Closing the lithium-ion battery life cycle

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Abstract

Electric drive vehicle sales are growing worldwide. The key component in these vehicles is the lithium-ion (Li-ion) battery. While it is possible to extend the life of Li-ion batteries in applications such as grid storage, eventually they reach their end-of-life (EOL) and are available for recycling. The reason behind recycling these batteries include: to reduce net energy requirements; to reduce environmental impacts; to reduce potential supply constraints by replacing extracted materials with recovered materials; to generate cost-offsetting revenues and; to comply with government mandates for EOL battery recycling. To identify the potential impacts of the growing market for automotive lithium-ion batteries, Argonne researchers are examining the material demand and recycling issues related to lithium-ion batteries. Research includes: estimating material demand and comparing to world supplies; conducting studies to identify the greenest, most economical recycling processes; investigating recycling practices to determine how much of which materials could be recovered with current or improved methods, and; quantifying the environmental impacts of both battery production and recycling processes through life-cycle analyses using Argonne's GREET model. Researchers leverage Argonne's Bat Pac model to determine the material quantities and compositions needed to perform demand studies and life-cycle analyses on different lithium-ion battery chemistries. Although there are many challenges to successful recycling of lithium-ion batteries, we are confident that the research we are pursuing will be instrumental in overcoming them.

Image

CHALLENGES TO RECYCLING CAN BE ADDRESSED BY R&D

Challenge	R&D needed to address
Long-term performance of some recycled materials is not proven	Long-term testing
There is no standard chemistry or design	Convergence of chemistries and designs Flexible processes Design for recycling Automation
There are no regulations, so restrictive ones could be imposed	Fashioning regulations that will protect health and safety without hindering recycling
Many of the constituents have low market value	Process development to recover multiple high-value materials
Low value of mixed streams, prevention of fires and explosions	Effective labeling and sorting

Recent Publications

1. J B Dunn, L Gaines, J C Kelly, C James and K G Gallagher (2015) The significance of Li-ion batteries in electric vehicle life-cycle energy and emissions and recycling's role in its reduction. Energy & Environmental Science 8(1):158-168.

2. Gaines Linda (2014) The future of automotive lithium-ion battery recycling: Charting a sustainable

course. Sustainable Materials and Technologies 1-2:2-7.

3. Li, L., Dunn J B, Zhang X X, Gaines L, Chen R J, Wu F, Amine K (2013) Recovery of metals from spent Li-ion batteries with organic acids as leaching reagents and environmental assessment. Journal of Power Sources 233:180-189.

4. Dunn JB, Gaines L, Sullivan J, Wang MQ (2012) Impact of recycling on cradle-to-gate energy consumption and greenhouse gas emissions of automotive lithium-ion batteries. Environmental Science & Technology. 46(22):12704-12710.

5. Linda Gaines (2012) To recycle, or not to recycle, that is the question: Insights from life-cycle analysis. MRS Bulletin 37(4): 333-338.

Biography

Linda Gaines is a Transportation Systems Analyst at Argonne National Laboratory. She holds a BA in Chemistry and Physics from Harvard, and a PhD in Physics from Columbia. Her primary interest is efficient use of resources. She began her career by writing a series of handbooks on energy and material flows in energy-intensive industries. These provided background for studies of the costs and impacts of production, use, and recycling of advanced-design automobiles, trucks, and trains, and batteries. Her recent work involves recycling of lithium-ion batteries and also reducing vehicle idling. She is an Editor of *Sustainable Materials and Technologies*.

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Notes/Comments: