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Energy Measurement and Verification of Building Energy Reduction Measures at an FDACS Facility



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Florida Energy Investment Collaborative Project

Report on Energy Measurement and Verification of Building Energy Reduction Measures at an FDACS Facility









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Executive Summary

This report covers the process and results of a building energy study conducted in a state-owned commercial building utilized for office and laboratory operations. The energy evaluation process is covered from the initial Level 1 energy audit results, energy study methodology, recommended energy saving measures (ESM), implemented ESM, and the measured impacts from implemented ESM.

This effort covers one aspect of a wider effort to assist state and local governments in their goals towards implementing cost-effective energy reduction efforts. The Florida Energy Investment Collaboration (FEIC) project is a partnership between the Florida Solar Energy Center and the Florida Department of Agriculture and Consumer Services Office of Energy with the primary goal to help local governments identify, prioritize, and schedule cost-effective options to meet their energy goals. The energy monitoring project served two-fold. One was to assist the state in improving energy sustainable practices at prioritized facilities. The second was to measure and verify cost-effective ESM that demonstrate responsible use of public resources that can be used to promote and increase confidence in small and local governments pursuing more energy sustainable operations.

Four ESM were recommended during the energy monitoring period and two were able to be implemented, although the LED lighting retrofit could not be implemented in its entirety. Space heating and cooling thermostat setback control, and a small-scale LED retrofit were able to be completed within the energy study period. Thermostat setback control is the practice of scheduling higher cooling and lower heating setpoints during non-business periods.

The project found that the lighting retrofit and thermostat setbacks were very cost-effective. The simple payback of the LED lighting retrofit was 4.4 years. The payback of thermostat setback was less than one year. Annual cooling energy reductions of 24% are possible from thermostat setback control in central Florida. However, the project learned that specific cooling zones with a large amount of heat generating equipment (such as the lab in one zone) may have negative weekday cooling setback savings. Some guidance is discussed within the report to assist in predicting the potential cooling energy savings percent based upon the time-weighted thermostat schedules of a setback. The savings potential is also applicable to any new building built after energy codes required heating and cooling equipment thermostat control capable of managing night and weekend setbacks. While the control may be present, it may not be utilizing its full potential as demonstrated in this study. The obtained savings from thermostat setback were accomplished without altering the occupied setpoints occupants were used to and as expected there were no reported comforts complaints.

The pros and cons of two different energy measurement methods are also discussed. It is expensive to install individual energy meters in small commercial buildings. The meters and data collection also require someone to analyze data. Energy utility companies are already

collecting whole building or facility data that is available at no cost. Utility data is typically available at approximately monthly intervals. Using monthly building data may be possible for measurement and verification, but has limitations that should be considered by someone experienced in analyzing such data. There was not enough time to acquire a full year after the thermostat setback ESM to allow the best possible utility billing analysis. There were five months available which allowed the methodology to be demonstrated and compared to the sub metered energy analysis. This comparison resulted in specific factors to be demonstrated that must be considered by others planning to measure and verify energy impacts from ESM.

Introduction

Building energy Measurement and Verification (M&V) is an important part of being able to identify if systems are working within expected levels. M & V may also be a requirement within some energy conservation programs or grants that provide funds toward energy reduction retrofits. M &V is a keystone of contracting with Energy Service Companies business (ESCOs) that are paid for service through energy reduction savings. The FEIC project conducted a demonstration of energy monitoring before and after energy reduction measures at a Florida Department of Agriculture and Consumer Services (FDACS) owned and operated building. This effort was the fourth task of a five-task project. This report provides details about the whole energy evaluation process for one building that covers:

- Starting with a Level 1 energy audit including energy utility billing analysis
- Installing energy meters on specific building systems as well as temperature and humidity sensors in zones months prior to making improvements
- Making recommended energy savings measures (ESM) during the monitoring period
- Reporting energy reduction results of implemented ESM using two different levels of monitoring and analysis

Not all recommended ESM were able to be implemented during the monitoring process. Due to limited study time and late ESM implementation, ESM that impacted cooling and heating systems were not able to be monitored during peak summer conditions after implementation, which involved more analysis than may be required otherwise. The level of analysis is covered in fair detail as a means for consideration by others that may also lack the benefit of a full year before and after ESM for analysis.

