RETROCOMMISSIONING A SMALL COMMERCIAL BUILDING TO ACHIEVE NET-ZERO ENERGY

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ABSTRACT

The Bayer EcoCommercial Buildings Conference Center (ECB CC) located in Pittsburgh, PA, formerly the Penn State 2009 Solar Decathlon home (*Natural Fusion*), has undergone an extensive retro-commissioning process to achieve net-zero energy performance. This work has been focused on adapting the building to its current location and use schedule through active control strategies, while remediating issues such as infiltration derived from moving the building several times. A comprehensive energy simulation has been developed in the Transient System Simulation tool (TRNSYS) that incorporates all of the building's energy systems in their current configuration. Innovative systems and features of the building include photovoltaics, solar hot water, phase change materials, ductless mini-split heatpumps, floor radiators, and high levels of insulation in the walls and ceiling. Extensive data has been collected on the building over a year cycle including weather, energy consumption, and envelope performance and has been used to benchmark the model over the past year, followed by TMY data forecasting ongoing net-zero energy performance for the future. The modeling results show the largest areas of impact on the energy budget. Recommendations are made regarding the critical issues to focus on when undertaking a retrocommissioning projects targeting the goal of net-zero energy.

Fig. 1: Photo of the Bayer MaterialScience EcoCommercial Building Conference Center.[1]

1. INTRODUCTION

The U.S. Department of Energy (DOE) and the National Renewable Energy Lab (NREL) have hosted five Solar Decathlon competitions since 2002. Each decathlon is an international competition to design, build, and operate a solar powered home. Following the 2009 Solar Decathlon competition, the Penn State entry was acquired by Bayer MaterialScience to become the first North American showcase for the EcoCommercial Building program.[1] On May 26, 2010, following the construction and set-up of the building after moving it from the competition location in Washington D.C., the EcoCommercial Building

Conference Center (ECBCC) was officially unveiled at the Bayer MaterialScience headquarters in Pittsburgh.

With all of the complexities involved in renovating a building for something other than its intended use, moving a building several times, and dealing with unique systems designed by students that are both prototypes and intended to push the boundaries of engineering, it should be apparent that significant retrocommissioning was necessary to target the goal of a net-zero energy building.

2. RETROCOMMISSIONING

Retrocommissioning is the first step to assess what energy systems are doing compared with what they should be doing, and step by step guides have been laid out by groups including the EnergyStar program.[2] Through this process, HVAC controllers are checked for the best schedules and setpoints, the building is tested for infiltration and appropriate insulation, and energy generation systems are evaluated for performance. The end goal of the work performed here is a net-zero energy building.

2.1 HVAC Controls

As designed, the building had two ductless mini-splits that were to be operated solely by a remote. The systems did not have scheduled programmable capabilities. This style of operation is acceptable for an occupant-controlled residential building, however potential energy savings were lost with the building as a commercial conference center. New thermostats were installed and programmed to utilize a night time and weekend set-back schedule, realizing significant energy savings.

2.2 Building Envelope

Figure 2 shows IR thermography that was used to identify locations for additional air sealing. These included areas around door and window frames. Figure 3 shows a blower door test device that was empoyed to identify additional areas to target. The blower door test revealed a significant amount of leakage through the building envelope with an ACH/50 rating of 11.74. A large portion of this leakage was found to be around the frames of the movable southern door system, highlighting the need for these types of door systems to be precisely installed. Figure 4 shows smoke testing that revealed a number of previously unknown leakage areas, including seals around the skylight frames and low voltage wiring boxes.

Fig. 2: Thermal imaging of the outside of the building, showing heat loss through door and window frames.

Fig. 3: Photo of the blower door test device installed in a doorway.

Fig. 4: Photo of smoke testing revealing infiltration.

2.3 On-site Energy Conversion

After the initial 6 months of operation, it was identified that the PV system was performing at less than 50% its rated capacity, rendering the buildings net-zero energy goal out of reach. Efforts to identify the cause of this revealed that half of the panels on the main array had an open circuit, and that one third of the panels on the secondary array were not correctly wired into the junction box. This was a symptom of the removal of the PV system for the building's transportation. After the move, the system was not reconnected carefully with attention to detail.

