MINVIRO

Future Propulsion Conference 2025

From Mine to Motor

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Agenda

01 Introduction to Minviro

02 What is Life Cycle Assessment? …and why do it?

03 Key Powertrain Materials, from Mine to Motor

04 Case Studies

Introduction

About Minviro

Who is Minviro?

We guide businesses in the raw material, clean technologies, and battery value chains globally with life cycle assessment (LCA) consultancy and software.

Our award-winning consultancy offers advanced sustainability expertise, using science-backed solutions to measure and reduce environmental impacts.

250+
Successful Global LCA consultancy projects

Launched **LCA Software XYCLE**

Global
presence through offices in the UK, AUS and CN

ISO/PEFCR
compliant

Active research & development into **Advanced Technology**

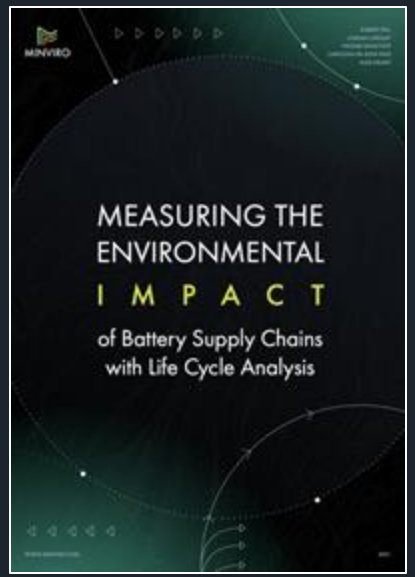
15
Industry Partners

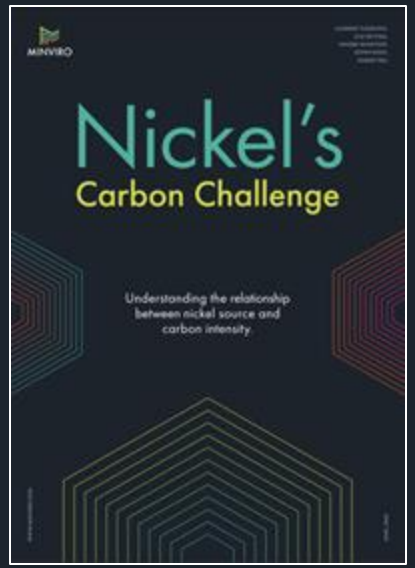
Some of our clients

Businesses we have worked with

Our intelligence

Explore our white papers






What is Life Cycle Assessment?
…and why do it?

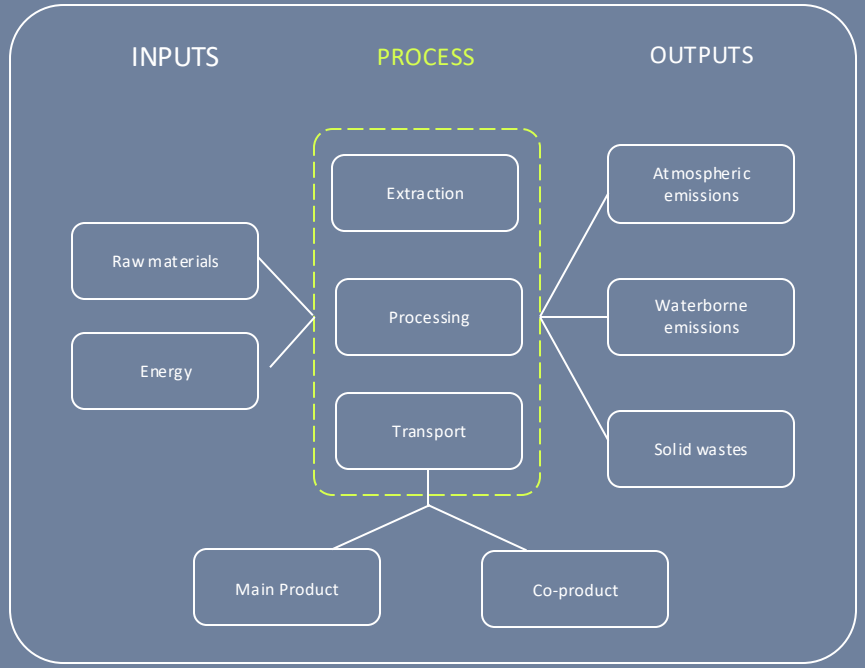
What is a Life Cycle Assessment?

Life Cycle Assessment (LCA) is an analysis technique to assess environmental impacts associated with all the stages of a products life, from raw material extraction through processing, manufacturing, distribution, use and disposal/recycling.

LCA Methodology

What it is and how it serves you

- LCA has been around for 50 years with the first studies dating back to the early 1970s.
- One of the most standardised, scientific and well regarded methodologies for quantifying impact
- **Beyond just CO_2 impact**, quantify acidification, water scarcity, eutrophication, particulates and more.
- This is the only way to ensure that the raw materials for the **low-carbon economy** are **sourced at minimum environmental impact**.



Key aspects

1. LCA take a life-cycle approach
2. LCA covers environmental impacts beyond CO_2
3. LCA is based on data: foreground and background
    - Data quality is of utmost importance!

The Value LCA Can Bring You

Realise the opportunities with Minviro

Regulations Compliance
Quantify your environmental impact

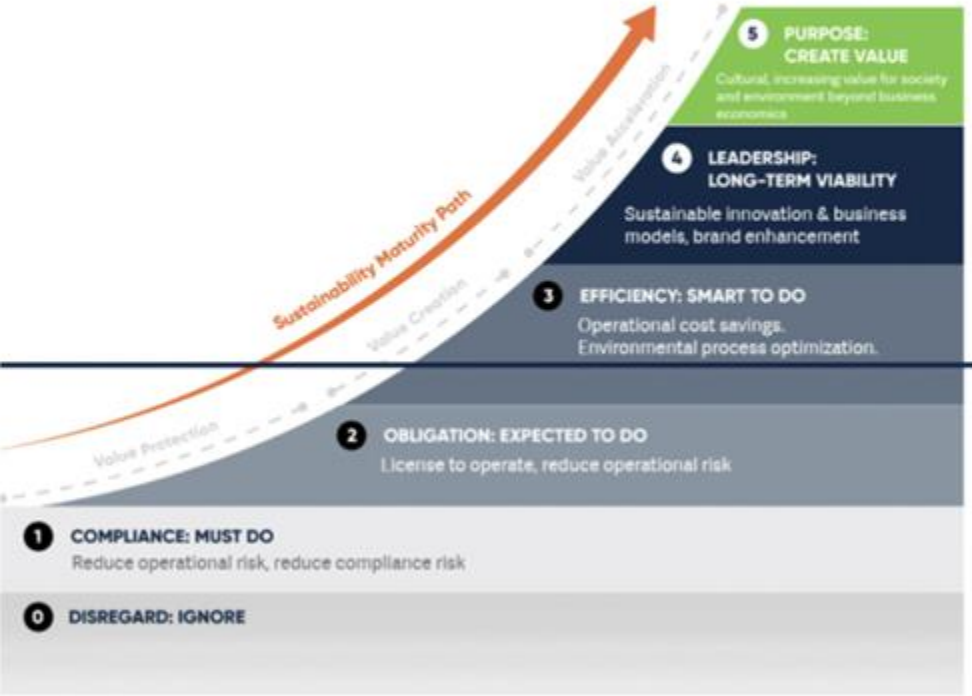
Comparison scenarios
Find the right region to focus on

Investor Attraction & Confidence
Find your hotspots

Decarbonisation Opportunity
Flowsheet optimisation

Sustainability Landscape

Drivers and focuses



INTERNAL

DRIVER

EXTERNAL

Design for Environment & circularity	Integrated Core processes	Organisational Change
Climate neutral product	Automation	New Business Model
System Integration	Climate Neutral Value Chain	
Design for Environment	Roadmap & Strategy,	Scope 3
Comparative Assess	Circular Economy	SBTI
LCA, EPD, PEF	Supplier Engagement	
Product Carbon (PCF)	Materiality Assess	Carbon Footprint (CDP)
LCA, EPD, PEF	Target Dev	Sustainability Report
Screening LCA	Benchmarking & Gap Analysis	
Shadow PEF, PEFCR		Non Financial Reporting

PRODUCT — FOCUS — CORPORATE

Fair Project Comparisons

Standardised Carbon Footprint Method

Development of **standards** :

