

BERC Energy and Resources 101

Strategic Minerals for Clean Technologies

Sep 11, 2020

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Resourceful Paths



Outline

- Mining and strategic minerals
- Strategic minerals, sustainability and demand shifts
- Strategic minerals for EVs – Li, Ni, Co, graphite
- Sustainability metrics and ESG
- Conclusions

Big Picture on Mining and Metals

- Major mining companies focus on bulk commodities, base metals
 - Steelmaking ingredients (iron ore, metallurgical coal, nickel, manganese)
 - Bauxite and alumina (for making aluminum)
 - Copper
- Smelting and refining mostly in China from ores/intermediates
 - Steelmaking; copper, zinc, lead, nickel smelting; alumina refining, aluminum smelting
- Strategic minerals often smaller markets, companies, geographically limited

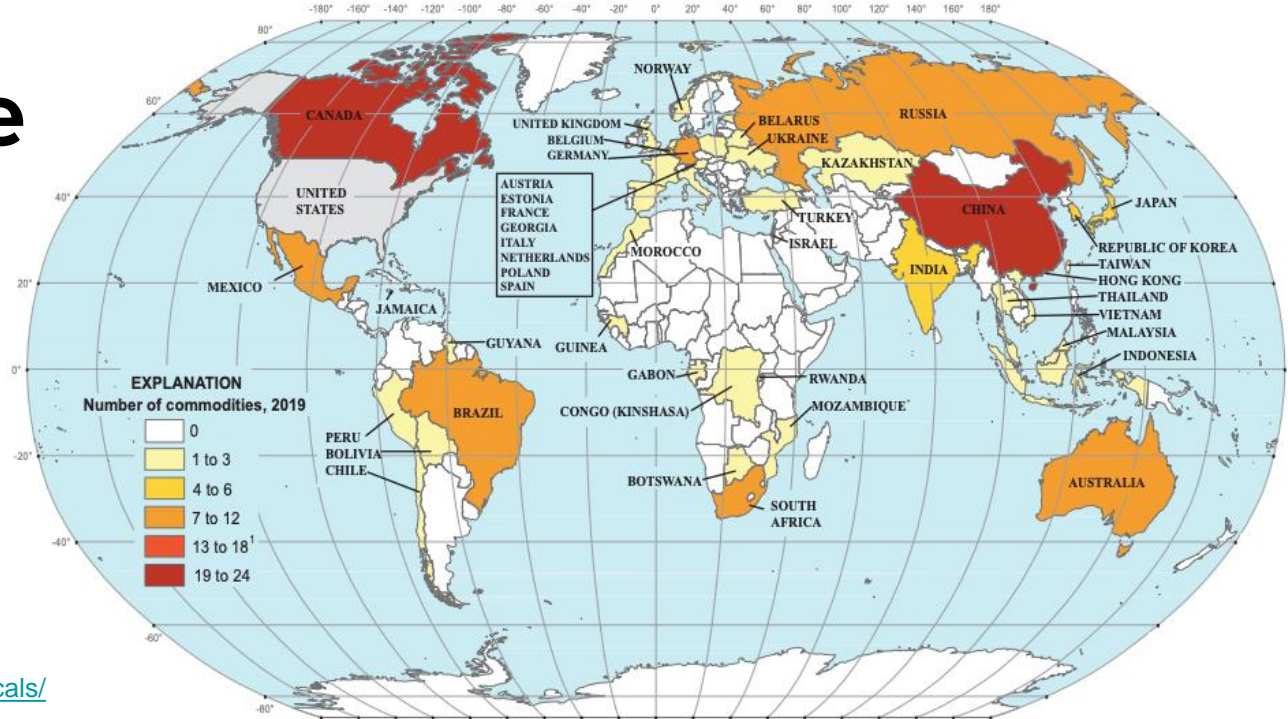
The BHP logo features the letters 'BHP' in a bold, orange, sans-serif font, set against a white rectangular background.The RioTinto logo consists of the words 'RioTinto' in a white, sans-serif font, centered within a solid red rectangular background.The Glencore logo displays the word 'GLENCORE' in a black, serif font, with a distinctive underline on the letter 'E', all set within a white rectangular background.

What are Strategic/Critical Minerals?

- Various lists of minerals/metals: US, EU, Japan, S Korea
 - Strategic importance – needed for sustainable futures, technology applications, military uses
 - Geopolitical considerations between USA and China (e.g. REEs)
 - Resource security/self-sufficiency drivers in Europe, Japan, S Korea
- Sustainability aspects include
 - Responsible/ethical supply (e.g. no child labor, conflict-free, environmental controls)
 - Ingredients for low carbon economy, as well as low GHG intensity of production

US Import Reliance

**MAJOR IMPORT SOURCES OF NONFUEL MINERAL COMMODITIES
FOR WHICH THE UNITED STATES WAS GREATER THAN 50% NET IMPORT RELIANT IN 2019**



USGS 2019,
<https://pubs.usgs.gov/periodicals/mcs2020/mcs2020.pdf>

Strategic Minerals Groupings

- Specialty steelmaking ingredients – advances steels, lower GHG in use
 - Alloy components – Cr, Mn, Mo, Nb, Ni, V
- Sustainable technologies – EVs, renewable energy
 - Battery ingredients – Li, Ni, Mn, Co, graphite
 - Renewable power – REE (wind), Ga, Ge, In, Te (solar)
- Military – high strength materials, aerospace, instrumentation
 - Nb, V, Co, Ge, REEs

What are Strategic Minerals/Metals?

Mineral/Metal	Country				Refining capacity	
	USA	EU	Japan	South Korea	USA	Canada
Chromium	✓		✓	✓		
Cobalt	✓	✓	✓	✓		✓
Copper			✓		✓	✓
Gallium	✓	✓	✓	✓		
Germanium	✓	✓				✓
Graphite	✓	✓	✓			
Indium	✓	✓	✓	✓		✓
Lithium	✓	✓	✓	✓		
Manganese	✓		✓	✓		
Molybdenum			✓	✓	✓	
Nickel			✓	✓		✓
Niobium	✓	✓	✓	✓		✓
PGEs	✓	✓	✓	✓	✓	✓
Rare earth elements	✓	✓	✓			
Tantalum	✓	✓	✓			
Tellurium	✓			✓		✓
Vanadium	✓	✓	✓	✓		

Metals marked in orange: byproducts produced in refining other primary metal ores/concentrates

Where is the refining?

