Critical raw materials for Electric Vehicles

Final online workshop Austria of IEA HEV TCP Task 40

15.12.2022, 2 – 4:30 p.m.

International Energy Agency

hevtcp

CRM4EV
Critical Raw Materials Electric Vehicles

International Collaboration

This work is hosted by JOANNEUM RESEARCH within the **Technology Collaboration Programm** (TCP) on **Hybrid & Electric Vehicles** (HEV)

of the **International Energy Agency** (IEA)

in **Task 40 CRM4EV Critical Raw Materials for Electric Vehicles**

Objective: share and disseminate information in workshops and reports with stakeholders from international research, industry and public institutions

Organisation:

- Bert Witkamp / Valuad, Belgium, Operating agent of Task 40
- 12 countries participating in Task 40
- BMK as Austrian ExCo representative in the TCP HEV
- JOANNEUM RESEARCH as Austrian designated partner in Task 40
- The Austrian participation is financed by
- www.ieahev.org

Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

FFG
Forschung wirkt.

Please mute your microphone (and camera) during presentations!

After each presentation we have 5 min for questions directly related to the presentation.

After the block of presentations we have 15 min time for overall discussion.

Please write your question into the chat and to whom you adress the question.

The workshop will be recorded.

The presentations are planned to be made available (via website of Joanneum Research)

Agenda of the Workshop

Workshop objectives are to disseminate results of Task 40 to Austrian stakeholders (2 presentations) and to support networking between Austrian stakeholders and research activities (3 presentations)

- *14:00 – 14:10* **Welcome**
- *14:10 – 14:35* **Overview of results from international network activities in IEA HEV Task 40 Critical Raw Materials for Electric Vehicles** (Bert Witkamp, Operating Agent Task 40)
- *14:35 – 15:00* **Critical raw materials in the context of battery life cycle assessment** (Martin Beermann, JOANNEUM RESEARCH, Institute LIFE for Energy, Climate and Society)
- *15:00 – 15:25* **Responsible sourcing of minerals** (Marie-Theres Kügerl, Montanuniversität Leoben, Chair of Mining Engineering and Mineral Economics)
- *15:25 – 15:50* **Future Li-Ion battery recycling** (Elizaveta Cheremisina, K1-MET, Metallurgical Competence Center)
- *15:50 – 16:15* **Perspectives of battery development based on non-critical raw materials** (Ilie Hanzu, TU Graz, Institute for Chemistry and Technology of Materials)
- *16:15 – 16:30* **Discussion and closing remarks**

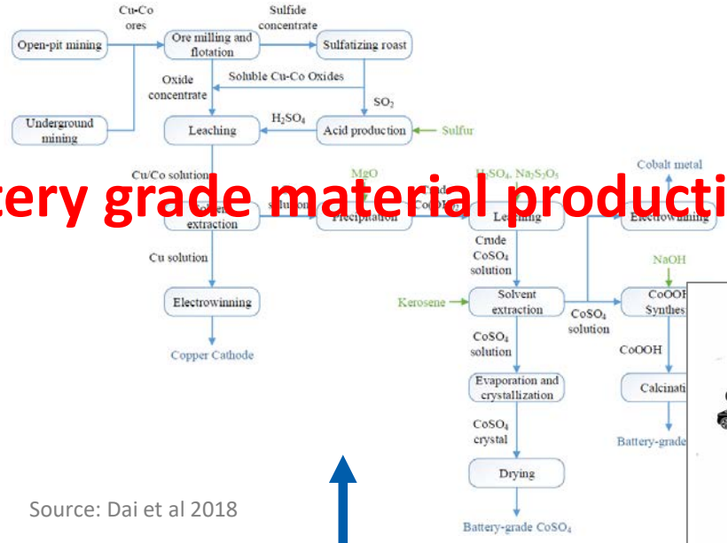
Critical raw materials in the context of battery life cycle assessment

Martin Beermann

Final online Workshop of IEA HEV TCP Task 40
15.12.2022

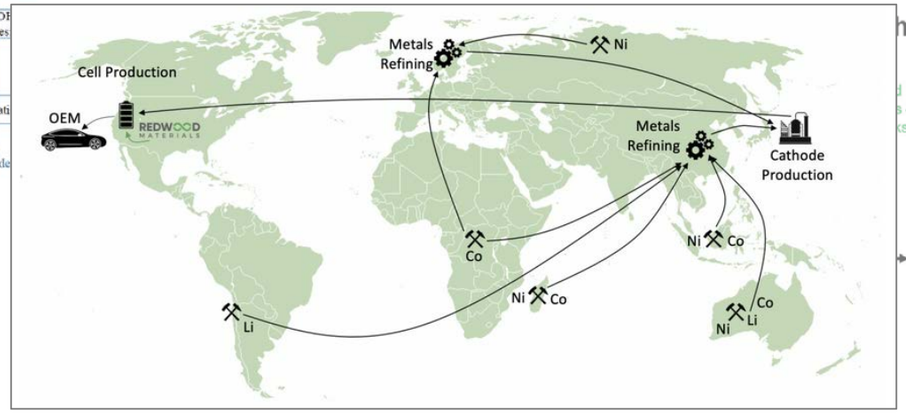
JOANNEUM RESEARCH LIFE

EV production is based on many different raw materials, processes and energy carriers in different regions around the globe

