The Pennsylvania State University
Retrofit Housing April 5, 2022

Solar Flair

Project Summary

The MorningStar House is a solar home originally submitted by the 2007 Penn State Build Team to the Solar Decathlon competition. The home now permanently resides on Penn State's campus as a teaching building. The Sustainability Institute, who currently operates the house, has requested that it be retrofitted to meet an updated standard of technical and renewable energy needs, as well as adapt to a new phase of life as a permanent structure on campus.

This year we have invested time into engaging the original designers of the MorningStar House to understand and honor the history of Penn State's Solar Decathlon Team. Our multidisciplinary team consists of students majoring in architecture, engineering, and business. Our team is focused on updating the building to a new level of performance, while respecting the original intent and efforts behind the MorningStar House.

Design Strategy

This retrofit will update the technical and construction details of the MorningStar House to bridge the gap between the standards of 2007 and today. Updates include replacing outdated energy and mechanical systems, refining the envelope to ensure air tightness and thermal insulation, and updating interior spaces and site design to match the needs and activities of its current users. Despite its name, the building will not necessarily be used as a home. Instead, it will be operated as a teaching and education space for visitors to explore sustainable design and observe building science principles in action. This concept aligns with the Solar Decathlon goals of leading the building industry using innovative technology and science.

Project Data

- State College, Pennsylvania, USA, Climate Zone 5A
- 725 ft^2 Building Size, 24,000 ft^2 Lot Size
- 1 bed / 1.5 bath, 1 story residential + full conditioned basement, two occupants
- Existing EUI: **27.1 kBTU/ft^2/yr,** Target EUI : **14 kBTU/ft^2/yr**
- $5/month Utilities
- 0-ton CO_2e/ft^2/yr Annual Carbon Emissions

Technical Specifications

- Wall = 42, Roof = 51, Foundation = 20
- **Existing window**: Insulated Double-Pane, Low-E, U = 0.30 **Proposed:** Insulated Triple Pane, Argon Filled, Low-E
- **Existing**: Radiant Floor Heating, Air Source Heat Pump **Proposed**: ERV, Heat Pump WH
- **Existing:** Solar Thermal Energy Storage **Proposed:** Automated Logic BAS/Data Monitoring
- **Existing:** 8kW solar array **Proposed:** 8+ kW solar array

Project Highlights

1. **Architecture**: New architectural elements will be added to help settle the building in its permanent site and improve occupant comfort. These will include more intricate landscaping design, an emphasized entryway marked by a vestibule, accessible site pathing, and updated interior finishes and appliances.

2. **Engineering**: Based on analysis of past performance of the building systems, we have taken steps to optimize performance. Mineral wool will be added in the basement, and caulking will be used at key locations to improve air tightness. An ERV will be added to comply with campus regulations for a building used as an educational space rather than the intended use as a home.

3. **Market Analysis**: The team is working with the Sustainability Institute on a two-tiered budget approach to ensure cost effective energy retrofit strategies in alignment with the building's goal as an outreach tool, while also exploring long-term investments to enhance and maintain the beauty and appeal of this resource.

4. **Durability and Resilience**: The site features (e.g. plants, trees, swales, etc.) will help mitigate intense stormwater common for our climate zone. A backup energy system will be in place in the event that the solar panels are out of operation due to intense storms or snow. Thermal, air, and moisture control barriers were added selectively to improve building envelope performance.

5. **Embodied Environmental Impact**: The embodied impact of the existing home was analyzed and then compared to the alternatives of new construction or retrofit. The resulting life cycle analysis supported our choice to conduct a retrofit. Materials replaced or gotten rid of in the retrofit will be kept on site as sculptures and site features, or as educational materials in the basement museum.

6. **Integrated Performance**: Changes to architectural features and systems will be done in conjunction to ensure optimum features with new features. For example, the new PV array will provide a larger output than the previous array to accommodate the new use of the basement as a historical teaching space.

7. **Occupant Experience**: The new design features will focus on making the space more livable, such as a canopy at the front entrance, and gardens throughout the site. Interior features will be updated and refined to be more pleasant and more easily operable.

8. **Comfort and Environmental Quality**: The envelope will be sealed to improve air tightness and quality of construction that may have been lacking in the initial student project or deteriorated over time. Based on our blower door test, the existing air tightness is around 13 ACH50, and we are aiming for 3 ACH50 given results of the test.

9. **Energy Performance**: Energy models, thermal imaging, and PV calculations are being used to determine the existing conditions of the home and analyze the reduction of energy load with each design choice. Strategies include improving air sealing, providing an updated PV array, updating major appliances, and upgrading to a heat pump water heater.