Pinoleville Pomo Nation Sustainable Home:

A case study of energy modeling on sustainable design

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Abstract

The purpose of this research was to investigate the feasibility of energy modeling in order to determine the performance of a prototype sustainable home. EnergyPlus energy modeling simulation software was used to evaluate an energy model and its temperature data for various thermal zones within the model. The temperature data was compared to real data acquired from the actual prototype home. Results indicate that the energy model is much more insulated in comparison to the prototype model. Improved input parameter accuracy should provide for more accurate energy model results. Future added design choices and improvements to the home may be added to the energy model in order to access the home's potential performance.

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Introduction

Recently, there is considerable interest in the fields of sustainable design and environmental consciousness.

The Community Assessment of Renewable Energy & Sustainability (CARES), the Departments of Mechanical Engineering and Architecture at the University of California, Berkeley (UCB), and the Pinoleville Pomo Nation (PPN) have collaborated to co-design a sustainable prototype home which incorporates traditional Pomo Nation values with regards to natural materials and integrated renewable energy systems such as geothermal heat pumps (GHP), photovoltaic (PV) cells, rainwater catchment and grey-water systems.

Because the prototype home was novel in terms of building practices, building materials, and energy systems, it is important to be able to determine a baseline for the home's energy performance.

The purpose of this project is to develop a performance baseline through the use of energy modeling. The energy model will then be evaluated to determine if it is a good indicator of real experimental results. If deemed sufficient, the energy model will allow designers to suggest future design improvements and evaluate the performance changes due to those improvements. Furthermore, a robust energy model can allow designers to perform future predictive modeling on the home's performance.

Experimental Methods

An energy model will be developed using available and robust software in order to develop a performance baseline. The energy model will provide hourly and daily temperature data for various thermal zones in the modeled prototype home for a specified simulation period. This theoretical temperature data will then be compared to experimental temperature data acquired by measuring tools placed in the home during the specified simulation period.

EnergyPlus Energy Model

Software Selection

In order to build the energy model necessary to develop the performance baseline for the prototype home, a whole building simulation engine needed to be selected. *EnergyPlus* was selected because it has a large energy modeling community and features multiple capabilities such as heating, cooling, lighting, ventilation, and water use which make it a robust system to build a model upon for future use (EnergyPlus, 2014).

In order to generate the geometry used for the energy model calculations, *OpenStudio* was used in conjunction with *SketchUp*. SketchUp is a 3D modeling program owned by Trimble Navigation which allows users to quickly and easily generate model geometry (SketchUp, 2014). OpenStudio is a cross-platform, open source SketchUp plugin which allows users to run EnergyPlus simulations on complex models generated in the SketchUp modeling environment (OpenStudio, 2014).

Model Geometry

Once the software used for the energy modeling was selected, the prototype home was modeling in SketchUp.

The bidding documents for the construction of the home were provided by PPN for use in the geometric model (Associates, 2010). The documents detailed the prototype home's blueprints as well as all building materials and methods. However, there were alterations from the original bid to the home's current finished state.

Most notably, the home was extended to what was originally the garage, and the garage was converted into a fourth bedroom without major changes to its exterior construction. Furthermore, a bedroom was converted to the master bedroom, the old master bedroom was sized down to expand the kitchen, and the additional space from the home extension was used for a master bathroom addition to the bedroom. Additionally, the original intentional use of particular rooms were changed. Figure 1 provides the original floorplan of the PPN Gardens Site home and its current alterations. The space types modeled for use in the energy model were: bedroom 1, bedroom 2, bedroom 3, corridor, dining room, gathering center, guest bath, heater room, kitchen, master bath, master bedroom, mech room, and the roof.

For unknown dimensions, it is assumed to follow schematics similar to what is illustrated in Figure 1. These drawings are considered insignificantly different from the actual final prototype model and will be assumed to be suitable for the purposes of this investigation.

Figures 2-5 illustrate the prototype home in SketchUp from the cardinal directions.

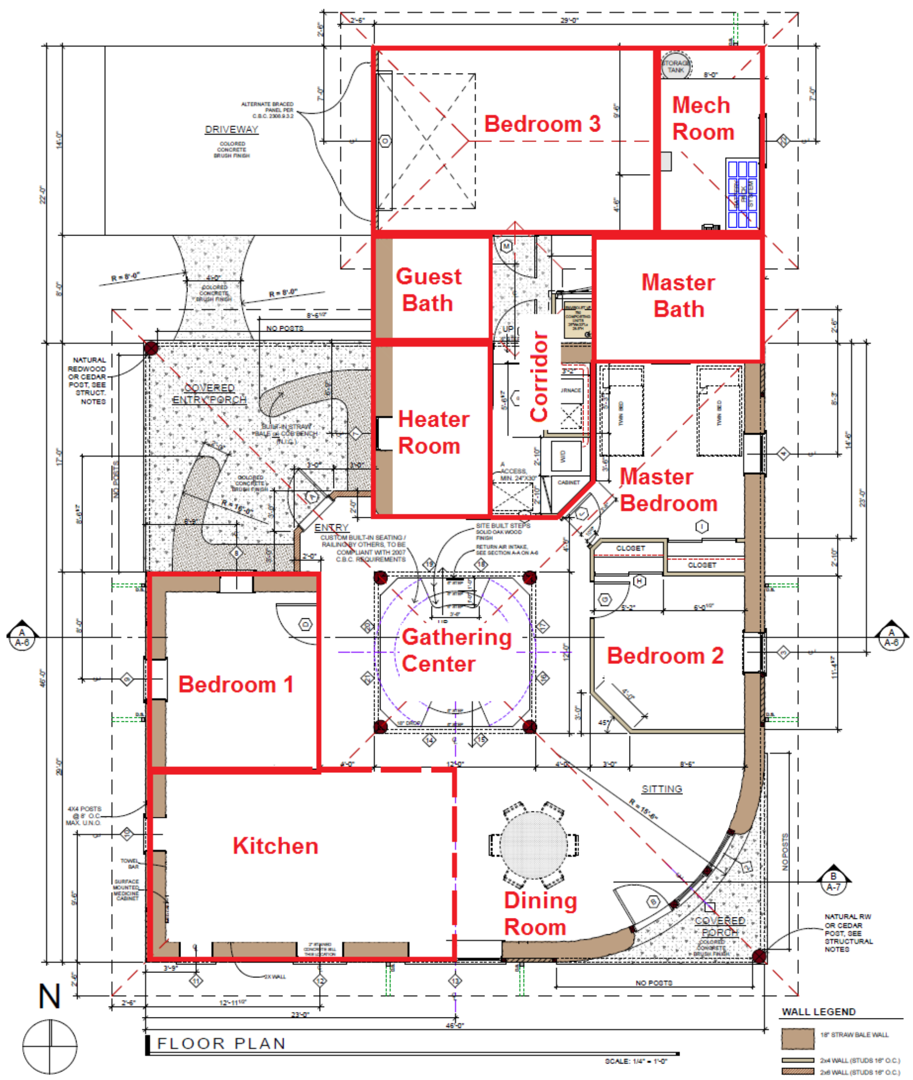

FIGURE 1: PPN PROTOTYPE HOME (GARDENS SITE) (ASSOCIATES, 2010)

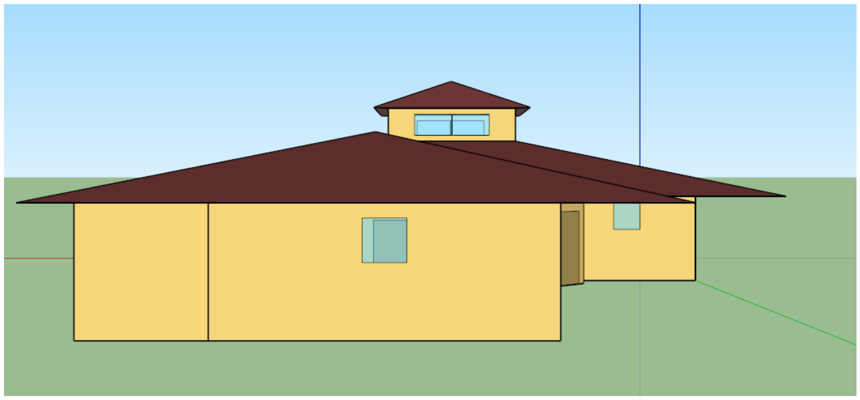

FIGURE 2: PPN PROTOTYPE HOME (NORTH FACE)

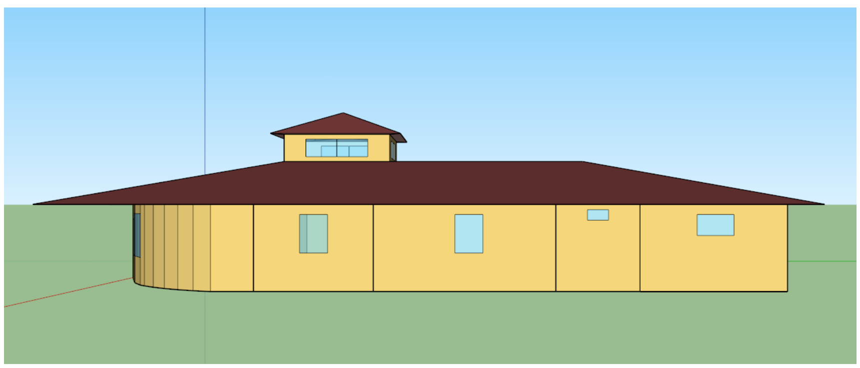

FIGURE 3: PPN PROTOTYPE HOME (EAST FACE)

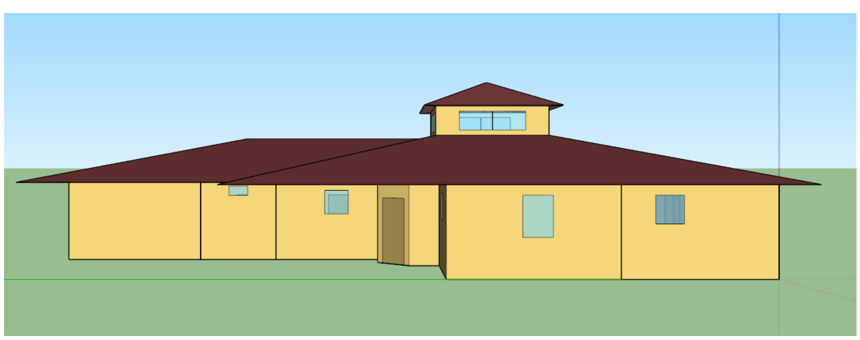

FIGURE 4: PPN PROTOTYPE HOME (WEST FACE)

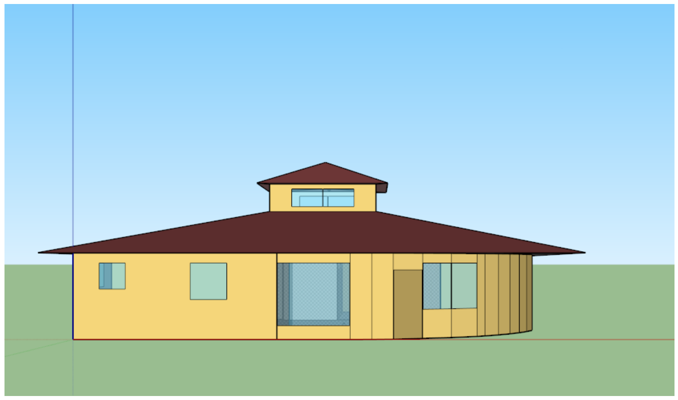

FIGURE 5: PPN PROTOTYPE HOME (SOUTH FACE)

Constructions

Once the geometric model was completed in SketchUp, construction sets and constructions were built for each space type. Constructions are combinations of materials in a specific layering order to build a specific structure. Construction sets are a list of typical constructions used for similar space types.

Additionally, some space types utilized multiple constructions for the same surface types (i.e. both standard interior wall construction as well as air walls for interior wall surface designations).

While the documentation provided allowed for a general overview of the constructions required, there were many equivalencies not listed in the blueprints. For these constructions, it is assumed that the simplification of the construction (use of industry standards, uniform layering, etc,) is sufficient for the purposes of this investigation.

The standard construction layers and space type alternate construction usage are listed in Tables 1 and 2 respectively. Detailed construction data, including materials, layer thicknesses, thermal conductivity, density, and specific heats are included in the appendix.

