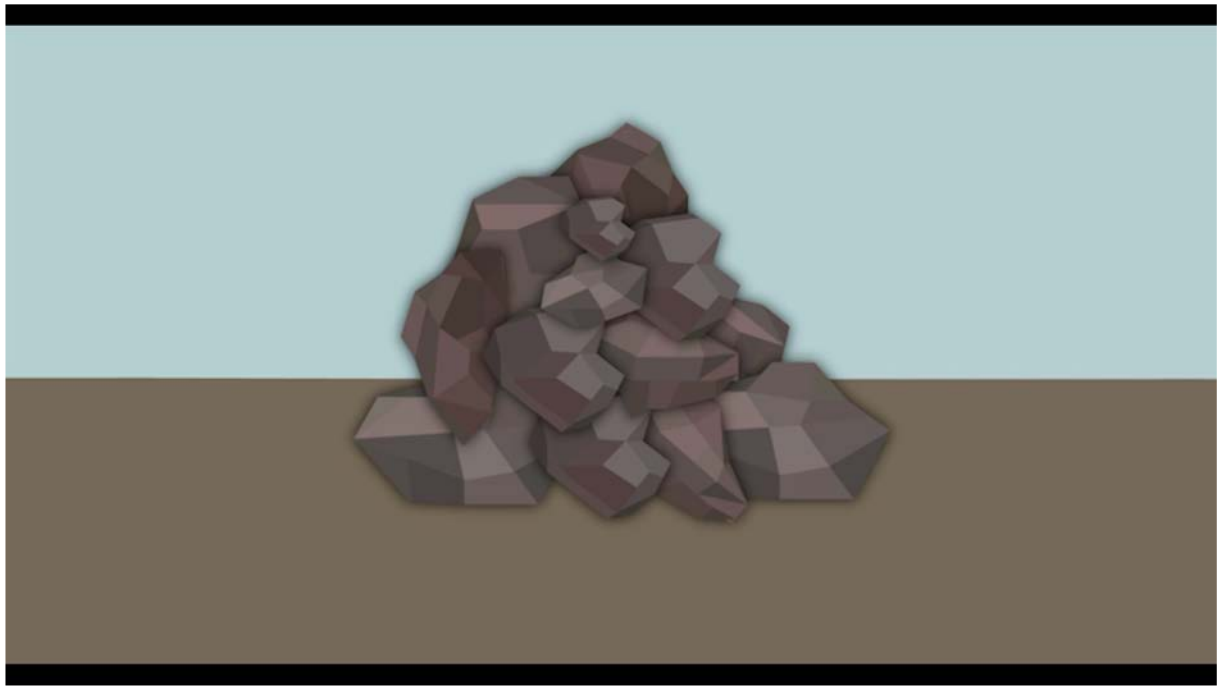




Mine waste streams still contain some valuable metals.
When is the extraction cost worth the effort of reprocessing these wastes to extract more value?

