LCA of Automotive Batteries for Electric Vehicles

A Literature Review

Christian Aichberger, Gerfried Jungmeier

JOANNEUM RESEARCH LIFE

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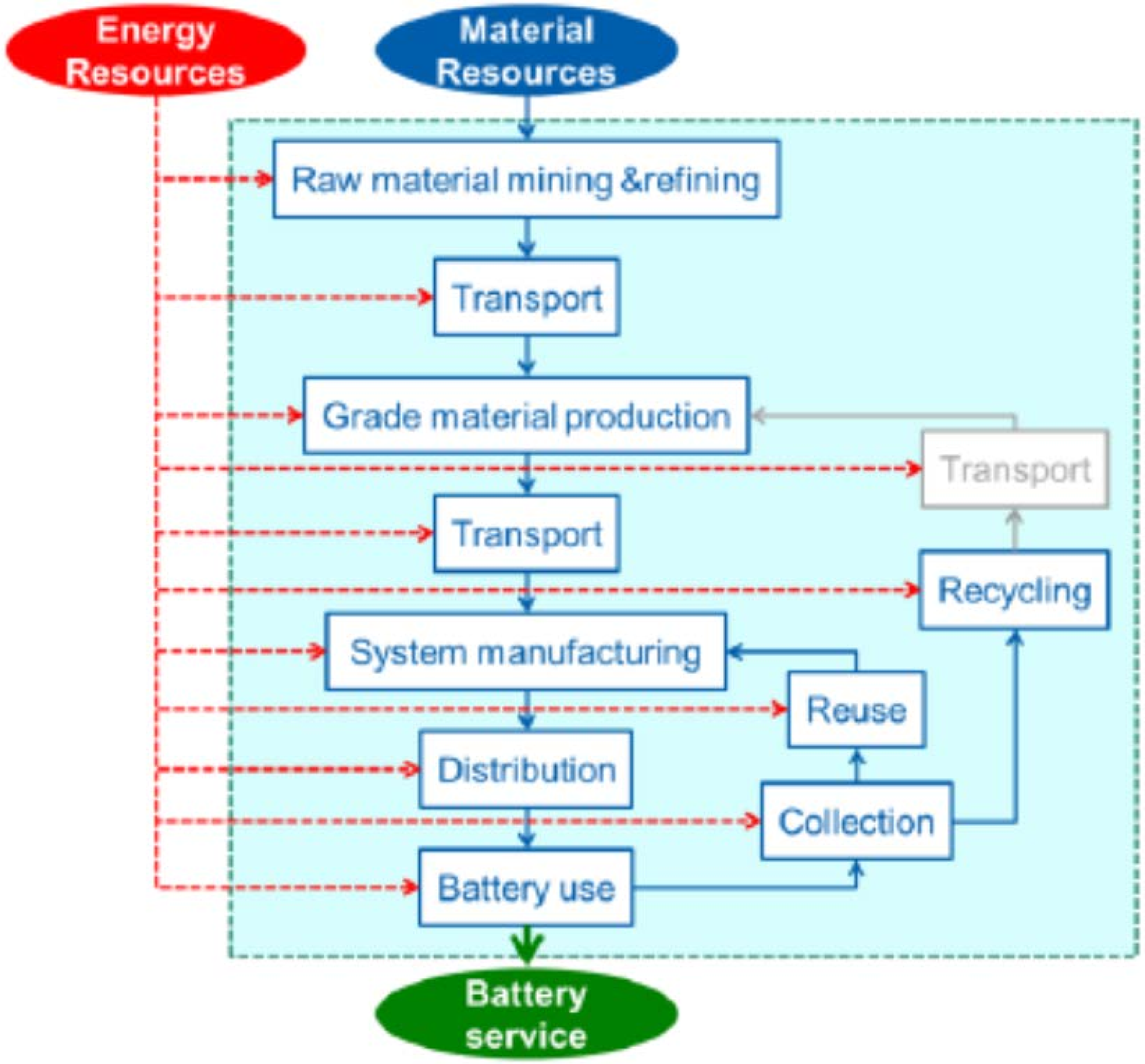
Life cycle assessment (LCA)



- **Source:** Jungmeier, G. (2018). Towards Green Batteries – LCA of Automotive Battery Systems

Problem definition

- Variation in LCAs between:
  - Qualitative data
  - Quantitative data
  - Key environmental influences

Which aspects influence the environmental performance of electric vehicle batteries?