TABLE 1: STANDARD CONSTRUCTION SET LAYERS

Construction		Layers					
Air Wall	OUTSIDE	Air					INSIDE
ASHRAE 189.1-2009 Ext Window CZ 3		Theoretical Glass [202]					
PPN Concrete Floor		6” Vermiculite Aggregate	1.5” Rigid EPS Insulation	2” Concrete Block	0.5” #4 Rebar	2” Concrete Block	
PPN Exterior Door		F08 Metal Surface	I01 25mm Insulation Board				
PPN Exterior Roof		Metal Roofing	Roof Insulation [18]	2x6 Douglas Fir Wood			
PPN Exterior Wall		1.5” Concrete Plaster	18” Straw Bale	1” Gypsum Plaster			
PPN Interior Ceiling		0.625” Gypsum Board	R-42 Wall Insulation				
PPN Interior Door		G05 23mm Wood					
PPN Interior Wall		0.5” Gypsum Board	R-12 Wall Insulation	0.5” Douglas Fir Plywood	0.5” Gypsum Board		

TABLE 2: SPACE TYPE ALTERNATE CONSTRUCTION USAGE

Space Type	Additional/Alternate Construction (Usage)
Bedroom 3	Alt: PPN Interior Wall (Exterior Wall)
Corridor	Add: Air Wall (Interior Wall)
Dining Room	Add: Air Wall (Interior Wall)
Gathering Center	Add: Air Wall (Interior Wall)
Kitchen	Add: Air Wall (Interior Wall)
Mech Room	Alt: PPN Interior Wall (Exterior Wall)
Roof	Alt: Air Wall (Floors)

Thermal Zones

In OpenStudio, thermal zones are regions which EnergyPlus can perform calculations and determine outputs for. Thermal zones can be a single space type or can contain multiple space types. For the purpose of this experiment, each space type will represent its own thermal zone.

Weather Data & Design Days

EnergyPlus allows the use of weather files and design days to import historical weather data for use in the energy simulation. Energy data was taken from the US department of Energy for the Ukiah region (Ukiah Weather and Design Day Data, n.d.). The most recent weather data is from 2005, and will be assumed to give sufficient predictive data for the intended simulation period.

Schedules

EnergyPlus allows the use of schedules in order to dictate when people are using the building and when specific energy systems are in use. Currently, the building construction is complete and there is little to no personnel working in the building. Additionally, there are no occupants living in the building as the Pinoleville Pomo Nation is still processing applications for residency. This led to the assumption that the HVAC was not in operation for occupant comfort (to save on energy expenditure). Furthermore, at the time of the simulation period, the geothermal heat pumps were not operating and the PV cells were not installed.

Because of these conditions, it was assumed that the schedule would operate as if there were no occupants, and no external energy inputs.

Air Loads

EnergyPlus allows the modeling of air leakage and various ventilation and circulation schemes. For the purpose of this investigation, ideal air loads were assumed in all thermal zones.

Simulation Period

The EnergyPlus energy model was selected to run from October 24, 2014 to November 5, 2014 (runs up to, but does not include midnight November 6, 2014).

Data Analysis

Thermal zone air temperature was selected for hourly and daily recording and calculation in the OpenStudio plugin. OpenStudio's native 'ResultsViewer' was used to view and save the auto-generated thermal zone air temperature vs simulation time plots for all thermal zones.

Experimental Temperature Data

The data acquisition tool used to measure air temperature for various thermal zones in the prototype home were 'HOBO Pro RH/Ext. Temp' sensors/data loggers. These sensors have a temperature range from -22°F to 122°F with an accuracy of +/- 0.33°F at 70°F (Tool Library, n.d.).

Sensor Locations

The sensors were placed in bedroom 3, the dining room, the gathering center, and the master bedroom as shown in Figure 6.

These particular locations were of interest for their unique properties. Bedroom 3 was converted from a garage is to use a different wall construction than the rest of the home. The dining room is the edge-most thermal zone with significant window space. The gathering center is in the center of the home and is under a high ceiling with windows. Finally, the master bedroom is the largest of the future-occupied rooms.

Data Acquisition Period

The data acquisition sensors were placed in the home to collect data from about noon October 24, 2014 to mid-day November 7, 2014. However, the sensors were unintentionally moved and relocated on November 6, 2014. Therefore, only experimental data up until midnight November 6 was used for this investigation.

Data Analysis

The sensor data can be extracted using its own native “Boxcar Software” which provides the raw data in csv file format. Because the OpenStudio temperature results can only be displayed in Celsius, the data from the HOBO sensors were converted to Celsius as well for plot uniformity.

The sensors were set to sample at a rate of once every 5 minutes. Temperature vs data acquisition period were plot for all thermal zones with HOBO sensors for the 5 min sample rate as well as for daily averages.

Finally, as a reference, the high, low, and average temperatures in Celsius for Ukiah during the simulation period are listed in Table 3 (Ukiah Weather History (10/24-11/6), n.d.)

TABLE 3: UKIAH TEMPERATURE DATA (10/24-11/6)

Date	Low Temperature (C°)	Average Temperature (C°)	High Temperature (C°)
10/24	10.00	13.33	20.00
10/25	8.89	12.22	14.44
10/26	4.44	10.00	16.11
10/27	2.22	9.44	18.33
10/28	3.33	11.11	21.67
10/29	6.67	13.89	26.11
10/30	8.33	13.89	21.67
10/31	8.89	12.22	16.67
11/1	3.33	9.44	15.56
11/2	1.11	13.89	17.78
11/3	3.33	9.44	18.33
11/4	3.33	11.11	21.67
11/5	5.00	12.78	23.33
11/6	6.67	12.78	21.67

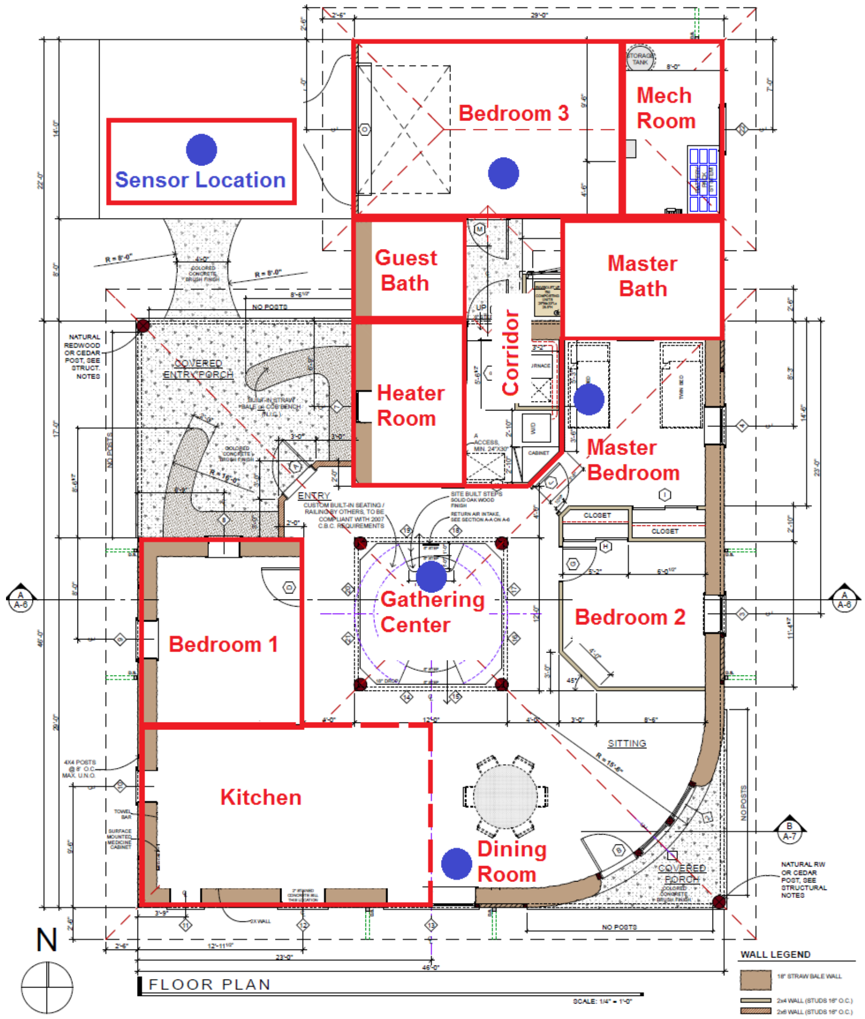

FIGURE 6: HOBO SENSOR LOCATIONS

Results

EnergyPlus Energy Model

Hourly Thermal Zone Temperature

Hourly temperatures for the prototype home's EnergyPlus model were recorded for all the modeled thermal zones. Hourly Temperature in Celsius vs Simulation time for bedroom 3, the dining room, the gathering center, and the master bathroom are illustrated in Figures 7-10 respectively. Additional hourly thermal zone temperature for the energy plus model is located in the appendix.

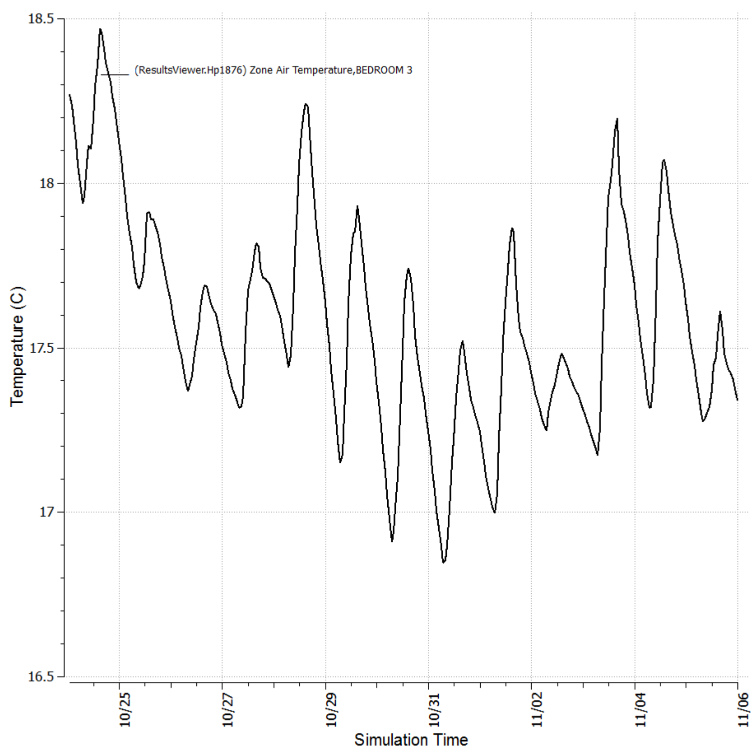

FIGURE 7: HOURLY THERMAL ZONE TEMPERATURE (BEDROOM 3)

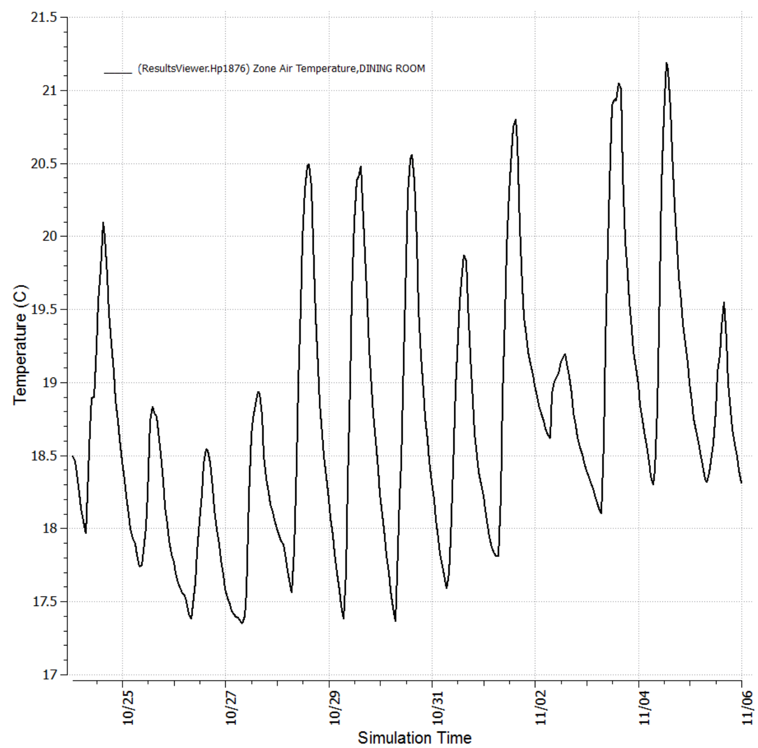

FIGURE 8: HOURLY THERMAL ZONE TEMPERATURE (DINING ROOM)

