



# Critical Minerals Webinar Series

## Part 5: Sourcing critical minerals – processing and recycling

Malte Ebach

TESEP Regional Co-ordinator

Teacher  
Earth  
Science  
Education  
Programme Ltd



We wish to acknowledge the Traditional Owners of the land on which we meet today.

We also wish to pay our respects to Elders past, present and future.

Teacher  
Earth  
Science  
Education  
Programme Ltd



## PARTNERS

### PLATINUM

- Sydney Mineral Exploration Discussion Group (SMEDG)



AUSTRALIAN  
INSTITUTE OF  
GEOSCIENTISTS  
Supporting Geoscientists

### GOLD

- Australian Institute of Geoscientists



### SILVER PLUS

- South 32
- Minerals Council of Australia (Vic. Div.)
- Evolution Mining Limited



### SILVER

- Yancoal
- AIC Mines
- Australian Society of Exploration Geophysicists

### In-kind support

- AusGeol.org – Virtual Library of Australia's Geology
- Australian Geoscience Council
- Australian Museum
- Australian National University – RSES
- Australian Rare Earths Ltd
- Bureau of Meteorology
- Federation University Australia
- Geological Society of Australia
- Geological Survey of New South Wales
- Macquarie University
- Monash University
- OzMinerals
- Pyrenees Quarries
- Quantum Victoria College
- Rob Kirk Consultants
- Scienceworks
- Victorian Space Science Education Centre

### BRONZE

- Aeris Resources
- ATCO Australia
- Atmos Renewables: Cherry Tree Windfarm
- Australian Rare Earths Ltd
- Energy Australia
- iTech minerals
- Geological Society of South Australia
- VHM Limited (Melbourne)
- Geological Survey of Australia (VIC)
- VHM Limited



## SPONSORS OF ROCK KITS TO SCHOOLS & SCHOOL VISITS

### SILVER PLUS

- BHP Olympic Dam
- South 32

---

### BRONZE

- Aeris Resources Ltd
- Alkane Resources Ltd
- Astron Corporation (Donald Mineral Sands)
- Atmos Renewables (Cherry Tree Windfarm)
- Aurelia Metals Ltd (Peak Gold Mines)
- Australian Rare Earths Ltd
- Ballarat Gold
- Bengalla Mining Co (New Hope Group)
- Dart Mining
- Energy Australia
- Glencore Coal
- Gnostic Exploration Services
- Haines Educational
- H&S Consultants
- iTech Minerals
- Kalbar Operations
- Kingston Resources Ltd (Mineral Hill)
- Linex Pty Ltd
- MACH Energy
- Mercator Gold Australia Pty Ltd
- Navarre Minerals
- OZ Minerals
- Providence Gold Minerals Pty Ltd
- Squadron Energy
- Stawell Gold Mine
- Sydney Mineral Exploration Discussion Group (SMEDG)
- Whitehaven Coal
- WIM Resource
- Yancoal



# TESEP Rock Kit and Plate Tectonics Poster



A great to teach where rocks form and the industries that extract and use them.

Get them from [haines.com.au](http://haines.com.au) or host a [PD at your school!](#)

You can also get them as a [bundle](#)

# TESEP Australian Critical Minerals Kit



2 boxes with 26 minerals:

- Critical minerals
- Metallic minerals
- Rock forming minerals
- Moh's scale of hardness
- Online resources include:
  - Mineral Stories
  - Questions for students
  - 3D renders

# TESEP Rock and Mineral Check



With each School visit we offer a free rock and mineral check:

- To identify specimens no longer useful for teaching (e.g., pebbles, small specimens etc.)
- To identify any misplaced specimens or valuable specimens (for display only)
- To identify any hazardous material (e.g., asbestos, pitchblende etc.)

# TESEP Rock Kit and Plate Tectonics Poster



TESEP Rock and Mineral kits (numbers) will be referred to in each episode



## All TESEP webinars are recorded

After each webinar episode you will be sent a link with:

- access to the slide set for that episode (including any embedded videos and links)
- access to a recording of that episode (YouTube)

After each episode you will also be sent:

- A TESEP Certificate of Attendance (NESA Recognised)

Please [subscribe](#) for news about forthcoming and new webinar series!



## Australian Curriculum v.9 (F-10)

We will be following the Australian Curriculum v.9 (2022):

- Curriculum content for Years 7-10 only
- Focus on the Earth and Space science sub-strand
- Will follow as many other sub-strands as possible



## Australian Curriculum v.9 (F-10)

Much of this webinar is dedicated to Year 8, “... continue to develop a view of Earth as a dynamic system, in which change occurs across a range of timescales”.

Rocks and Minerals for the classroom, and Plate Tectonics webinars cover this fully.

This webinar series will follow the following sub-strands:



# Australian Curriculum v.9 (F-10)

## Years 8 & 9 (Earth and Space Sciences)

- Explaining the uses of different types of rocks with reference to their properties and formation (AC9S8U04) - **Covered in Episode 1**
- Exploring how the mining of ores and minerals impacts on local environments and examining environmental rehabilitation initiative (AC9S8U04) - **Covered in Episodes 4 - 5**
- Analysing how sustainability priorities such as efficiency and limiting environmental impact have led to innovative practices in mining and mine site regeneration (AC9S8H01) - **Covered in Episodes 4 - 5**
- Examining how the development of hybrid and solar, electric and hydrogen-powered vehicles are applications of contemporary science responses to the depletion of fossil fuels and exploring environmental considerations (AC9S8H03) - **Covered in Episodes 2 - 4**
- Investigating how an understanding of materials and concern for the environment have led to the adoption of widespread recycling practices (AC9S8H03) - **Covered in Episode 5**

<https://v9.australiancurriculum.edu.au/>



# Australian Curriculum v.9 (F-10)

## Years 8 & 9 (Chemical Sciences)

- Examining how the physical and chemical properties of a substance will affect its production or use (AC9S8U07) - **Covered in all Episodes**
- investigating why most elements are not found in their elemental state and processes which are used to obtain the element (AC9S9U06) - **Covered in Episodes 2 - 4**
- predicting how ideas of green chemistry such as minimising the amount of unusable waste products, energy use and using more environmentally friendly chemical processes will affect the environment (AC9S9U06) - **Covered in Episodes 4 - 5**

## Year 9 (Physical Sciences)

- Explaining efficiency and recognising that in energy transfer and transformation a variety of processes can occur, so that the amount of usable energy is reduced and the system is not 100% efficient (AC9S9U06) - **Covered in Episodes 3 - 6**
- Comparing the efficiency of electricity generation from coal and other sources such as nuclear, hydroelectricity, gas, solar and wind (AC9S9U06) - **Covered in Episodes 3 - 6**

## Year 10 (Biological Sciences)

- Outlining processes involved in natural selection including variation, isolation and selection - **Covered in Episode 1**

<https://v9.australiancurriculum.edu.au/>

# Critical Minerals PD overview

This PD has 6 parts:

1. Introduction and overview
2. Critical mineral uses – our high tech lives
3. Critical mineral uses – energy transition
4. Sourcing critical minerals – natural resources
5. **Sourcing critical minerals – processing and recycling**
6. Australian focus

# Recap and introduction

In plain language ...

- A critical mineral is a mineral that a jurisdiction is worried about the supply of, as their economy will be impacted if the supply is not ensured.