Byproducts

Strategic metal	Primary metals
Cobalt	Copper, nickel
Gallium	Zinc, aluminium
Germanium	Zinc
Indium	Zinc
PGEs	Nickel
Tellurium	Copper

Strategic Minerals Groupings

Mineral/Metal	Sustainability			Tech	Military
	EVs	Renewable power	Advanced steels		
Chromium			✓		✓
Cobalt	✓	✓		✓	✓
Copper	✓	✓		✓	
Gallium		✓			✓
Germanium		✓		✓	✓
Graphite	✓				
Indium		✓		✓	
Lithium	✓	✓		✓	
Manganese	✓		✓		✓
Molybdenum			✓		✓
Nickel	✓	✓	✓		✓
Niobium			✓		✓
PGEs		✓			
Rare Earth Elements	✓	✓			✓
Tantalum				✓	✓
Tellurium		✓			
Vanadium		✓	✓		✓

Batteries for EVs



Solar panels



Wind turbine generators



Commodity Shifts for Sustainability

		Metal or mineral	Reason for growth potential
Potential winners		Lithium	Battery ingredients, esp. for electric vehicles. Relative demand for cathode metals (Mn, Ni, Co) will depend on preferred battery chemistry. Nickel Manganese Cobalt (NMC) has been preferred cathode type recently but trend has been to reduce Co ratio in NMC batteries. Other alternatives like Nickel Cobalt Aluminum (NCA) and Lithium Iron Phosphate (LFP) also being pursued.
		Graphite	
		Manganese	
		Nickel	
		Cobalt	
		Niobium	
		Vanadium	Steel strengthening ingredient, reduce steel weight for given function. Future battery applications.
		Copper	Increased intensity for electric vehicles and renewable power installations.
		Uranium	Nuclear power plant fuel – particularly growth in China and India, but uncertainty on nuclear power risks post Fukushima.
		Rare Earth Elements	Renewable electricity - magnets for wind turbines. EV drive trains.
		High quality iron ores	Those compatible with future low-emissions steelmaking (e.g. hydrogen fired direct reduction shaft furnace).
Potential losers		Metal or mineral	Reason for potential demand reduction
		Thermal coal	Carbon pricing, emissions reduction mandates, e.g. Europe; cancellation/curtailment of coal power plant expansions in Asia.
		Metallurgical coal	Potential steelmaking technology developments allowing substitution with hydrogen/natural gas. Recycling, dematerialization.
		Low quality iron ores	Poorer quality iron ores require carbon intensive processing via traditional sinter-plant-blast furnace-BOF steelmaking route.
		Platinum Group Metals	Drop in catalyst demand from ICE vehicles may exceed growth in demand for fuel cells
		Lead	Eventual substitution of internal-combustion engine automobile battery applications with Li-based EV batteries.

Reducing Steel GHG Emissions

- Steel by far the most important metal and highest GHGs
- Reduced GHG intensity of steel production
 - Recycled steel (EAF technology) instead of from iron ores (blast furnace-BOF - primary)
 - Substitution of metallurgical coal with natural gas or hydrogen in primary steelmaking
- Dematerialization
 - Smaller weights of advanced steels – improved steel properties from alloying
 - Cr, Mn, Mo, Nb, Ni, V  Strategic/Critical Minerals
 - High Strength Low Alloy (HSLA), Stainless steels

Copper

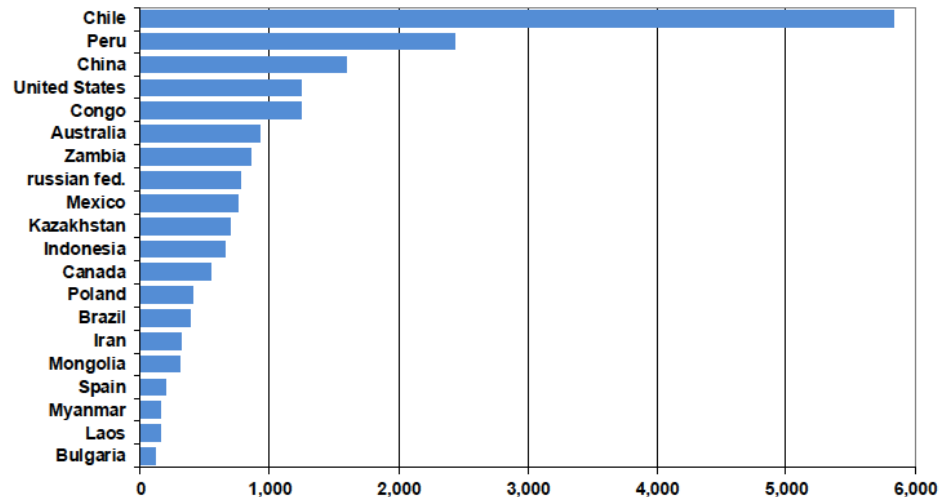
- Most important metal after steel
- Underpins clean technology - electrical uses
- Two main deposit sources
 - Oxide deposits – sulfuric acid leaching, solvent extraction, electrowinning to make Cu cathode
 - Sulfide deposits – crushing, grinding, flotation, smelting, electrorefining to make Cu cathode
- High capital cost to bring new mines into production – falling ore grades leading to larger and larger scale projects
- Water and tailings management are the main environmental challenges



Copper Mine Supply

The World Copper Factbook 2019

Copper Mine Production by Country: Top 20 Countries in 2018
 (Thousand metric tonnes copper)
 Source: ICSG



South America dominates – mostly copper in sulfide concentrates (~25% Cu)

Chile accounted for almost a third of world copper mine production in 2018 with mine output of 5.8 million tonnes copper. Peru, which has seen a sharp increase in output since 2015, accounted for 12% of world mine production.

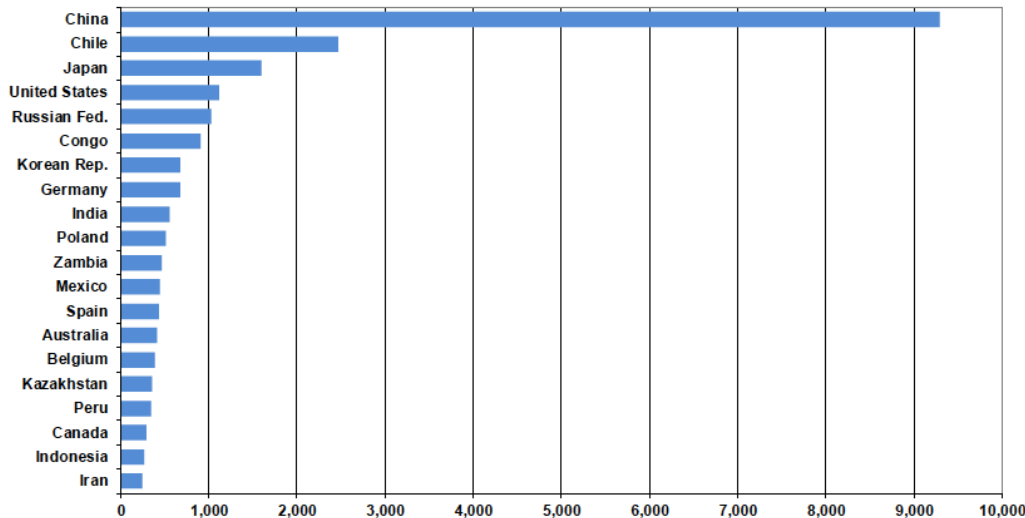
Refined Copper Production

The World Copper Factbook 2019

Refined Copper Production by Country: Top 20 Countries in 2018

Thousand metric tonnes copper

Source: ICSG



In 2018, China accounted for 39% of world copper refined production, followed by Chile (10%), Japan (7%) and the United States (5%).