Energy savings analysis was performed using two different levels of data. The first involved using energy utility billing data since this is the most common and least expensive method of measuring energy use. However, billing data usually does not provide the resolution or accuracy to determine the impact of individual improvements especially when multiple improvements occur within the same year. The second method involved installing individual energy meters on lighting and HVAC systems several months prior to making any improvements and then monitoring after improvements. This method is also referred to as sub metering within this report.

Energy Monitored Facility Description

After FSEC completed energy audits at five different FDACS facilities around the state of Florida, FDACS selected the Winter Haven Plant Industry site to be used for this energy impact demonstration project. An aerial view of the whole complex consisting of offices and labs as well as several unconditioned greenhouses and shop facilities is shown in Figure 1. The primary business function is to inspect and study various types of citrus plants with a focus on pest eradication and control within Florida. This includes an environmentally controlled budding lab that provides the genesis for potential new cultivars of commercial citrus in Florida. Much of the grounds are used to grow more than 250 cultivars of citrus.



Figure 1. Aerial view of the Winter Haven Plant Industry site with the Cowperthwaite office and lab buildings within red rectangle.



Figure 2. Cowperthwaite Buildings as they looked sometime after original construction in the 1950s.



Figure 3. Buildings after roof and window renovations at the time of energy audit study.

The Cowperthwaite facility building was the primary focus of energy assessments. The total conditioned area is 7,452 ft^2 and the total gross area under roof is 8,651 ft^2. The gross area under the roof includes covered parking and entry areas as well as an exterior mechanical room. The original building was built in the late 1950's. The original structure (Figure 2) has had major energy-impacting improvements over several years. Figure 3 shows an exterior view of the southwest side after major roof and window renovations. Daily operations at the Cowperthwaite facility occur from 8am-5pm Monday through Friday. There are no typical

business operations on the weekend. The Cowperthwaite building is comprised of two building sections connected by a short corridor. Each building section will be referred to as the east and west buildings or by the space conditioning zone from hereon. Figure 4 shows a floorplan view with highlighted zones. Each zone is conditioned by its own central ducted split-DX heat pump systems. The NW and SW zones each had identical four ton cooling systems. The SE zone had a two-stage cooling system with a total of ten tons of cooling capacity. The thermostats for each zone are shown in Figure 4 as red circles. The east building houses the budding lab, a conference space, and some offices as well as two bathrooms. The west building has office space with two bathrooms. The occupancy varies through the day as inspectors leave offices to go out to perform site visits.

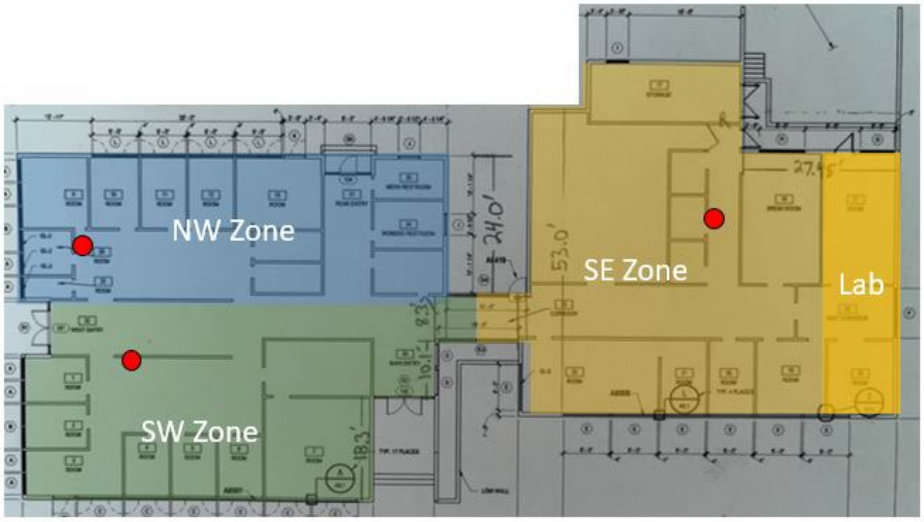


Figure 4. Cowperthwaite floorplan with the three space conditioning zones and thermostat locations indicated with red circles.

