

# Exploring the environmental impacts of batteries and EV motors using LCA

Minviro is a consultancy and technology company applying life cycle assessment approaches to quantify and mitigate environmental impacts for mining and metals projects.

robert@minviro.com

### Quantifying environmental impacts

# Internationally recognised approach

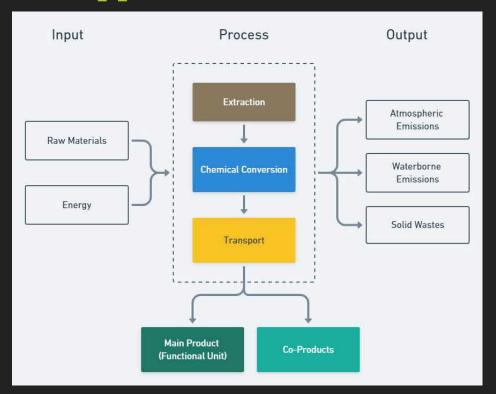
### What is a life cycle assessment?

Minviro's Life Cycle Assessment service is an inventory of environmental impacts tailored for mining, mineral processing and refining projects.

The LCA models a range of environmental impacts, ranging from CO<sub>2</sub> intensity to water use and particulate matter formation and complying with ISO 14040-14044 standards. ISO 14067 follows the same guidelines, only reporting on the climate change impact category.

Minviro's approach makes the environmental impacts of resource projects and operations clear and transparent through quantification.

Environmental hotspots are identified, providing insights into suitable mitigation strategies ensuring that the raw materials for the low-carbon economy are sourced at minimum environmental impact.

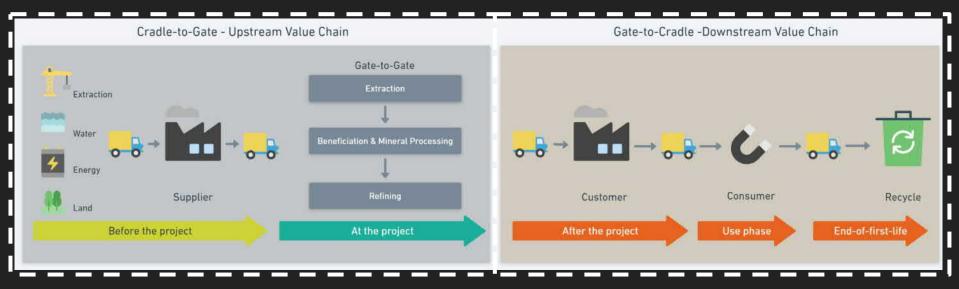


### Climate Change is one of many impact categories

## Global Warming Potential (kg CO<sub>2</sub> eq. per kg product)

Mining industry commonly reports on foreground processes:

- Scope 1 emissions: represents direct combustion of fuel and energy sources on site
- Scope 2 emissions: represent embodied emissions of consumed electricity
- Scope 3 emissions (upstream) represents embodied emissions of other consumables (eg. reagents)



# Impact of EV battery

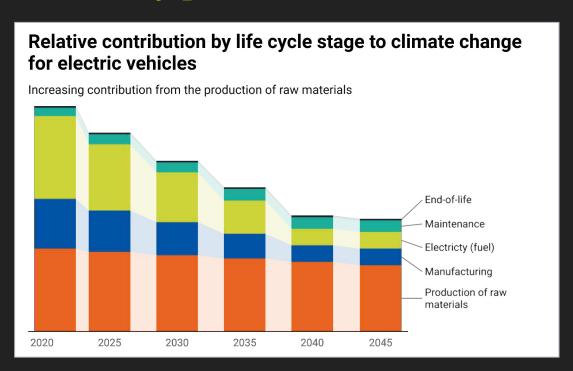


Impacts associated with EV battery production over time

# Trend for impacts for battery production

In the coming years, many regions will see increased renewable energy & lower CO<sub>2</sub> per kWh of power generated.

