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Towards development of sustainable battery industry
Focus: use of LCAs in battery industry

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Enabling the future of energy

Northvolt was founded with the mission to build the **world's greenest battery** and enable the transition to a decarbonized society and industry.

- European leadership with European roots
- World's greenest battery
- Unique vertical integration done at scale
- Industry leading technology and industrialization platform

"A battery will do for the electricity supply chain what refrigeration did to our food supply chain"

Prof. Donald Sadowav

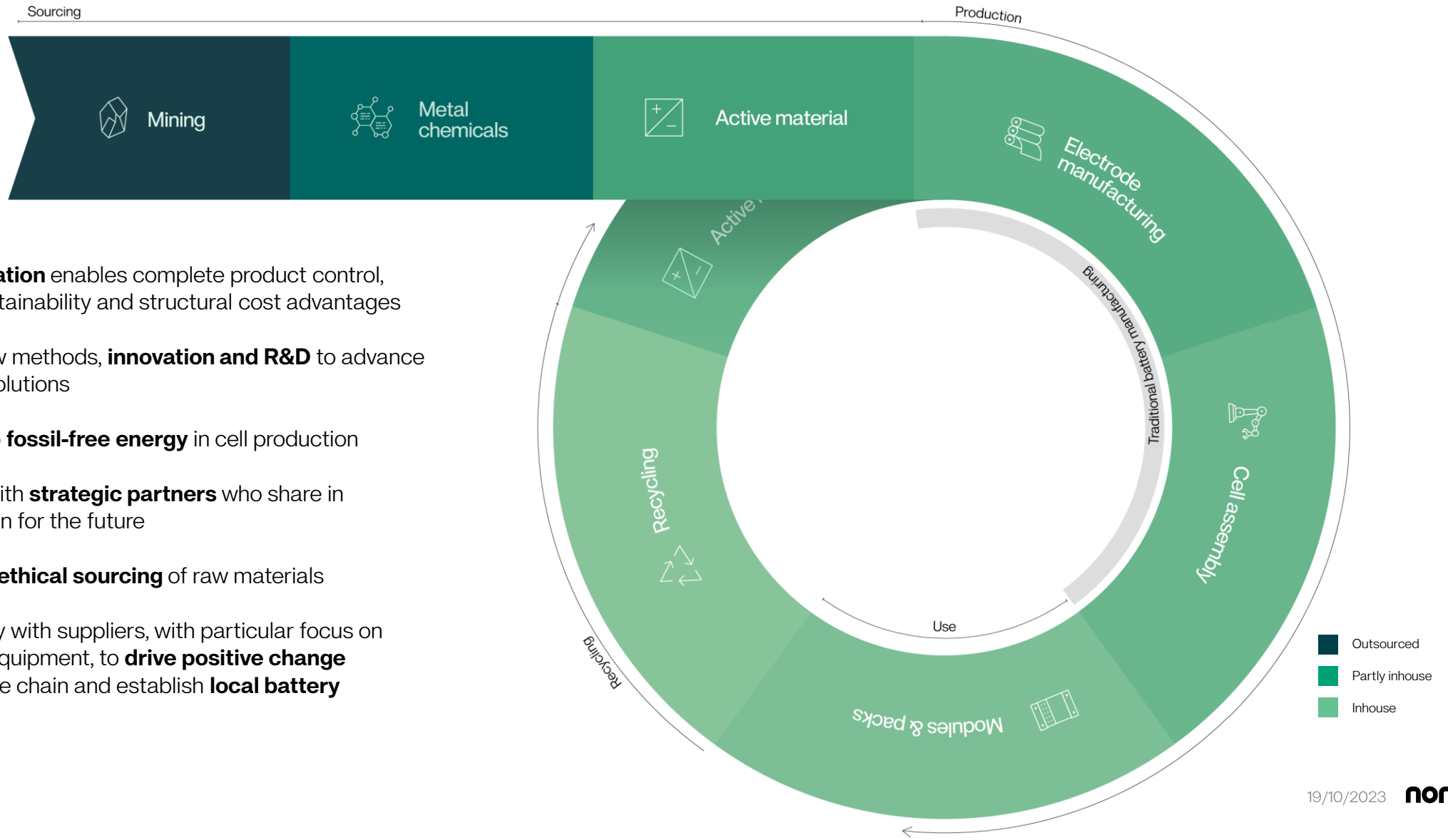
Electrochemist, MIT Materials Science

7	**$9 bn**	**$55 bn**	**5000**
Years since foundation	Raised to date in equity, debt and grants	Contracted order book	Employees from 100+ nationalities