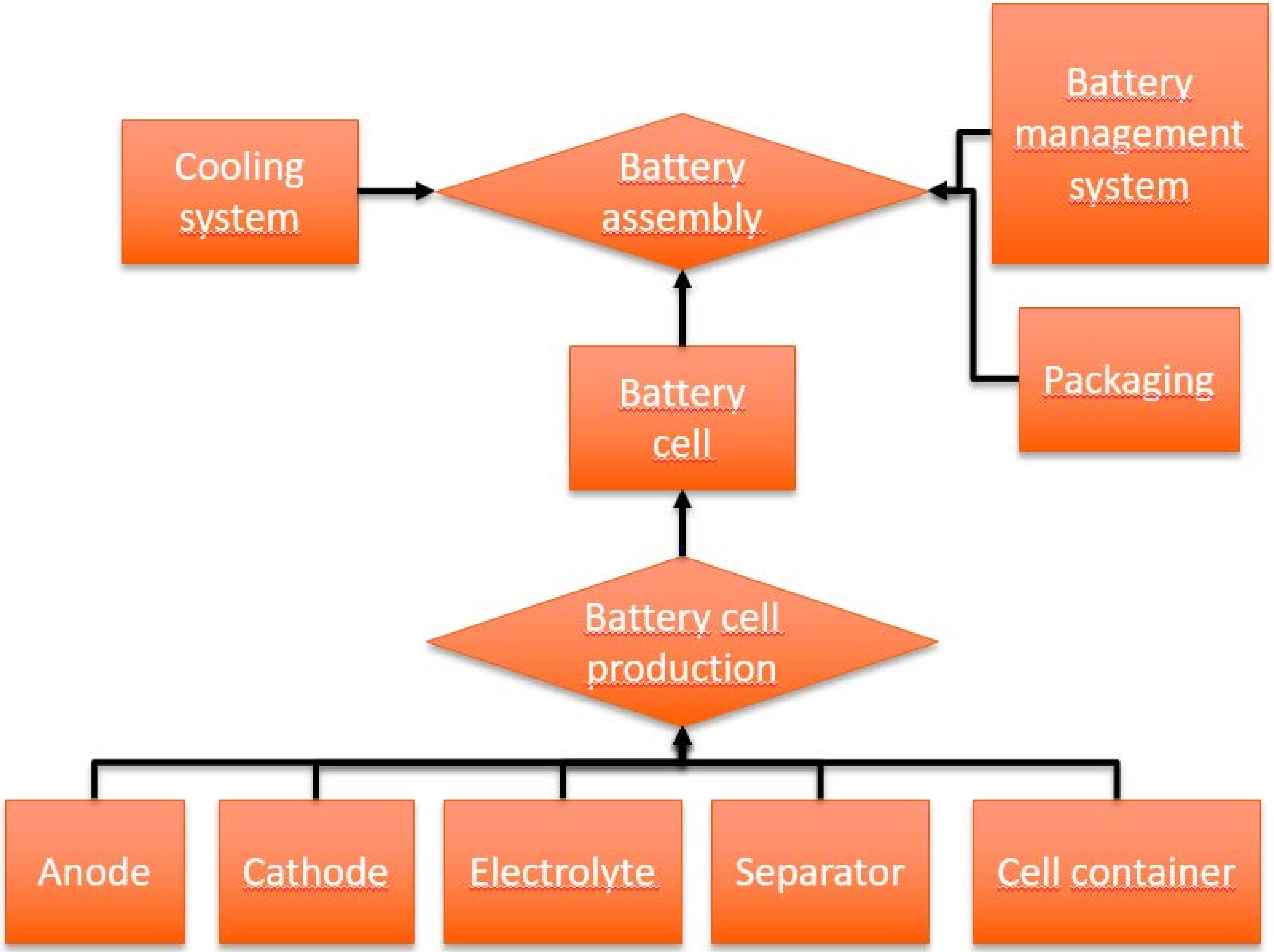
Objectives

- Collection and review of 46 LCA studies in Excel database
- Gathering of qualitative and quantitative data from LCAs
- Identification of main environmental aspects
- Assessment of differences and coherences
- Pointing out further research and development issues and recommendations for LCAs

Lithium-ion battery pack

Main materials:

- Positive active material (incl. Lithium, Nickel and Cobalt)
- Aluminum
- Graphite
- Copper
- Solvent (N-methyl-2-pyrrolidon or water)
- Binder
- Lithium hexafluorophosphate (Electrolyte)
- Polyolefin (Separator)
- Steel
- Polymer



Adapted from: Ellingsen et al. (2013). Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack. *Journal of Industrial Ecology*. 18. 10.1111/jiec.12072

