Advanced Vehicles Group

Center for Transportation Technologies and Systems

A researcher prepares a large calorimeter that is used for evaluating the thermal characteristics of advanced energy storage devices at NREL's Energy Storage Laboratory.

Highlights

NREL's Advanced Power Electronics R&D enables smaller, lighter, and less expensive power electronics systems by increasing heat removal through novel techniques such as single- and two-phase jets and sprays.

NREL's Energy Storage R&D focuses on modeling and testing batteries, ultracapacitors, and hybrid storage systems to increase their efficiency, reliability, and lifetime while decreasing their cost.

NREL's Vehicle Ancillary Loads Reduction R&D is decreasing the amount of fuel required for climate control by reducing solar loads on vehicles while increasing delivery and equipment efficiency and maintaining or improving thermal comfort.

NREL's Advanced Vehicles Group works closely with clients to apply experimental, numerical, and analytical techniques to develop vehicle thermal management solutions for advanced fuel-efficient vehicles.

Researchers in the Advanced Vehicles Group contribute to our country's goal of reducing our dependence on imported oil by developing cost-effective solutions to complex thermal problems in vehicles.

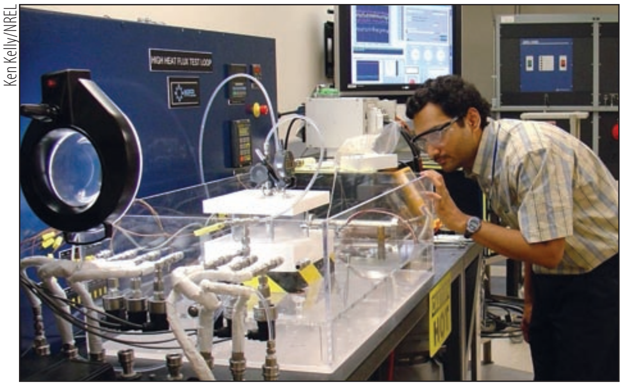
As part of the U.S. Department of Energy's National Renewable Energy Laboratory, our areas of research include experimental methods and multi-physics computational modeling, focusing on heat and mass transfer and fluid dynamics. We work with automobile and truck manufacturers and suppliers; federal agencies such as DOE, the Environmental Protection Agency, the Department of Defense, and NASA; state agencies; and organizations such as SAE International. In numerous projects with industry, we are developing and validating cost-effective technologies for electric, hybrid electric, plug-in hybrid electric, and fuel cell vehicles. We specialize in analyzing and developing vehicle thermal management systems that include advanced power electronics, energy storage systems, and ancillary loads, such as cabin heating and cooling.

Advanced Power Electronics

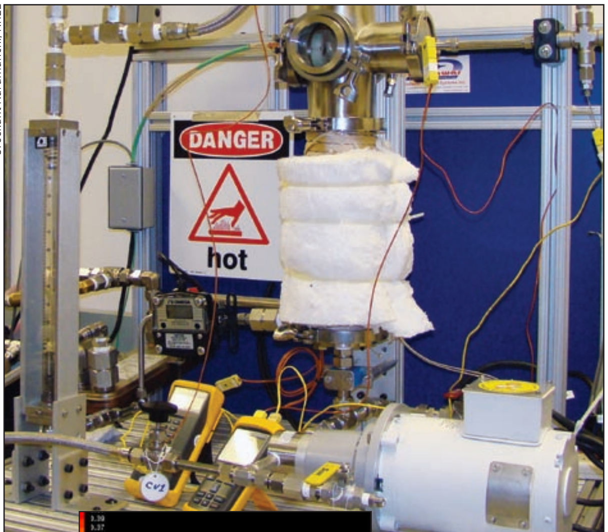
The power electronics module and electric motor are critical systems for advanced technology vehicles—most of which have electric powertrains and accessories. Power electronics control the flow of electricity between the electric motors and the energy storage system. They can generate excessive heat, which degrades their performance, reliability, and life. Our research focuses on developing thermal management technologies that help to increase power density and lower system costs. To do this, NREL uses its state-of-the-art equipment and cutting-edge computer models.

