Environmental Impact and Economical Analysis of Sodium and Lithium-Ion Battery Manufacturing

Cradle-To-Gate Life Cycle Assessment of Sodium and Lithium-Ion Batteries

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Abstract

The increased demand for sodium-ion battery (SIB) manufacturing in the UK has raised awareness of the negative environmental impacts and costs associated with battery production. However, the lack of data about SIB production makes these hard to assess. This study aids to present UK specific Life cycle assessment (LCA) for the production of a sodium-ion battery with a sodium nickel manganese magnesium titanium layered oxide (NMMT) cathode and hard carbon (HC) anode and its comparison with lithium-ion battery (LIB) production with lithium nickel cobalt manganese layered oxide (NCM) cathode and graphite (Gr) anode.

SIB production was found to be environmentally and economically more advantageous, making SIB a promising alternative for LIB.

Scope of the study

- The system boundaries for this study cover material preparation and battery production, excluding transport, battery use and disposal (*Fig. 2*). Three different transport scenarios for SIB were assessed in Nicholas Gerard FUSE project.
- The manufacturing steps are assumed to be the same for LIB and SIB. Most commonly used cell designs were selected: pouch cell for LIB and cylindrical for SIB with pack density of 105 Wh/kg and 102 Wh/kg respectively.

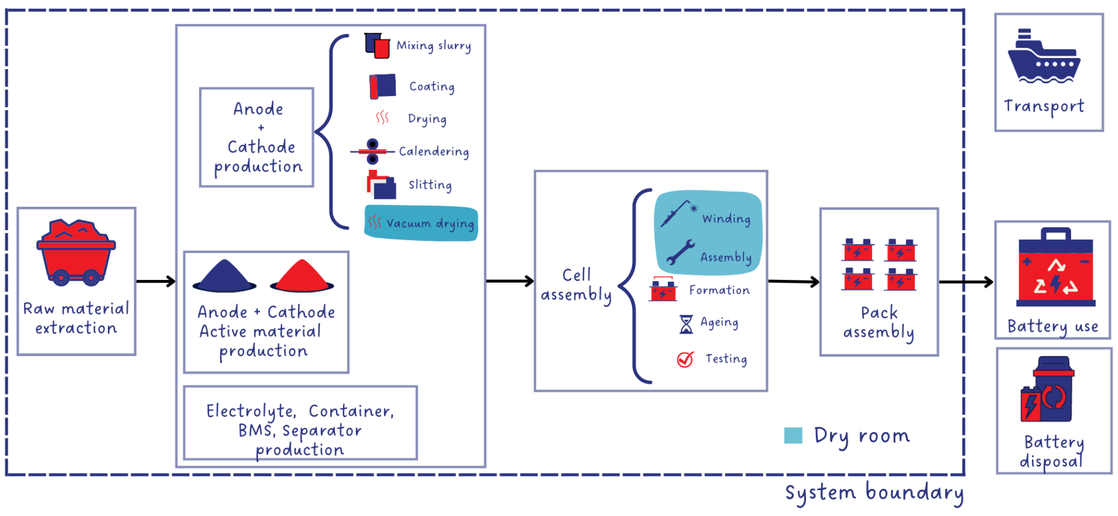

Fig. 2. Cradle-to-gate product system studied. The winding step was replaced for stacking for pouch cell production for LIB.

Inventory analysis

- LIB inventory data was used from *Kallitsis et al. , 2020.*
- SIB inventory was based on *Peters et al., 2016.* Raw material production processes were updated based on *Kallitsis et al. , 2020*. Energy requirement of the SIB manufacturing steps was recalculated based on *Degen et al., 2022* (*Fig. 2*).
- LCA for two methods for hard carbon production for SIB anode was performed prior the cradle-to-gate analysis (*Fig. 3*). Petroleum coke was chosen for further calculations as it shows considerably better results in most categories.