- ISO Standards (Minviro involved in lithium and REE TC)
- PEFCR (Minviro involved through RECHARGE)
- Global Battery Alliance (GBA)
- Product Category Rules (PCR)
  - Graphite - Minviro leading
  - Rare earth elements - Minviro leading
  - Lithium - With International Li Association
- Upcoming - Delegated Act

Approaches within LCA

- Consistent system boundary
- Consistent functional units

When **data quality** is inconsistent

- Sensitivity and uncertainty analysis
- Independent third-party review → avoid **greenwashing**

Europe leading the change

LCA as the “go-to” methodology

LCA methodology being integrated in legislation:

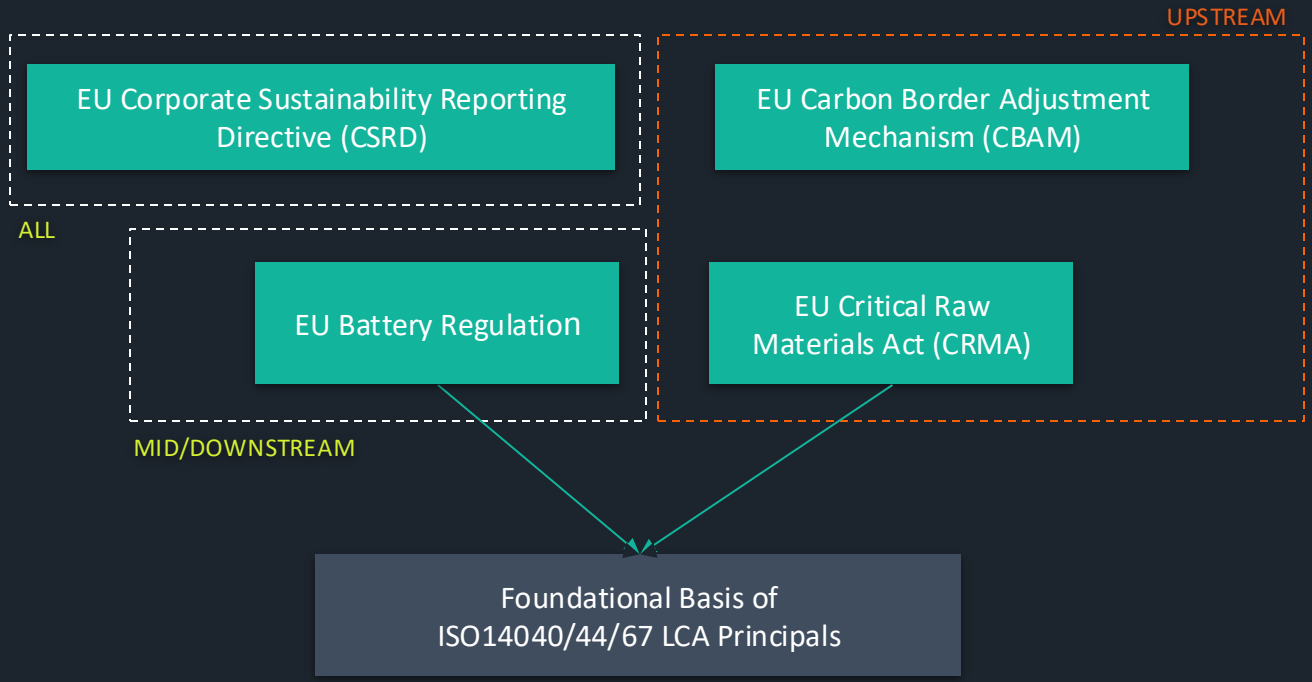
- EU Battery Regulation
- EU Critical Raw Materials (CRMA)
- EU Green Claims Directive
- EU Net Zero industry Act
- Eco-design (ESPR)

Life-cycle thinking considerations in legislation:

- **EU Carbon Border Adjustment Mechanism (CBAM)**
- GHG Avoidance Methodologies
- Corporate Sustainability Reporting Directive (CSRD)

LCA as a Foundational Methodology

Most relevant European legislation



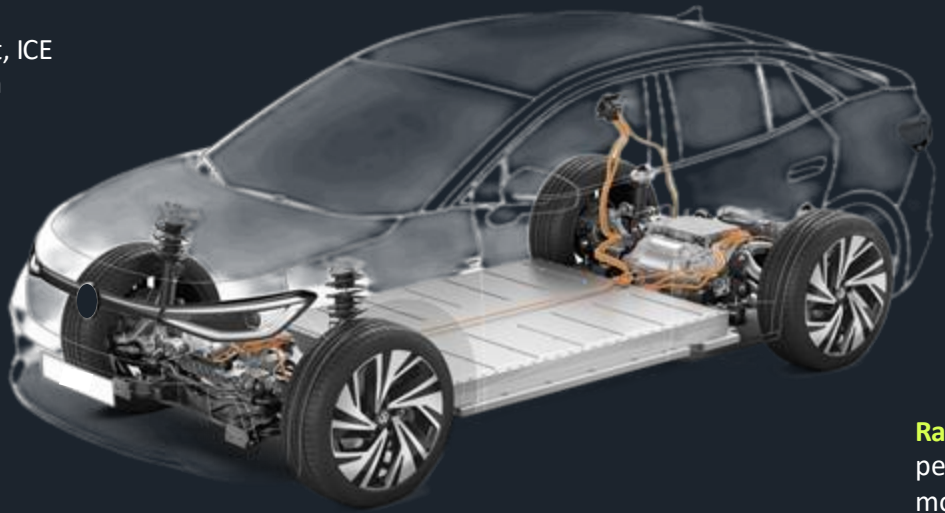

Materials Across the
Powertrain Supply Chain

Key Powertrain Materials

From from Mine to Motor!

Lithium, Cobalt, Nickel, Manganese
Found in batteries, varies depending on chemistry
E.g., NMC, LFP, or NCA

Iron & Steel
Structural components, gears, and reinforcement, ICE engines and transmission components



Aluminum
EV motor housings and battery enclosures, for ICE used in cylinder heads, pistons

Copper
Wiring, busbars, EV electric motor windings, and power electronics.

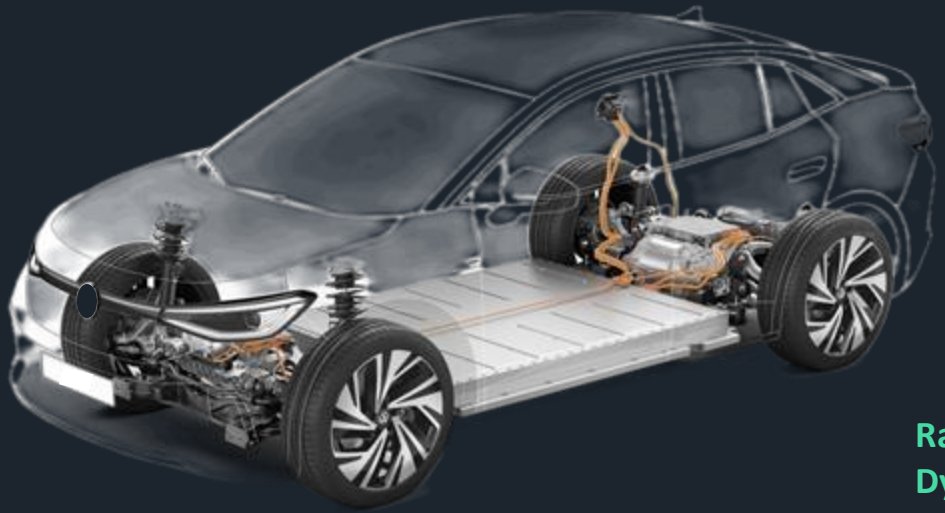
Rare Earth Metals (Nd, Dy, etc.)
permanent magnets for electric motors

Key Powertrain Materials

From from Mine to Motor!

Lithium

Iron & Steel



Copper

Rare Earth Metals (Nd, Dy, etc.)