The list differs for each national / state / territory government globally, depending on supply risk and economic importance

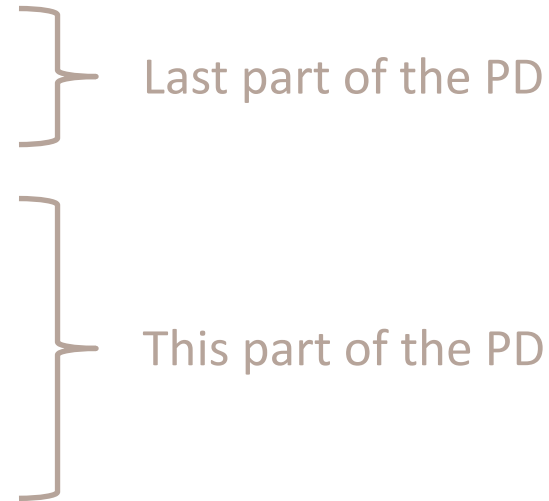
Defined lists usually includes minerals important for our high tech lives and for the energy transition

This part of the PD examines sourcing minerals from processing and recycling

# Where do we source critical minerals?

Three main methods:

- Mined as primary products
- Recovered as by-products from processing of other minerals.
- Recycling.



# Why recycle and process?

Our high-tech lives, and the transition from renewable to non-renewable energy has increased the demand for minerals.

- Minerals are becoming harder to find and more expensive to mine. It also takes time from exploration to production.
- Not every country has a minerals endowment.

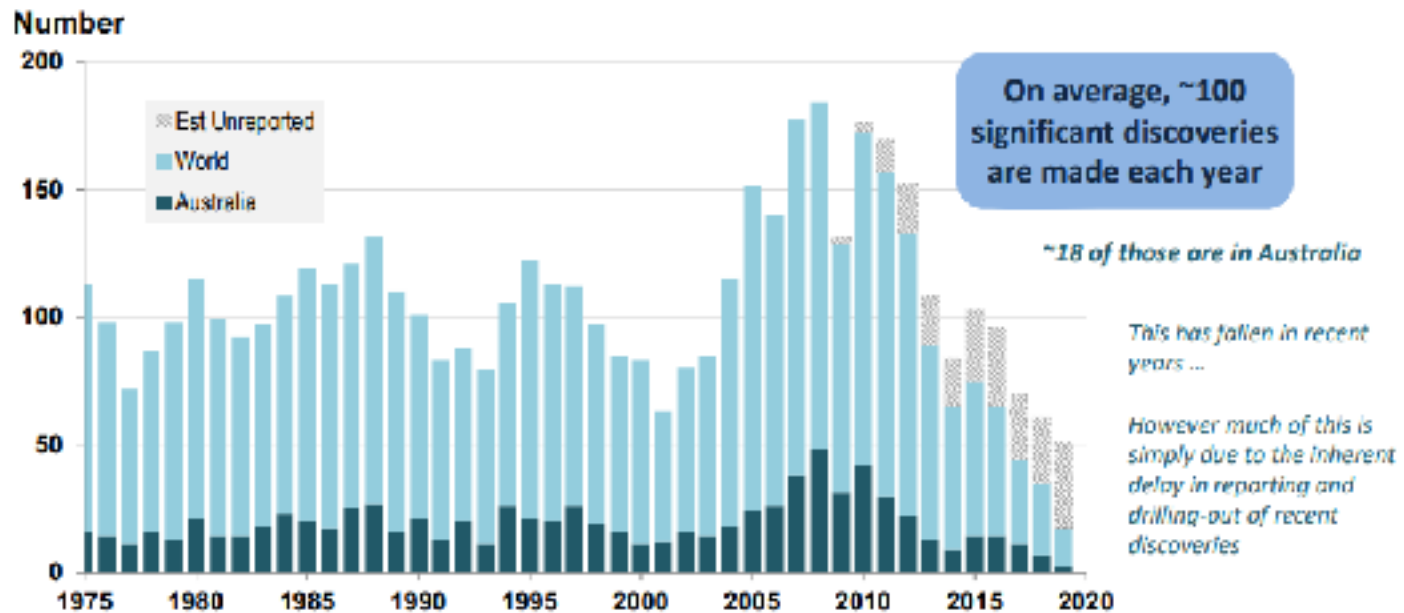
In addition, society is more conscious of the environmental and community aspects of mining, and need to recycle.

Can we meet mineral demands by recycling and / or improved processing from already disturbed land?

Source: [Figure-7.-Copper-demand.jpg \(4363x2982\) \(eurogeologists.eu\)](#)

# Exploration challenge: decreasing discovery

## Number of Significant Discoveries Australia versus the World : 1975-2019

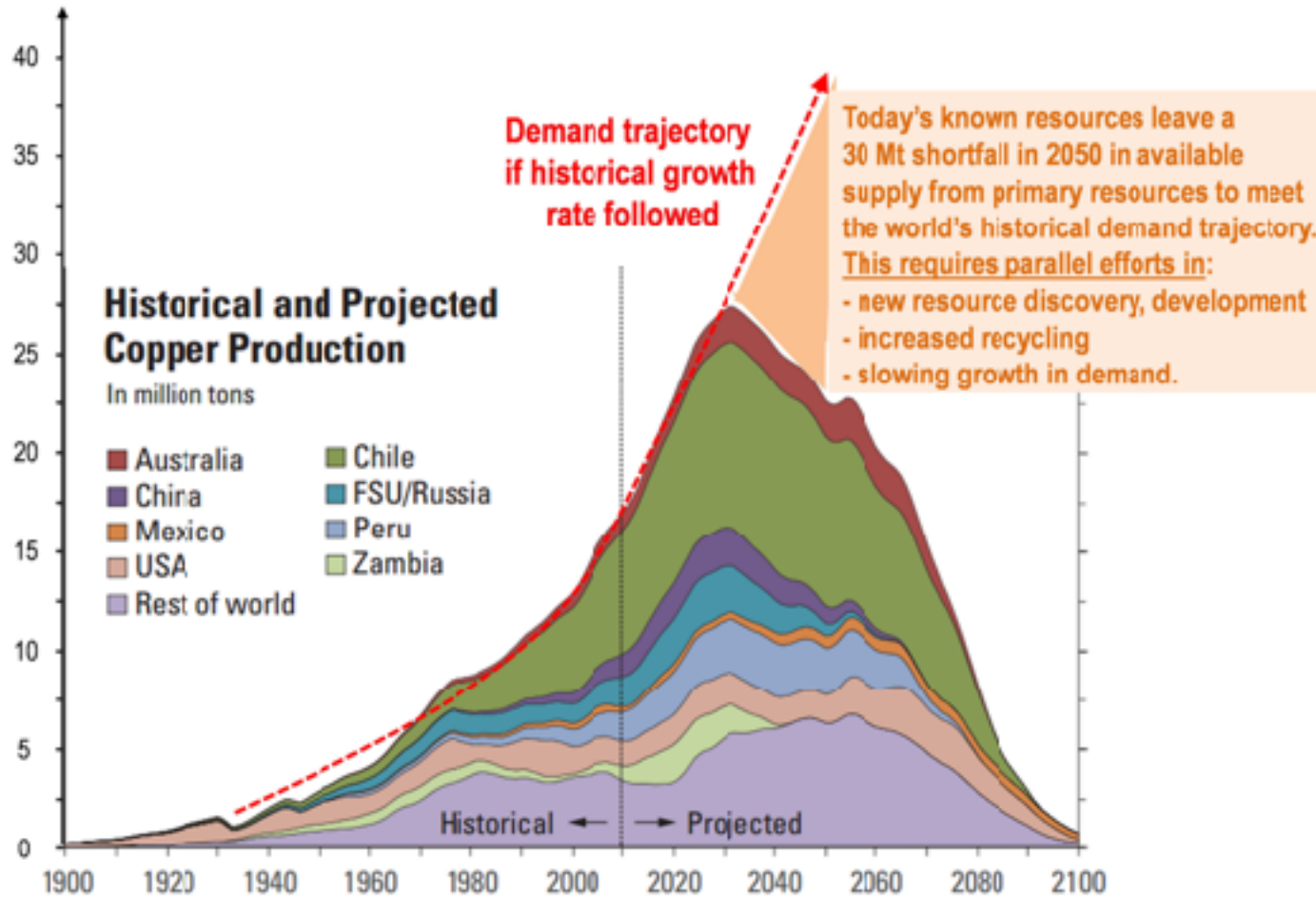


Note: Includes Bulk Minerals (i.e. Coal, Iron Ore and Bauxite)  
 Reserves (excluding "Mezzanine") in-place: Fe >100Tn Au, >10Tn Ni >100M Tn Zn >5M Tn Pb >5M Tn U<sub>3</sub>O<sub>8</sub>  
 >5 M Heavy Minerals, >20 M Pb, >20 M Thermal Coal >10 M Met Coal, >3 M P<sub>2</sub>O<sub>5</sub> and >3 M K<sub>2</sub>O