3. MODELING

A whole building energy model was developed using the Transient System Simulation tool (TRNSYS).[3] Figure 5 shows the simplified building in Trimble Sketchup, designed using the TRNSYS3D plugin that is based on OpenStudio. For the purpose of using the detailed radiation mode in TRNBuild, the building was split into 24 convex zones. The interior surfaces seen through the windows in Figure 5 are mostly virtual surfaces, as the building consists of two primary zones, each with a ductless mini-split heat pump system for climate control.

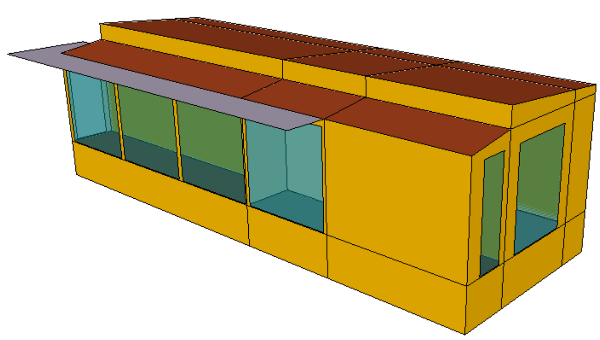

Fig. 5: Screenshot of the building for energy modeling.

To model the glycerin-based phase change material housed within most of the exterior walls, the energy model includes a place-holder material with a high thermal capacitance that behaves in a similar manner, storing thermal energy. At the time of model development, a model for this phase change material was not readily available. Further, the floor in most of the building contains water storage for thermal mass just beneath the floor, in between the joists. This was modeled in a similar manner.

Infiltration rates were applied to the building in accordance with the blower door test results. Ventilation was applied with an air-to-air energy recovery ventilation unit that was readily available within TRNSYS. Heat exchange rates were applied per manufacturer's specifications. The windows were modeled as double pane argon-filled windows with a low solar heat gain coefficient, matching those on the building. The photovoltaic arrays on the two roofs as well as the awning were lumped as one horizontal array and performance was benchmarked against real energy conversion data. In reality, the two main arrays consist of Solyndra panels and have different properties based on the underlying roofs and slight differences in tilt while the small awning array tracks on one axis from east to west. The modeled approximation was very close to the actual production over the whole year.

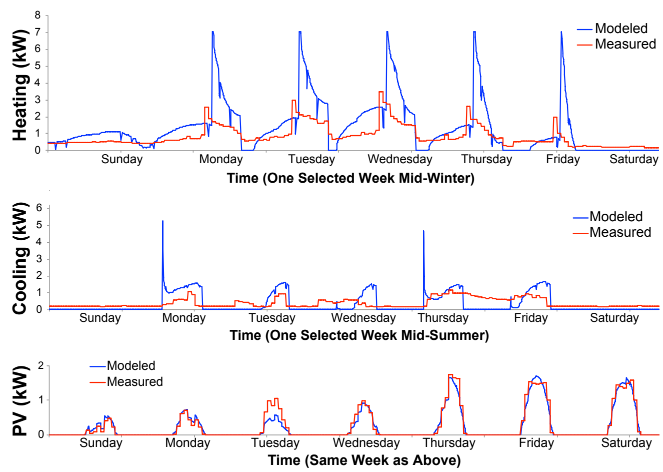

Fig. 6: Top: A typical heating week. Middle: A typical cooling week. Bottom: A typical week of PV generation.

Figure 6 shows a typical week in heating mode, followed by a typical cooling week. Examining the load profiles for the building shows a lack of base load in the evenings and higher spikes at the beginning and throughout the day. Future work will focus on a closer match of the model to the measured data. There are times throughout the year when unpredictable energy use occurred. These incidences are taken into account by focusing on the annual net use and bench-marking against the total energy consumed. The bottom graph in Figure 6 shows a very close match to the PV generation curve profiles.

