

A HOUSE & A LABORATORY

NIST's NEW Home Tests Energy Efficient Technology

by Mary Lou Jay



THESE SOLAR PANEL INSTALLATIONS HEAT THE HOME'S WATER, WHILE A LARGER ARRAY ON AN UPPER ROOF HELPS GENERATE ENERGY.



DURING NZER PHASE, AUTOMATED SYSTEMS CONTROL THE APPLICATION OF ENERGY AND WATER USAGE IN THE HOME AND THROUGHOUT THE NEIGHBORHOOD, REPLICATING THE AMOUNT OF ENERGY AND WATER THAT A TYPICAL FAMILY OF FOUR WOULD USE DURING THAT TIME.



The construction of a two-story, four-bedroom home isn't a typical job for Therrien Waddell Construction Group. But then, there is nothing typical about the National Institute of Standards and Technology's (NIST's) Net-Zero Energy Residential Test Facility (NZERTF), located on the grounds of the NIST in Gaithersburg, Maryland.

A net-zero energy home is one that generates as much energy from renewable sources as it uses over the course of a year. We wanted to design a facility where we can demonstrate net-zero energy for a home that is similar in size, amenities and features to those in the surrounding communities, said Hunter Faney, chief of the Energy and Environment Division within NIST's Engineering Laboratory. More importantly, we wanted to design a test bed to develop methods of test

and performance metrics for energy efficient technologies of the future.

NIST engineers and scientists brainstormed for six months to decide on the type of test capabilities they wanted to incorporate in the house. The architectural firm of Building Science Corporation of Boston, Massachusetts, took their ideas and molded them into a design. Their services were paid for by the U.S. Department of Energy's Building America program; the remainder of the project funding came from the federal American Recovery and Reinvestment Act.

Experience Counts

Therrien Waddell (TW), which is active in the local U.S. Green Building Council, heard about the project from NIST engineers who came to TW's lunch-and-learn seminars on green construction. Although TW initially


had some reservations about building a house-like structure, the company decided to team with a residential builder to bid on the job. (The home builder soon dropped out of the project, but TW brought some of its experienced staff members on board to assist.)

Therrien Waddell's previous work in green building technology was an advantage.

Awards were made on a best value basis, and our evaluation was based on qualifications and past experience, rather than just low price, said Dan Coffey, TW's vice president of business development. We had been doing many of the things they were asking for in the commercial sector for a long time. Applying them to residential wasn't a problem.



THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY'S NET-ZERO ENERGY RESIDENTIAL TEST FACILITY (NZERTF) LOOKS LIKE A HOME BUT SERVES AS A RESEARCH CENTER TO TEST HIGH-EFFICIENCY ENERGY SYSTEMS AND PRODUCTS AND TO DEVELOP WAYS TO MEASURE THEIR PERFORMANCE.



THE TWO POWER INVERTERS AND MAIN ELECTRICAL PANEL, LOCATED IN THE ATTIC SPACE, ARE CONNECTED TO THE SOLAR PANELS LOCATED ON THE ROOF. THE INVERTERS GENERATE OR CONVERT THE SOLAR ENERGY TO 120/240 VOLT POWER AND PASS THIS ENERGY TO THE ELECTRICAL PANELS FOR USE EITHER BY THE HOME OR THE LOCAL ELECTRICAL COMPANY.



“We understand how to put these structures and these systems together,” Coffey added. “We also brought our team of very specialized subcontractors with us.”

TW was awarded the project in January 2011, and started construction a few months later, completing the job in June 2012.

Meeting Schedules with BIM

Although the NIST Net-Zero Energy House looks like a home, it includes many features normally found only in a laboratory. “It has the same fire protection systems found in all the laboratories at NIST,” said Faney. “It has over 500 sensors throughout it so that we can measure the energy used by every individual device in the home. We can control the lights and all the appliances and simulate a family of four living in the home.”

Because it will be used to set standards for many different types of energy systems, the house has many built-in redundancies. There are three different types of earth-coupled heat pump systems, each of which can operate independently, and the house is also set up for a gas furnace and central air conditioning. There are three different ways of moving heating and cooling around the building: a traditional metal duct system, a high velocity air distribution system and a system that will move refrigerant around the house to avoid all the heat losses and air losses of ductwork.

