Research Performance Progress Report (RPPR) for DOE/EERE

Project Title: The Nest Home

Covering Period: April 15, 2014 to April 15, 2016

Approved Project Period: April 15, 2014 to April 15, 2016

Submission Date: July 11, 2016

Recipient: Missouri S&T Solar House Design Team
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Award Number: DE-EE0006562

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Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number DE-EE0001217.

Project Overview:

The purpose of the project was to build a competitive solar-powered house for the U.S. Department of Energy Solar Decathlon 2015 held in Irvine, California.

Background:

The 2015 Solar House was Missouri University of Science and Technology's sixth entry in the DOE Solar Decathlon. Missouri S&T has been invited to compete in six of the seven decathlons held, more than any other university worldwide. The highly energy efficient, net zero structure was built by students at the S&T campus in Rolla then disassembled and transported to Irvine, California to compete. It was reassembled at the decathlon for the competition that took place from October 8-18, 2015. It was ultimately disassembled again and brought back to Rolla where it has been placed in its permanent location on the S&T campus.

The house, named the Nest Home, was an innovative design that works with the environment to meet the needs of the occupants, identified as a growing family. Reused materials were instrumental in the design. Three refurbished shipping containers composed the primary structure of the house, creating an open floor plan that defies common architecture for container homes. The exterior siding was made of deconstructed shipping pallets collected locally. Other recycled products included carpet composed of discarded fishing nets, denim batting made of recycled blue jeans that outperform traditional fiberglass insulation in sound proofing and thermal resistance, and kitchen cabinets that were purchased used and refinished. Collectively these elements formed a well-balanced blend of modern design, comfort, and sustainability.

The house was built on a steel foundation that kept the structure strong and allowed the house to be assembled with relative ease as steel maintains its shape and does not warp. The Nest Home was placed upon a temporary foundation of screw jacks that could be readily adjusted to keep the house level on any surface. Steel struts further stabilized the house and protect against earthquakes. Steel was a logical choice since it is renewable and the most recycled material in the world. Over 500 million tons are recycled each year.

The photovoltaic array of 24 solar panels was designed to power the Nest Home as well as an electric vehicle. The unique system contained a micro-inverter, eliminating the need for collected power to be sent to a shared inverter before being converted to alternating current. This greatly decreased the amount of direct current wiring needed, making the transfer of power more efficient and protecting the home from associated electrical hazards. Solar thermal panels were also used to heat water with energy from the sun for use throughout the home, further reducing overall energy consumption. Water in the collectors was directly heated by the sun before being transported throughout the house. The pump in the system was driven entirely by solar power. Since heating water can account for up to 18% of a home's energy usage, installing a solar thermal system can save upwards of 4800 kWh of electricity per year.

The Nest Home used predictive technology that allows the house to automatically choose the best adjustments to efficiently regulate the indoor environment. The home automation system continuously monitored environmental conditions, making adjustments to the heating, ventilation, and air conditioning (HVAC) system, humidity, exterior and interior lighting, fans, and windows. It also integrated weather forecasts and user preferences to meet the needs of the occupants. Automated window controls can be programmed by the user to respond to changing conditions and support the HVAC system in maintaining a comfortable interior climate. More energy savings occur as the system utilizes light harvesting technology to dim or brighten lights in real-time as needed. The homeowners can control the house remotely from a wireless device, such as a smartphone or tablet. This allows a homeowner to turn lights off, reset the HVAC thermostat, and even track energy usage.

Other systems incorporated into the design to conserve resources included a greywater reclamation system and hydroponic gardens. The greywater reclamation system treats water from the bathroom sink, shower, and laundry for reuse in other parts of the house. A series of filters are used to treat the water. These include sediment filters to remove relatively large particles and small particulates that may escape through the waste stream, carbon block filters to remove chlorine and other unhealthy chemicals, and UV filters to destroy harmful pathogens that may cause disease in plants. After passing through the filters, the treated greywater is clean enough to meet all applicable building codes for use as source water in a garden or hydroponic system. Greywater contains nitrogen, phosphorus, and potassium, all nutrients essential for growing healthy plants. This makes it an ideal feed for gardens. The Nest Home featured three types of hydroponic gardens: a vertical garden, two tower gardens, and a shade garden. Hydroponic gardens can accommodate high-density growing and allow plants to grow faster while using up to 90% less water than traditional soil gardens.

2. ACCOMPLISHMENTS:

a. Major goals of the project

The major goals of the Nest Home were to provide an affordable house that could be set up quickly and constructed to last. The house included reused, repurposed, and recycled products. Just as birds build nests with materials they find in their environment, the Nest Home mimicked this approach by using items found in local surroundings to create a home. The Nest Home proved that solar-powered homes can be attractive, efficient, and affordable and that individuals do not need to compromise any aspect of their existing lifestyle to live a more sustainable life.

Overall, the Team's goal was to improve quality of life by integrating student-designed and existing technologies into a fully-operable, net-zero solar-powered home. All design aspects focused on creating a house that is both attractive and accessible, that all types of people can enjoy. The Team intended to show the public through the design that living in a solar-powered home increases one's awareness of the environment and environmental impact and can provide a sense of accomplishment and well-being.

b. Significant accomplishments under the major goals

The Nest Home was shipped to Irvine, California, the site of the 2015 Solar Decathlon, where it was judged against 13 other houses from competing teams.