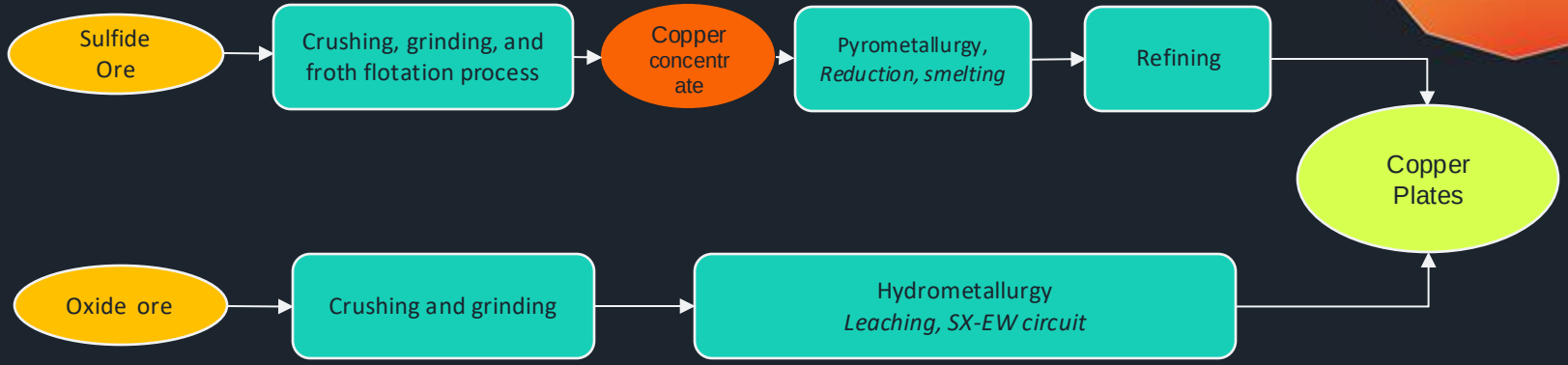
LCA Data and Database

Minviro's Copper Supply Chain Data

Task: Assessing the environmental impact of Copper

Functional unit:
1 kg Cu

Key points!
The impact varies depending on the deposit type and processing technologies

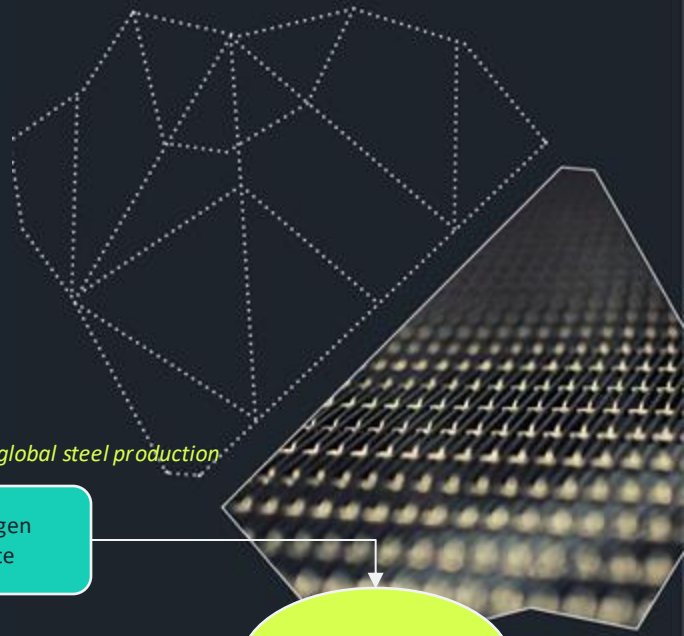


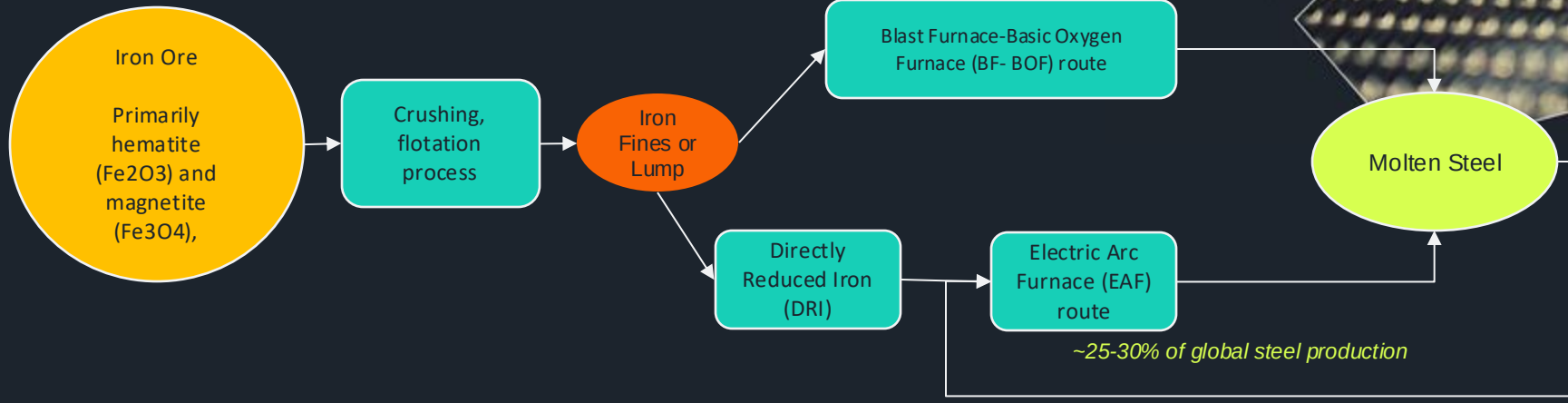
LCA Data and Database

Minviro's Steel Supply Chain Data

Task: Assessing the environmental impact of Steel

Functional unit:
1 kg Steel





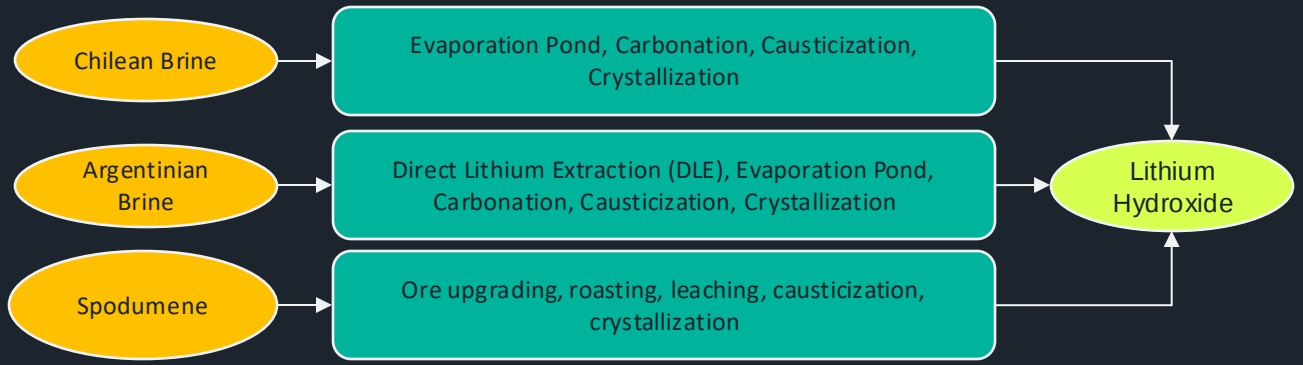
LCA Data and Database

Minviro's Lithium Supply Chain Data

Task: Assessing the environmental impact of Lithium Hydroxide Monohydrate

Functional unit:
1 kg battery-grade LiOH.H2O

Key points!
The impact varies depending on the deposit type and processing technologies



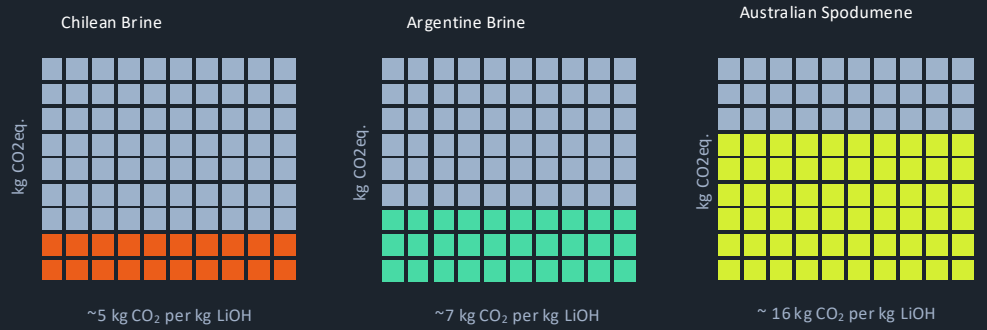
Lithium LCA

Same functional material, different environmental impacts

- ➔ Battery raw materials can have a range of impacts across all impact categories
- ➔ For example lithium hydroxide can vary from less than 5 to over 16 kg CO_2 eq.
- ➔ The variation in impact can be due to a number of factors including material and energy intensity of processes
- ➔ This includes reagents and consumables (these have embodied impacts)
- ➔ Background infrastructure such as grid mix CO_2 intensity

