NREL
Transforming ENERGY

Today's Energy Challenges, Tomorrow's Solutions

Circular Economy: Designing to Reduce, Reuse, and Upcycle

The 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 will our demand on the world's energy resources.

NREL is meeting this challenge head-on by focusing our expertise and resources on three research areas that will accelerate the transformation of traditional energy products, practices, and industries. This requires more than simply enabling low-cost renewable and low-carbon electricity generation. It also means moving toward two-way power flow and digitization, developing new methods to convert carbon molecules derived from today's fossil fuels and using them in new ways, and rethinking how products are designed and recycled for maximum material efficiency.

NREL is Transforming Energy—how we generate, consume, store, and distribute it. And we invite you to join us in that effort.

Research Area: Circular Economy for Energy Materials

The days of taking, making, using, and disposing of materials are rapidly coming to a close. This linear economy is not only inefficient and unsustainable, but we will ultimately face resource limitations, which will make it impossible to maintain.

Circular Economy for Energy Materials

Circularity for Polymers and Composites

Advanced Energy Materials and Technologies

Future Adaptive Materials for Energy Systems

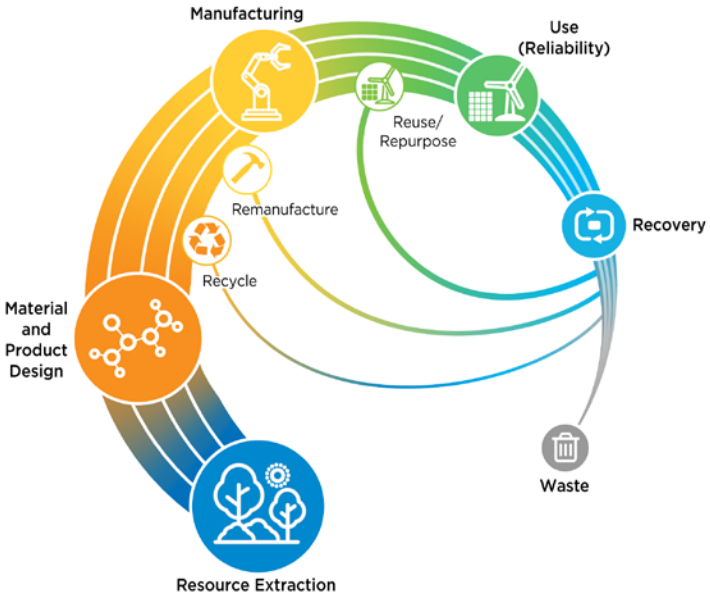
That's why NREL is dedicating resources to research that will underpin a circular economy—designing clean energy technologies with reducing, reusing, and upcycling in mind for energy-relevant and energy-intensive materials, processes, and technologies. This effort will help mitigate supply issues, promote upcycling, reduce waste, and add value to materials at end of life.

The Challenge

Many renewable energy and electronics technologies are highly complex and require high-quality materials as well as critical and rare metals that will become progressively scarcer with increased deployment or disruptions to the supply chain. Complex products are difficult to deconstruct at end of life, because the products are not designed to be disassembled and the recycling infrastructure does not have the processes and technologies needed to reclaim many of the components and high-value minerals—so all or part of these devices end up in landfills as waste.

Adding to the problem are plastics and composites manufacturing technologies. According to experts, plastics and composites are on track to produce approximately 12 billion metric tons of plastics-based materials by 2050, the vast majority of which will accumulate in landfills or, worse, in the environment. Based on current and future projected plastics input to the oceans, there is predicted to be more plastics than fish by mass by 2050.

As renewable energy generation and storage become central components of a sustainable and prosperous economy, novel materials and manufacturing strategies will be required to ensure that these technologies are not contributing to the problem at end of life.



How We Get There

Advanced energy materials/technologies: Improved clean energy technology product design and a more effective recycling and upcycling system would allow recovered materials to be of higher quality. We must:

- Assess emerging critical materials and better understand when they will become critical if deployed at scale, as well as develop substitution technologies that are in abundance with similar or better properties and minimal negative economic, human health, and environmental impact.
- Determine how we can design for modularity, upgrades, and deconstruction as well as how to create a longer-lasting product by designing it for upgrades and reparability.
- Explore the design of products to allow for use of lower purity materials (recovered materials), as well as the possible trade-offs.

Plastics, composites, and polymers: We aim to develop the science and technologies necessary to make the recycling, upcycling, and reuse of these materials ubiquitous in developed and developing economies alike. We must:

- Design and develop science, concepts, and technologies for reclamation, cost-effective recycling, and upcycling of existing composites and plastics, as well as next-generation feedstocks, composites, and plastics (including bio-based systems).
- Demonstrate value added to plastics/composites waste, decreased waste and environmental impact, and advanced manufacturing.

Future adaptive materials for energy systems: We aim to learn from natural systems to develop energy technologies that are cheaper, lighter weight, more flexible, more resilient, and more adaptable to their environment. We must:

- Design and develop new materials, innovative concepts, and next-generation technologies for sustainable energy generation, storage, and utilization.
- Develop new tools, data, analytics, and science for lifetime prediction of new, recyclable, or upcycled materials, components, and systems.
- Establish new concepts and processes for the upcycling, reclamation, reprocessing, and remanufacture of elements, materials, components, devices, and systems.
- Provide advanced science and technology that enables the design and development of recyclable plastics, polymers, and composites.
- Integrate analytical frameworks, tools, and modeling for decision making and benchmarking spanning materials discovery to deployment of circular, sustainable materials, devices, and systems.

Working Together

These challenges require sensible solutions. Working with industry, government, research, and nonprofit partners, we can achieve them far faster and more efficiently than working on them independently.

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.

Such partnerships create powerful synergies between NREL's early-stage research and industry's market-focused activities, which will unleash the creativity of both. By transforming our science, we can accelerate the development of new energy technologies through "de-risking" the early-stage research needed to innovate.

Together, we can bridge the gap from concept to market, linking our renewable energy and energy-efficient technologies with strategies to achieve real-world impact.

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