This will cut environmental impacts during the manufacturing and use phase of batteries and EVs, but the relative contribution to produce the raw materials will increase



Production of NMC-811

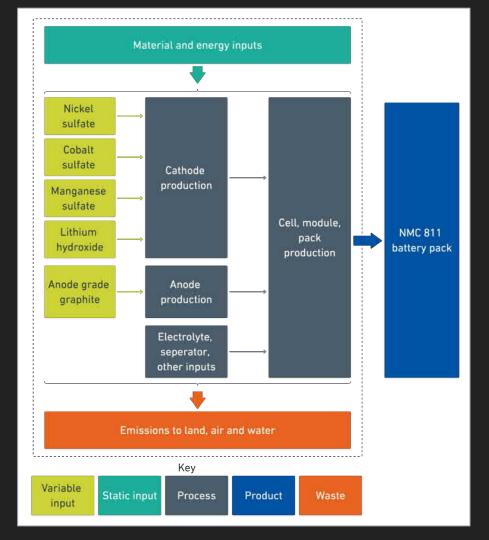
# System boundary

Functional unit - 1 kWh NMC-811

Cradle-to-gate study

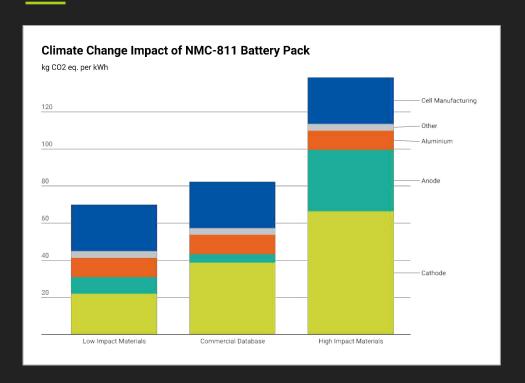
Production of nickel sulfate, cobalt sulfate, manganese sulfate, lithium hydroxide, and anode grade graphite from different production routes.

All other inputs are static in the model.



### Shifting the lens

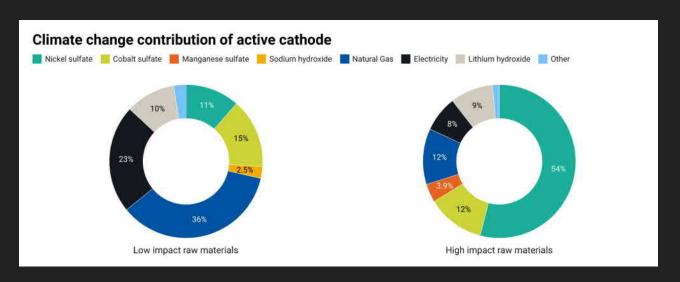
# LCA of battery raw materials





### Sourcing scenarios dictates the hotspots

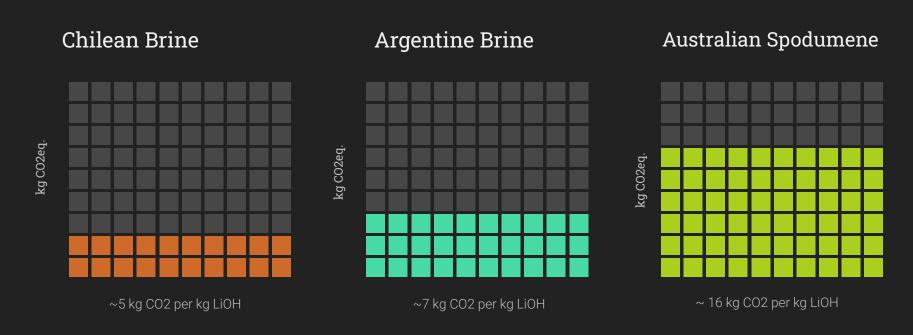
# Impact contribution to the cathode



This study of NMC-811 battery packs illustrates how sourcing different raw materials within a single supply chain can produce a wide range of impacts. Cathodes in particular are subject to highly variable climate change impacts depending on each precursor component.