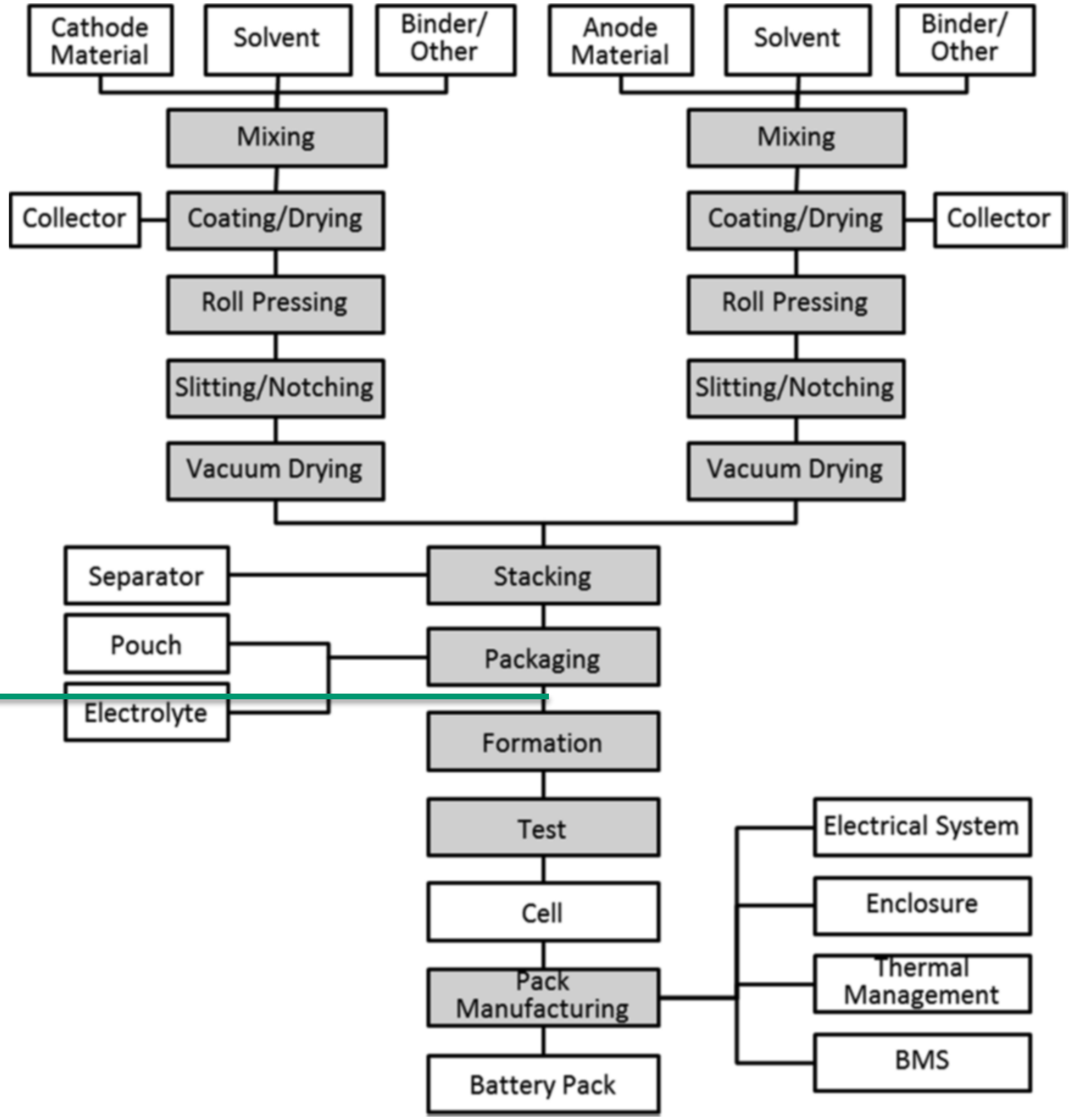
Battery production steps

1. Material extraction
2. Material processing
3. Cell production
4. Pack production

Cell + pack production

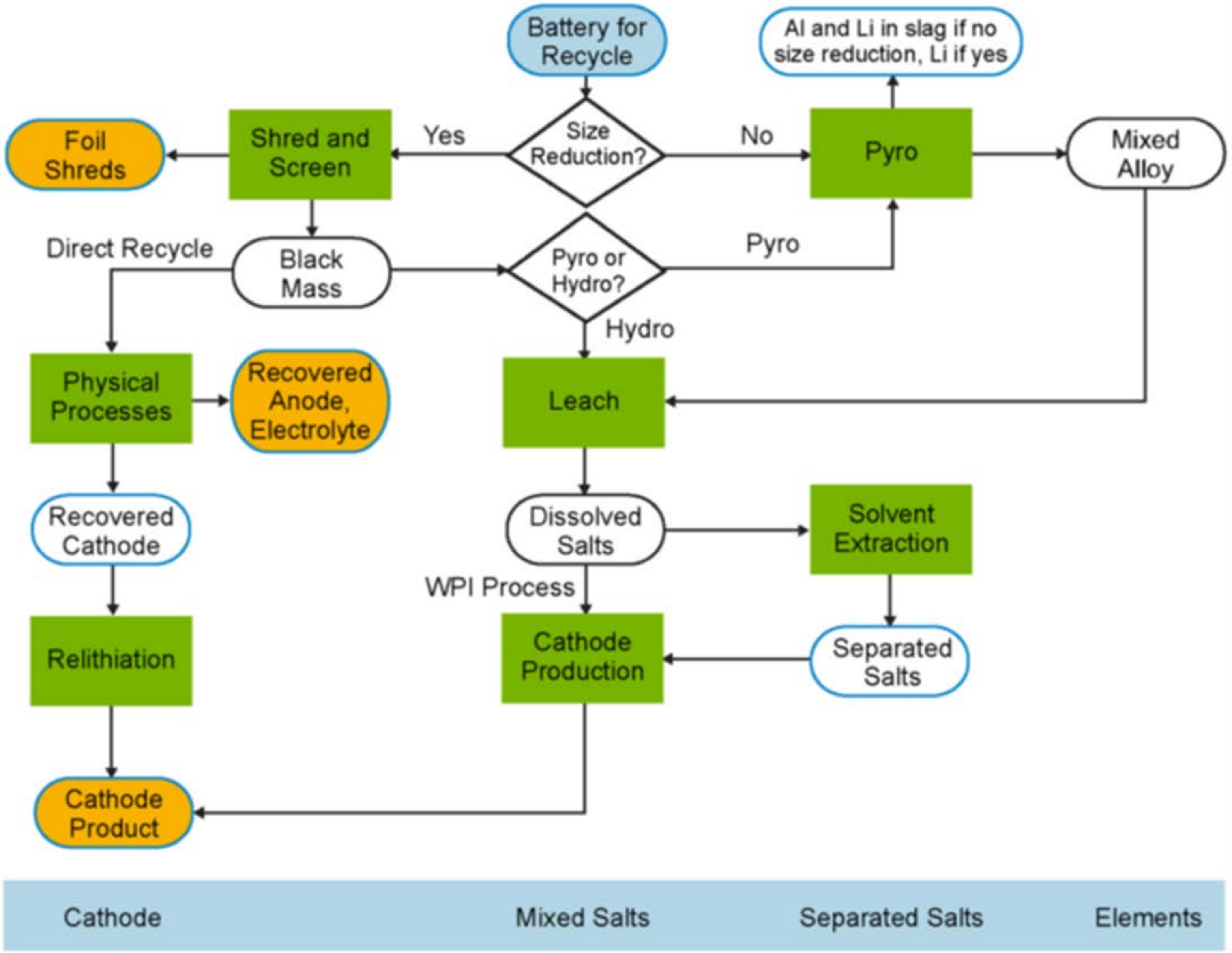
- **Source:** Kim et al. (2016). Cradle-to-Gate Emissions from a Commercial Electric Vehicle Li-Ion Battery: A Comparative Analysis. *Environmental Science & Technology*. 50. 10.1021/acs.est.6b00830.

