A Direct Waterjet-Based Recycling Process for Lithium-Ion Cathodes in the Context of Sustainability and Requirements for a European Circular Economy

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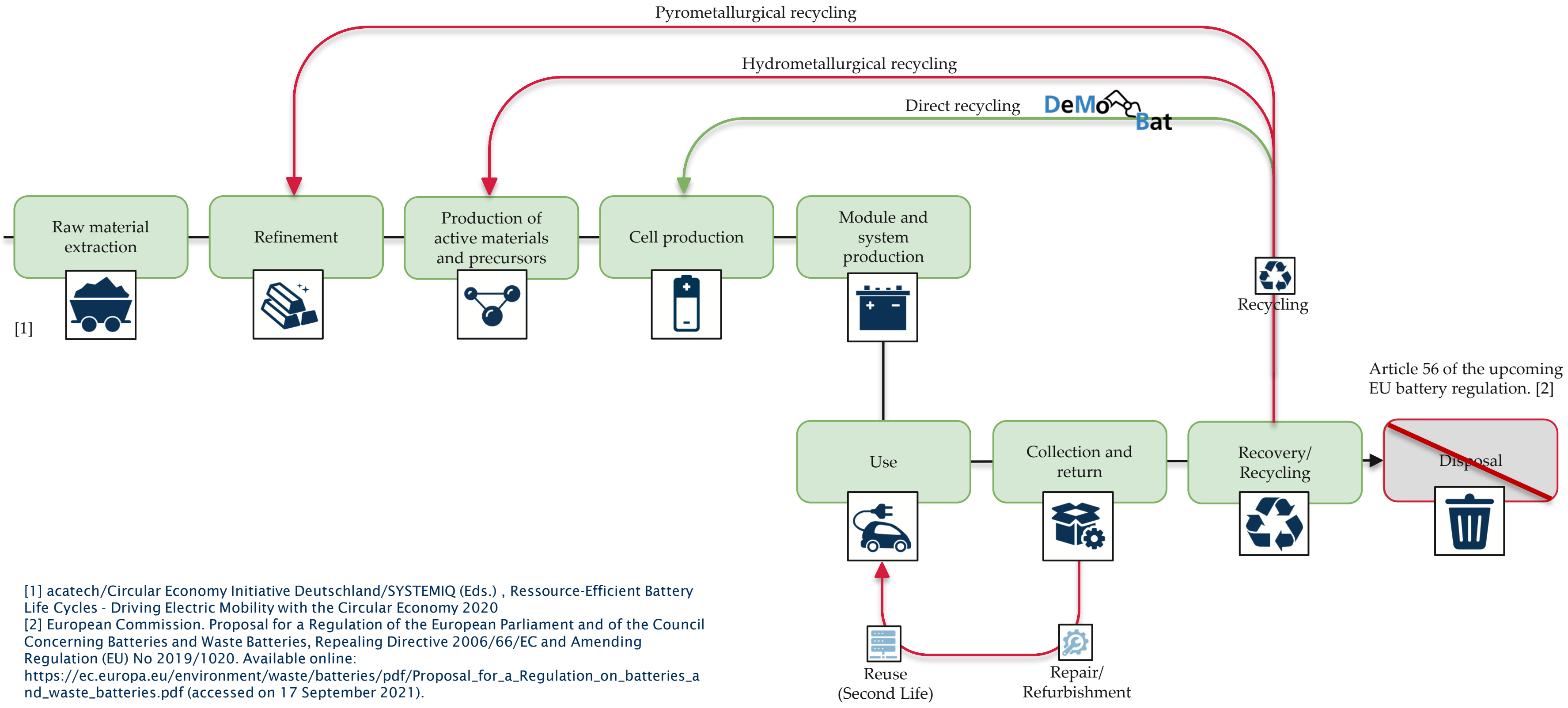
AGENDA

- Circular economy for traction batteries
- Waterjet-based direct recycling of Li-Ion cathodes
- Recycling efficiency and EU recovery targets
- Life Cycle Assessment
  - Goal and scope
  - Life cycle inventory
  - Life cycle impact assessment
  - Evaluation
- Conclusions