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

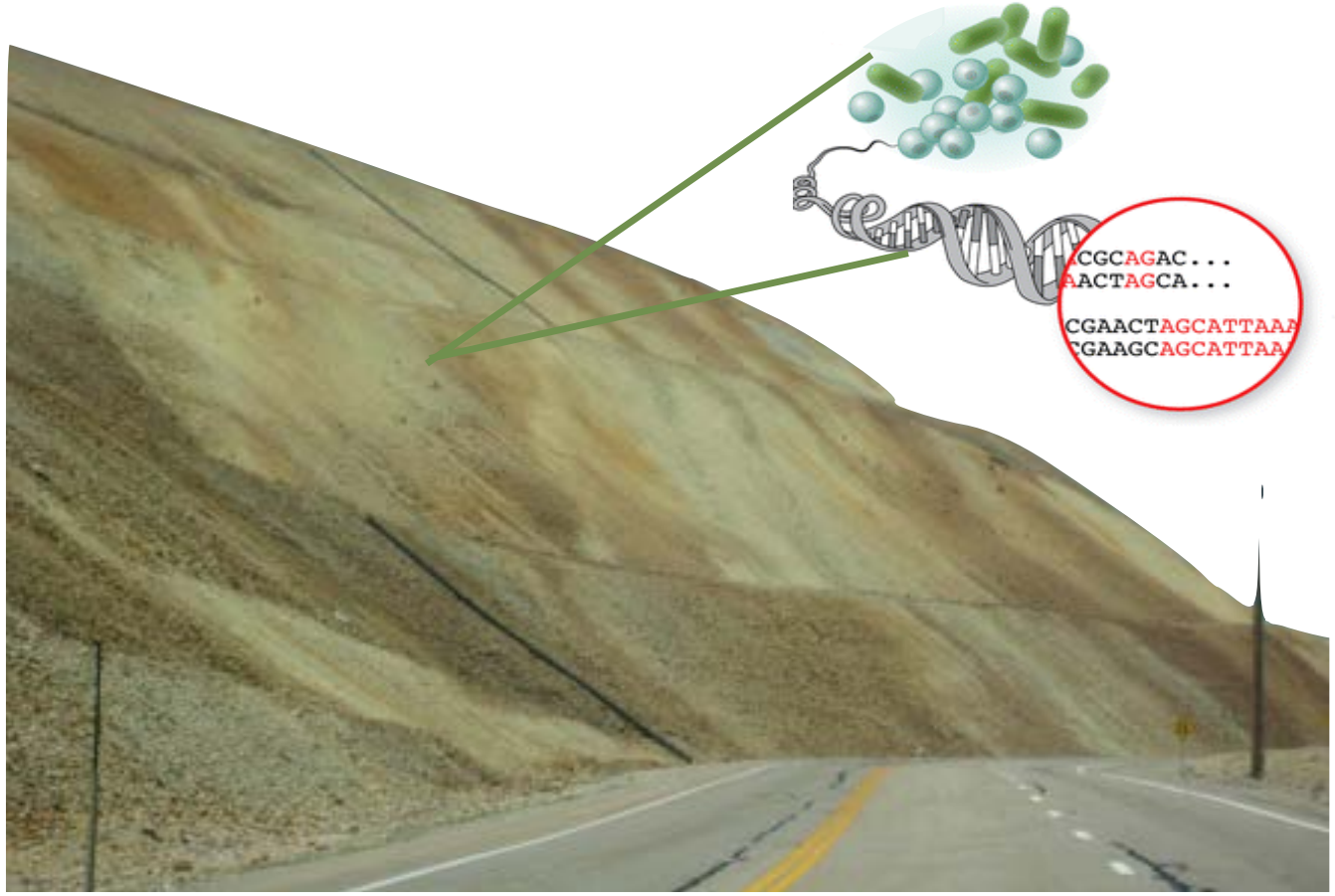
Au

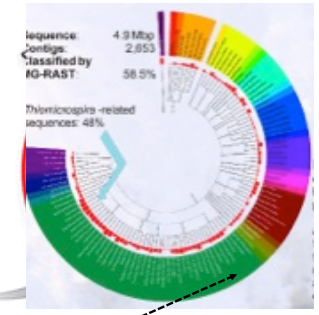
Refractory gold bioreactors, China

Ni

Terrafame heap leach, Finland

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

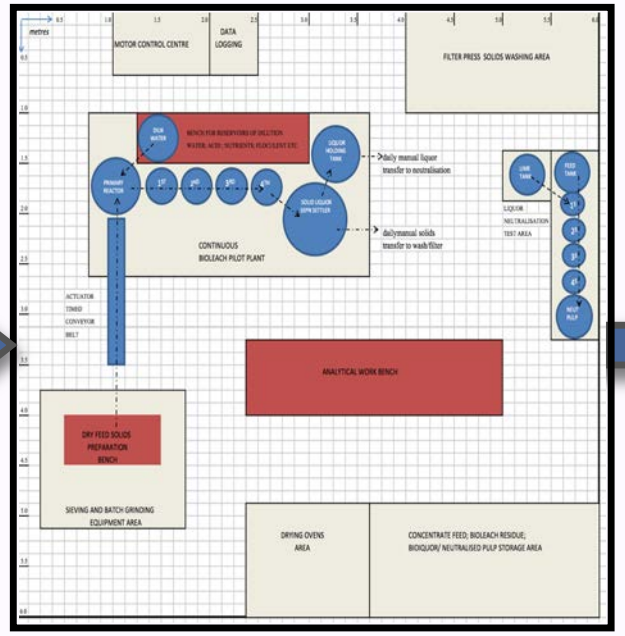
- keep your “catalyst” happy and active

Developing and scaling-up bioleaching technology

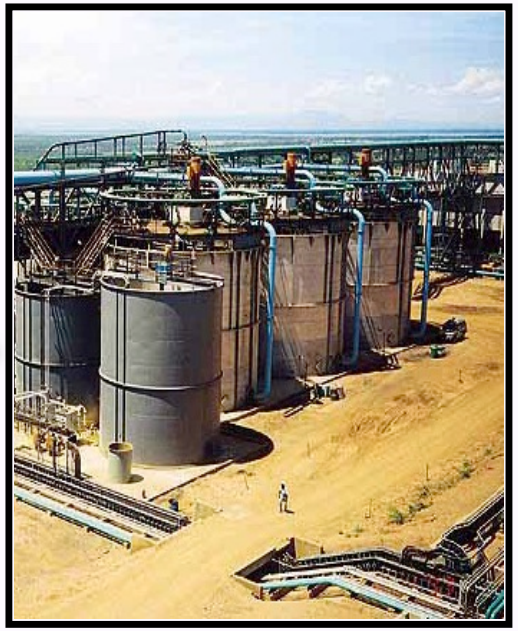
1. Bench-scale

2. Bench-scale

3. Pilot

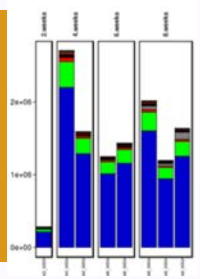


4. Demonstration



Gold recovery > 83%

Arsenic stabilization > 99%



Pilot project for Sudbury pyrrhotite for recovery of Co Ni

mirarco MINING INNOVATION

- Sudbury pyrrhotite stockpiles represent $8-10B in Ni/Co value (0.8% Ni, 0.1% Cu, 0.03% Co,
- Optimization and piloting of sulfide tailings processes
  - Comparing 3 different processes:(both Vale and Glencore feedstock)

Elements of Bio-mining

UNIVERSITY OF TORONTO

Stage 1
- Dissolution of Po
- Release of Fe^{2+} and Ni^{2+}

Fe^{2+}

Stage 2
- Fe^{3+} regeneration

Abiotic Ferric Leaching of Po (80 °C, pH <1)

Oxidation of Fe^{2+} to Fe^{3+} (30-50 °C, pH ~ 1.5)

Fe^{3+}

1. Inorganic Reagents
2. Bio-catalyzed aeration

Requirements: fast, economical, >95% Fe(II) oxidation, not oxidize S^0

Natural Resources Canada / Ressources naturelles Canada

Canada

- reduced capex/opex Ni/Co bioleaching

Oxic biotic leach, 40 C°, pH 3

mag separated Po Ni (0.5%, Co (0.016%)) → selective dissolution Ni, Co

- Production of EB minerals from tailings
- (Ni and Co sulfates)

BacTech

S recovery Pretreat.

Oxic biotic leach, pH 2

Ni and Co recovery (Cu if present)