China dominates because it has by far the largest copper smelting capacity, treating copper sulfide concentrates imported from Chile and Peru

Most refined copper production from Chile and USA from Leach-SXEW processing of oxide ores

Rare Earth Elements

HEAVY Rare Earth Elements
LIGHT Rare Earth Elements
by Geology.com

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La-Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac-Lr	Rf	Db	Sg	Bh	Hs	Mt									
Lanthanides																	
		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
Actinides																	
		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

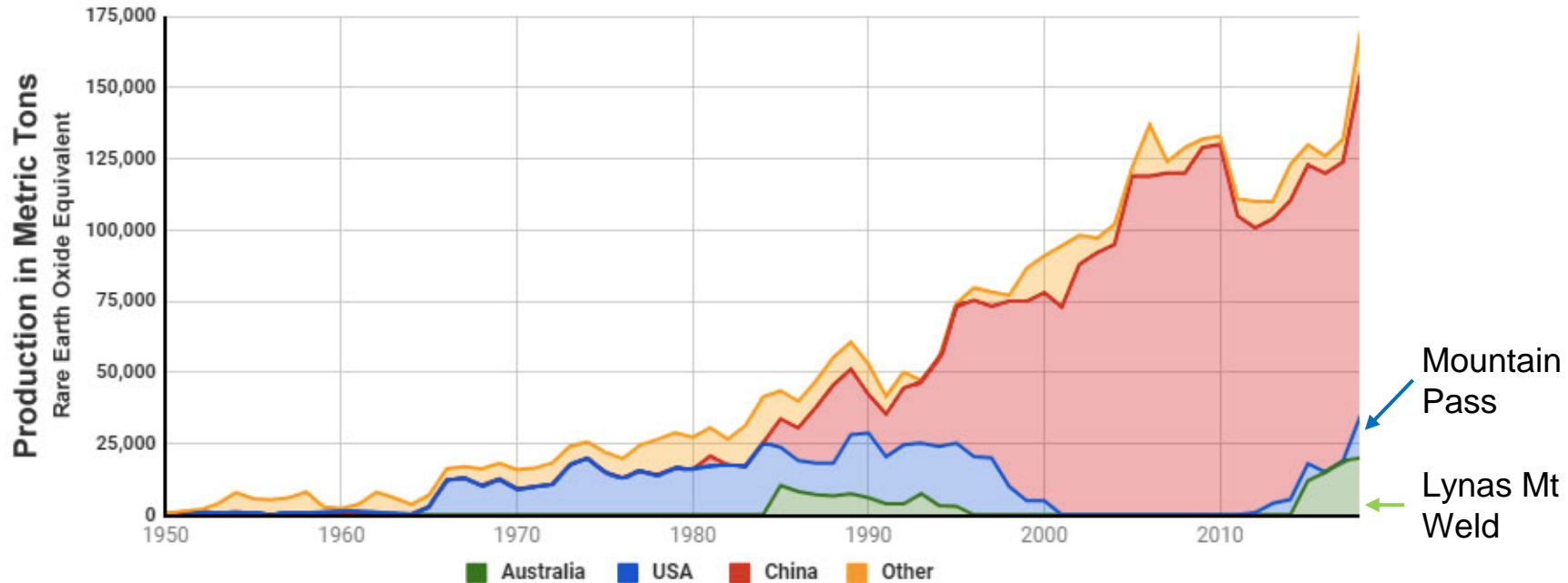
Group of many chemically similar elements with wide range of strategic uses

Complex chemistry for refining and separating individual rare earth oxides

US interest is mainly due to resource security for military uses

Neodymium, Dysprosium and Samarium are of main interest for magnets used in wind power and EV drive trains

Rare Earth Elements Mine Production



Bayan Obo World's Biggest REE Mine



Mining since 1927

REE produced as a by-product of Fe and Nb mining

Major environmental challenges – tailings management, water quality, radioactivity

https://file.ejAtlas.org/img/Conflict/5130/Bayan_Obo_mining_area_own_map.png

REE outside China – Lynas Corporation



Mt Weld mine in
Western Australia

LAMP refining plant
Malaysia

COMMODITIES APRIL 22, 2020 / 12:19 AM / UPDATED 5 MONTHS AGO



Australia's Lynas wins funding for U.S. heavy rare earths facility

By Reuters Staff

2 MIN READ



(Reuters) - Lynas Corp said on Wednesday the U.S. military will give it initial funding for a heavy rare earths separation facility in Texas as part of Washington's push to secure domestic supply of the essential minerals that China currently dominates.

Malaysia tells Lynas to remove rare earths radioactive waste

Decision follows an expert review of the east coast facility's operations. It has until September to remove the waste.

4 Dec 2018



Strategic Minerals for Solar Power

Base metal	Lead and Zinc	Copper	Nickel
Major economic companions (revenue paid to mine)		Gold	Platinum group
		Silver	
			Cobalt
		Molybdenum	Copper
Minor economic companions (generally not paid to mine, revenue to refinery)		Uranium	
	Copper	Zinc	Silver
	Gold	Lead	Gold
	Germanium	Selenium	
	Indium	Tellurium	
	Bismuth		
	Antimony		
Cadmium			
Deleterious (mine penalized)	Arsenic		
	Mercury		

Solar panel types

- CdTe thin film
- CIGS – copper indium gallium selenide
- GaAs – with germanium wafer

Ingredients are byproducts recovered in refining – supply is inelastic

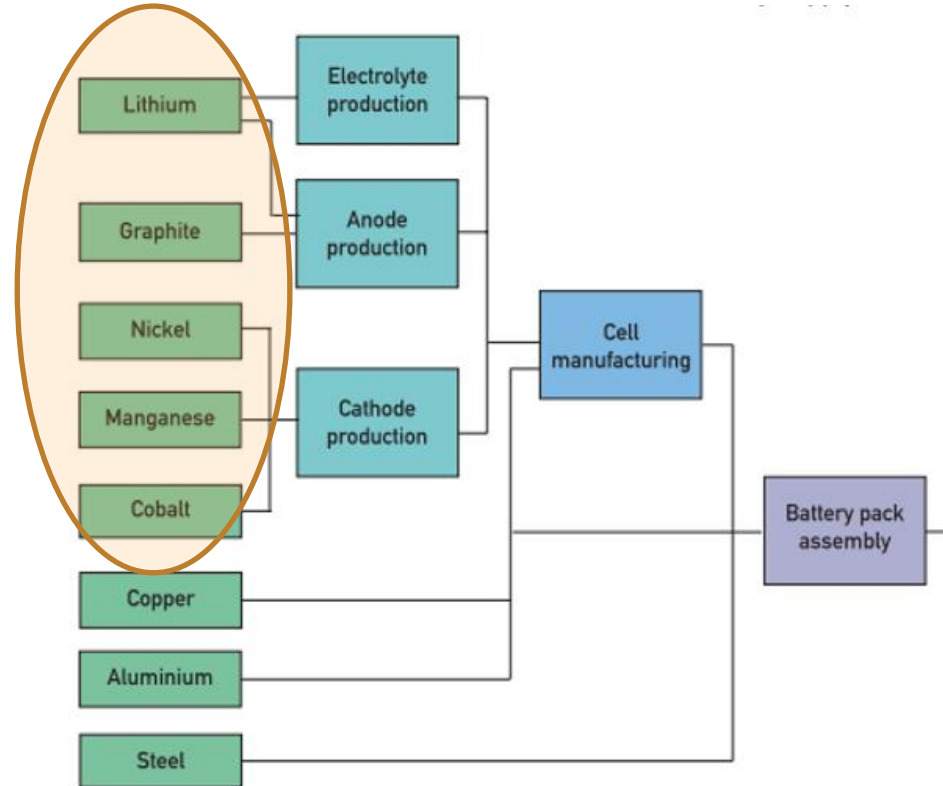
Refining of Cu, Pb and Zn dominated by China

Strategic Minerals for EVs

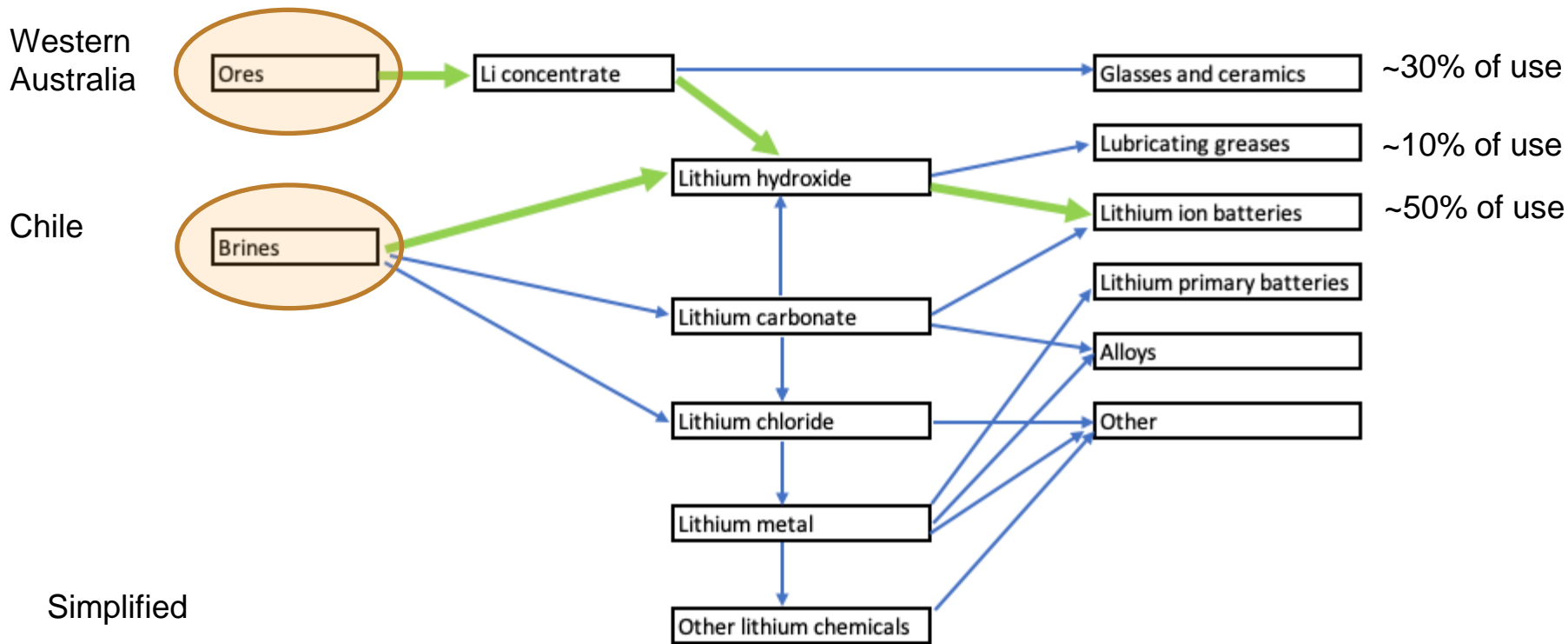


Battery Ingredients for EV

- Li-ion batteries dominant
 - Different cathode chemistries, currently NMC is favored
 - Substitution shifts – e.g. changing NMC ratio for less Co 622 to 811 and switch to new cathode chemistries, e.g. LFP
 - Lithium and graphite are key anode materials



Lithium Product Forms



Simplified

World's Largest Lithium Mine

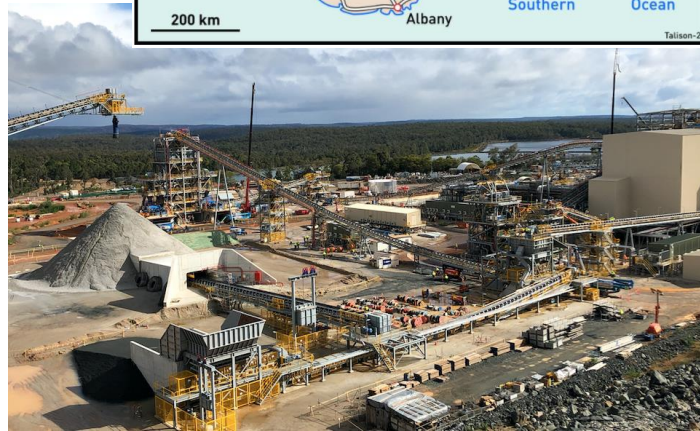


Talison Greenbushes Mine
(Tianqi – Albemarle JV)
located near Perth,
Western Australia

Pegmatite rock
with spodumene –
Li mineral



Crushing, grinding,
separation plant making
Li concentrate



Lithium Converters

- Spodumene concentrates roasted in large kilns and leached to produce lithium hydroxide and sodium sulfate byproduct
- Major new plants currently and recently built in Western Australia
- Very strong long-term growth potential for lithium ion-battery ingredients. Timing doesn't always work out