The Missouri S&T Solar House Design Team designed and constructed the house, procured all necessary materials, submitted all deliverables to DOE on time, reached out to partners for donations, and participated in community outreach events to spread the word on the team and the project. A send-off event was hosted to give family, friends, and community members the opportunity to visit the home before its departure to competition. A crowdfunding campaign also successfully raised over $7500 to send the team to competition. In addition, all team members were trained in OSHA 30.

The Team received most of its support from the University and surrounding community. Most of the design work for the project took place in the Student Design and Experiential Learning Center. Missouri S&T Design and Construction Management further provided valuable mentorship for the Team throughout the design and construction process. The following information provides significant tasks in each project phase:

- The design phase included schematic design, design development, and the creation of construction documents. All of these steps aided in the formation and implementation of

detailed design drawings, plans, and documents.

- The construction phase included the preparation of the construction site, the procurement of materials and services for the project, and the actual construction of the house.
- After the house was constructed, the Team began preparing for competition, completing the testing of the house, and relocating the house to California to compete.
- The competition phase resulted in a fifth place overall.
- The final phase included returning the house to the Missouri S&T campus and placing it on a permanent foundation for use as student housing.

The 2015 Solar Decathlon was a success for Missouri S&T. The team was honored to host the Secretary of Energy, Dr. Ernest Moniz, as one of only three houses he toured during opening-day ceremonies. Throughout construction, competition, public tours, and deconstruction phases of the Decathlon, 26 team members participated and more than 40 worked on the project throughout the process. The team led the competition during the categories measuring the home's energy management systems. It completed the competition in fifth place, which is Missouri S&T's highest placing.

Status Summary Table:

	Phase	Planned Completion	Complete	Notes
Design Phase	Schematic Design	9 May 2014	X	Completed on-time
	Design Development	8 October 2014	X	Completed in November 2014
	Construction Documents	14 November 2014	X	Will be complete by 12 February 2015
Construction Phase	Site Preparation	31 October 2014	X	Completed in November 2014
	Procure Services and Materials	12 December 2014	X	Materials will be procured as needed on-site
	Construction	30 April 2015	X	On-track for completion by mid-August
Competition and Preparation	As-Built Documents	14 May 2015	X	Completed on-time
	Testing, Shipping, Rebuilding	8 September 2015	X	Summer 2015
	Competition	18 October 2015	X	Finished in 5th place
	Post-Competition	24 October 2015	X	Shipped the house back to campus in Rolla

	Installation at Permanent Location	30 November 2015	X	Set on permanent foundation; two team members moved into the house in January

c. Opportunities for training and professional development

The Missouri S&T Solar House Design Team is a student organization that seeks to better the University, community, and environment through focused research, public education, and sustainable design. The Team provides opportunities for members to expand their knowledge and innovation skills regarding the integration of architecture and technology with dwelling space design and function. Students also learn how to collaborate in a large team and receive hands-on experience designing and constructing a complex project. Other skills such as product development, marketing, and financial management are developed through the administration of duties necessary to run the team, further preparing members for future leadership roles in industry. The Team is run entirely by student officers responsible for collaborating with a board of advisors in order to ensure the success of the team.

Leadership training was accomplished by students working closely with the Missouri S&T Student Design and Experiential Learning Center (SDELC), Physical Facilities, advisors/professors, and industry professionals. The SDELC offers shop and training classes. These workshops vary from general shop safety, required for all team members working on-site, to more specific topics such as electrical safety. The SDELC staff ensures trainings run smoothly. The SDELC organized both OSHA-30 and OSHA-10 trainings for team members who participated in the construction of The Nest Home. Physical Facilities was extremely valuable in providing guidance throughout the design development phase and the construction phase to ensure that the Team stayed on schedule and designed a constructible and affordable house. Communications with advisors/professors aided to refine the construction documents. Leaders on the Team also attended workshops focused on project management, leadership, and collaboration. This included working closely with advisors/professors and professionals in industry to understand the skills and knowledge required to succeed both in the project and in the future.

d. Dissemination of results to communities of interest

Results and learning are provided through outreach opportunities. Team representatives attend public exhibition events both on and off campus. Several of these events are held for the benefit of new freshman students entering Missouri S&T in the fall, helping raise both awareness of the team's mission and encourage recruitment. Off-campus events are held with both alumni and the general public in open exhibitions and occasionally encourage support donations. The 2015 house is now a part of the Missouri S&T Solar Village. The houses are used for student housing and public tours to promote solar technologies and sustainable living. Tours are given to interested persons in the community as well as industry professionals. In addition, the houses are used for interdisciplinary research by faculty and students.

e. Plan for next reporting period – NA

Nothing to Report – final report being submitted

3. PRODUCTS – Optional

This project has not produced any products such as publications, conference papers, presentations, technologies or techniques, inventions, or patents.

4. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS – Optional

Nothing to Report

5. IMPACT

The project has had a positive impact on the students involved as well as the public who visited the house during competition and since it was placed in its permanent location on campus.

6. CHANGES/PROBLEMS – NA

Nothing to Report – final report being submitted

7. SPECIAL REPORTING REQUIREMENTS – NA

Nothing to Report

8. BUDGETARY INFORMATION

Final budgetary information previously submitted.

9. PROJECT MANAGEMENT PLAN (PMP) – NA

Nothing to Report – final report being submitted