Source: MinEx Consulting © Oct 2020

Source: [Schodde presentation - IMARC Nov 2020 Vn2 \(minexconsulting.com\)](#)

# Copper demand: future shortfall from mining



Source: [Figure-7.-Copper-demand.jpg \(4363x2982\) \(eurogeologists.eu\)](#)

# Recycling copper

Includes copper in electric cables and wires, copper coils, white goods, TVs, some cookware etc

In the European Union

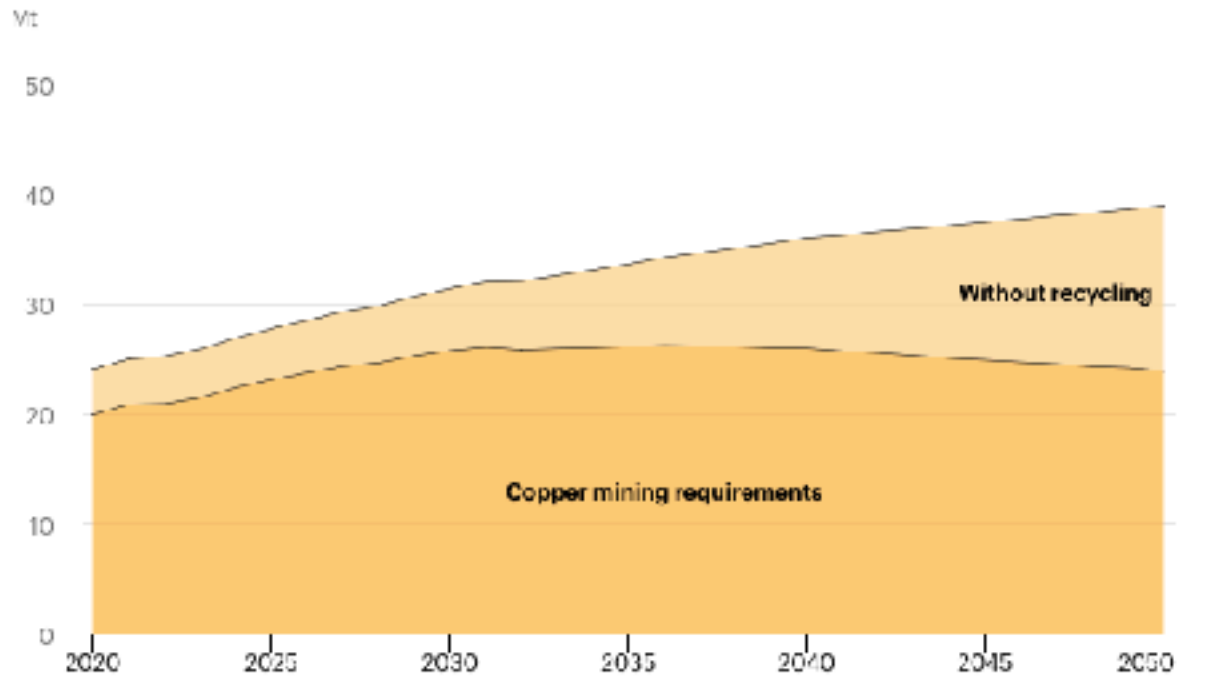
- 50% of Cu demand from recycling
- <85% less energy to recycle than for primary production



Source: [copperalliance.eu](http://copperalliance.eu)

### Copper: mining requirements in the Announced Pledges Scenario, 2020-2050

[Open](#)



[EA License: CC BY 4.0](#)

● Copper mining requirements ● Without recycling

# Recycling copper



Source: [https://youtu.be/IDSkijn\\_ml](https://youtu.be/IDSkijn_ml)

Activity: Who recycles batteries? Where do you take them?



# Lithium demand: Greenbushes mine v EVs example

Greenbushes in WA is the biggest operating lithium mine in the world

- aiming to produce 160 000 metric tons of LCE concentrate p.a.
- ~30,080 metric tons Li pa (~30,080,000 kg Li pa)

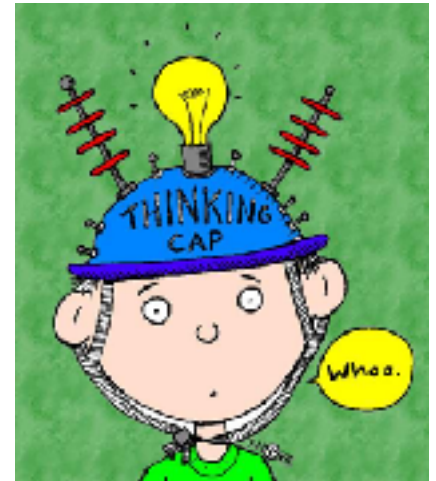
Each Tesla Model S uses 7kg of Li in its batteries

- Greenbushes will supply enough Li for ~4.2 million EVs p.a.

In 2021, EV sales topped 6.4 million units globally

- Forecast to rise to ~25 million globally in 2030

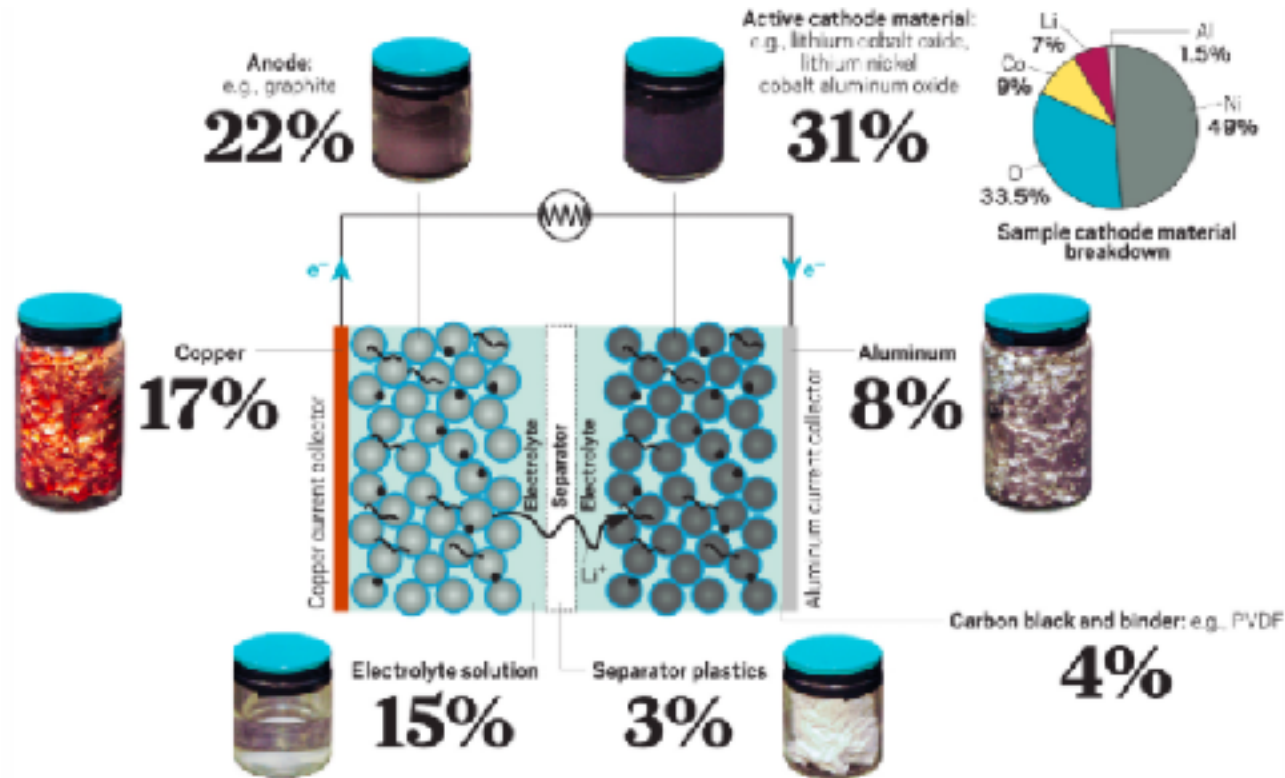
i.e. we will need much  
more Li than currently mined



