Energy Quarterly

News and analysis on materials solutions to energy challenges

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Inside:

"Sustainable design of fully recyclable all solid-state batteries" title image credit: Shutterstock.

"Considerations for leveraging flexible loads to decarbonize electricity and transportation" title image: Hele-On 29-passenger fuel cell electric bus. Credit: US Hybrid.

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Design for recycling: The circular economy starts here

"If it can't be reduced, repaired, rebuilt, refurbished, refinished, resold, recycled or composted, then it should be restricted, redesigned or removed from production." –Peter Seeger

Over the last few decades, renewable energy technologies and storage have matured and increased their penetration into the worldwide energy portfolio. However, after >20 years in service, the earlier generations of renewable technologies, such as wind and solar, are nearing the end of their service lifetime. The result is a potential glut of components such as photovoltaic (PV) cells and wind turbine blades without a clear path to recycling or reuse. According to the International Renewable Energy Agency, by 2050, 78 million tons of PV panel waste will be generated. As first-generation turbines reach end of life, thousands of 15–20-m-long blades await incineration or recycling/reuse. Batteries for energy storage contain critical elements such as cobalt and lithium that are not easily recovered. Even though many components can be recycled or reused, the process often requires thermal, chemical, and mechanical processes that are often expensive and complex and deter industry from committing funds and efforts to reuse or recycle. Therefore these "green" technologies, over their lifetime, turn out to be less environmentally friendly than originally intended.

To combat inadvertent creation of waste from green technology, there has been increasing effort to espouse a circular economy, in which the linear approach to manufacturing is replaced by a system in which products are reused, repurposed, or recycled, thus closing the loop. However, to successfully reach this end point, careful consideration must be given to the beginning of the loop. As stated by Shahbazi and Jönbrink "circular economy business models and closing the loop can be functional only if the products and services are designed for circularity (e.g., to be easily disassembled and segregated into different components and materials to facilitate the exchange of faulty components to increase the lifespan of products in different ways)" (doi:10.3390/su12093679). In other words, we must rethink the design of renewables and storage to incorporate facile recycling or reuse of components from the outset (i.e., Design for Recycling [DfR]).

The field of DfR is ripe for contribution from the materials community. Minimization or replacement of hazardous materials requires the development and synthesis of new, more benign materials, for example, the design of PV panels that foregoes the use of lead, antimony, and fluoropolymers. Lead, in particular, is a potent neurotoxin even at low ppb concentrations. One GW of electrical power from 20% efficient Pb-containing perovskite solar cells can contain tens of tonnes of soluble Pb, which pales in comparison to the millions of tonnes utilized in Pb-acid batteries that await recycling. Fabrication of parts that can be more easily disassembled and reprocessed necessitates the development of component materials that are complementary and can be easily reused or recycled. This idea is exemplified by the "all solid-state battery" concept reported in this section of EQ. The battery is designed to be easily disassembled, and the solid electrolyte and cathode can be separated and reprocessed to make fresh batteries without the need for a resynthesis step.

Adoption of DfR and the circular economy in general will require political and financial willpower to become reality. The materials community can play a key role to make DfR more economically attractive through the identification, synthesis, and development of new materials and processes that can close the loop in a meaningful way.

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