# LCA of Li-ion batteries: current state and prospects

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Presentation at the 68. LCA Forum 16. April 2018, ETH Zürich

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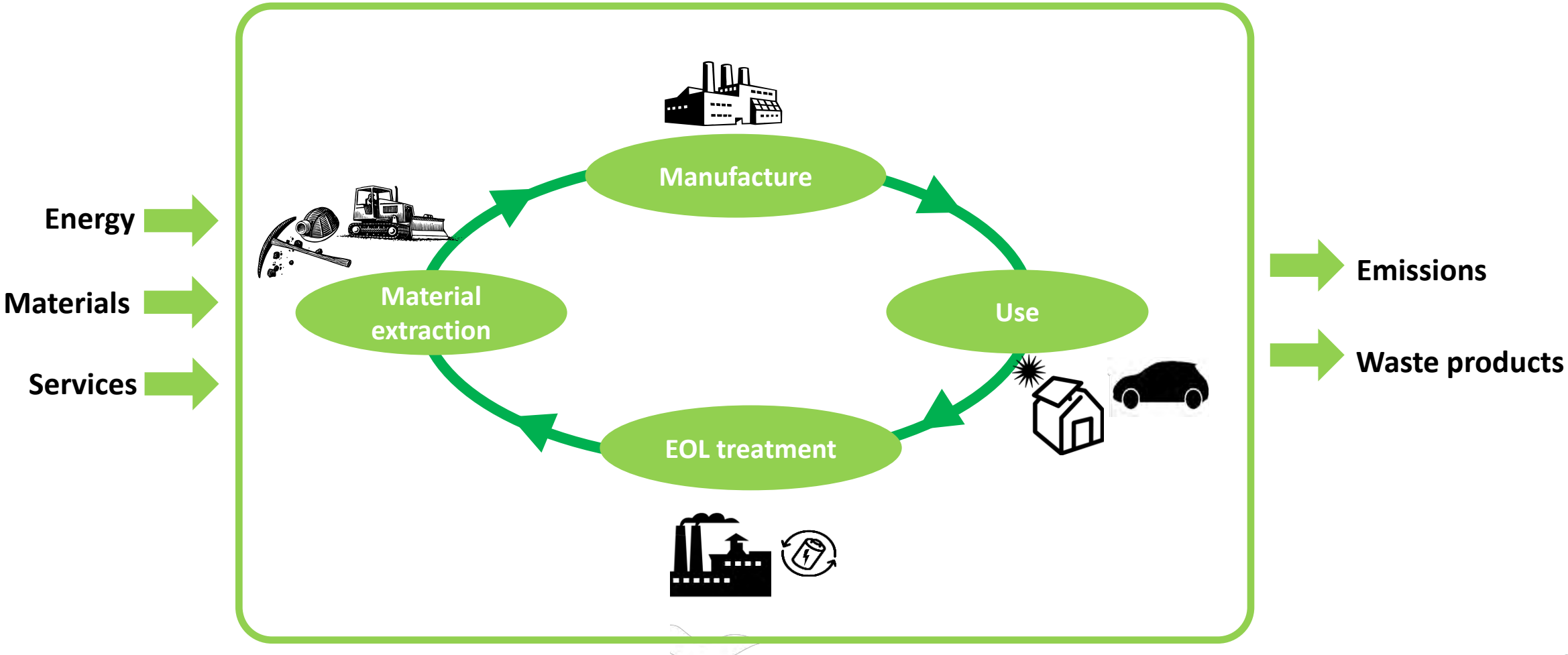
# LCA of Li-ion batteries

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# Interconnection of LCI data sources in cradle-to-gate studies