Source: [Greenbushes Lithium Mine - world's largest operating lithium mine \(nenergybusiness.com\)](#) Savannah Resources | [Lithium Overview](#) [How Many Electric Vehicles Sold in 2021? | GreenCars car-3.png \(1667x810\) \(bloomberg.com\)](#) [Electric vehicle trends | Deloitte Insights](#)

# Recycling Li-Ion batteries (LIB)

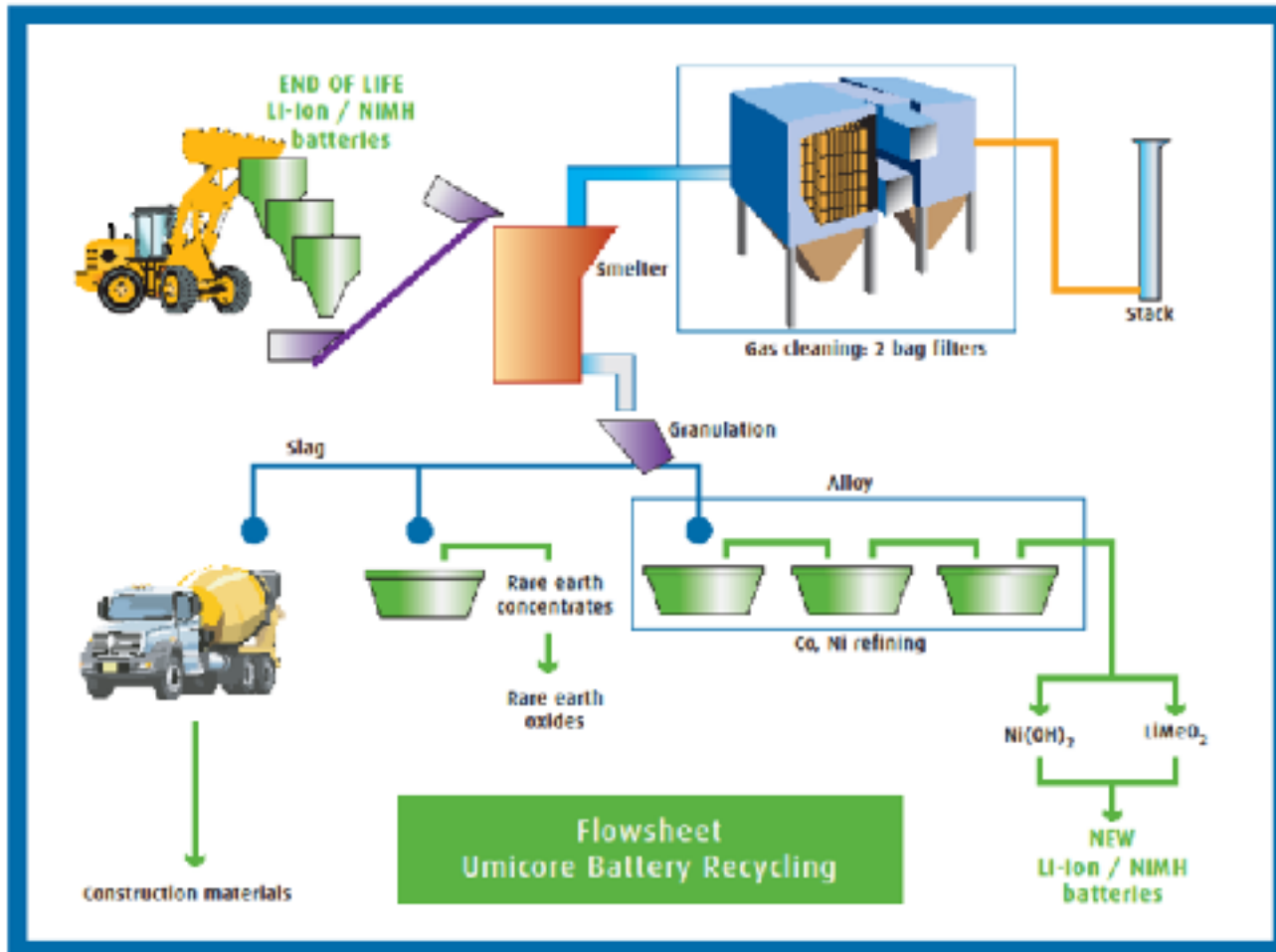
Nearly all components (95%) of a LIB can be recycled.



Source: Argonne National Laboratory.

Credit: Mitch Jacoby/C&EN

# Recycling Li-Ion batteries (LIB)



Source: [recycling-01-00025-g005.png \(2955x2191\) \(mdpi.com\)](#)

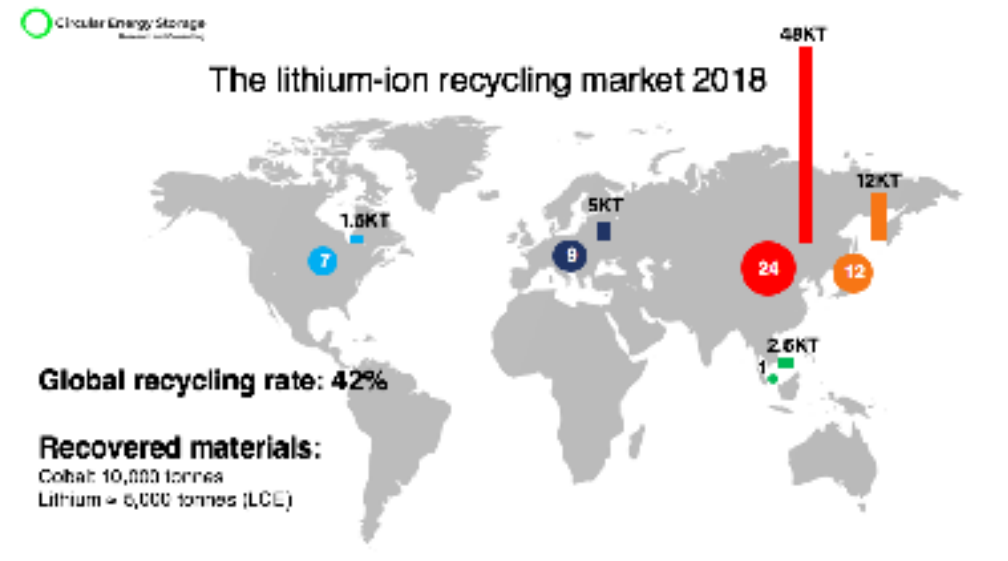
# Recycling Li-Ion batteries (LIB)

In Australia in 2021:

- Only 10 per cent of Australia's lithium-ion battery waste is recycled (99% for Pb batteries)
- Growing by 20 per cent per year and could exceed 136,000 tones by 2036
- EV batteries not being recycled at scale

Globally numbers are disputed:

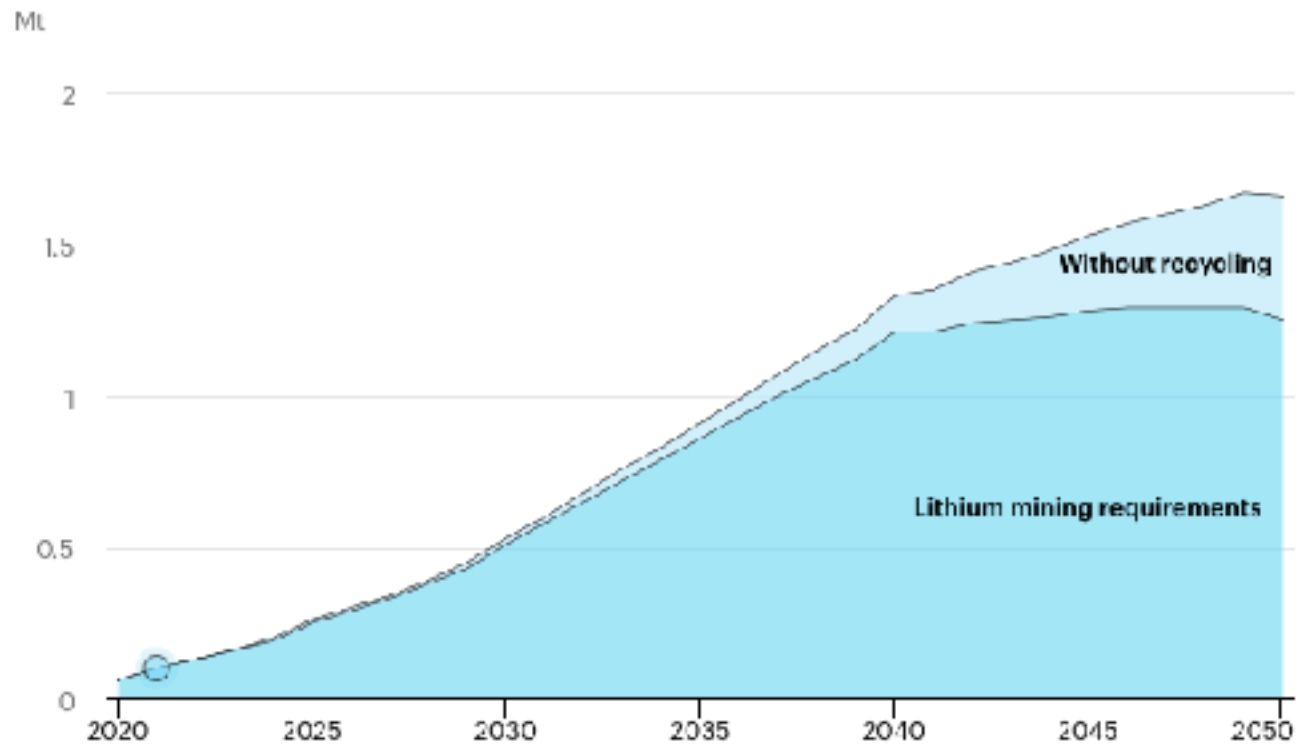
- Recycling rate between 1 - 18%
- Dominated by China, USA catching up – evolving quickly!





Source: [CSIRO Research Publications Repository – Publication](#) image-asset.png (734x418) (squarespace-cdn.com)

## Lithium: mining requirements in the Announced Pledges Scenario, 2020-2050

Open 



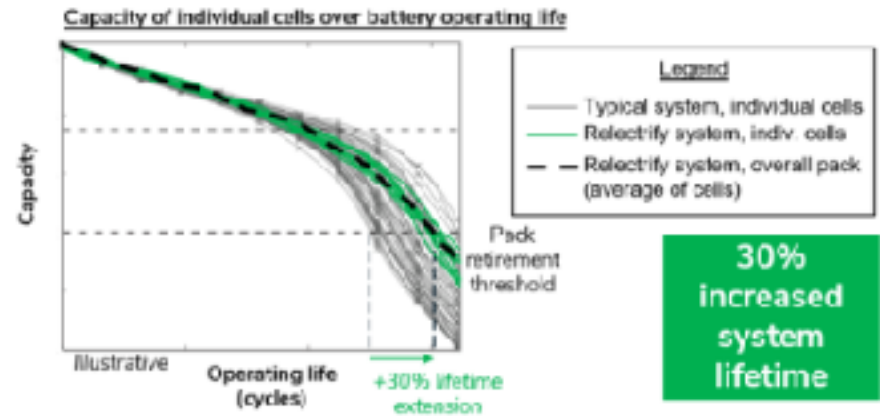
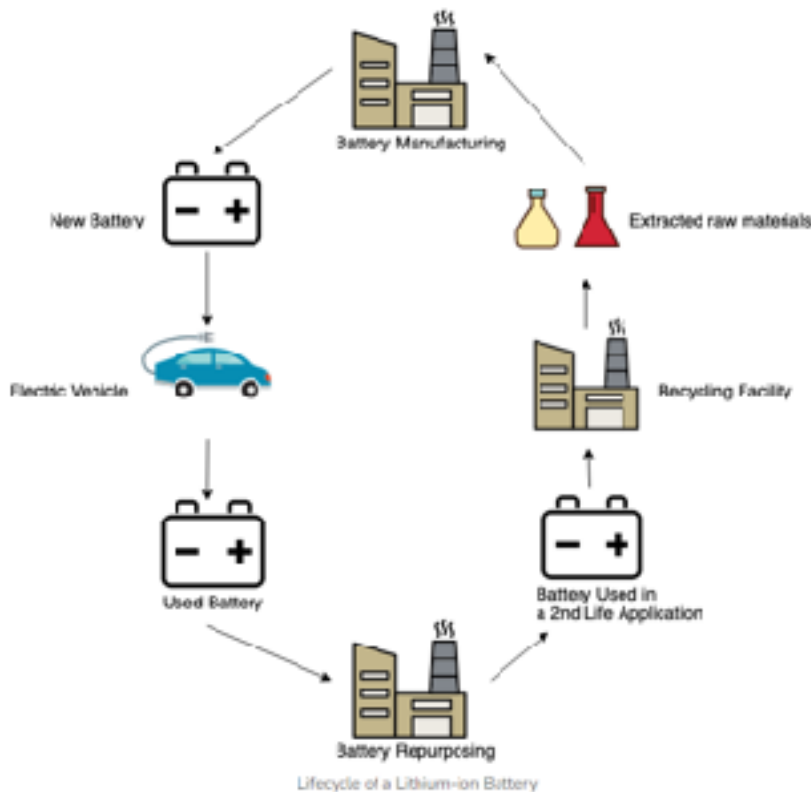
IEA. Licence: CC BY 4.0

 Lithium mining requirements  Without recycling

# Repurposing and maximising efficiency of Li-Ion batteries (LIB)

LIB can be repurposed for a second life – and then recycled.

Life of a LIB pack governed by weakest cell – using more from strong cells, less from weak cells extends life (e.g. Relectrify).