The same functional material can have different environmental impacts

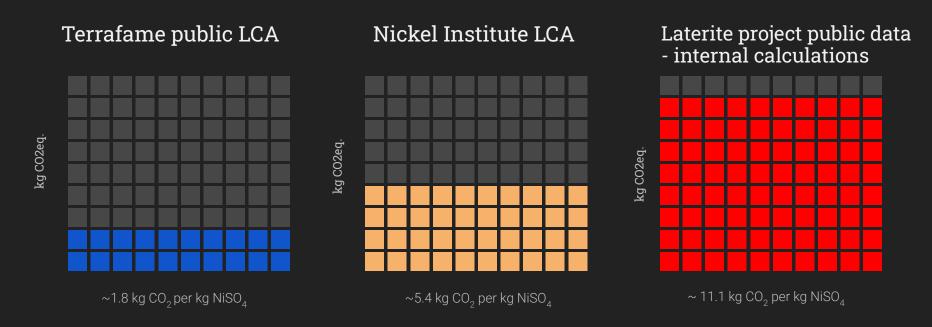
# Minviro's study on lithium hydroxide production



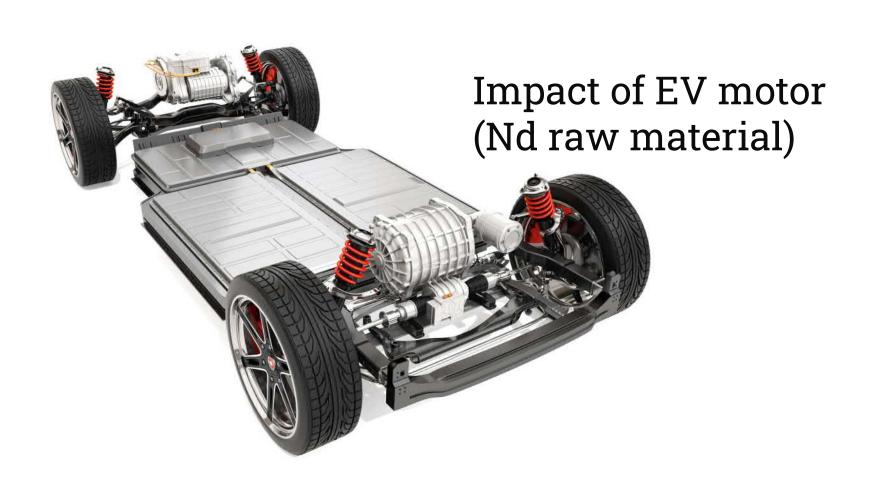
See the full whitepaper on this link: The Climate Change Impact of Lithium Hydroxide for the 2020s

The same functional material can have different environmental impacts

# Cradle-to-gate study on NiSO<sub>4</sub> production



The internal LCA calculations should not be considered as equivalent to an ISO compliant LCA and numbers should be interpret as indicative.

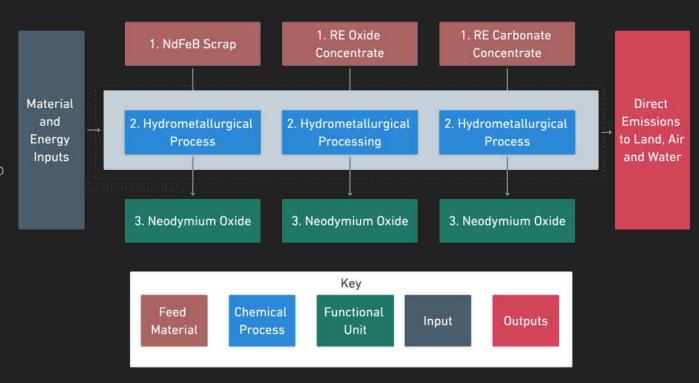


# System boundary for Nd

Functional unit: 1 kg of neodymium oxide

Processed through three different routes, all assumed to be based in China:

- Hydrometallurgical recycling of NdFeB magnet scrap (gate to gate)
- Production from rare earth oxide concentrate (Bayan Obo mine, cradle to gate)
- Production from rare earth carbonate concentrate (leaching of ion adsorption clays, cradle to gate)