Fe recovery

- production of saleable Fe, S, Ni and Co products

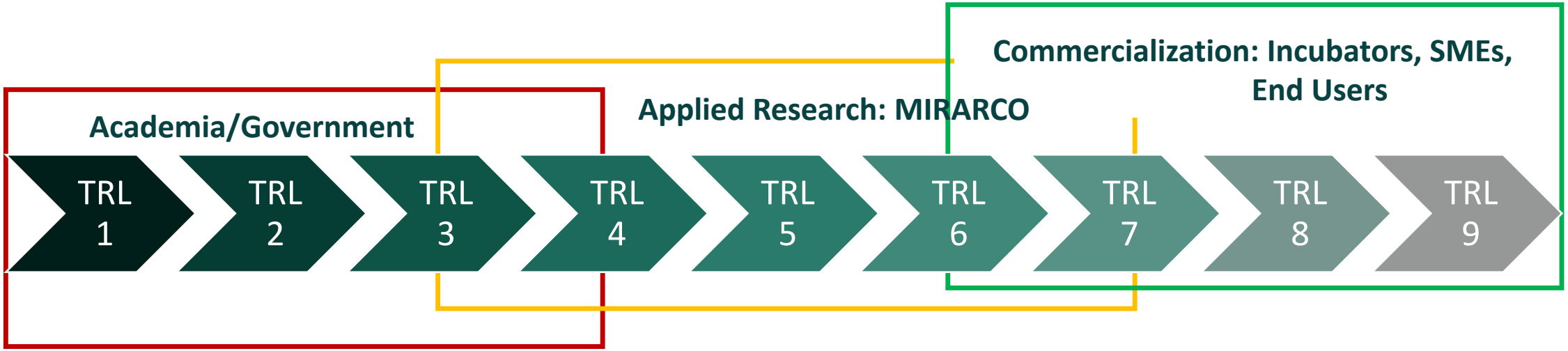
Pilot data

Co Ni

Battery Mineral/salts

TEA

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



Funding support

Introducing the Centre for Mine Waste Biotechnology

Biomining

Bioreactors

Soil/phyto remediation

Treatment wetlands

STILETTO

Completed feasibility study and business case April 2022

Applied Research: MIRARCO

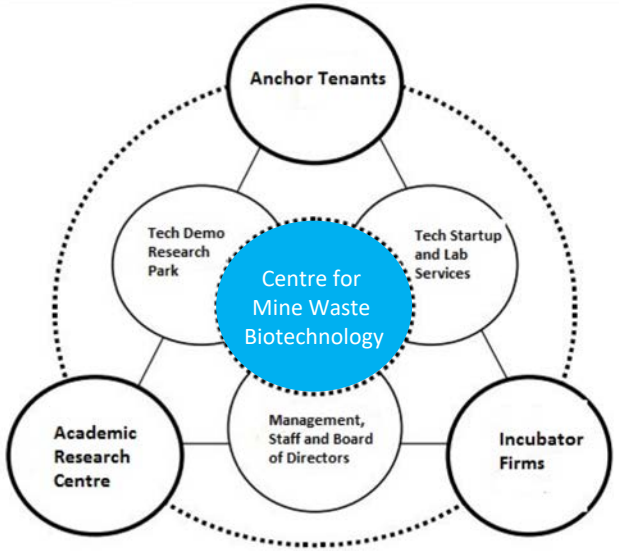
The Centre

Filling a Gap

The Centre for Mine Waste Biotechnology, will **focus and in the scale of the facilities and testing it can offer on site and in partnership with other groups**. Specifically, the Centre fills the following gaps:

- The need to focus on biotechnology as a mine waste strategy
- The need for bench-to-market biomining innovation support
- The need for pilot-scale mining biotechnology facilities
- The need to coordinate research in biotechnology

Vision



Research Lens

Interdisciplinary techniques from mineralogy, hydrometallurgy, process design and engineering, microbiology and biochemistry, genomics and bioinformatics and multivariate analysis

Commercialization Lens

Demonstrating, optimizing and implementing new approaches to transform mining practices

Collaborative Lens

Fostering unique collaborations among a dynamic team of researchers and subject matter experts in multiple academic institutions, research institutes, government agencies, the mining industry, the private sector, and mining innovation ecosystem

