Energy Storage for Sustainable Transportation

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Not since Henry Ford's introduction of a mass-produced version of the Model T a century ago has the transportation sector faced such a pivotal moment as it does today. Growing recognition of the environmental impacts of CO_2 emissions coupled with limited and geographically concentrated fossil fuel reserves have conspired to induce a shift away from the internal combustion engine and towards more sustainable automotive technologies.

Arguably the most promising pathway for achieving sustainable mobility is via vehicle electrification. These technologies include plug in hybrid electric vehicles (PHEV), battery electric vehicles (BEV), and fuel cell electric vehicles (FCEV). Indeed, the energy conversion processes in electric vehicles can be significantly more efficient than those in conventional vehicles, with the added benefit of employing electricity (or hydrogen) generated from renewable, carbon-neutral power sources. Nevertheless, this increase in tank-to-wheels efficiency comes at the cost of dramatically lower densities for on-board energy storage. For example, the specific energy density of state-of-the-art Li-ion battery systems (~150 Wh/kg) is more than 50 times smaller than that of a gasoline-based fuel system (~10,000 Wh/kg). Consequently, BEVs exhibit driving ranges far shorter than those of conventional vehicles (Fig. 1, left panel). In addition, today's batteries are costly, prone to performance degradation, and can take hours to recharge. Given that batteries are a centuries-old technology, which approaches (if any) can be expected to dramatically increase the performance of electrochemical energy storage devices?

This presentation will summarize the current status of vehicular energy storage systems and describe potential pathways for radically improving their performance. Speculative battery concepts based on Li-air (Fig. 1, right panel) and Li-sulfur chemistries will be introduced, and their performance gaps summarized. Techniques for probing limiting mechanisms, the role of modeling and simulation, and the need for advanced materials will also be described.

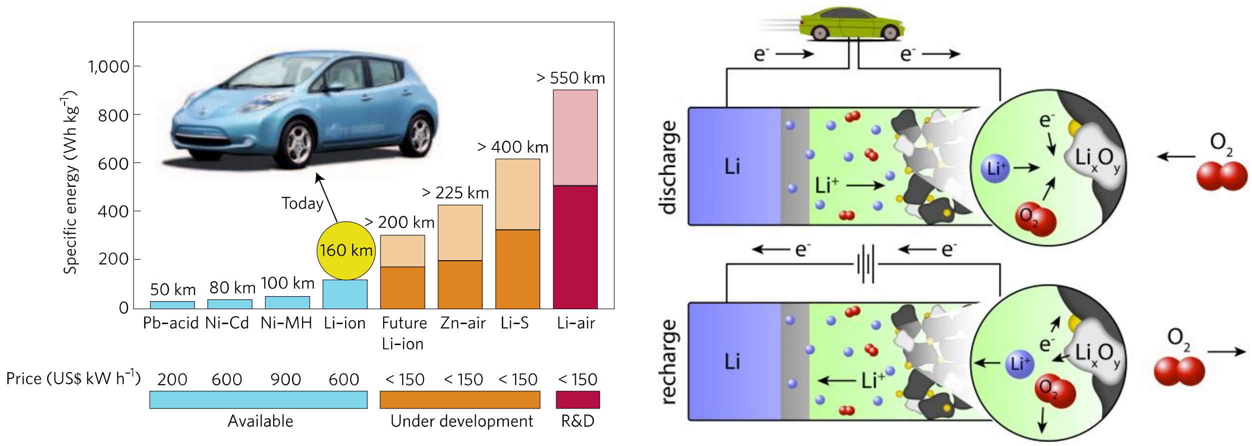

Fig. 1: (left) Specific energies for present and future battery chemistries, along with their respective costs and driving distances. The range of possible energies for the future technologies is given by the height of the lighter shaded region of the bar. Adapted from Ref. 1. (right) Schematic illustrating the charge/discharge process in a Li-air cell.

[1] P. G. Bruce, S. A. Freunberger, L. J. Hardwick, and J.-M. Tarascon, *Li-O_2 and Li-S Batteries with Higher Energy Storage*, Nature Materials **11**, 19-29 (2012)