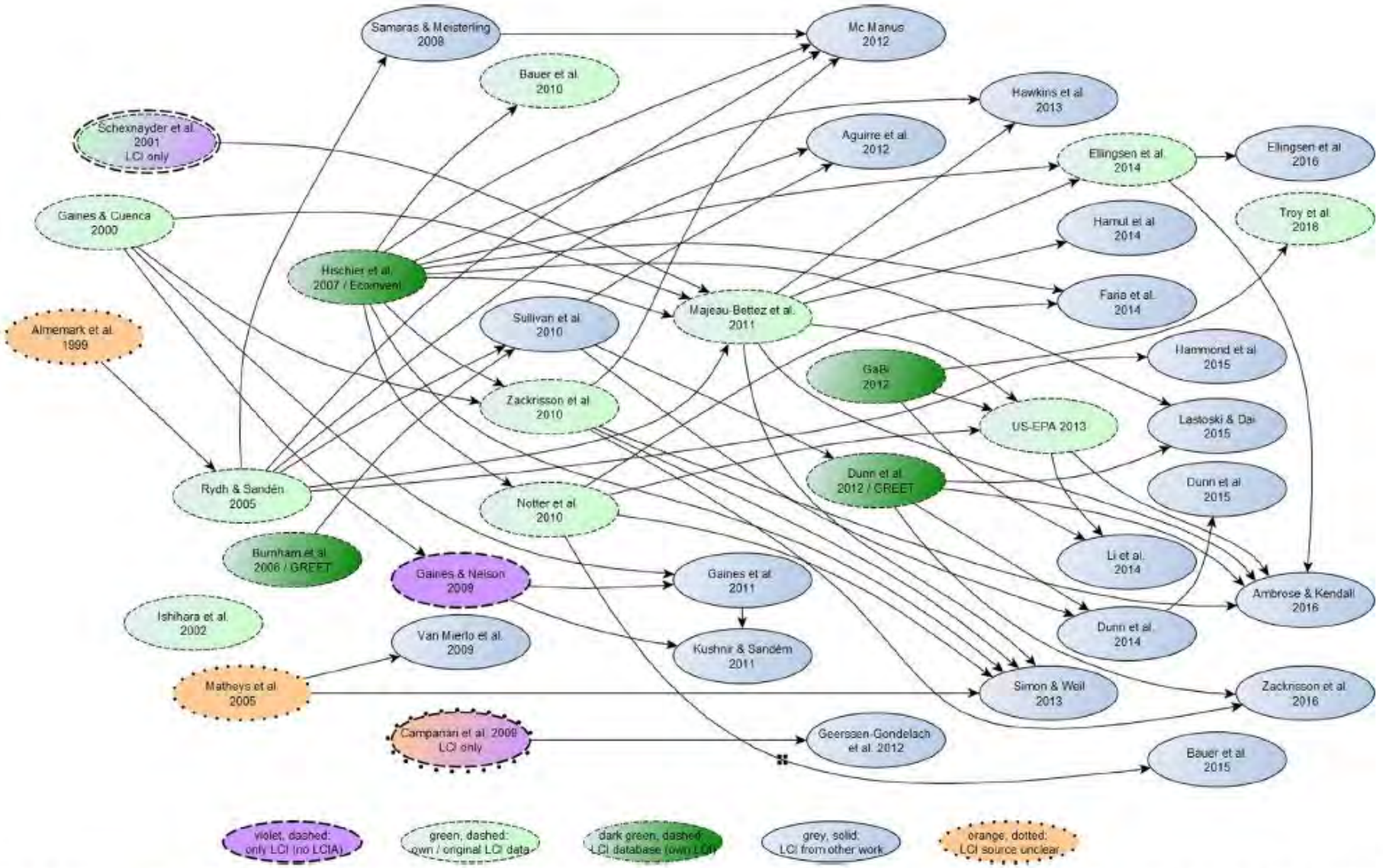


**Fig. 2.** Interconnection of LCI data sources used in the analysed studies. Dependencies refer only to primary inventory data; background processes are taken from standard databases in the majority of the studies; this is not indicated in the figure. The corresponding references are provided in Table 1.

Peters et al. (2017)

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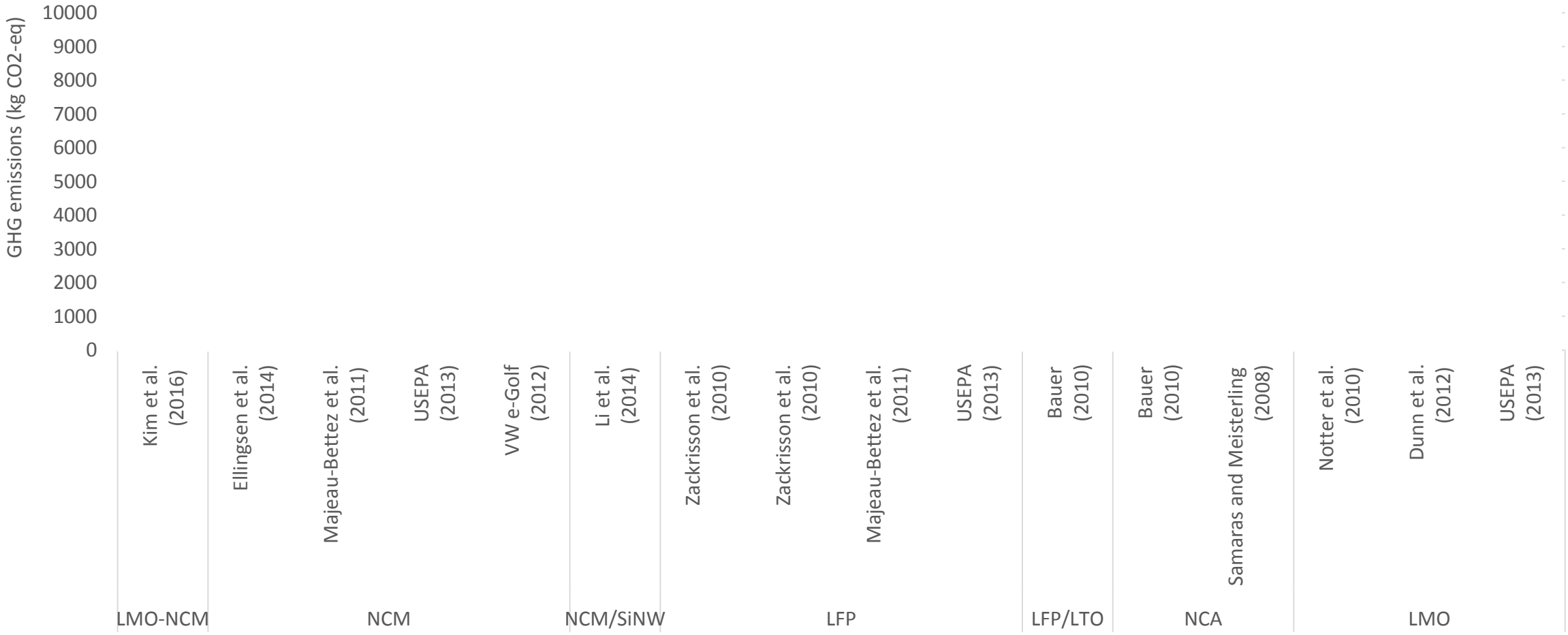
# Cradle-to-gate GHG emissions of a 26.6 kWh Li-ion battery