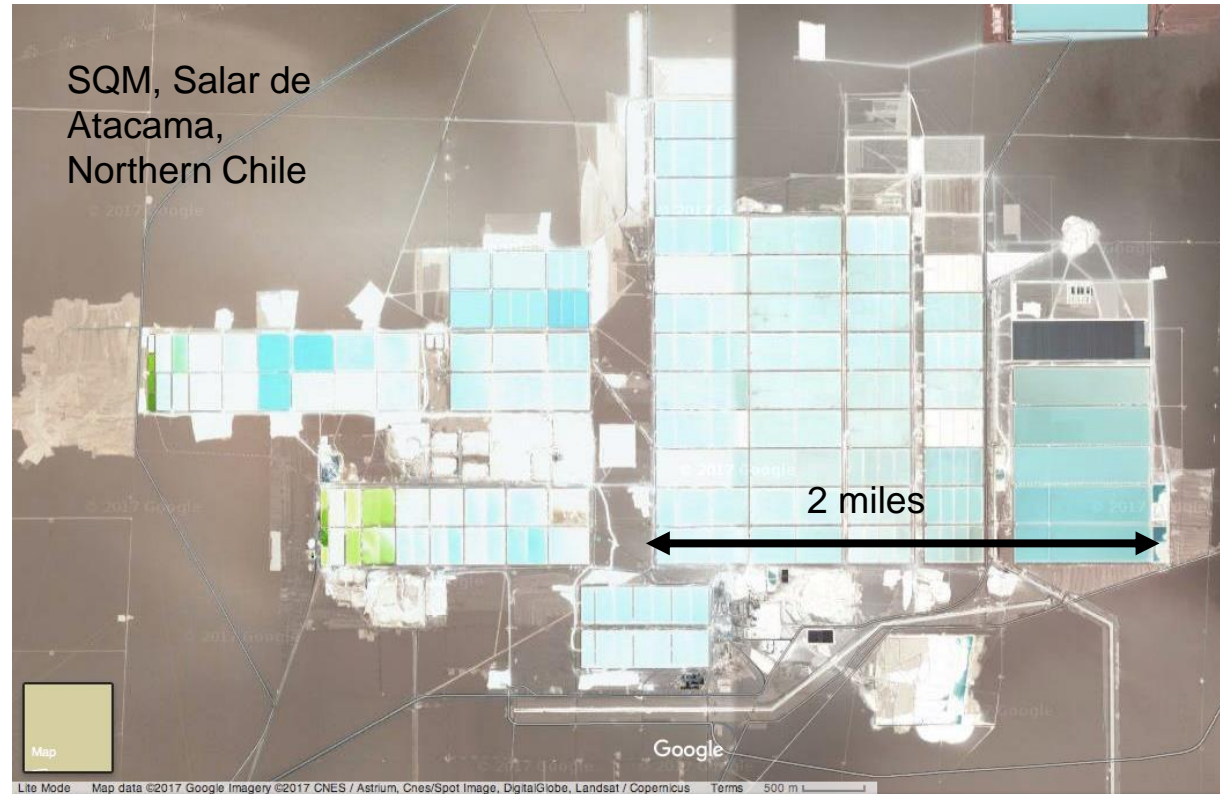
BASIC MATERIALS MARCH 22, 2020 / 8:00 AM / UPDATED 6 MONTHS AGO



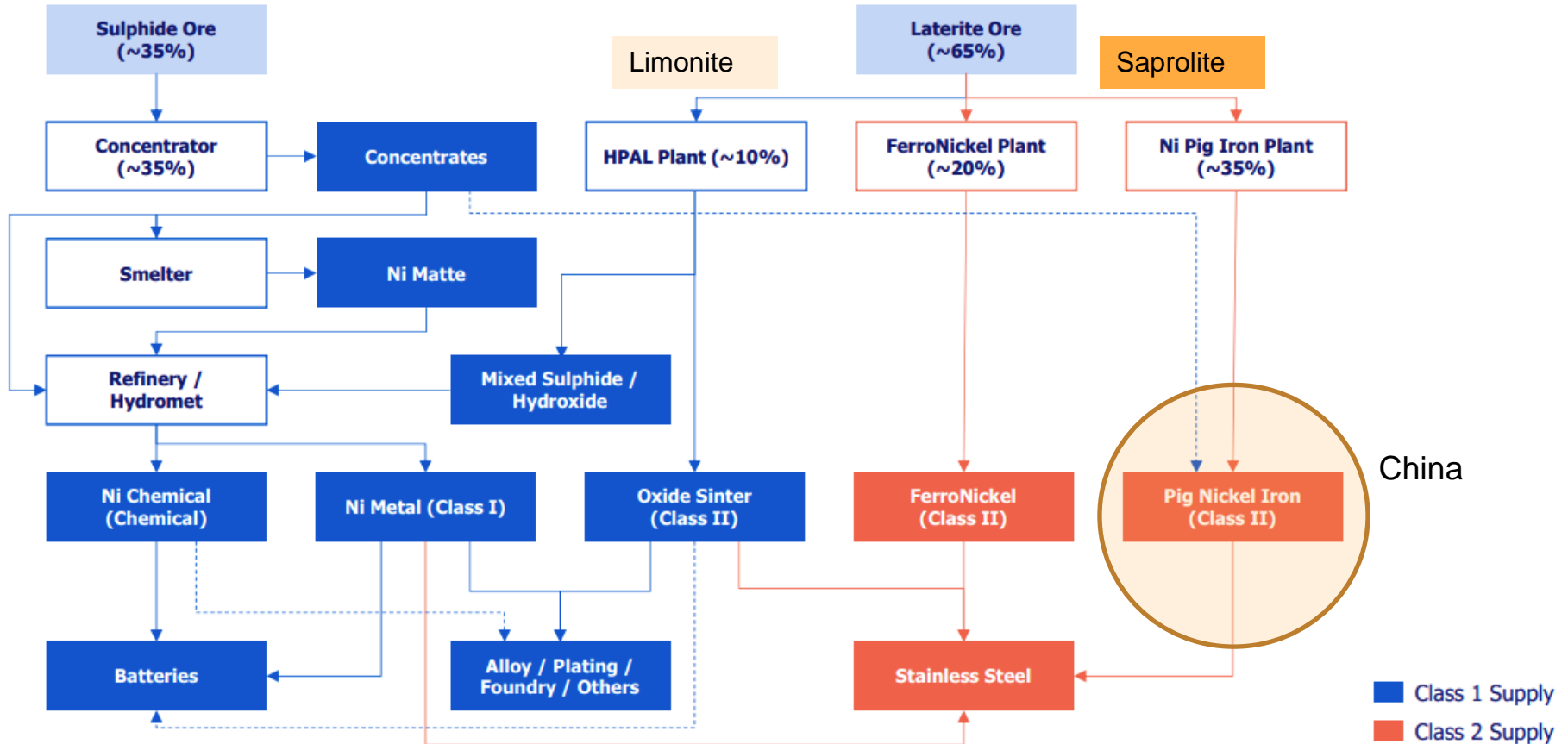
China's Tianqi postpones commissioning of Australia lithium plant amid liquidity problems

Lithium Brines

Salars of Northern Chile and Argentina
 SQM, Albemarle,
 FCM, Orocobre
 Large evaporation ponds, recover Li salts with potential potash (KCl) by-product



Nickel Supply Chain



Sulfide Producers

- Integrated producers, often making Cu, PGM and Co byproducts
 - Nor Nickel – Russia
 - Vale – Canada
 - Glencore – Canada and Norway
 - BHP Nickel West – Western Australia
- Concentrate producers selling to Chinese smelters



Example: BHP Nickel West

- Integrated complex
 - Several sulfide mines
 - Nickel smelter producing Ni matte and sulfuric acid
 - Nickel refinery making pure Ni powders