CIRCULAR ECONOMY FOR TRACTION BATTERIES

inem
Institut für Nachhaltige Energietechnik und Mobilität

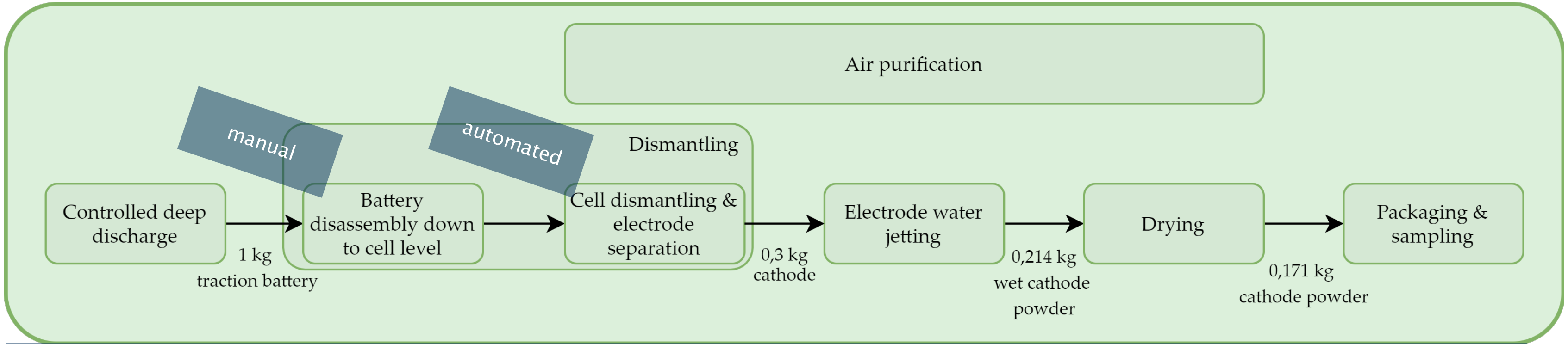
HOCHSCHULE ESSLINGEN



[1] acatech/Circular Economy Initiative Deutschland/SYSTEMIQ (Eds.) , Ressource-Efficient Battery Life Cycles - Driving Electric Mobility with the Circular Economy 2020

[2] European Commission. Proposal for a Regulation of the European Parliament and of the Council Concerning Batteries and Waste Batteries, Repealing Directive 2006/66/EC and Amending Regulation (EU) No 2019/1020. Available online: https://ec.europa.eu/environment/waste/batteries/pdf/Proposal_for_a_Regulation_on_batteries_and_waste_batteries.pdf (accessed on 17 September 2021).

WATERJET-BASED DIRECT CATHODE RECYCLING



Production environment at the Erlos GmbH (Zwickau, Germany).

Traction battery

Single cell

Electrodes and separator

Erlos water-jetting

Dry recyclate

ERLOS Produktion und Montagen GmbH

RECYCLING EFFICIENCY

Efficiency targets of the upcoming EU battery regulation [2]

Commodity	Mandatory target	Mandatory target	Mandatory target	Erlos recycling efficiency
Date from	01.01.2025	01.01.2026	01.01.2030	
Copper	-	90 %	95 %	Min. 99 %
Cobalt	-	90 %	95 %	96 – 97 %
Nickel	-	90 %	95 %	
Lithium	-	35 %	70 %	~ 86 % Li recovery

wt% of battery system

0,0552 wt% Li from $LiPF_6$ [b] → Not recovered

1,2 wt% Li from active materials [b] → 90 % recycling efficiency → ~ 86 wt% Li from battery recovered

