NREL | THERMAL TEST FACILITY

U.S. DEPARTMENT OF ENERGY

Maximizing Thermal Efficiency and Optimizing Energy Management

Photo by Warren Gretz, NREL/PIX 01014

Scientists at this living laboratory develop optimal solutions for managing energy flows within buildings and transportation systems.

The built environment is stressing the utility grid to a greater degree than ever before. Growing demand for electric vehicles, space conditioning, and plug loads presents a critical opportunity for more effective energy management and development of efficiency technologies.

Researchers at the Thermal Test Facility (TTF) on the campus of the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) in Golden, Colorado, are addressing this opportunity. Through analysis of efficient heating, ventilating, and air conditioning (HVAC) strategies, automated home energy management (AHEM), and energy storage systems, scientists uncover solutions for cost-effectively reducing the nation's electric demand and fossil fuel consumption, expanding the use of renewable electricity to transportation, and enhancing the reliability and stability of the power grid. TTF researchers also study replacement of high-global-warming-potential (High GWP) refrigerants, improving health and durability of buildings, effectively using available solar resources, and improving performance of electric vehicle energy storage components and systems.

Addressing Industry Challenges

Industry seeks performance data to advance efficiency for improving system-level operation of energy infrastructure. This data is costly to develop, so is often kept proprietary. Economic, environmental, and regulatory challenges increasingly demand innovative approaches. By taking a broad strategic view of supported industries, and targeting key opportunities, the TTF laboratories leverage public and private resources to maximize the value and impact of research results.

Managing energy demand and improving cost effectiveness of energy technologies are the primary purposes of the TTF and industry partnerships behind this exciting research.

Labs and Equipment

To support this research, the TTF houses four fully equipped, best-in-class laboratories and outdoor test capabilities.

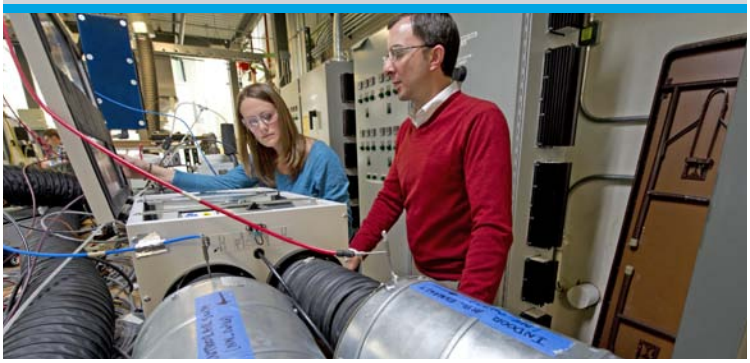
- **Advanced HVAC Systems Laboratory**
- **Automated Home Energy Management Laboratory**
- **Hot Water Systems Laboratory**
- **Energy Storage Laboratory**

These laboratories will be linked virtually with NREL's Energy Systems Integration Facility (ESIF) as "hardware-in-the-loop" to validate real-time multi-scale interactions. The TTF includes a complete machine shop and experimental assembly area, and also supports residential and commercial building field tests.

Overview of the Thermal Test Facility (TTF)

TTF is a flexible multi-purpose laboratory facility that enables detailed evaluation and development of building and thermal energy systems.

- Research Space: 11,000 sq. ft
- Advanced HVAC Laboratory enables rapid, accurate and robust measurement of space conditioning equipment, from bath fan size up to 10-tons
- Automated Home Energy Management Laboratory provides flexible test bed for device, whole-house, and grid-level strategies
- Hot Water Systems Laboratory provides gas, electric, and solar hot water evaluation
- Energy Storage Laboratory is home to the world's most accurate battery calorimeters of their kind, thermal imaging, battery testers, and environmental chambers, with controlled duty cycling at every step



Researchers accurately monitor the nation's emerging efficiency products for indoor comfort at the Advanced HVAC Systems Laboratory. *Photo by Dennis Schroeder, NREL/PIX 20008*

Integrated Buildings Focus

Reducing energy consumption of buildings has been proven to be more cost- and resource-efficient than construction of new power plants. The research motivation for buildings integration is to identify technical and market drivers for energy efficiency on whole-building and community scales. To optimize a building's energy use and operational cost, the performance of the components must be measured and understood. The TTF laboratories were built with this vision.

The TTF serves as a "living laboratory" where energy performance is continually monitored and improved. The TTF incorporates intelligent orientation, geometry, and window-to-wall ratios, increased insulation, daylighting and controls, passive heating and exposed mass, engineered window shading, clerestories, direct/indirect evaporative cooling, and high-efficacy lighting. Lessons learned from this building have served to increase the efficiency of many buildings across the country, and influenced future energy-efficient construction on NREL's campus including the Research Support Facility (RSF).

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Ideally Situated

The Thermal Test Facility (TTF) is oriented east-west to maximize daylighting and control solar transmittance for winter heating and shading in summer. This improves experiment effectiveness and also helps minimize the facility's own energy use. It's just one more way that NREL is "**Walking the Talk**."

