



Photo by Dennis Schroeder, NREL 19932

## Vehicle Testing and Integration Facility

### Integrated PEV Charging Solutions and Reduced Energy Use for Occupant Comfort

Plug-in electric vehicles (PEVs) offer the opportunity to shift transportation energy demands from petroleum to electricity, but broad adoption will require integration with other systems. While automotive experts work to reduce the cost of PEVs, fossil-fueled cars and trucks continue to burn hundreds of billions of gallons of petroleum each year—not only to get from point A to point B, but also to keep passengers comfortable with air conditioning and heat.

Engineers at the National Renewable Energy Laboratory's (NREL's) Vehicle Testing and Integration Facility (VTIF) are developing strategies to address two separate but equally crucial areas of research: meeting the demands of electric vehicle (EV) grid integration and minimizing fuel consumption related to vehicle climate control.

Dedicated to renewable and energy-efficient solutions, the VTIF showcases technologies and systems designed to increase the viability of sustainably powered vehicles. NREL researchers instrument every class of on-road vehicle, conduct hardware and software validation for EV components and accessories, and develop analysis tools and technology for the Department of Energy, other government agencies, and industry partners.

Research conducted at the VTIF examines the interaction of building energy systems, utility grids, renewable energy sources, and PEVs, integrating energy management solutions and maximizing potential greenhouse gas (GHG) reduction, while

smoothing the transition and reducing costs for EV owners. NREL's collaboration with automakers, charging station manufacturers, utilities, and fleet operators to assess technologies using VTIF resources is designed to enable PEV communication with the smart grid and create opportunities for vehicles to play an active role in building and grid management. Ultimately, this creates value for the vehicle owner and will help renewables be deployed faster and more economically, making the U.S. transportation sector more flexible and sustainable.



Car undergoing climate control analysis at the VTIF.

Photo by Dennis Schroeder, NREL 19931

# Vehicle Instrumentation

## Primary Use

The VTIF accommodates a wide range of vehicles for modification and testing. SAE International, IEEE, and Institute of Energy Conversion standards related to vehicle charging and communication technology are advanced through vehicle modification projects. A machine shop and circuits lab make it possible to complete vehicle modifications and instrumentation in-house.

## Facilities and Features

- Four bays (three passenger, one heavy vehicle) for vehicle modifications, instrumentation set-up, and experiments
- Room to accommodate high-clearance vehicles
- One 50kW DC fast PEV charger (CHAdeMO)
- Three outdoor AC Level 2 electric vehicle supply equipment (EVSE) units
- One wireless vehicle charging station
- Electronics fabrication, machine, and welding shops
- AC and DC bus lines to interconnect solar energy sources, vehicles, energy storage, smart grid controls, and emulated renewables
- 24 locking high-power outlets to accommodate future EV charging components or renewable energy systems
- Approximately 2,800 sq. ft.



PEV charging in the VTIF. Photo by Dennis Schroeder, NREL 19758

## LEED-Gold Certified

The VTIF has been designated a Leadership in Energy and Environmental Design (LEED) facility by the U.S. Green Building Council. Gold certification means that this is one of the most environmentally friendly structures in the country. Its green features include:



- Water-efficient fixtures and landscaping
- Energy-efficient systems
- Recycled and regionally sourced construction materials
- Low-emitting paints, sealants, and flooring
- Daylighting and lighting controls.



Automotive fast charger enabling 60 miles of range from 20 minutes of charging. Photo by Dennis Schroeder, NREL 20041

## EV Infrastructure Highlights

VTIF EV infrastructure accommodates testing of EVSE, vehicle, and grid interaction. This flexible system provides full monitoring and control at each grid access point. Charging points can range from 3kW to 150kW using AC, DC, and wireless power transfer technology.

- Bi-directional energy management of PEVs
- Public fast charging in 15 to 30 minutes
- Simultaneous charging of multiple vehicles
- Wireless drive-on vehicle charging
- Charging control via ethernet, WiFi, WiMax, ZigBee, USB, satellite, RFID, ModBus, smartphone, and serial connections.

# Vehicle Thermal Testing

## Primary Use

The VTIF site provides a south-facing secure test pad for conducting multiple concurrent light and heavy vehicle thermal soak testing and stationary HVAC load testing.

## Facilities and Features

Designed to support vehicle thermal efficiency research in areas including:

- Light- and heavy-duty vehicle climate control load reduction
- Minimization of the impact of climate control on EV range
- Minimization of heavy-duty vehicle fuel consumed by engine idling for climate control
- Approximately 10,000 sq. ft., enough space to accommodate simultaneous thermal testing of up to six Class 8 trucks
- South-facing vehicle orientation with minimal shading from surrounding environment for maximum solar exposure
- High-fidelity weather station in close proximity to the test pad, providing continuous data stream on temperature, humidity, wind speed, and solar energy intensity
- Convenient power pedestals supplying ample energy for computers, data acquisition systems, and grid-powered climate control systems.