An expanding presence

1. **Northvolt Ett**
   Skellefteå, Sweden
2. **Northvolt Dwa**
   Gdansk, Poland
3. **Northvolt Drei**
   Heide, Germany
4. **Northvolt–Volvo Joint Venture**
   Gothenburg, Sweden
5. **Northvolt Fem**
   Borlänge, Sweden
6. **Northvolt SIX**
   Montreal, Canada
7. **Northvolt Labs**
   Västerås, Sweden
8. **Volthouse**
   Stockholm, Sweden
9. **Hydrovolt**
   Fredrikstad, Norway
10. **Cuberg**
    San Francisco Bay Area, USA
11. **Aurora Lithium**
    Setúbal, Portugal

Vertical integration across the battery supply chain



- ✓ **Vertical integration** enables complete product control, traceability, sustainability and structural cost advantages
- ✓ Embrace of new methods, **innovation and R&D** to advance products and solutions
- ✓ Commitment to **fossil-free energy** in cell production
- ✓ Collaboration with **strategic partners** who share in Northvolt's vision for the future
- ✓ **Sustainable & ethical sourcing** of raw materials
- ✓ Working actively with suppliers, with particular focus on materials and equipment, to **drive positive change** throughout value chain and establish **local battery ecosystem**

A holistic approach to sustainability from the start

Ensuring that decarbonization does not come at the expense of people and nature

Northvolt commits to sustainability across all activities:

Slashing the carbon footprint

Targeting **10kg CO2/kWh** for battery cell production by 2030

Engaging with and supporting suppliers on decarbonization roadmaps.

100% fossil free fuel in our production.

10 kg CO_2e/kWh

Northvolt's 2030 emission goal for battery cells, covering scope 1,2,3

Recycling- limiting fresh resource use

Targeting a **50% recycled content** in our cells by recycling by 2030

Raw Materials recycled through our own **Revolt** facilities.

Implementing energy efficiency and circularity in our production processes

50%

recycled material target in new battery cells by 2030

Responsible Supply Chains

A holistic approach to sustainability, with **100% traceability** of key raw materials

Detailed **due diligence** of suppliers

Strong commitment to supporting communities, policies and legislative change

100%

Traceability target for all metals and key raw materials

Key components in NMC cells include:

Cathode: Ni, Mn, Co, Li

Anode: Graphite, Si

Cells: Cu foil, Alu foil, electrolyte, separators, steel or alu cans etc.

Deepdive: LCA at Northvolt

1. Use of Life cycle thinking to make sustainable decisions
   - Tracking impacts across the product development phase
   - Identifying and improving hotspots

2. Northvolt LCA results
   - Importance of primary data
   - Underrepresented secondary data
     - Nickel
     - Graphite

3. Methodological choice and the implications on the LCAs
   - Functional unit
   - Scope

4. Recycling and Circular thinking
   - Closing the loop
   - Improving environmental impacts of recycling using LCAs

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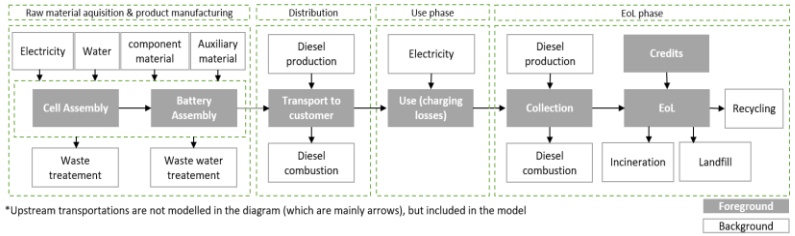
Monitoring and improving the environmental performance of battery production