Up to this point: dry room operation at around 22°C



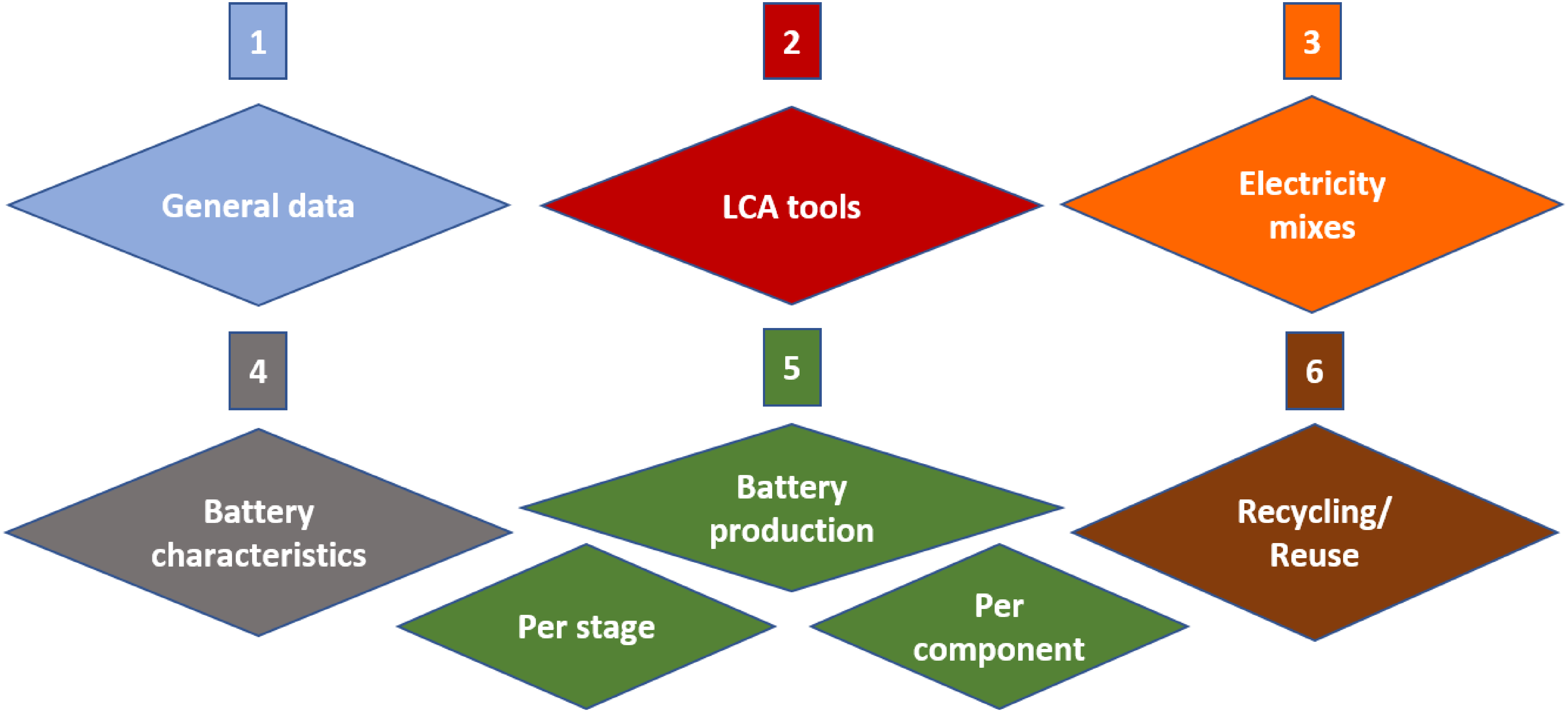
Three possible recycling processes

- Pyrometallurgy
- Hydrometallurgy
- Direct method



Source: Gaines L. (2018). Lithium-ion battery recycling processes: Research towards a sustainable course. *Sustainable Materials and Technologies*. 17. e00068. 10.1016/j.susmat.2018.e00068.

