NREL
Transforming ENERGY

Partnering with U.S. Department of Defense

Transforming Energy:

PARTNERING FOR A SECURE ENERGY FUTURE

The National Renewable Energy Laboratory (NREL) supports the U.S. Department of Defense (DoD) in developing systems-level energy strategies and leading-edge technologies necessary to accomplish operational and installation energy objectives.

By collaborating with the only U.S. national laboratory solely dedicated to advanced renewable energy, energy efficiency, and energy systems integration, DoD can leverage NREL's facilities and expertise to accelerate achievement of the following energy objectives:

- Provide reliable, flexible, and resilient supplies of energy to meet current installation and mission needs
- Improve future warfighting capabilities by leveraging integrated, resilient, and efficient energy systems that reduce logistics and operational risks
- Validate technologies and provide systems-level analysis to increase energy surety and resiliency
- Expand the supply of distributed (on-site) energy for mission assurance at DoD installations
- Improve the energy grid and storage resilience at DoD installations
- Improve control system cybersecurity at mission-critical facilities.

NREL researcher Kate Anderson meets with Col. Wortlinger, the Fort Carson Garrison Commander, at the base's utility-scale lithium-ion Battery Energy Storage System (BESS).

Collaboration and Innovation

NREL's fundamental research has led to breakthroughs in solar, wind, and power systems that are helping transform the way DoD meets its energy demands and accelerating the implementation of solutions to reduce the supply chain burden of fossil-fuel systems. The following solutions demonstrate pathways to reduce costs, minimize risks in the field, and improve energy security:

- Microgrids
- Solar Technology Applications
- Grid-Interactive Efficient Buildings
- Energy Storage
- Electric and Alternative Fuel Vehicles
- Wind Technology Development.

Our R&D Programs

Foundational Science

Biological Systems Science
Materials Science
Computational Science and Visualization

Renewable Power
Geothermal
Solar
Wind
Water

Sustainable Transportation
Bioenergy
Hydrogen and Fuel Cells
Vehicles and Transportation Systems

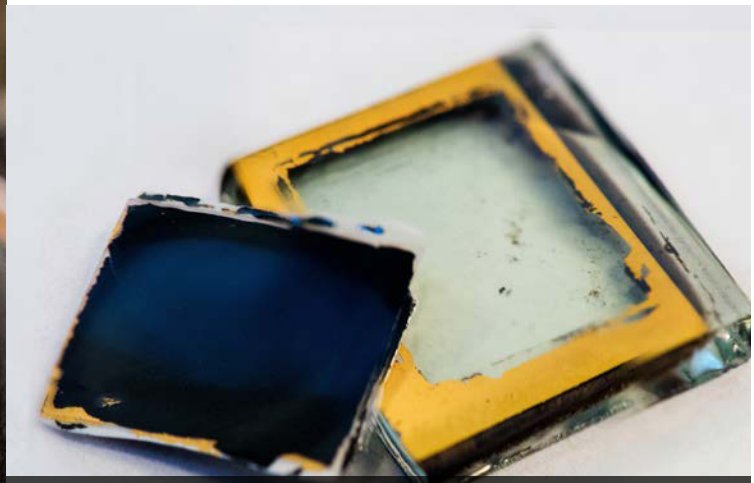
Energy Efficiency
Advanced Manufacturing
Buildings

Energy Systems Integration
Multi-Pathway Systems Integration
Grid Modernization
Energy Storage

Energy Innovation in Installation and Operational Settings

NREL's unique capabilities support energy innovation in military installation and operational settings in four focus areas:

- Innovative R&D
- Resilience Planning Tools/Processes
- Technology Validation
- Cybersecurity.



NREL scientist Deborah McGott separates a polymer and cadmium telluride (CdTe) layered structure from a glass substrate by dipping it into liquid nitrogen, causing the polymer to shrink quickly and pull the CdTe solar cell off of the glass. Without the heavy glass layer, the separated CdTe cell can now be integrated into lighter plastic packaging, increasing the power-to-weight ratio of the CdTe device.

Research and Development That Advances Energy Technology

Fundamental research at NREL has created quantifiable impacts for DoD across the energy technology spectrum. Microgrid technology, advanced photovoltaics, energy storage systems, and innovative biofuels are examples of technology advancements that have increased resilience, improved mission capabilities, and provided significant cost savings at DoD facilities.

