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Sci-fi no longer, NREL engineers smart homes

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NREL engineers Dane Christensen and Bethany Sparn test advanced power strips at NREL's Automated Home Energy Management Laboratory. The lab enables researchers to study the complex interactions of appliances and other devices in connection to the energy grid. Credit: Dennis Schroeder

Thanks to TV shows such as *The Jetsons* and *Star Trek*, many Americans grew up dreaming that homes of the future would be equipped with fantastic high-tech features. From automatic food dispensers to sliding doors, to Rosie the Robot doing the household chores, the imagined homes of the future seemed to be driven by an unlimited supply of energy.

Research engineers at the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) have a different vision for the home of the future. The team is working on a "smart" home that will communicate with the electricity grid to know when power is cheap, tell appliances when to turn on or off, and even know when renewable energy resources are available to offset peak demand.

NREL is leveraging two laboratories to make its dream home a reality — the soon-to-be-built Smart Power Laboratory, which is part of the new Energy Systems Integration Facility (ESIF), and the Automated Home Energy Management Laboratory.

Smart Power for the Next Generation

NREL's 5,300-square-foot Smart Power Laboratory will focus on two key areas: the development and testing of power electronics systems and controls, and the implementation of newer control approaches for smart energy management devices and systems. The lab will feature three power electronics test bays with sound abatement walls and a 96-square-foot walk-in fume hood for testing early prototype systems that have a higher risk of failure. There will also be four smart grid test bays capable of testing a variety of household appliances and systems.

"A part of our research in the Smart Power Laboratory will focus on the integration of distributed energy resources using power electronics; we want to develop a new generation of power electronics systems that will provide advanced functionalities to consumers and utilities, and lead to more efficient integration of renewable energy into the smarter electric grid," NREL Senior Research Engineer Sudipta Chakraborty said. "The present work being done at NREL is on a smaller scale because we are constrained by the size and infrastructure of our current lab. The lab in ESIF will greatly enhance our ability to develop and test bigger power electronics systems."

The Smart Power Laboratory will allow NREL to perform equipment testing for industry. For example, if a manufacturer builds a new inverter, it can be tested and validated at NREL before the manufacturer takes the system for certification. This will greatly reduce the risk of failure for the manufacturer during the certification testing.

"We've found that a large number of manufacturers don't have all of the necessary equipment to do the required testing — like having a grid simulator to see how their inverter behaves if there is a disturbance in the grid frequency," Chakraborty said. "ESIF will have equipment that can test this type of power electronics system, and thanks to our large grid simulators, load banks, and DC sources, connected through the Research Electrical Distribution Bus (REDB), we can be a test bed for even bigger inverters — which is the current trend in the market."

NREL engineers Sudipta Chakraborty and Bill Kramer examine the design of the power block at an NREL lab. Along with an industrial partner, NREL engineers have developed the power block for renewable and distributed energy applications. Credit: Dennis Schroeder

In addition to the power electronics research, the Smart Power Laboratory's smart grid test bays will be used to develop newer grid-monitoring equipment and to test smart appliances and home automation, energy management, and heating, ventilating, and air conditioning (HVAC) systems. The hardware-in-the-loop system and the capability of real-time control of the megawatt-scale power equipment will enable NREL to simulate integrated system responses such as household loads and generation as seen by the utility, and will ultimately lead to the development of better energy management algorithms.

"People are really looking at the whole integration of these energy systems," Chakraborty said. "At the residential level, you'll have your house with a photovoltaic system on the roof, with smart appliances inside, and we'll look at the data to see how those systems work together. The utility companies are interested in seeing how they can control those appliances to offset loads and make the peak power demands more stable. To do that, all of these pieces have to work together, which they don't do today."

The Home of the Future

To help figure out how those pieces must work together inside a home, NREL has built the Automated Home Energy Management (AHEM) Laboratory as part of NREL's advanced residential buildings research.

We are very cognizant of the fact that every home is part of a larger energy system," NREL Senior Engineer Dane Christensen said. "We've modeled the AHEM Lab around a real home, with the same plugs, panels, and appliances. The idea is that eventually our appliances and homes are going to be able to 'talk' to the grid. We are trying to figure out how demands from the grid and the dynamics of residential energy can be coordinated."

NREL researchers have found that power is viewed differently from either side of the grid. The homeowner sees that power is always available, at a uniform cost, so there is little motivation to save power during high-demand times and then use power later when it is less constrained. Currently, it doesn't matter to homeowners if they use a clothes dryer while they bake a cake, watch TV, and have all the lights turned on in their house. But, for the grid, that kind of behavior has a huge impact, especially during summer months when air-conditioning is added to the demand mix. Today, utilities have no way to mitigate that power consumption; they simply have to generate and deliver more power.

"There has to be something in the home to receive communications about energy availability and use built-in intelligence to act on it — especially when people aren't home to do it," Christensen said. "Just like in cars, you have systems that will automatically brake for you, or protect you. In the home, the only thing automated right now is probably your thermostat."

According to Christensen, the goal is to have communications coming into the home from the utility that include pricing, requests to conserve energy, and rebates to homeowners who can act quickly to reduce power when needed. Conversely, the power company could also send a signal letting homes know that it is OK to go ahead and do laundry while cooking dinner, because there is more power available.

"We're working on building systems for homes that can take the information from the utility, along with input from the homeowner, and manage the home's energy to satisfy both the homeowner and the utility," Christensen added. "The homeowner will still be in control, with built-in overrides and the ability to change settings. But we also want to help the utility meet its needs and keep costs down, while maintaining comfort."

Making it Work for the Long Term

Home energy management is a critical area for the DOE Building

America program to reach its long-term goals of at least 50 percent energy savings for new construction and 40 percent savings over the minimum code for building retrofits.

Building America is the flagship program for residential research within the Building Technologies Program at DOE. The goal is to make energy efficiency cost effective for residential buildings; NREL is the technology lead and manager for the program.

"Work we did seven years ago is now being adopted into the current energy codes," Christensen said. "We are ahead of industry because it takes time for results of our research to make their way to the consumer. From where we sit right now, it looks like there is a big challenge in getting beyond the 50 percent energy savings for new home construction and 40 to 50 percent savings in retrofits, without home energy management technology in place.

"The technology created and tested at NREL's Smart Power Lab or Automated Home Energy Management Lab will enable those home-energy puzzle pieces to fall into place — helping people turn the lights off when nobody is at home, helping people adjust their thermostat when they are not at home, helping people understand that energy is expensive at a particular time of day so they can avoid running an energy-intensive appliance until power is less expensive — all of that helps save energy and costs across the board."

Provided by National Renewable Energy Laboratory