Cradle-to-gate

Lithium hydroxide production

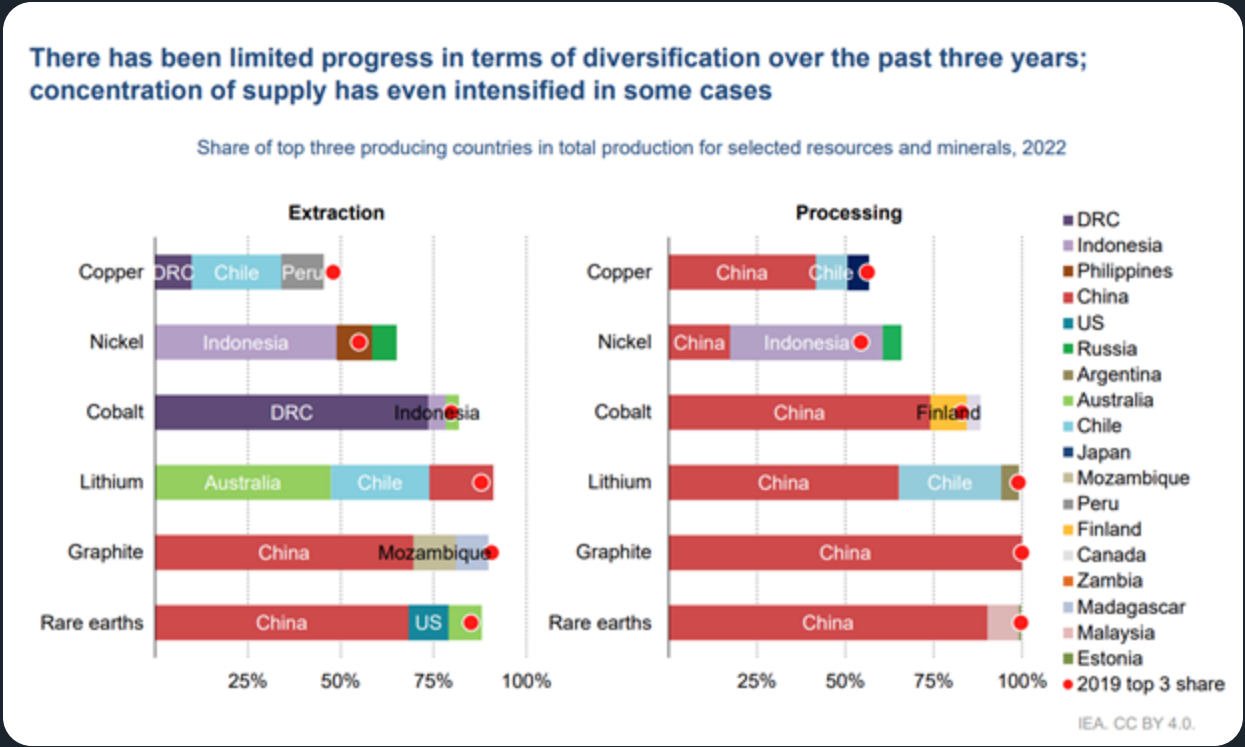


References

The CO2 Impact of Lithium Hydroxide, Minviro

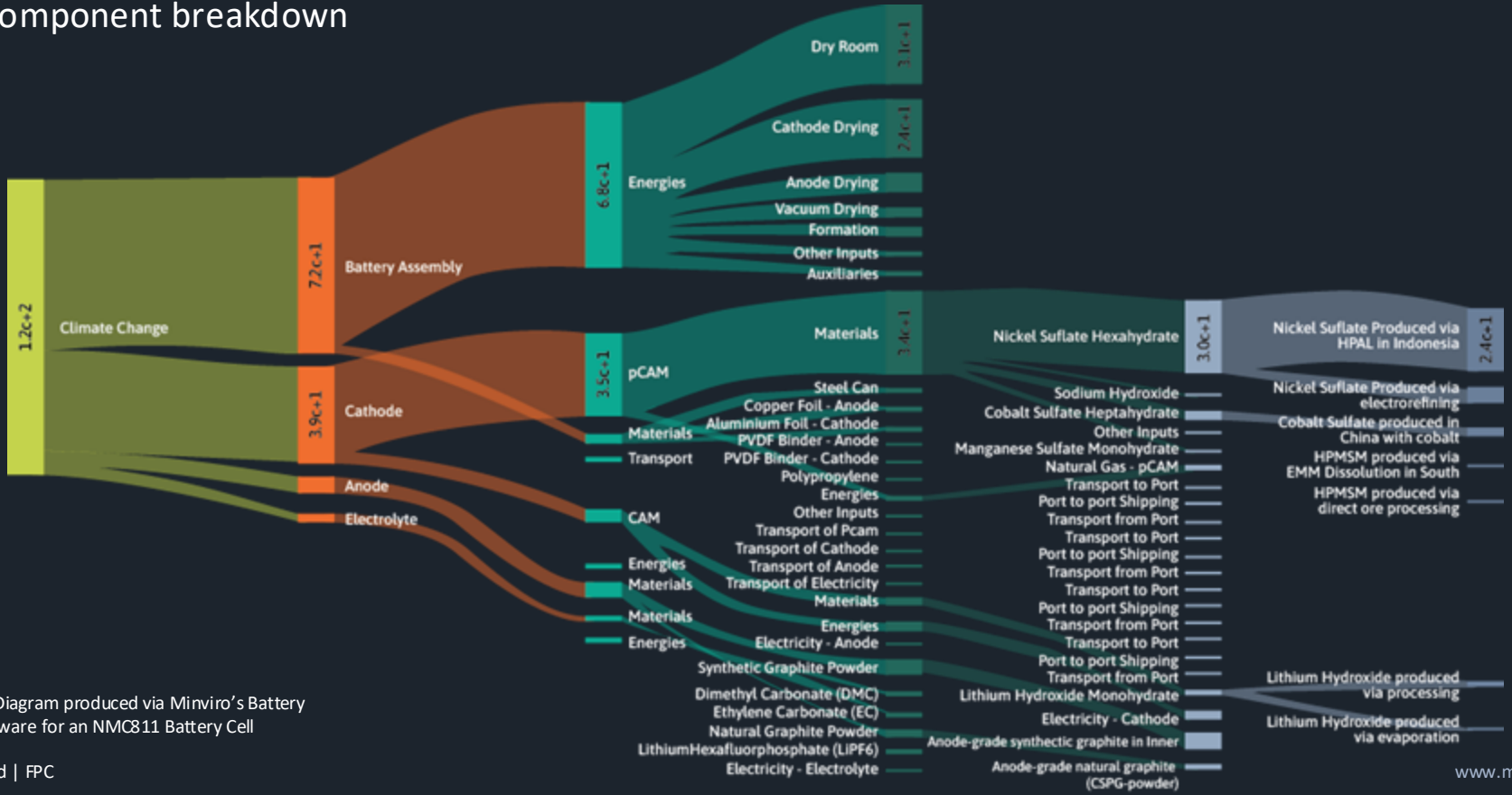
Raw Material Database

Global Raw Material Supply Chain



Climate Change Impacts of Battery

Component breakdown



Sankey Diagram produced via Minviro's Battery LCA software for an NMC811 Battery Cell

Climate Change Impacts of Battery

System Boundary

Task: Evaluate the **climate change impact** of producing 1 kWh NMC-811 battery pack.