With so many systems hidden behind the walls, Therrien Waddell put together a BIM model at its own expense. “We decided because of the intense



coordination required between trades BIM was the only way to effectively minimize any conflicts pre-construction,” said Coffey. “We had to make sure that the materials that NIST asked for were going to fit; we could not add extra fittings or offset pipes because they had designed the systems very precisely and wanted them built exactly as they were designed.”

The BIM model found 105 conflicts. Most were minor, but one major problem in the kitchen ended up requiring some architectural and engineering redesign.

“BIM was an invaluable tool for us,” said Jerry Therrien, principal at Therrien Waddell. “Although it was not a requirement for the project, it was well worth the investment we put in to make sure that everything worked smoothly.”

“Once the contracting people and the building scientist people at NIST experienced BIM, they said they should require it on every project,” added Coffey. “At the ribbon-cutting ceremony the NIST representatives told us this was one of the few projects performed on campus in three years that came in on time and on budget.” The use of BIM was a key factor in that success.

Putting it to the Test

TW built the NZERTF using the optimal lumber framing technique. “A common practice in traditional wood frame construction is to use extra framing without considering whether or not it is truly necessary from a structural standpoint,” said Therrien. “With optimal lumber framing, we’re putting in only the materials that the engineers

THROUGH ITS COMPLEX SYSTEM OF CONTROLS AND MEASUREMENT INSTRUMENTS, NIST CAN COMPARE THE ENERGY USAGE OF THREE DIFFERENT TYPES OF GEOTHERMAL SYSTEMS.



THE ORANGE SLAB-ON-GRADE TUBING IS PART OF THE RADIANT FLOOR HEAT TUBING LOOP THAT WAS EMBEDDED IN THE CONCRETE FLOOR OF THE BASEMENT. NIST WANTED THE RADIANT BASEMENT FLOOR TO MEASURE THE HEAT/COOLING TRANSFERENCE FROM THE GROUND. THE OPEN WEB FLOOR JOISTS ABOVE THE TUBING WERE SET ON THE TOP OF THE FOUNDATION WALL.

have calculated and verified are actually needed.”

Where home builders would traditionally use stud frames that were 16 inches on center, the NIST home was built with studs 24 inches on center. TW also used singled studs instead of double studs around openings and removed some of the usual framing at corners. That required crews to carefully align the wall framing with the truss and floor framing members.

“The whole idea was to maximize the insulation space and to minimize the possibility of transmission of heat through the studs. The fewer studs you have, the larger the cavity and the lesser number of possible conduits for the transfer of heat or cooling through the structure,” said Coffey. TW also installed a rubber membrane weather barrier system that helped seal the house.

NIST engineers tested the tightness of the home’s building envelope several times during and after construction. Its performance each time has exceeded the NZERTF standards and the Department of Energy’s Building America target goals.

“We went through a number of tests like that on the project,” said Coffey. “For example, once the manufacturer’s recommended pressure on tests of the window systems was achieved, the scientists wanted to test the window systems until they failed so they could see what extremes they could push them to. The manufacturers of the windows were also present with us during this test because they were interested in seeing the results. They got a little nervous, but as we tested it we took the windows to another

threshold, everyone was very pleased; we didn’t think it would perform to that standard.

“One of the really interesting dynamics of the project was that as we were building we were really learning some of the applications of the field of building science, which was an interesting process. It was very different than a traditional government contracting experience. It was very collaborative in the sense that everyone was helping each other and focusing on a common goal for the project,” he added.

Made in America Made Project Difficult

The biggest challenge on the job turned out to be meeting the requirement that all materials used in the home be American-made. “It was very difficult to satisfy the government requirements for verification that something was made in America,” said Therrien. “I never would have imagined a house of this size would take the 15 months we were given to construct it, but in retrospect, with the requirements we had to meet, I now understand why it took so long.”

In some cases, such as one mechanical system, the product was primarily built in the U.S., but one key component was not. “We had to use very specialized controls for the mechanical system but the controls were made in Canada, so we had to figure out how to make the system work without these controls, and get that reviewed and modified,” Coffey said.

The only piece of American-made equipment TW could not find was a heat recovery ventilator. “With the help of the architects and engineers, and with Hunter and his team we searched high



A SLINKY LOOP IS ONE OF THREE GEOTHERMAL SYSTEMS INSTALLED IN THE HOME.