Database structure



Main quantitative results

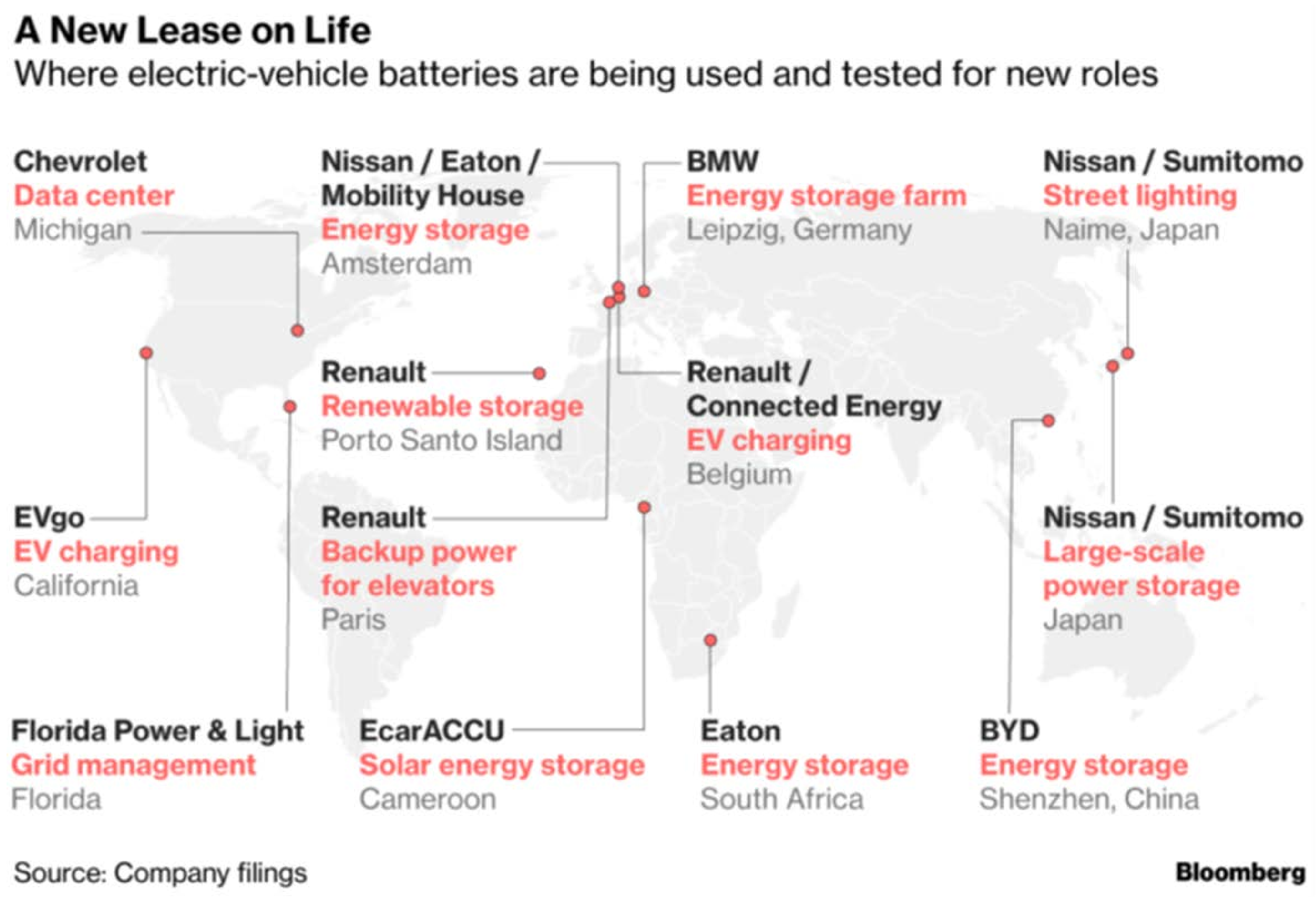
- Primary energy consumption: **1,000 MJ/kWh** *(700 – 1,900)*
- Global warming potential: **120 kg CO2eq/kWh** *(70 – 170)*
  - Recycling net effect: **20 kg CO2eq/kWh** *(10 – 30)*
- Battery capacity: **30 kWh** *(20 – 40)*
- Battery lifetime: **180,000 km** *(150,000 – 200,000)*