Functional unit: **1 kWh NCM-811 battery pack**

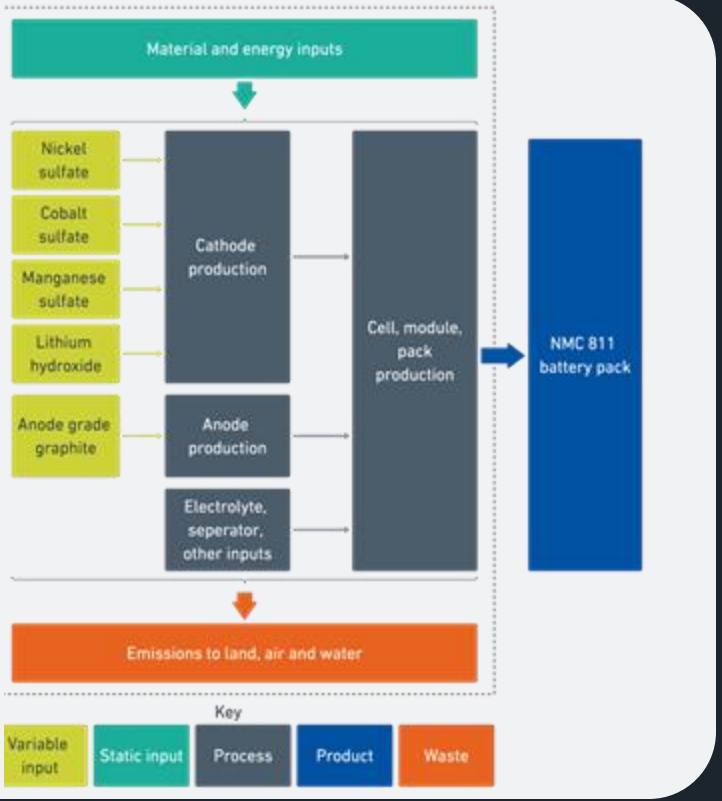
System boundary: **cradle-to-gate**

Key points

- In LCA, most of the time **assumptions** need to be made
- Battery manufacturing location is kept fixed
- Total raw materials input for battery pack is constant

Variable factors are the raw material sources, considering high carbon footprint routes of:

- Nickel sulfate
- Lithium hydroxide
- Cobalt sulfate
- Manganese sulfate
- Anode-grade graphite (synthetic and natural)



Climate Change Impacts of Battery

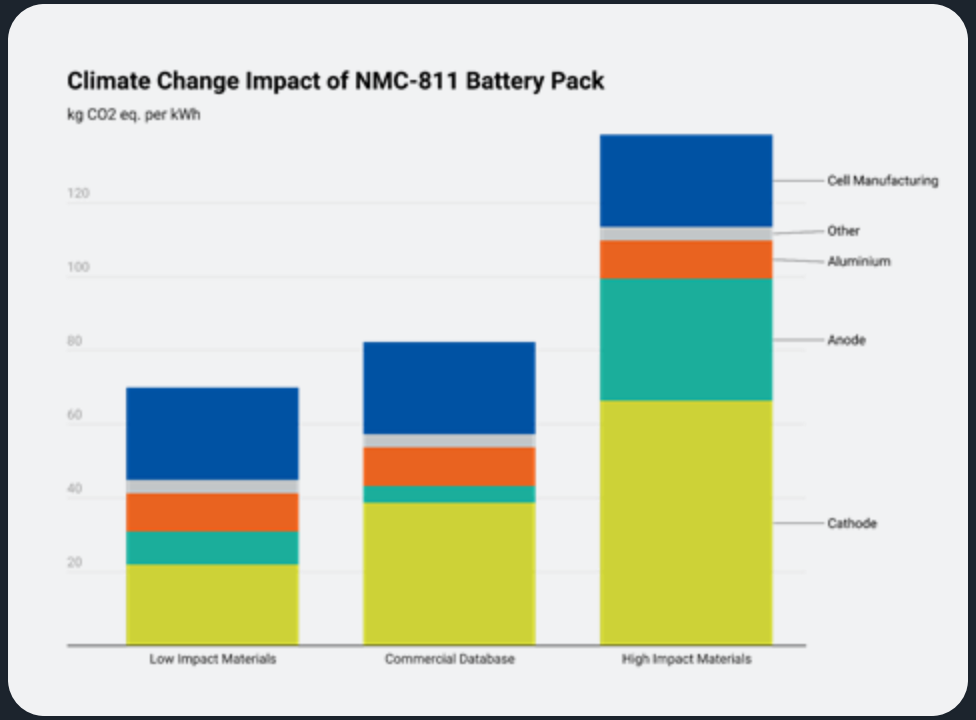
Comparing different scenarios

This figure shows the carbon footprint per kWh of a battery assuming:

- Raw material averages in **databases**: **82 kg CO_2 eq. per kWh**
- Low impact raw materials (Minviro's database): **70 kg CO_2 eq. per kWh**
- High impact raw materials (Minviro's database): **135 kg CO_2 eq. per kWh**

Perspective of Customer

- Contribution of cathode per kWh can increase significantly depending on **where the raw material is sourced from.**
- Why would they buy your high **CO_2** material if this could damage their access to the EU market and thus penalise their investors? (i.e EU Battery Regulation)

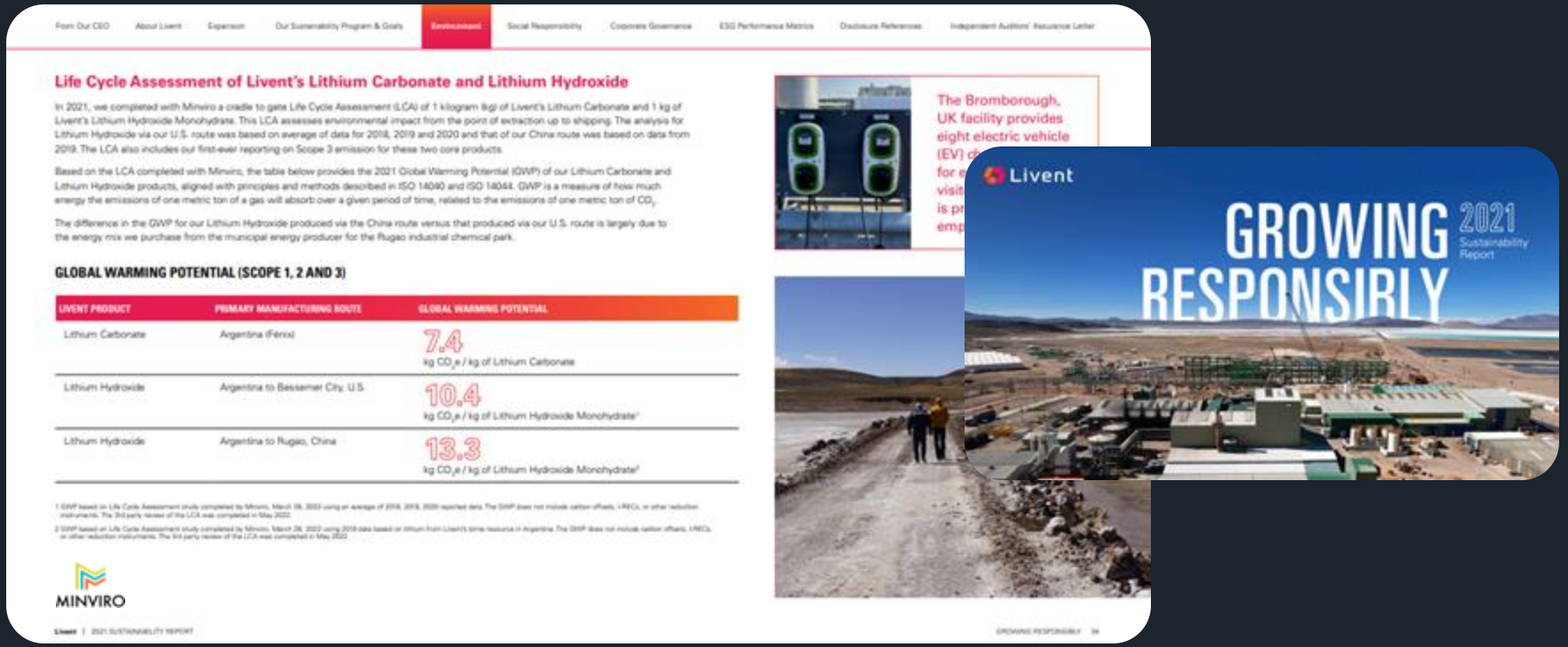


Company Case Studies

Life Cycle Assessment
In Action

Livent's Lithium Products

Lithium Carbonate and Hydroxide for Downstream Propulsion



From Our CEO | About Livent | Expansion | Our Sustainability Program & Goals | Environment | Social Responsibility | Corporate Governance | ESG Performance Metrics | Disclosure References | Independent Auditors' Assurance Letter

Life Cycle Assessment of Livent's Lithium Carbonate and Lithium Hydroxide

In 2021, we completed with Minviro a cradle to gate Life Cycle Assessment (LCA) of 1 kilogram (kg) of Livent's Lithium Carbonate and 1 kg of Livent's Lithium Hydroxide Monohydrate. This LCA assesses environmental impact from the point of extraction up to shipping. The analysis for Lithium Hydroxide via our U.S. route was based on average of data for 2018, 2019 and 2020 and that of our China route was based on data from 2019. The LCA also includes our first-ever reporting on Scope 3 emission for these two core products.

