EXHIBIT A: Statement of Work

"Impacts of Thermal Conditioning on Battery Packs Efficiency, Range, and GHG Reduction - Literature Review"

CRC Project Number: AVFL-45

Background

As the light-duty automotive segment shifts towards electrification, challenges regarding EV use under different ambient temperature conditions throughout the year remain. Charging and operating EVs at extreme temperatures is known to have temporary as well as potentially permanent effects on battery function. Cold temperatures slow down the electrochemical processes taking place in the cells, which results in slower charging and reduced range. On the other hand, hot temperatures make it more difficult to dissipate the heat generated in the battery pack as needed in order to avoid thermal runaway. Therefore, thermal management of the EV battery is critical; effective thermal management could result in an enhanced user experience while still maintaining the state of health of the battery, which could have an indirect impact on the overall GHG emissions. While several solutions exist today to address these issues [1], it remains unclear what their effects are on user experience, battery health and resulting GHG emissions. An assessment of the different thermal management techniques that seek to optimize the trade-offs amongst the factors determining battery healthy operation, overall efficiency and user experience is needed in order to inform further EV technology development.

Objective

Collect information about 1) battery thermal preconditioning methods relevant to automotive applications being used and developed in different settings, 2) the impacts of each of these methods on overall energy efficiency, charging time, vehicle range, battery life, and GHG Scopes 1, 2, and 3, as defined by the Greenhouse Gas Protocol [2], and 3) an analysis on the viability of the different methods and the gaps in research areas where future focus will be needed for EV development and GHG emissions reduction.

Scope of Work

Perform a literature review of publicly-available information including articles, research reports/publications and patents in industry, academia, or government settings*. Topics for review include:

- Description of battery thermal conditioning methods relevant to automotive applications currently being used and explored
    - Internal and external (to the battery) methods [1]
    - Methods that use only in-vehicle systems and methods that require interaction with a charger
    - Methods used and explored in any market in the world
- Impacts of each method described and dependence on different factors
    - Impacts on user experience include
        - Charging time
        - Battery performance
        - Vehicle range
        - Battery life
    - Environmental impacts include
        - Well-to-wheel energy efficiency
        - GHG Scopes 1, 2, and 3
    - The dependence of the impacts above on different factors including

*Only English language literature is expected to be reviewed

        - Ambient temperature dependence
        - Method's operating parameters dependence (if applicable)
- An analysis of the technical challenges of the different methods and the gaps in research and areas where future focus will be needed for EV development on GHG emissions.
    - Evaluate strengths and weaknesses of the various methods
    - Assess the level of development of the different methods

Schedule

Expected to require no more than 6 months.

Deliverables

Deliverables include:

- A kickoff call with the CRC project panel and contractor to discuss project scope and align expectations.
- A mid-project call with the CRC project panel and contractor to discuss preliminary results and identify any information gaps before finalizing findings and starting the final report.
- The CRC project panel may schedule additional calls with the contractor as needed during the project duration to discuss issues that arise.
- Brief written monthly progress reports to inform the CRC project panel. These reports describe at a high level what was done in the previous month, what is planned for the next month, and problems encountered, if any.
- A final report, the draft of which will be reviewed by the CRC project panel and AVFL committee before final release.

References

1. Qin, Y., Du, J., Lu, L., Gao, M., Haase, F., Li, J., & Ouyang, M. (2020). A rapid lithium-ion battery heating method based on bidirectional pulsed current: Heating effect and impact on battery life. Applied Energy, 280, 115957.
2. The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard, 2015

Cost Estimate

Rough estimate $30k based on similar previous projects.