Energy Audit Summary

A level 1 energy audit was completed on March 8, 2023. The building was maintained well with regularly scheduled air filter replacement of the HVAC systems. It was comfortable, clean, and dry. Measurement of illumination at representative locations showed that spaces were adequately illuminated at the time of the energy audit. The energy audit found the following significant findings:

- In 2007 a new trussed metal roof was built over the existing flat built-up roof with R19 insulation added to the metal roof deck noted on plans.
- HVAC ductwork was replaced with R6 insulated ducts in 2010.
- The age of the heat pump systems could not be determined, but were found to be approximately 8-10 years old, in good working condition, but likely approaching end of life in a few more years.
- Beginning in 2021, three different major renovations occurred to windows, walls and lighting. The renovations spanned from approximately fall 2021 through spring 2022.
    - Original single-pane clear jalousie windows were replaced with double-pane, low-emissivity tinted insulated glass units, and thermal blinds were added.

- Exterior block walls had moisture retarder added to control moisture issues, ~R3 wall insulation added and covered by painted drywall on the interior side of the wall in office spaces.
- East building fluorescent T8 lamp and fixture lighting was changed to LED lamps and fixtures. Existing 2' x 4' troffer fluorescent fixtures used LED lamps with ballast bypass. The site manager indicated that lighting retrofits to LED in the west building were also planned in the future.
- Occupancy lighting control were installed in the east conference and east and west bathrooms.

The adjusted 2022 total annual energy use was 132,276 kWh. Normalizing the site energy use by conditioned area established an energy use intensity (EUI) which can be compared to other buildings of similar use and size. The EUI was 52.2 kBtu/ft^2/yr. The summary of site energy use, EUI, and utility cost is shown in Table 1. Utility cost of energy (kWh) includes non-fuel, fuel, and any other cost that is associated with kWh consumption.

Table 1 2022 Adjusted Energy Use Summary

Floor Area (ft^2)	Annual kWh	Annual Peak kW (max / avg)	EUI kBtu/ft^2/yr	$/kWh	$/peak kW
8,651	132,276	(37 / 34)*	52.2	$0.04992	$16.53

* 37 kW based on estimate disregarding winter 2022 anomaly of 51kW

This site is comprised of about 90% office space and approximately 10% laboratory space with relatively low exhaust and ventilation requirements compared to whole buildings classified as laboratories. The electric baseload energy use is about 10%-15% higher than most office buildings which is believed to be due to the lab appliances. Since much of the Cowperthwaite building offices support work beyond the bud lab, we suggest comparing this site EUI of 52.2 to a hybrid weighted EUI consisting of 90% office and 10% lab.

Table 2 shows different published sources of historical existing EUI data as well as the EUI target goal of net zero energy (NZE) for office and also for lab spaces. Net zero energy is where building energy efficiency and conservation are used along with renewable energy such that the net annual energy consumption is near zero. The NZE target goal EUI reflects the utility energy use without renewable energy accounted for. For fairer comparison, the weighted hybrid EUI comparison was derived once for existing buildings and also for the NZE target.

THE ENERGY REDUCTION MEASURES ALREADY IMPLEMENTED IN THIS FACILITY PRIOR TO THE ENERGY AUDIT RESULTED IN AN EUI LOW ENOUGH, THAT THE LBNL BENCHMARK TOOL CONSIDERS THIS BUILDING OPERATING AT BEST PRACTICE. HOWEVER MORE ENERGY REDUCTION OPPORTUNITIES STILL EXISTED.

LBNL LABS 2 ZERO HTTPS://LBT.I2SL.ORG/

Lawrence Berkeley National Lab (LBNL) considers a lab EUI less than the 10th percentile of peer group using the LBNL Laboratory Benchmark Tool (LBT) to be operating at "Best practice". The

LBNL LBT peer group consists of 92 different Bio/Chem labs located in hot humid climate zones 1A, 2A, and 3A (southeast United States). The 10th percentile EUI of this group is 169 kBtu/ft^2/y.

The Winter Haven Plant Industry Cowperthwaite Building EUI of 52.2. is less than the derived existing building hybrid of 64.5, which indicates that it is more efficient than existing buildings similar in use. With further energy efficiency improvement, the EUI could be reduced closer to the NZE weighted target EUI of 31.