- New nickel sulfate plant to produce feed for Li-ion battery market



Laterite Leaching Plants

- Large, complex, high capital cost, controversial, fail to meet production goals

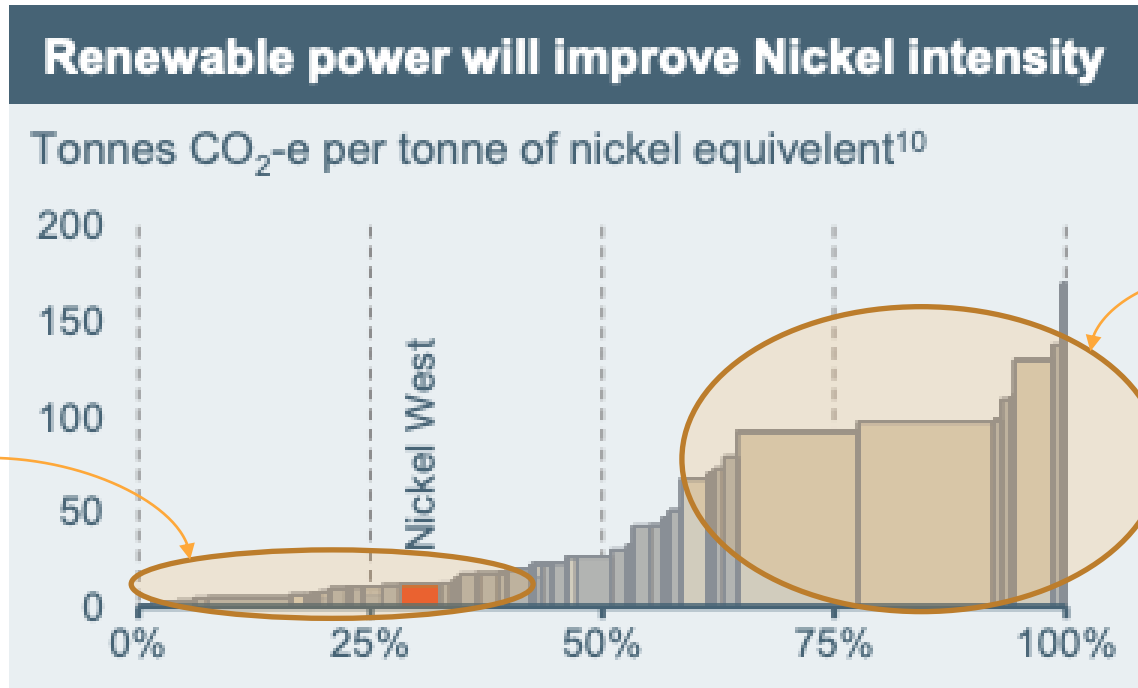


Ambatovy, Madagascar
34 kt Ni, 2.9 kt Co in 2019
Sherritt International wrote down \$5 B
then exited



Goro, New Caledonia
23.4 kt Ni, 1.7 kt Co in 2019 (< half capacity)
Vale wrote down \$ billions, sale for \$1 failed.
To be placed on care and maintenance.

GHG Intensity of Ni Metal Production



Ni pig iron – very high GHG intensity

Type of mineral resources and process route can dramatically affect emissions

Sulfide producers – ingredients for batteries for EVs – low GHG intensity

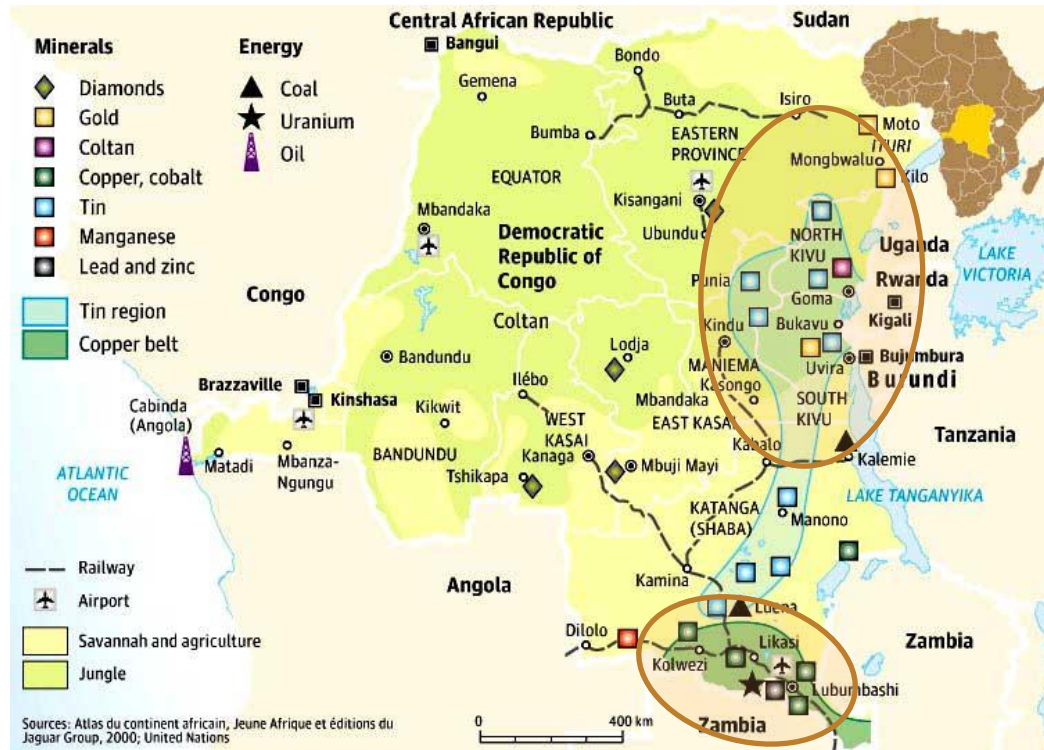
Cobalt – DRC is Largest Mine Producer

GLENCORE

Two major Cu-Co mines using leaching technology

Mutanda (care and maintenance)

Katanga (expanding)



Conflict zone

Cu-Co mining region

Glencore Cobalt Production

~ 1/3 of global supply = market power

	Cu Copper	Co Cobalt	Ni Nickel
Application	Batteries Solar Power Wind Power Mobility Electronics Grid	Batteries Wind Power Mobility Electronics Grid	Batteries Solar Power Wind Power Mobility Electronics Grid
Glencore production⁽¹⁾	1.37Mt	46kt	121kt
Global supply⁽²⁾	20.6Mt	140.5kt	2.45Mt

Glencore Cobalt Marketing

Responsible sourcing

18

Enabling the energy and mobility transition

- Cobalt is a key lithium-ion battery raw material, essential for the electric vehicle and mobile phone markets

Our cobalt hydroxide marketing strategy

- Long-term supply agreements with geographically diversified key players along the lithium-ion battery supply chain

Our commitment to responsible production:



- Our DRC cobalt operations will be independently audited each year against the “Cobalt Refinery Supply Chain Due Diligence Standard”.
- This standard is defined by the Responsible Mining Initiative (RMI)