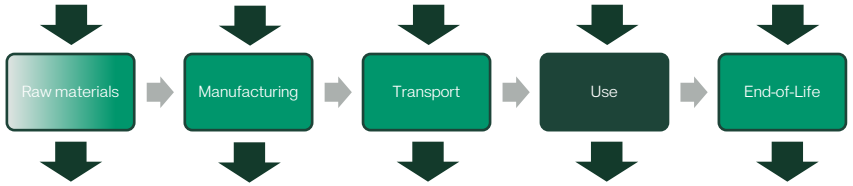
With the **iterative life cycle thinking** Northvolt is developing processes and supply chains which are designed to be sustainable, where early on process and product design choices include the impact reduction as a key step

Example: Iterative life cycle environmental impact assessment coupled with measured data

Analysis over product lifetime



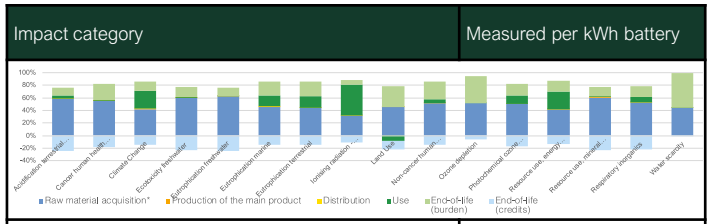
Resource consumption: energy, water, chemicals, raw materials, land



Emissions: land, water, air, radiation, biproducts

Specific improvement measures to be implemented either directly or with the help of different stakeholders in product life cycle stages

Identification on product life cycle stage specific improvement measures and implementation in next design iteration



Impact category	Measured per kWh battery
Acidification terrestrial and freshwater	[Mole of H+ eq.]
Cancer human health effects	[CTUh]
Climate Change (carbon footprint)	**[kg CO2 eq.]**
Ecotoxicity freshwater	[CTUe]
Eutrophication freshwater	[kg P eq.]
Eutrophication marine	[kg N eq.]
Eutrophication terrestrial	[Mole of N eq.]
Ionising radiation- human health	[kBq U235 eq.]
Land Use	[Pt]
Non-cancer human health effects	[CTUh]
Ozone depletion	[kg CFC-11 eq.]
Photochemical ozone formation - human health	[kg NMVOC eq.]
Resource use, energy carriers	[MJ]
Resource use, mineral and metals	[kg Sb eq.]
Respiratory inorganics	[kg PM2.5 eq.]
Water scarcity	[m³ world equiv.]

Estimated product environmental impacts and identification of key hotspots early on

Production and monitoring

1. Construction of the facilities
2. Monitoring the production phase impacts and resource consumptions
3. Planning the improvements in current operation and design of the next setup

Key takeaway :
Energy, resources (water, gases) and chemicals (NMP, ammonia) consumed are calculated and optimized in the similar fashion to improve the environmental performance of the products and production processes