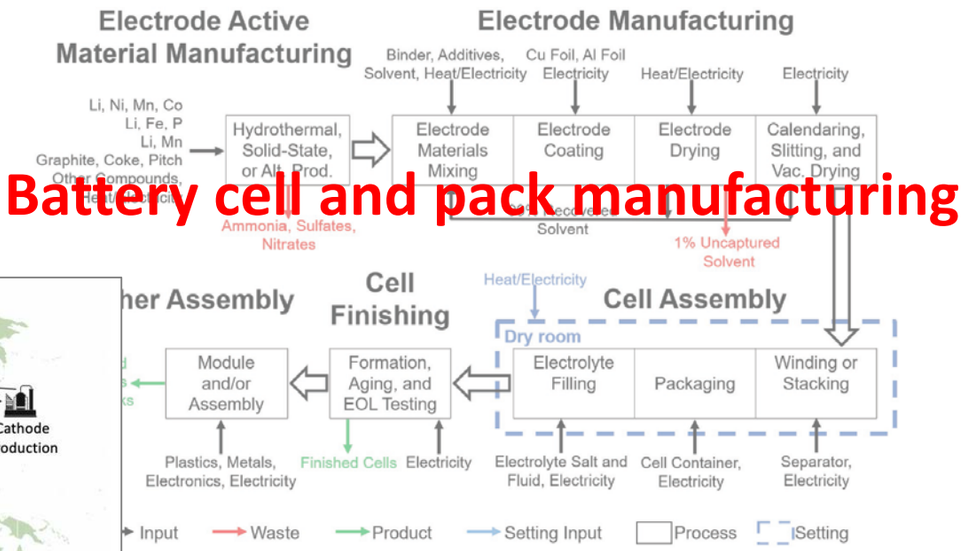


Source: Dai et al 2018

Battery grade material production

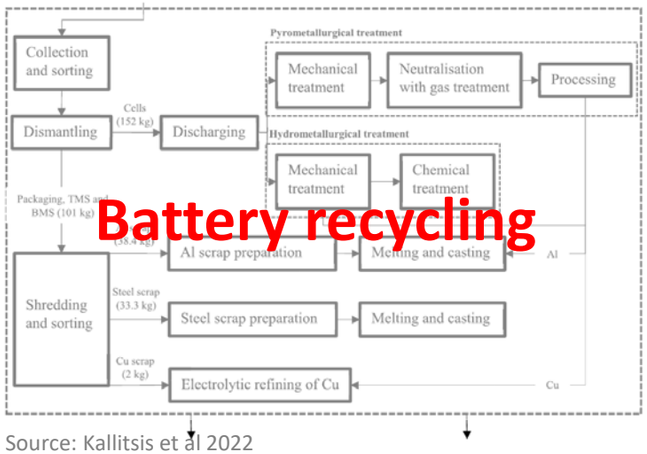


Source: Redwood materials 2022



Source: Porzio et al 2021

Battery cell and pack manufacturing



Source: Kallitsis et al 2022

Battery recycling

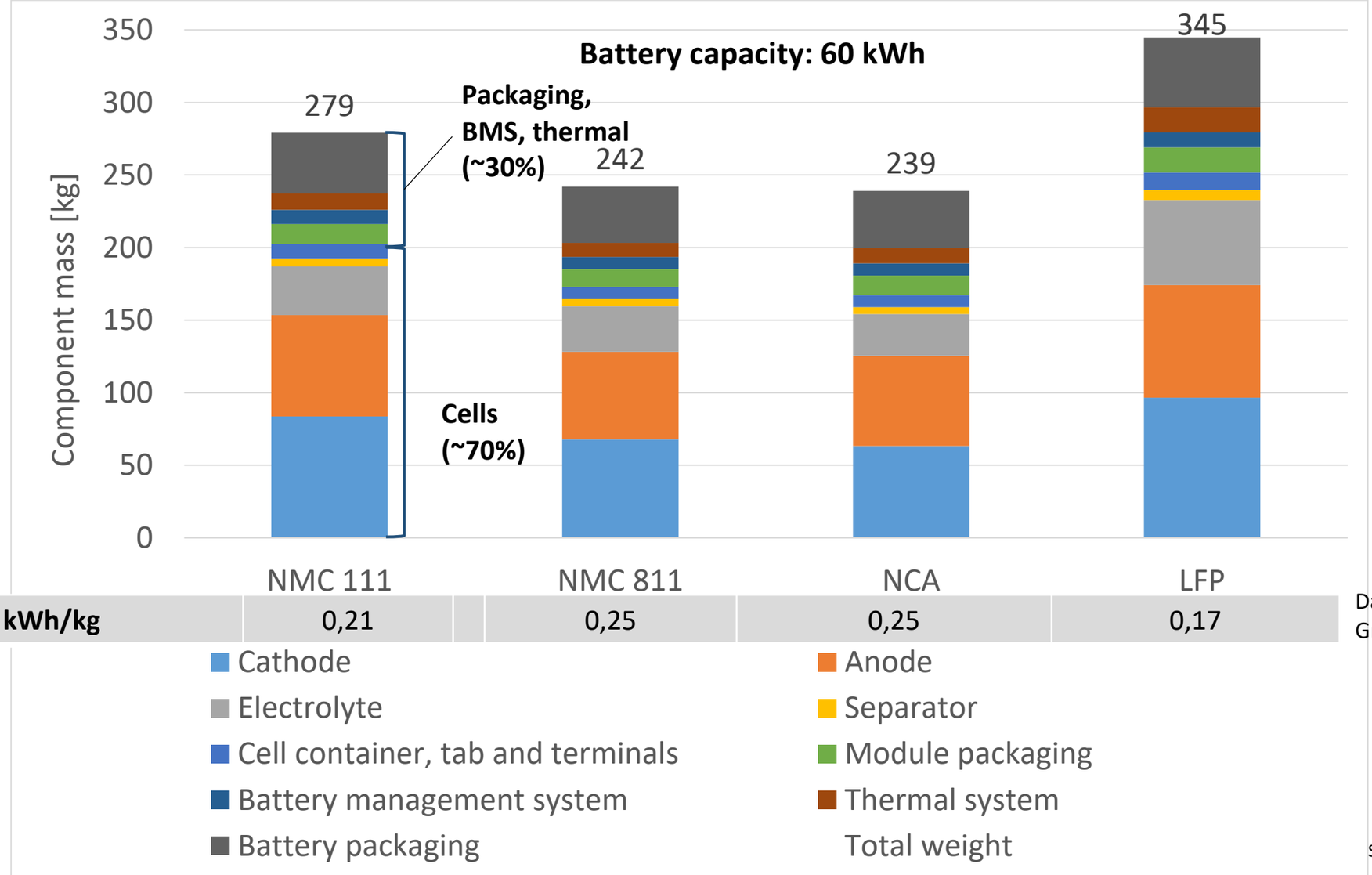
Source: Falk et al 2020

Battery first / second life

Motivation, benefit and challenge of battery LCA

- **Motivation:** EVs are backbone of mobility transformation to reach climate targets (Zero GHG emissions during EV use), but EV production (and EoL) also requires transformation (Zero GHG emissions upstream and downstream)
- **Benefit:** Life Cycle Assessment (LCA) includes all upstream and downstream processes of the value chain and offers insights into the impacts of EV / battery production and contributions of energy carriers / materials / regions
- **Challenge:** consistent data collection and modelling covering complex process chains, considering
  - Dynamic field of technology developments (e.g. battery chemistries, recycling technologies)
  - Primary data availability in all sectors (limited due to non-disclosed industrial data or future technologies), good examples covering todays production are:
    - Argonne US (Task 40 partner) with the most consistent primary data source published
    - Nickel Institute (Task 40 partner) with recent averaged LCA-data on Nickel-production published
  - Variety of influencing parameters on LCA results
- **Objective of this LCA-presentation:** give an insight into relevant parameters of material and battery production and recycling on GHG emissions

EV Batteries – mass balance of components

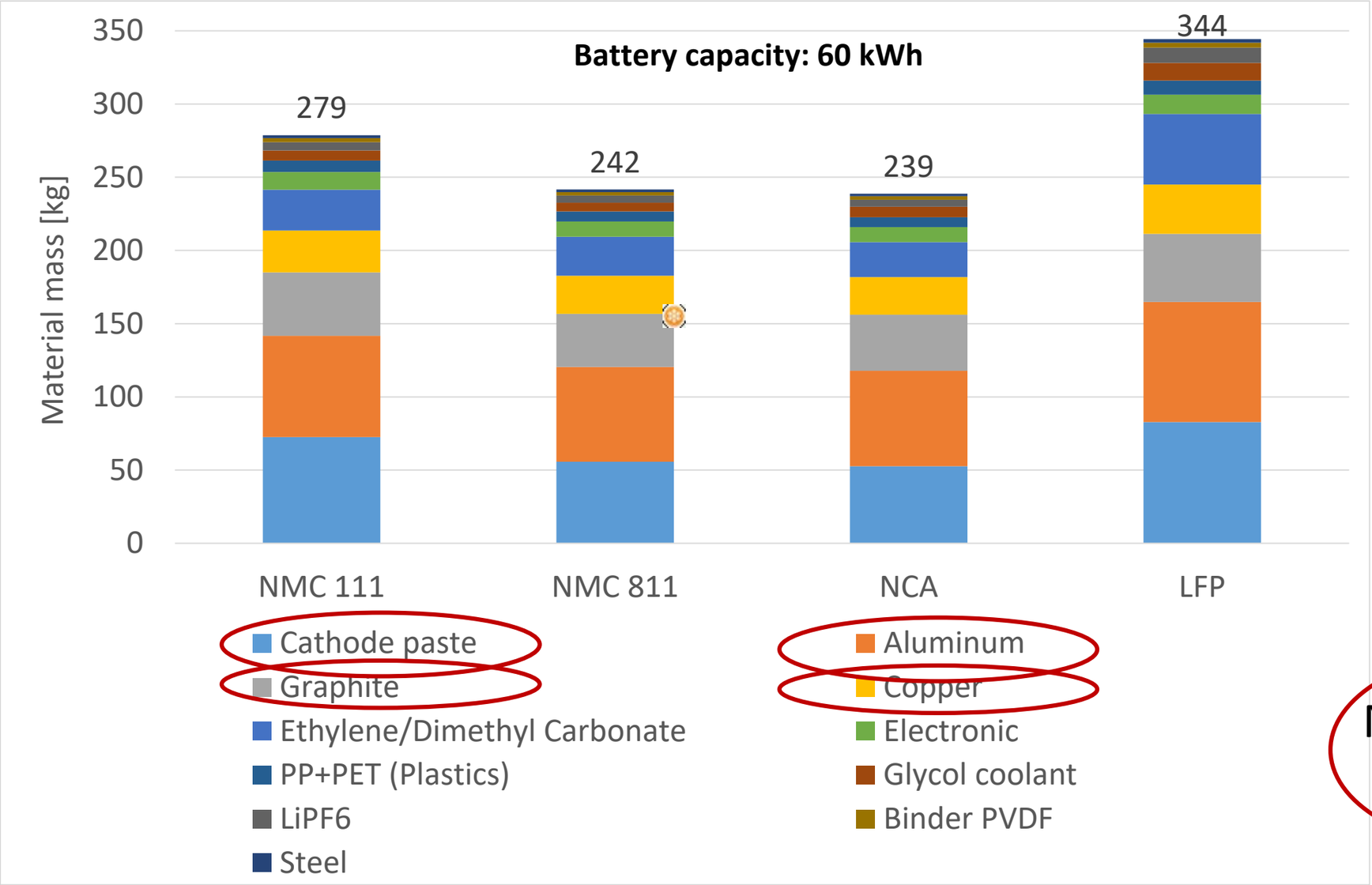


Pack energy density kWh/kg	0,21	0,25	0,25	0,17

Data source:
Greet2 (Argonne2021)

Source: Argonne, GREET 2021

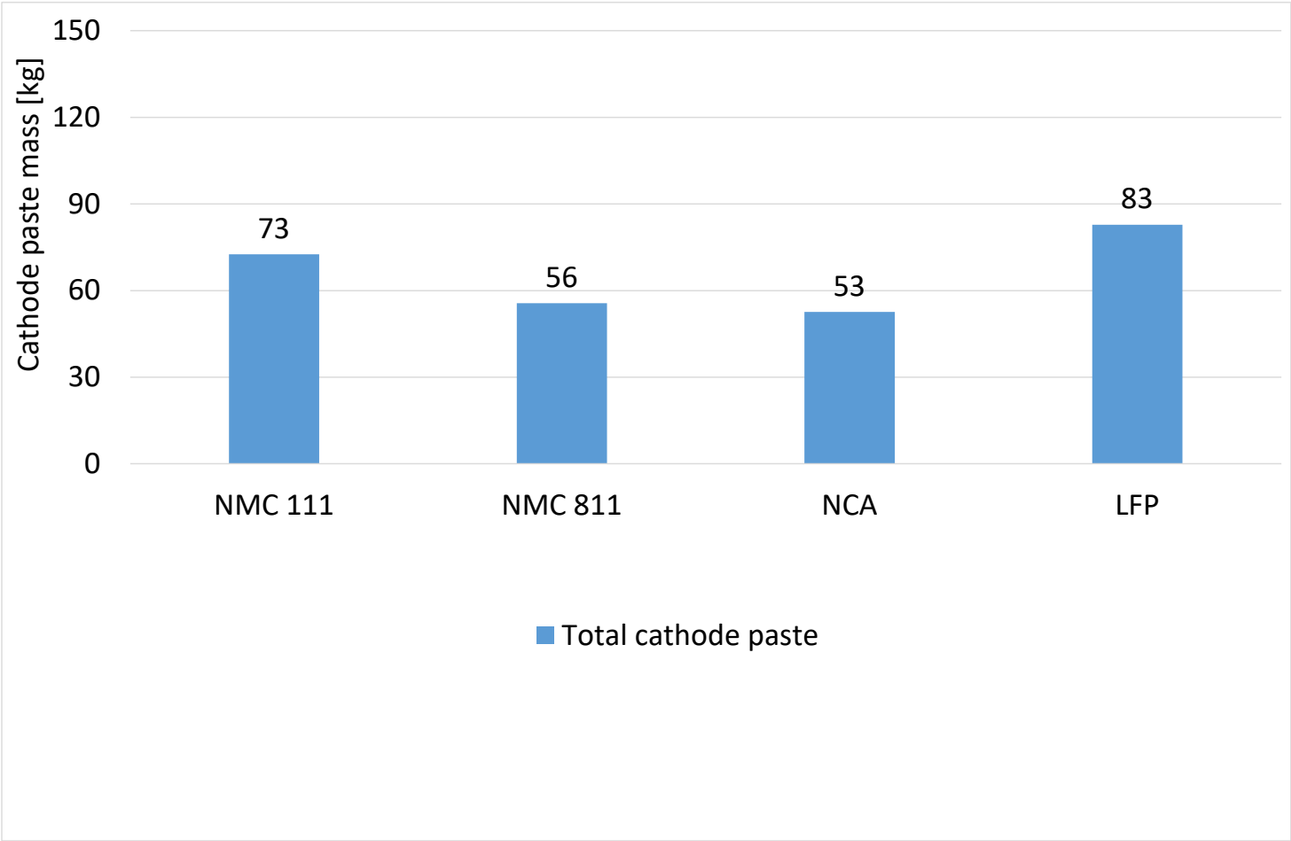
EV Batteries - mass balance of materials