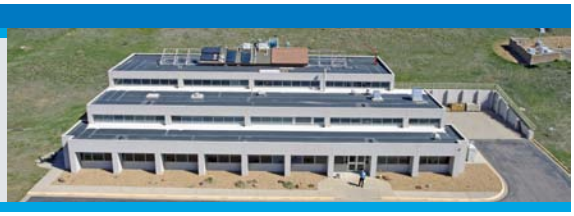


Photo by Patrick Corkery, NREL/PIX 15013

Advanced HVAC Systems Laboratory

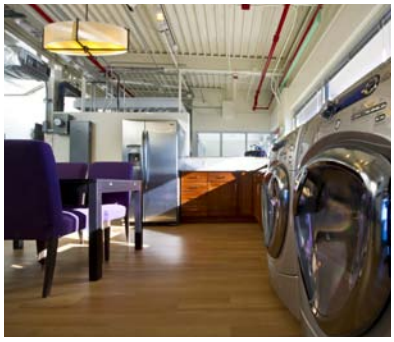
Researchers at the cutting-edge Advanced HVAC Systems lab study the efficiency of HVAC equipment, using its unique capabilities to develop next-generation technologies that improve occupant comfort and energy performance. NREL researchers leverage the facility's world-class accuracy and speed to design and evaluate technologies that maintain comfort in buildings, including:

- **Desiccant-based air conditioning and energy storage**
- **Evaporative air conditioning of all types**
- **Refrigeration-based air conditioning and heating**
- **Advanced ventilation technologies including Energy- and Heat-Recovery Ventilators (ERVs and HRVs)**
- **HVAC systems that combine multiple technologies, such as refrigeration systems with desiccant enhancement.**

Research results are delivered to industry in order to accelerate adoption of best practices and technologies. In this way, building owners can manage energy cost and enhance building comfort, safety, health, and durability.

Automated Home Energy Management Laboratory

NREL's Automated Home Energy Management (AHEM) lab is a robust test bed for home energy systems. Any product developed for home sensing, energy management and control can be studied at multiple scales, from component to whole-house to community level.



Up to 20% of a home's energy can be saved in a seamless, unobtrusive way. The AHEM lab is developing strategies to get us there. *Photo by Dennis Schroeder, NREL/PIX 20007*

This lab boasts unique capabilities such as:

- **Fully instrumented electrical system, from smart meter to every plug, light, and hardwired component**
- **3.2 kW photovoltaic (PV) array**
- **Complete suite of residential appliances and end use loads**
- **High frequency spectrum analyzer to study electrical noise**
- **Multiple communication protocols are supported**
- **EV charging stations and dynamic windows**
- **System-in-the-loop link to the ESIF Research Electrical Distribution Bus enables detailed evaluation of smart-grid technologies.**

This lab is leveraging market drivers for energy savings to develop and study systems that effectively manage energy cost and enhance building comfort and usability. Research results will enable system-wide integration of smart-grid and demand response products that also help homeowners achieve their cost- and energy-saving goals.

Hot Water Systems Laboratory

Low-cost solar collectors for cold climates are being developed and studied at the TTF's Hot Water Systems Lab. *Photo by Warren Gretz, NREL/PIX 06439*

The Hot Water Systems lab provides a suite of evaluation capabilities for a wide variety of hot water components and assemblies including natural gas heaters from tankless to small boilers, electric heaters from on-demand products to large heat pump water heaters, and solar water heaters. Detailed distribution and draw profile simulation can be applied to explore system performance at many scales. The lab will also provide the ability to simulate hydronic heating systems and condition inlet water to simulate mains water temperature for any U.S. climate region.

The TTF rooftop hot water test bed has been used to measure thermal efficiency of solar thermal collectors of all types. Current research efforts include a national initiative to drive down the installed cost of solar hot water systems and testing of innovative solar designs such as low-cost hot water systems, solar assisted heat pumps, and solar regeneration devices for liquid desiccant space conditioning equipment. Low-cost collectors and systems are being fabricated using new designs and low-cost materials such as polymers. Future integration of a large-scale, walk-in research-grade freezer for freeze characterization of collectors, piping, and tanks will further enhance the lab's capabilities.

Energy Storage Laboratory

At the Energy Storage lab, minute heat losses from batteries are accurately measured and studied to help electric and hybrid cars run more efficiently, longer, and more safely. *Photo by Dennis Schroeder, NREL/PIX 18904*

The Energy Storage lab houses several revolutionary capabilities that have set the stage for current and future energy storage technology research and development. NREL has recently doubled the capabilities of the Energy Storage lab and added accelerated life-cycle testing to NREL's evaluation suite.

The unique features of this laboratory include:

- **The world's most accurate battery calorimeters including a cell, a module, and a sub-system calorimeter**
- **More than ten environmental chambers and isothermal baths to perform accelerated lifetime and duty cycle testing across a wide thermal range**
- **Thermal imaging to inspect for hot spots in cells and battery packages during charge and discharge cycles**
- **Several cell, module, and system power conditioning units for battery and ultracapacitor testing and cycling.**

The Energy Storage lab staff partner with the world's leading battery and electric vehicle manufacturers to improve the thermal performance, capacity, longevity, and durability of energy storage systems for future transportation technologies.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

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