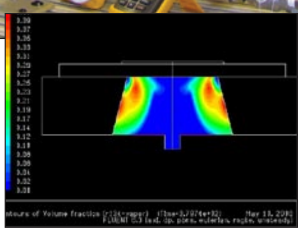
NREL National Renewable Energy Laboratory
Innovation for Our Energy Future

Ken Kelly/NREL



Sreekant Narumanchi/NREL





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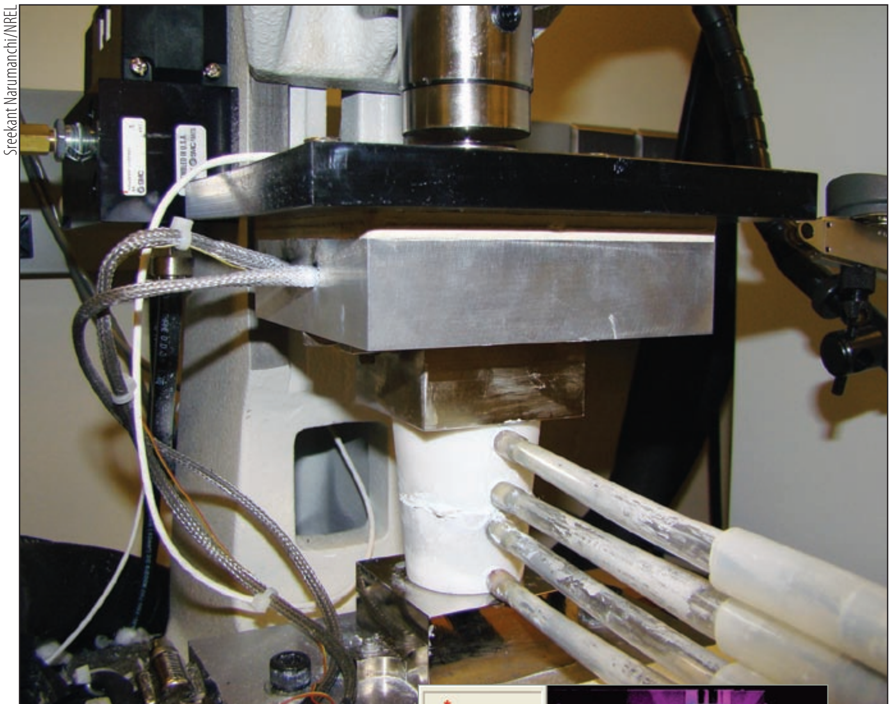

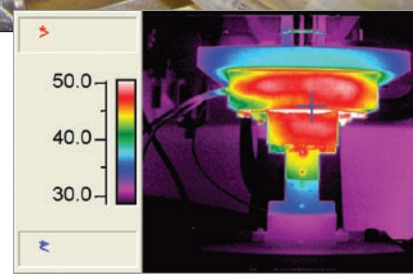

NREL's Advanced Power Electronics capability includes liquid jet and spray cooling (top left) and two-phase cooling testing (left) and modeling (lower left). NREL researchers also evaluate thermal interface materials (top right and right).

Liquid Jet and Spray Cooling. Liquid jet and spray cooling can achieve higher heat fluxes than standard cooling methods. We use advanced computational fluid dynamics (CFD) and experimental techniques to develop and evaluate high-performance jet and spray technologies for cooling power electronics, as well as surface enhancements, microchannels, and self-oscillating jets.

Two-Phase Jet and Spray Cooling. Jet or spray cooling systems with liquid-to-vapor phase change can significantly enhance heat transfer. We have developed complex numerical models of two-phase jets and sprays that are being validated in our two-phase test loop, which is used to evaluate various coolants and nozzle geometries.

Direct Air Cooling. All the heat in power electronics is eventually transferred to the air. Direct air cooling has the potential to substantially reduce the cost, weight, and complexity of the power electronics system by eliminating a separate liquid cooling loop. We are developing promising techniques through modeling optimization and experiments using our air cooling test stand.

Thermal Interface Materials. Thermal interface material (TIM) can be a major obstacle to removing heat from components. We have developed accurate and consistent testing protocols for characterizing the thermal resistance of TIMs, which include greases, phase-change materials, thermoplastics, and graphite materials, as well as some promising new materials such as carbon nanotubes.

Thermal Modeling and Systems Analysis to Improve Reliability. Our researchers use advanced vehicle systems models coupled with thermal and stress models to study the dynamic heat generation in power electronics components and identify potential reliability and failure issues. The goal is to reach a 15-year life target for all components without adding to the cost of components through over-engineering.

Dean Armstrong, NREL

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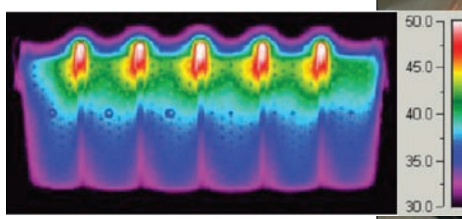
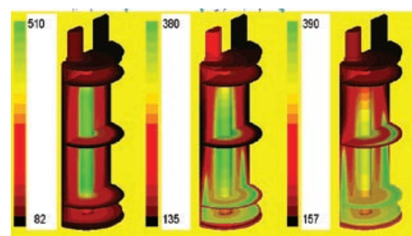


NREL's extensive Energy Storage capability includes our battery cycler (top left) and large calorimeter (top right) supplemented by infrared imaging (bottom center) and extensive multi-physics, 3-D, transient modeling (lower right).