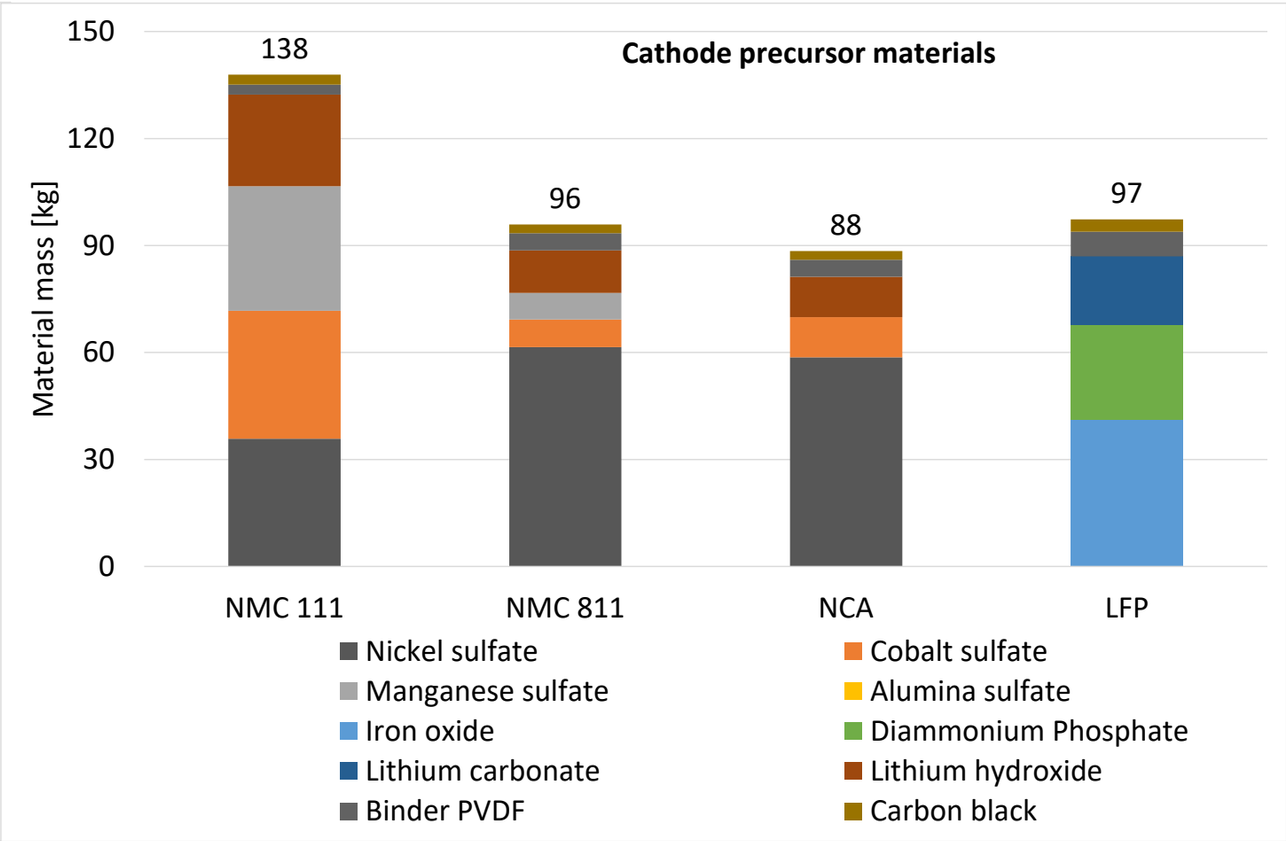


Most relevant materials

EV Batteries - mass balance of cathode materials

Battery capacity 60 kWh

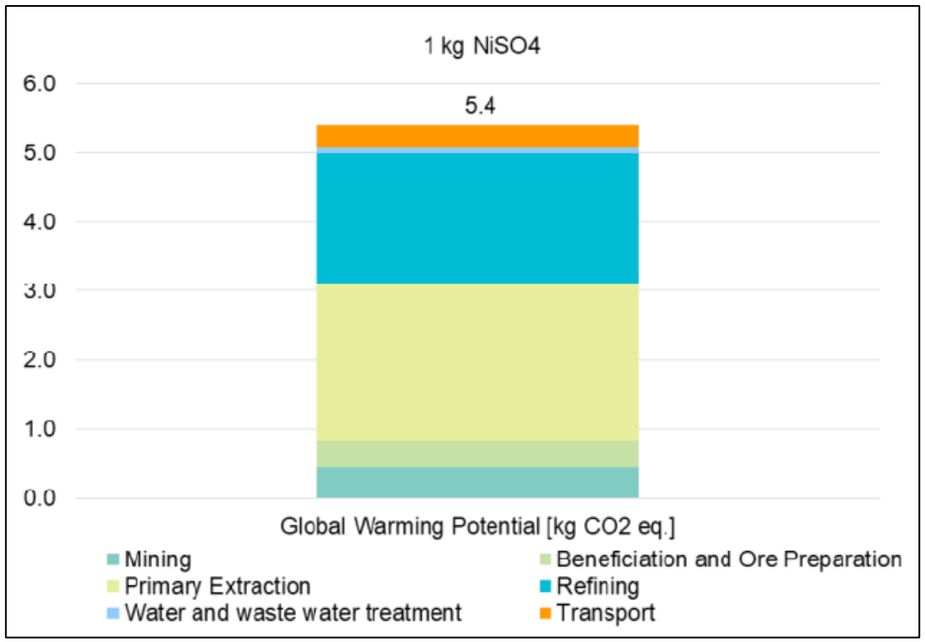




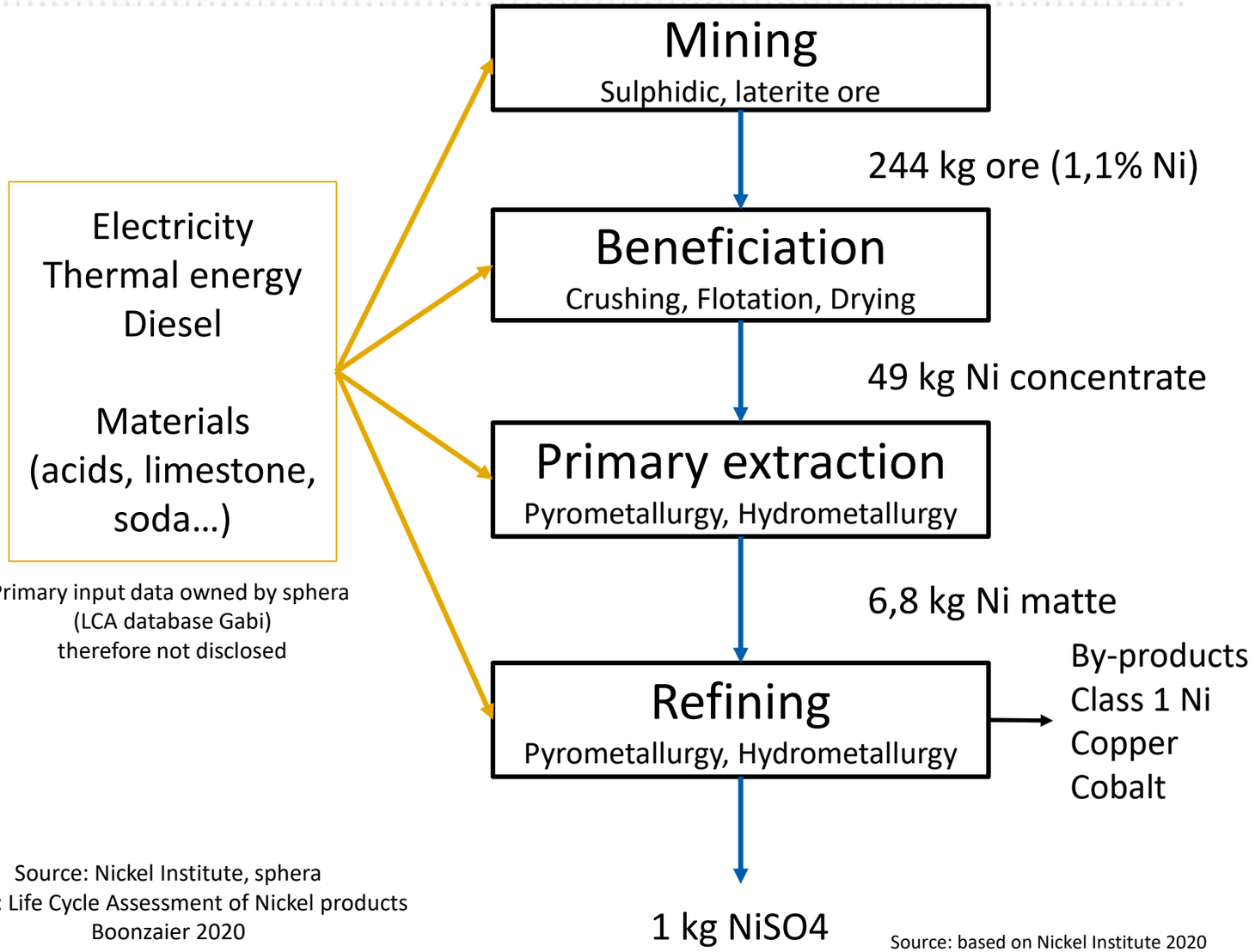
Example Production of battery grade material: Primary NiSO4

