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

BATTERY LIFETIME
- Correlation between TMS, maximum cell temperature and battery lifetime for an NMC/CoCr EV battery is established.
- Maximum cell temperature is derived from coolant inlet temperature \( T_{\text{inlet}} \) and Cell Cooling Coefficient (CCC) (Eq. 1).

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T_{\text{max}} = T_{\text{inlet}} + \frac{Q_{\text{gen}}}{\text{CCC}} 
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Equate, low power demand, zero performance.

Fig. 1. Battery value chain.

Fig. 2. Thermal management systems.

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.

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.

SENSIVITY 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.

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).

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

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