Without consideration of second life applications and recycling:

10 – 70 **g CO2eq/km** (median: **20**)

0.3 – 2.5 **l/100 km gasoline** (median **0.7**)

Second life applications → usually not assessed



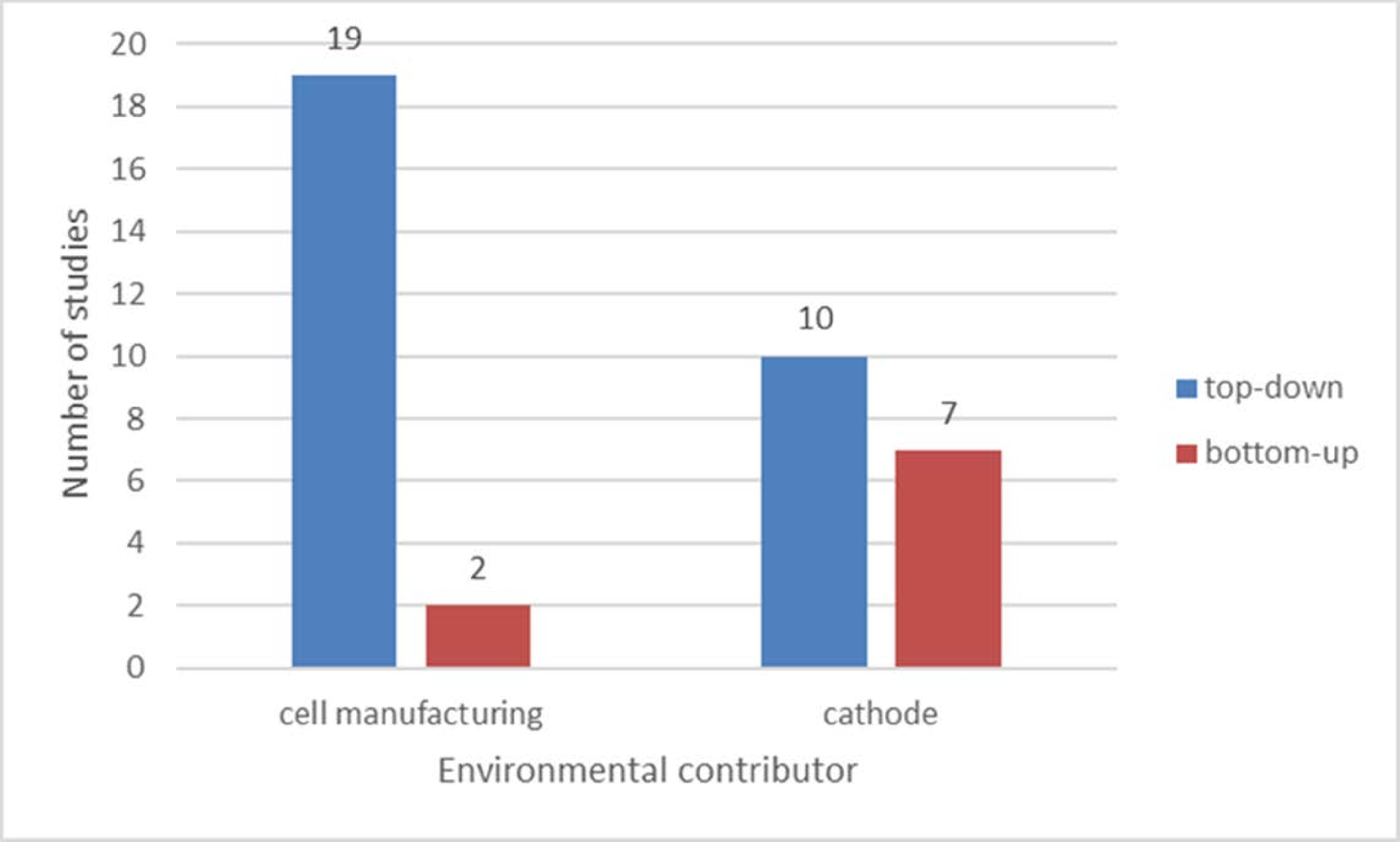
Remaining battery capacity after use in electric vehicle: around **70%**

