From Atoms in the Ground to Atoms in a Gigafactory

Battery Trends & Transforming the Supply Chain to Meet the Demands of the Growing EV Industry

BEV In Depth
Mines to Mobility Conference 2023
Cambrian College, Sudbury, Ontario

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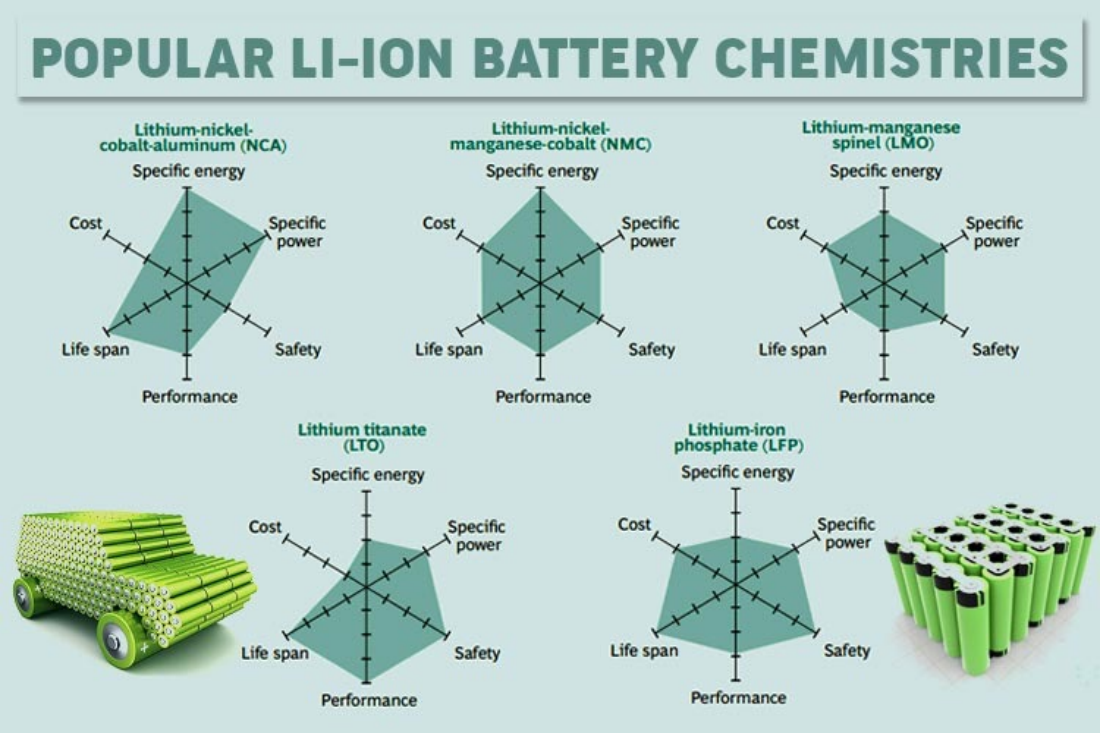
May 2023

Why EVs?

Battery trends - primer

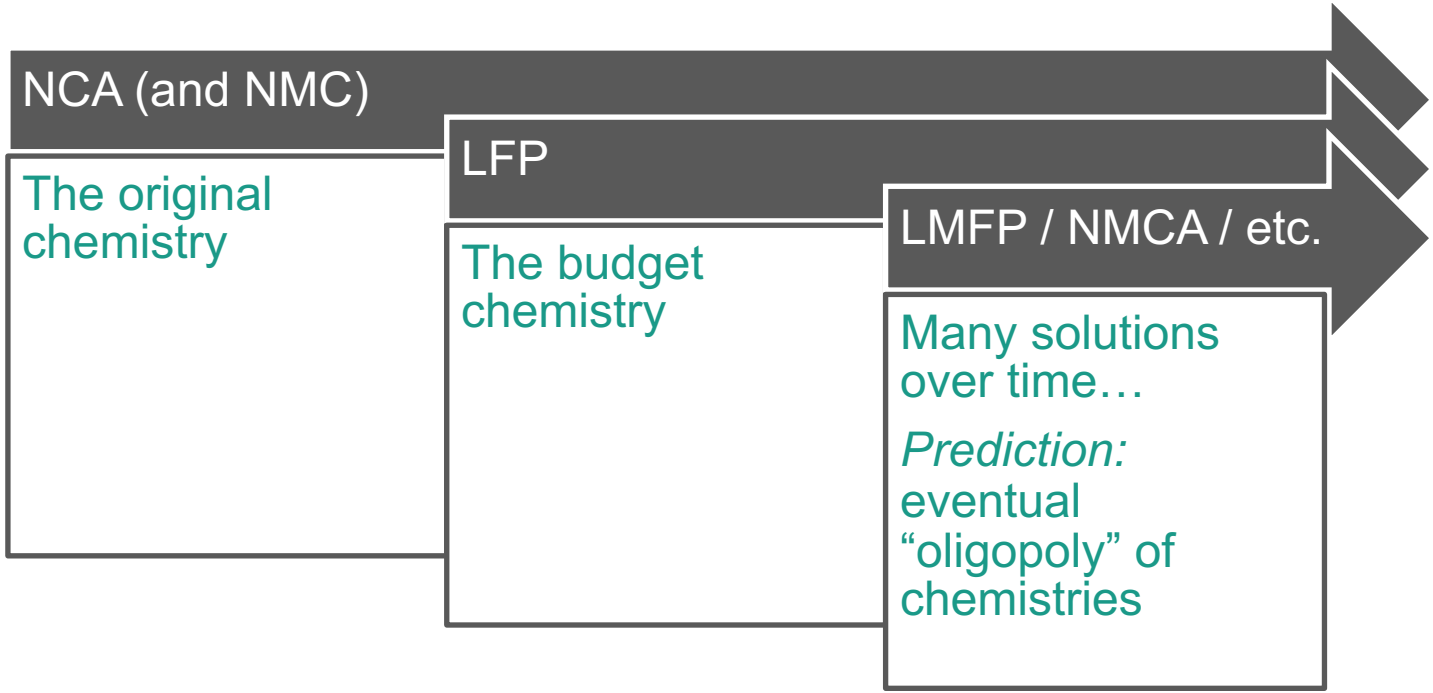
What makes a great EV / battery?