Education & Training Lens

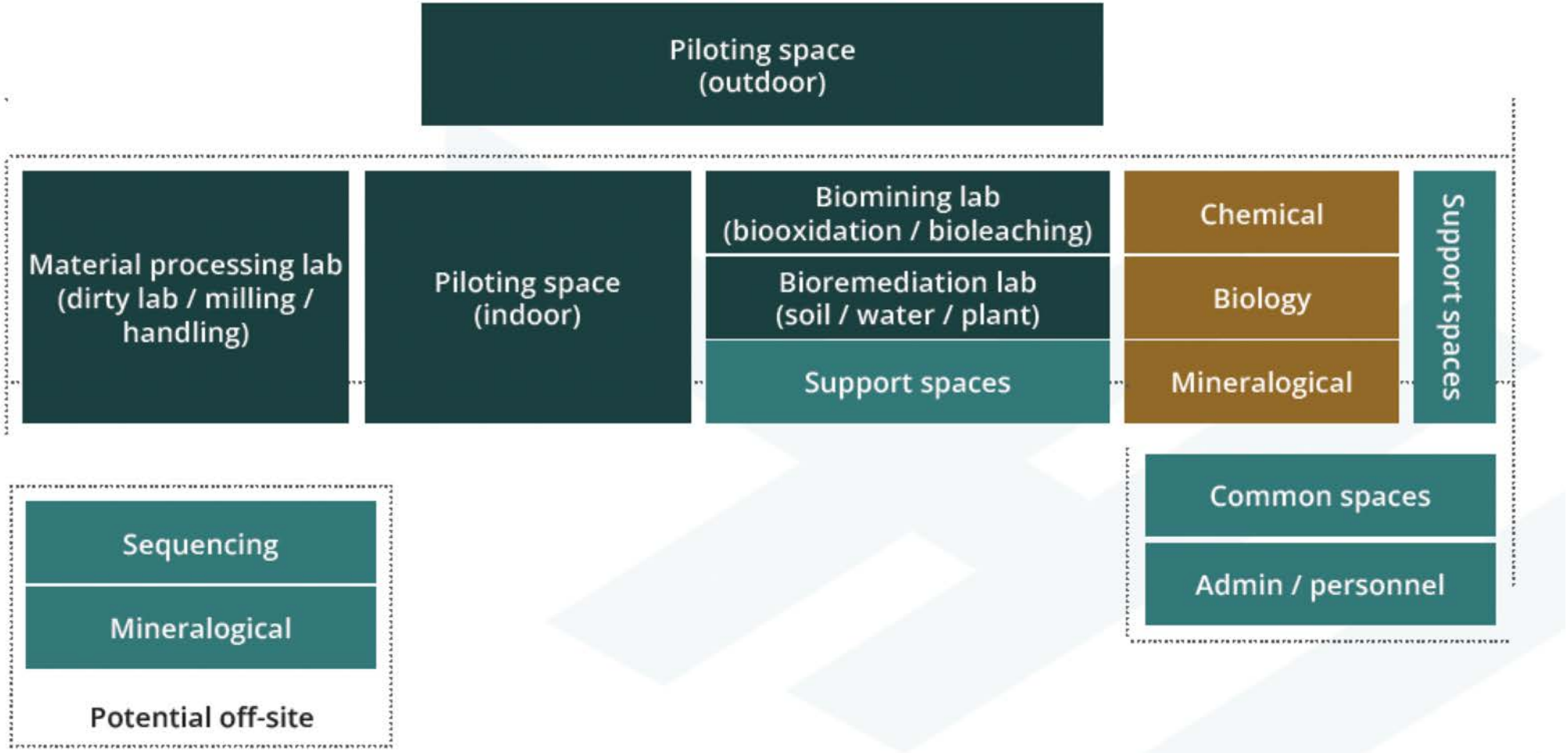
Providing training and support for HQP

Attracting top international students, researchers and companies

Goals of the Centre

1. Serve as the core facility for mine waste processing and mine site restoration
2. Provide scalable, proof-of-concept biotechnologies
3. Accelerate the commercialization of bioleaching and bioremediation technologies for improved mine waste management in northern Ontario, Canada, and globally.
4. Foster market confidence in new biotechnologies
5. Facilitate on-site mining research in partnership
6. Create opportunities for cross-pollination
7. Promote technology entrepreneurship and the development of a competitive biotechnology research cluster
8. Support the economic growth of tenant firms with connections to local, provincial, and federal resources
9. Provide a regional site for training in biomining and bioremediation techniques and technologies
10. Develop best practices, regulations, and standards for mine waste processing

Centre Facilities



Feasibility considered a 30,000 or 45,000 sqft facility

Next steps and building the future, together

For the Centre for Mine Waste Biotechnology to meet its goals, intentional and focused action is required across seven fundamental components:

1. Industry / Company buy-in
2. Institutional Support
3. Partnerships
4. Assets and Infrastructure
5. Vision and Mission
6. Financial Positioning
7. Programming / Content

Creating synergies among Canada's mining innovation ecosystem to accelerate the development and commercialization of biotechnology solutions

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:
$17.3 M
For 45,000 sqft. Facility and infrastructure

Thank you


BEV IN DEPTH
REGISTER TODAY!
Mines to Mobility Conference 2022
May 25 to 26
Science North, Sudbury, Ontario, Canada
sudbury

> **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) 566-8108 x 7802