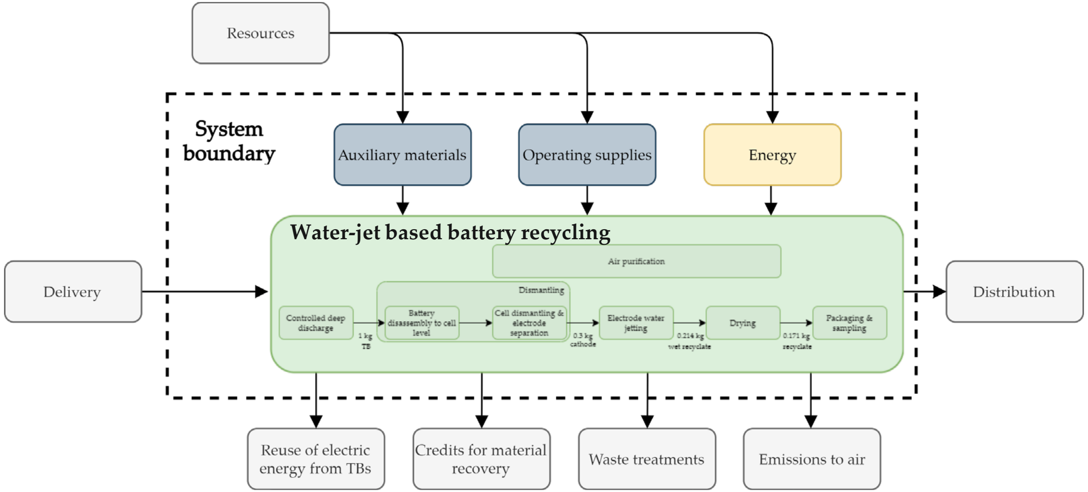
[2] European Commission. Proposal for a Regulation of the European Parliament and of the Council Concerning Batteries and Waste Batteries, Repealing Directive 2006/66/EC and Amending Regulation (EU) No 2019/1020. Available online: https://ec.europa.eu/environment/waste/batteries/pdf/Proposal_for_a_Regulation_on_batteries_and_waste_batteries.pdf (accessed on 17 September 2021).

LIFE CYCLE ASSESSMENT

Goal and scope of the study

Ecological evaluation of the **direct water-jet based recycling process** for cathode materials of Li-Ion batteries, performed by Erlos GmbH (Zwickau, Germany), using **life cycle assessment** methodology according to the standards DIN EN ISO 14040/14044.

Focus on the evaluation of the **global warming potential (GWP)**.

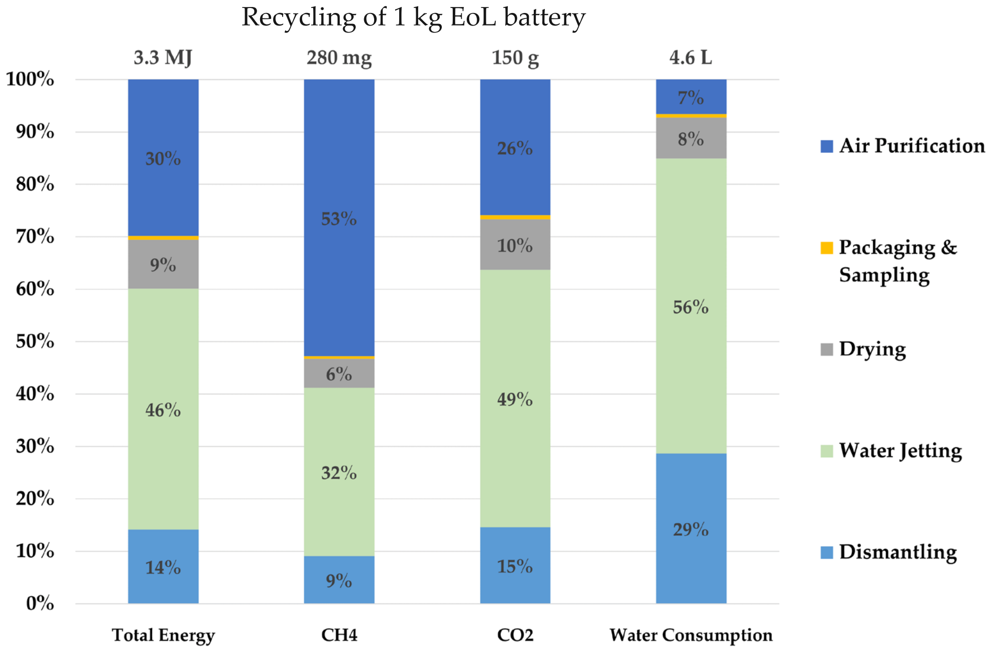


System boundary of the LCA study for the Erlos direct battery recycling.

- **Functional unit (FU):**
  Recycling of 1 kg EoL traction battery (TB).
- **Data sources:**
  Primary data from Erlos GmbH, secondary data from literature and GaBi database.
- **LCA Software:**
  GaBi, Sphera Solutions Inc. (Chicago, IL, USA), Version 10.0.0.71
- **Methodology of impact assessment:**
  CML 2001 (Centrum voor Milieukunde, Leiden University); impact-oriented.
- **Function of the system:**
  Recovery of cathode material from NMC cells.