EV	Battery
Range	Energy density
Speed	Power
Longevity	Cycle/calendar life
Safety	SAFETY!
Cost	Cell vs. pack



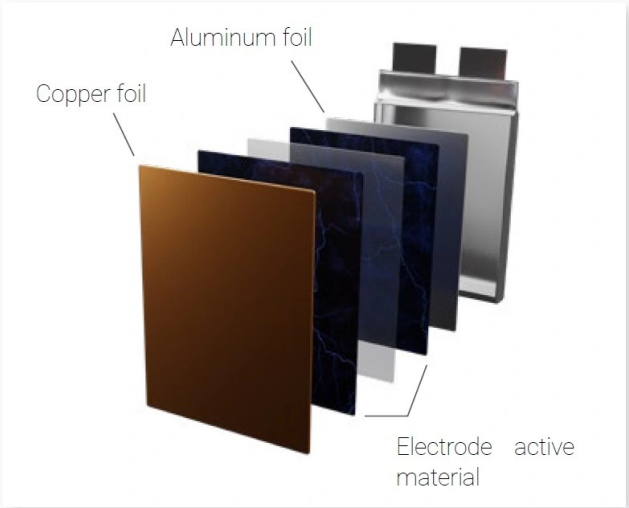
Source: Sharad Bhowmick (2022)

Battery trends – EV industry



Battery trends – examples

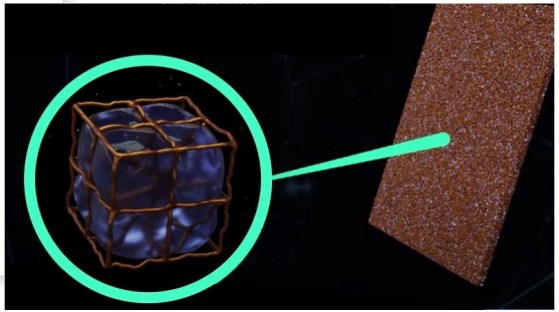
Traditional Battery Structure



Addionics 3D Structure (3D Electrodes)

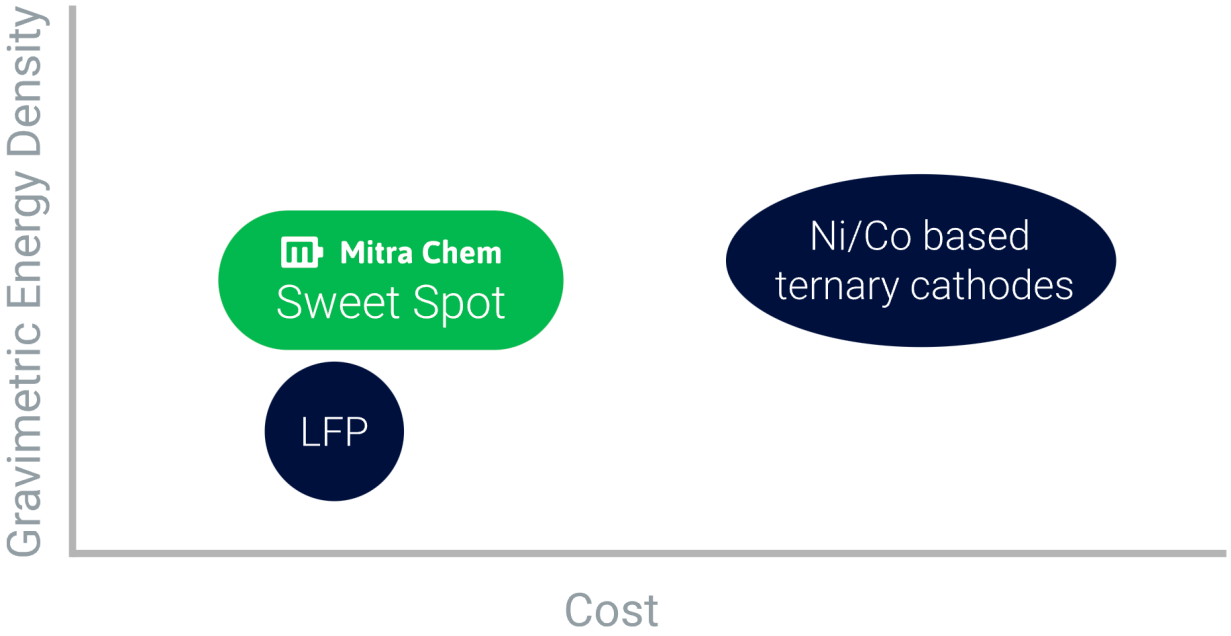
Addionics

- A focus on physics, not chemistry
- Benefits across the board



Source: Addionics (2023)

