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Cost and Carbon Footprint Reduction of EV LIBs Through Efficient Thermal Management

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INTRODUCTION

- A prolonged battery use phase can reduce life cycle environmental and economic impacts as it compensates for manufacturing impacts (Fig.1).

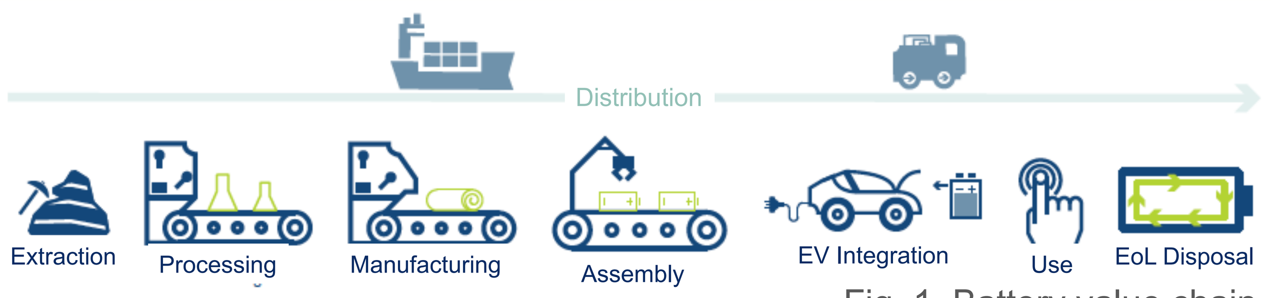


Fig. 1. Battery value chain.

- Engineering solutions e.g. thermal management systems (TMS; Fig. 2) can help to extend the battery lifetime and thus the use phase.

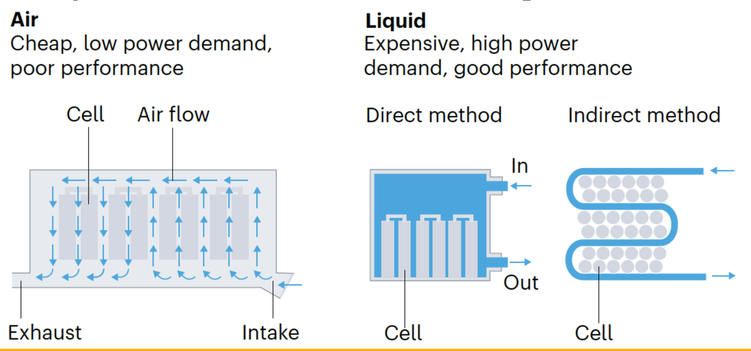


Fig. 2. Thermal management systems.

BATTERY LIFETIME

- Correlation between TMS, maximum cell temperature and battery lifetime for an NMC/Gr EV battery is established.
- Maximum cell temperature is derived from coolant inlet temperature (T_{inlet}), heat generation ($\dot{Q}_{gen}$) and Cell Cooling Coefficient (*CCC*) *(Eq. 1)*.