For a period of one year, from June 3, 2011 to June 2, 2012, the building model was compared against measured energy use data. During this time, the building used 4348 kWh while the bench-marked model showed consumption of 4413 kWh. This is a prediction of 1.5% more energy consumption than reality. The PV

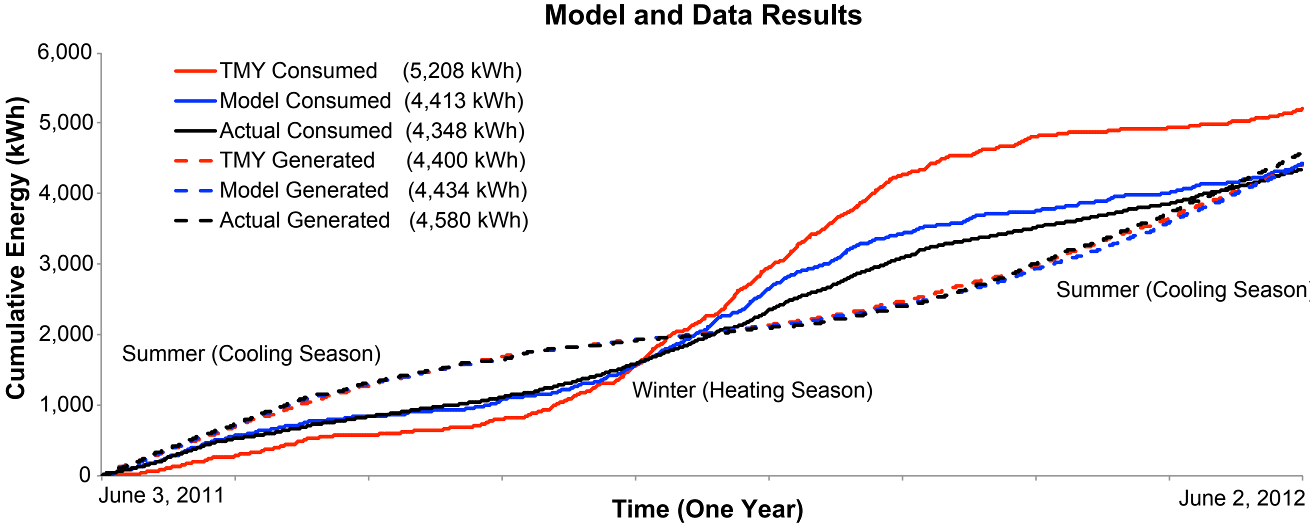

Fig. 7: Cumulative energy use and generation for one year.

generation systems produced 4580 kWh while the model predicted production of 4434 kWh. This is a prediction of 3.2% less than reality. The result is a slightly conservative model that over predicts energy use while under predicting energy production. During this period, the building achieves a net-zero energy balance. However, the 2011 to 2012 winter in Pittsburgh was abnormally temperate, and the net-zero, or net-positive, margin is very slim with the conservative model.

Figure 7 shows the cumulative energy path from June 3 to June 2 for both generation and consumption for the measured data (2011-2012), bench-marked model, and finally the TMY model. Running the bench-marked model with a typical meteorological year data file for Pittsburgh, PA, the building and its users are estimated to use 5208 kWh per year while the PV system produces 4400 kWh per year. This is a net-energy deficit of 808 kWh per year, or 15.5% less energy than is needed to achieve net-zero energy status. Currently, the building is still undergoing various retrocommissioning improvements including measures against infiltration and window/door frame energy loss. Continuing to reduce the energy consumed positions this building well for achieving net-zero.

As a final recommendation, if the building energy reduction process does not lower total energy use below the PV system production in its current configuration, a few additional PV panels or a reconfigured array with higher efficiency panels should meet the necessary requirements. The current PV array is horizontally mounted. A slight tilt to the south would boost annual production, potentially enough to meet demand.

4. ACKNOWLEDGMENTS

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Bayer MaterialScience, LLC.

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