Southface | Advanced Commercial Buildings Initiative

Under the Microscope: Greenstone on Fifth Building Performance Analysis

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The work presented in this report does not represent performance of any product relative to regulated minimum efficiency requirements.

The laboratory and/or field sites used for this work are not certified rating test facilities. The conditions and methods under which products were characterized for this work differ from standard rating conditions, as described.

Because the methods and conditions differ, the reported results are not comparable to rated product performance and should only be used to estimate performance under the measured conditions.

Contents

List of Figures

List of Tables

Executive Summary

Greenstone on Fifth Community Building at Blue Ridge Apartments in Charlottesville, Virginia, is a 3,531 square foot, two-story commercial building that was certified in the EarthCraft Light Commercial (ECLC) green building certification program in 2014. The building owners partnered with Southface to participate in the U.S. Department of Energy-sponsored Advanced Commercial Buildings Initiative project to develop a pathway for deep energy savings through the ECLC program. Southface studied the energy performance of the Greenstone building with circuit-level monitoring, hourly energy simulation modeling, and energy efficiency measure analysis.

The all-electric Greenstone is currently saving 30% in electricity consumption relative to a code-equivalent building per ASHRAE 90.1-2007, without accounting for the installed rooftop solar photovoltaic (PV) array. Including the PV, Greenstone is saving 80% in electricity consumption relative to a code-equivalent building. These savings are due to reductions in interior lighting (42%), cooling (19%), fan energy (18%), heating (14%), and exterior lighting (6%).

The project team earned points on the ECLC worksheet that are directly related to the achieved energy reductions. These include reduced interior lighting power density and usage of sensors and controls, as well as higher efficiency heating and cooling equipment.

The post-occupancy circuit-level monitoring allowed Southface to identify additional areas for improvement. For instance, starting December 26, 2014 there was a change in exterior lighting controls that has resulted in some of the lights being on 24 hours a day. Addressing this issue, as well as updating sensors and controls to optimize efficiency and safety are recommended improvements.

Importantly, the client has only utilized the installed energy recovery ventilator for five (5) days out of the entire year. When the ERV was turned on in August of 2014, the occupants experienced increased humidity levels. They disabled the system, resulting in no outside air ventilation for the entire building. Southface has examined the monitoring data, site visit reports and design documents. When the ERV was active, it ran continuously, including overnight when the air conditioning was in setback mode. The ERV controls should follow the occupancy schedule and should not run during unoccupied periods. Further, recommendations are made to address issues related to both the ERV flow rate and ducting configuration that will likely result in improved performance and indoor air quality.

1 Purpose

The purpose of this report is to present to the client engineering conclusions based on our analysis of detailed building energy monitoring, hourly energy modeling simulations, and energy efficiency measure implementation achieved through the EarthCraft Light Commercial (ECLC) green building certification program. This analysis describes current performance as well as identifies opportunities for improvement in energy and comfort through re-tuning current systems.

2 Data Monitoring Introduction

The Advanced Commercial Buildings Initiative (ACBI) is a three-year project led by Southface Energy Institute and sponsored by the U.S. Department of Energy to increase energy and water efficiency in small commercial buildings. One ACBI project goal is to create a pathway to deep energy reduction within the EarthCraft Light Commercial (ECLC) green building program. The goal for the ECLC Deep Energy package is to reach the Architecture 2030 50% target, which is a 25% reduction in energy consumption below ASHRAE 90.1-2007 levels.

In order to achieve this goal, five ECLC projects were recruited to participate in helping Southface gain a greater understanding of the energy performance of buildings in the current program. Circuit-level energy monitoring, hourly energy models, and measures chosen by the design/ownership team on the ECLC worksheet were analyzed collectively. While participants were not given access to energy data during the one-year monitoring period, this process enables Southface to provide feedback to the client after the research period has concluded. This feedback has the potential to assist in operations and maintenance enhancements that may result in further energy consumption reductions or comfort improvements for the client.

In the summer of 2014, 44 SiteSage current transducers were installed in the electrical panels at Greenstone to measure electricity consumption of every circuit in one-minute time increments. Four temperature and humidity sensors (LASCAR EL-WiFi-TH+) were installed at the site, with one next to each thermostat (3 total), and one deployed in a protected location outside. This report presents the findings of the electricity, temperature, and humidity monitoring data, with the ECLC credits as a guide for the analysis. Electricity, temperature, and humidity monitoring data are transmitted to cloud-based data storage systems, which require a subscription fee for continued usage. Monitoring subscriptions at Greenstone concluded on June 17, 2016. Circuit level monitoring equipment will not be removed from the electrical panels, and the electricity monitoring subscription may be renewed by the client to activate the monitoring dashboard if desired.

3 Assumptions

Findings in this report are based on circuit level monitoring, EnergyPlus v8.4.0 models, site visit data collection, the ECLC certification worksheet, and permit drawings, as available. Circuit energy end use was assigned based on the circuit labels at the electrical panel. Where building-specific data was not available, industry defaults were assumed. Code-minimum models are based on ASHRAE Appendix G protocol.

4 Greenstone Community Building Summary

Greenstone on Fifth Community Building at Blue Ridge Apartments in Charlottesville, Virginia, successfully completed an EarthCraft Light Commercial Certified Level certification with a total of 126 points in 2014. The building is a 3,531 square foot new construction project in International Energy and Conservation Code (IECC) Climate Zone 4.

The building has two floors that are accessed from separate elevations and act independently. The first floor is used as an office space, while the second floor is composed of classrooms and a community gathering place. The first floor also has a crawlspace with a 10 mil vapor barrier over 4” compact stone fill that is below grade. One of the three air handling units (AHU-2) and energy recovery ventilator (ERV) are located here and are easily accessible. The AHU-1 is located in a storage room on the first floor and AHU-3 is located on the second floor. All AHUs are located inside the building envelope.

The building foundation is a combination of the crawlspace described above and a 4” thick concrete slab over a 10 mil vapor barrier over 4” aggregate over compacted fill. The first floor walls are composed of CMU blocks with 1” extruded polystyrene rigid foam insulation on the interior wall that are partially below grade where the crawlspace is located. The rest of the building is built of standard 2x6 wood-framing at 16” on center (OC). The wood-framed walls have exterior structural insulated sheathing (SIS) of R-5.5 in select areas and cellulose cavity insulation R-19 for majority of the walls. The flat unvented roof is composed of pre-engineered wood trusses at 24” OC has R-38 cellulous insulation on the ceiling. The roof deck has a continuous polyisocyanurate rigid insulation board of R-10.

The building energy systems are all electric. In addition to using energy from the electric grid, the building has a roof-mounted photovoltaic (PV) array.

5 Energy Consumption Analysis

5.1 Where is energy being used in Greenstone?

The annual energy end use breakout of measured data from July 1, 2014 to June 30, 2015 is shown below in Figure 1. This chart breaks the total electric consumption for the 12-month period into end use categories. The AHU Fans, in orange, are used for heating and cooling, but is broken out due to convention.

Heating is the single largest energy use by the building, at 29%, followed by interior lighting and interior equipment at 21% and 18%, respectively.