NREL researchers Greg Martin and Mariko Shirazi work on the Consolidated Utility Base Energy (CUBE) System at NREL's Energy Systems Integration Facility.

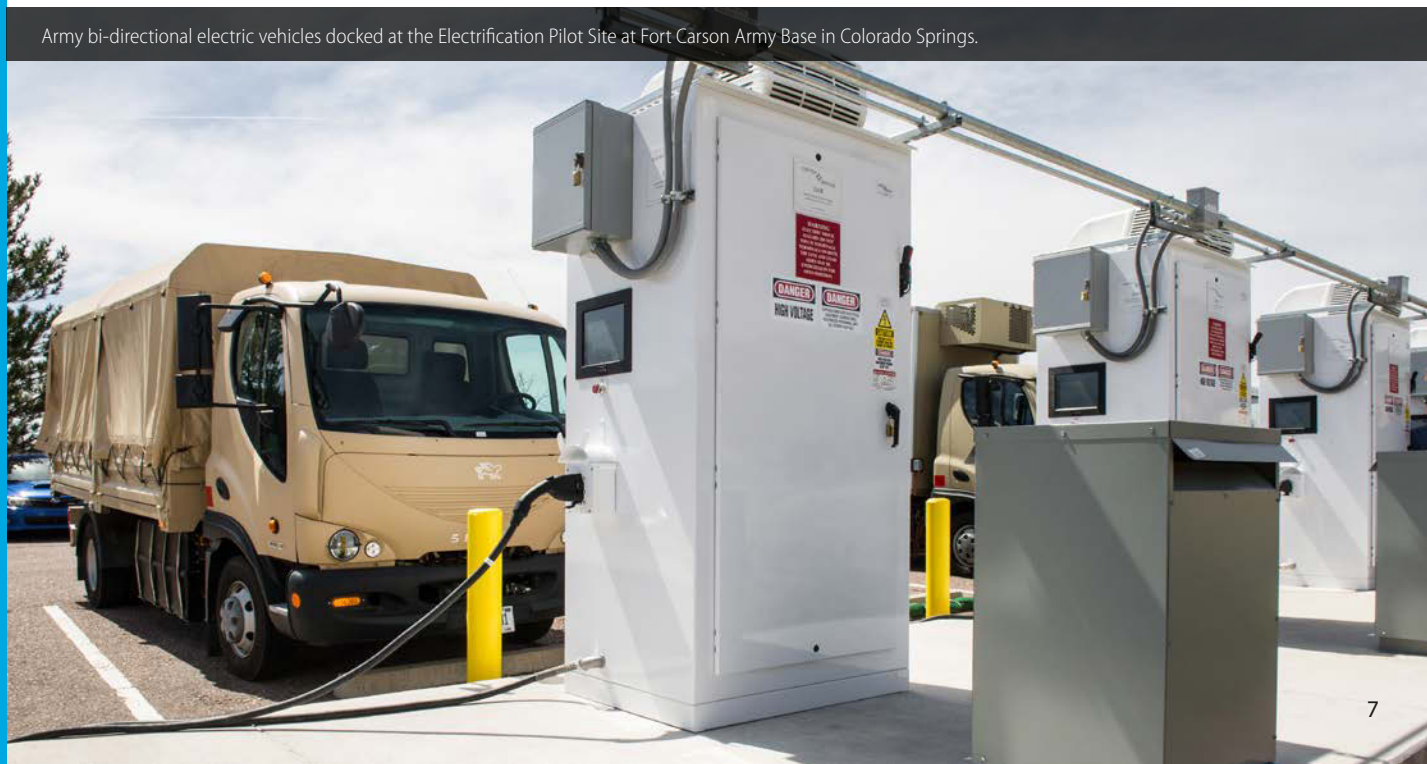
NREL's **Consolidated Utility Base Energy (CUBE)** sytem has greatly reduced the total fuel requirements needed to generate power by accepting a variety of energy sources–including solar, batteries, and generators–and switching among them as necessary without interrupting the power supply. The CUBE was designed specifically to meet military specifications, handling temperatures as low as -40ºF and as high as 140ºF. During a 24-hour lab study, the CUBE demonstrated a 31% reduction in fuel use and a 42% reduction in overall diesel run-time relative to the diesel-only case.