(Study by Nickel Institute based on global mix of processes + average industry data)

NMC811 battery cathode production requires ~1 kg NiSO4 per 1 kWh battery capacity

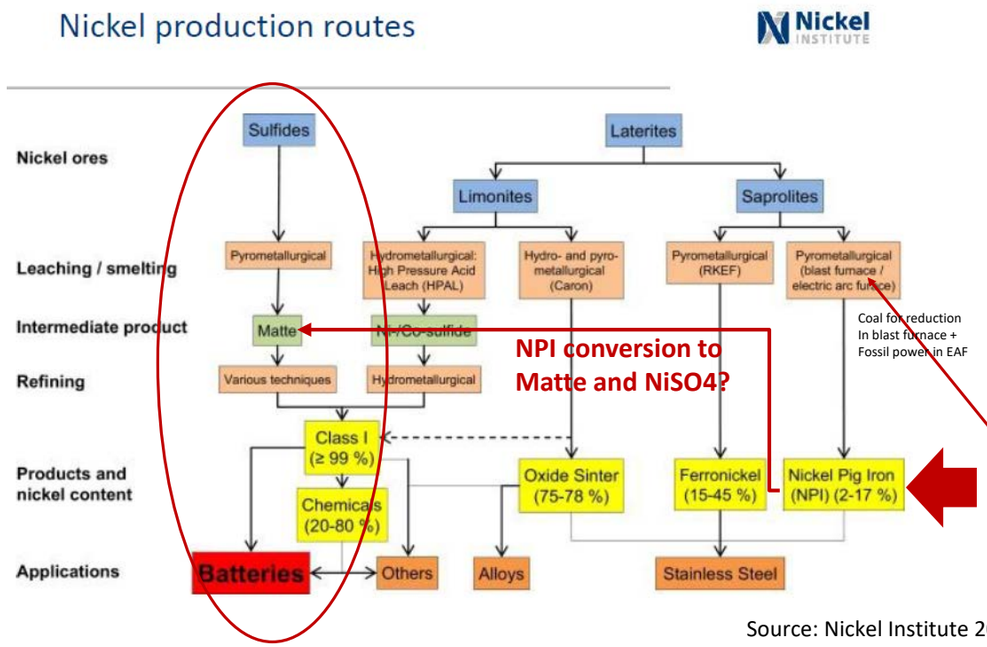


Source: Nickel Institute, sphera
Report: Life Cycle Assessment of Nickel products
Boonzaier 2020



Source: based on Nickel Institute 2020

Behind averaged data: future uncertainties of Ni supply and related GHG emissions

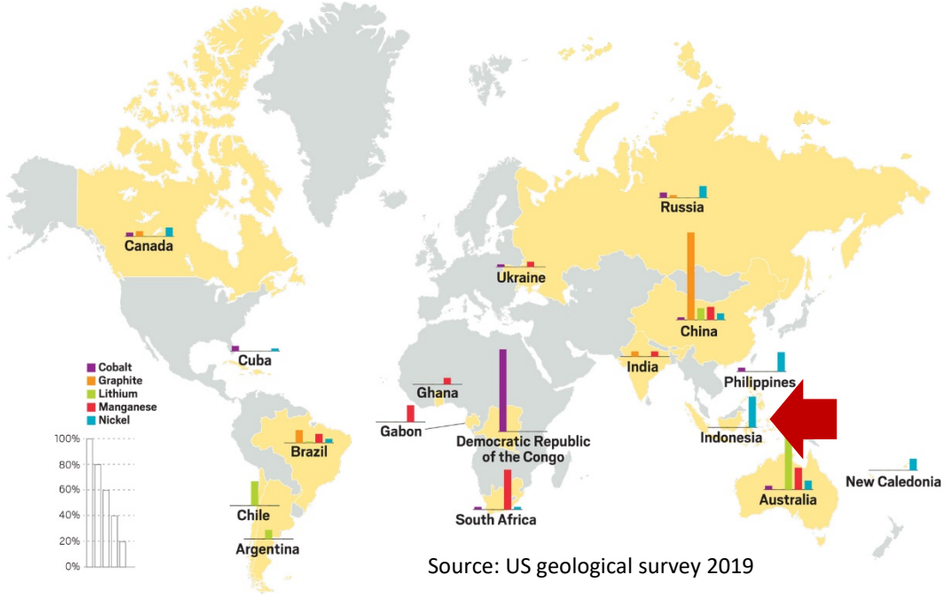


Source: Nickel Institute 2020

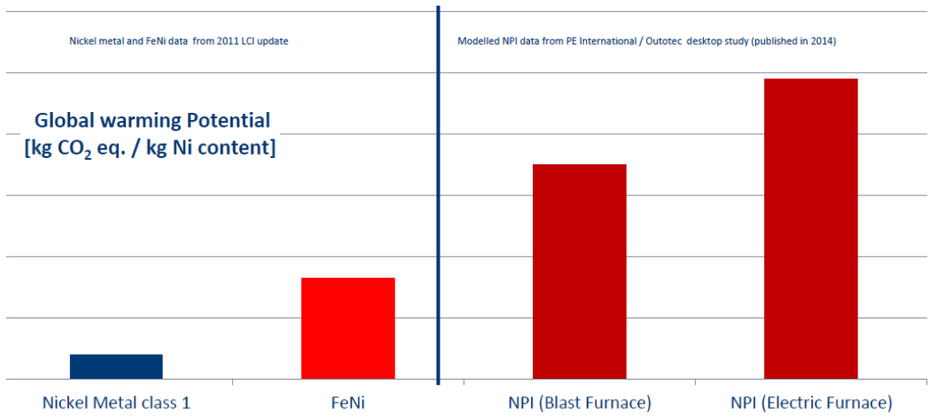
Significant growth in NPI production (SE-Asia) due to stainless steel production in China

BUT

CO2-emissions per ton Ni via NPI 3-10 times higher (70-100 t CO2-e/t Ni) than via sulfidic Ni (~13 t CO2-e/t Ni)

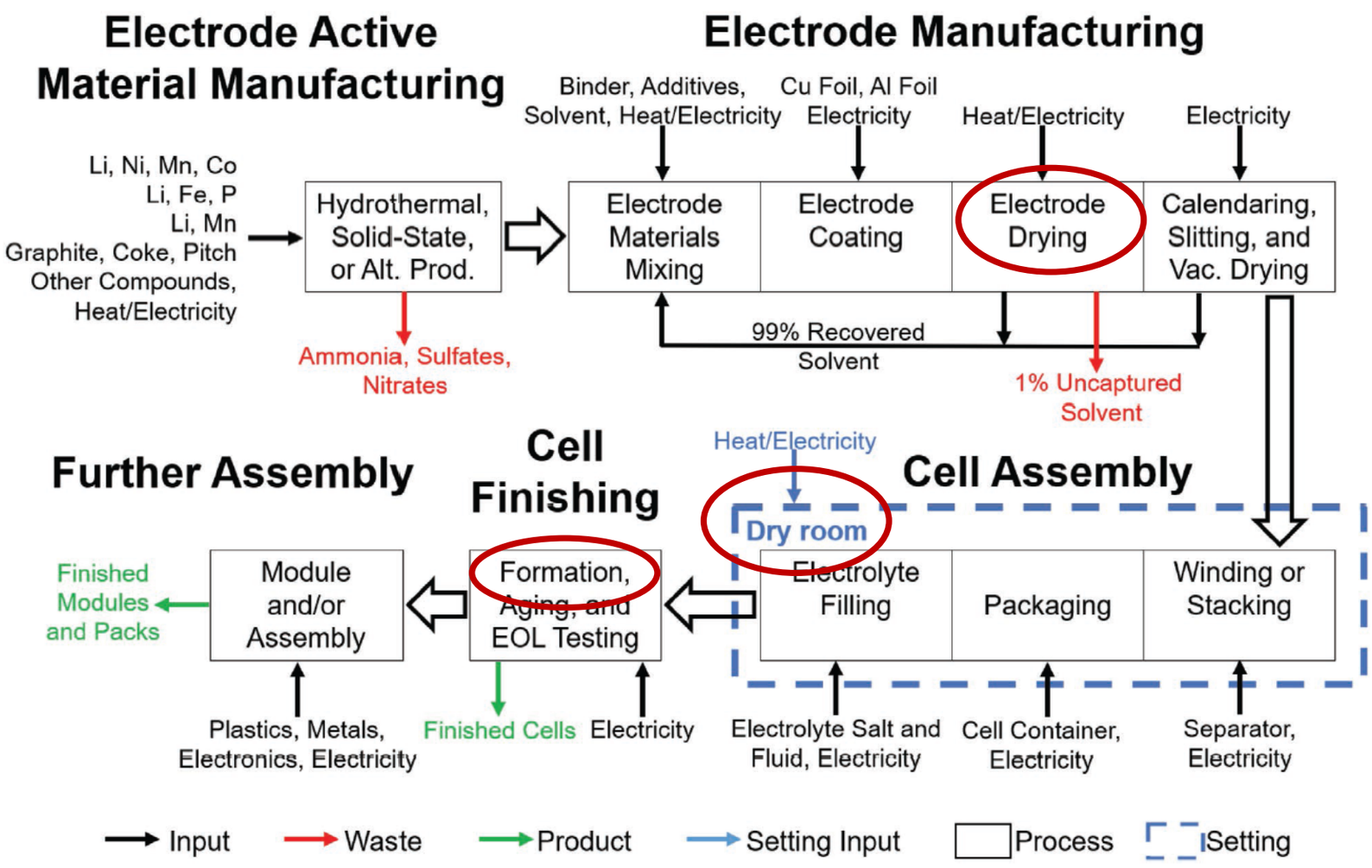


Source: US geological survey 2019



- Investments in new Ni Class I production have been low in the past years (low Ni price)
- Investment focus in Indonesia for NPI for stainless steel (CN)
- **Potential bottleneck of NPI to high-grade Nickel conversion**:
  - **High GHG emissions** (coal fired local energy supply)
  - **Siginificant local environmental impacts** (surface mines in virgin rainforest areas)

