

# Sustainable Transportation

## Accelerating Widespread Adoption of Energy-Efficient Vehicles & Fuels

Transportation accounts for 70% of U.S. petroleum use and 27% of the nation's greenhouse gas (GHG) emissions, and predicted surges in population growth will trigger ever greater demand for fuel to power vehicles. While energy-efficient transportation strategies have the potential to simultaneously slash oil consumption and reduce GHG emissions, a truly sustainable solution will require more than just putting drivers behind the wheels of new fuel-efficient cars.

As the only national laboratory dedicated 100% to renewable energy and energy efficiency, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) accelerates widespread adoption of high-performance, low-emission, energy-efficient passenger and freight vehicles, as well as alternative fuels and related infrastructure. Researchers collaborate closely with industry, government, and research partners, using a whole-systems approach to design better batteries, drivetrains, and engines, as well as thermal management, energy storage, power electronic, climate control, alternative fuel, combustion, and emission systems.

NREL's sustainable transportation research, development, and deployment (RD&D) efforts are not limited to vehicles, roads, and fueling stations. The lab also explores ways to save energy and reduce GHGs by integrating transportation technology advancements with renewable energy generation, power grids and building systems, urban planning and policy, and fleet operations.

Researchers' deep understanding of factors that impact industry and consumer acceptance breaks down market barriers and speeds deployment of new technologies. Unbiased expert research and guidance—backed by real-world data and analysis, as well as proven systems, tools, and processes—empower partners to make informed sustainable transportation decisions that fit operational priorities.

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*Photos from top: Electric vehicles at a Vehicle Testing & Integration Facility (VTIF) charging station connected to a solar microgrid. Photo by Dennis Schroeder, NREL 26238.*

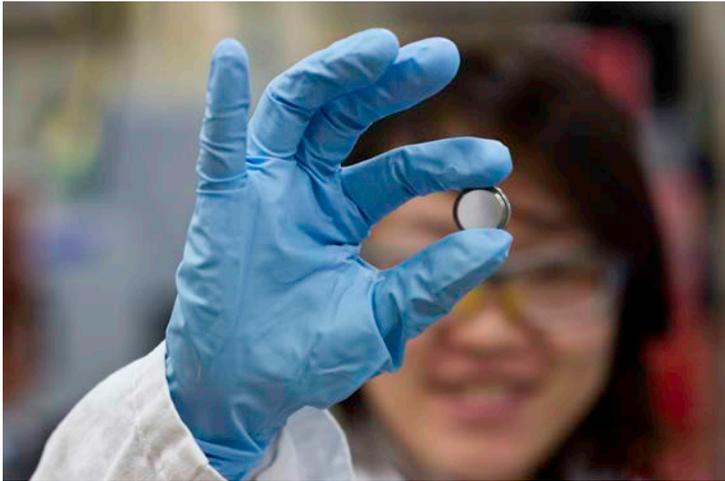
*Thermograph of a heavy-duty vehicle undergoing evaluation at NREL's VTIF. Photo by Dennis Schroeder, NREL 26770.*

*NREL's Hydrogen Infrastructure Testing and Research Facility. Photo by Ellen Jaskol, NREL 34856.*



## Innovative Vehicle, Fuel & Infrastructure RD&D

While electric-drive vehicles (EDVs)—hybrid, plug-in hybrid, and fully electric battery and fuel cell vehicles—promise to curb GHGs and diminish America’s need for imported oil, they currently command a relatively tiny market share. NREL researchers are simultaneously exploring ways to optimize the legacy internal combustion technology that makes up the vast majority of vehicles on today’s roads, while developing the EDV, fuel cell, and biofuel technologies and infrastructure needed to transition to a virtually net-zero emissions, non-polluting fleet. This research and development (R&D), paired with deployment support, touches nearly every type of automotive system and class of on-road vehicle, at scales ranging from component materials to vehicle fleets.



### Energy Storage

The design of high-performance, cost-effective, and safe EDV energy storage systems can present considerable challenges, especially in the critical area of thermal control. The most expensive of EDV components, batteries have a profound impact on vehicle performance and range, as well as sticker price. As the country’s recognized leader in battery thermal management research, NREL conducts testing, modeling, simulation, and system evaluation activities to assess energy storage components at the materials, cell, pack, and systems levels.



### Power Electronics & Electric Machines

While power electronics help run a wide range of systems in conventional gas-fueled automobiles, EDVs rely even more heavily on these components. NREL R&D is making wide-scale adoption of EDVs more feasible by developing power electronics and electric motor technologies and components with superior reliability, efficiency, and durability while dramatically decreasing costs. This work has established the lab as a vital resource for reliability and thermal management of motor controllers, inverters, and traction motors.



### Fuels & Engines

More energy-efficient and environmentally friendly vehicles call for simultaneous increases in powertrain efficiency and reductions in emissions, requiring substantial advances in internal combustion engines. In turn, advances in engine combustion rely on thorough understanding of fuel properties, especially ignition kinetics behavior. By focusing on the intersection of fuel physical and chemical properties, ignition kinetics, combustion, and emissions, NREL is supporting coordinated development of biofuels, advanced petroleum-based fuels, advanced combustion engines, and infrastructure.