Based on the LCA completed with Minviro, the table below provides the 2021 Global Warming Potential (GWP) of our Lithium Carbonate and Lithium Hydroxide products, aligned with principles and methods described in ISO 14040 and ISO 14044. GWP is a measure of how much energy the emissions of one metric ton of a gas will absorb over a given period of time, related to the emissions of one metric ton of CO_2.

The difference in the GWP for our Lithium Hydroxide produced via the China route versus that produced via our U.S. route is largely due to the energy mix we purchase from the municipal energy producer for the Rugao industrial chemical park.

GLOBAL WARMING POTENTIAL (SCOPE 1, 2 AND 3)

LIVENT PRODUCT	PRIMARY MANUFACTURING ROUTE	GLOBAL WARMING POTENTIAL
Lithium Carbonate	Argentina (Fénix)	7.4 kg CO_2e / kg of Lithium Carbonate
Lithium Hydroxide	Argentina to Bessemer City, U.S.	10.4 kg CO_2e / kg of Lithium Hydroxide Monohydrate[1]
Lithium Hydroxide	Argentina to Rugao, China	13.3 kg CO_2e / kg of Lithium Hydroxide Monohydrate[2]

1 GWP based on Life Cycle Assessment study completed by Minviro, March 28, 2022 using an average of 2018, 2019, 2020 reported data. The GWP does not include carbon offsets, I-RECs, or other reduction instruments. The 3rd party review of the LCA was completed in May 2022.

2 GWP based on Life Cycle Assessment study completed by Minviro, March 28, 2022 using 2019 data based on lithium from Livent's brine resource in Argentina. The GWP does not include carbon offsets, I-RECs, or other reduction instruments. The 3rd party review of the LCA was completed in May 2022.

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Livent | 2021 SUSTAINABILITY REPORT

The Bromborough, UK facility provides eight electric vehicle (EV) ch... for e... visit... is pr... emp...

Livent

GROWING RESPONSIBLY 2021 Sustainability Report

GROWING RESPONSIBLY 39

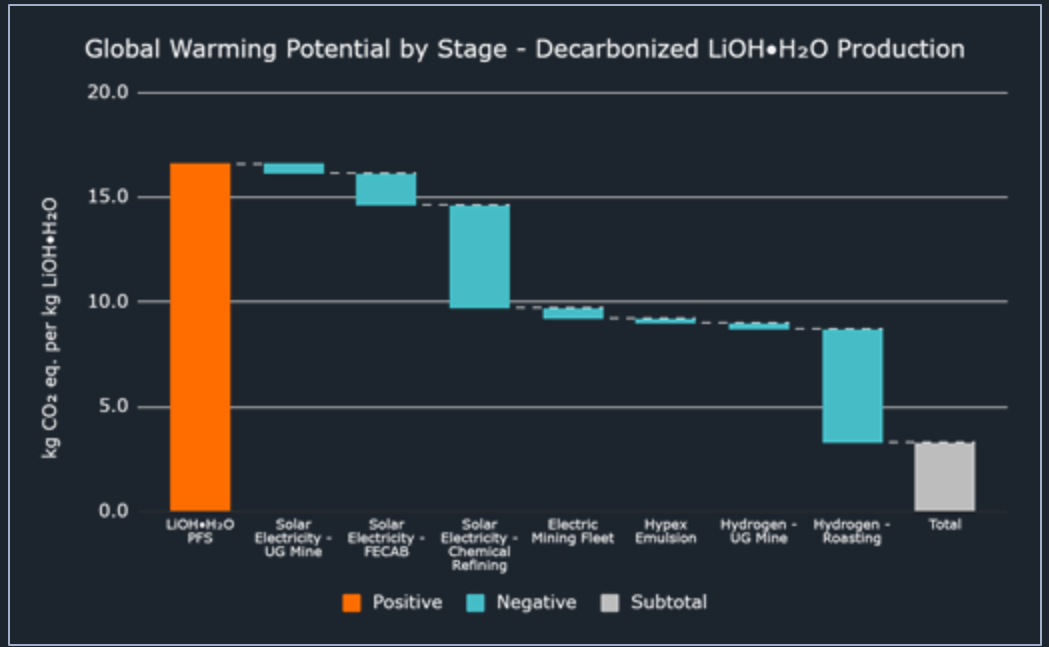
Lithium Decarbonisation

Impact reduction pathways

For battery-grade lithium hydroxide monohydrate produced from spodumene in Australia, some **initiatives** that help reduce the impact of the current process are evaluated.

Examples are:

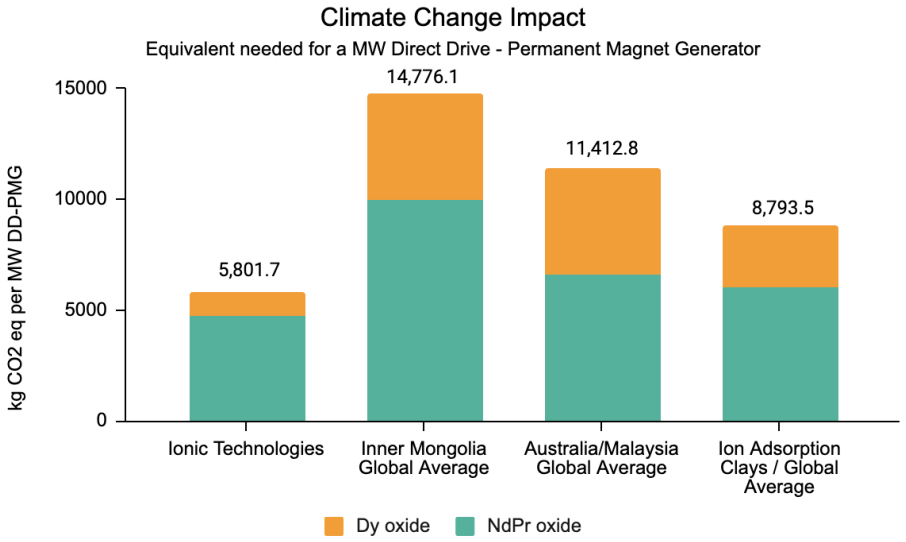
- Solar electricity, UG mine
- Solar electricity, chemical refining
- Electric fleet
- Hypex emulsion (nitrate free)
- Hydrogen for roasting