Source: [Trends in Lithium-ion Battery Reuse and Recycling](#) • Evreporter [Our Technology](#) — Relectrify

# Rare Earth Elements in Trade and Tariffs: Geopolitical Implications 2025

BY JOHN ZADEH ON APRIL 29, 2025

## The Urban Mine: Untapped Potential

Decades of importing rare earth-containing products have created substantial "urban mines" in Western countries:

- End-of-life electronics, vehicles, and industrial equipment contain valuable rare earths
- Wind turbines, electric motors, and hard drives represent concentrated sources
- These materials are currently being lost to landfills or downcycled
- An estimated 20 years of imported rare earths exist in Western waste streams

TECH

## Recycling rare-earth elements is hard — but worth it

Scientists are inventing new — and greener — ways to reuse these valuable metals

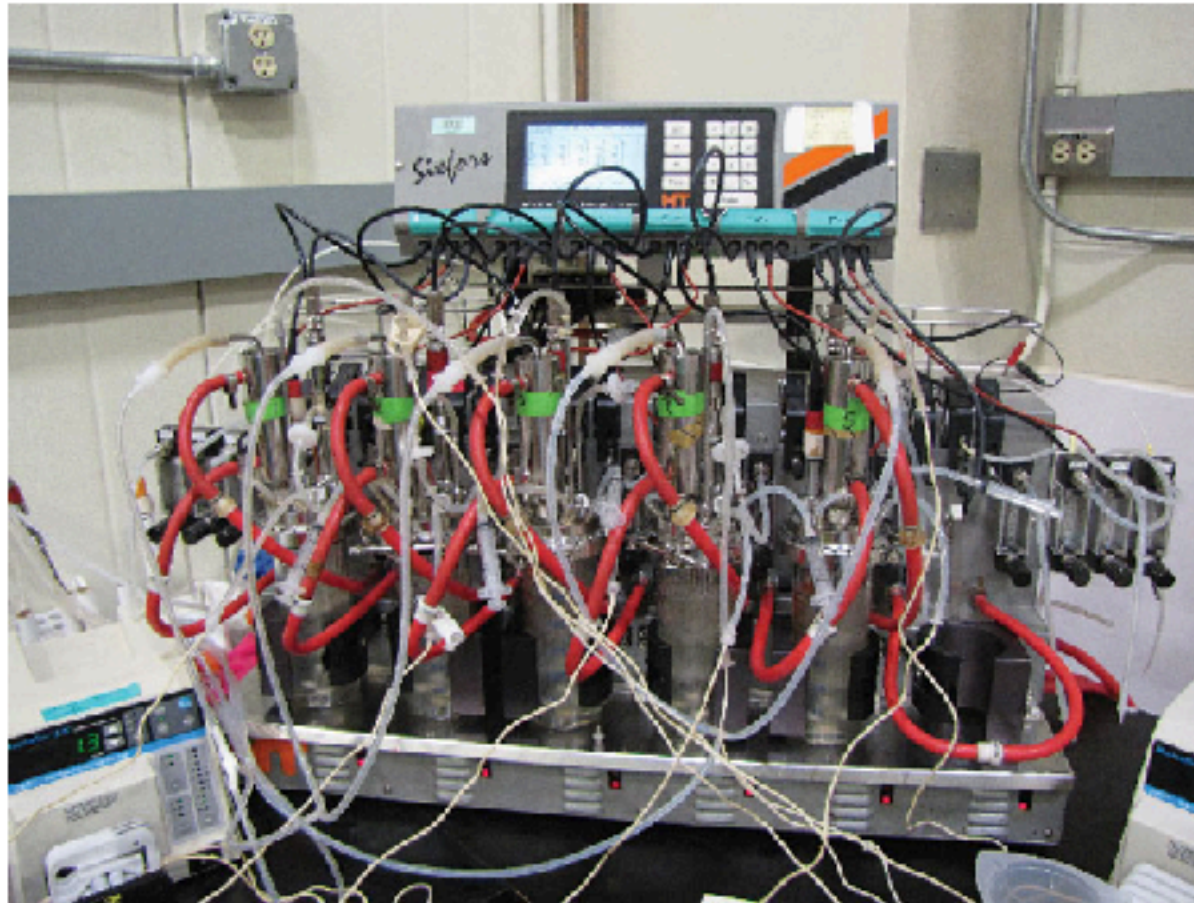
Within 10 years, Nlebedim says, recycling could meet up to one fourth of the need for rare earths. If true, he says, that would be “huge.”



Rare-earth recycling tends to use hazardous chemicals, such as hydrochloric acid. It also uses a lot of heat — and thus a lot of energy. And that effort may only recover a tiny amount of metal. A computer's hard-disk drive, for instance, might contain just a few grams (less than an ounce) of rare-earth metals. Some products might have just a thousandth as much.

But scientists are trying to develop better recycling approaches to reduce the need for mining more of these metals.

Source: <https://www.snexplores.org/article/recycling-rare-earth-elements-hard-reuse-greener-technology>



to one fourth of  
huge."

Rare-earth re  
hydrochloric  
that effort ma  
drive, for inst  
rare-earth me  
  
But scientists  
the need for r

One experimental recycling approach uses organic acids to extract rare earths from waste products. Bacteria make those acids. This reactor at the Idaho National Laboratory is preparing an organic acid mixture for such recycling.

IDAHO NATIONAL LAB

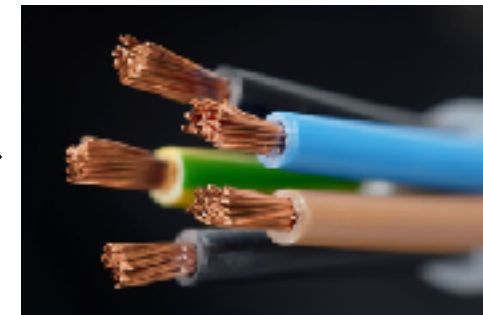
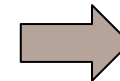
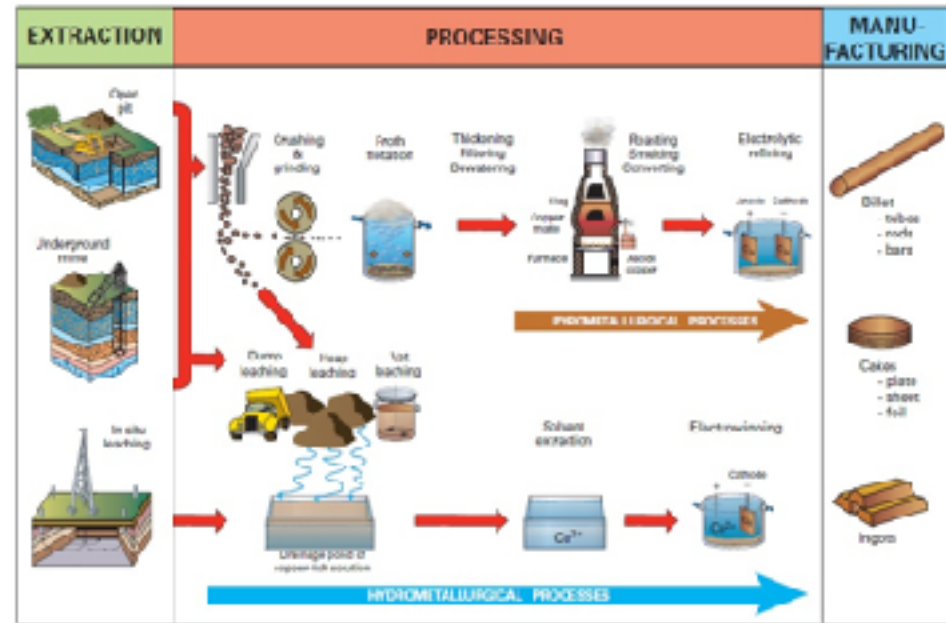
Source: <https://www.snexplores.org>

# Mineral processing

Mines aim to recover specific minerals from the ore they extract.

Ore is sent to a refinery / smelter to separate the target minerals from the waste.

The complex process may include crushing, separation by physical properties, flotation, chemical treatment, roasting etc.