$$T_{max} = T_{inlet} + \frac{\dot{Q}_{gen}}{CCC} \quad \text{(Equation 1)}$$

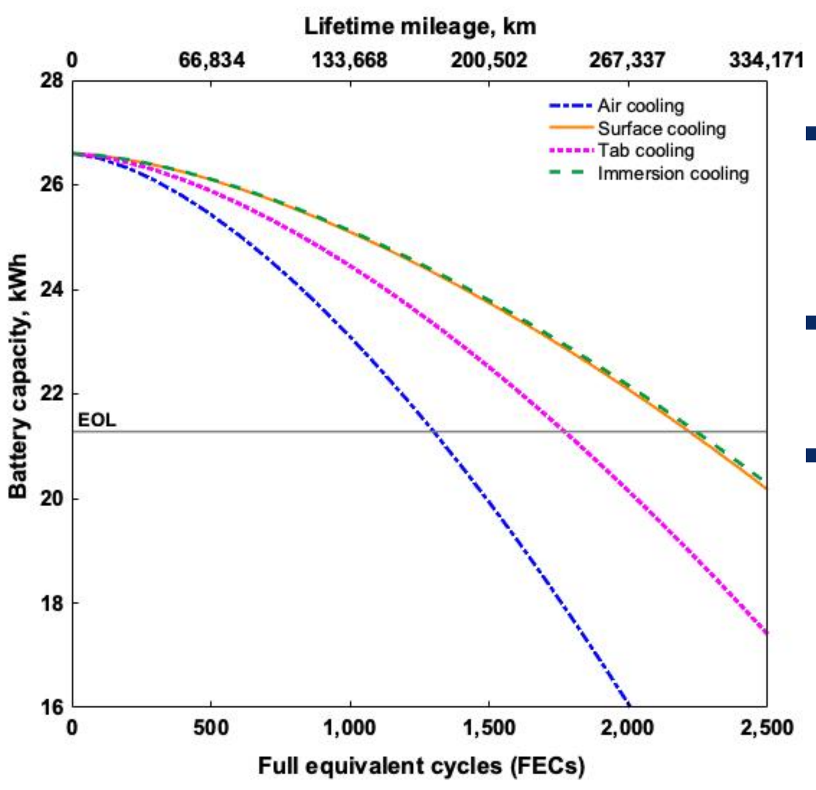
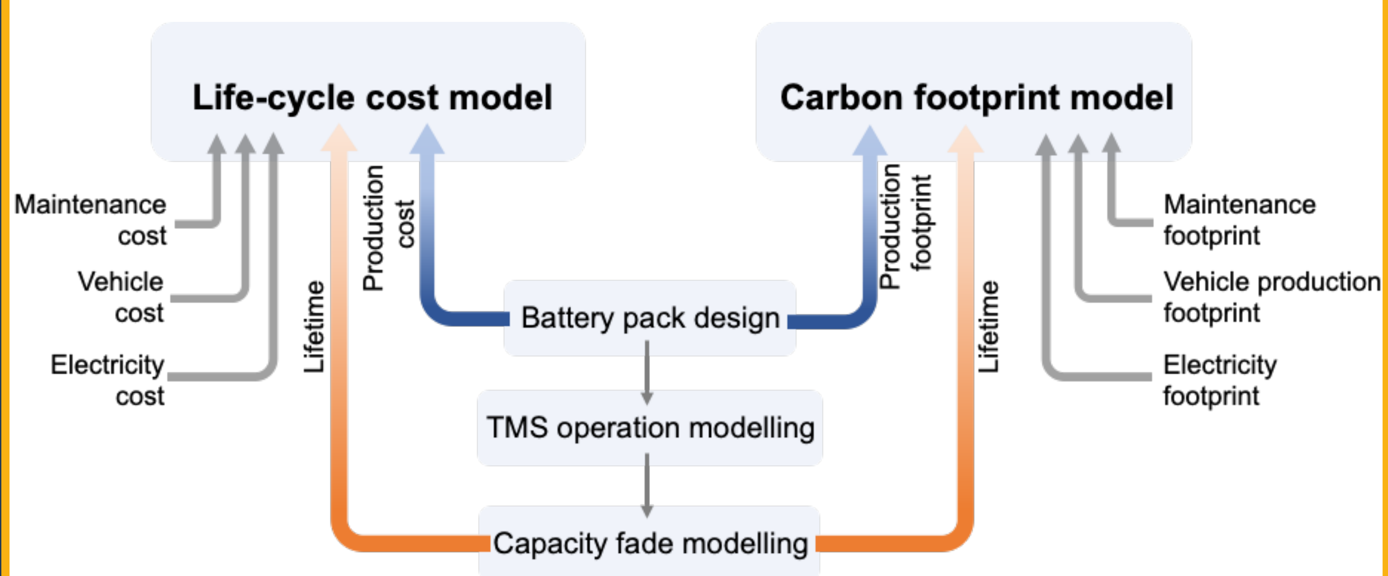


Fig. 3. Relative capacity degradation as a function of the max. operating temperature for various cooling methods.