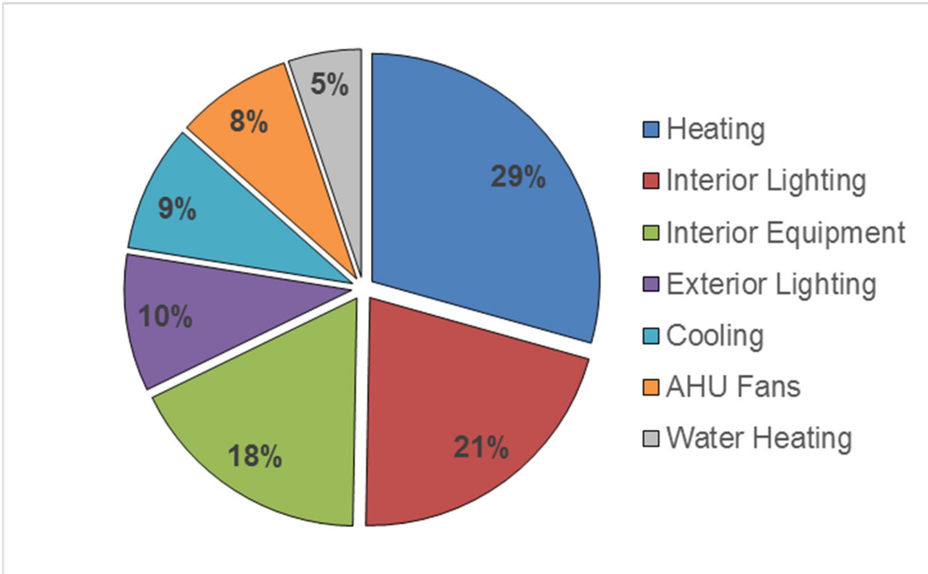

Figure 1. Greenstone Annual Energy Consumption by End Use

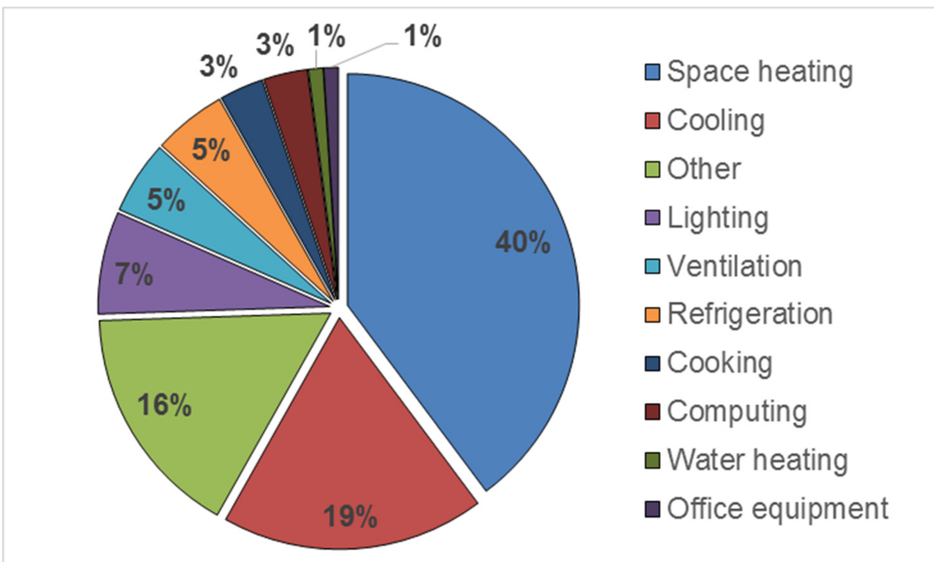

Figure 2. Average Public Assembly Annual Energy Consumption by End Use (2012 CBECS)

As a comparison, average total major fuel consumption for public assembly building types collected in the 2012 Commercial Buildings Energy Consumption Survey (CBECS) is shown (Figure 2)[1]. CBECS is a nationwide survey that included all building sizes, most of which are much larger than Greenstone. From this chart, it can be seen that the total Greenstone heating consumption (heating plus ½ AHU fans) is close to the national average in terms of percentage,

[1] http://www.eia.gov/consumption/commercial/reports/2012/energyusage/xls/table1_by%20source.xlsx

while cooling (cooling plus ½ AHU fans) is proportionally smaller. Water heating is a larger percentage in Greenstone than the national average.

5.2 How much energy is Greenstone saving compared to a code-equivalent building?

Southface built an hourly energy model of this building as if it were built to code. While the building model has the same geometry as the actual building, the building components are code-equivalents. For instance, the energy model used the wall insulation and window u-factors that are required in ASHRAE 90.1-2007. Southface also built an hourly energy model of the actual, "as built", building. The monitored data was used to calibrate the energy model of the actual building, so that the energy consumption of the model matches what was measures (within a margin of error). Both models use the schedules of the actual building. Importantly, this includes the fact that the building does not have any outdoor air ventilation running, which means it is technically not operating as required by code. The chart below highlights the differences in modeled energy consumption of the code and actual buildings, without ventilation (Figure 3). Annual electricity consumption over the monitoring period totaled 32,536 kWh for the code-equivalent building, and 22,904 kWh for the modeled actual building. Measured annual energy consumption from the monitoring data totaled 23,610 kWh.

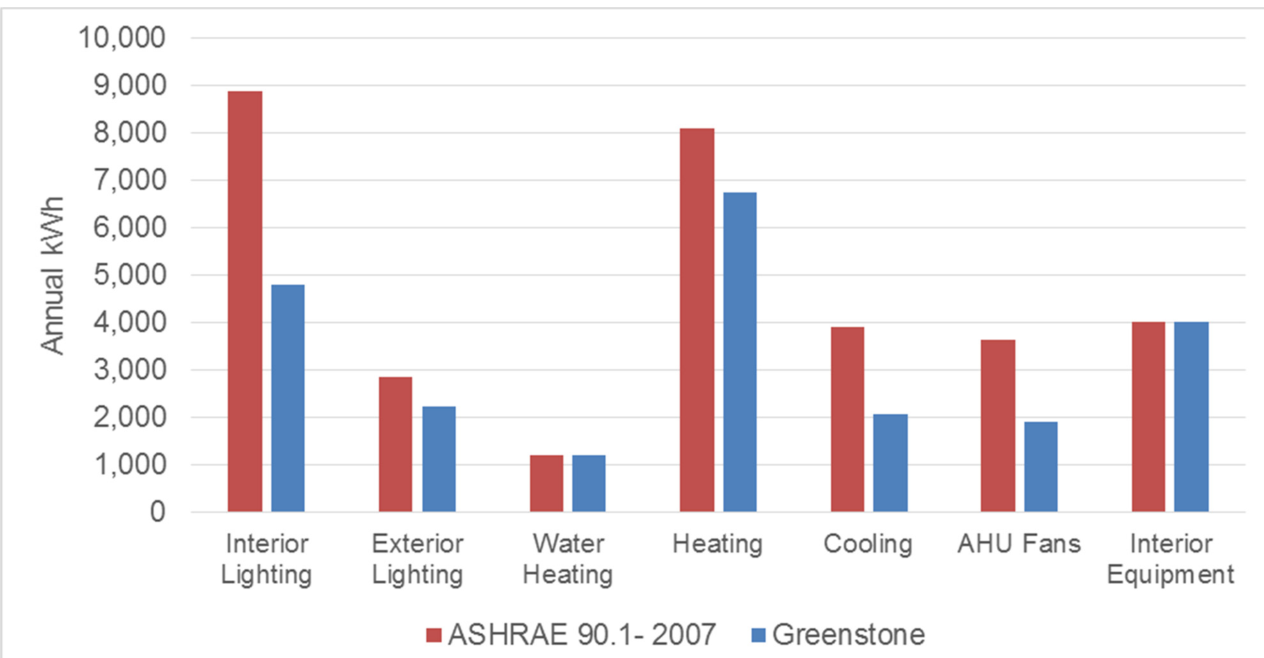

Figure 3. As-Built vs. Code End Use Comparison (No Ventilation)

Adding ventilation to the as built and code models changed the end use and total consumptions. (Figure 4). The installed ERV was used for the as built building. Central fan integrated supply ventilation was used for the code building. Both systems were run at ASHRAE 62.1-2007 ventilation rates during occupied times. Annual electricity consumption over the monitoring period for the code built and as built models with ventilation was 37,405 kWh and 23,624 kWh, respectively.

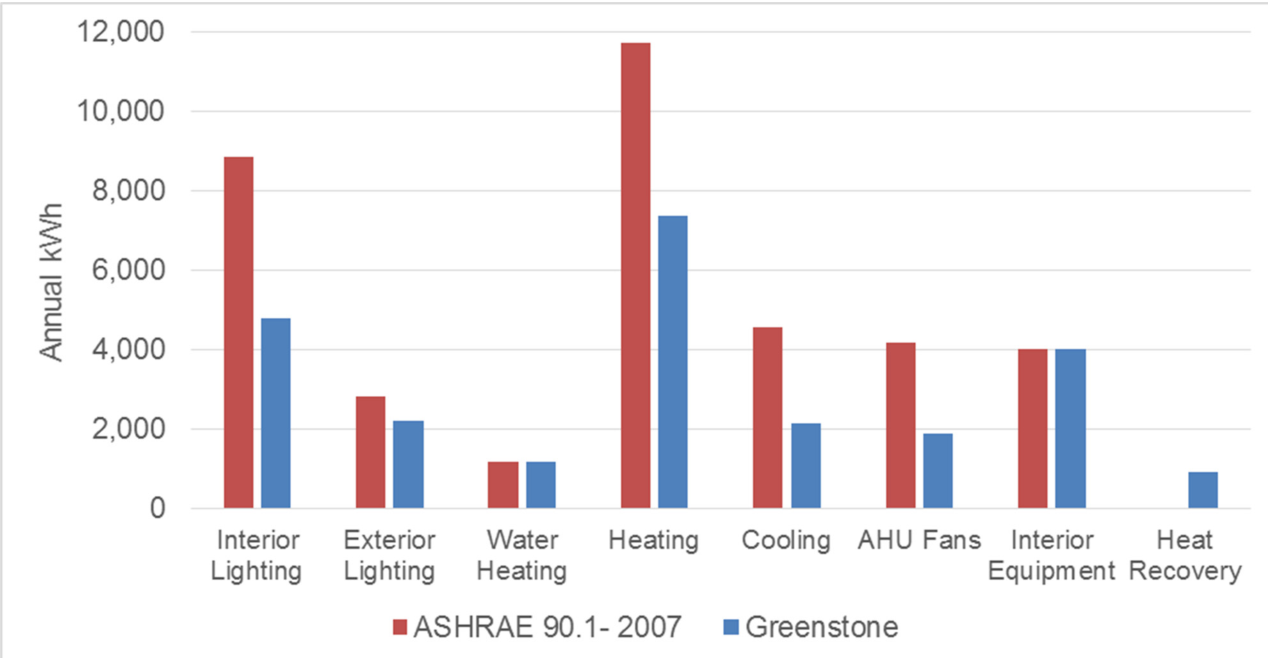

Figure 4: As-Built vs. Code End Use Comparison (w/ Ventilation)

Overall, without including PV panel production, the modeled as-built Greenstone building is performing 30% better than a code-equivalent building (built to ASHRAE 90.1-2007, without ventilation) and exceeds the Architecture 2030 challenge 50% savings performance target (Figure 5). Including photovoltaic (PV) electricity production, Greenstone is performing 81% better than code[2]. Total 12 month electricity cost was $1,064 (includes cost savings due to photovoltaic production).

[2] From July 2014 to June 2015, PV production = 16,602 kWh (12.3 kW system)

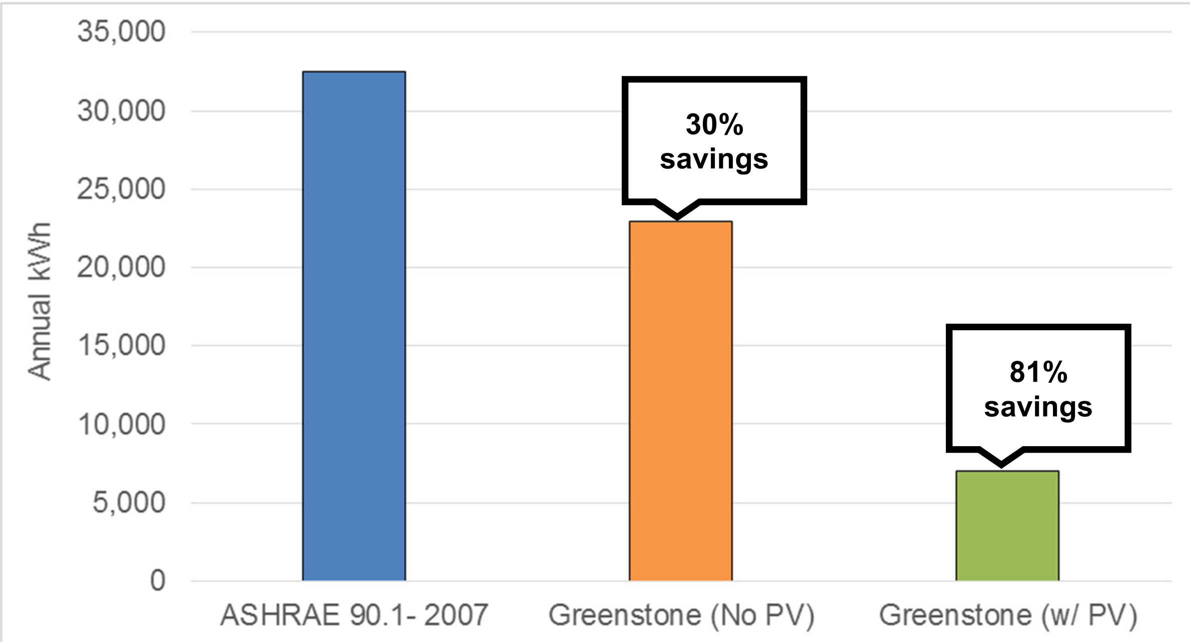

Figure 5. Code and As-Built Annual Energy Use Comparison

5.3 What's driving energy savings?

Without including PV production, the largest portion of total energy savings is from interior lighting (Figure 6). Increases in interior lighting efficiency (fixtures and controls) contribute almost half the total energy savings (43%). Increases in heating, cooling, and fan efficiencies contribute 14%, 19%, and 18% energy savings, respectively. Exterior lighting efficiency measures accounted for 6% energy savings. PV panel energy production accounts for 51% of the building energy savings.

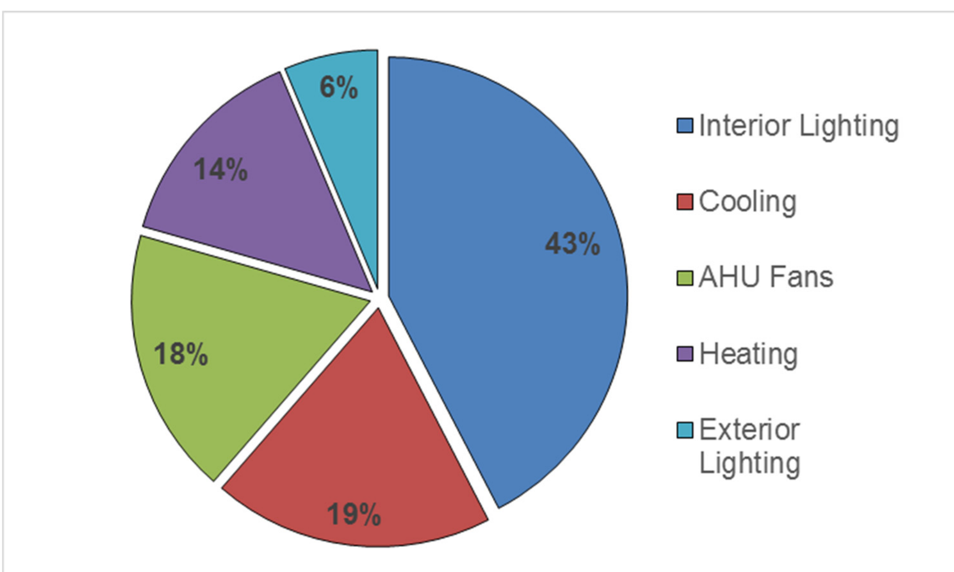

Figure 6. Percent of Total Energy Savings by End Use

6 EarthCraft Light Commercial Worksheet Analysis

The EarthCraft Light Commercial program is composed of ten categories and sub-categories in which Greenstone earned points toward certification. The worksheet was examined in order to draw connections between measured building performance and ECLC credits achieved.

- Site Planning & Development (SP)
  - Site Selection
  - Site Design
  - Site Preparation & Preservation
- Construction Waste Management (CW)
- Resource Efficiency (RE)
- Durability & Moisture Management (DU)
- Indoor Air Quality (IAQ)
  - Ventilation
  - Pollution Source Control
- High Performance Building Envelope (BE)
  - Air Sealing & Insulation
  - Glazing
- Energy Efficient Systems (ES)
  - Heating & Cooling
  - Ductwork & Air Handler
  - Interior Lighting
  - Exterior Lighting
  - Water Heating
  - Energy Star Labeled Appliances & Equipment
  - Renewable & Alternative Energy
- Water Efficiency (WE)
  - Indoor Water-Use
  - Outdoor Water-Use
- Education & Operations (EO)
- Innovation (IN)

6.1 Interior Lighting and Controls

6.1.1 ECLC Criteria Achieved

ES 14: Increased Interior Lighting Efficiency- Interior Lighting Power Density (LPD) is at least 30% lower than maximum LPD allowed per ASHRAE 90.1-2007.

ES 16: Vacancy/Occupancy Sensors - Install occupancy/vacancy sensors for 75% of continuously and intermittently occupied spaces

6.1.2 Data Monitoring Observations

Greenstone achieved ES 14 by installing lighting with a Lighting Power Density (LPD) at least 30% lower than code. The code-maximum LPD for this building is 1.15 W/Sq-Ft; therefore, the maximum allowable value for this credit is 0.81 W/Sq-Ft. Per the permit drawings, the installed LPD was 0.72 W/Sq-ft. From the monitoring data, interior lighting power peaked at 2,330W, equating to an installed LPD of 0.66 W/Sq-ft and exceeding code by 42%.

Lighting energy consumption during unoccupied periods was calculated. Building occupancy schedules were determined based on the monitored lighting data. During the week, interior lights in the building were first turned on between 7AM and 9AM. Lights were turned off between 5PM and 8PM. Building occupied hours for the data analysis were set from 7AM to 8PM to be conservative with the unoccupied interior lighting energy use. Saturday building occupancy hours varied drastically. Again, conservative occupancy schedules were used, with the Saturday occupancy schedule set from 7AM to 8PM. For the vast majority of Sundays, interior lights were not turned on, hence the building was determined to be unoccupied.