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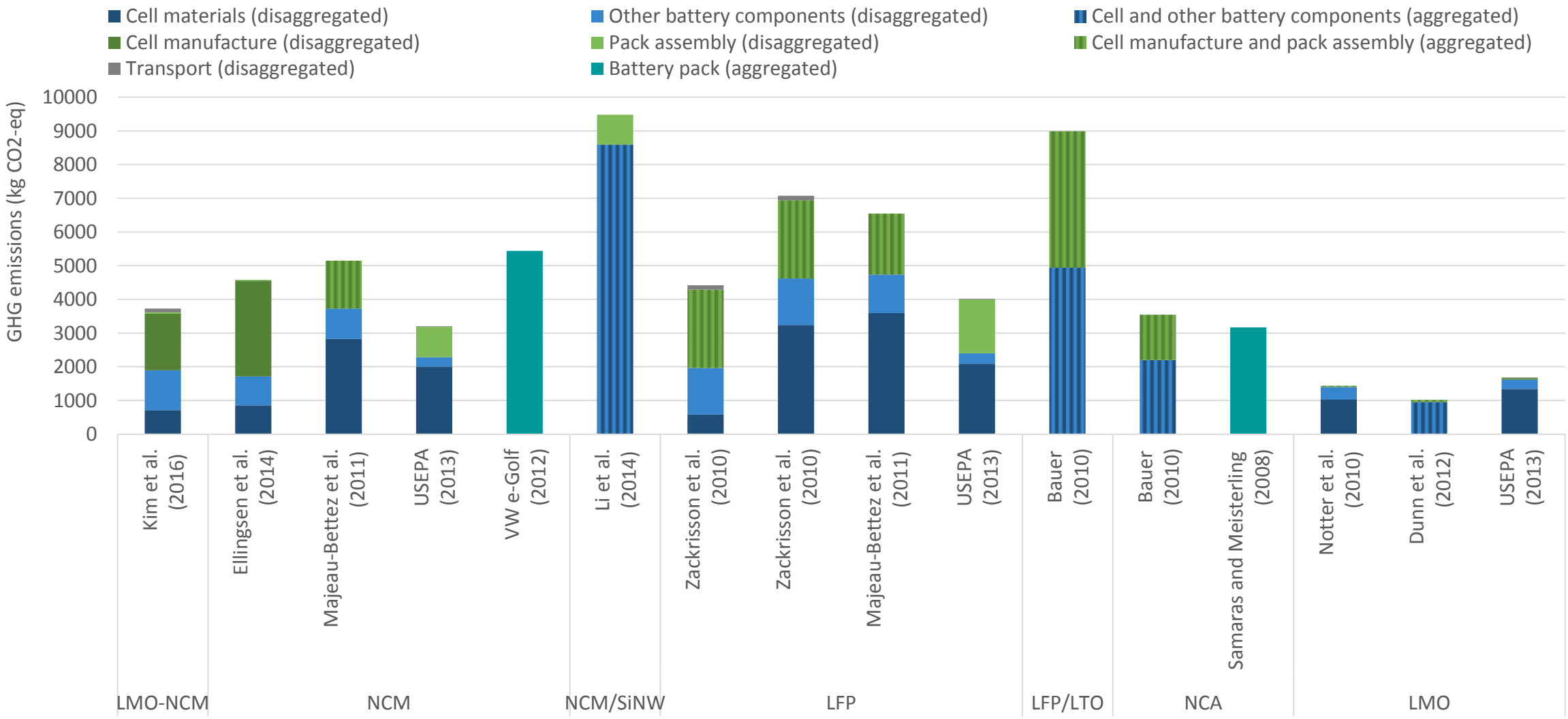
Ellingsen et al. (2017)

