Life-cycles of Lithium Ion Batteries: Understanding Impacts from Extraction to End-of-Life

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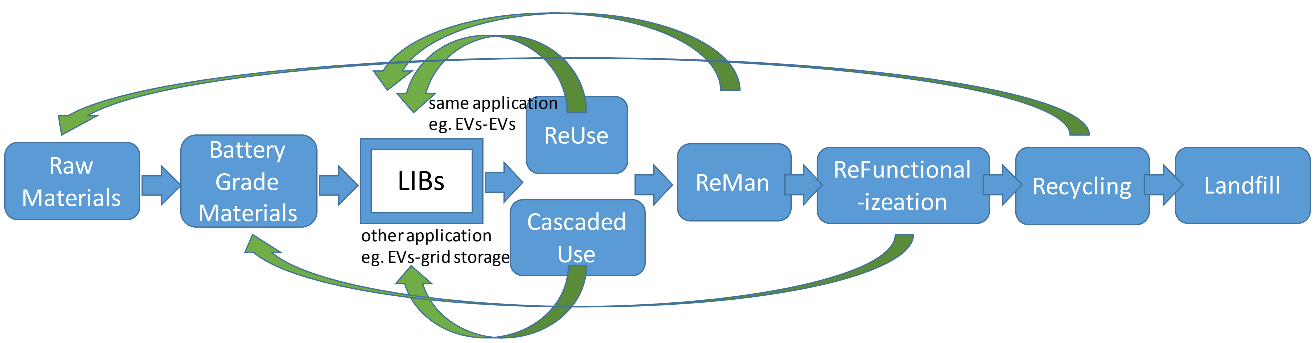
Since first being introduced for commercial use in the early 1990s, lithium-ion batteries (LIBs) have quickly become the most popular power source for a wide variety of products due to their higher power and energy densities. These include a wide array of consumer electronic devices such as laptops, mobile phones, digital cameras, electronic readers, and portable tools, as well as electric vehicles (EVs). This rapidly growing demand for LIBs may bring a variety of sustainability challenges through-out the battery life-cycle from depletion of critical metals and minerals to end-of-life waste management issues. This talk will provide an introduction to the sustainability challenges faced by LIBs with a focus on both resource constraints and economic and environmental tradeoffs at end of life, specifically for secondary life and recycling.

With the potential for widespread adoption of EVs, key concerns around resource constraints in the LIB supply chain have emerged. Specifically, lithium, cobalt, natural graphite, and manganese have key criticality issues and little opportunity for material substitution. Whilst LIBs are considered less toxic compared to lead acid and nickel-cadmium batteries, direct landfill disposal of huge amounts of end-of-life LIBs has potential to cause issues including resource depletion, energy waste, land and groundwater pollution, etc. Such impacts have inspired a variety of legislation including recycling targets like the European Union Battery Directive and landfill bans in states like California and New York in the United States. Understanding the right path for batteries at their end-of-life is complex given the many options available combined with the rapid technology trajectory of LIBs creating changing volumes, sizes, form factors, and cathode chemistries. This hierarchy of options includes reuse in the original application, cascaded use in other applications, remanufacturing or refurbishment, cathode or anode refunctionalization, recycling, and ultimately, disposal.



Reuse, remanufacturing, or recycling of these batteries at their end-of-life has the potential to distribute costs over multiple lifespans and reduce the overall environmental impact of these products. Any reuse or recycling infrastructure will need to be responsive to a stream of diverse and continually changing materials as a variety of sizes, form factors, cathode chemistries, and morphologies are being used with an even greater variety under development. Results to be shared include compositional characterization of EOL LIBs, economic feasibility of US-based recycling operations given this uncertain waste stream, environmental impacts of cascaded use of EV batteries, policy comparison for EOL LIBS across countries and sectors, criticality and scarcity indicators for LIB materials, and technology development work in the pre-processing and hydrometallurgical extraction field.