Table 1: Greenstone Occupancy Schedule

Day(s) of Week	Occupied
Monday - Saturday	7AM – 8PM
Sunday	Not occupied

Lighting energy usage during occupied and unoccupied hours was calculated and is presented in Table 2 below. Of the total building interior lighting energy consumption, 16% occurred during unoccupied hours, even with the conservative occupancy assumptions.

Table 2: Interior Lighting Energy Consumption

Area	Total Lighting Energy Use (kWh)	Lighting Energy Use During Occupied Hours (kWh)	Lighting Energy Use During Unoccupied Hours (kWh)	Percent Lighting Energy Use During Unoccupied Hours
1st Floor	2,257	1,931	326	14%
2nd Floor- North	1,112	1,008	104	9%
2nd Floor- South	2,207	1,734	473	21%
Total	**5,576**	***4,673***	***903***	***16%***

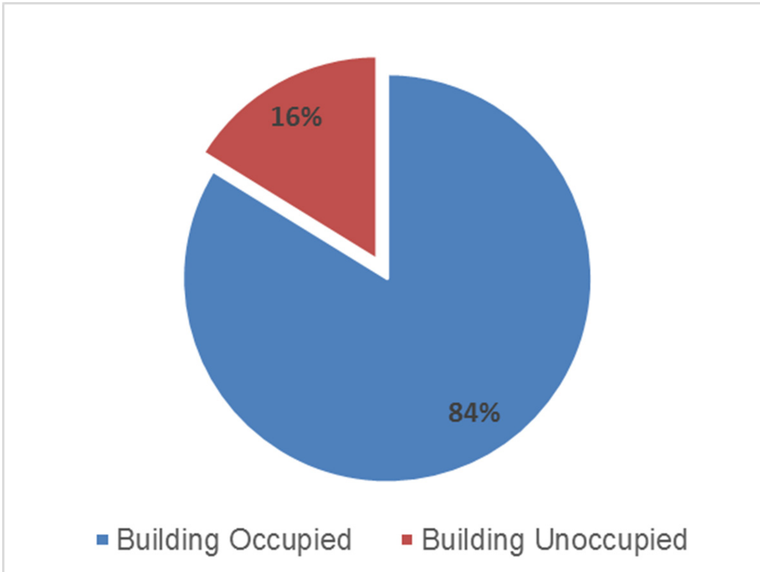

Figure 7. Interior Lighting Energy Consumption during Occupied and Unoccupied Periods

Passive infrared (PIR) occupancy sensors are installed in the bathrooms, kitchen, classrooms, and work room. Dual technology occupancy sensors are installed in all offices. Lights in the lobby, vestibule, corridor, and storage rooms are controlled with switches. Lights controlled by switches, PIR, and dual technology are on the same circuit; therefore, patterns associated with each type of lighting control was unable to disaggregated. In the graph below showing one full week of data, the blue line represents total building interior lighting power (Figure 8). The red blocks indicate when the building is unoccupied. Interestingly, lights are regularly turning on and off in the middle of night, illustrated by the lighting power fluctuations during the unoccupied periods highlighted in red below. One possible cause of such fluctuations is a falsely triggered occupancy sensor.

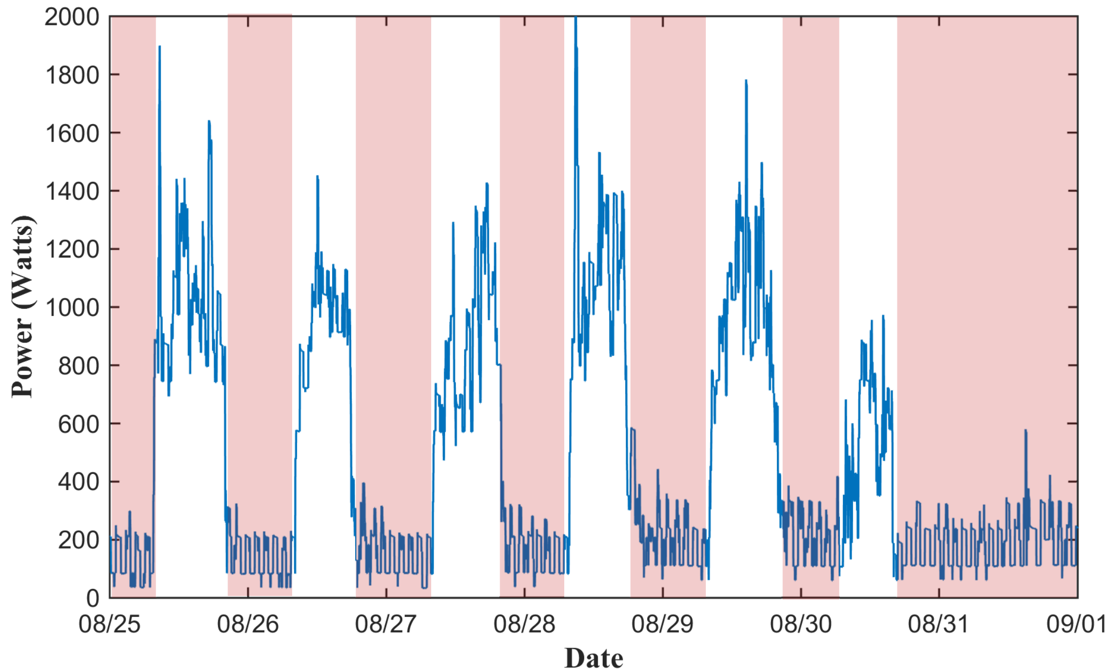

Figure 8. Greenstone Total Interior Lighting Power

6.1.3 Recommendations

1) Turn off all lights when building is not occupied.

2) Retrofit occupancy sensors with vacancy sensors in rooms with daylight. Existing lighting sensors in the building are all occupancy sensors. An explanation of occupancy and vacancy sensors is included below to provide guidance for the most appropriate sensor type based on location. Sensors that can be set to both vacancy and occupancy mode are also available.

   a) *Occupancy sensor*: light turns on whenever the sensor detects movement in the space. It also turns off after a predetermined period when it no longer senses movement in the space. The "occupancy" mode is appropriate for rooms where the lights must always be turned on in order to be able to see in the room, such as an interior closet or restroom where there are no windows.

   b) *Vacancy sensor*: lights must be turned on manually. It then turns off lighting after a predetermined period when it no longer senses movement in the space. The "vacancy" mode is appropriate for rooms where there may be daylight or light from an adjacent space that provides adequate lighting for activities in the room. The purpose of the vacancy mode is to provide light when it is needed, and this is accomplished by a manual action. The lights should not turn on automatically if someone were not otherwise physically turning them on.

3) Conduct an evening building walk through to identify lights that are left on, or that are being continually triggered by occupancy sensors.

4) Avoid mounting sensors close to air vents, as the vibration and air flow can reduce the effectiveness of the sensor (PIR sensors should not be within 4 ft of an air vent, and ultrasonic sensors should not be within 6 ft of an air vent)[3].

6.2 Exterior Lighting and Controls

6.2.1 ECLC Criteria Achieved

ES 18: Increased Exterior Lighting Efficiency – Exterior lighting efficiency is 20% better than ASHRAE 90.1-2007.

ES 19: Advanced Exterior Lighting Control - (A) Automatic after-hours shut-off controls for exterior signage and decorative lighting (B) Curfew lighting; reduce lighting levels by 50% during (11:00 pm to dawn)

6.2.2 Data Monitoring Observations

Monitoring data showed the actual exterior lighting wattage is 380 watts. This is 21% less than the wattage allowable by code, thus meeting ES 18 described above.

Decorative lighting does not appear to turn off during unoccupied hours, as required by ES 19. In addition, a lighting sensor may be dysfunctional as the exterior lighting power does not reduce by 50% from 11PM to dawn (require by ES 19). The exterior lighting energy consumption pattern changed after December 2014. Prior to December 26, 2014, exterior lighting consumption followed the pattern shown by the blue line in the graph below (Figure 9). After December 26, 2014, more exterior lights were consistently on during the day, as shown by the orange line in the graph below. The exterior lighting power during the night remains the same, approximately 380W. However, during the day the exterior lighting power consumption increased from 22W to 150W. This trend remains the same during the writing of this report (April 2016). This increase in lighting usage is due to an unknown source, however is likely from a failing photocell.