Table 2 EUI Comparison to Office, Lab, and Weighted Hybrid Spaces for Existing and NZE Target Goals

EUI of Existing Buildings of Various Age (kBtu/ft^2/yr)			EUI of NZE Target Goal (kBtu/ft^2/yr)		
Office CBECS Data (peer)	Lab LBL/LBT S.E. U.S. 10th percentile (peer)	Weighted EUI 90% Office CBECS & 10% 10th prcnt. Lab	Office NZE (FL)	Lab NZE	Weighted EUI 90% Office 10% Lab
52.9	169	64.5	23	<100	31

A linear regression analysis was conducted with data from the monthly utility bills which were provided for the Winter Haven Plant Industry site, to estimate the amount of heating, cooling, and baseload energy used at the site monthly and annually. The model predicted an annual baseload energy use that is about 79,507 kWh/y (60% of total), cooling energy of about 48,758 kWh/y (37%) and heating of about 3,866 kWh/y (3%). The baseload was mostly lighting, budwood lab operations as well as other plug loads. Cooling energy is the single largest use during the summer months. Indicated heating energy use is modest as is normal for central Florida offices. The existing electric heat pumps heating the space are much more efficient than electric strip heat and are already helping to keep heating costs lower.

Based upon the energy audit several recommendations were made. The most important recommended energy savings measures were:

1. Upgrade all remaining fluorescent lights with LED lamps and fixtures. Offices with exterior windows should have LED lamps or LED fixtures compatible with dimming control.
2. Install lighting control in offices that dim with adequate daylight and turn off when there is no occupancy.
3. Replace existing heat pump systems at end of life with new heat pumps having a seasonal energy efficiency ratio (SEER) rating of at least 17 and a heating seasonal performance factor (HSPF) of at least 9. Size cooling capacity appropriately for ASHRAE Ventilation Standard 62.1 mechanical ventilation and refer to recommendation #8.
4. Raise the occupied cooling set point to no lower than 73°F. The nighttime cooling temperature setback should be raised to 80°F. To begin the higher occupied setpoint, try a gradual increase of 1 degree per week from 69°F to 73°F over 4 weeks. There is approximately 8% cooling energy decrease for every degree of cooling set point increase. Cooling energy could potentially decrease by 32% from an increase of 4 degrees in setpoint. This is a conservation measure with no implementation cost,

however thermal inefficiency of the building may result in local discomfort that could impact productivity thereby rendering this recommendation unacceptable.

Energy Monitoring Results

Following the energy audit, the energy audit recommendations and discussions with the facility managers were used to identify systems considered highest priority of improving within about a year allotted for the monitoring project. Monitoring equipment was installed that allowed greater detail analysis than the Level 1 Energy Audit permitted, which enabled lighting and HVAC energy use patterns to be identified. This information was used to write an energy retrofit recommendation and schedule for consideration during the FEIC project. This section provides details on the monitoring process, retrofit recommendations, implemented retrofits and energy savings measured from retrofits.

Energy Monitoring Process

The FDACS chose the Winter Haven Plant Industry site for the energy monitoring demonstration project in the first quarter of 2024. Energy meters as well as indoor temperature and humidity sensors were installed and pre-retrofit data collection began April 25, 2024. Monitoring ended April 19, 2025. Figure 5 shows and example of some of the monitoring equipment used. There were three different central ducted split-DX heat pump systems serving the building. The energy of every outside condensing unit as well as indoor air handling unit had a dedicated energy meter. All lighting in the west side building also had an energy meter. The east side building had previously converted to LED lighting prior to this study so this energy was not sub metered. The indoor temperature and humidity were measured at each thermostat as well as in a few additional locations representative of exterior offices, conference room and the laboratory. Carbon dioxide measurement within the closet return was also measured as a metric representative of the west building relative occupancy where most of the occupancy occurs to observe significant long-term changes in occupancy patterns that may impact energy use. Periodic site visits were conducted to verify if any significant changes had occurred to the study building and to make additional site test measurements. Illumination levels were measured with hand held devices throughout the building in anticipation of LED lighting retrofits to enable