Source: Stringer, David & Ma, Jie (2018). Where 3 Million Electric Vehicle Batteries Will Go When They Retire.

Major environmental production impacts

1. Cell manufacturing
2. Cathode production

- Comparison: top-down vs. bottom-up



Summary of quantitative results

- Cathode and cell manufacturing impacts most significant
- Low variation between material impacts and battery types
- High variation between cell manufacturing impacts and electricity mixes
- Pack manufacturing impacts negligible
- Recycling net effect is visible, but often not assessed/included

Explanation for results of most top-down LCA studies

- **Overestimation** of electricity consumption in cell manufacturing possible:
  - Small production scales
  - 100 % electricity share in production process unlikely

- **Underestimation** of material processing impacts (important: metals)
  - Limited primary data for cathode active material production → neglecting of production steps
  - Material emission values based on US production (GREET database), Chinese values assumed to be higher

Effect on new publications → depends on data source for primary energy consumption of cell manufacturing

- **Based on primary data:**
- Reduction of global warming impact when higher production scale assessed

- **Based on secondary data from literature:**
- Reliance on old data with small production scales → no reduction of global warming impact

Conclusion

- High reliance on secondary data
- Focus on direct environmental impacts
- Focus on primary energy consumption + GWP
- Often overestimation of cell manufacturing
- Underestimation of material processing
- Battery lifetime often neglected
- Recycling and second life application infrequently assessed

International Collaboration

This work is done in the **Technology Collaboration Programm** (TCP) of the **International Energy Agency** (IEA) on **Hybrid & Electric Vehicle** (HEV) in two tasks operated by JOANNEUM RESEARCH

- Task 30: Environmental Effects of Electric Vehicles (7 Countries)
- Task 33: Battery Electric Buses (6 countries)
- The Austrian participation is funded by
- www.ieahev.org

Danke für Ihre Aufmerksamkeit!

JOANNEUM RESEARCH
Forschungsgesellschaft mbH

LIFE – Zentrum für Klima,
Energie und Gesellschaft

Science Tower
Waagner-Biro-Straße 100, 8020 Graz
Tel. +43 316 876-7600
life@joanneum.at

www.joanneum.at/life

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