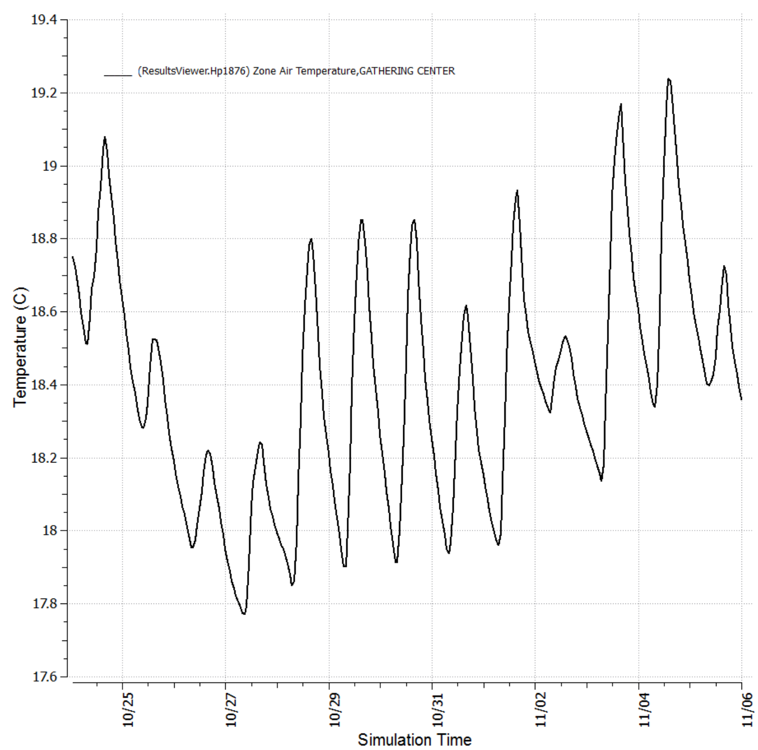

FIGURE 9: HOURLY THERMAL ZONE TEMPERATURE (GATHERING CENTER)

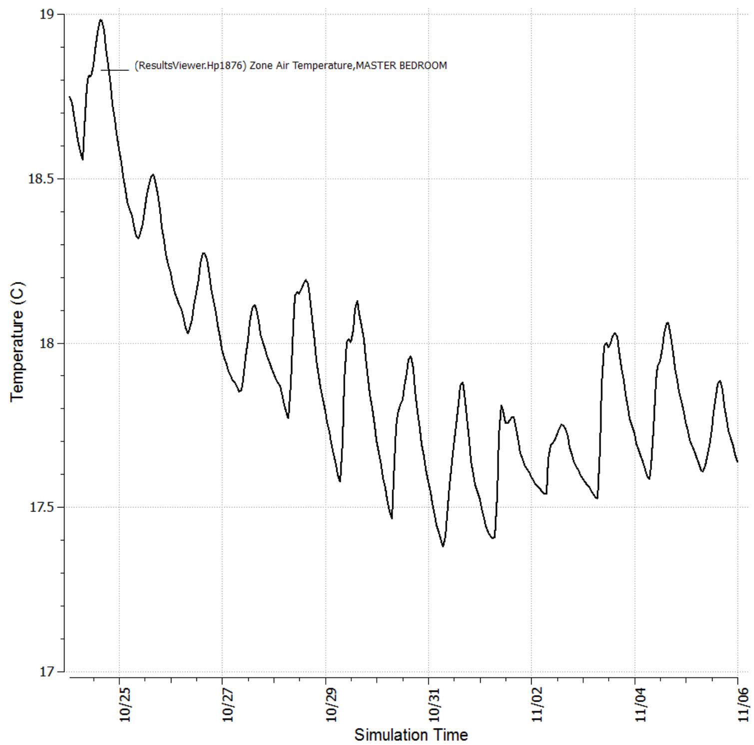

FIGURE 10: HOURLY THERMAL ZONE TEMPERATURE (MASTER BEDROOM)

Daily Thermal Zone Temperature

Daily temperatures for the prototype home's EnergyPlus model were recorded for all the modeled thermal zones. Daily Temperature in Celsius vs Simulation time for bedroom 3, the dining room, the gathering center, and the master bathroom are illustrated in Figures 11-14 respectively. Additional daily thermal zone temperature for the energy plus model is located in the appendix.

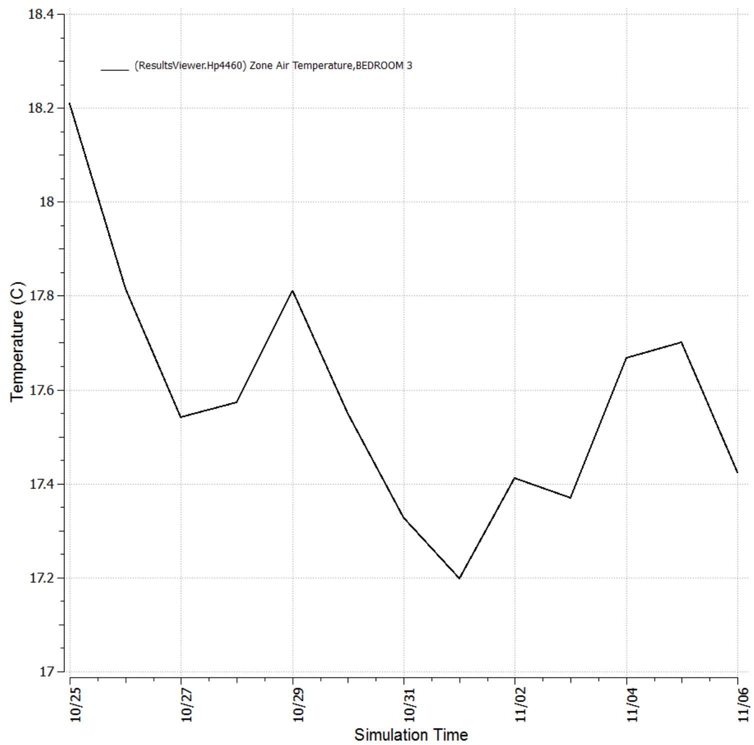

FIGURE 11: DAILY THERMAL ZONE TEMPERATURE (BEDROOM 3)

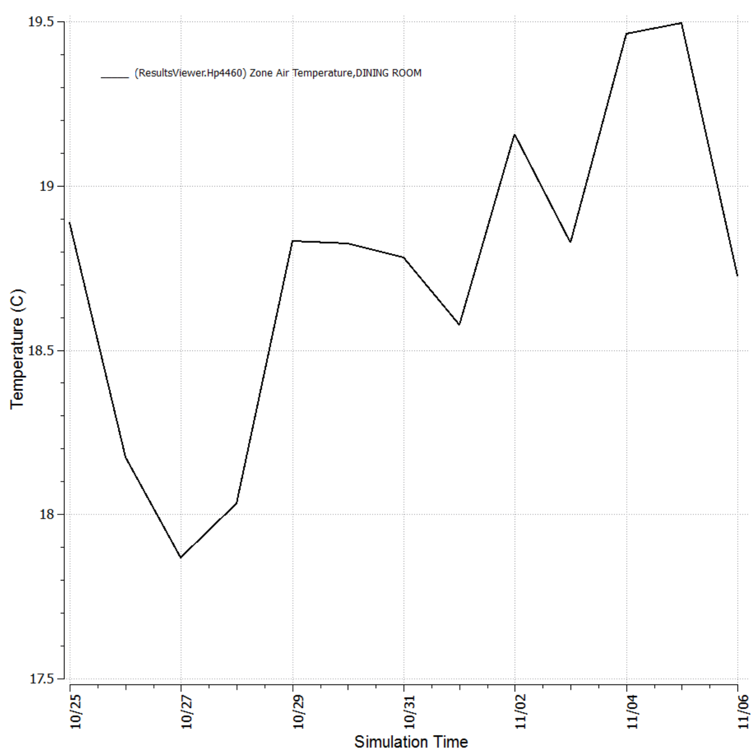

FIGURE 12: DAILY THERMAL ZONE TEMPERATURE (DINING ROOM)

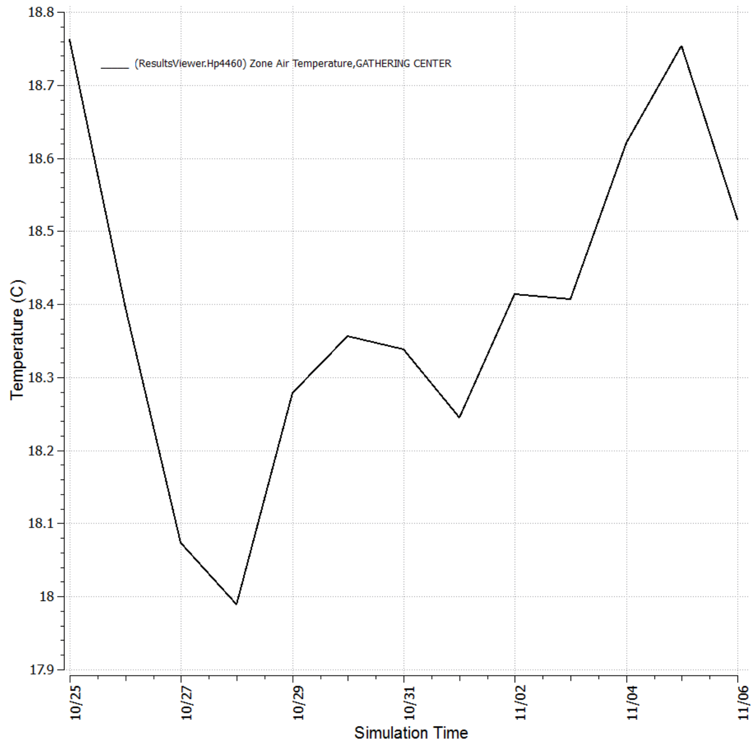

FIGURE 13: DAILY THERMAL ZONE TEMPERATURE (GATHERING CENTER)

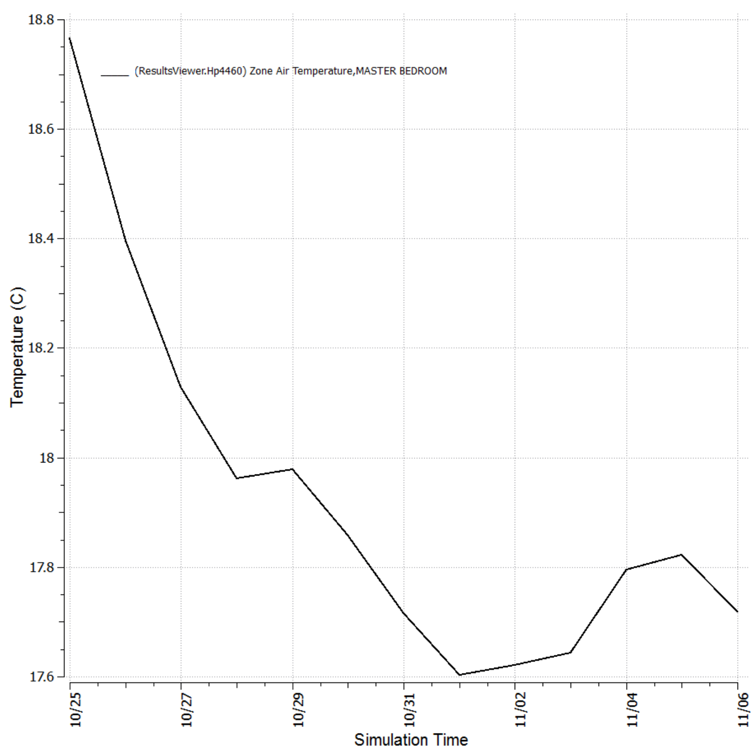

FIGURE 14: DAILY THERMAL ZONE TEMPERATURE (MASTER BEDROOM)

Experimental Temperature Data

5 min Interval Temperature

Temperatures for the prototype home were recorded by HOBO sensors in 5 minute intervals for the simulation period. Temperature in 5 min intervals vs data acquisition period for bedroom 3, dining room, gathering center, and master bedroom are illustrated in Figures 15-18 respectively.