$LiMnO_4$ – LMO; $LiNi_xCo_YMn_{(1-X-Y)}O_2$ – NCM; SiNW – Silcon nanowire; $LiFePO_4$ – LFP; $Li_4Ti_5O_{12}$ – LTO; $LiCoO_2$ – LCO; $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$ - NCA

# Cradle-to-gate GHG emissions of a 26.6 kWh Li-ion battery

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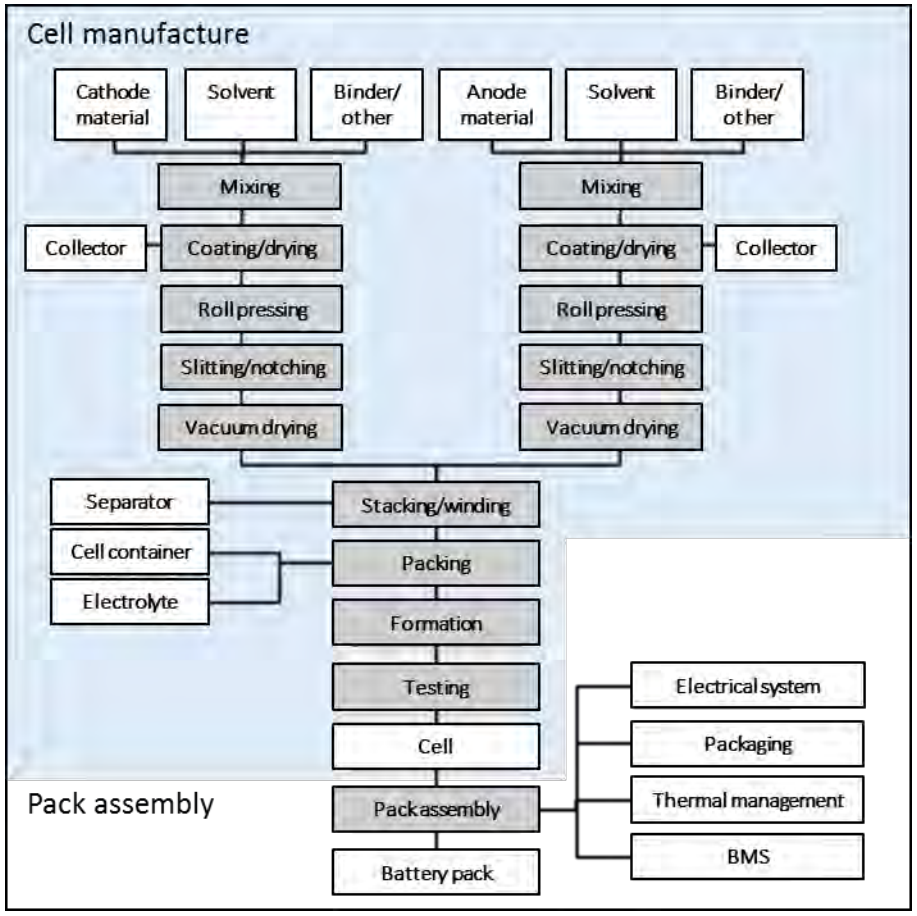
Ellingsen et al. (2017)

# Battery production energy inputs




| *Study* | *Cell manufacture (MJ/kWh)* | *Pack assembly (MJ/kWh)* | *Cell manufacture and pack assembly (MJ/kWh)* | *Energy data sources* |
|---|---|---|---|---|
| *Kim et al. (2016)* | | | 530* | Primary data |
| *Ellingsen et al (2014)* | 586 | 0.01 | 586 | Primary data |
| *Majeau-Bettez et al. (2011)* | | | 463-590* | Secondary data |
| *USEPA (2013)* | 0-10 | 0-400 | 10-403 | Majeau-Bettez et al. (2011), Notter et al. (2010), and primary data |
| *Li et al. (2014)* | 0.36 | 0.41 | 0.77 | Author estimates |
| *Zackrisson et al. (2010)* | | | 450* | Secondary data |
| *Bauer (2010)* | 326-1060 | 109-278 | 434-1338 | Secondary data |
| *Notter et al. (2010)* | 3.1 | 0.11 | 3.21 | Author estimates |
| *Dunn et al. (2012)* | 2.7 | 2.9 | 5.6 | Author estimates |