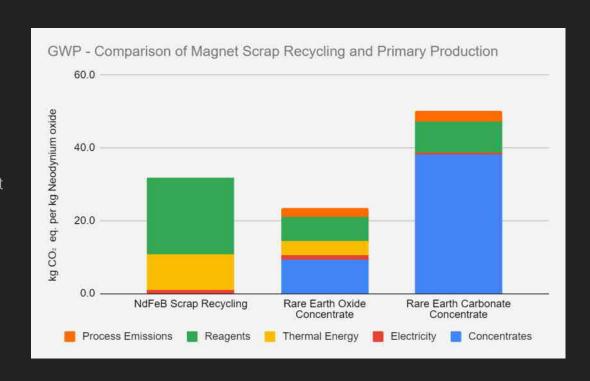
### Neodymium oxide

# Different production routes

GWP of NdFeB magnet scrap (31.8 kg  $\rm CO_2$  eq.) recycling is higher impact than the REO route (23.5 kg  $\rm CO_2$  eq.) but lower than the RE Carbonate route (50.2 kg  $\rm CO_2$  eq.)

For the rare earth carbonate route, the upstream production of producing rare earth carbonate concentrate is the largest impact driver: 38.1 kg CO<sub>2</sub> eq.

Relative contribution of process inputs (materials and concentrates) the largest GWP driver for each route.



### Nd scrap recycling impact

# Results - Climate change impact

Total impact of recycling process is 31.8 kg CO2 eq. per kg  $Nd_2O_3$ 

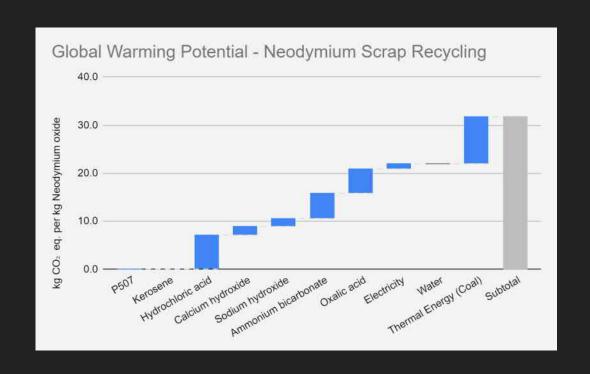
Thermal energy input from combusting coal has an impact of 9.7 kg  $CO_2$  eq. per kg  $Nd_2O_3$ 

Embodied impact of hydrochloric acid consumed in the process contributes 7.1 kg  $\rm CO_2$  eq. per kg  $\rm Nd_2O_3$ 

Oxalic acid and ammonium bicarbonate each contribute 5.1 kg CO<sub>2</sub> eq. per kg Nd<sub>2</sub>O<sub>3</sub>

Consumption of calcium hydroxide and sodium hydroxide in the process each contribute 1.7 kg CO<sub>2</sub> eq. per kg Nd<sub>2</sub>O<sub>3</sub>

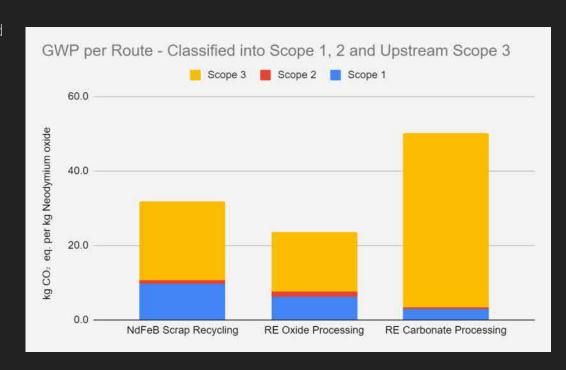
Use of electricity has an impact of 1.1 kg  $\rm CO_2$  eq. per kg  $\rm Nd_2O_3$ 