Battery production
Process and energy demand



Porzio (2021): Life-Cycle Assessment Considerations for batteries and Battery Materials

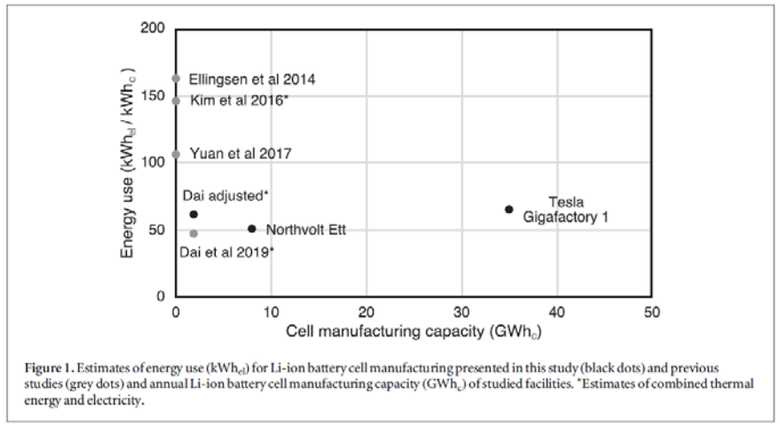


Figure 1. Estimates of energy use (kWh$_{td}$) for Li-ion battery cell manufacturing presented in this study (black dots) and previous studies (grey dots) and annual Li-ion battery cell manufacturing capacity (GWh$_c$) of studied facilities. *Estimates of combined thermal energy and electricity.

Kurland (2020): Energy use for GWh-scale lithium-ion battery production

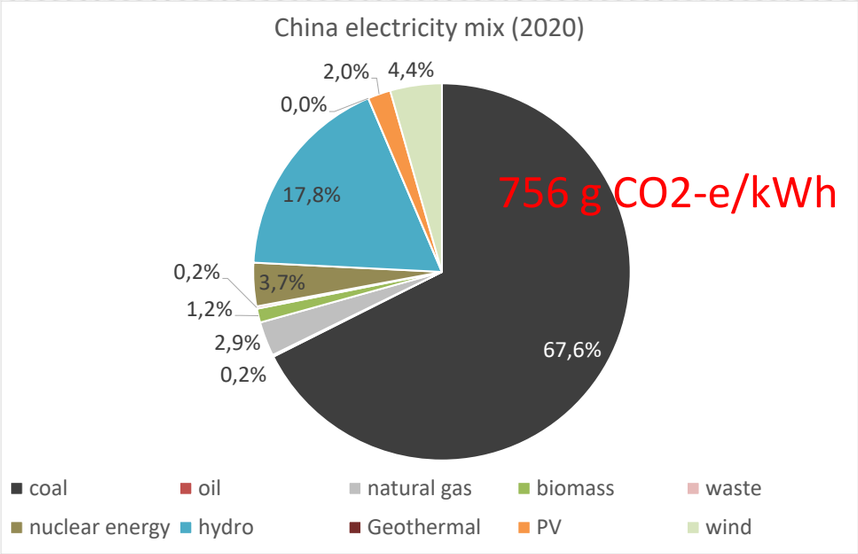
This study:

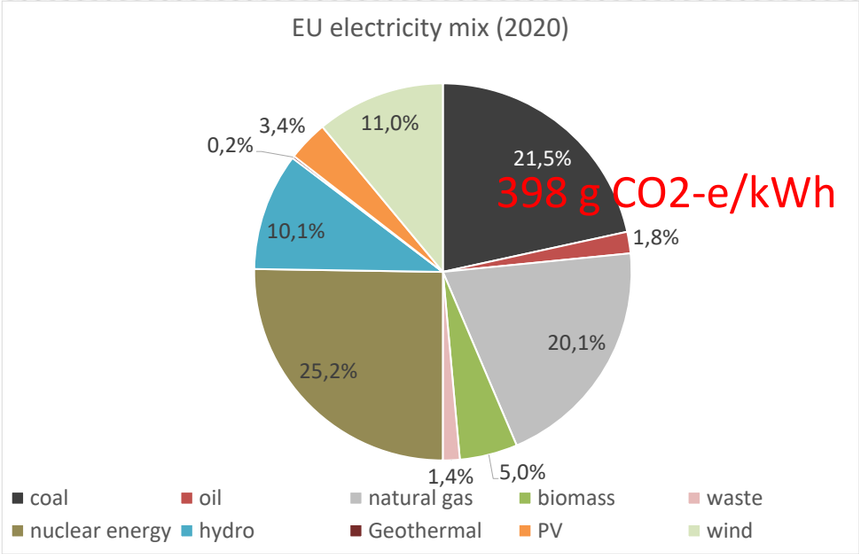
Energy demand	60	kWh/kWh
Dry room energy share	36%	
Electrode drying energy share	33%	
cell formation energy share	20%	(100% electricity)
other processes energy share	10%	(100% electricity)
Heat demand	30	kWh/kWh
Electricity battery production	50%	
Electricity demand	30	kWh/kWh
Electricity from Electricity Mix	100%	