*Study only provides the combined energy demand for cell manufacture and pack assembly

Kim et al. (2016) ; Ellingsen et al. (2017)

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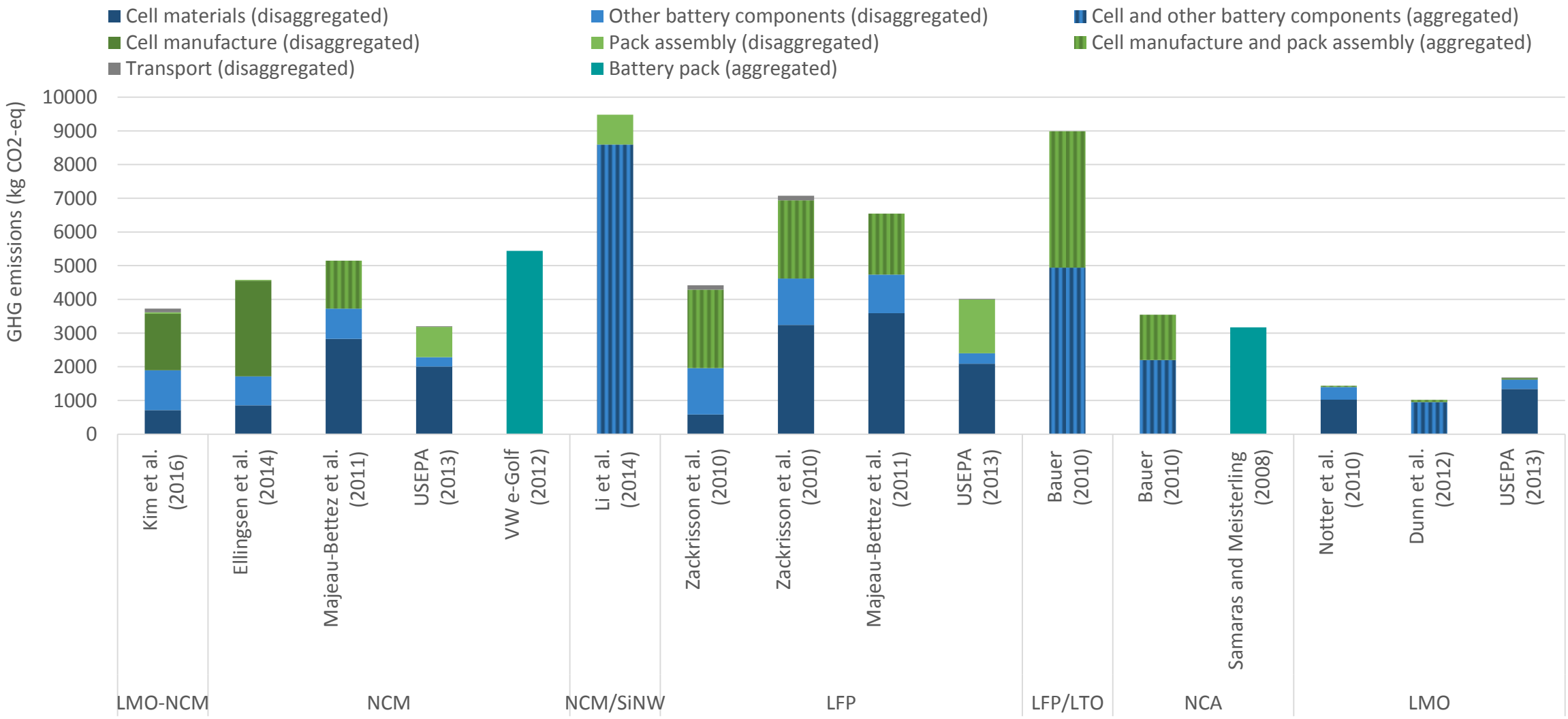
# Cradle-to-gate GHG emissions of a 26.6 kWh Li-ion battery