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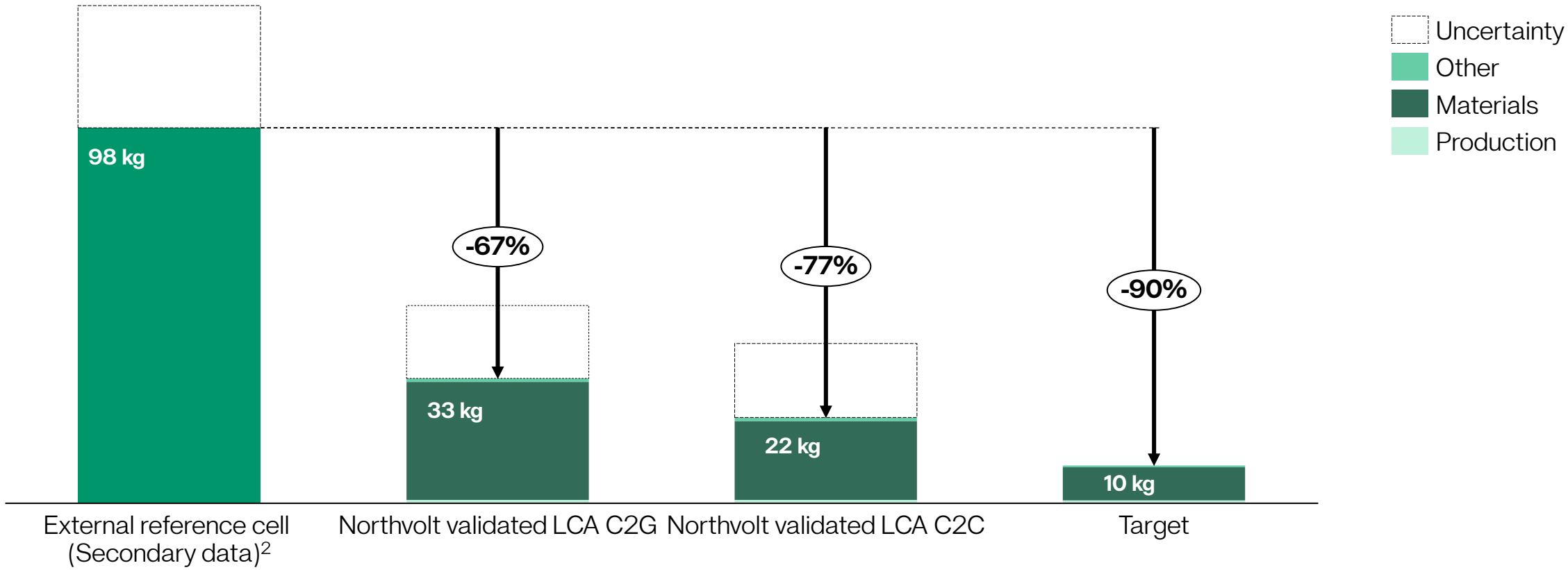
ISO 14040:2006
ISO 14044:2006

Northvolt LCA results

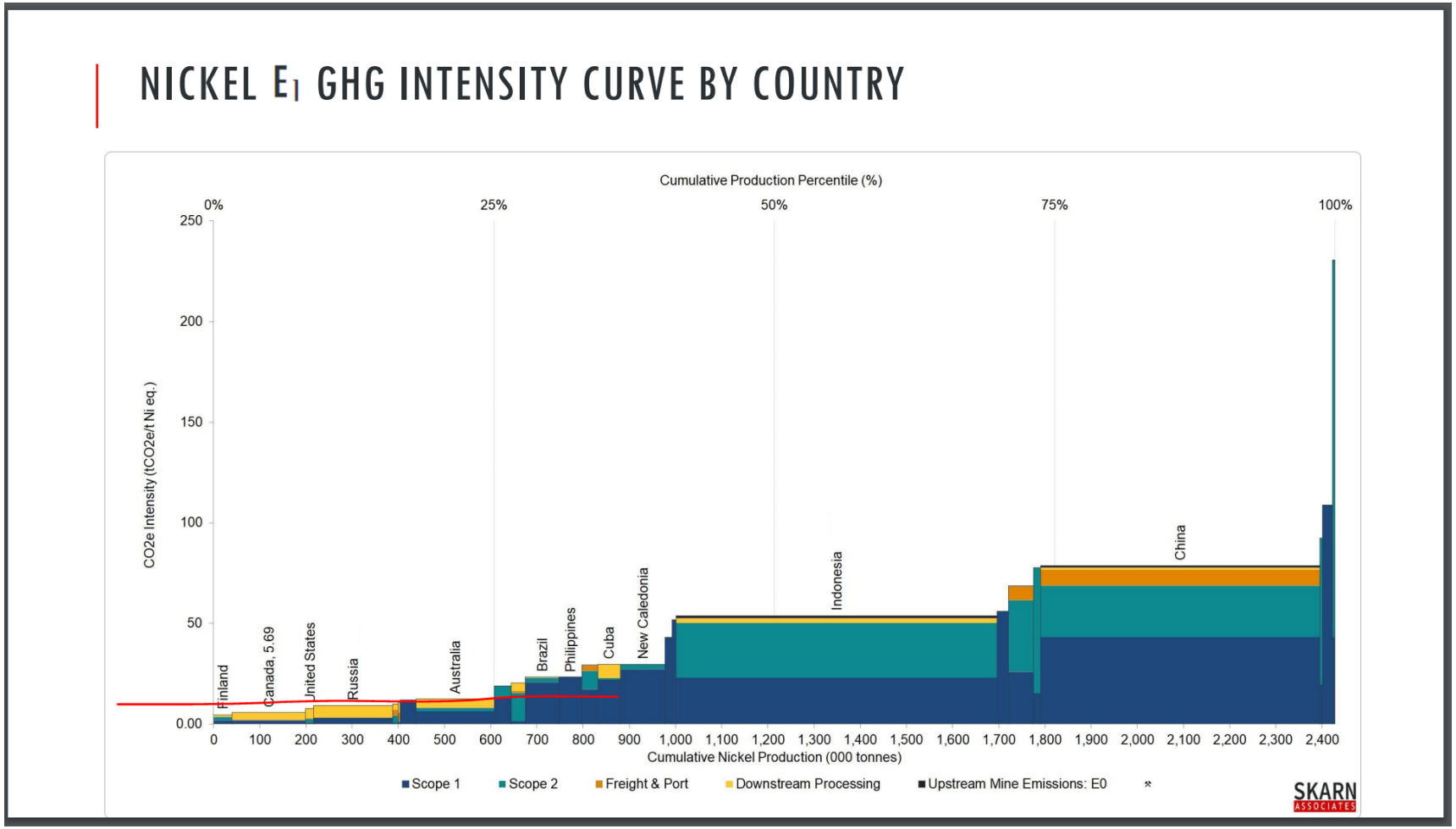
The LCAs allow Northvolt to quantify the product lifecycle impacts, identify the hotspots and draw detailed emission reduction measures in order achieve the carbon footprint target **10 kg CO_2/kWh** cell energy by 2030.