[3] www.lutron.com/TechnicalDocumentLibrary/3683197.pdf

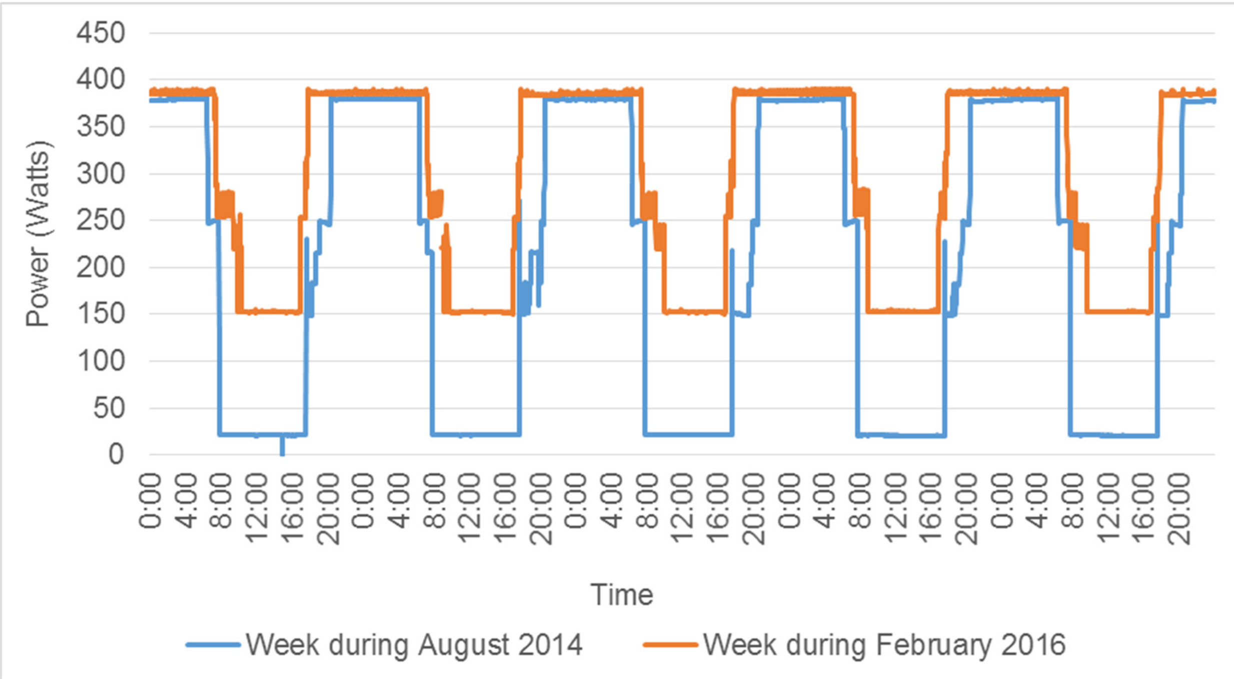

Figure 9. Exterior Lighting Power Consumption Trends

The chart below shows the weekly energy consumption of the exterior lighting during the daytime and the nighttime over two separate weeks (blue and orange). Ideally, exterior lighting consumption during the day should be zero, as was nearly the case in August 2014. Daytime exterior lighting power consumption was 6 times higher in the spring 2015 compared to the summer 2014. Across the 12 month monitoring period, more than a quarter (26%) of the exterior lighting energy consumption occurred during the day (Figure 10).

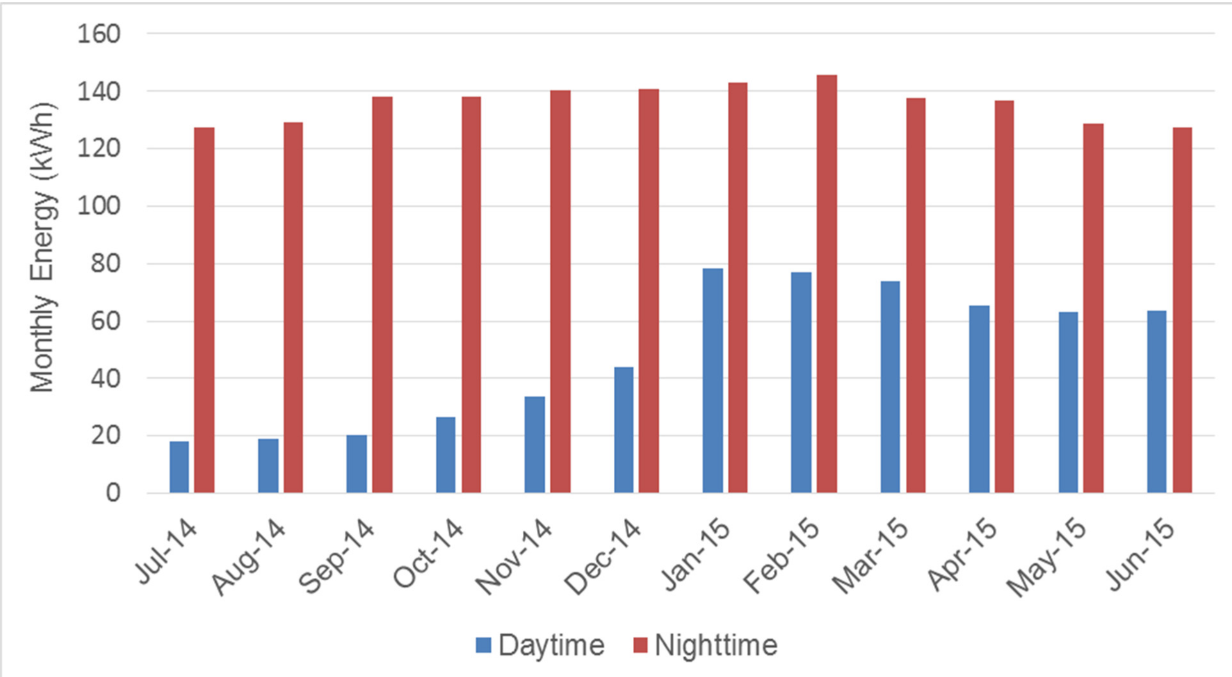

Figure 10. Monthly Exterior Lighting Consumption

6.2.3 Recommendations:

1) Repair or add controls to exterior lighting so that all fixtures only turn on during the night (e.g. photocell controls)

2) Repair or add controls so that exterior lighting levels dim by at least 50% from 11PM to dawn. Security lights may be brought up to 100% by occupancy sensors, and then revert back to 50% after a preset duration of not sensing movement.

6.3 Heating & Cooling

6.3.1 ECLC Criteria Achieved

1) **ES 2: Increased Cooling Equipment Efficiency** - 3 SEER –or- 2 EER better than code

2) **ES 3: Increased Heating Equipment Efficiency** - Air source heat pump with HSPF 8.2 / COPH 2.4 or greater

6.3.2 Data Monitoring Observations

The installed heat pumps were all equal to or great than 15 SEER and 3.5 COP, meeting the ECLC requirements stated above. All the heat pumps were equipped with electric resistance auxiliary heat. The measured impact of the auxiliary heat on energy use is described below.

It was observed that the auxiliary electric resistance heaters for the heat pumps were turning on when the outside temperature was greater than 40°F (Figure 11). This auxiliary strip heat was the single largest contributor to heating and cooling energy consumption, and is the reason that heating is the largest component of total energy consumption for the building. ASHRAE 90.1-2007 states,

> "If a heat pump equipped with auxiliary internal electric resistance heaters is installed, controls shall be provided that prevent supplemental heater operation when the heating load can be met by the heat pump alone during both steady-state operation and setback recovery…Two means of meeting this requirement are (1) a thermostat designed for heat pump use that energizes auxiliary heat only when the heat pump has insufficient capacity to maintain set-point or to warm up the space at a sufficient rate or (2) a multistage space thermostat and an outdoor air thermostat wired to energize auxiliary heat only on the last stage of the space thermostat and when outside air temperature is less than 40°F".

Heat pump auxiliary heat energy use when the outside temperature was greater than 40°F accounted for 26% of total auxiliary heat consumption. This energy use equates to approximately $133 per year[4]. Of the total energy use from heating, cooling, and ventilation, 42% was from the auxiliary heat (Figure 12).