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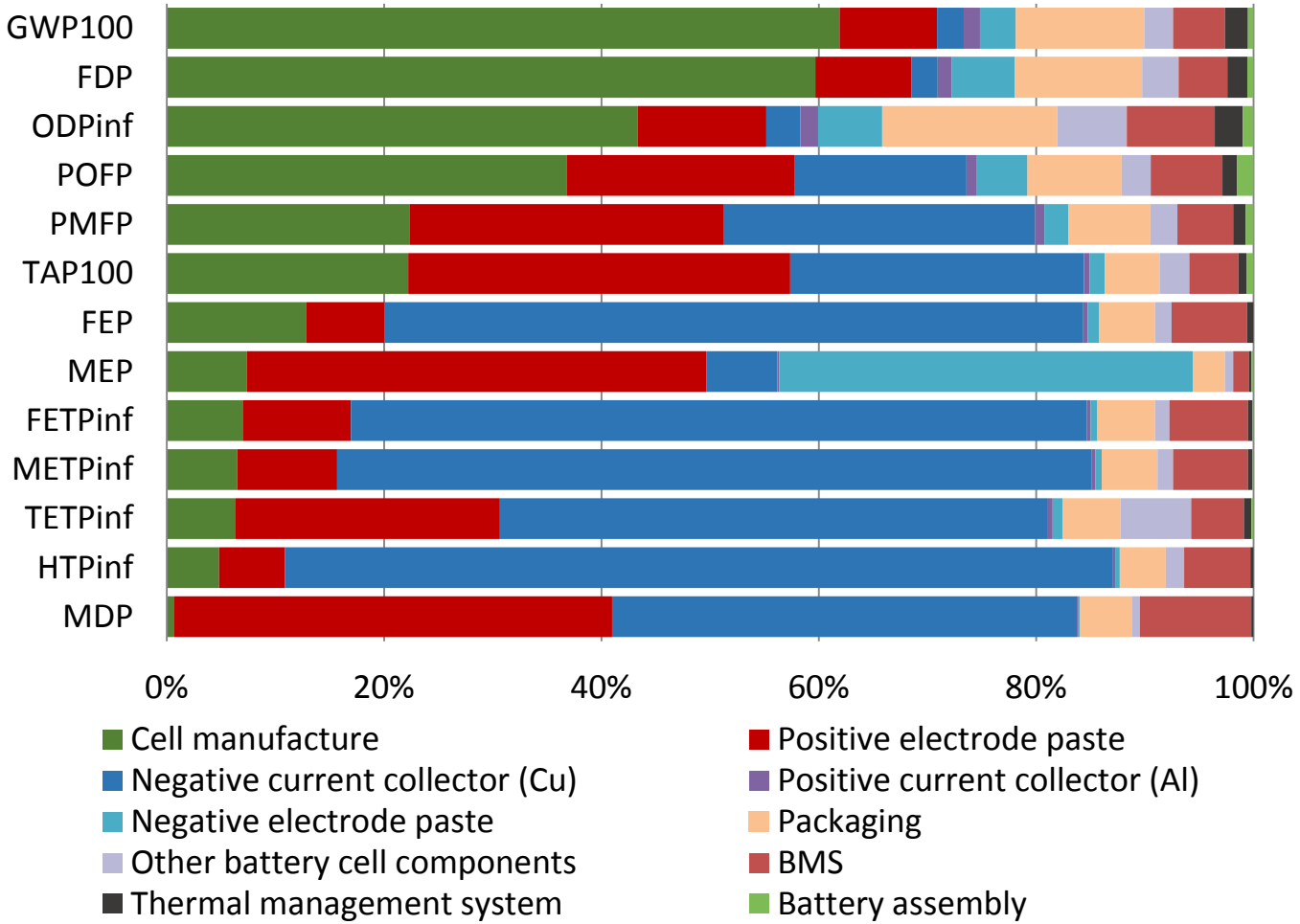
Ellingsen et al. (2017)

# Cradle-to-gate impacts of a 26.6 kWh Li-ion battery




- Transferable to other Li-ion battery types and applications
- Some differences among the Li-ion battery types
- Use of renewable energy and recycled metals can reduce impact

Ellingsen et al. (2014)

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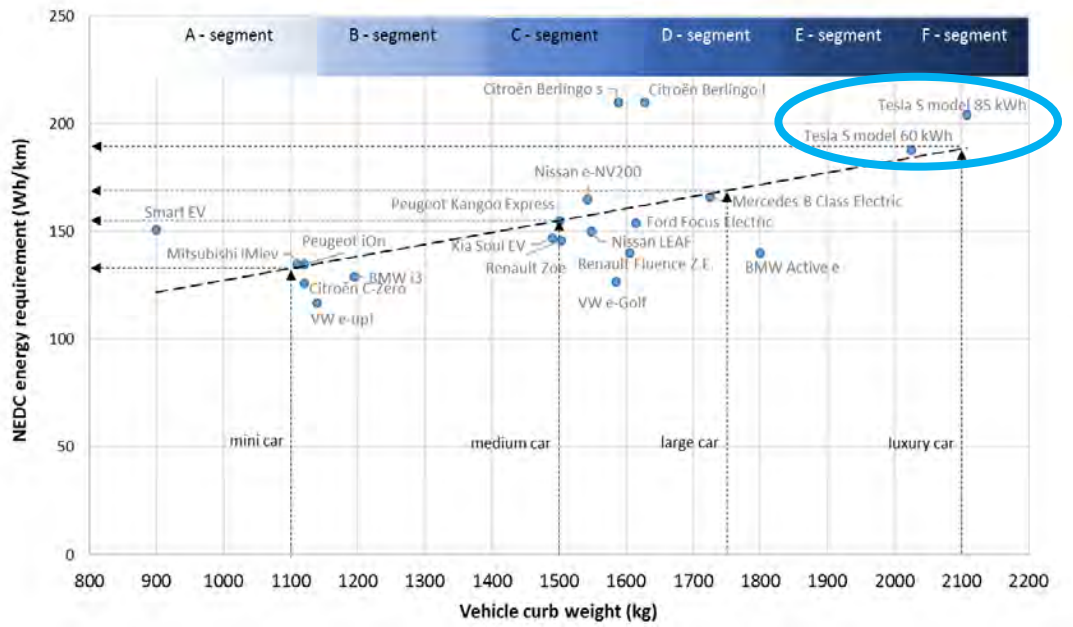
# Use phase