Weather station and vehicles on the VTIF test pad.  
Photo by Dennis Schroeder, NREL 19930

## Impact of HVAC Systems

- Each year, air conditioning light-duty vehicles in the United States consumes 7 billion gallons of gasoline
- EV range is reduced by 30%–45% due to heating and air conditioning
- Rest-period idling of long-haul trucks burns 667 million gallons of diesel annually, much of which is for occupant comfort.

# VTIF Testing, Analysis, and Demonstration Capabilities

## Vehicle Energy Management with Smart Grid

- Optimize vehicle energy flow with residential grids and distributed renewables
- Manage energy demand in military and commercial settings to reduce costs and increase robustness
- Create information flow requirements and support standards development efforts
- Coordinate multiple PEVs and EVSEs with smart grid
- Simulate smart grid, energy storage, renewables, and PEV system scenarios.

## PEV Charge Integration with Renewables Research

- Demonstrate grid-connected vehicle load-supply coordination using renewable and conventional energy sources.

## Off-Board Bidirectional Vehicle Charger Testing and Demonstration

- Identify and quantify potential efficiency, cost, and integration benefits of DC off-board PEV charging.

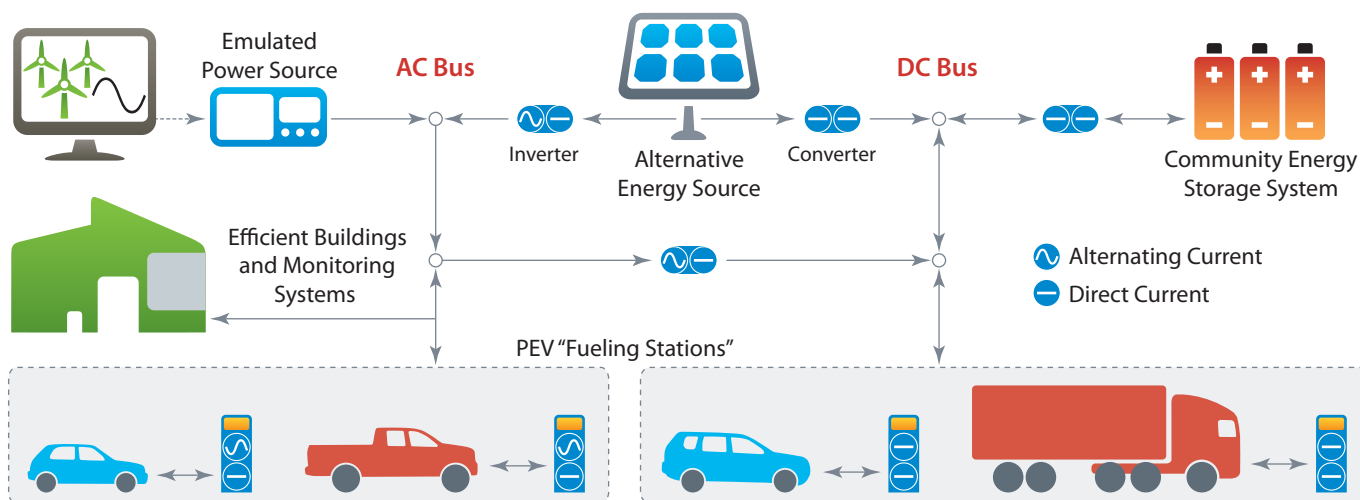
## EVSE Testing and Verification

- Assess response of PEVs and EVSEs to grid communications.

## Vehicle Thermal Management

- Reduce EV climate control loads
- Decrease heavy-duty vehicle idle requirements
- Assess the impact of insulation, reflective materials, and other vehicle modifications on thermal loads
- Predict the effect of thermal loads on fleet fuel consumption and related expenses.

## Grid and Vehicle Systems Integration



### Primary Use

This experimental system enables hardware and hardware-in-the-loop simulation of command, communication, and control systems for vehicle-to-grid integration, while maximizing the benefits of energy provided by renewable resources (e.g., wind and solar).

### Facilities and Features

- Purpose-built multi-bus-configurable distribution grid to support advanced energy management concepts
- PEV "fueling" station with four parking spaces
- Solar tree with tracking system (~20kW)—enough energy to deliver more than 300 electrified miles per day
- Ability to simulate wind turbines or loads from other sources
- Two DC fast chargers—up to 150kW
- Community energy storage system
- EVSEs from multiple vendors, providing resources to investigate various methods of Level 2 charging
- Low-power DC charging facilities for integrating with building DC power networks
- Smart grid interface monitor and controls.



Electric vehicles parked under the solar tree charging system.  
Photo by Dennis Schroeder, NREL 22837

### NREL's Sustainable Transportation RD&D

As the only national laboratory solely dedicated to renewable energy and energy efficiency, NREL spearheads the research, development, and deployment (RD&D) needed to put sustainable transportation solutions on the road. The laboratory's innovative and integrated approach helps government, industry, and other partners develop and deploy the components and systems needed for market-ready, high-performance, low-emission, fuel-efficient passenger and freight vehicles, as well as alternative fuels and related infrastructure.

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)

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  
NREL/BR-5400-63744 • March 2015  
NREL prints on paper that contains recycled content.