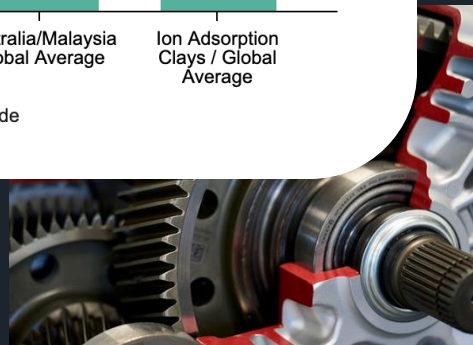


Ionic Technologies' REE Circularity

Circular REEs in the Powertrain Market, for Magnets

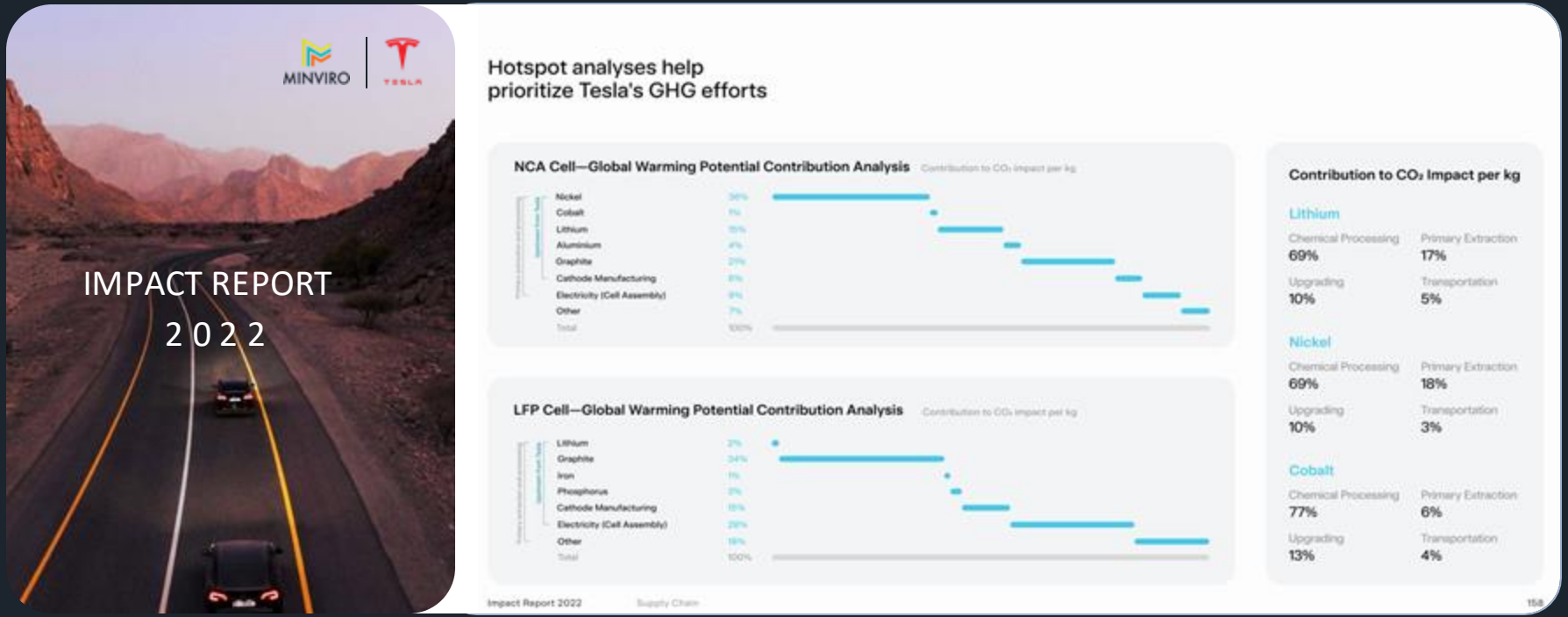
- Recycling of EoL magnets from wind turbine generators, to create **NdPr oxide and Dy oxide products, sold back to the magnet market**
- This study shows **significant reductions in CO_2 emissions** when compared with primary REE extraction
- Exciting implications and opportunities for **powertrain supply chain decarbonisation!**





Electric Vehicles - Battery Case Study

Tesla's NCA and LFP Batteries



Looking Beyond Climate Change

Looking beyond CO_2 emissions, for further environmental impact reductions

Climate Change

Ozone Depletion

Human Toxicity

Particulate Matter, Respiratory

Ionising Radiation, Human Health

Photochemical Ozone Formation

Acidification

Eutrophication

Ecotoxicity Freshwater

Land Use

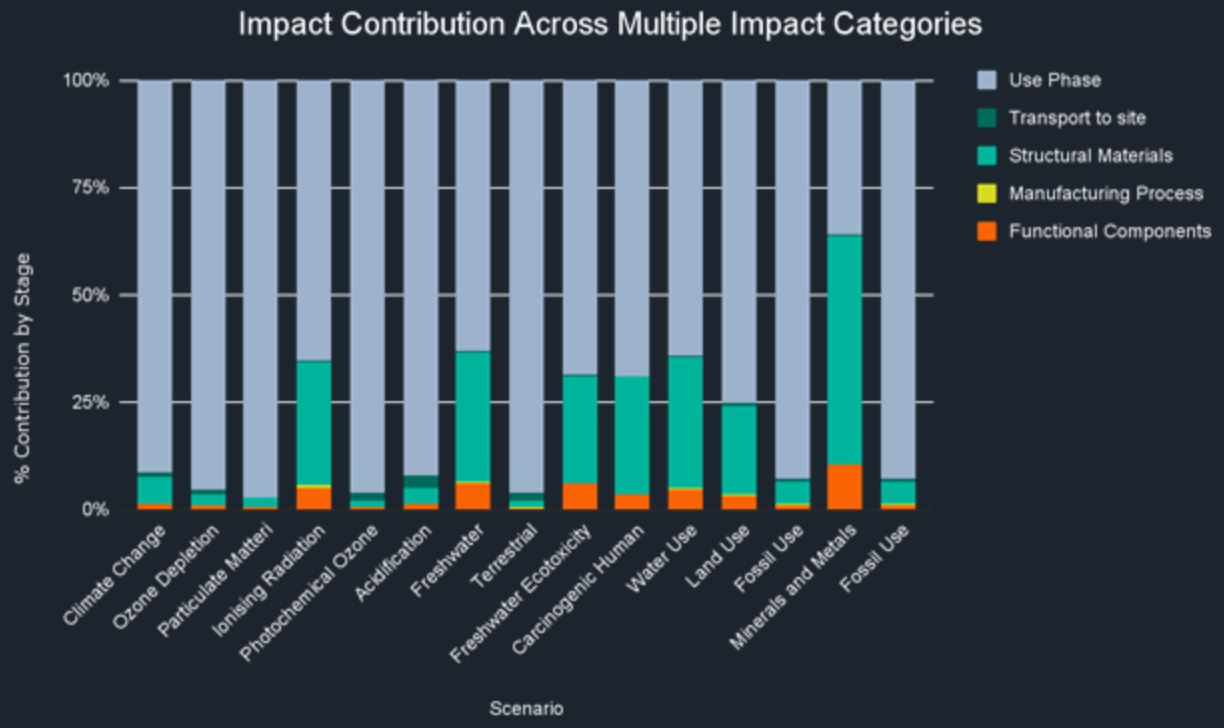
Water Scarcity Footprint

Resource Use Minerals & Metals

Resource Use, Energy carriers

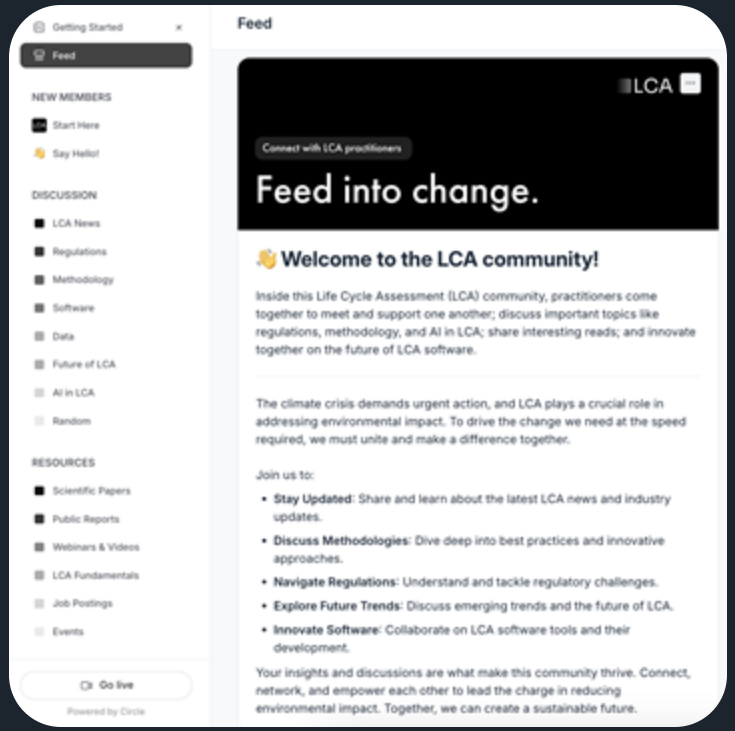
Looking Beyond Climate Change

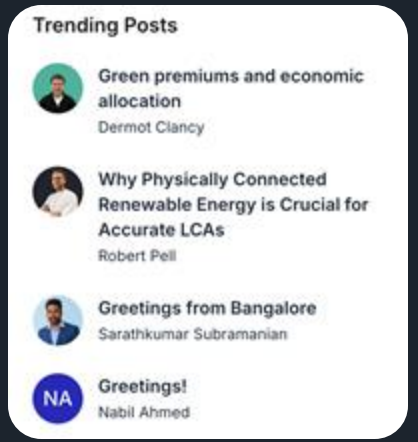
Looking beyond CO_2 emissions, for further environmental impact reductions



Join our LCA community for more

An active community with industry thought leaders, dedicated to the LCA conversation





156 Members

+15 Thought Leaders

MINVIRO

Thank you

Questions?