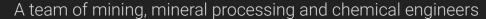


#### LCIA Results - GWP

### Scope emissions for magnet scrap recycling and primary production

- GWP for each production route is classified into scope 1, scope 2 and upstream scope 3 emissions
- Upstream scope 3 emissions (embodied impact of materials used) causes more than half of the impact for each route, ranging from 16 to 47 kg CO<sub>2</sub> eq. per kg Nd<sub>2</sub>O<sub>3</sub>
- Scope 1 emissions (process emissions or from combusting fuels on site) range from 2.9 to 9.7 kg CO<sub>2</sub> eq. per kg Nd<sub>2</sub>O<sub>3</sub>
- Scope 2 emissions (embodied impact of energy imported to site) contribute between 0.5 to 1.1 kg CO<sub>2</sub> eq. per kg Nd<sub>2</sub>O<sub>3</sub>







### Minviro's Team



Robert Pell PhD. Laurens Tijsseling Founder & Director

Robert founded Minviro after completing his PhD at Camborne School of Mines previously worked as a & Tsinghua. He is a specialist in REE.



Sustainability Manager

Laurens is Sustainability Manager at Minviro. He Process Engineer in Sibelco Group.



Phoebe Whattoff Sustainability Analyst

Phoebe is Sustainability Analyst at Minviro. She is a geologist by training and has of Lilac Solutions, a Silicon previously studied the carbon sequestration potential of minerals.



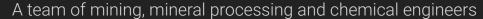
**Alex Grant** Snr. Lithium Expert

Alex is Principal at Jade Cove Partners & co-founder Valley direct lithium extraction technology company.



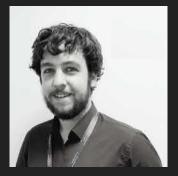
David Deak PhD. Snr. Lithium Expert

David obtained his PhD at the University of Oxford. His experience includes Tesla, Lithium Americas and currently works with Azimuth Capital Management





### Minviro's team



Conor Hickey
Snr Full Stack Developer

Conor has completed a undergraduate and masters in software development. He has extensive experience developing both front and back end having previously worked with Ericsson.



Feruzjon Majidov

Junior Developer

Feruzjon recently completed undergrad studies in software development.



Jordan Lindsay
Sustainability Analyst

Jordan recently completed his PhD at Camborne School of Mines and has experience in mining engineering. His PhD was focussed on PGM geology.



Carolina Paes
Sustainability Analyst

Carolina is MSc in Sustainable and Innovative Natural Resources Management with knowledge on LCA for Lithium and Cobalt.



Prof. Frances Wall
Academic Advisor

Frances has extensive experience in rare earth geology and has worked on a number of sustainability focused research projects.

Business Green Leaders Awards 2021 SHORTLISTED

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Thank you

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info@minviro.com

### More than carbon accounting

# Life Cycle Impact Categories

1 Global Warming Potential

(kg CO2 eq)

Radiative forcing as Global Warming Potential (GWP100)

Ozor.

Ozone depletion

(kg CFC-11 eq)

Steady-state ozone depletion potential

3

**Human Toxicity** 

(CTUe)

Comparative toxic unit for humans as provided in the USEtox 2.1.

4

#### Particulate Matter

(Disease incidence)

Human health effects associated with exposure to PM2.5 from the PM method recommended by UNEP 5

### **Ionising Radiation**

(kBqU)

Human exposure efficiency relative to U235 using the Human health model as developed by Dreicer et al 1995 6

#### Photochemical ozone formation

(kg NMVOC)

Tropospheric ozone concentration increases from LOTOS-EUROS as applied in ReCiPe 2008

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### Internationally accepted and best practice

# Life Cycle Impact Categories

7

#### Acidification

(Mol H+ eq)

Accumulated Exceedance



### Eutrophication

(Mol N eq)

Accumulated Exceedance



#### Ecotoxicity freshwater

(CTUe)

Comparative toxic units for ecosystems derived from USEtox 2.1.derived from the HC20 instead of the HC50.



#### Land Use

(Dimensionless)

Soil quality index (biotic production, erosion resistance, mechanical filtration and groundwater replenishment) based on LANCA



#### Water Use

(kg world eq. deprived)

User deprivation potential (deprivation-weighted water consumption) from the AWARE method



#### Resource Use

(MJ)

Abiotic resource depletion from fossil fuels using CML