Source: [copper mine operation schematic.au - Bing images](#) 1113657.jpg (1280x1280) ([weinrichmineralsinc.com](#))  
[SPS\\_HerolImage\\_Demarco\\_123rfLtd\\_3315684\\_l\\_copy.jpg](#) (1130x757) ([sciencelearn.org.nz](#))

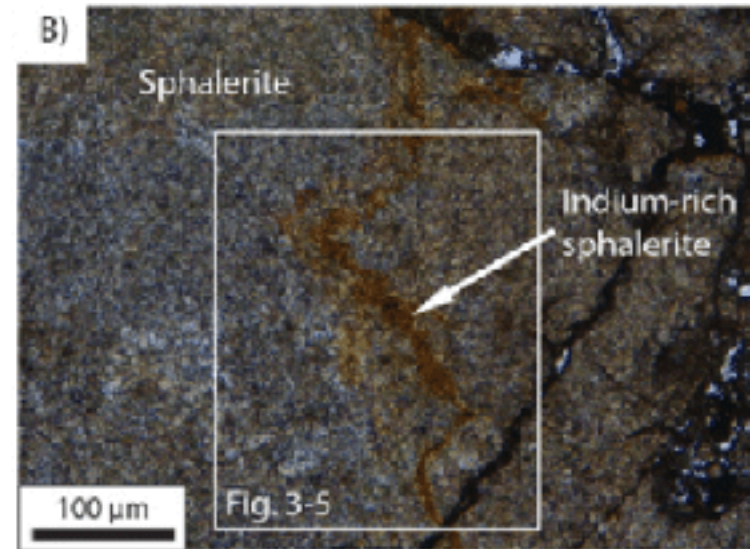
# Mineral processing

By-products of refining major minerals (like Zn, Cu, Pb, Au and Ni) may include critical minerals

- e.g. PGEs, REE, Cr, W, Co, Cd, Ge, In, Se, Te, Re
- e.g. Indium is common in sphalerite.

However, many of these have not been a target mineral for many reasons.

- Lack of knowledge about minor minerals in ore.
- Minerals weren't known about
- There was no market (value or use) for other minerals in the past.
- Metallurgical issues in extraction.



Source: [2.11 Potential for Australian critical commodity production | Geoscience Australia \(ga.gov.au\)](#) [Critical Minerals | Geoscience Australia (ga.gov.au)]  
A) Photograph of a sphalerite-galena vein in drill core from the Mt... | Download Scientific Diagram (researchgate.net)

# Reprocessing waste materials

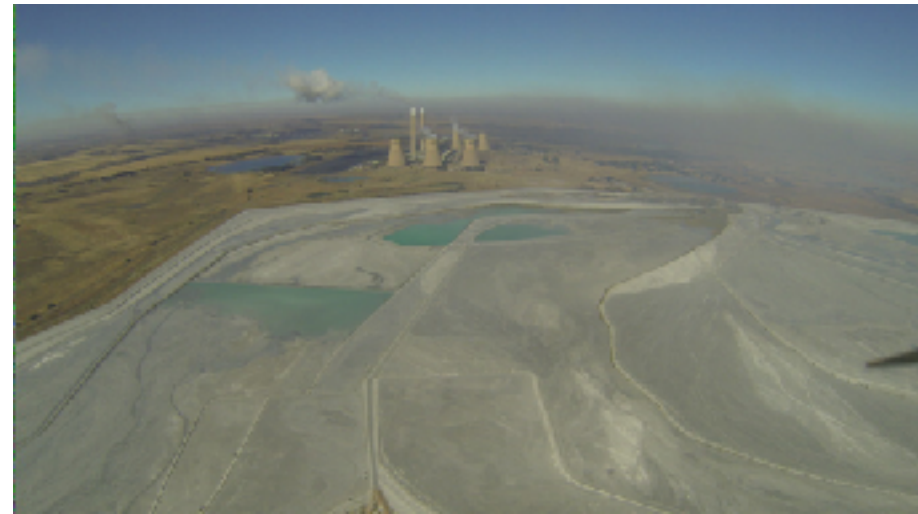
Waste material from metalliferous mines is known as 'tailings'.

'Fly ash' is the left over material when coal is burnt.

'Slag' is the waste product from smelting.

Many waste materials contain major and minor minerals not recovered from original mining.

- Better technology now
- Also aids rehabilitation



Source: [Giant-ash-dam.jpg \(1024x576\) \(oxpeckers.org\)](#) Goggle Maps

# Reprocessing waste materials: Zn recovery

The Century mine (NW of Mount Isa) was one of the world's largest zinc mines

- Produced a Zn and Pb concentrate from 1999 to 2016.
- After the higher grade ore was mined, another company has been processing the tailings to extract remnant Zn.
- Although the Zn is lower grade the operation is lower cost as it uses existing infrastructure – and is rehabilitating the tailings dam by storing materials in the pit.

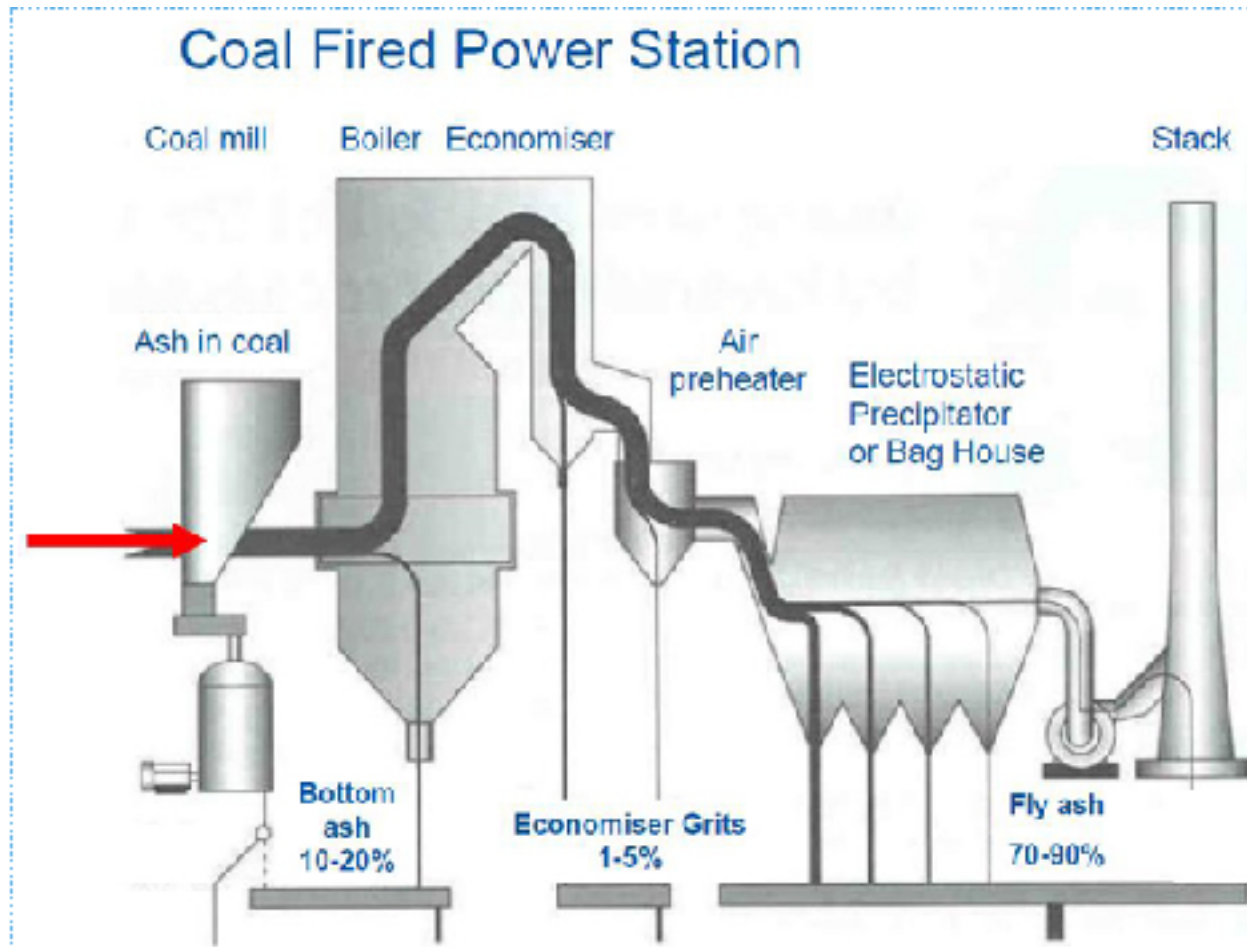
Zn is important in renewable (solar, wind and hydro) energy to galvanise steel to stop rust.