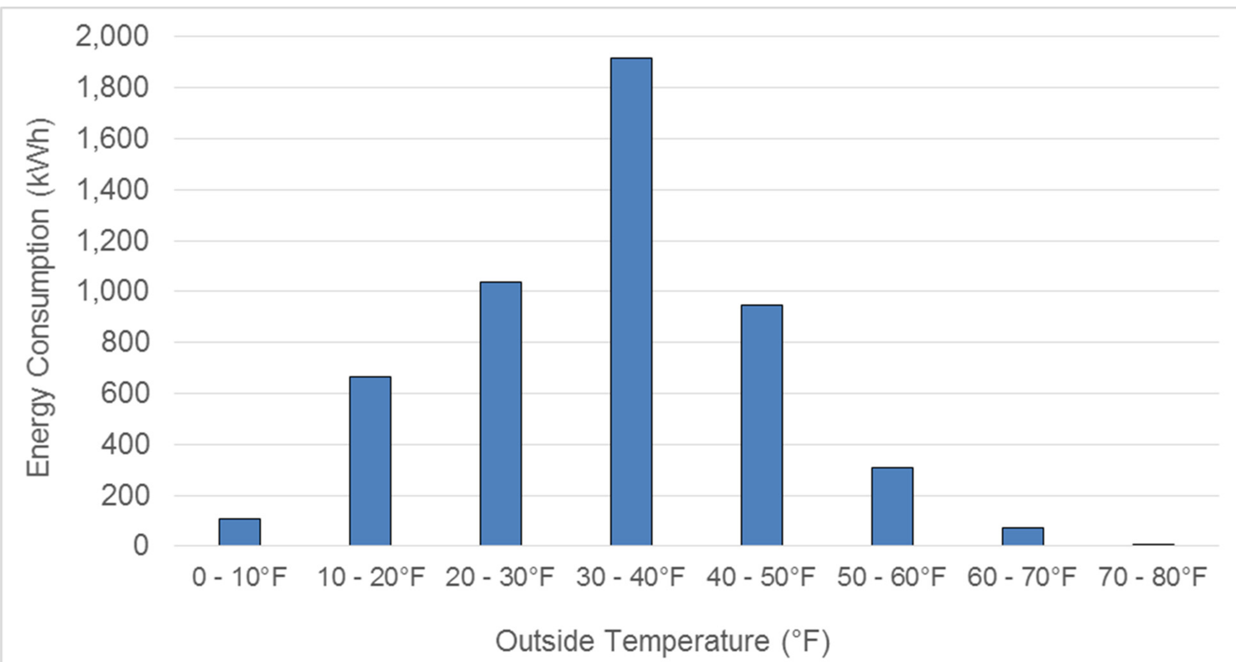

Figure 11. Auxiliary Heat Energy Use Compared to Outside Temperature

[4] Assuming $0.10 per kWh

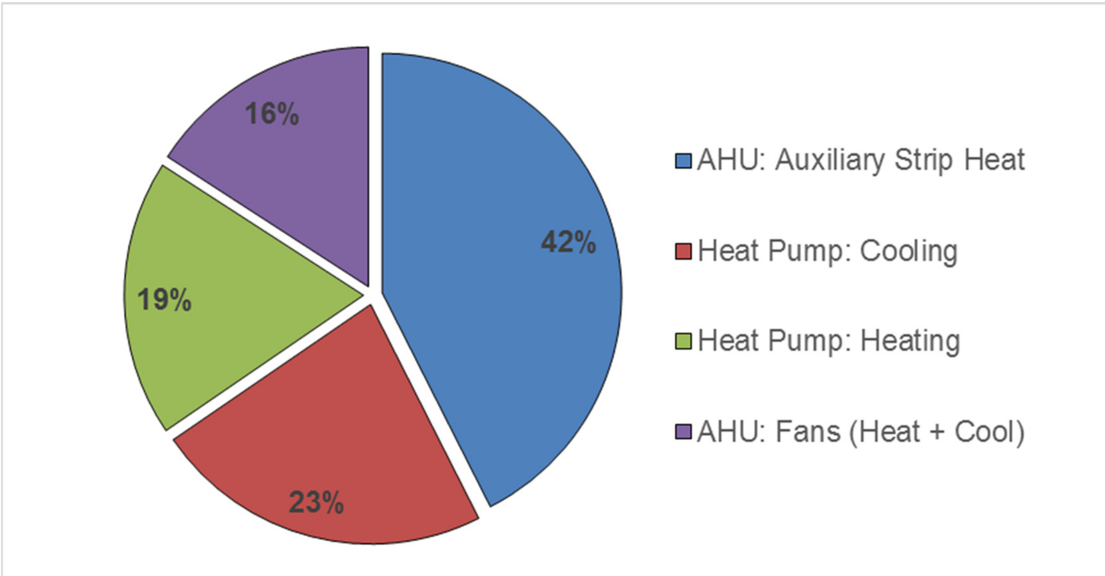

Figure 12. Greenstone Heating and Cooling Energy Breakdown

6.3.3 Recommendations

1) Configure or replace all thermostats so that one of the following criteria is met:
   - During the morning, heat the building in multiple stages via multiple programs in the thermostat. Most thermostats activate the auxiliary heat when there is a temperature difference of 4°F or more between the outside temperature and the set point. Gradually increasing the set point temperature when heating the building in the morning can prevent auxiliary heat activation. Thermostats are also available with built in algorithms to optimally start equipment.
   - Activate auxiliary heat only on the last thermostat heating stage and when outside air temperature is less than 40°F.

6.4 Ventilation

6.4.1 ECLC Criteria Achieved

IAQ R1: Minimum Outside Air Requirements - Meet ASHRAE 62.1-2007, Ventilation for Acceptable Indoor Air Quality

6.4.2 Data Monitoring Observations

An S&P model TR800 energy recovery ventilator (ERV) is installed in the sealed crawlspace. The ERV ducting configuration in the permit drawings details the ERV fresh air supply and return air connected to each air handler's return system. In the AHU returns, the ERV supply air duct is downstream (closer to the AHU) of the ERV return air duct. This ducting configuration is included as an *example common installation approach* in the manufacture's Installation and Operations Manual. A diagram of all the listed common duct installation approaches can be found below. The installed ducting configuration at Greenstone is the third example. Notably, with the third ducting configuration, the manufacturer recommends the AHU fan to operate in "on" mode when the ERV is running.

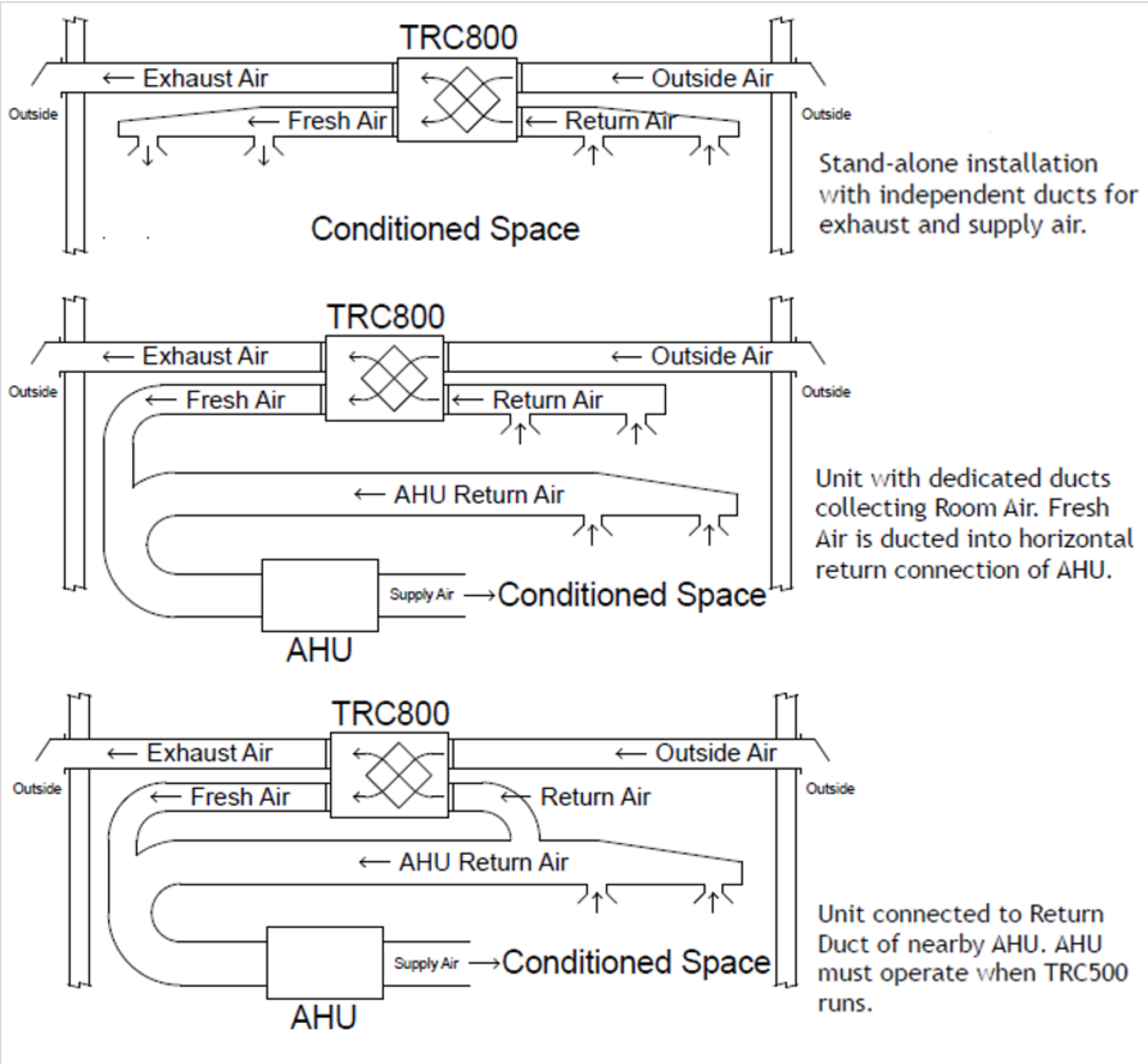

Figure 13: TRC800 ERV Common Ducting Installation Configurations

Air handler design supply flow rate, design outdoor air flow rate, and actual supply flow rate are included in the table below. Given the design occupancy provided in the plans, the design outdoor airflow met ASHRAE standard 62.1-2007, and was not oversized.