Battery trends – examples

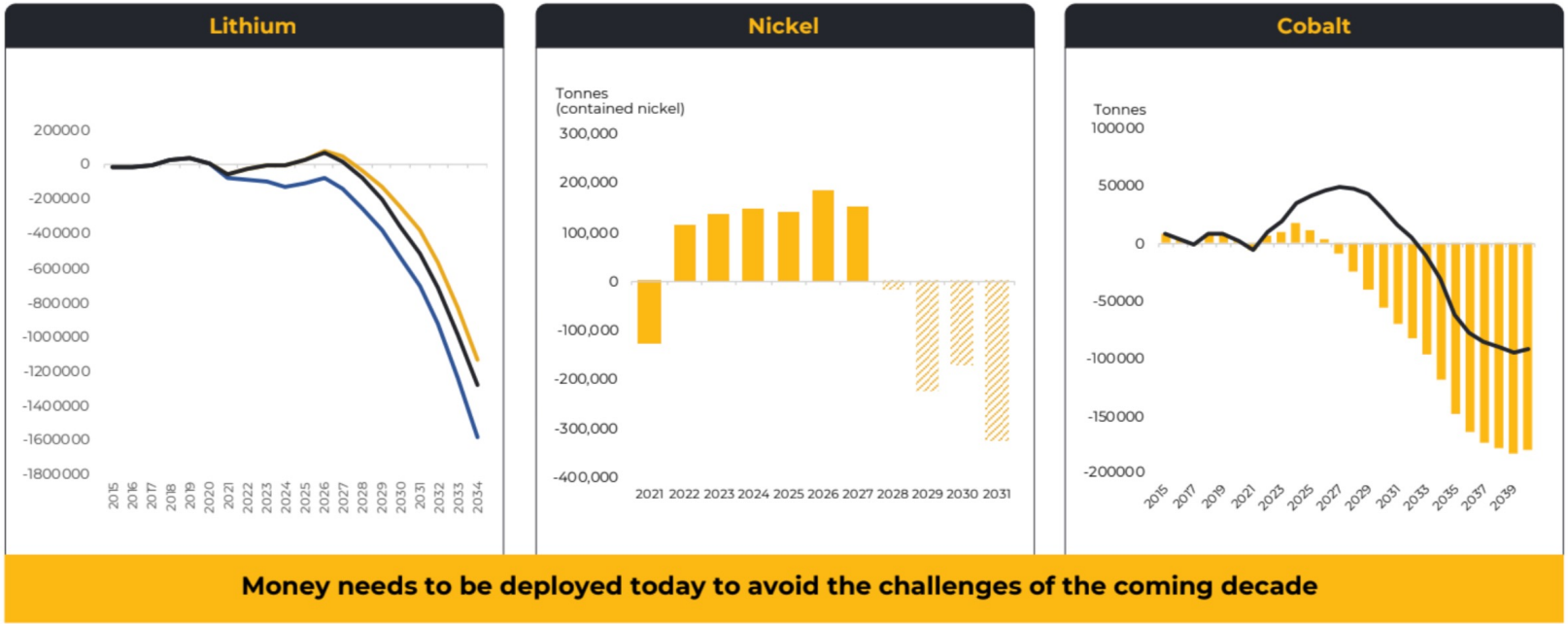


Mitra Chem

- A focus on iron-based cathode chemistries
- It is “a solution” but will not displace high energy Ni/Co cathodes

Source: Mitra Chem (2023)

Battery trends – raw material cliff edge is here



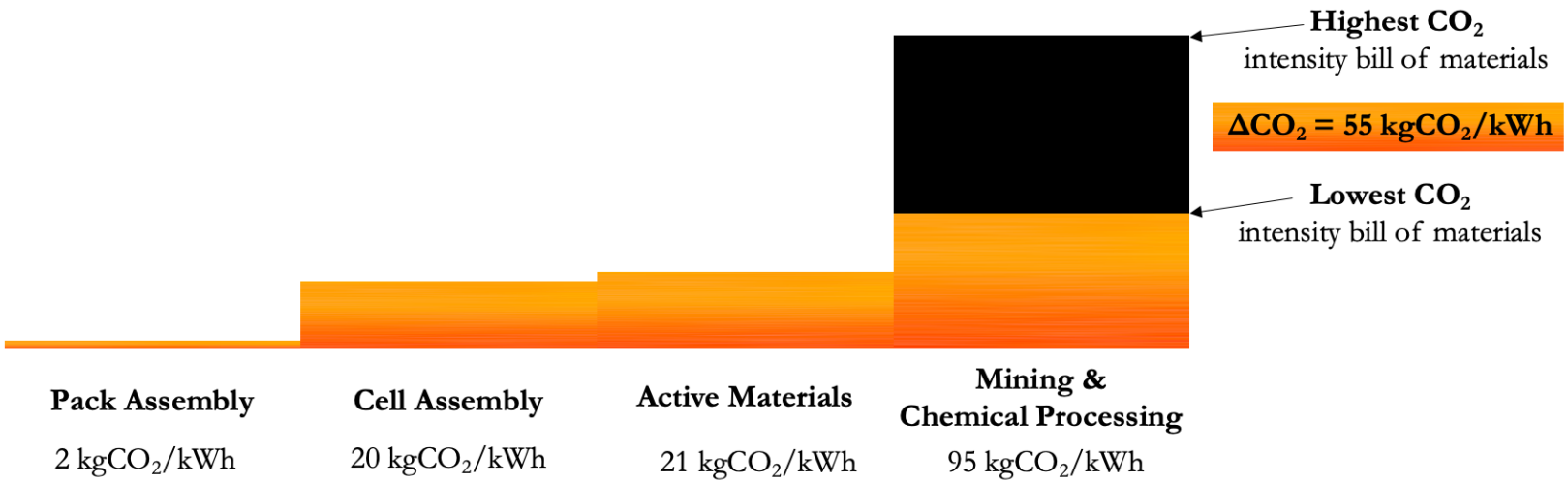
Source: Benchmark Mineral Intelligence (2023)

Solution: innovate to (a) material abundance (b) zero emissions, small-footprint supply chains?