Providing security of supply to our customers

- Long term availability of responsibly sourced cobalt from a reliable supplier for our customers

Cobalt strategic long-term contracts



29 May 2019

“Long-term revolving agreement for the supply of cobalt hydroxide to Umicore’s battery materials value chain”



7 October 2019

“A minimum of 61,200 tonnes of Cobalt between 2020 and 2024”



19 November 2019

“Up to c.30,000 tonnes of cobalt contained in hydroxide between 2020 and 2025. With this contract, SK Innovation can produce batteries for 3 million EVs”



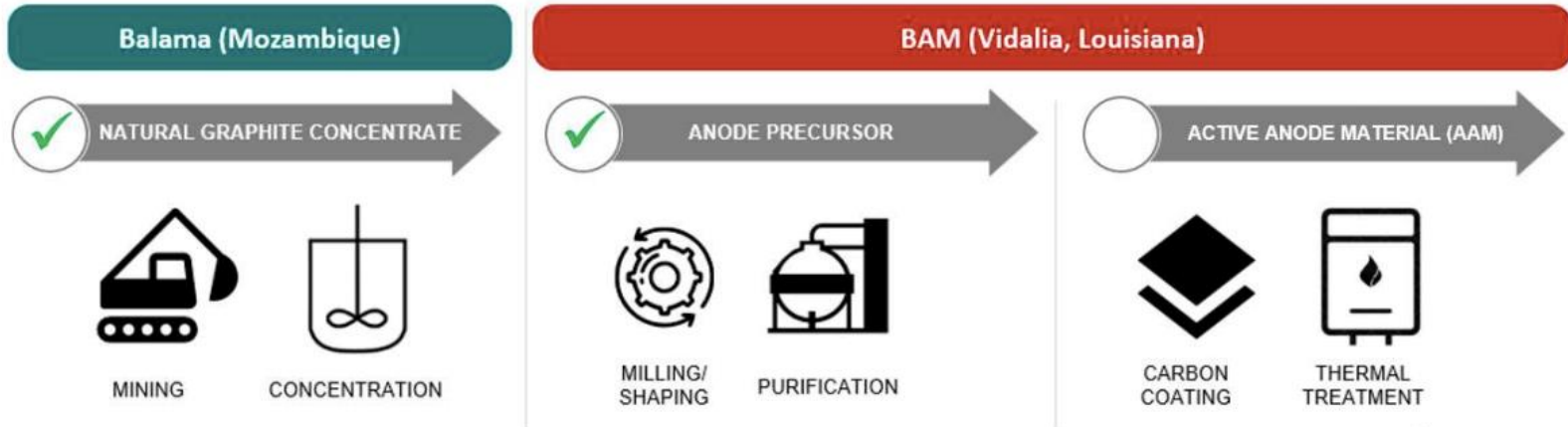
SAMSUNG SDI


10 February 2020

“Up to 21,000 tonnes of cobalt contained in cobalt hydroxide between 2020 and 2024”

<https://www.glencore.com/dam/jcr:b1255e80-aef0-4ea8-9e6d-294382a723ab/20200902-GLEN-Sustainability-in-Mining.pdf>

Graphite – Syrah Resources



 CVBAU RESOURCES

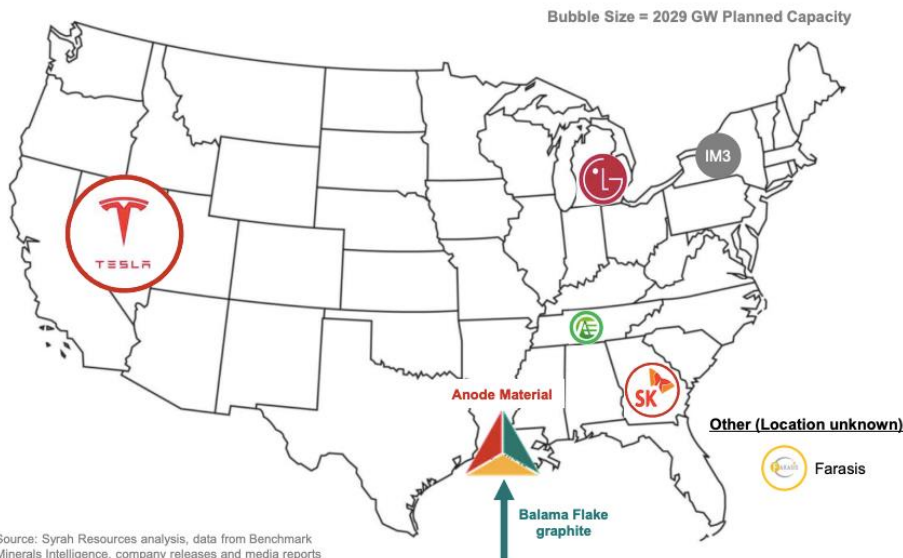
Balama Product Mix	Upper Size (US mesh)	Applications
Jumbo	+35	Industrial (e.g. steelmaking, iron casting, foundries, automotive parts, lubricants)
Large Flake	-50	Industrial (e.g. steelmaking, iron casting, foundries, automotive parts, lubricants)
Medium Flake	-80	Industrial (e.g. steelmaking, iron casting, foundries, automotive parts, lubricants)
Fines	-100	Spherical graphite for anode in Lithium-Ion batteries

Syrah Resources Graphite Strategy

Co-location with planned USA battery factories

Syrah plans to provide a co-located and ESG verifiable source of anode material supply to the USA battery supply chain

Planned 2029 GW Planned Capacity in USA



Benefits of co-location:

- ✓ Increased security of critical battery materials
- ✓ Security of supply from localised supply chain
- ✓ Optimisation of supply chain management
- ✓ Ease of co-development or partnerships with potential local partners (governments, other supply chain participants)

China currently dominates graphite supply and LIB precursor market

Supply Chains

- What part of the value chain?
 - Geological endowment is key if a country or region is to be self-sufficient
 - Metal use in manufacturing requires refining infrastructure
 - Sourcing raw materials from reliable trading partners may give resource security 
- Environmental, Social and Governances (ESG) expectations rising
 - Supply chain transparency – responsible sourcing initiatives including climate change, waste management and fair labor metrics

ESG and Mining

The Sydney Morning Herald

Rio Tinto CEO, top executives resign amid cave blast crisis

By [Nick Toscano](#) and [Hamish Hastie](#)

Updated September 11, 2020 – 9.55am, first published at 9.46am

Rio Tinto boss Jean-Sébastien Jacques and two senior executives will be replaced after an investor revolt forced the mining giant's board to escalate its response to the blasting of the ancient Juukan Gorge rock shelters.

ESG and Mining

ESG AUGUST 14, 2020 / 12:17 AM / UPDATED A MONTH AGO



BHP to steer mining lobby groups' climate change policies

MELBOURNE (Reuters) - BHP Group [BHP.AX](#) said on Friday it will closely monitor the work of industry associations to ensure they match its climate position on keeping the world's warming to less than 2 degrees Celsius.