Table 3. HVAC Design and Actual Supply and Outdoor Airflows

Air Handler	Area Served	Area (Sq-Ft)	Design Occupants (per plans)	Design Supply Airflow (CFM)	Measured Supply Airflow from TAB[5] (CFM)	Design Outdoor Airflow (CFM)
AHU-1	First floor offices	1209	13	650	Unavailable	125
AHU-2	Second floor Classroom 1 and 2	825	Total 66	800	812	350
AHU-3	Second floor community spaces and Classroom 3	1496		1100	1144	305
Total		**3530**		**2550**	**1956**	**780**

From July 2014 to June 2015, the client only used the ERV for a 5-day period in August. During this period, the ERV timer controls were not utilized, and the ERV operated during the entire time period. Relative humidity levels in the building peaked at 81% (Figure 14). The ERV was turned off because of moisture and comfort concerns, and has not been utilized since. Below is a discussion of the monitoring findings during ERV operation, and recommendations for improving building comfort, durability, and indoor air quality in the future.

The graph below shows the interior and exterior relative humidity levels from 8/4/2014 to 8/15/2014 (Figure 14). During this time, the ERV was turned on for a 5 day period, which can be seen by the black line representing ERV power, which spikes up from zero to approximately 1,300W and then back down to zero. Relative humidity levels peaked at 76%, 72% and 81% on the first floor, second floor community room, and second floor classrooms, respectively. OSHA's Technical Manual defines comfortable indoor air conditions as temperatures between 68°F and 76°F and relative humidity levels between 20% and 60%[6]. From 8/4/2014 to 8/15/2014, interior temperatures remained between 68°F and 76°F. The green box in Figure 14 indicates the relative humidity range where the occupant comfort criteria specified by OSHA is met.

[5] Test and Balance report

[6] https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_2.html#5

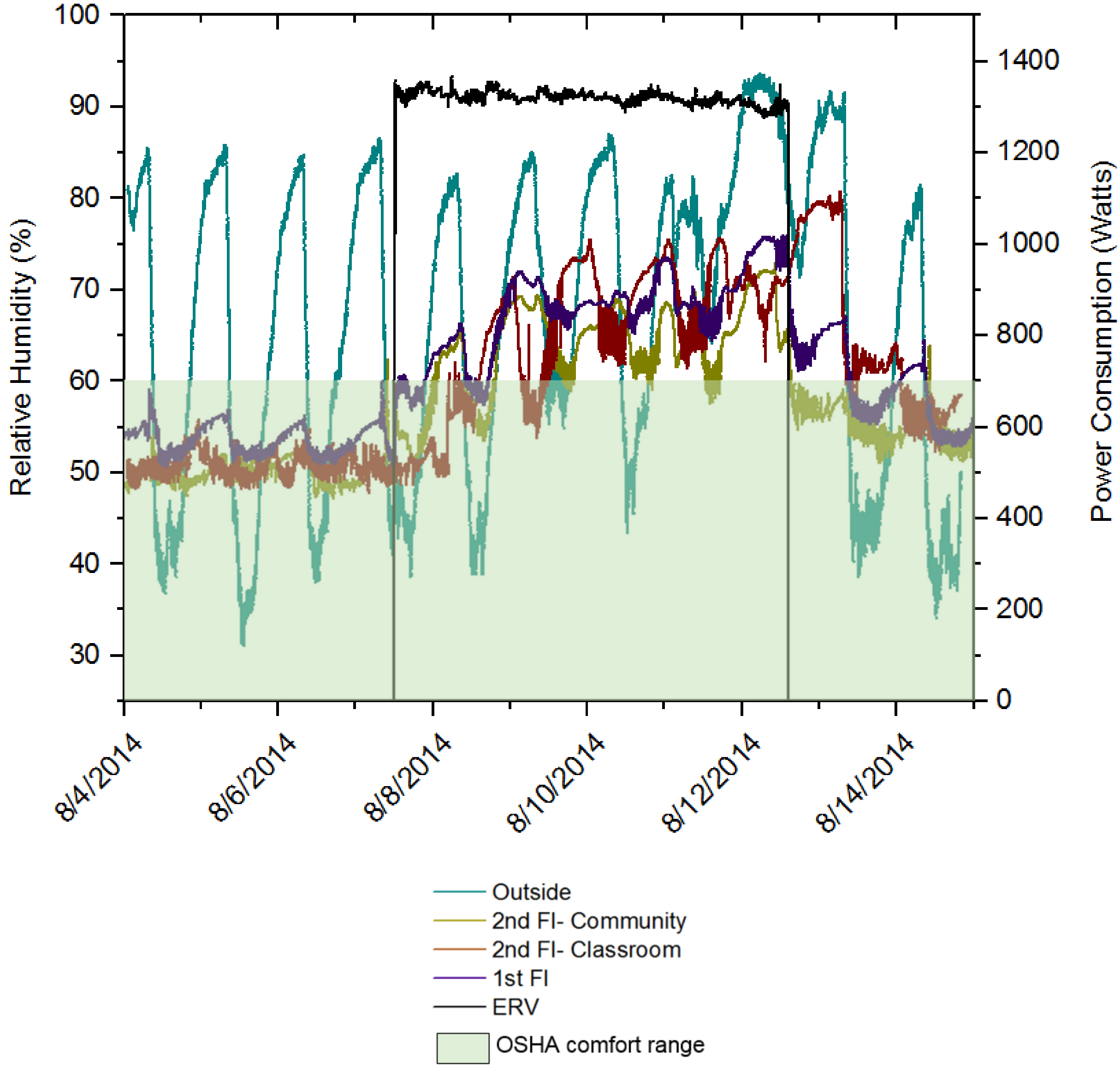

Figure 14: Interior and Exterior Relative Humidity during ERV Operation

The graph below shows the interior and exterior absolute humidity levels during the same time range. When the ERV is operating, interior absolute humidity levels converge with exterior absolute humidity levels.