Vision of abundance:
- Lower footprint
- Higher margins
- Everyone benefits

EV supply chain: emission sources

Mining is "the source" of emission
And source of innovation opportunity



Data From:
Argonne NATIONAL LABORATORY
MINVIRO

Battery materials: wide-ranging emissions

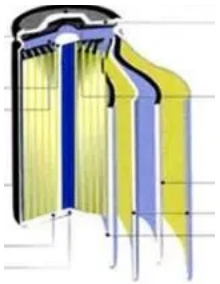
	Clean Product (low tCO_2/t)	Dirty Product (high tCO_2/t)	Ratio of CO_2 Intensity for Dirty/Clean
$LiOH \cdot H_2O$			9
$NaOH$			2
$NiSO_4 \cdot 6H_2O$			5
$MnSO_4 \cdot H_2O$			3
$CoSO_4 \cdot 7H_2O$			4
Graphite			6

Data From:

MINVIRO

Battery supply chains: it starts with the mines

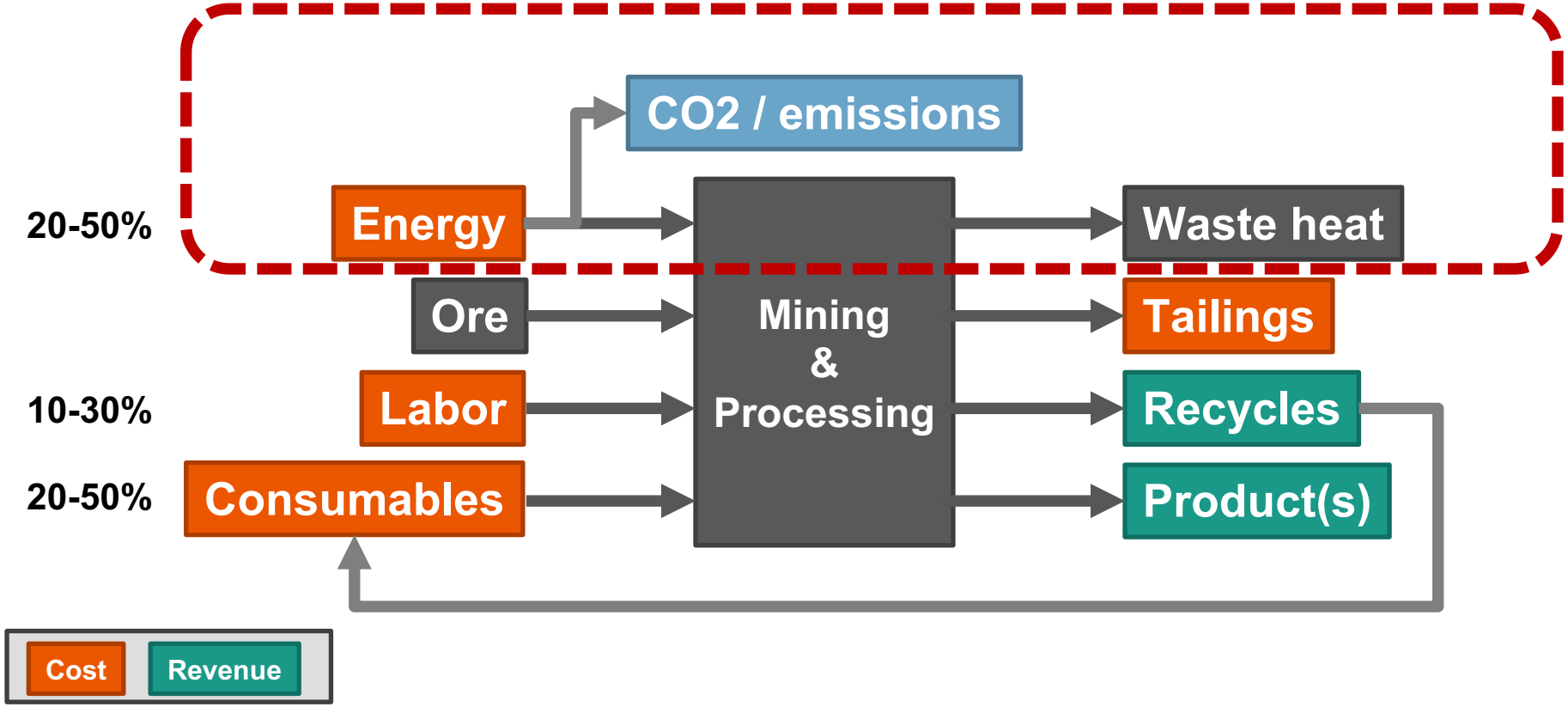
- **Define sustainable:** low footprint, profitable + human factor
- **Measure what matters:** energy/carbon, water, reagents, land, transport ++
- **Work from first principles:** from the ground up and cascade downstream
- ***Start from the beginning:*** the mine