The world's largest listed miner has faced increasing pressure from investors worried that some mineral lobby groups, particularly in Australia, are promoting coal in contravention of the goals of the Paris climate pact, and have urged BHP to stop funding them.

Key Takeaways

- Sustainability and resource security are major drivers in strategic mineral demand – both quantities, product forms and location of production
- Geological, geographical influences on markets but China dominates refining
- Sustainability metrics of production can vary dramatically – deposit characteristics, process technology and end use matter
- Rising power of ESG in setting sustainability standards in mining aligns with focus on supplying ingredients for clean technologies
- Significant opportunities for responsible supply to meet clean tech needs

Questions?

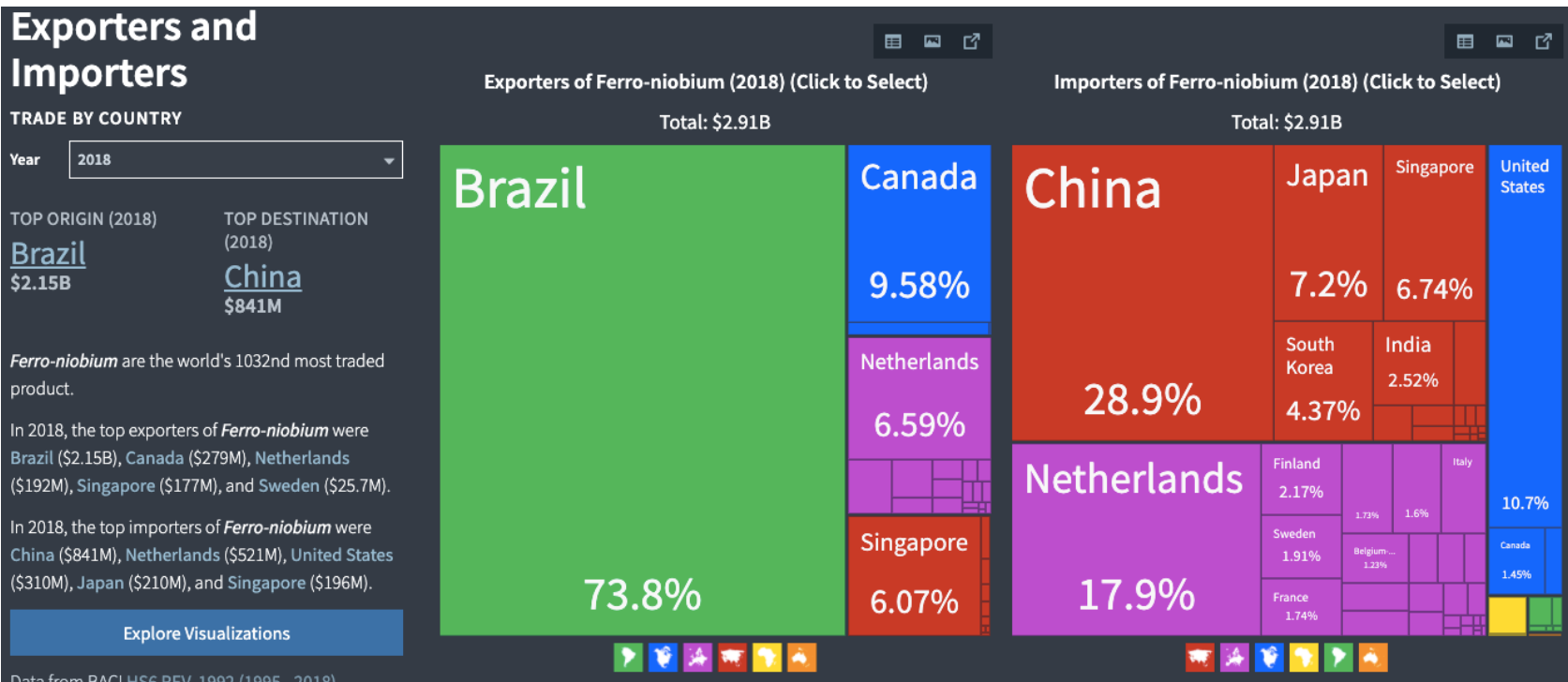
laurie@resourcefulpaths.com

Resourceful Paths



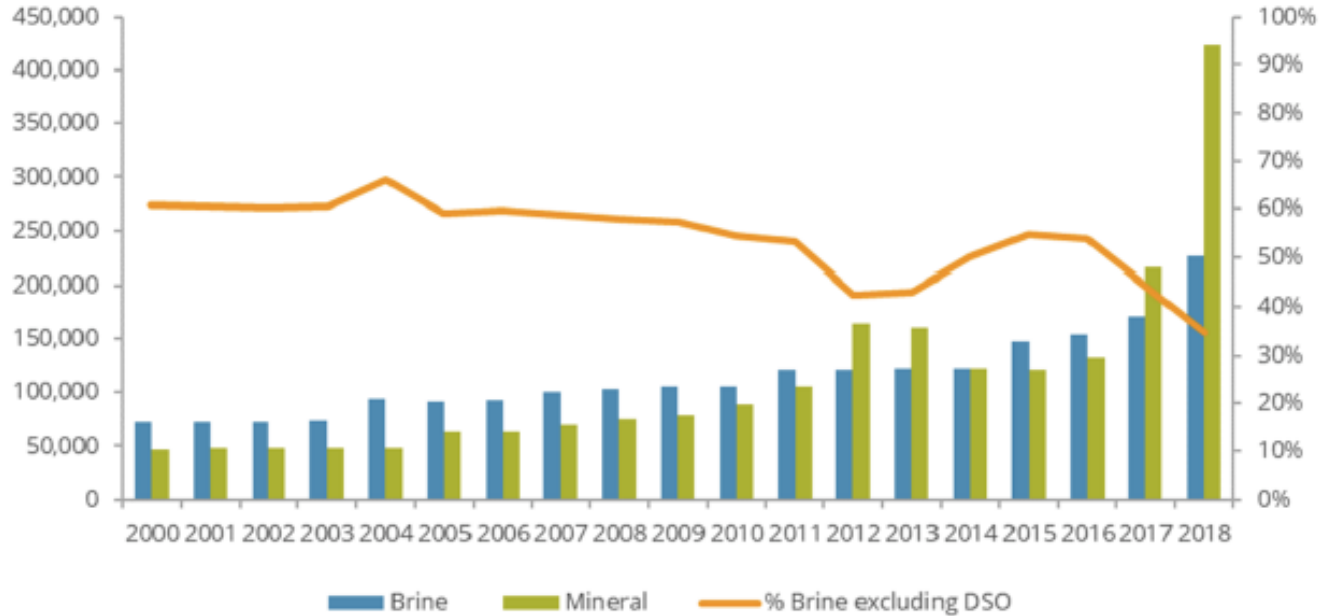
www.resourcefulpaths.com

Example Trade Data - Niobium



Lithium Supply

**Figure 19.1 – World Mine Capacity of Lithium by Type, 2000-2018
(tpy LCE and % Brine)**



Source: Roskill estimates