- Highest cell operating temperature for air cooling (41 ºC), lowest for surface and immersion cooling (25 ºC).
- Battery cycle lifetime is modelled using an Arrhenius-based model.
- Lowest cycle lifetime for air cooling, highest for surface and immersion cooling (Fig. 3).

METHODOLOGY

- Development of life cycle cost (LCC) and carbon footprint (CF) models taking into account battery lifetime.
- "Real world" cycle lifetime of EV battery is estimated using capacity fade models at different cell operating temperatures.



SENSITIVITY ANALYSIS

- Battery lifetime as well as cost and carbon footprint of electricity and pack production were varied to understand their impact on LCC and CF (Fig. 5).
- Increasing battery lifetime by 50 % reduces LCC by 33 %.
- Reduced electricity footprint and increased battery lifetime can significantly reduce overall life cycle CF.
- Battery pack production has marginal impact on LCC and CF.

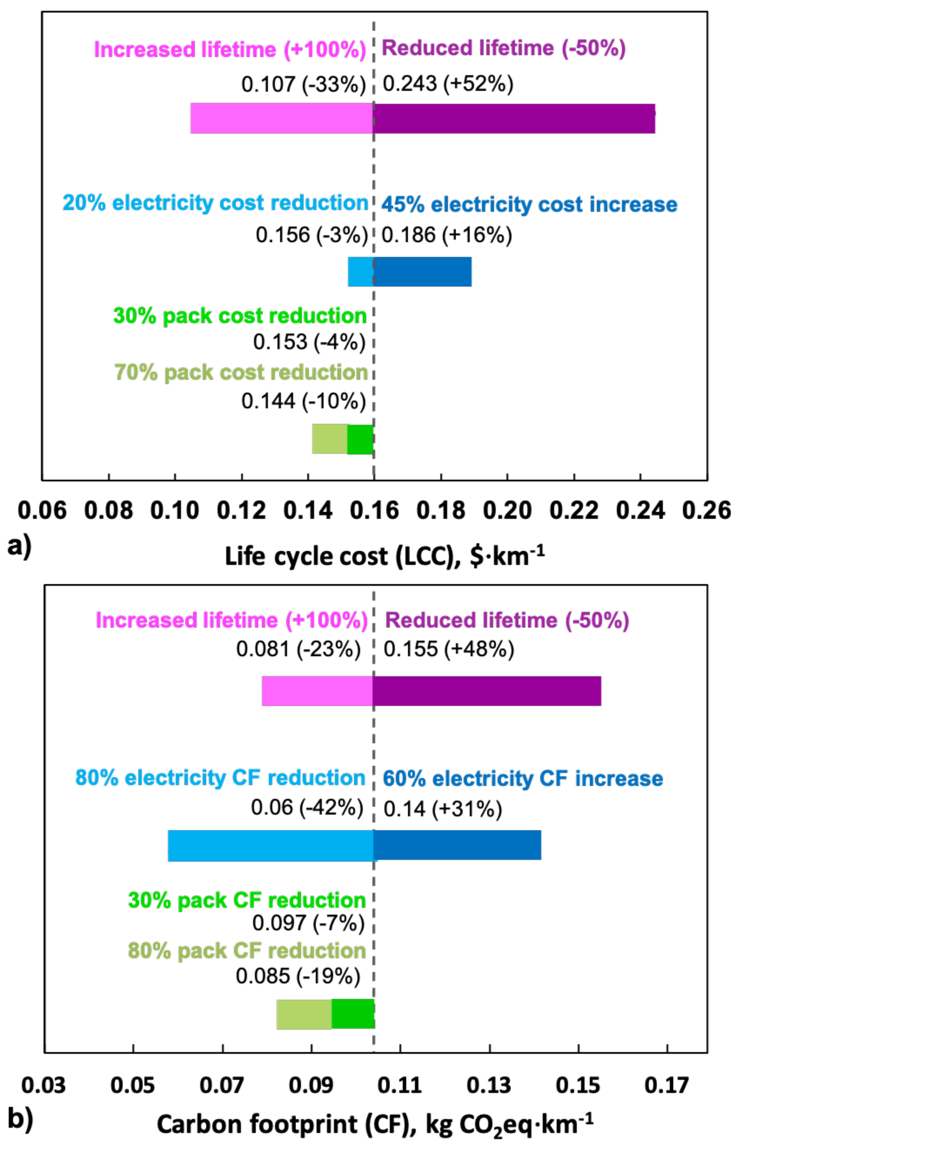


Fig. 5. (a) LCC and (b) CF sensitivity analyses for surface cooling. The dashed lines indicate the base value for surface cooling.

OPTIMISED CELL DESIGN

- Comparison of battery lifetime for two different cell designs.
- Kokam cell with tab cooling has lower degradation rate than A123 cell for surface cooling (Fig. 6).
- Optimised cell design with tab cooling increases battery lifetime by 36 % compared to surface-cooled cell.
- LCC and CF for optimised cell with tab cooling are reduced by 40 % and 35 % compared to air cooling (Fig. 7).

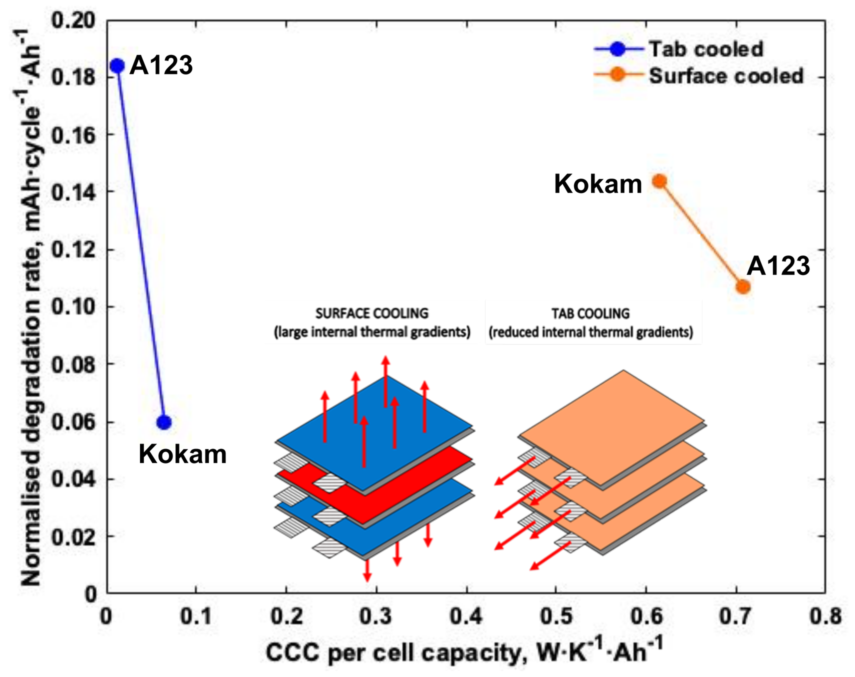


Fig. 6. Degradation rate plotted against cell cooling coefficient (*CCC*) for two-sided surface and tab cooling.