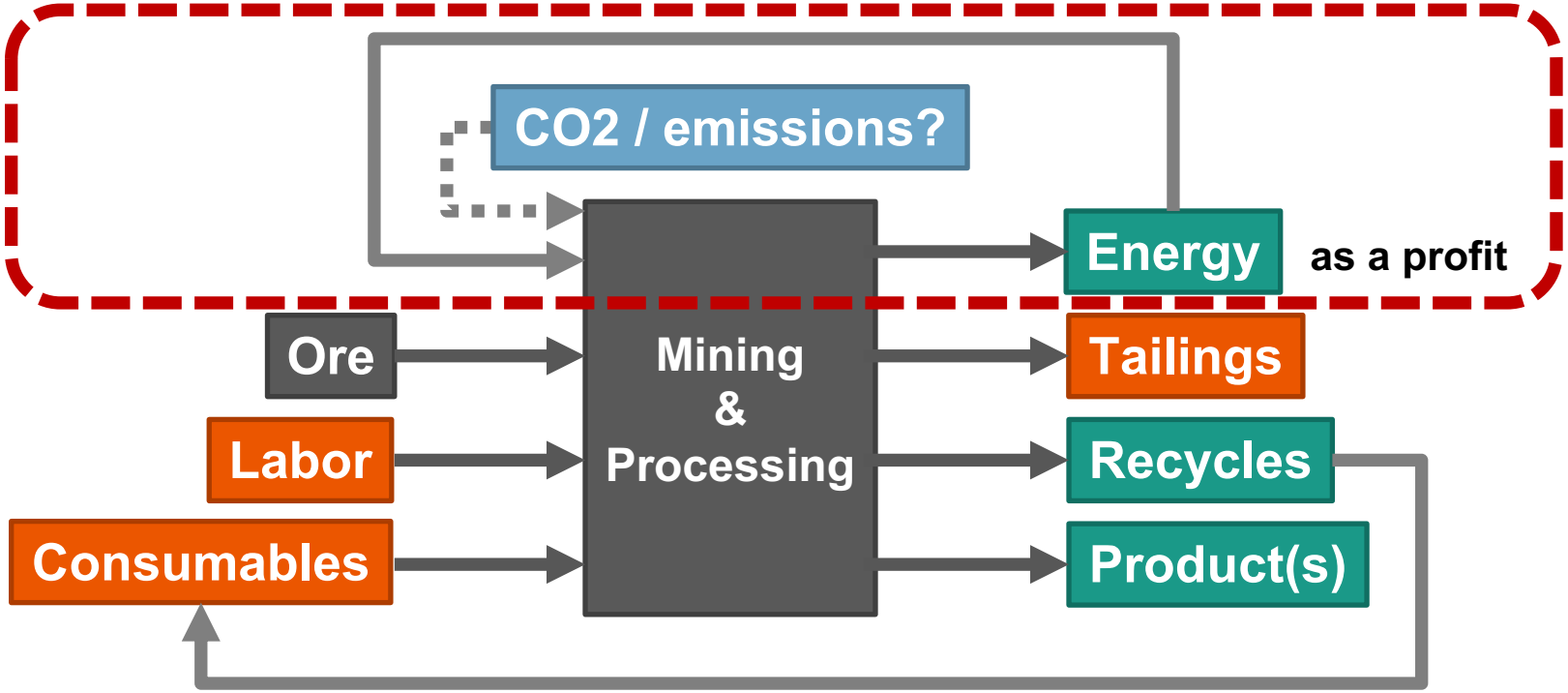
Guiding principle of mining & processing:

Principle	Example
Mass is **finite**	*Inputs:* Ore, reagents, water *Outputs:* tailings, emissions
Energy is **abundant**	*Past:* hydrocarbons *Future:* geothermal, hydro, nuclear, wind+solar+storage
Cost is king	Innovate to lower footprint, higher efficiency, lowest-cost source of energy • ***Eliminate the cost of hydrocarbons?*** • ***Energy as a source of profit instead of cost?***

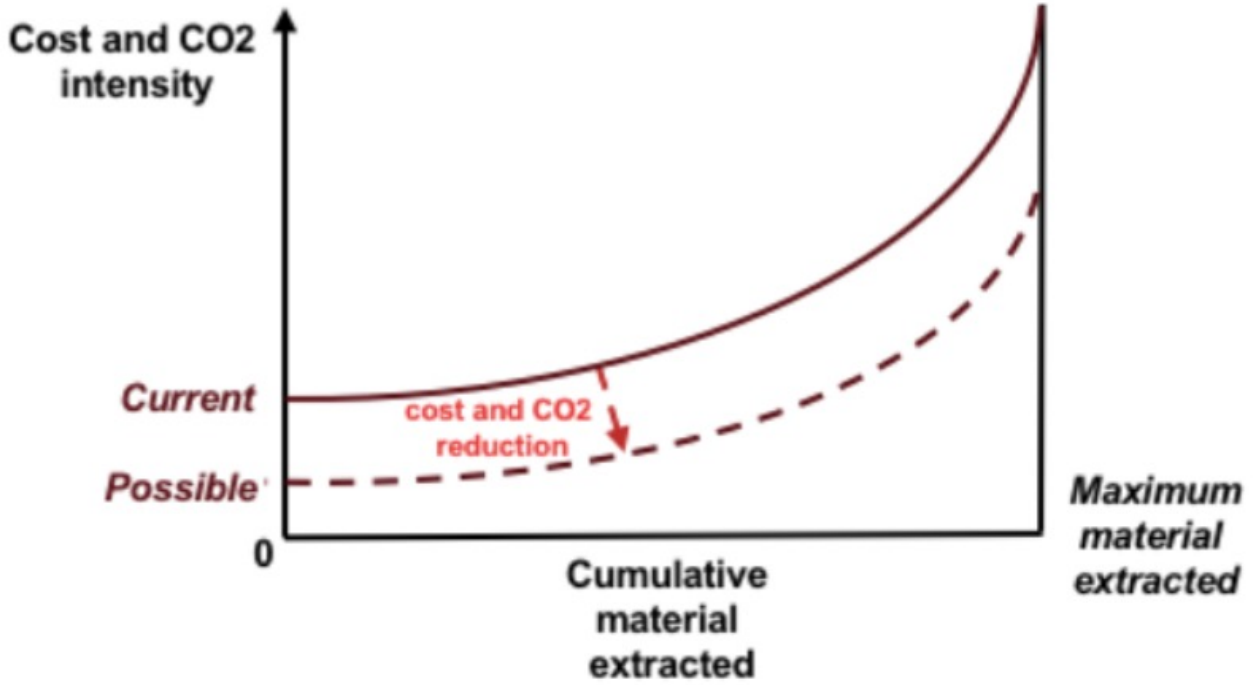
Production of materials today: *energy is a cost!*