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*Photos from top: Researcher with coin cell battery in NREL’s Materials Laboratory. Photo by Dennis Schroeder, NREL 21993.*

*Engineer calibrating equipment in NREL’s Power Electronic Laboratory. Photo by Dennis Schroeder, NREL 22321.*

*Researchers with test samples in NREL’s Fuel Chemistry Laboratory. Photo by Dennis Schroeder, NREL 21940.*

## Hydrogen & Fuel Cells

NREL researchers assess and validate hydrogen fueling infrastructure and fuel cell-powered light-duty vehicles, buses, forklifts, and backup and stationary power systems in real-world operation. The National Fuel Cell Technology Evaluation Center provides secure management, storage, and processing of proprietary data from industry, playing a crucial role in the independent analysis of hydrogen fuel cell technologies. The lab also guides stakeholders in the safe operation, handling, and use of hydrogen.

## Medium- & Heavy-Duty Fleets

Trucks move more than 13 billion tons of freight across the United States each year. NREL helps truck manufacturers and fleet managers pinpoint fuel-efficient and low-emission strategies that support bottom line and operational goals. Researchers' customized evaluations—of existing equipment, infrastructure, operational practices, energy-saving alternatives, and implementation considerations—along with web-based tools using validated data from field-based measurements factor in the multitude of fleet-specific variables needed to ensure meaningful benefits for large-scale deployment.

## Climate Control

Range anxiety presents a major barrier to EDV adoption, and energy consumed for heating and air conditioning can reduce EDV range by as much as 68%. More efficient climate control systems can increase the range of electric-drive passenger vehicles while diminishing fuel consumption of diesel-powered heavy-duty vehicles. NREL researchers are exploring thermal load reduction strategies and improving energy efficiency while maintaining the comfort that drivers expect.



## Partners in Innovation

Partners from government, industry, and academia tap NREL vehicle and fuel, hydrogen and fuel cell, biomass, deployment, energy analysis, and energy system integration expertise for innovative RD&D in support of:

- Electric, hybrid, fuel cell, and conventional vehicle technologies
- Biofuels, hydrogen, natural gas, propane, and petroleum-based fuels
- Charging and fueling infrastructure.

For information on sustainable transportation partnership opportunities, visit [www.nrel.gov/transportation/working-with-us.html](http://www.nrel.gov/transportation/working-with-us.html).

*Photos from top: Robot used to test hydrogen coupling hardware in the Energy Systems Integration Laboratory (ESIL). Photo by Dennis Schroeder, NREL 33366.*

*Engineer assessing performance of a fleet vehicle at NREL's Renewable Fuels & Lubricants Laboratory. Photo by Dennis Schroeder, NREL 22750.*

*Technician connecting a car and thermal manikin to climate control monitors at the VTIF. Photo by Dennis Schroeder, NREL 32142.*

## Cross-Cutting Initiatives

A truly sustainable transportation future will rely on widespread adoption of multiple solutions, including alternative fuels, EDVs, a grid powered by renewable energy sources, new approaches to fueling and charging, and innovative systems of vehicle connectivity—as well as more fuel-efficient gasoline-powered vehicles. In addition to testing and evaluation activities that span a broad spectrum of research areas, NREL's expertise has established the laboratory as a national trailblazer in a wide range of cross-cutting areas.

## Sustainable Mobility

NREL's Sustainable Mobility Initiative approaches transportation as a network of travelers, services, and environments—rather than just vehicles and roads. Working with industry, research, and government sector partners, NREL is leveraging vehicle automation and connectivity innovations originally intended purely as safety measures to explore these technologies' effects on transportation energy use, emissions, and overall system efficiency.

## Fuel, Engine & Infrastructure Co-Optimization

New fuels, engines, and infrastructure will be required to meet ambitious energy-saving and GHG reduction goals. NREL is leading a multi-lab collaborative effort to simultaneously explore new options for low-carbon fuels and advanced combustion engines to maximize energy efficiency and on-road vehicle performance while dramatically reducing transportation-related petroleum consumption and emissions.

## Vehicle-to-Grid Integration

Vehicle-to-grid technology can balance intermittent renewable resources, enhance grid stability, reduce peak-hour electricity demand, and address electric vehicle driving-range limits. NREL researchers are developing and evaluating fully integrated systems that connect cars, power grids, and renewable energy sources.

## Thermal Management Research

Optimized thermal management can increase electric vehicle battery power by more than 20% and decrease climate control systems' energy demands by as much as 68%. NREL research focused on energy storage, power electronics, and climate control system operating temperature aims to improve vehicle performance, range, reliability, lifespan, and affordability.



Researchers explaining visualizations of transportation data analyses.  
*Photo by Dennis Schroeder, NREL 35357*

## Transportation Data, Analysis & Tools

Decisions are only as strong as the information that steers them. NREL serves as the nation's most credible and complete transportation energy-efficiency clearinghouse for validated, up-to-date statistics, data analysis, and tools, pairing information from government and private-sector partners with expertise in analysis and applications.

## Technical Assistance & Outreach

Widespread deployment of energy-efficient vehicles requires the education and support of end users. NREL experts support regional and municipal organizations with technical advice, market barrier identification and eradication, policy and compliance guidance, partnership cultivation, and stakeholder engagement.

## Reliability & Durability Research

Electric vehicle systems and components must perform reliably in a wide range of conditions to meet consumer expectations. NREL R&D focused on improving the reliability and extending the lifespan of power electronics, energy storage, and hydrogen infrastructure components and systems makes EDVs more viable in the marketplace.

### Learn More

To learn more about NREL's sustainable transportation RD&D, visit [www.nrel.gov/transportation](http://www.nrel.gov/transportation)

**National Renewable Energy Laboratory**  
15013 Denver West Parkway, Golden, CO 80401  
303-275-3000 • [www.nrel.gov](http://www.nrel.gov)

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