Projected cell carbon footprint[1] (kg CO2/kWh)



1: LCA performed using PEF methodology, EF2,0 impact assessment method and database
2: Industry reference IVL2019, NMC 111 cell

Underrepresentation of CF modelled by secondary datasets



Key Takeaway:

- Secondary datasets need to be improved and continuously updated
- Without uncertainty analysis there is limited incentive to use primary data if secondary data is not actual average but more optimistic representation

https://mining.ca/wp-content/uploads/dlm_uploads/2021/12/Introducing-Skarn-October-2021.pdf

Underrepresentation of CF modelled by secondary datasets

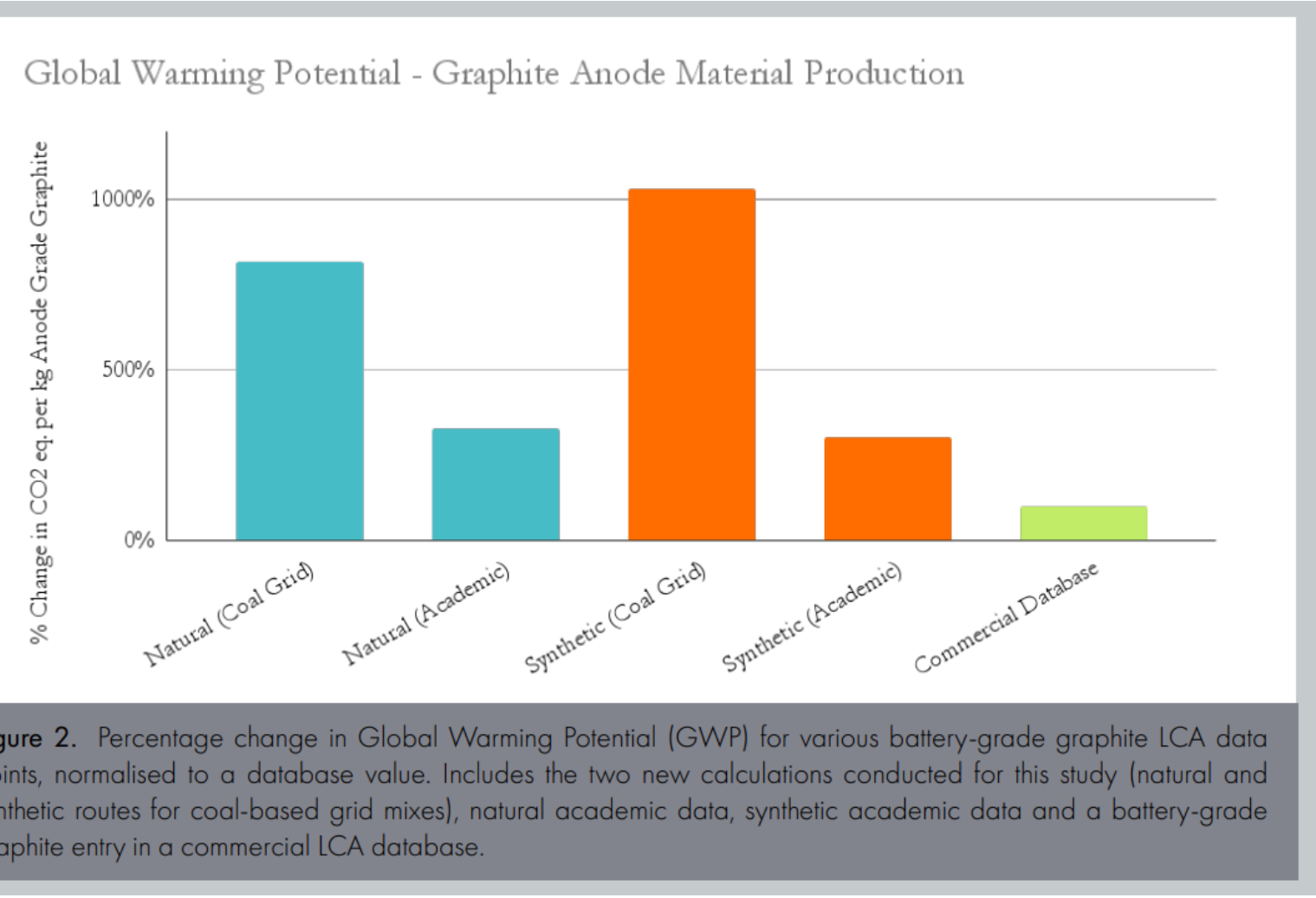


Figure 2. Percentage change in Global Warming Potential (GWP) for various battery-grade graphite LCA data points, normalised to a database value. Includes the two new calculations conducted for this study (natural and synthetic routes for coal-based grid mixes), natural academic data, synthetic academic data and a battery-grade graphite entry in a commercial LCA database.

It is very crucial to have correct representation of materials and not have a proxy processes which do not have similar mass and production processes.

https://www.minviro.com/wp-content/uploads/2021/07/Climate-Impact-of-Graphite-Production.pdf

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Setting the scene for battery LCA

Functional units:

- Per kg of battery
- Per battery cell
- Per kWh energy capacity
- Per kWh of energy delivered

System Boundary:

- Cradle to cradle
- Cradle to Gate
- Gate to gate

What is the goal of this LCA ?

Key Takeaways:

- There are various ways to set the boundary conditions for an LCA but it is always important to ask a question “why”?
- Each methodological choice has its merits and can shed light on different section of the value chain and drive different conclusions
- One thing is very clear

Materials are key to decarbonize batteries!