Energy Storage

Advanced energy storage systems are essential components of fuel cell, electric, and hybrid electric vehicles. NREL's Energy Storage (ES) project supports the nation's goal of cleaner, more secure transportation by developing and improving ES technologies (batteries and ultracapacitors). The ES Laboratory contains state-of-the-art equipment that complements extensive multi-physics models, including electric, electrochemical, thermal, fluid dynamic, and structural analysis.

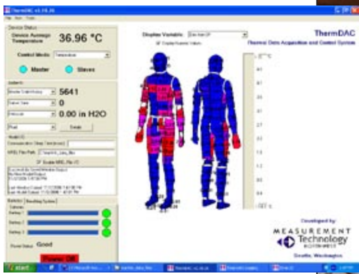
Thermal Characterization and Analysis. We have designed and built unique, state-of-the-art calorimeters for measuring heat generation from energy storage devices. The interior of our largest calorimeter is 60 cm x 40 cm x 40 cm. Our analysis capability includes 3-D electro-chemical-thermal modeling.

Li-ion Battery Thermal Abuse Modeling. Lithium-ion battery packs must be safe and resist thermal runaway. Our researchers model battery behavior during abuse conditions and design safe solutions. We use a differential scanning calorimeter and accelerating rate calorimeter to validate our models.

Environmental Testing. Effective thermal management of energy storage systems is critical to their life, performance, and cost. Our environmental chamber provides a 64-ft^3 controlled environment between -45°C and 190°C. We cycle energy storage devices with our seven high power battery cyclers, including a 125-kW, 1000-A, 420-V bidirectional, programmable power supply.

Identification and Analysis of High-Energy Materials. We perform research to identify inexpensive, high-capacity materials for cathodes and anodes, which are critical to the success of advanced batteries.

Life and Cost Requirements Analysis. Our ES team is developing life and cost computer models for identifying requirements and trade-offs between performance, life, and cost that can result in $300/kWh and a lifetime of 15 years.



John Rugh/NREL

Jason Lustbader/NREL

Indoor vehicle testing (far right) and the use of ADAM to assess the impact of climate control seats on thermal comfort and fuel economy in the Vehicle Climate Control Laboratory (right)

Vehicle Ancillary Loads Reduction

It takes about 7 billion gallons of fuel to cool light-duty vehicles each year in the United States. Our research team works with the automotive and truck industry to reduce the amount of fuel consumed by air conditioning while maintaining thermal comfort and lowering vehicle emissions. We use sophisticated computer modeling complemented by component and vehicle testing to achieve our goals.

Thermal Load Reduction. When a vehicle is parked, 50% to 75% of the thermal energy entering the passenger compartment is from solar energy transmitted and absorbed by window glazing. Lowering this thermal load makes it possible to reduce the air-conditioning system size.

Waste Heat Utilization and Thermoelectric Systems. We are investigating the use of engine waste heat to provide passenger cooling or electricity through thermoacoustics, absorption cooling, Rankine cycles, or thermoelectric devices. Thermoacoustic systems use heat to generate sound, which can then generate cooling or electricity. Thermoelectric systems can be used to generate electricity.

Thermal Comfort and ADAM. We have developed a suite of thermal comfort tools to develop more efficient climate control systems for automobiles. Our ADvanced Automotive Manikin, ADAM, has 120 individually-controlled surface zones, each with integrated heating, temperature sensing, and sweat dispensing. ADAM is controlled by a numerical model of the human thermoregulatory system that predicts bone, muscle, fat, and skin temperatures. ADAM has also been used for non-automotive applications, including the evaluation of liquid cooling garments for space walk applications and warming devices to prevent injured soldiers from going into shock.

Outdoor Vehicle Testing. Our researchers have extensive experience in testing components, systems, and vehicles under actual conditions. Test results guide development programs and validate numerical models. We have evaluated glazings, window shades, parked car ventilation, body insulation, climate control seats, infrared reflecting paint, and heat pipes in a variety of vehicle models and compared outdoor results with those from indoor testing.

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See our work on the following Web site: www.nrel.gov/vehiclesandfuels/

Transportation Technologies

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Photo on front: Dean Armstrong, NREL