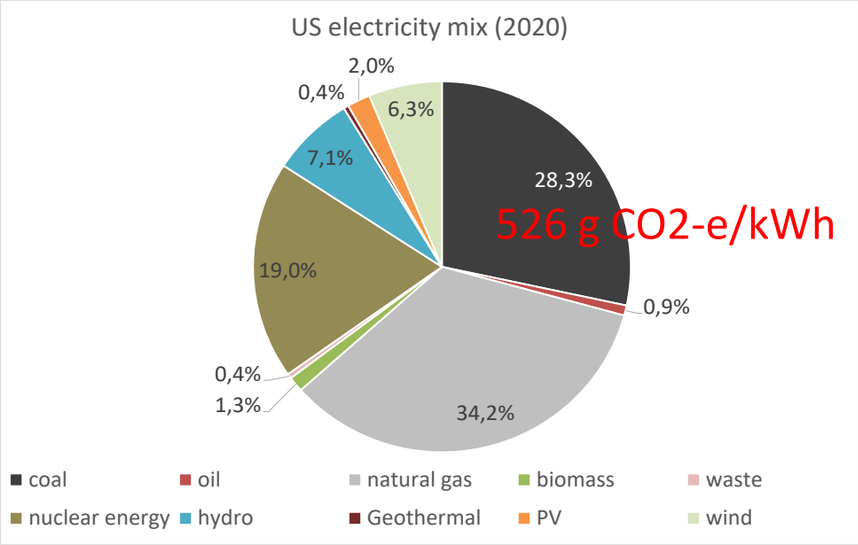
NMC=NCA=LFP

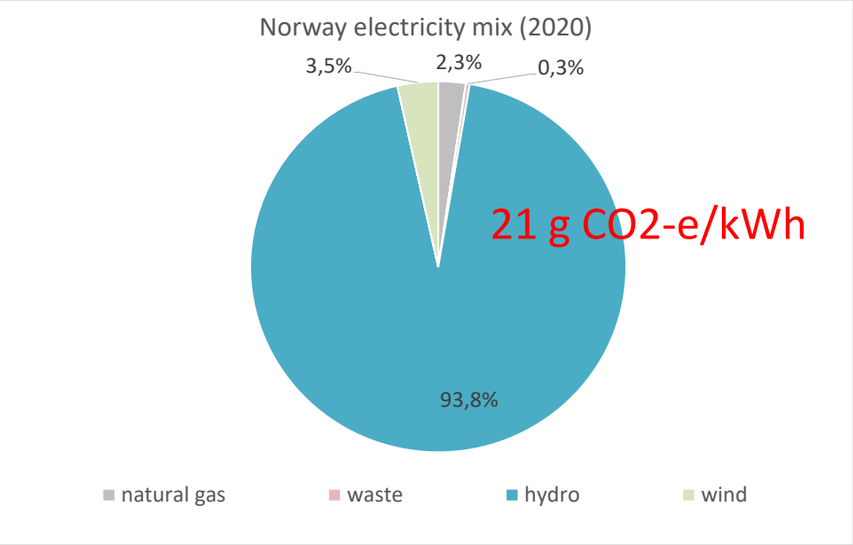
Battery production

Location dependent electricity mixes China, EU, US, Norway





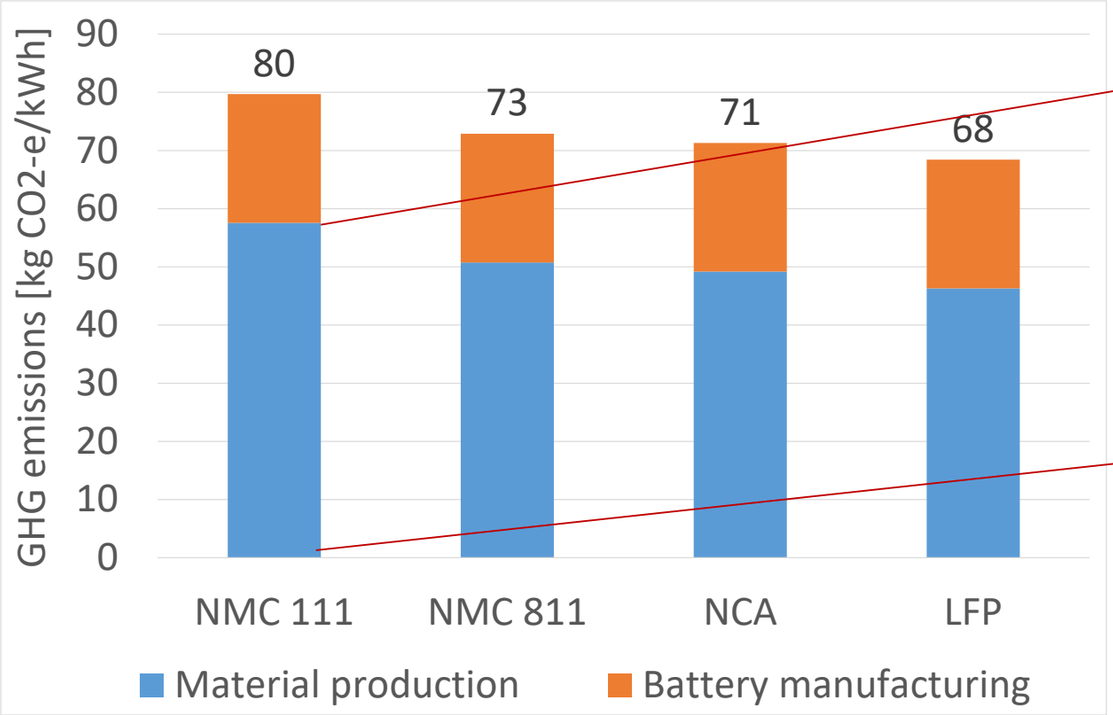




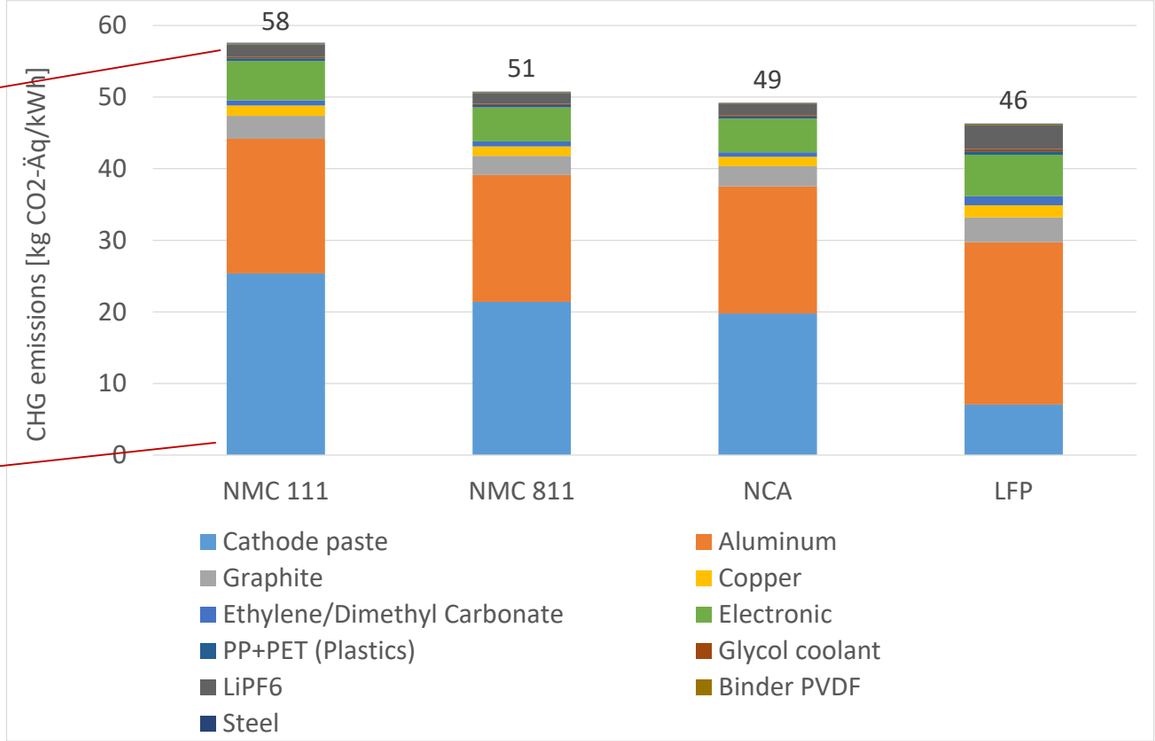
Source: IEA-statistics

RESULTS: GHG emissions of battery production (China, 2020)

GHG emissions of battery production (cradle to gate)



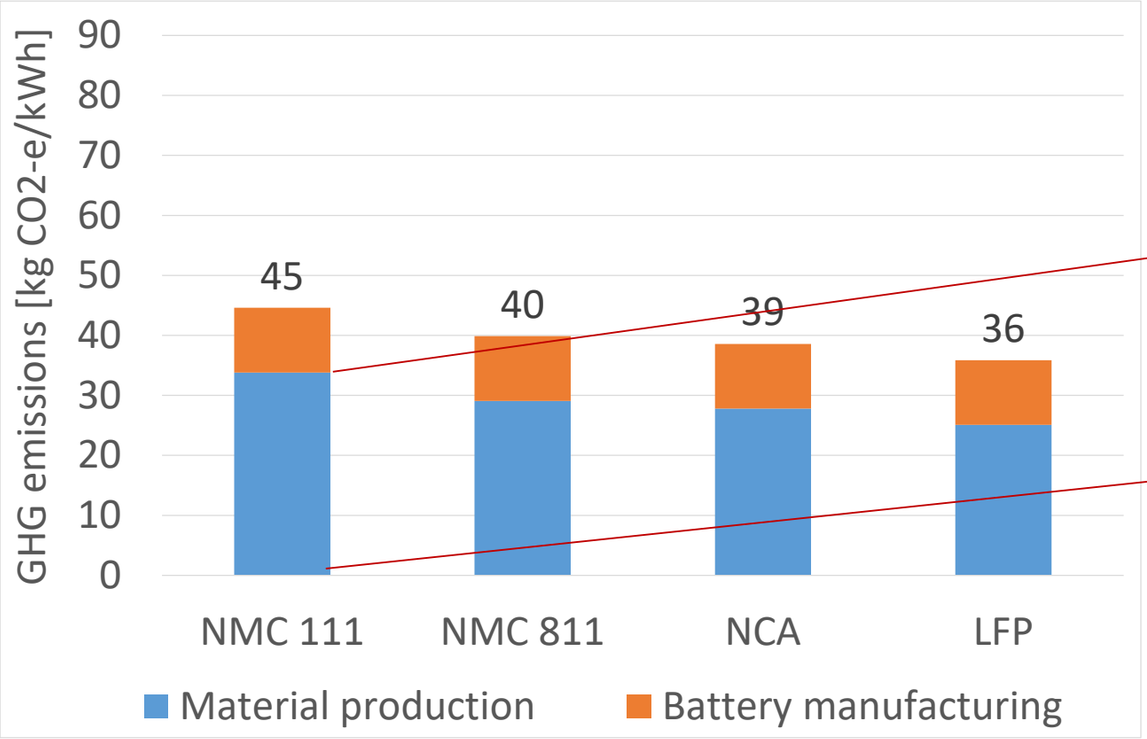
GHG emissions of material production (cradle to gate)



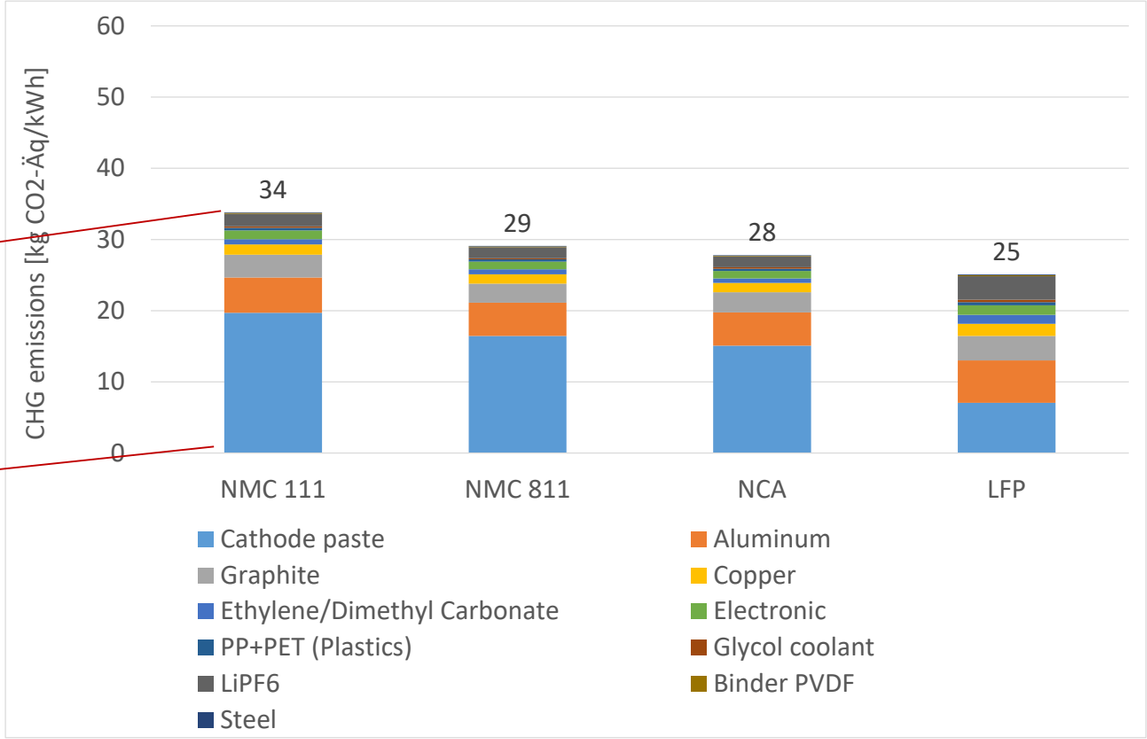
Source: Battery Lifecycle model, Joanneum Research

RESULTS: GHG emissions of battery material production (Norway, 2020)

GHG emissions of material production (cradle to gate)



