NREL researcher Ying Shi works on NREL's Centrica hybrid battery energy storage system, which includes second-life batteries. *Photo by Dennis Schroeder, NREL 62826*

Circular Economy for Energy Storage

As batteries proliferate in electric vehicles, stationary storage, and other applications, NREL is exploring ways to reduce the amount of critical materials they require and increase the lifetime value of the materials they contain. These efforts are designed to help transform the "linear economy"—where materials are simply used and disposed—into a circular one.

Our energy future will be defined not only by the need for more resilient and accessible energy, but also by greater and more varied types of demand. As our population grows and urbanization increases, so too will the demand on the world's energy resources. NREL is meeting this challenge head-on by focusing on improving the circularity of energy storage. A circular economy for batteries has the potential to lead to improved supply chain stability, reduced negative environmental impacts, decreased energy demands, and new and expanded market opportunities.

Why Partner with NREL?

- NREL, in collaboration with Argonne National Laboratory and Oak Ridge National Laboratory, is working to reduce or replace the content of critical materials in batteries while maintaining performance and safety, leading to improved supply chain stability.
- NREL is focused on finding ways to increase the lifetime of battery materials through restoring, repurposing, and recycling, which can reduce negative environmental impacts and lead to new and expanded market opportunities.
- NREL is committed to ensuring our research gets to market—where it can improve everyday life and strengthen our economy. We have nearly 900 active agreements with almost 600 partners, over half of which are private-sector companies.

NREL's work on developing a circular economy for energy storage takes a multipronged approach. In addition to reducing the amount of critical materials required for battery manufacturing, NREL is also exploring novel approaches to restoring, repurposing, and recycling batteries and battery materials.

Core Research Areas

- **Reducing Critical Material Use in Batteries**—Today's lithium-ion batteries contain critical materials, such as cobalt, that are primarily mined or refined in geopolitically sensitive areas. In addition, the demand for cobalt, as well as graphite and lithium, is expected to increase by nearly 500% by 2050. NREL, in collaboration with the U.S. Department of Energy/ Vehicle Technologies Office, is working to reduce or replace the content of critical materials in batteries while maintaining performance and safety.
- **Repurposing Used Batteries**—In many cases, batteries—especially in vehicles—can be restored and repurposed for a secondary use, such as stationary storage, even after they are retired from their first use. NREL is studying factors that could encourage battery restoration and repurposing, with the goal of increasing the lifetime value of battery systems.
- **Improving Battery Recycling Methods**—Batteries can also be recycled, but some recycling processes require energy-intensive or environmentally damaging aspects. As part of the ReCell Center, NREL is working with Argonne National Laboratory and Oak Ridge National Laboratory to improve restoration and direct recycling of lithium-ion batteries, using less energy and capturing more value-added materials. If this process can be made cost-competitive through process development, modeling of supply chains, and analysis of other barriers, it could help the United States develop a domestic economy for battery recycling and production.

NREL researcher Annalise Maughan purifies materials to be combined with silicon nanoparticles in support of NREL's work on the Silicon Anode Consortium. Silicon-based anodes represent a promising approach to replacing the graphite anode material typically used in lithium-ion cells. *Photo by Dennis Schroeder, NREL 61179*

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Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

NREL/FS-5700-82328 • March 2022