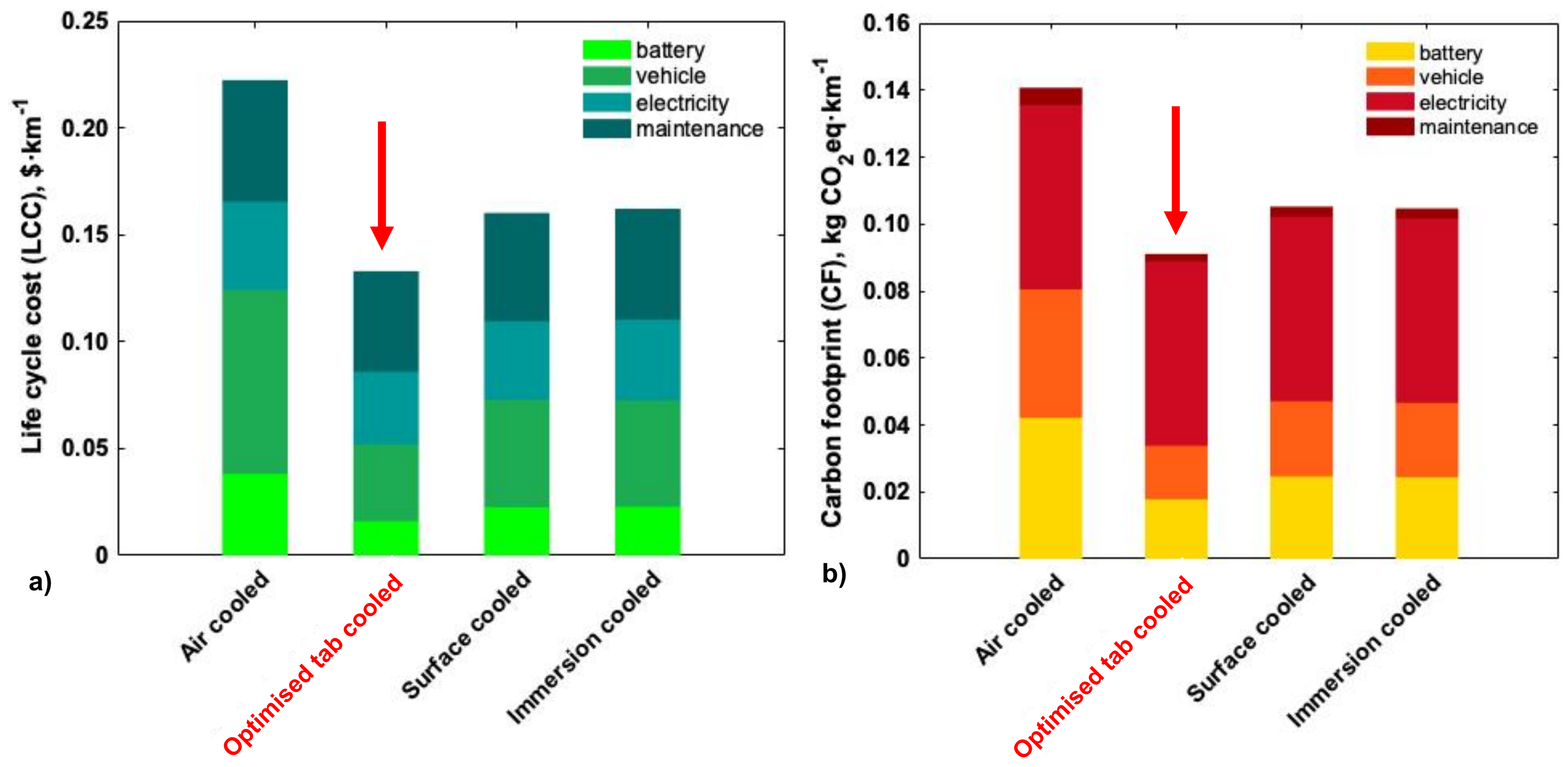


Fig. 7. (a) LCC and (b) CF for different TMS including optimised tab cooling system.

LIFE CYCLE COST & CARBON FOOTPRINT

- EV battery LCC and CF include cost and carbon footprint of battery and vehicle production, electricity for charging and maintenance.
- LCC and CF are reduced by 27 % and 25 % for surface/immersion cooling compared to air cooling (Fig. 4).
- Overall contribution of battery and vehicle production costs and footprint are reduced due to extended battery lifetime.