Production of materials tomorrow: *energy source?*

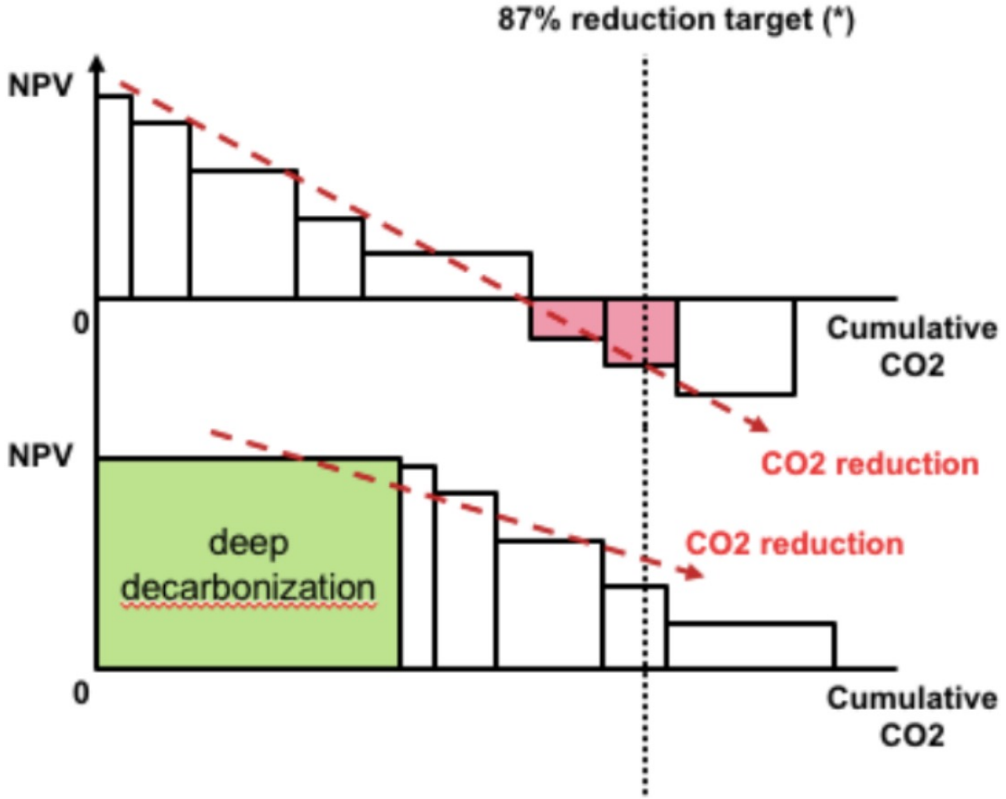


Profitable decarbonization: *eliminating fuel costs*



Profitable decarbonization: *energy as a profit?*

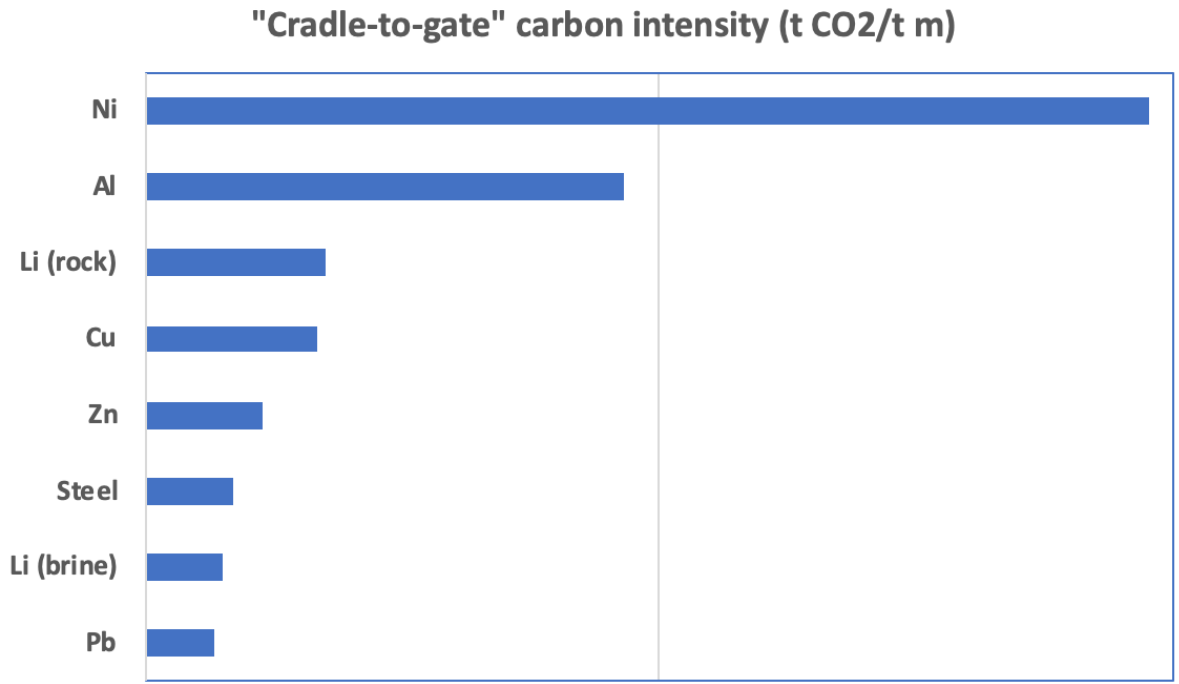
- Invest upfront, stay NPV positive
- Pursue ”low-tech” energy harvesting, generation
- No one-size-fits-all



What are the opportunities?

Commercially viable & ready solutions *today*

Target the high-carbon-footprint materials



- Al: Alcoa-Rio Tinto JV in QC
- Ni: significant opportunity
- Li: strong case for brines, CO2-consuming / sequestering

* Co: follows Ni and Cu

Source: Marbex (2019).

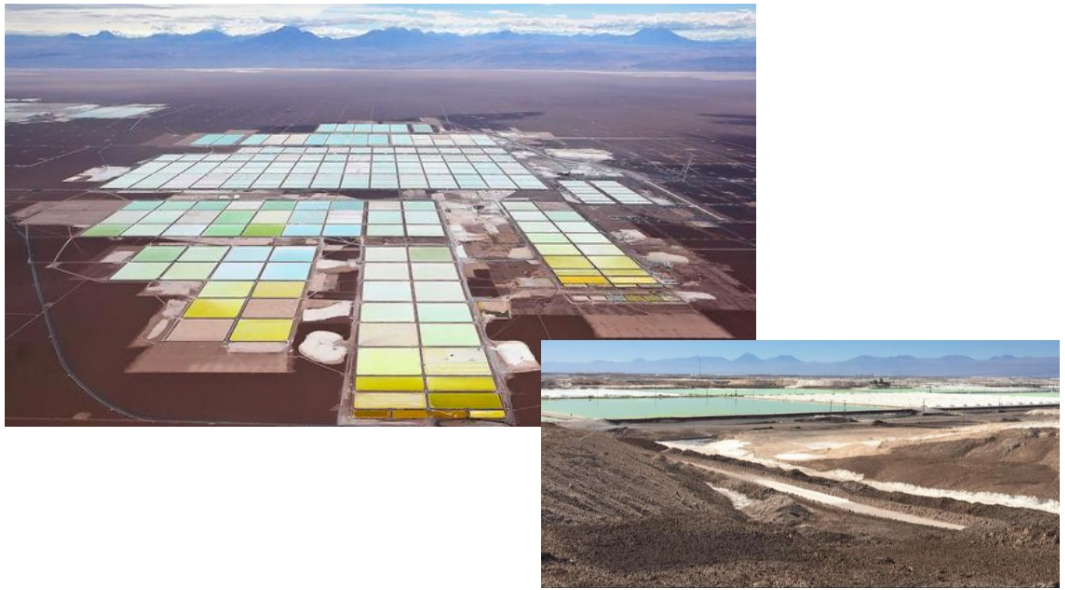
What are the opportunities?

The lithium example

Lithium Sources

Commercial lithium operations: today

Brine ponds – SQM, Chile

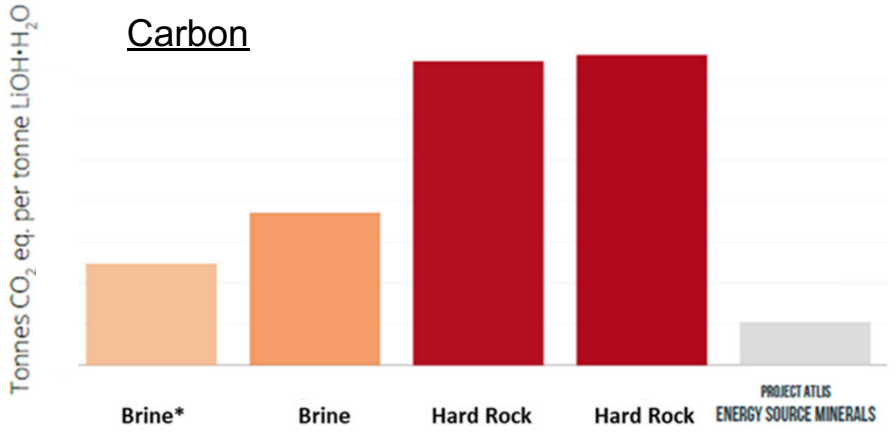


Spodumene mine – Greenbushes, Australia

Source: Vivas Kumar, Benchmark Minerals Intelligence / Stanford MBA Candidate (2020)