THERE ARE THREE ALTERNATIVES FOR COOLING AND HEATING THE NZERTF: A TRADITIONAL METAL DUCT SYSTEM, A HIGH VELOCITY AIR DISTRIBUTION SYSTEM AND A SYSTEM THAT WILL MOVE REFRIGERANT AROUND THE HOUSE TO AVOID ALL THE HEAT LOSSES AND AIR LOSSES OF DUCTWORK.

and low, looking at different American manufacturers, but their equipment just didn't quite meet the requirements. So we eventually conceded and went through the waiver process that took nine months for a \$2,000 piece of equipment," said Therrien.

The other construction challenge was the learning curve with subcontractors and suppliers. "We had a mix of commercial subcontractors and residential subcontractors because of the elements of the project," said Therrien. All of the subs received extensive orientation before they began work.

"In order to achieve a net-zero energy home, you have to pay extreme attention to the workmanship. Anytime there was something that was a little bit unusual, that subcontractors were not familiar with, we would have team meetings and we would go over procedures, then have a trial run," said Fanney.

Since some subcontractors had difficulty meeting the project's stringent buy-America and atypical construction requirements, TW had to hire replacements for them in mid-project to complete the job. But the additional effort was worth it, since working with the right craftsmen and

subcontractors enabled TW to reach the project goals. For example, to reduce waste, TW pre-cut all the lumber at an off-site factory, labeled every piece and had subcontractors follow a set of step-by-step instructions to put the pieces together. With this approach, the only lumber wasted on the job was the wood used for the fall protection safety barriers.

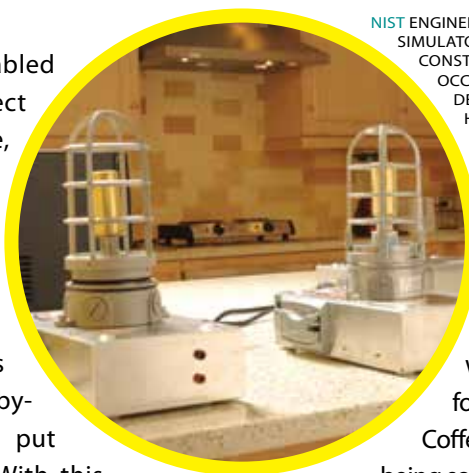
Learning from NZERTF

NIST researchers recently started a year-long experiment in which they will use the NZERTF's automated controls to simulate a family of four living in the home. That experiment should show that achieving net-zero energy in a home is achievable. After that, NIST will use the house/lab to test various high-efficiency and alternative energy systems and materials. NIST has set up a web page www.nist.gov/el/nzertf/ to share its research results.

Once the one year period of demonstrating net-zero energy operation is over, NIST will work with manufacturers, builders and code officials to improve measurement science that will better capture the performance of low energy homes. "That information will be used to provide guidance to code officials and standards officials to help them make better energy codes for the future," said Fanney.

Therrien Waddell has already gained some valuable information from its work on the job.

"What it did for us more than anything was validate some of the things that



NIST ENGINEERS INSTALLED SIMULATORS AFTER CONSTRUCTION TO REPRESENT OCCUPANTS OF THE HOUSE. DEVICES LIKE THESE HAVE BEEN POSITIONED IN ALL THE VARIOUS ROOMS AND CAN BE TIME-OPERATED BY COMPUTERS WHEN DESIRED TO THROW OFF HEAT AND HUMIDITY.

we had been doing for some time," said Coffey. "Instead of it just being something that we felt strongly about, from our own quality standards, we could see that it made sense, and that it actually was an economical way to build."

The company also learned more about setting up a building to be ready for connection to a smart grid, which enables homes to give power back to the grid, and about solar tank arrays. "We were able to meet and discuss with the researchers who are working on new solar panel technology and improvement," he said. "We got to understand from their perspective where the industry is and what's coming up in the future."

NZERTF was built to simulate a home, but Therrien believes that some research will also impact commercial building. "I can see that some of the concepts here, such as an airtight envelope, high efficiency equipment, controls and geothermal loops are frequently being used now, so I think some of the test results will have transference to commercial applications."

Although the made-in-America requirements, the challenges with subcontractors and the constant oversight of every step made the project stressful at times, Therrien is glad that his company took it on. "It's very satisfying when you look back and see that you could succeed so well in accomplishing the goals of the project and meeting all the requirements along the way." ■



WITH FRAMING ALMOST COMPLETE, THE NZERT LOOKS LIKE A TYPICAL SUBURBAN HOME.