Zn made it on to the Australian Strategic Minerals list in 2024.



Source: New Century Resources [Homepage](#) | [New Century Resources](#), Google Maps

# Reprocessing waste materials: REE from coal fly ash



Source: <https://www.flyashaustralia.com.au/WhatIsFlyash.html>

# Reprocessing waste materials: REE from coal fly ash

| <b>Factor</b>            | <b>Traditional REE Mining</b>             | <b>Coal Ash Extraction</b>                   |
|--------------------------|---|--|
| Initial capital costs    | Very high (new mine development)          | Moderate (processing facility)               |
| Resource concentration   | Higher grade deposits                     | Lower concentrations but vast quantity       |
| Processing complexity    | Complex separation required               | Similar separation challenges                |
| Environmental permitting | Lengthy and challenging                   | Potentially streamlined (remediation aspect) |
| Infrastructure needs     | Extensive new development                 | Often existing infrastructure                |
| Supply chain security    | Often in geopolitically sensitive regions | Domestic resource                            |

# Reprocessing waste materials: REE from coal fly ash

When coal is burnt, a non-combustible, fine-grained material called 'fly ash' is produced.

- Some coal includes REE concentrated in minerals like monazite, allanite, zircon, xenotime
- The USA has the world's largest coal reserves and produces vast amounts of fly ash, but only 9% of REE from a single mine.

USGS is researching the potential of extracting REE from coal

- REEs are redistributed into fly ash glass when coal burnt.
- Possible to recover REEs from fly ash glass – though probably requires an acid digestion plant.

Source: USGS. [FS 2019-3048: Rare Earth Elements in Coal and Coal Fly Ash \(usgs.gov\)](#),

# Mineral processing

The demand for critical minerals has led to:

- Some onsite plants being modified to recover critical minerals.
- Offsite refineries adapting to treat a range of materials to recover critical minerals.
- New plants being constructed to recover critical minerals
  - e.g. Kalgoorlie Rare Earths Processing Facility (Lynas)

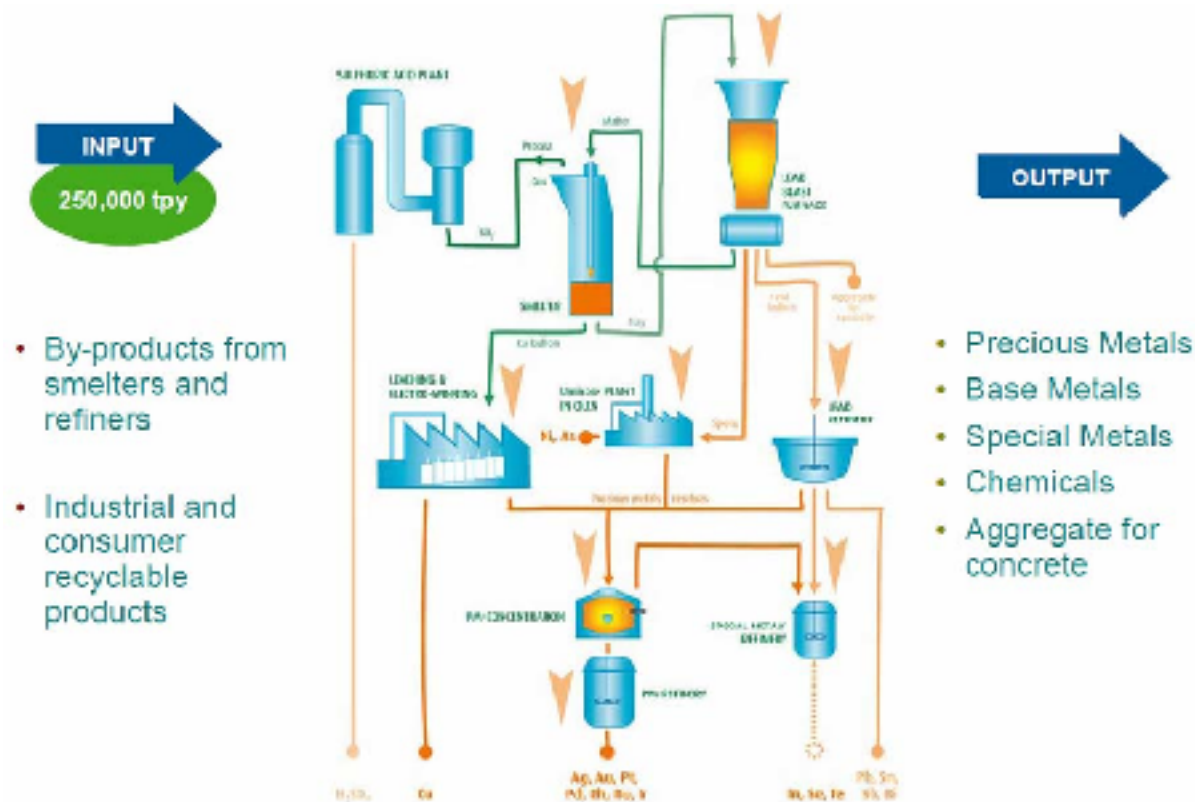


Source: [2.11 Potential for Australian critical commodity production | Geoscience Australia \(ga.gov.au\)](https://www.ga.gov.au/critical-minerals) [Critical Minerals | Geoscience Australia (ga.gov.au)] [WA Environment Minister gives green light to build \\$500m rare earths refinery at Kalgoorlie - ABC News Home - Lynas Rare Earths](https://www.abc.net.au/news/2023-06-22/wa-environment-minister-gives-green-light-to-build-550m-rare-earths-refinery-at-kalgoorlie-home-lynas-rare-earths)

# Mineral processing: Umicore

Global operations who recycle and refine from other smelters.

- Products include a range of critical minerals otherwise not recovered



Source: Umicore | Precious Metals Refining | Umicore Flowchart-for-Umicore-integrated-metals-smelter-and-refinery-Reprinted-from-Hagelueken.png (850x583) (researchgate.net)

# Mineral processing: Sun Metals Refinery, Townsville

Primarily produces zinc metals from raw materials mined in Australia, Alaska and South America.

By-products include sulphuric acid, agricultural and industrial grade gypsum, iron oxide, lead sulphate, copper cement, manganese dioxide.

Zinc refinery is 'energy hungry'.  
Committed to being the world's first refinery to produce zinc entirely from renewable energy (by 2040)



Source: [Sun Metals Zinc Refinery](#) [Sun-Metals-zinc-refinery-Townsville-855x0-c-default.png \(855x630\) \(pv-magazine-australia.com\)](#)

# Summary

Mining alone cannot meet the demands of critical (and other minerals) given the rapid escalation in demand.

Recycling of materials is under-utilised globally

Processing of existing ore and tailings can minimise new ground disturbance

Maximise efficiency of existing refineries.

All have energy requirements, and economic, environmental and social impacts.