A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

Center for Electric & Hydrogen Technologies & Systems

Working Toward a New Energy Future

The energy paradigm is shifting. The world is slowly moving from a hydrocarbon (fossil fuel) economy to a new hydrogen-electric economy that will rely on sustainable renewable energy resources. This future energy economy has the potential to solve the major energy challenges that face the United States today: reducing dependence on petroleum imports, increasing our nation's energy security, and reducing air pollution and greenhouse gas emissions.

In the future energy economy, small, distributed power systems will play an increasing role in meeting the nation's growing need for sustainable electricity and hydrogen supplies. These distributed generators — which include fuel cells, natural-gas turbines, solar power, wind turbines, and others — will be located at or near the point of energy consumption and rely on regionally-available domestic resources.

There are a wide variety of technical challenges with effecting this transition to the new energy economy. How do we inexpensively produce hydrogen from clean, domestic resources? How do we create the new infrastructure that will be needed to deliver hydrogen to consumers in a clean, affordable, safe, and convenient manner? And how do we produce small, affordable fuel cells to turn that hydrogen into electrical power?

In addition, many questions face the widespread use of distributed power systems in a hydrogen-electric future. How do we safely connect distributed generators to the electricity grid? How will those generators communicate with each other, loads, and system operators to allow integrated control and distribution of electricity? How do we integrate renewables into the new energy infrastructure?

Finally, transitioning from traditional fossil fuels to renewable energy sources presents additional challenges. Do we have sufficient resources to support a new hydrogen-electric economy? Which locations have the best resources for distributed renewable energy systems? Do we have the tools to measure renewable resources accurately?

NREL's Center for Electric and Hydrogen Technologies and Systems is addressing these issues and helping to facilitate a smooth transition to the new energy future. In collaboration with industry, other institutes, and national laboratories, the center provides the nation with expertise in hydrogen and distributed power technologies and systems, and renewable resource characterization and measurement.

Energy Systems

One of the major obstacles to expanded use of renewable energy has been the intermittency of solar and wind resources. Hydrogen is an energy carrier and storage medium that allows electricity generated from renewables to be dispatchable. The distributed power plants of the future could use renewable energy to produce and store hydrogen on site. Co-located fuel cells could then use the hydrogen to generate electricity when the wind isn't blowing or the sun isn't shining. Because fuel cells have zero emissions, this scenario is a key component of a clean energy future. Together, the Distributed Power Systems Integration (DPSI) Team and the Hydrogen Technologies and Systems Team are exploring the synergies between hydrogen and renewable electricity in integrated distributed energy systems.

The development of cost-effective hydrogen-electricity co-production systems of the future will depend on continued advancements in distributed power systems integration and hydrogen technologies and systems. These basic and applied research areas are the focus of the Energy Systems Group of the Electric and Hydrogen Technologies and Systems Center.

The Energy Systems Group's *Distributed Power Systems Integration Team* creates technologies and supports the development of policies that will enable the interconnection and integration of distributed energy resources with the electrical distribution system of the future. Key research activities include:

Engineering and test development — The Electric and Hydrogen Technologies and Systems Center's Distributed Energy Resources (DER) Test Facility supports standards development and investigates emerging complex systems integration issues. Scientists and engineers at this facility:

- Characterize, test, and evaluate DER systems to determine if they operate properly and meet inter-connection, communication, and other standards.
- Develop protocols and procedures for testing and evaluating systems to ensure that they meet performance, safety, and compatibility standards
- Test advanced designs for grid-connected, stand-alone, and hybrid systems.

- Coordinate laboratory and industry testing activities.

Interconnection standards and codes — The wide variety of utility and state requirements has led to a patchwork of prerequisites for interconnection, resulting in technical and economic inefficiencies, interconnection delays, and unnecessary expense. In response, the DPSI team provides expertise to support national consensus efforts to create a series of universal interconnection standards and establish uniform adoption toward eliminating barriers posed by project-specific interconnection requirements.

Regulatory policy issues — Market adoption of DER technologies requires profound changes in the traditional concepts and practices of state utility and environmental regulators. At the request of the Department of Energy, the DPSI team provides state regulators, their staff, and other policy makers with the background information and research needed to inform their decisions about policy issues related to distributed generation.

Applications and analysis — The DPSI team also conducts research on potential DER applications to address systems integration issues and benchmark integrated systems. The results of this research are analyzed to identify potential issues and opportunities.

The Energy Systems Group's *Hydrogen Technologies and Systems Team* develops and analyzes advanced hydrogen production and utilization technologies, facilitates the development of consistent codes and standards, and collaborates with universities, industry, international organizations, and other national laboratories to facilitate the transition to a hydrogen-electric economy. Key research areas include:

Infrastructure development — Making the shift from the current fossil-fuel supply infrastructure to a safe and widespread hydrogen production, storage, and delivery system.

Development of codes and standards — Establishing a market-receptive environment for commercializing hydrogen-based products and systems by ensuring the safety of hydrogen in storage and transport.

Coordination of analysis — Ensuring consistent methodologies are applied to the analysis being conducted on hydrogen and fuel cell systems.

Hydrogen production and utilization —

- Developing hybrid power systems incorporating renewable energy and fuel cells.
- Producing hydrogen from water in a one-step process using semiconductor materials.
- Improving the materials, manufacturability, and operation of fuel cells.

Resource Integration

Renewable resources can vary considerably from one geographic location to another. Consequently, optimal siting of renewable energy systems requires knowledge of the resource characteristics at any given location. NREL's Resource Integration Group brings expertise and resources to provide the data and tools necessary to address leading edge renewable energy resource issues, both domestically and internationally.

The Resource Integration Group's Geographic Information System (GIS) Team uses GIS tools to organize, display and analyze geospatial data important to solar, wind, biomass, and geothermal technologies for assessing optimized technology deployment scenarios. The Group's Measurement and Instrumentation Team measures and disseminates solar radiation and other meteorological data for use in climate change studies, atmospheric research, renewable energy conversion system testing and more. Together the Resource Integration Group:

- Provides reliable time-series resource data for thousands of locations worldwide.
- Develops manuals, maps, and other data products on renewable resources to support system design and project planning.
- Uses GIS mapping to manage, manipulate, and analyze resource, socioeconomic, and environmental data sets to evaluate development options.
- Maintains a Web site with access to data on geothermal, biomass, solar, and wind resources, allowing users to obtain customized resource analyses.
- Manages the Solar Radiation Research Laboratory in Golden, Colorado, which monitors and disseminates solar radiation and other meteorological information, and serves as the U.S. center for maintaining and transferring international radiometer standards to government, industry, and academic laboratories.

National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 · www.nrel.gov

Operated for the U.S. Department of Energy

Office of Energy Efficiency and Renewable Energy

by Midwest Research Institute · Battelle

NREL/FS-560-33504 · Revised February 2005

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% postconsumer waste.