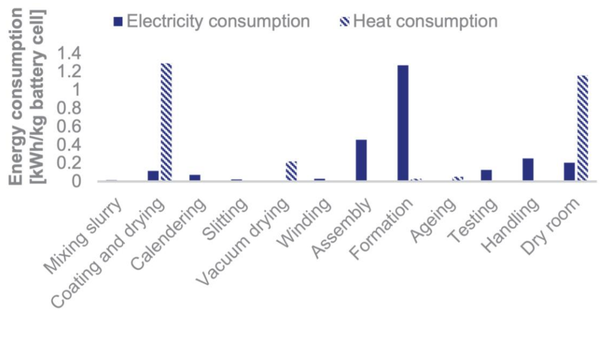

Fig. 3. Electricity and heat requirements for SIB manufacturing steps.

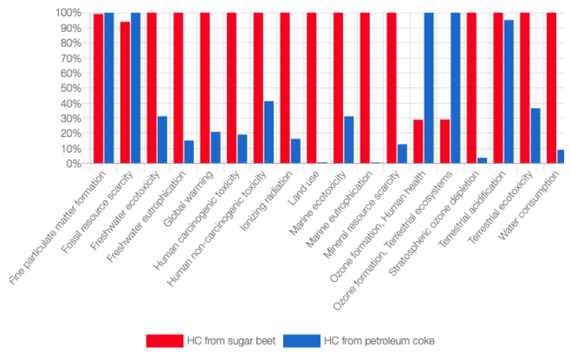

Fig. 4. Influence of 1 kg SIB hard carbon precursor production.

Impact / Next steps

- The impact of the updated SIB inventory data shows a more accurate comparison of LIB and SIB than in the original study *(Peters et al., 2016).*
- SIB production can be further improved by reducing the number of electronic components and decreasing the energy required for the manufacturing stages. The latter can be achieved by switching to dry manufacturing technology.
- Next step is to include battery usage and recycling in the model.

Motivation

- Assess the environmental impacts associated with the detailed production of non-commercialised SIBs in the UK looking for ways of improvement.
- Research a method to update existing SIB inventory data for more precise analysis.
- Compare UK specific LIB and SIB production.

Methods

- OpenLCA was used to compare the different types of batteries across 18 environmental impact categories and cost impacts based on the ReCiPe 1.08 Midpoint H characterisation method.
- The geographical boundary was limited to material inputs from China, production processes with LCI parameters reflecting the UK average. Data for UK Electricity mix was based on *Raugei et al., 2020* (*Fig. 1*).

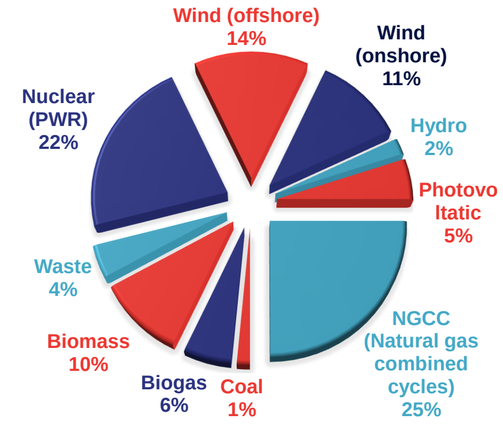

Fig. 1. Percentage contribution of natural gas, coal, nuclear, waste and renewable power to the UK electricity mix.

Results / Conclusions

- SIB shows great environmental advantages compared to LIB in all assessed categories despite Stratospheric ozone depletion *(Fig. 5).*
- The economic impact shows that 1 kg SIB pack production is cheaper than of LIB, with considerably cheaper anode and cathode production *(Fig. 6).*
- The anode and cathode production have the biggest contribution to the total environmental impact of SIB manufacturing, followed by the printed wiring board production *(Fig. 7)*. See further details about the results and inventory data in the supplementary information provided for this study.