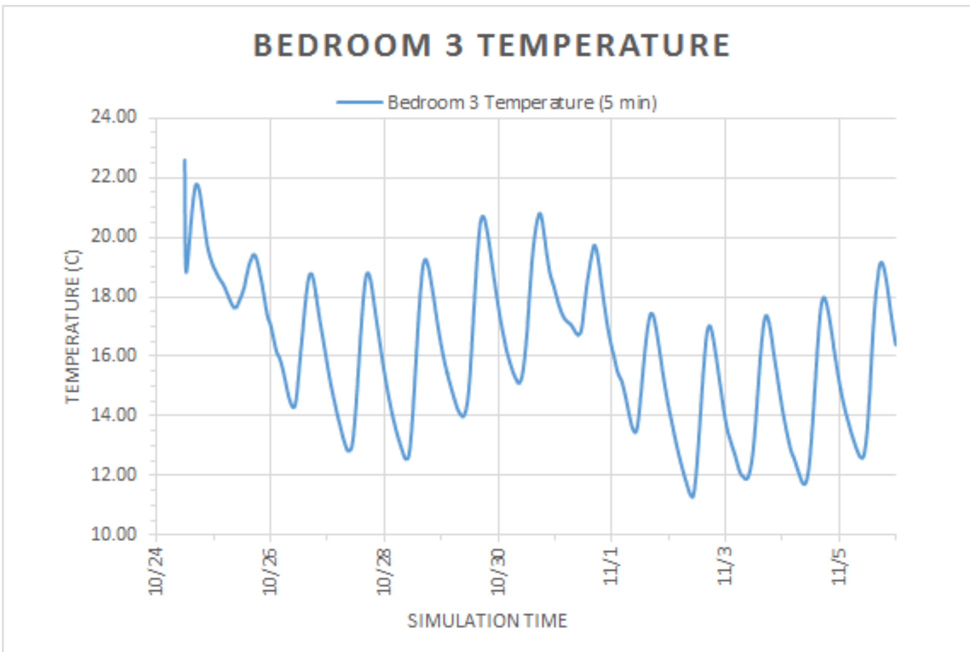

FIGURE 15: BEDROOM 3 TEMPERASURE (5 MIN)

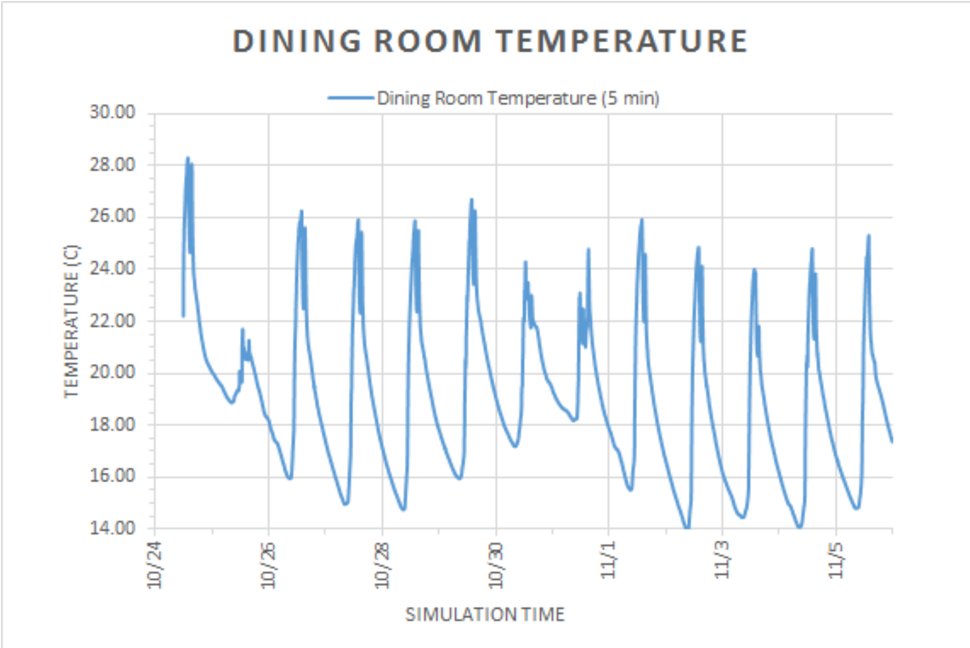

FIGURE 16: DINING ROOM TEMPERASURE (5 MIN)

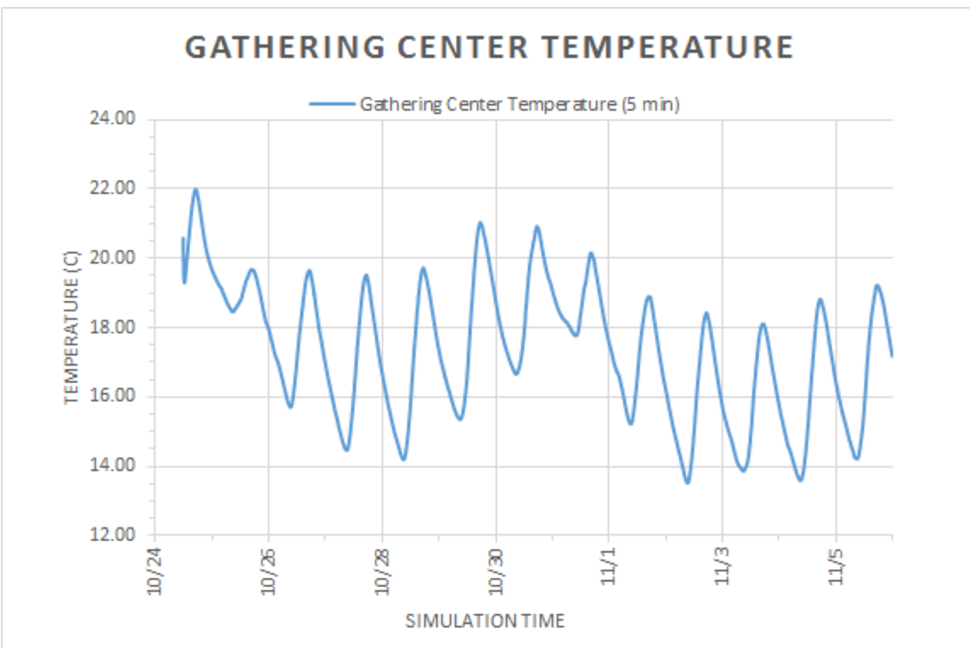

FIGURE 17: GATHERING CENTER TEMPERASURE (5 MIN)

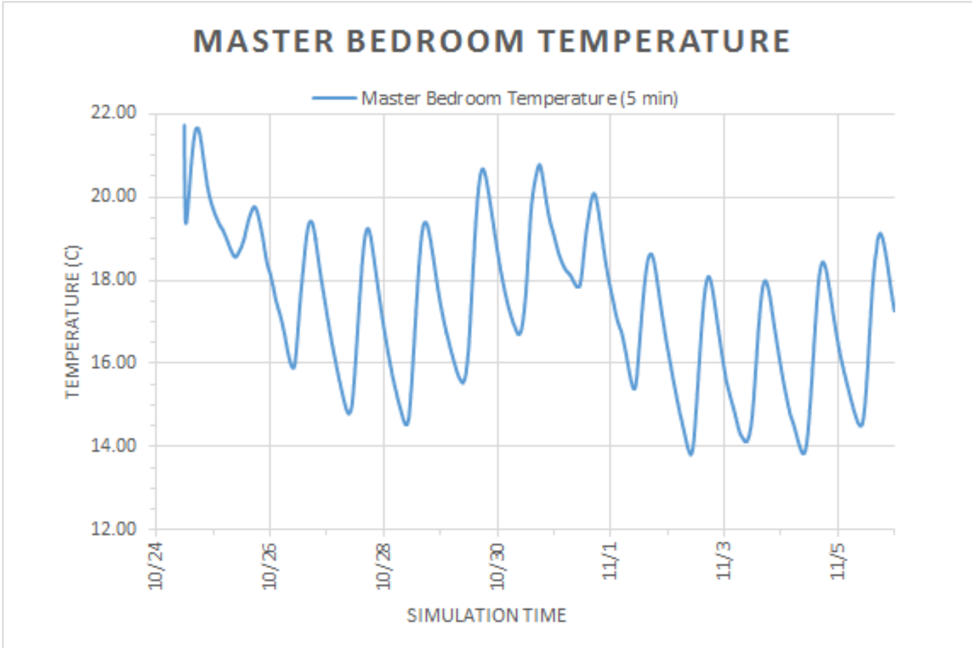

FIGURE 18: MASTER BEDROOM TEMPERASURE (5 MIN)

Daily Temperature

Temperatures for the prototype home were recorded by HOBO sensors in 5 minute intervals for the simulation period and then averaged daily. Daily Temperature vs data acquisition period for bedroom 3, master bedroom, gathering center, and dining room are illustrated in Figures 19-22 respectively.

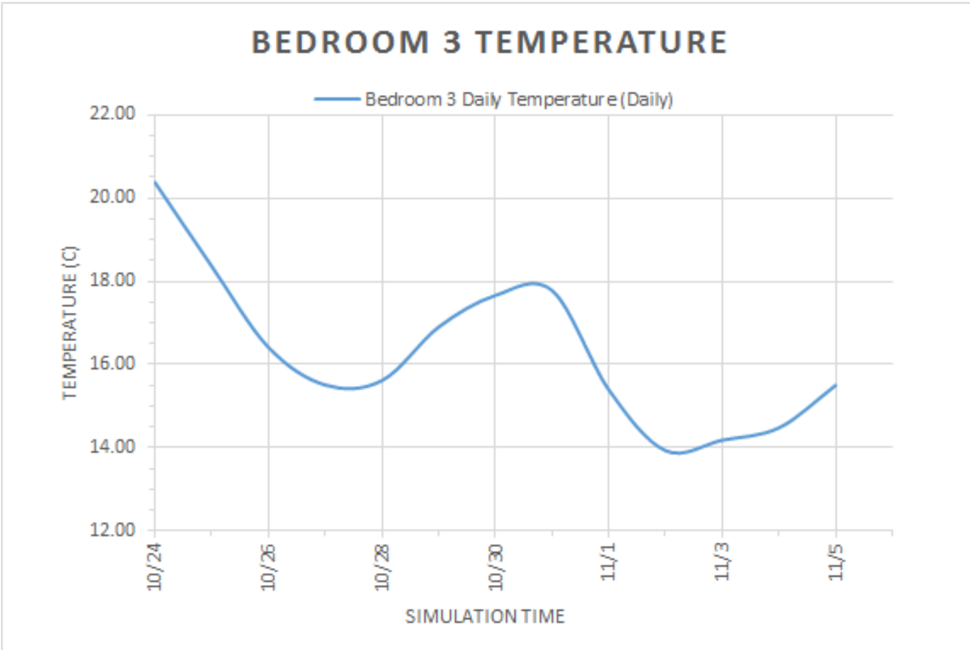

FIGURE 19: BEDROOM 3 TEMPERASURE (DAILY)

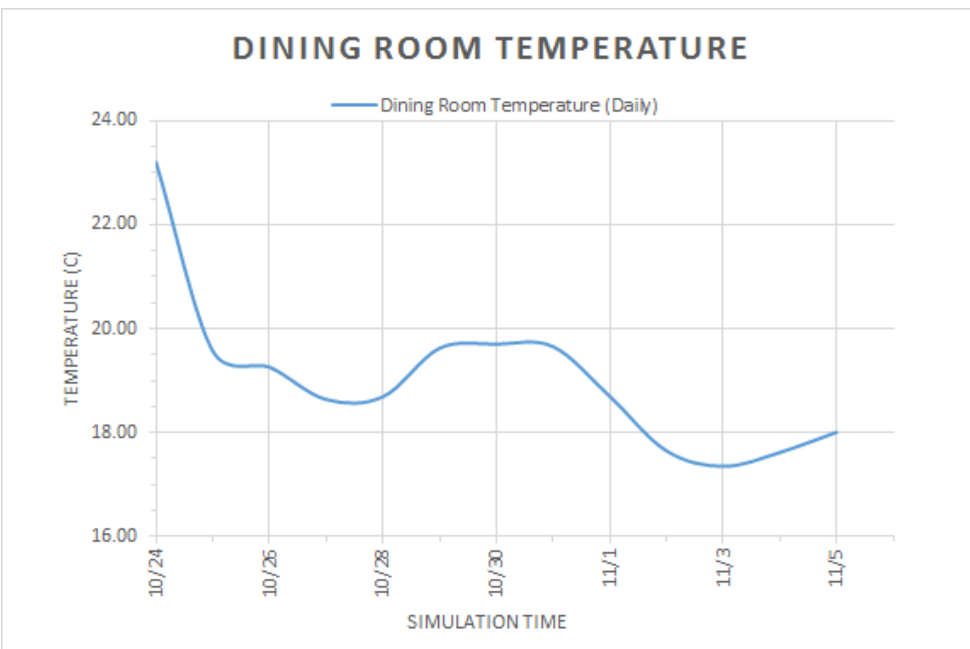

FIGURE 20: DINING ROOM TEMPERASURE (DAILY)

