Factors That Can Contribute to Cost Reduction of Lithium-Ion Batteries for Personal Vehicles

The cost of batteries is one of the major hurdles facing a meaningful level of penetration of electrified vehicles into the U.S. vehicle fleet. The National Academy of Sciences (NAS) estimates a specific cost to the manufacturer of $1,700 per kilowatt-hours (kWh) of usable energy from the battery pack in 2010, where usable energy is defined as the actual energy that can be cycled from the battery. This corresponds to battery pack cost estimates of $3,300 for a plug-in hybrid electric vehicle with 10-mile all electric range (PHEV-10) and $14,000 for a plug-in hybrid electric vehicle with 40-mile all electric range (PHEV-40). Costs vary with design and rate capability (ability to perform at different discharge current levels) as well as the size of the battery, amongst others.

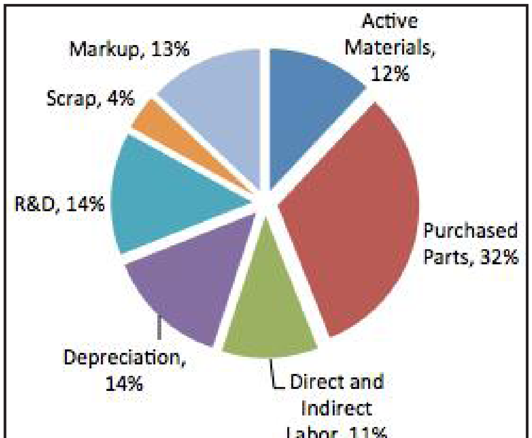

Figure 1: Cost Breakdown of a 15 kWh Lithium Ion Battery with Nickel-Cobalt-Aluminium Chemistry Assuming an Annual Production of 50,000 Cells and 500 Batteries (Source: BCG 2010)

Figure 1 shows the breakdown of battery cost as reported by The Boston Consulting Group (BCG 2010) for a typical supplier of a 15 kWh (Lithium-Nickel-Cobalt-Aluminum) battery using a modestly automated process to make 50,000 cells and a highly manual process for the assembly of 500 battery packs in a year. Of these costs, active materials account for only around 12%. Battery costs depend less on the active material costs and to a greater extent on the production volume of the batteries (Barnett et al. 2010) and are expected to decline as the batteries are mass-produced. The development of manufacturing equipment or processes that will result in decreased line-time requirements for the manufacture of the different components of the cells, primarily the electrodes, will also help reduce the costs (Barnett et al. 2010).

Apart from the anticipated reduction in the manufacturing costs with their mass-production, costs can also come down with better design (Barnett et al. 2010, Whitacre, work in progress) and integration of the battery packs by making better decisions on the rate capability and pack sizes of batteries. One way to estimate battery pack cost is to use the following expression (Kromer and Heywood 2008):

$$\text{Battery Cost} = (\text{Cost}_{\text{High Energy}}) * f\,(\text{Power-to-Energy Ratio})\ ,$$

where $\text{Cost}_{\text{High Energy}}$ is the base cost for a high-energy battery and f (Power-to-Energy Ratio) is a scale factor that is a function of the power-to-energy ratio of the battery.

Figure 2 shows the variation of costs for different electric vehicles at the pack level as estimated by Kromer and Heywood (2008) using the formula mentioned above. As can be seen, batteries for different applications incur different costs due to the requirement for different rate capabilities. Lithium-ion cells generally consist of thin laminate electrodes to allow the kinetics of the electro-chemical reactions to occur at appropriate time scales. Thinner electrodes generally provide higher power densities (for acceleration, as in the

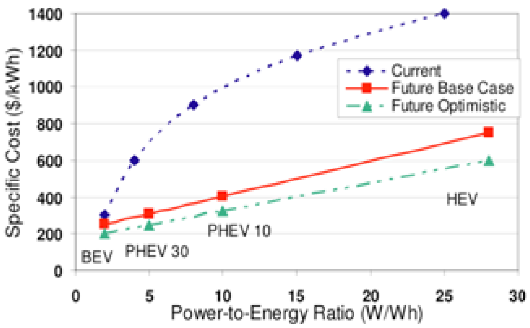

Figure 2: Estimated Battery Specific Cost as a Function of the Rate Capability (Source: Kromer and Heywood 2008)

case of hybrid-electric vehicles) whereas thicker electrodes deliver higher energy densities (for the all electric driving range like in a plug-in or electric vehicle).

Cells with thinner electrodes are more expensive to manufacture (Barnett et al. 2010). Developing materials that allow for thicker electrodes in a cell that still meets power requirements will help lower costs. Cost reduction may also be achieved by designing application-specific battery packs employing different types of cells to make up the battery pack: thicker electrode cells for energy storage requirements for the all-electric range and thinner-electrode cells for higher power requirements to satisfy acceleration needs (Sakti et al. work in progress). Developments that will allow the cell to operate in a wider state-of-charge window will be helpful in cost reduction as well.

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