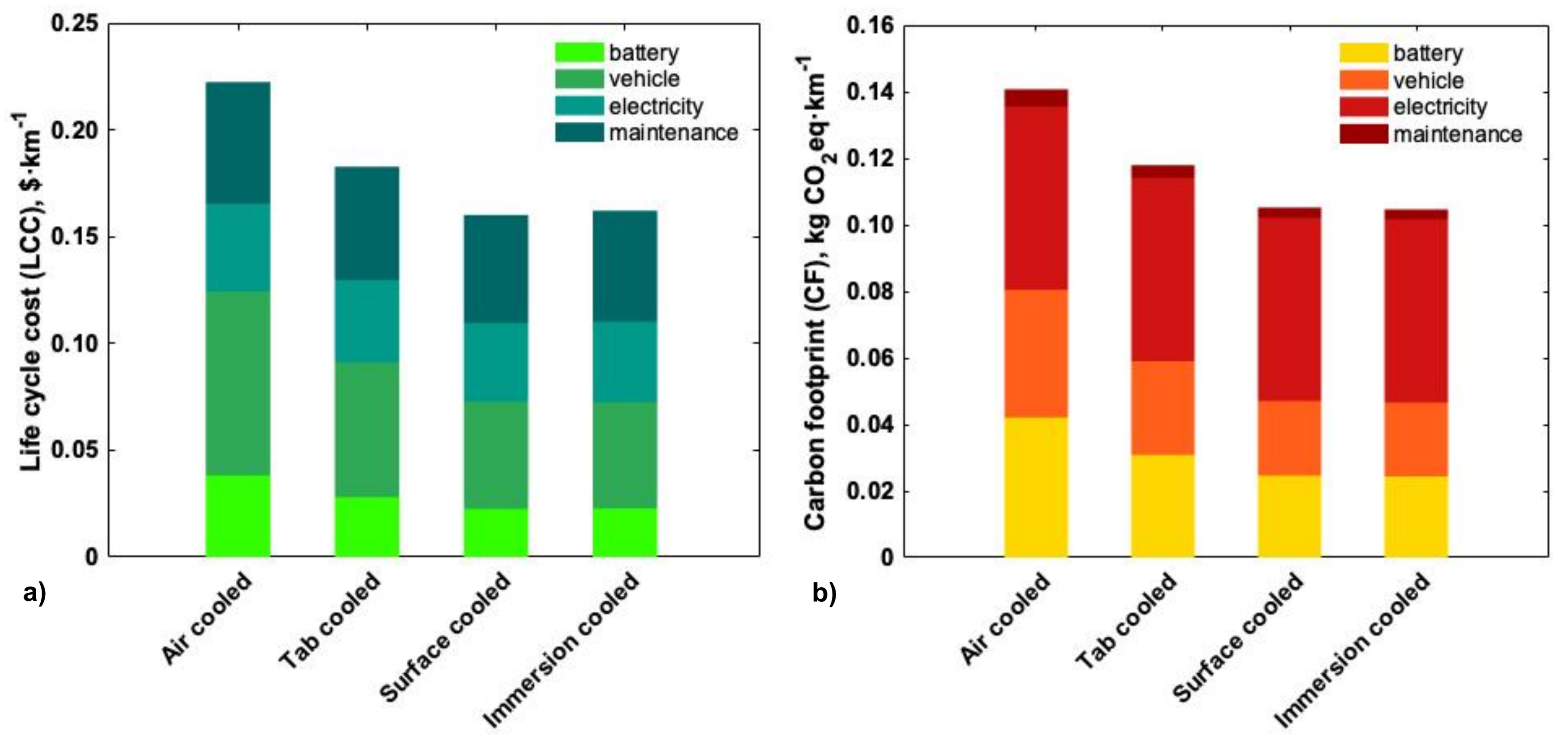


Fig. 4. (a) LCC and (b) CF for different TMS.

CONCLUSIONS

- It is shown that engineering solutions (e.g. thermal management systems) have the potential to significantly reduce life cycle cost and carbon footprint.
- Accounting for battery lifetime for real-life application conditions is crucial to assess the actual economic and environmental impacts and benefits of EV batteries.

REFERENCES

[1] G. Offer *et al. Nature 582*, 2020. [2] A. Hales *et al. J. Electrochem. Soc. 166*, 2019. [3] E. Kallitsis *et al. J. Clean Prod. 254*, 2020. [4] L. Lander, E. Kallitsis *et al. submitted*

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