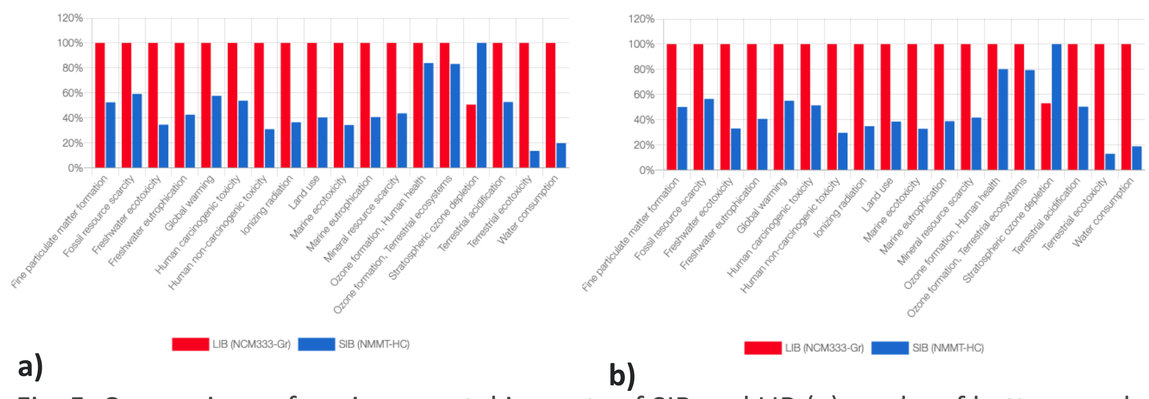

Fig. 5. Comparison of environmental impacts of SIB and LIB (a) per kg of battery pack and (b) per kWh of energy stored.

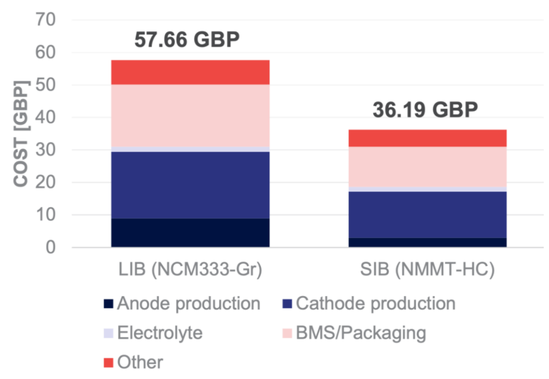

Fig. 6. Cost analysis of 1 kg SIB and LIB pack production.

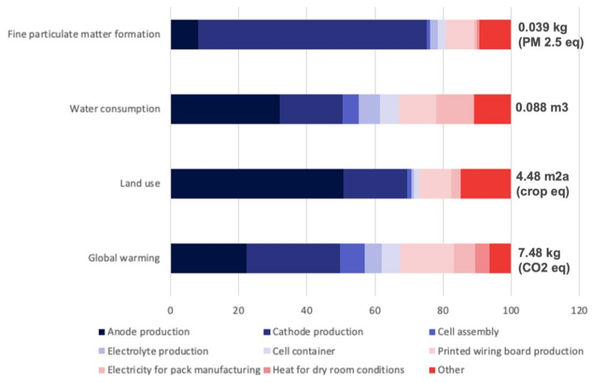

Fig. 7. Contribution of SIB components of the main environmental impacts.

References

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- Peters, J. *et al.*, 2016. *Energy & Environmental Science*, 9(5), pp.1744-1751.
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Further readings

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- Tapia-Ruiz, N. *et al.*, 2021. *J. Phys. Energy*, 3(3), p.031503.

Intern bio

Reka is studying Chemical Engineering at University College London. Interested in energy storage and renewable energy for a long time and wishes to undertake a PhD in a related field. Outside of her studies, she enjoys doing scientific-related artworks to motivate people to a more sustainable life.

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