NREL's fundamental research on **flexible solar technologies** has the potential to improve power-to-weight ratios, and advances in manufacturing could reduce the cost of current devices. These advances would increase portability, improve performance where weight is a concern, and broaden DoD applications. These include increasing the endurance of Intelligence, Surveillance, and Reconnaissance (ISR) drones; implementing ground vehicle rooftop generation for run-silent operations; creating lighter and more power-dense, man-packable systems; and reducing launch costs for space applications.

Innovations in **wide-bandgap semiconductor materials** have decreased the physical size of components while increasing efficiency and improving performance for hybrid and all-electric vehicles (EVs). Through partnerships with the automotive industry, NREL proved that hybrid-electric, heavy-duty construction vehicles and other power electronic devices can benefit from cutting-edge wide-bandgap materials and components. This research is foundational to developing efficient power electronic devices, which in turn helps the military develop advanced weapons, surveillance equipment, and power conversion technologies.

NREL's work in the area of **energy storage systems** leverages data from physical tests to develop and calibrate models for improved understanding of battery performance and safety in vehicle, shipboard, or other expeditionary applications relevant to the DoD mission. Partnerships with major automotive and battery manufacturers supply researchers with real-world driving data that act as the basis for these models, combined with data collected in NREL's thermal characterization laboratories. NREL also uses its Energy Systems Integration Facility (ESIF) to evaluate the impacts of battery energy storage system functionalities on distribution systems using power hardware-in-the-loop simulation.

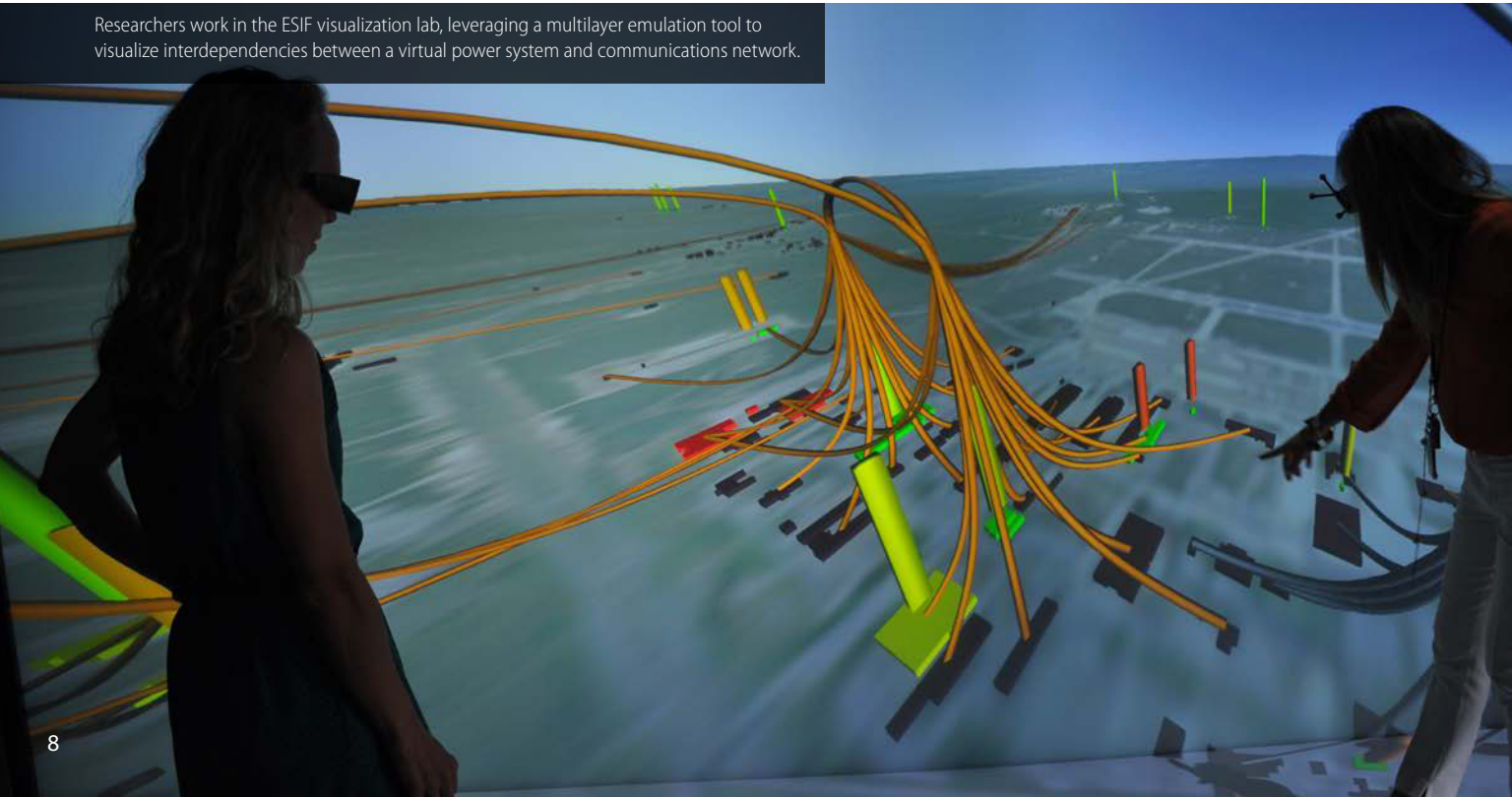
Army bi-directional electric vehicles docked at the Electrification Pilot Site at Fort Carson Army Base in Colorado Springs.