GHG emissions of material production (cradle to gate)

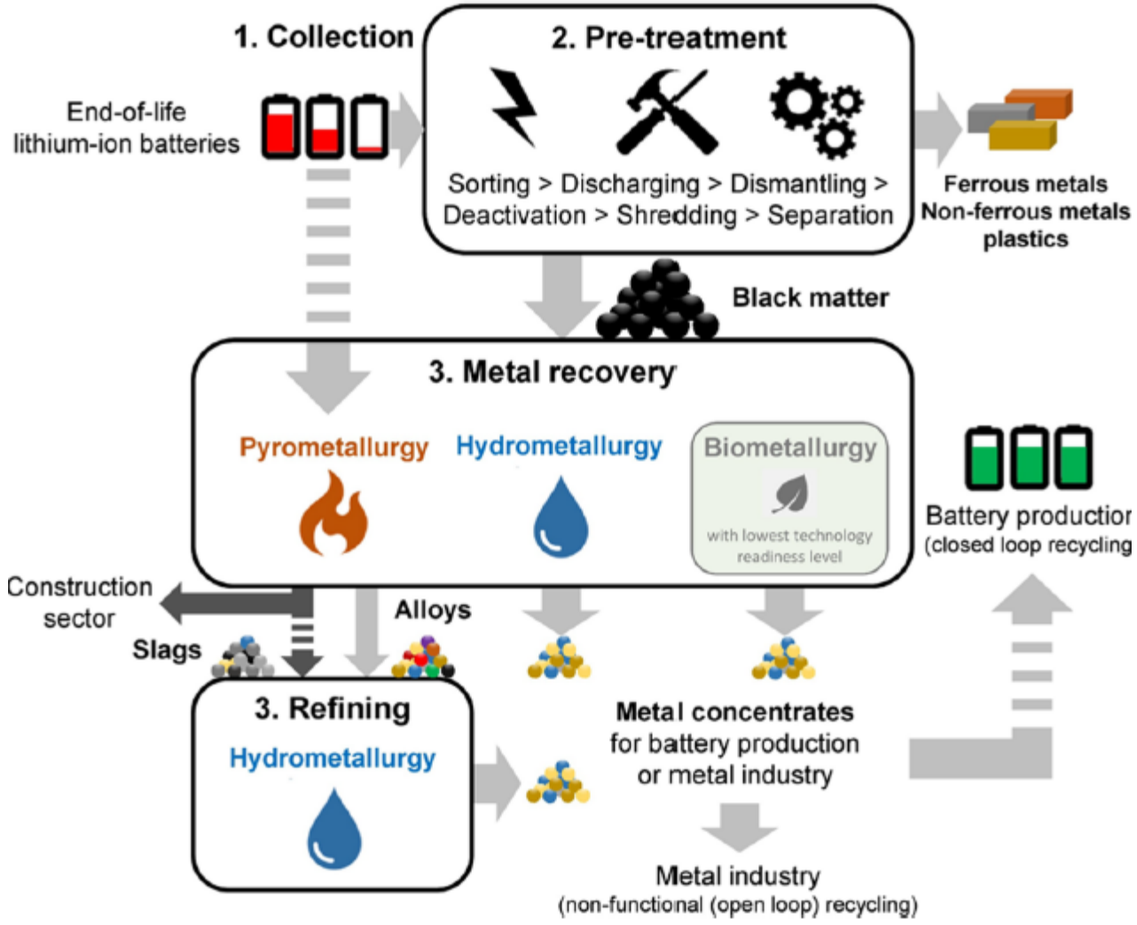


Source: Battery Lifecycle model, Joanneum Research

Battery LCA model – important parameters

State-of-the-art processes and challenges of battery-recycling

- **Pre-treatment** (**State-of-the-art**)
  - Challenges: thermal runaway, reduced aluminium yield with higher temperatures
- **Pyrometallurgy** (**State-of-the-art**)
  - Challenges: metal recovery as alloy (Ni, Co, Cu), requires hydrometallurgical refining for metal recovery. Li, Mn, Al into slag (recovery is challenging), energy intensive process.
- **Hydrometallurgy** (**in development**)
  - Challenges : pre-treatment / sorting of different battery chemistries for constant process input, long process time, waste water treatment
- **Direct recycling** (**in development**)
  - Challenges: sorting of different chemistries, very sensitive to changes in input material
- **Sequence and interplay of processes depending of input quality and chemistry, required quality of output material as biggest technical challenge to reach EU recycling targets**



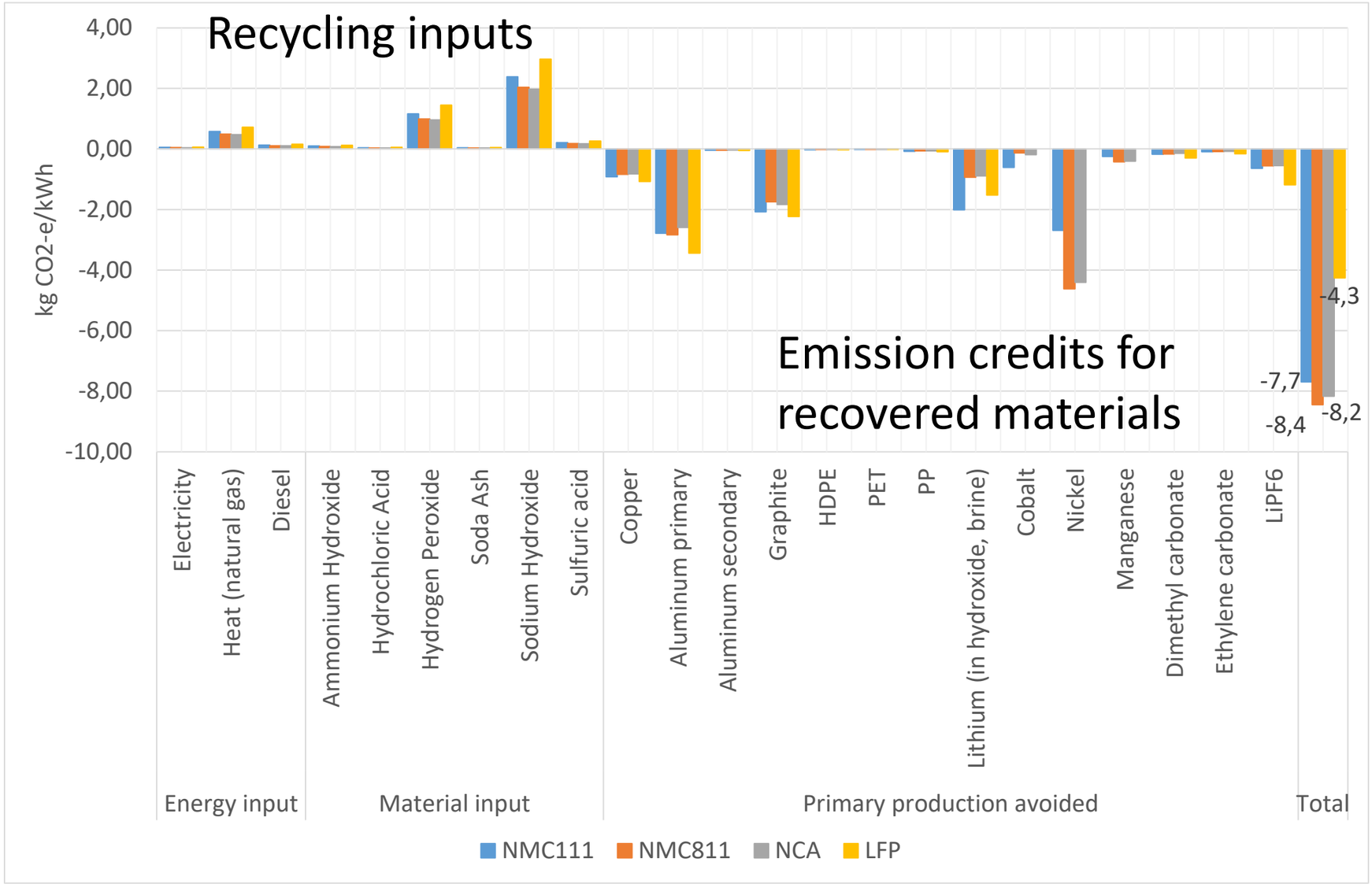
Source: Nigl 2021

Battery LCA model – important parameters

Battery recycling in this study

- **Hydrometallurgy as most likely technology in medium term,** since all metals can be recovered separatly which supports the main purpose of recycling of enabling circular economy
- Large-scale **NMC-recycling** can be **expected to be in place in 2030** (likely cost-efficient due to critical metals recovered)
- Large-scale **LFP-recycling** can be expected **to be in place later than 2030** (less cost-efficient since lithium and copper are the only electrode-metals to be recovered); BUT: new EU-battery directive (2023) will require recovery rates for Lithium (35% in 2026, 70% in 2030)
- **Recycling in LCA-model**: GWP recycling process minus GWP credit for (potential future) substituted primary material production.
- Primary material production after first life will be substituted > 2030 (resulting in a lower GWP-credit compared to today´s primary production)

RESULTS: GHG emissions of battery recycling (China, 2020)