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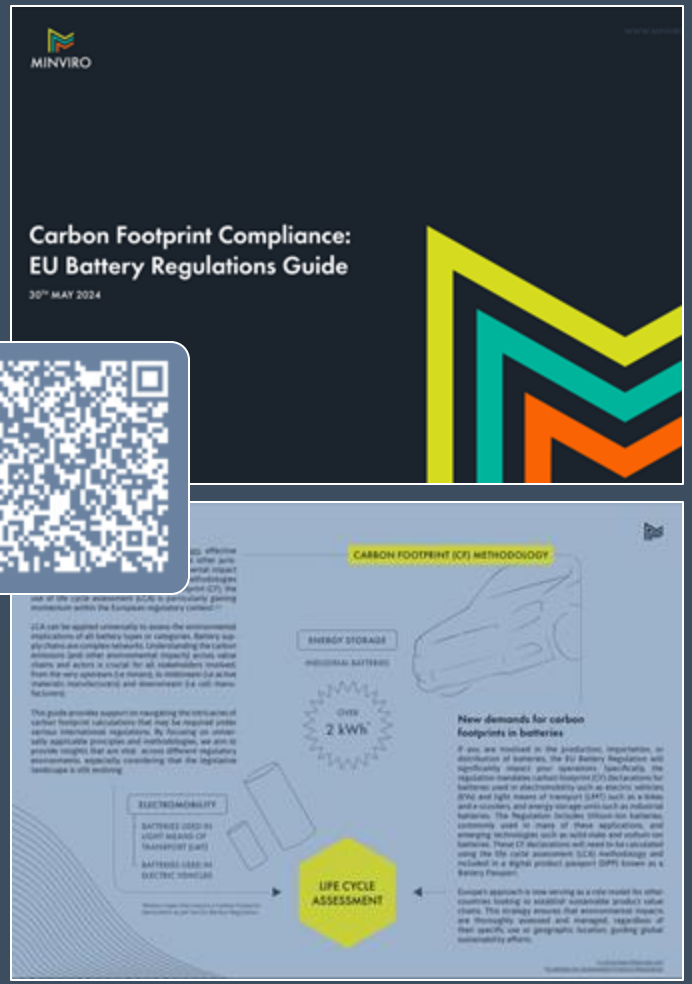
Appendix

Delegated Act: Carbon Footprint

10 LCA aspects to consider for accuracy and compliance with standards:

1. Cut-off criteria
2. Functional unit
3. Allocation hierarchy
4. Mandatory company-specific data
5. Non-mandatory most relevant processes
6. Representative EF-compliant datasets
7. Secondary data from commercial databases
8. Electricity modeling
9. Data quality
10. Declarations & verification



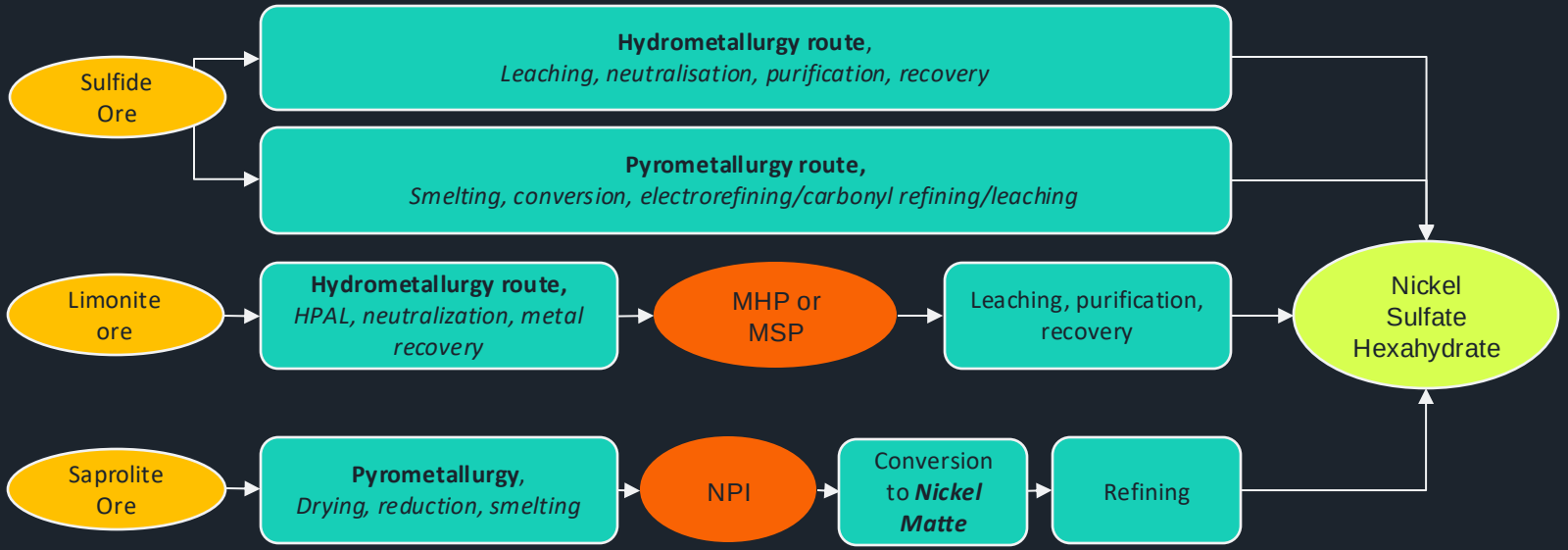
LCA Data and Database

Minviro's Nickel Supply Chain Data

Task: Assessing the environmental impact of Nickel Sulfate Hexahydrate

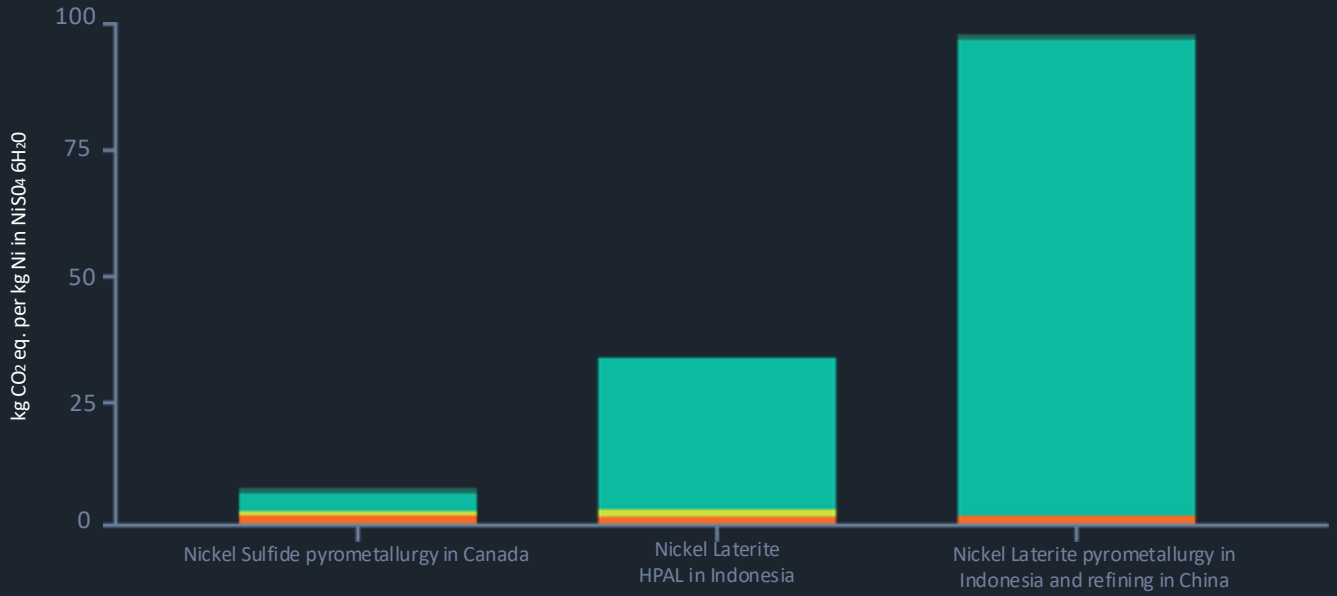
Functional unit:
1 kg battery-grade $NiSO_4.6H_2O$

Key points!
The impact varies depending on the deposit type and processing technologies



Nickel LCA

Nickel Sulfate Hexahydrate – Climate Change Impact By Stage



German Association of the Automotive Industry (VDA) commissioned Minviro to develop a climate change report on the climate change impact of three existing and emerging nickel sulfate hexahydrate production pathways.

VDA 2023 Nickel Sulfate Hexahydrate LCA Report