Resilience Planning Identifies Vulnerabilities and Prioritizes Solutions

NREL's resilience planning process and tools help DoD identify and prioritize vulnerabilities and implement solutions. NREL offers a wide range of services, including whole-community strategic energy planning, on-site technical assistance, energy-efficiency design and rebuilding strategies, and expert guidance in building a roadmap to resilience for communities preparing for extreme weather events and other potential threats.

- NREL-developed processes have already played an important role in helping communities and military bases recover from disasters and better plan for a future with increased energy resilience.
- NREL's Resilience Roadmap and its U.S. Air Force Risk Assessment Tool are examples of tools used to assess risk and prioritize improvements.



Researchers work in the ESIF visualization lab, leveraging a multilayer emulation tool to visualize interdependencies between a virtual power system and communications network.

Technology Validation

NREL collaborates with DoD to demonstrate leading-edge energy technologies at military test beds, enabling rapid deployment of next-generation energy solutions:

- Advanced Vehicles
- Buildings
- Cybersecurity
- Electric/Thermal Energy System Components
- High-Performance Computing.

Cybersecurity researchers evaluate vulnerabilities and mitigation options for distributed energy resources in NREL's emulated cybersecurity test range.

Cybersecurity Research Helps Protect Energy Investments

NREL's cybersecurity team utilizes an emulated environment as a test range to evaluate cybersecurity vulnerabilities and mitigation measures for distributed energy resources. With the ESIF's flexible, cyber-physical research capabilities—including an emulated grid environment that connects to real grid devices throughout the facility—NREL cyber analysts can safely assess distributed energy resources and the control systems that support them. Research at the ESIF is focused on evaluating new grid technologies and energy systems for their security and resilience, pinpointing potential threats in the early stages of technology development.

Across NREL, cybersecurity research is strengthening the grid against tomorrow's threats. It spans the fundamentals—from cybersecurity for distributed energy systems to cybersecurity industry standards for interconnecting new devices.

NREL R&D Programs Support U.S. Department of Defense Installation and Operational Energy Needs

NREL Research Areas

- Advanced manufacturing
- Basic science
- Batteries, storage
- Bioenergy
- Buildings
- Cybersecurity
- Energy analysis
- Energy systems integration, energy security and resilience
- Geothermal
- Grid modernization, distribution, transmission, efficiency
- Hydrogen and fuel cells

Research Area utilized by Installation Energy

Research Area utilized by Operational Energy

- Materials science
- NREL's scientific expertise
- Partnerships, licensing, and technology transfer
- Solar technology
- Tools, models, apps enabled by high-performance computing and advanced analytics
- Transportation
- Water power
- Wind technologies

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