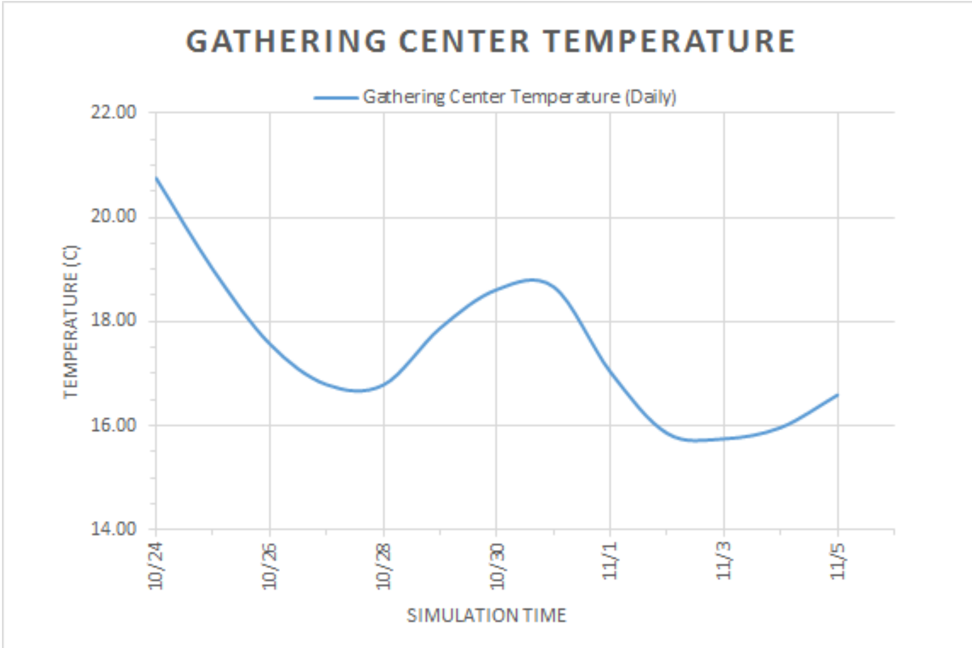

FIGURE 21: GATHERING CENTER TEMPERASURE (DAILY)

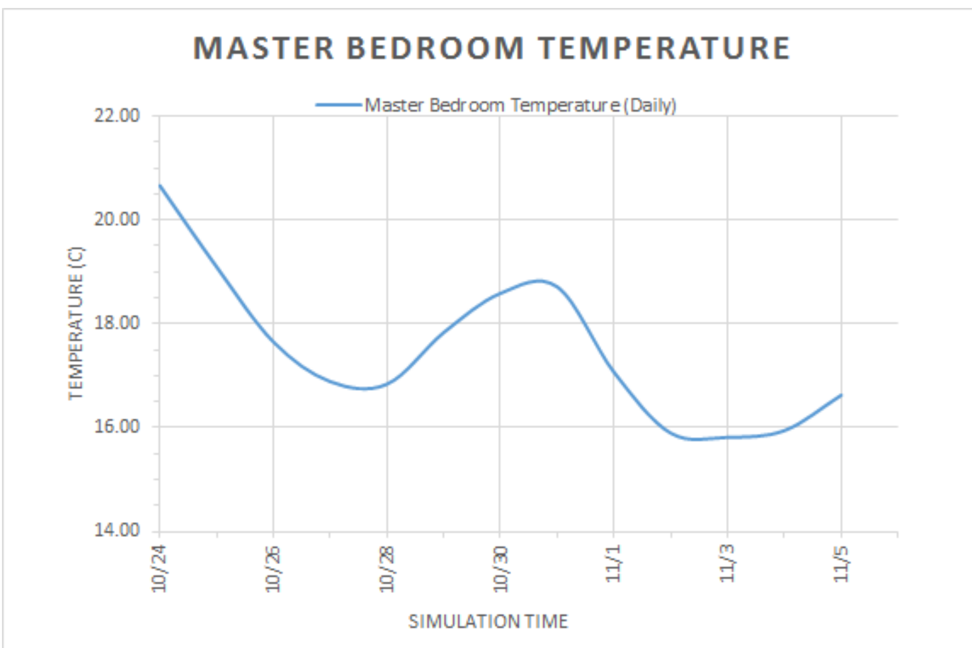

FIGURE 22: MASTER BEDROOM TEMPERASURE (DAILY)

Discussion

The hourly temperature data from the EnergyPlus Model and the 5 min interval temperature data from the experimental temperature data were compared for the following four (4) thermal zones: bedroom 3, dining room, gathering room, and master bedroom. Findings are summarized as follows

Bedroom 3

The daily average temperature data for the energy model predicts a small decrease in temperature for bedroom 3 (~0.6°C) followed by a small increase (~0.2°C), another small decrease (~0.6°C) and finally a small increase (~0.6°C). The multiple daily fluctuations can probably be attributed to the fact that the thermal zone for bedroom 3 uses the interior wall construction which is less insulating than the standard exterior wall construction.

The daily average temperature data of bedroom 3 for the experimental data initially shows a moderate decrease (~5.5 °C), followed by a moderate increase (~3.5°C) and finally a moderate decrease (~4.0°C). The fluctuations (as shown later) are consistent throughout the model and can probably be attributed to the outdoor ambient temperature during the data acquisition period. The temperature for the data acquisition period is listed in Table 3.

The energy model predicts an extremely small daily fluctuation (approximately 0.75 °C) where the experimental data shows a much larger daily fluctuation (5°C). The trend that the energy model is much more conservative in modeling fluctuations are consistent throughout the investigation (as shown later).

Dining Room

The daily average temperature data for the energy model predicts a small decrease in temperature (~1.0°C) for the dining room followed by a small increase (with small fluctuations) over the remainder of the simulation period (~1.7°C)

The daily average temperature data of the dining room for the experimental data follows a moderate decrease in temperature at first (~4.0°C), followed by a small increase (~1.0°C), and ending with a small decrease (~1.5°C). Again, this is consistent with the outdoor ambient temperature during the data acquisition period.

The energy model predicts a moderate daily fluctuation (approximately 3.0 °C) where the experimental data shows a much larger daily fluctuation (11°C). The dining room has the largest daily fluctuation of all the compared thermal zone (for both the energy model and the experimental data). This large fluctuation is probably attributed to the proximity to multiple fenestrations which could allow for outdoor air infiltration, as well as large window area providing significant light fluctuations throughout the day. Again, the trend that the energy model is much more conservative in modeling fluctuations are consistent throughout the investigation.

Gathering Center

The daily average temperature data for the energy model predicts small decrease in temperature (~0.75°C) for the gathering center followed by a small increase over the remainder of the simulation period (~0.75°C) (with minor fluctuations in between).

The daily average temperature data of the gathering center for the experimental data starts with a moderate decrease (~4.0°C), followed by a moderate increase (~2.0°C), and ending with a moderate decrease (~3.0°C). Again, this is consistent with the outdoor ambient temperature during the data acquisition period.

The energy model predicts a small daily fluctuation (approximately 0.75 °C) where the experimental data shows a larger daily fluctuation (5°C). This fluctuation is probably attributed to the window area directly above the gathering center which provides significant amounts of light during the day. Unlike the dining room though, this area is not as close to fenestration and the effects of outdoor air infiltration are lessened. Additionally, the trend that the energy model is much more conservative in modeling fluctuations are consistent throughout the investigation.

Master Bedroom

The daily average temperature data for the energy model predicts small decrease in temperature for the master bedroom (1.2°C) and generally remains there for the remainder of the simulation period. The consistency of this master bedroom is due to the fact that is it not near any exterior fenestrations (aside from its own windows) and does not receive the same sort of light some of the other thermal zones due. Finally, this room is insulated from the outside boundary with the PPN external wall which includes straw bale insulation.

The daily average temperature data of the master bedroom for the experimental data shows a moderate decrease (4°C), followed by a small increase (2°C), and followed again by another small decrease (3°C) for the remainder of the data acquisition period. Again, this trend is due to the outdoor ambient temperature during the data acquisition period.

The energy model predicts a small daily fluctuation (approximately 0.50 °C) where the experimental data shows a much larger daily fluctuation (4.5°C). This large fluctuation is probably attributed to the window area directly above the gathering center which provides significant amounts of light during the day. Additionally, the trend that the energy model is much more conservative in modeling fluctuations are consistent throughout the investigation.

Energy Model vs. Experimental Data

In general, the energy model insulates better than the actual prototype home. The energy model consistently has higher minimum temperatures, lower maximum temperatures, and much less daily fluctuation than the actual prototype home. Table 4 compares the approximate minimum temperatures, maximum temperatures, and typical daily fluctuations of the four compared thermal zones for both the energy model and the actual prototype home.

In general, temperature differences between the energy model and the prototype home can be attributed to differences in the construction simplification and equivalent material use, schedule assumptions, and weather data extrapolation.

The construction simplification and equivalent material use are probably the biggest factors in the insulation and fluctuation differences between the energy model and the actual prototype home.

The effects from the scheduling assumption are probably minimal, as there should not be significant occupation to significantly affect the predicted temperature data.

The weather data extrapolation is probably the largest overall contributor to the temperature difference between the energy model and the actual experimental data. The current weather file being utilized has data only up until 2005 and extrapolated from perceived trends. This extrapolation probably gave inaccurate outside ambient temperature which resulted in the overall temperature differences (specifically the short temperature spike seen in the middle of the data acquisition period).

TABLE 4: MINIMUM TEMP, MAXIMIMUM TEMP, AND TYPICAL DAILY TEMP FLUCTUATION

	Actual Prototype Home			Energy Model		
Thermal Zone	**Min Temp (C°)**	**Max Temp (C°)**	**Daily Fluctuation (C°)**	**Min Temp (C°)**	**Max Temp (C°)**	**Daily Fluctuation (C°)**
Bedroom 3	11.5	22.5	5.0	16.7	18.5	0.75
Dining Room	13.75	28	11.0	17.4	21.5	3.0
Gathering Center	13.75	22	5.0	17.8	19.25	0.75
Master Bedroom	13.75	22	4.5	17.3	19	0.50

Conclusions and Future Work

With the emergence of sustainable design as a viable building method for new homes, the need for a performance baseline in order for designers to evaluate future design changes can be clearly seen.

Energy modeling allows designers to take the first step in accessing a home's energy performance even before the first nail is hammered. In this investigation, EnergyPlus was used to build and evaluate an energy model for a prototype home built for the Pinoleville Pomo Nation. The energy model temperature results for a designated simulation period was compared to actual experimental temperature results obtained from a data acquisition period.

The results conclude that the energy model, in general, is a much more conservative model than the actual prototype home. Results show that the energy model predicts higher minimum temperatures, lower maximum temperatures, and smaller daily temperature fluctuations than the actual prototype home.

The differences between the actual and theoretical model can be attributed to a few factors. First of all, the constructions were simplified to use industry standards and equivalents for some materials. The real materials used may vary from the materials used in the energy model. Additionally, the weather data used for the energy model is only up to date until 2005. The weather data must extrapolate to the desired simulation time (2014) and is probably significantly different than the actual weather.

Overall, energy modeling is an extremely useful tool for initial sizing and sustainable design performance evaluation. While the exact values do not match from the model and real data, the trends generally hold across all tested thermal zones. Improving the accuracy of the input information (weather, construction materials, etc) should drastically improve the accuracy of the energy model performance predictions.

In the future, it is advised to improve the accuracy of the input parameters (through use of subscription based services with more accurate information than the free information used). Furthermore, it will be advantageous to model the HVAC, ventilation, sustainable energy systems (PV cells, GHP, and water systems), proposed occupant scheduling, and local lighting conditions in order to evaluate the performance of the home with regards to future design changes.

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Appendix

Constructions

TABLE 5: CONSTRUCTION MATERIAL PROPERTIES

Material	Thickness (m)	Thermal Conductivity (W/m·K)	Density (kg/m^3)	Specific Heat (J/kg·K)
0.5” Douglas Fir Plywood	0.0127	0.1200	540.00	1200.00
0.5” #4 Rebar	0.0127	50.000	7800.00	480.00
0.5” Gypsum Board	0.0159	0.1600	800.00	1090.00
0.625” Gypsum Board	0.0159	0.1600	800.00	1090.00
1” Gypsum Plaster	0.0254	0.4200	1200.00	837.00
1.5” Concrete Plaster	0.0381	0.7200	1860.00	800.00
1.5” Rigid EPS Insulation	0.0381	0.0350	25.00	1400.00
2” Concrete Block	0.0508	0.5100	1400	1000.00
2x6 Douglas Fir Wood	0.1524	0.1200	600.00	2720.00
6” Vermiculite Aggregate	0.1524	0.1700	450.00	837.00
18” Straw Bale	0.4572	0.0560	104.00	2000.00
F08 Metal Surface	0.0008	45.280	7824.00	500.00
G05 23mm Wood	0.0254	0.1500	608.00	1630.00
I01 25mm Insulation Board	0.0254	0.0300	43.00	1210.00
Metal Roofing	0.0015	45.006	7680.00	418.400
R-12 Wall Insulation	0.4200	0.0350	25.00	1000.00
R-42 Wall Insulation	1.4700	0.0350	25.00	1000.00
Roof Insulation [18]	0.1693	0.0490	265.00	836.80
Theoretical Glass [202]	0.0030			

EnergyPlus Energy Model Additional Data

Hourly Thermal Zone Temperature

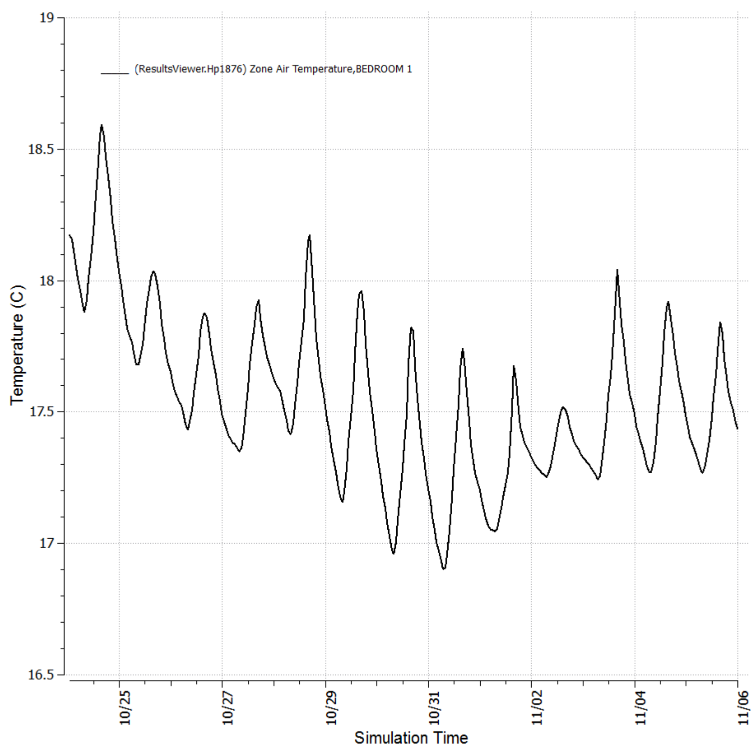

FIGURE 23: HOURLY THERMAL ZONE TEMPERATURE (BEDROOM 1)

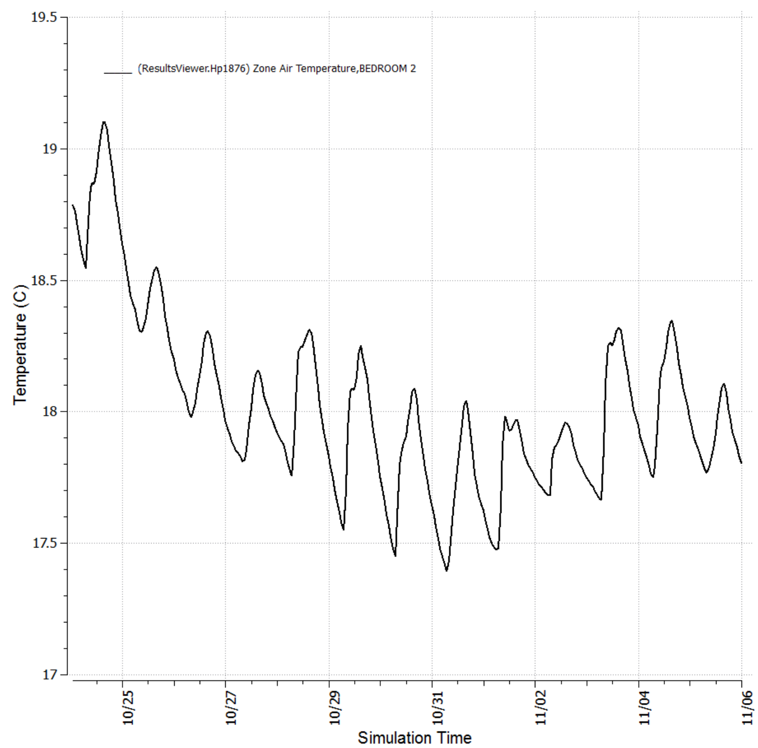

FIGURE 24: HOURLY THERMAL ZONE TEMPERATURE (BEDROOM 2)

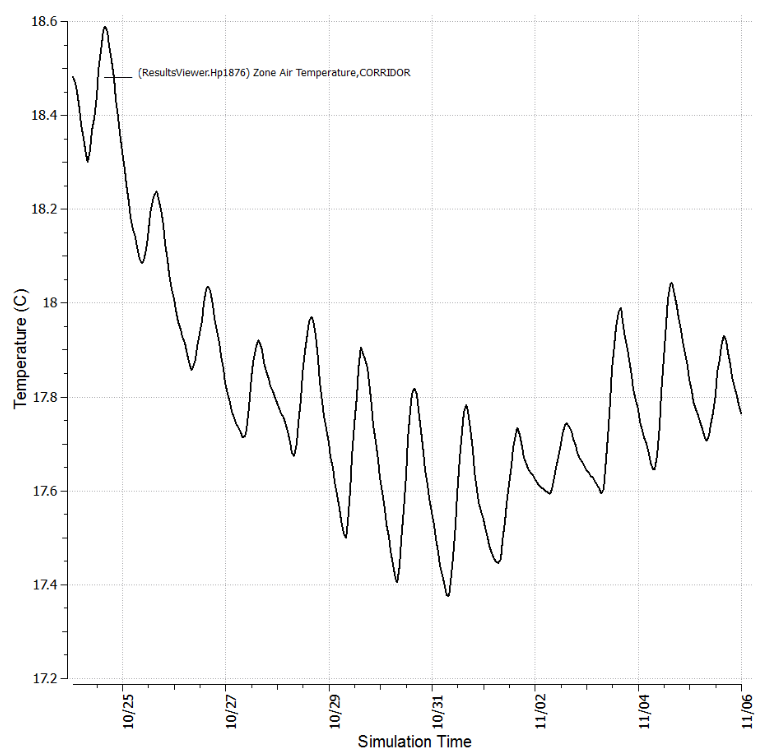

FIGURE 25: HOURLY THERMAL ZONE TEMPERATURE (CORRIDOR)

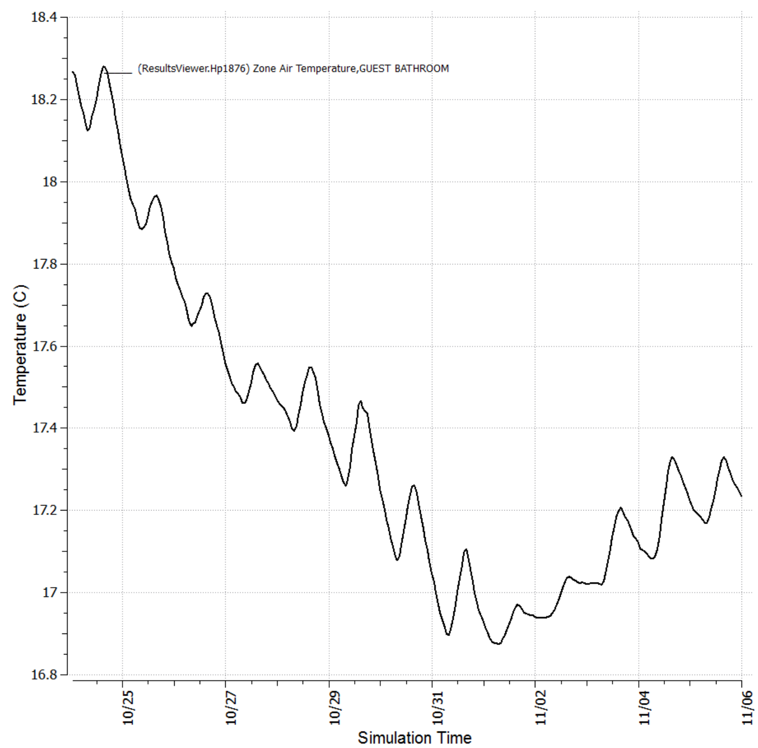

FIGURE 26: HOURLY THERMAL ZONE TEMPERATURE (GUEST BATH)

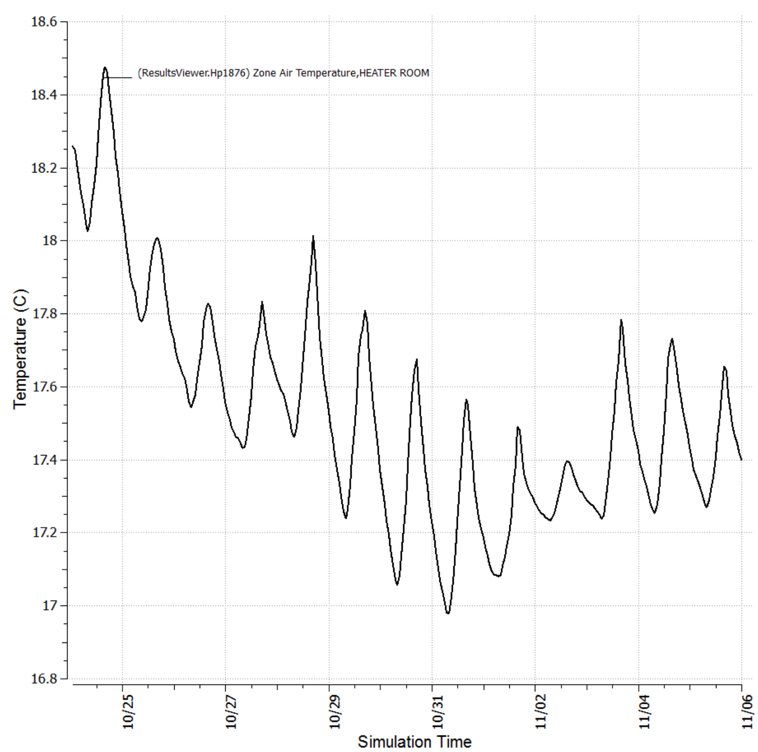

FIGURE 27: HOURLY THERMAL ZONE TEMPERATURE (HEATER ROOM)

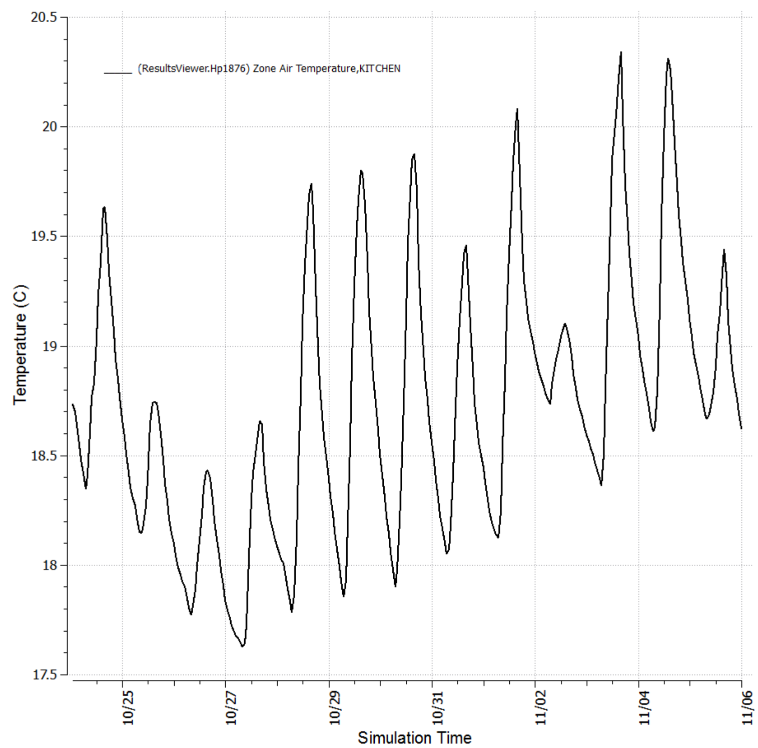

FIGURE 28: HOURLY THERMAL ZONE TEMPERATURE (KITCHEN)

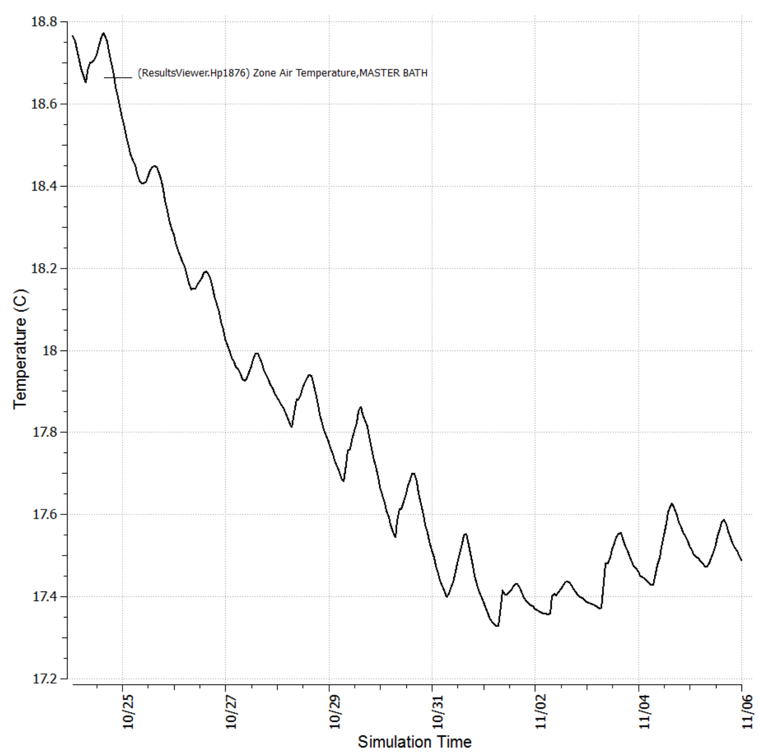

FIGURE 29: HOURLY THERMAL ZONE TEMPERATURE (MASTER BATH)

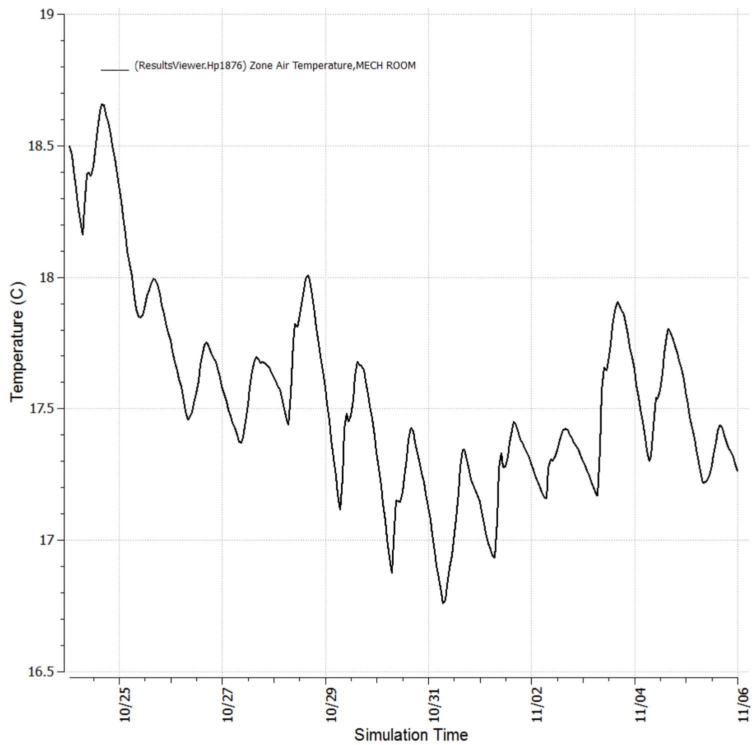

FIGURE 30: HOURLY THERMAL ZONE TEMPERATURE (MECH ROOM)

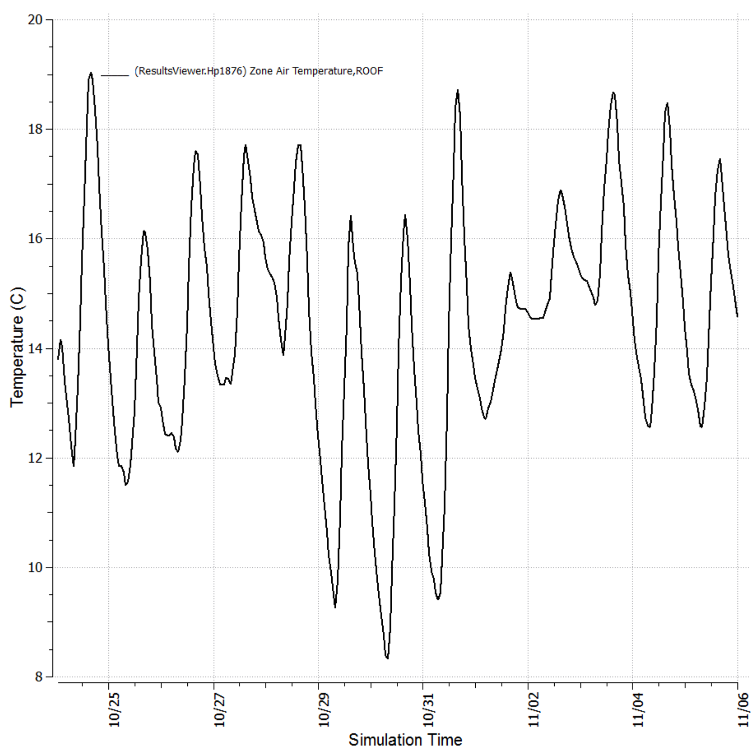

FIGURE 31: HOURLY THERMAL ZONE TEMPERATURE (ROOF)

Daily Thermal Zone Temperature

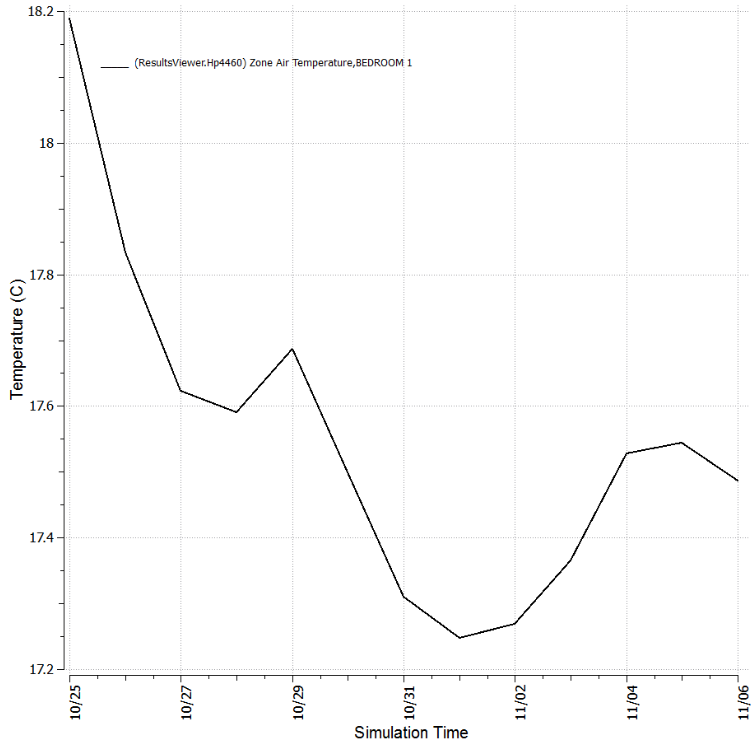

FIGURE 32: DAILY THERMAL ZONE TEMPERATURE (BEDROOM 1)

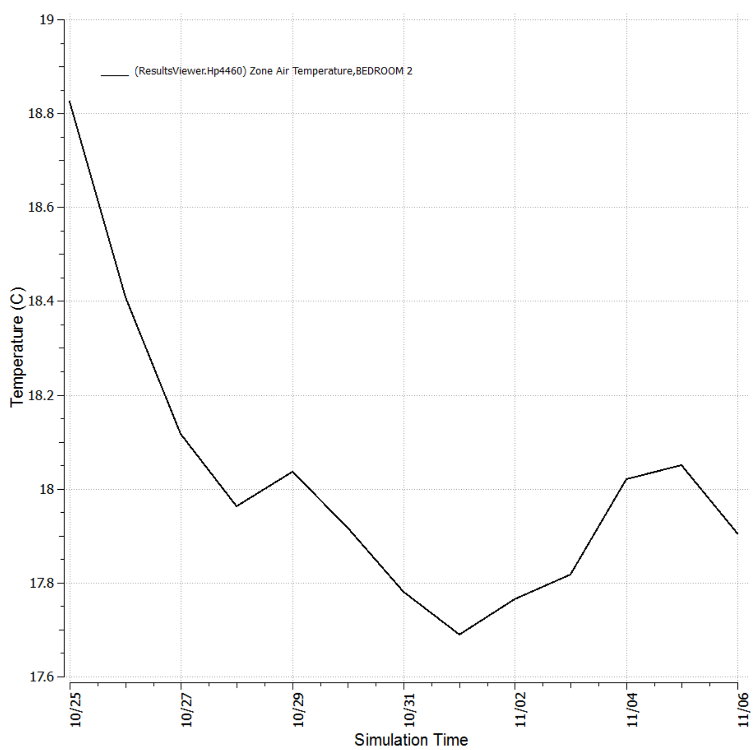

FIGURE 33: DAILY THERMAL ZONE TEMPERATURE (BEDROOM 2)

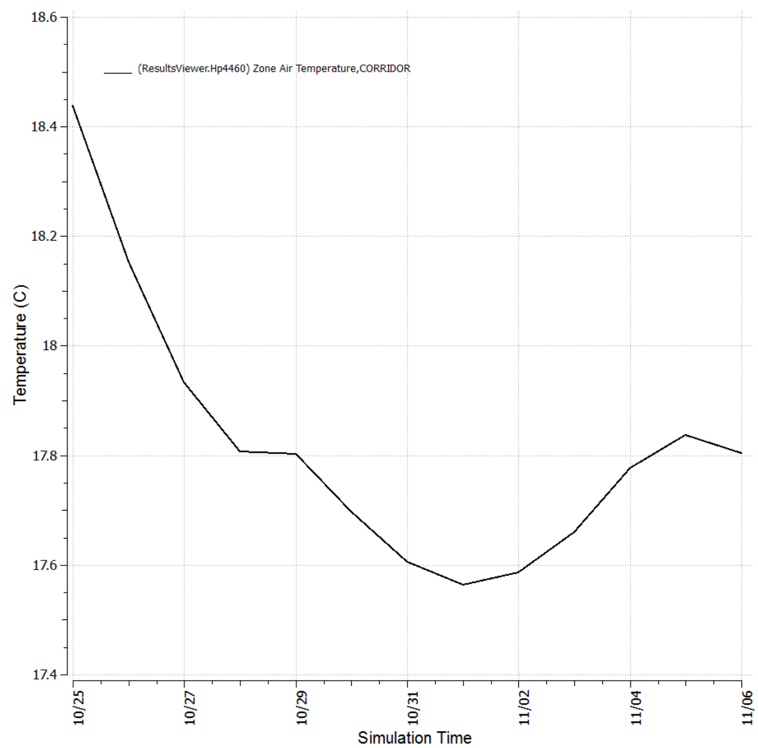

FIGURE 34: DAILY THERMAL ZONE TEMPERATURE (CORRIDOR)