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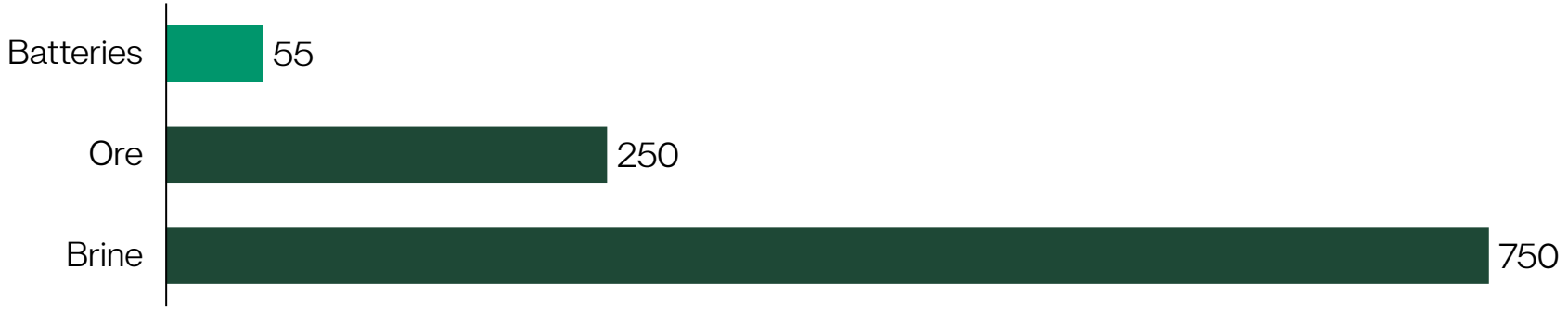
Resource consumption - Recycled vs Virgin material

Lithium: Amount of material treated to extract 1 ton



Cobalt: Amount of material treated to extract 1 ton

Amount of material treated to recover per ton metal are **significantly lower** when recycled from Li-ion batteries reaching their end-of-life compared to virgin extraction from the respective ore.

Recycling process & environmental benefit

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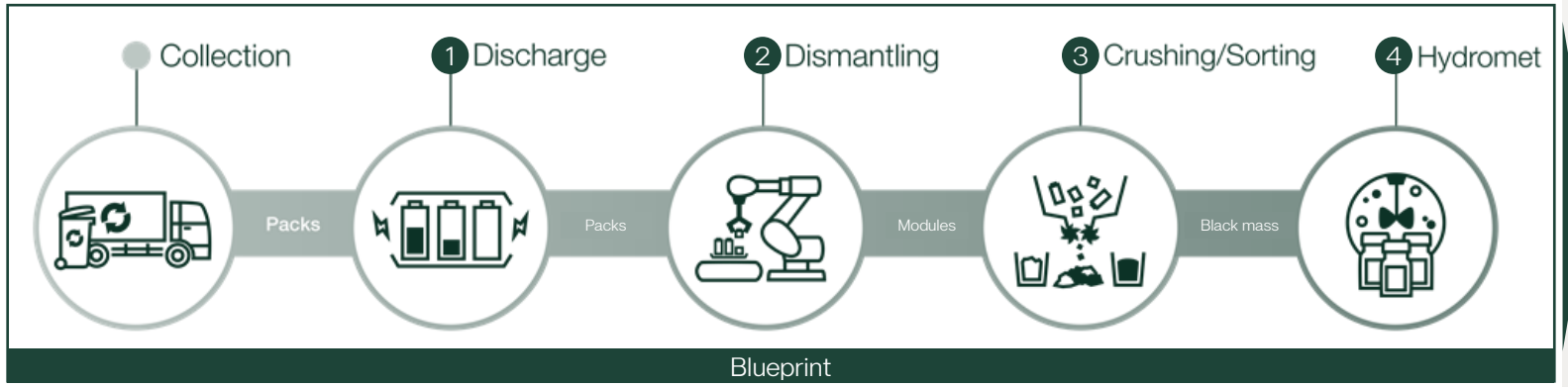

1 Discharging
Discharge batteries of all energy to make them safe to recycle. Energy will be recovered to power later steps in the recycling process.

2 Dismantling
Remove the modules from the packs via manual or robot dismantling

3 Crushing and sorting
Using a variety of techniques to separate fractions of metals and plastics. Electrolyte is also isolated and recovered

4 Hydrometallurgical treatment
Purify to recover materials that can be used in the production of fresh batteries

Use of recycled material could decrease CO_2 footprint even further
compared to Northvolt green production setup using virgin materials.

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