LIFE CYCLE ASSESSMENT

Life Cycle Inventory (LCI) Analysis



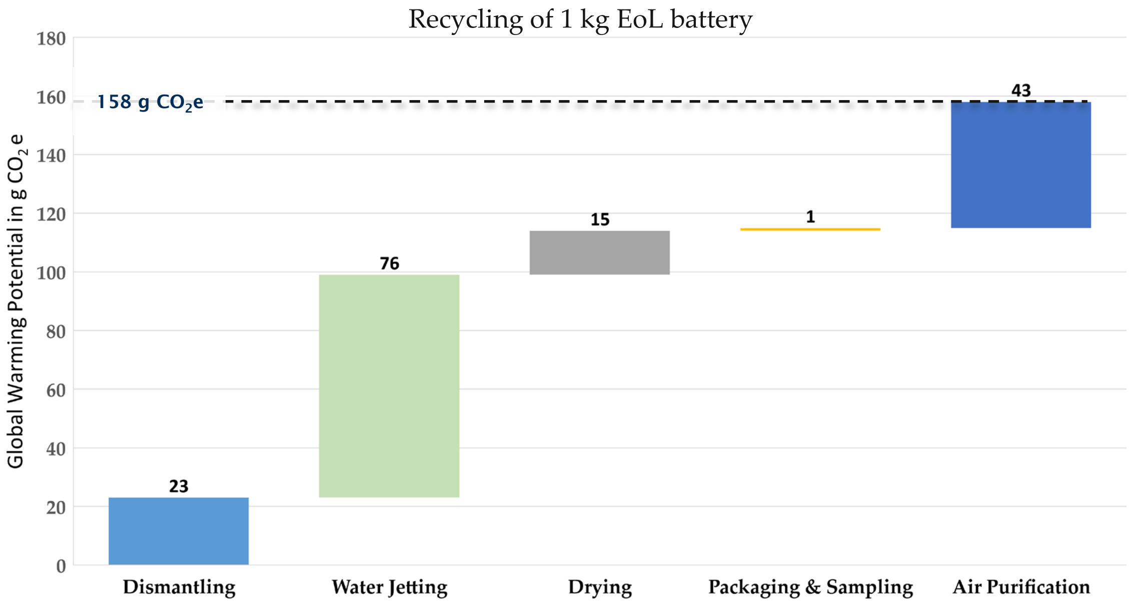
Life cycle inventory of the waterjet-based battery recycling. Selected emissions/consumptions in the individual process steps.

- Water jetting dominant in all categories except CH_4.
- Air purification with largest emissions for CH_4 caused by activated carbon.
- Overall low emissions, <u>in comparison:</u>
  - 39.5 MJ total energy input for same amount of pristine NMC111 material. [3]
  - 7665 liters of water consumption per liter of biodiesel production. [4]

[3] Dai, Q.; Kelly, J.C.; Gaines, L.; Wang, M. Life Cycle Analysis of Lithium-Ion Batteries for Automotive Applications. Batteries 2019, 5, 48, doi:10.3390/batteries5020048.
[4] Hammond, G.P. and Li, B. (2016), Environmental and resource burdens associated with world biofuel production out to 2050: footprint components from carbon emissions and land use to waste arisings and water consumption. GCB Bioenergy, 8: 894-908.

LIFE CYCLE ASSESSMENT

Life Cycle Impact Assessment (LCIA) - Global Warming Potential (GWP)