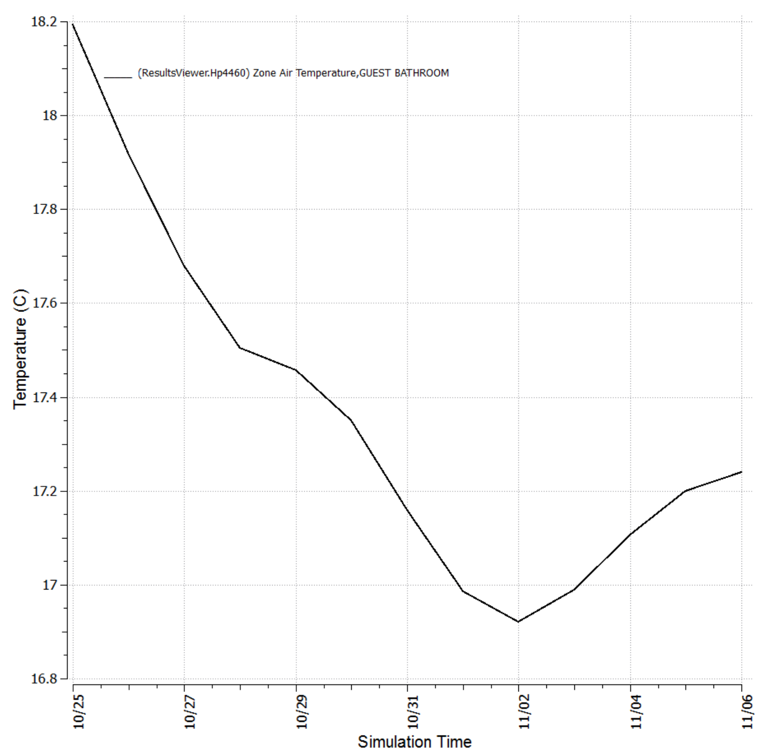

FIGURE 35: DAILY THERMAL ZONE TEMPERATURE (GUEST BATH)

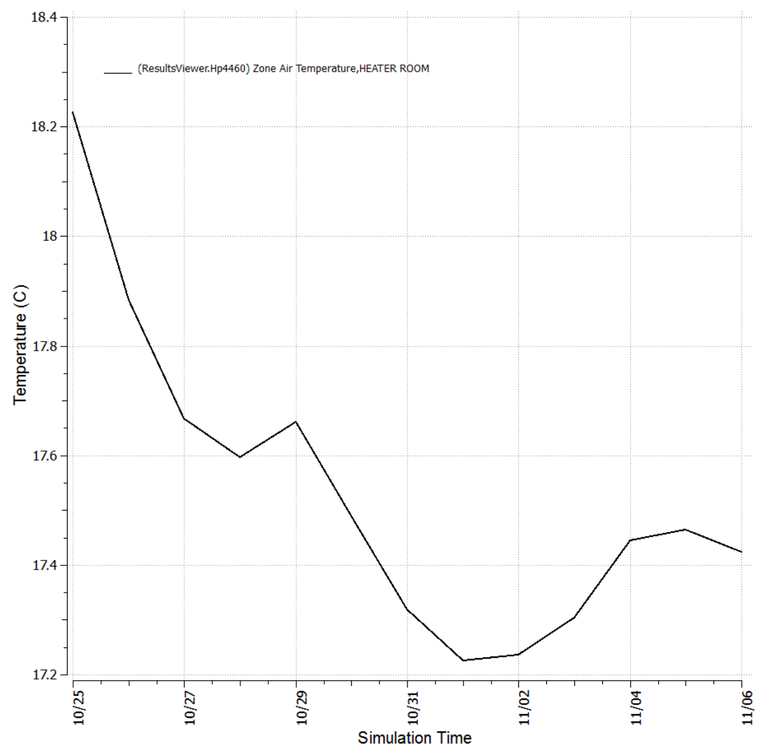

FIGURE 36: DAILY THERMAL ZONE TEMPERATURE (HEATER ROOM)

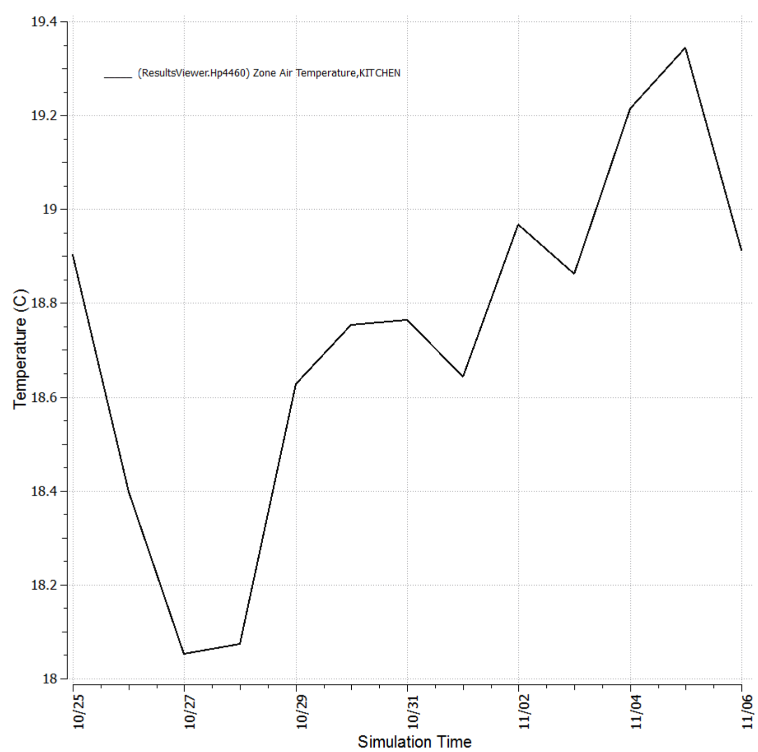

FIGURE 37: DAILY THERMAL ZONE TEMPERATURE (KITCHEN)

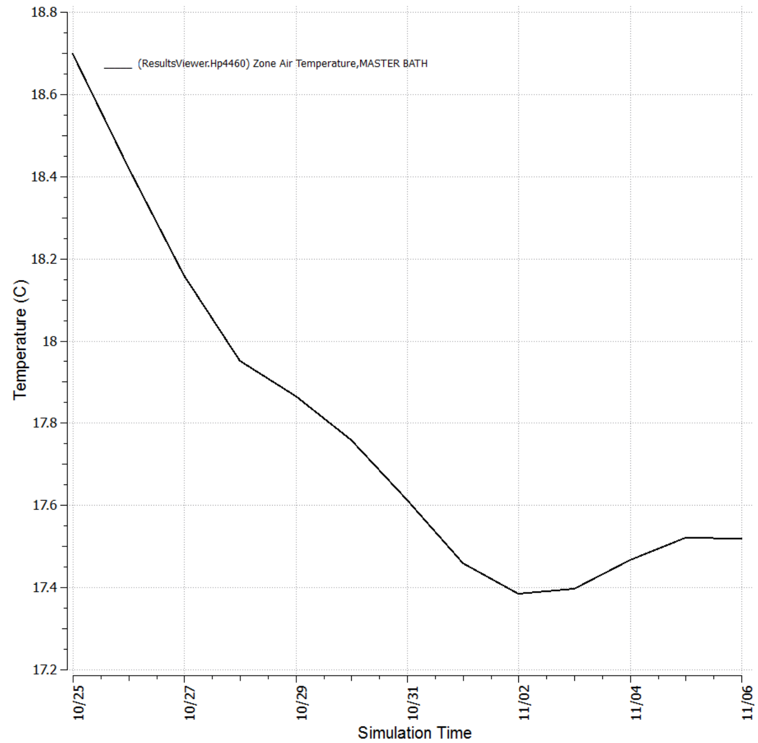

FIGURE 38: DAILY THERMAL ZONE TEMPERATURE (MASTER BATH)

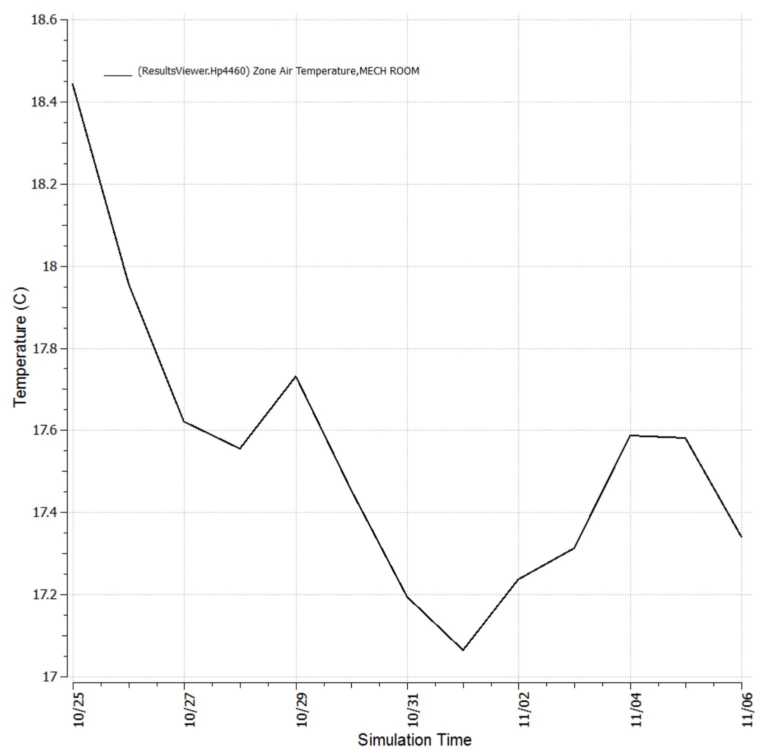

FIGURE 39: DAILY THERMAL ZONE TEMPERATURE (MECH ROOM)

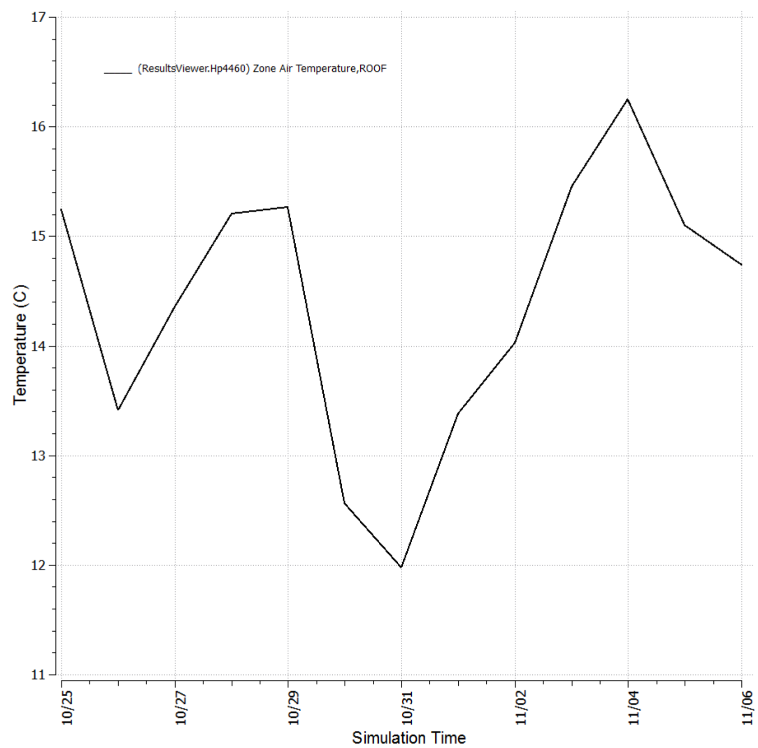

FIGURE 40: DAILY THERMAL ZONE TEMPERATURE (ROOF)