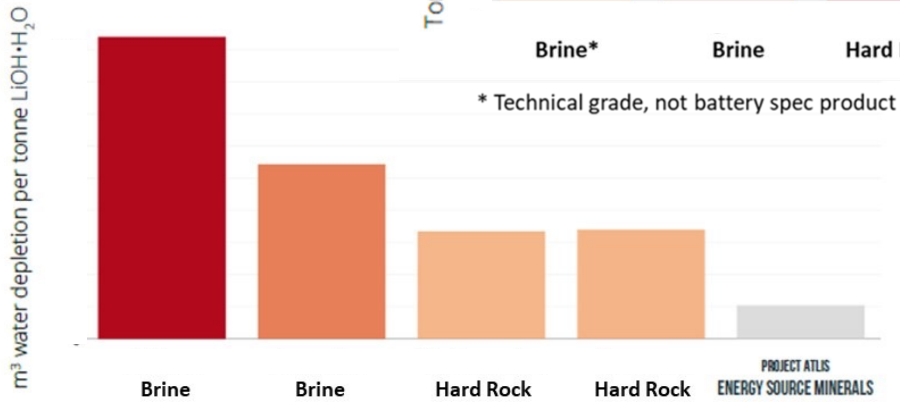
Life-Cycle Analysis

Carbon

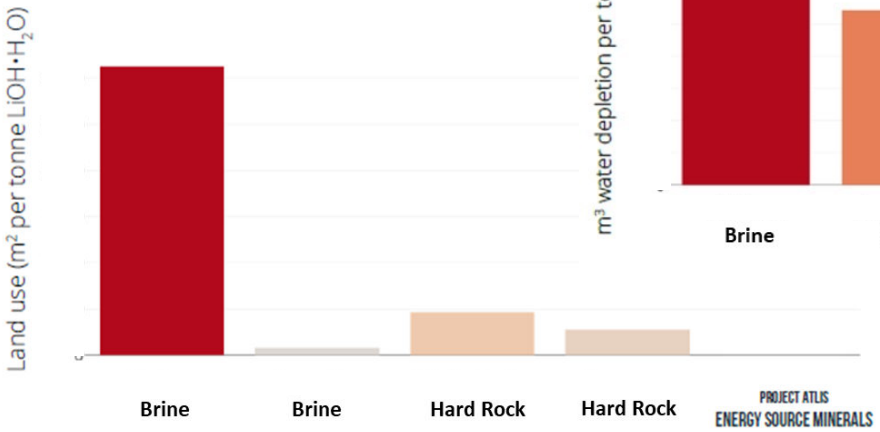


* Technical grade, not battery spec product

Water



Land



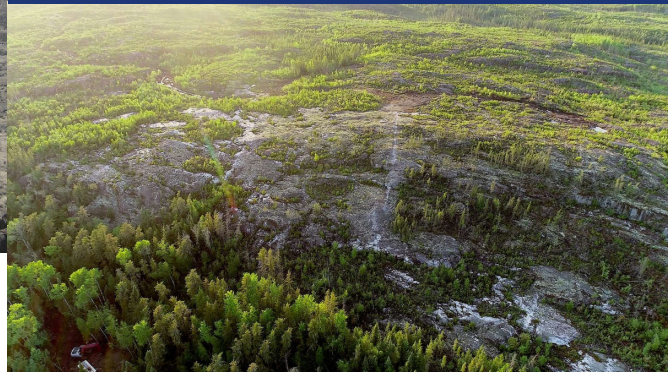
Source: Minviro Ltd (UK) / ES Minerals LLC (2019)

Commercial lithium operations: tomorrow

Geothermal brine - California

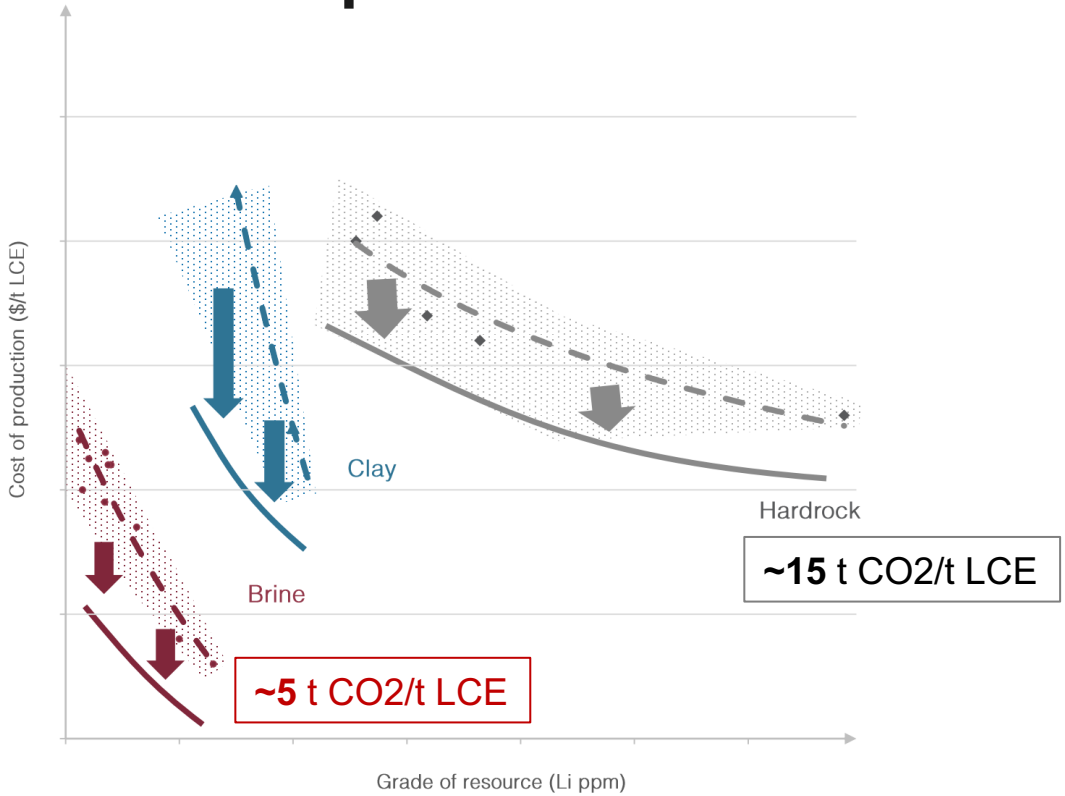
Sediments - Nevada

High grade rock - Ontario



Source: ES Minerals LLC, Lithium Americas Corp. (2019)

Lithium production costs fall with carbon footprint



Example innovations to lower cost and lower carbon footprint:

- **Hardrock:** Hydropower + high-grade ore + CO2-as-a-reagent
- **Brines:** geothermal integration
- **Clays:** on-site acid production w/energy co-production

Source: D.Deak (2016-2018)

Innovating to lowest-cost and footprint

- Ultimate goal: “cradle to cradle” circular economics
  - Step 1: Establish a baseline through M&E B, FM + **LCAs**
  - Step 2: Design for harvested energy, zero-fossil fuels
  - Step 3: Vertically integrate
  - Step 4: Material, reagents, and water are recycled
  - *Consider: carbon sink incentives*

Case study: A zero-emission, low-footprint mine-to-Gigafactory ecosystem in Ontario?

Three ingredient…