Three decisive factors for traction batteries:

- Energy conversion losses
- Energy required to transport the weight of the battery
- Environmental intensity of the electricity

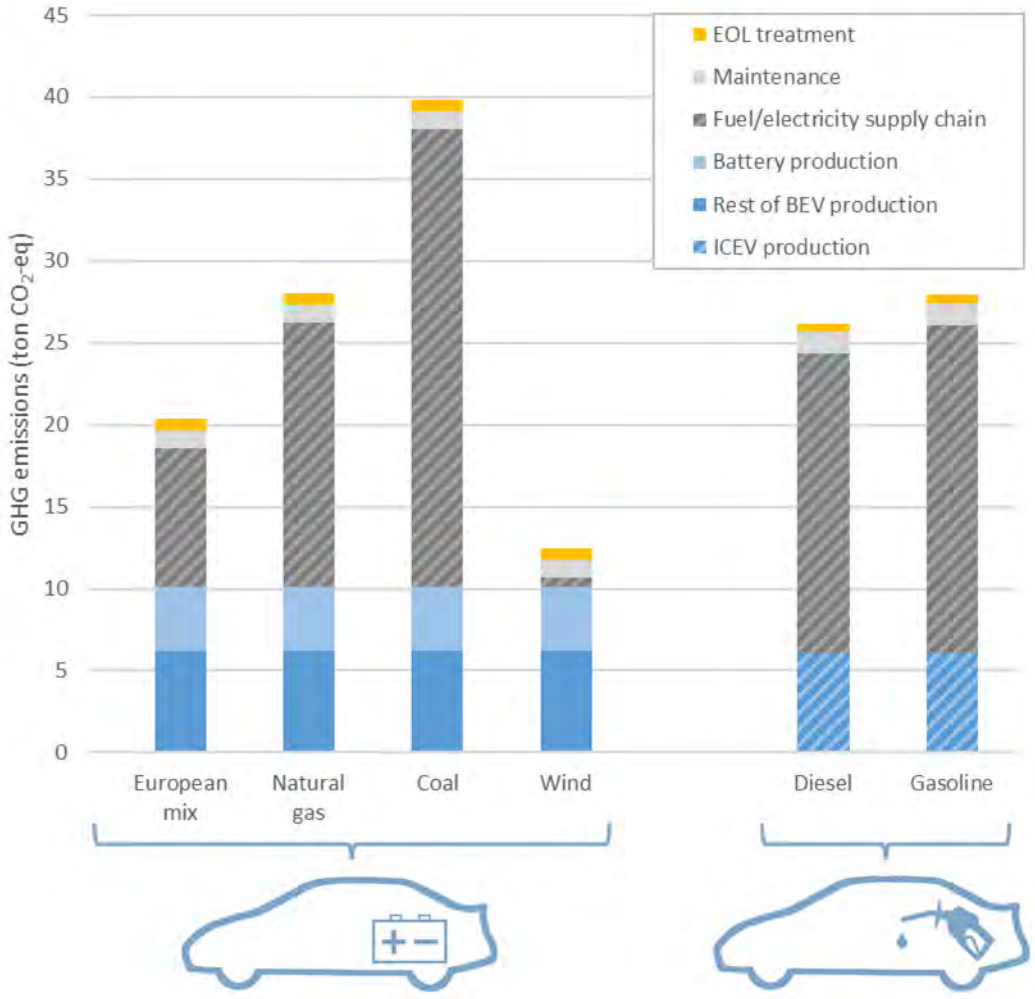


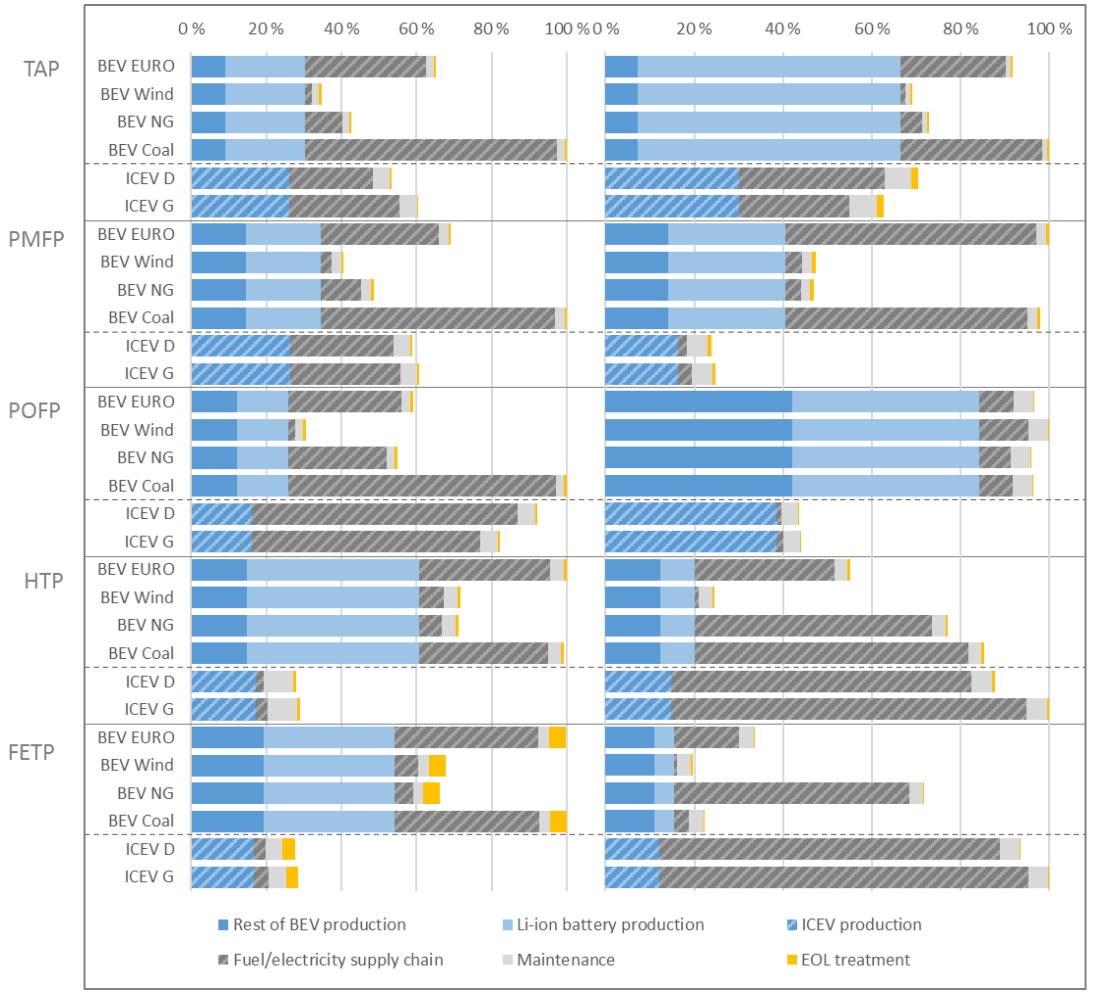

Ellingsen et al. (2016)

# End-of-life treatment

- Variety of industrial recycling schemes
- Few LCA studies assess EOL and high uncertainty
- Two modelling approaches
  - Recycled content approach: 100 to 700 kg $CO_2$-eq per 26.6 kWh battery
  - End-of-life approach : -400 to -850 kg $CO_2$-eq per 26.6 kWh battery

# Environmental implications for electric vehicles




Terrestrial acidification potential (TAP), Particulate matter formation potential (PMFP), Photo oxidation formation potential (POFP), Human toxicity potential (HTP), Freshwater ecotoxicity potential (FETP), Marine eutrophication potential (MEP), Freshwater eutrophication potential (FEP), Metal depletion potential (MDP), Fossil depletion potential (FDP), Ozone depletion potential (ODP)

Ellingsen & Hung (2018); Figure based on: Hawkins et al. (2013) and Ellingsen et al. (2014)

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# Current and future Li-ion battery developments


- More energy data on cell manufacture available
  - More process specific data still needed
- Higher specific energy – new electrode materials
  - Anode: introduction of silicon nanomaterial
  - Cathode: change in composition (e.g., NCM) and new materials (e.g., sulphur)
- Tesla Gigafactory 1
  - Renewable energy
- Li-ion battery recycling
  - Process data required!

Umicore (2017)

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# Thank you!

**References:**


Picture opening slide https://besthqwallpapers.com/

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