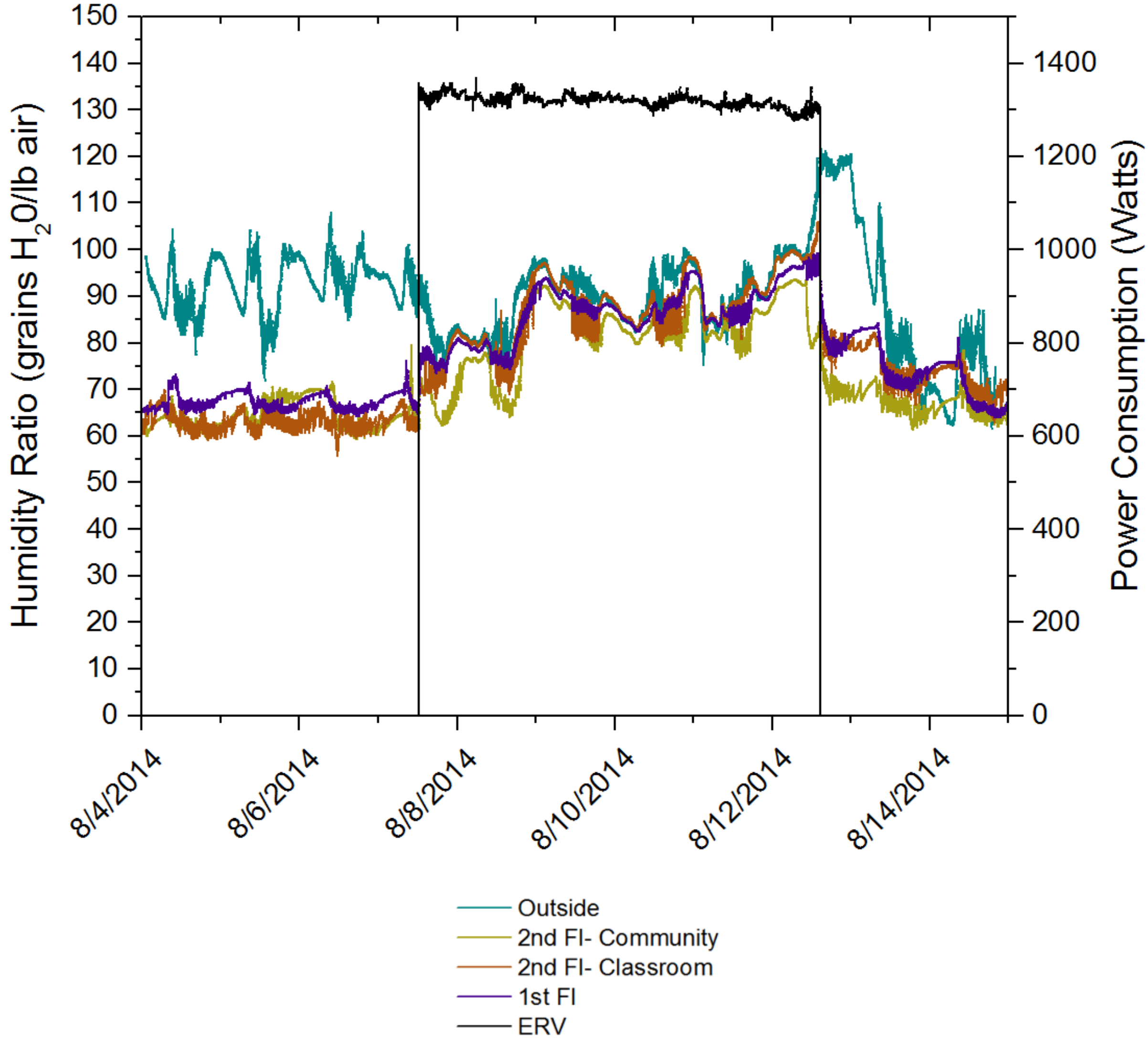

Figure 15: Interior and Exterior Humidity Ratio during ERV Operation

The following details several observations from Figure 14 and Figure 15:

ERV controls: The ERV is equipped with a wall mounted digital timer switch. The timer switch allows the ERV to be programmed with up to 8 on/off cycles per day or 56 per week[7].The ERV timer switch was not utilized, and it operated throughout the night when the building was unoccupied and the air conditioning was rarely operating. By bringing in outdoor air during periods of minimal dehumidification through air conditioner operation, humidity levels rose inside the building during the night.

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[7] http://www.solerpalau-usa.com/Brochures/Residential_Light_Comm/ERV_HRV_Brochure.pdf

AHU controls: Air handler fan mode during ERV operation was set to "auto". The manufacturer specifies that with the installed ERV ducting configuration, AHU fan mode should be set to "on" during ERV operation (Figure 13). Air handler fan operation during ERV operation prevents the ERV supply air from short circuiting and going directly into the ERV return duct nearby. Short circuiting of the ERV supply air will drastically reduce ERV efficiency.

Building comfort and durability: Building comfort is dependent on air temperature and humidity levels. When outside air was introduced into the building, interior relative humidity levels clearly exceeded the comfortable range specified by OSHA. Sustained high levels of relative humidity (>70%) also poses a risk for mold growth[8]. Prior to the ERV's activation, interior relative humidity remained within OSHA-defined comfortable conditions, and rarely exceeded 60% in any zone.

ERV duct configuration: The installed ERV ducting configuration (third option in Figure 13) is dependent on the air handler running in "on" mode when the building is occupied. The first and second options in Figure 13 do not rely on air handler fan operation, and will lead to decreased air handler energy use if implemented.

ERV flow rate: The nominal flow rate of the S&P USA TRC800-230 ERV is 800 cubic feet per minute (CFM). Given the design occupancy in Table 3, building ventilation rates are reasonable per ASHRAE 62.1 Standard for Ventilation for Acceptable Indoor Air Quality. Actual building occupancy rates should be reviewed to determine if the design occupancy reflects actual building operations.

The contractor HVAC load calculations, which include outside ventilation air, were compared against the cooling capacities for the installed equipment in Table 4 to evaluate potential design issues with regards to humidity control issues. The installed HVAC equipment has a sensible cooling capacity of 54,500 Btu/hr, which is a nearly perfect match to the calculated sensible cooling load of 54,510 Btu/hr. However, latent cooling capacity at peak design conditions is 10,682 Btu/hr lower than the total latent cooling load, and does not appear to be adequate to sufficiently dehumidify the air at design outside air flowrates.

[8] http://buildingscience.com/documents/reports/rr-0203-relative-humidity/view

Table 4: Cooling Equipment Capacity and Building Load Comparison

Unit	Total Cooling (Btu/hr)	Sensible Cooling (Btu/hr)	Latent Cooling (Btu/hr)	Outside Air (CFM)
HP-1	18,700	14,400	4,300	125
HP-2	24,200	18,300	5,900	350
HP-3	30,000	21,800	8,200	305
Total Installed Equipment Capacity	**72,900**	**54,500**	**18,400**	**780**
Total Building Load	**83,592**	**54,510**	**29,082**	**820**
Difference	**10,692**	**(10)**	**(10,682)**	**(40)**

6.4.3 Recommendations

Overall, it is recommended that the ERV be utilized to provide fresh air to the occupants, meet ventilation code, and improve indoor air quality. The following recommendations involve changes to the ERV and air handler systems, and aim to reduce the risk of uncomfortable and unsafe humidity levels in the building as experienced during ERV operations in August 2014. The first recommendation offers two pathways, which are dependent on whether the ERV configuration is adjusted. It is highly recommended that the ERV ducting configuration is changed (Pathway 1), however if this is not feasible, recommendations without changes to the ducts are provided in Pathway 2.

1) ERV Recommendations

   1. **Pathway 1: Change ERV ducting configuration.**
      - Retrofit the existing ERV return ducts so that the ERV return duct is not located next to the ERV supply in the AHU return. Relocate the ERV return ducts so that it returns air from a main space (office, classroom). This follows option 2 recommended by the manufacturer.
      - Operate AHU fans on "auto" mode at all times.

   2. **Pathway 2: No change to ERV ducting configuration.**
      - Program all three AHU thermostats to run in "on" mode when the ERV is operational (i.e., when the building is occupied), as recommended by the manufacturer.

   For both Pathways 1 and 2, the following should be reviewed/implemented:

      - Utilize the existing ERV digital timer switch controls to ensure the ERV only runs when the building is occupied

- Determine if the design occupancy rates (First floor = 13 people, second floor = 66 people), reflects actual building occupancy. If actual occupancy is lower than design occupancy, the client's mechanical designer/contractor should determine the appropriate ventilation rate for the building based on the actual occupancy. Ventilation rates with the existing ERV can be reduced by adjusting the digital timer switch controls, or adjusting the damper position.

- Program all thermostats so the unoccupied cooling set-points (i.e., the setback) switch to the occupied cooling set-points prior to building occupation (approximately an hour beforehand). This will allow for additional cooling and dehumidification for the building to be comfortable when occupants first arrive.

- Add greater moisture removal capacity by installing a supplemental in-line dehumidifier to the outside air stream which supplies the ERV.

2) Air Handler Recommendations

- The installed air handling units feature an ECM supply fan with adjustable fan speeds. Adjust all air handler DIP switch settings to enable the fan to operate at a reduced speed. Reducing the fan speed can increase latent cooling by increasing the contact time between the supply air and the cooling coil.

- Add greater cooling capacity by replacing the evaporator coil in the existing air handler unit with a coil designed to deliver greater latent cooling capacity.

6.5 Replace the evaporator coil in the existing air handling units with a coil designed to deliver greater latent cooling capacity. Additional Areas For Potential Energy Savings

Based on review of all available data, Southface has highlighted several areas with energy savings potential where points were not necessarily earned in the ECLC program. These suggestions are specific to this project, based on observations from energy consumption trends.

6.5.1 ES 25 ENERGY STAR Labeled Appliances and Equipment - Option B. Computers and Electronics

Develop a sustainable purchasing policy for future purchases of computers and electronics to only allow ENERGY STAR labeled in order to reduce building plug loads.

- Recommend purchase of laptop computers rather than desktop computers as an energy savings measure.

- Set all computers to utilize the sleep mode when not in use.

6.5.2 IO 3 Innovation Strategy

Provide staff with task lighting to facilitate improved job-specific lighting and reduction of overhead interior lighting demand.

6.5.3 EO 2 Facility Operations Manual

Recommend for facility management to create/expand on manual.

6.5.4 EO R2 Provide Maintenance Schedule to Owner/Occupant

Recommend to expand Community Housing Partner's (CHP) Employee Manual to include information on best practices for employee engagement and ownership with energy efficiency. Educate occupants on their impact on the building energy and water consumption.

6.5.5 Monitoring Continuation

Recommend continuation of monitoring. Two-year subscription, including user-friendly dashboard to be shared with client is $350. This will allow Southface and client to measure impact of improvement measures. Also, potential to engage Southface in performance coaching and check-up.