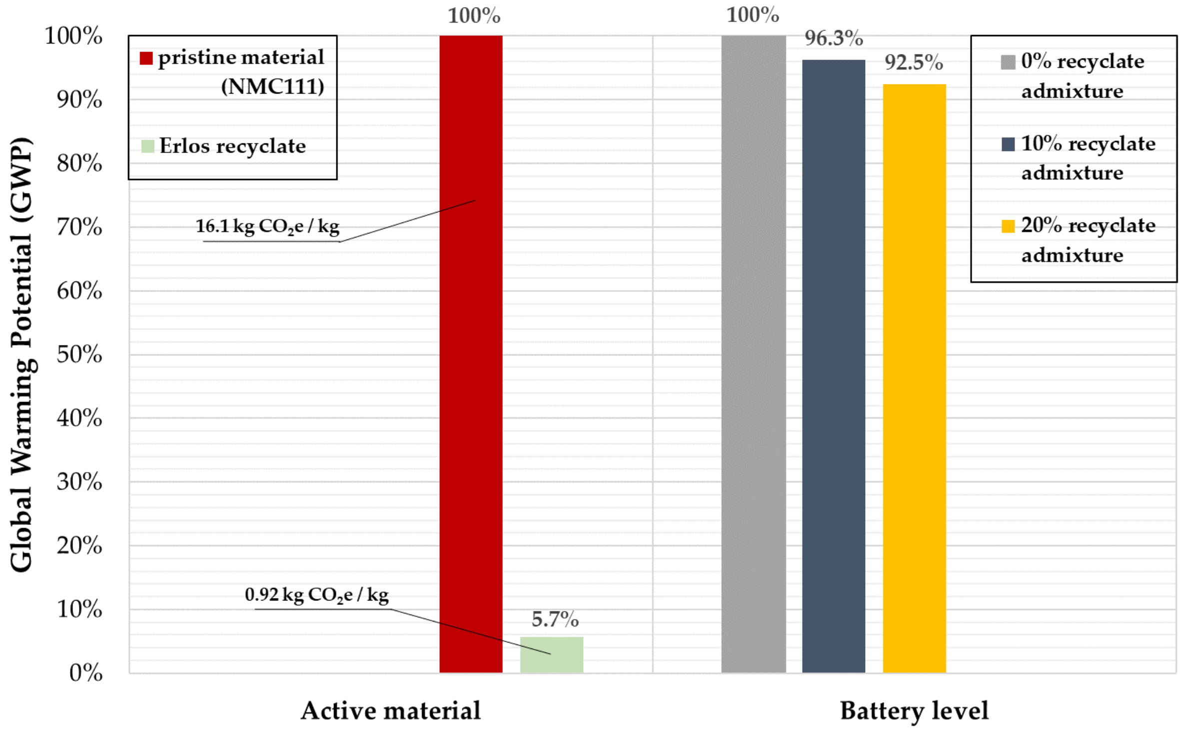
Global warming potential of the waterjet-based battery recycling in the individual process steps. [5]

- Emission of 924 g CO_2equivalents (CO_2e) for the recycling of 1kg NMC material.
- Water jetting process step largest emitter at 48%.
- Emissions during exhaust air purification mainly due to activated carbon as filter medium.

[5] Kurz, L.; Faryadras, M.; Klugius, I.; Reichert, F.; Scheibe, A.; Schmidt, M.; Wörner, R. Global Warming Potential of a New Waterjet-Based Recycling Process for Cathode Materials of Lithium-Ion Batteries. Batteries 2021, 7, 29. https://doi.org/10.3390/batteries7020029

LIFE CYCLE ASSESSMENT

Evaluation of the Results



Reduction potential for reuse in new batteries in terms of global warming potential.

- High savings potential for cathodes. Due to the very good ecological performance of the Erlos recyclate.
- In comparison:
  - **Better environmental performance by a factor of 8 to 26 compared to the hydro- and pyrometallurgical recycling route.** [6-8]

[6] Buchert M.; Sutter, J. Aktualisierte Ökobilanzen zum Recyclingverfahren LithoRec II für Lithium-Ionen-Batterien, Berlin, Darmstadt, 2016.
[7] Buchert, M.; Sutter, J. Aktualisierte Ökobilanz zum Recyclingverfahren EcoBatRec für Lithium-Ionen-Batterien, Berlin, Darmstadt, 2016.
[8] Buchert, M.; Jenseit, W.; Merz, C.; Schüler, D. Verbundprojekt: Entwicklung eines realisierbaren Recyclingkonzepts für die Hochleistungsbatterien zukünftiger Elektrofahrzeuge - LiBRi: Teilprojekt: LCA der Recyclingverfahren, Berlin, Darmstadt, 2011.

CONCLUSIONS

- Direct recycling route seeks to recover black mass unchanged and enables avoiding of costly manufacturing process steps.
- Waterjet-based direct recycling process for Li-Ion cathodes can meet the upcoming recovery targets of the EU battery regulation.
- Life cycle inventory analysis shows that the process is capable of detaching and recovering cathode material from the collector foil with minimal use of resources.
- Global warming potential of the recyclate is significantly lower than that of pristine material, which can lead to a high reductions in the global warming potential of new cells by admixture.
- Compared to the hydro- and pyrometallurgical recycling route, this direct recycling process performs significantly better from an ecological perspective.
- Electrochemical activity of the recyclate is still being researched as part of the project DeMoBat.

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