Recycling via 100% hydrometallurgy

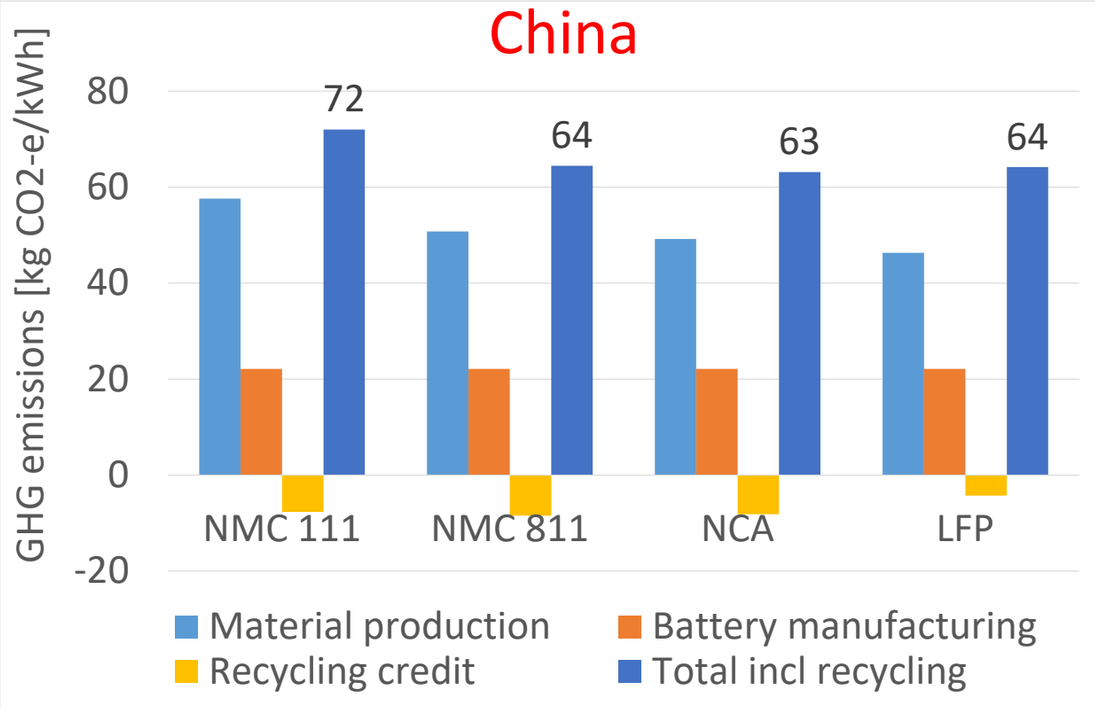
Extracted materials	Recovery rates
Copper	90%
Steel	90%
Aluminum	90%
Graphite	90%
Plastics	50%
Lithium	90%
Cobalt	98%
Nickel	98%
Manganese	98%
Electrolyte solvents	50%
Electrolyte salts	50%

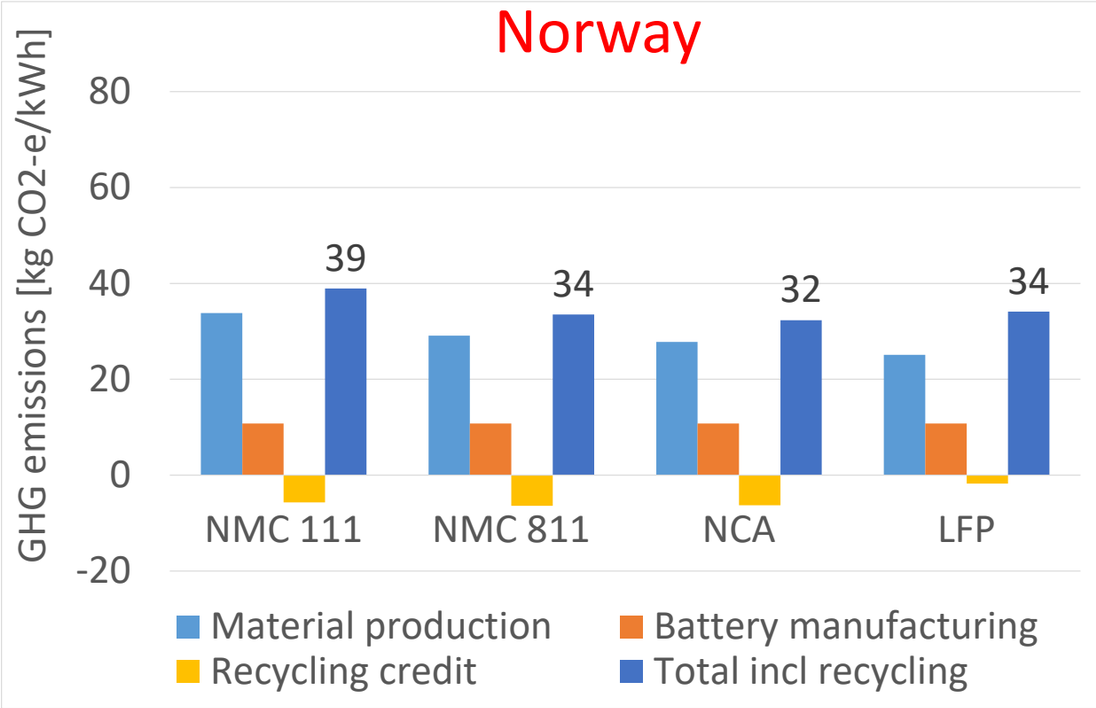
Credit for avoided future primary material production (compared to 2020):

- -20% material production emission reduction
- -10% material production efficiency

RESULTS: GHG emissions of battery pack production including recycling

GHG emissions of battery production + recycling
(cradle to cradle)



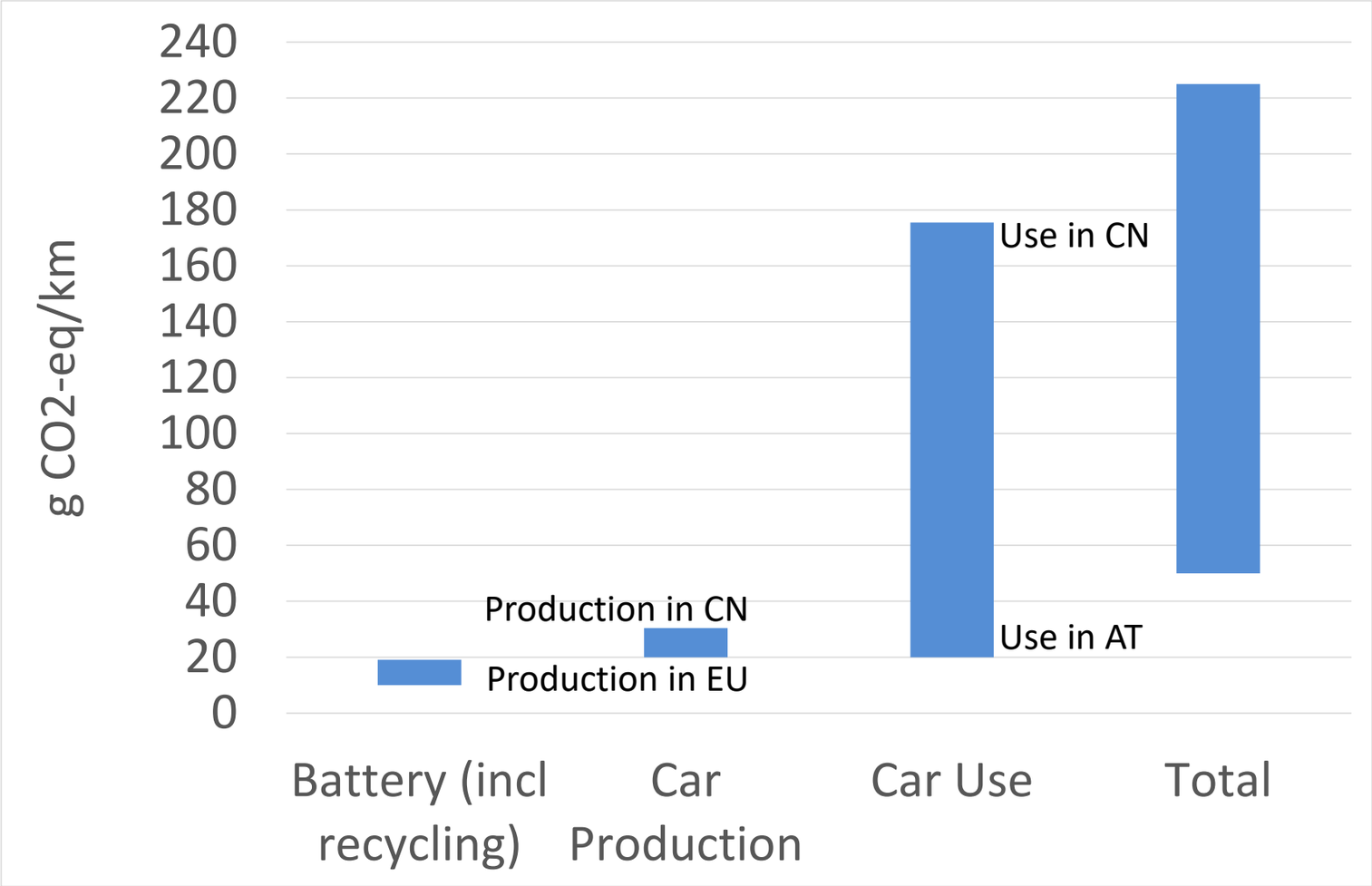


Source: Battery Lifecycle model, Joanneum Research

GHG emissions per km of EV life cycle (2020)

Example

- Li-ion battery (NMC, NCA, LFP)
- Capacity: 50 kWh
- Energy density: 175-250 $Wh/kg_{Battery\ pack}$
- Use in BEV passenger car in Austria / China 19 kWh/100km
- Lifetime: in BEV passenger car: 250,000 km
- EoL – recycling: substituting primary Al, copper, thermal energy use of plastics



Most relevant parameters influencing the GHG emission profiles of EV batteries

- Battery material production
  - Mining and manufacturing of battery cell cathode and anode materials
    - NMC-battery: Ni-, Co-, Mn-Sulfate, Graphite
    - LFP-battery: Li-Carbonate, Graphite
  - Mining and manufacturing of module and pack material
    - NMC- & LFP-battery: Aluminium, electric parts (BMS)
- Battery cell and pack manufacturing
  - Energy demand and mix for cell production in dry room
- Battery specific energy kg/kWh capacity
- Battery lifetime and EoL
  - Second life: remaining cycles, application, allocation of GWP to first/second life
  - Recycling path: metallurgical technology and energy demand

Contact

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