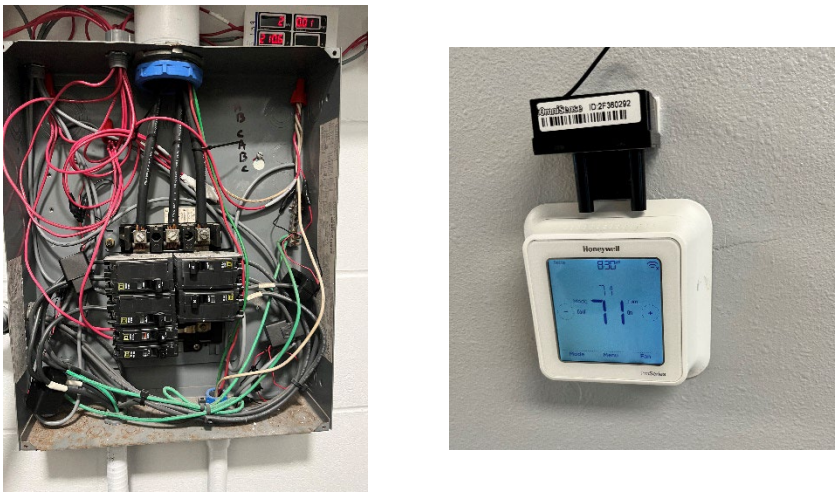


Figure 5. Beginning of energy meter installation on sub metered equipment shown at left and a temperature and humidity sensor above one of the thermostats shown at right.

pre-post retrofit comparisons. Infrared thermography was also completed within cooling zones found to have large air temperature differences between rooms.

Although this site had already begun a gradual process of energy efficiency improvements prior to the FEIC project involvement and had a relatively low EUI for a building with lab operations, there was still an opportunity for energy efficiency improvements. Approximately half of the building still had old T8 Fluorescent light fixtures. Energy monitoring confirmed the practice of habitual long-term overcooling, the need for proactive maintenance on a ten-ton cooling system, and zonal temperature distribution problems with the SE zone served by the ten-ton cooling system. Monitoring lighting and HVAC as well as zonal indoor air temperature and humidity enabled the FEIC project to confirm that lighting and cooling energy schedules were very consistent. Non-essential indoor lighting was regularly turned off (mostly manually) during unoccupied periods demonstrating good lighting control even though much had to be manually controlled. The lighting use schedule was also observed to be very consistent.

Heating and cooling however did not have efficient thermostat control schedules. Heating and cooling setpoints were set at fixed temperatures and not changed even though the thermostats had full weekday and weekend programmable capability.

The energy monitoring effort provided additional information that the Level 1 energy audit had to make assumptions about. For example, the light and cooling schedule trends as well as cooling setpoints were measured. Problems with distribution effectiveness and inefficient AHU fan operation were also verified. Site visits and monitoring verified:

- Very low cooling setpoints between 71°F – 73°F were left unchanged for several months in all zones.
- The air handler unit (AHU) fan of the SE zone unit was always left on instead of cycling on and off with cooling cycles. Facilities staff did this intentionally since it made a very loud belt screeching sound of short duration at the start of every on cycle that was startling. Research staff confirmed it was indeed a startling noise.
- Portions of the SE zone were unoccupied and grossly overcooled while the lab space was still very warm.
- Indoor humidity control was very good. This was somewhat unexpected in the SE zone given that the AHU fan was constantly on which prior research has shown can result in poorer humidity control as the airflow over a warm condenser coil re-evaporates moisture back into the air stream during off-cycles.
- Research staff believe the good humidity control in the SE zone was fortunately due to this zone having two-stage cooling with two separate coils, low cooling setpoint, and very high internal cooling load generation. This combination resulted in the first stage of cooling being engaged most of the time during hot weather. Normally any fixed-capacity air conditioner operated with the fan on during cooling off-cycles will have higher indoor humidity and it is recommended to operate with the fan in the “auto” setting cycling on and off with cooling cycles.

Energy Efficiency Improvement Plan

An Energy Efficiency Improvement Plan was submitted to the facility Director and Manager in September 2024 to consider implementation during the monitoring project.
Following are the recommended improvements requested to be made during the energy monitoring project. They were listed from highest priority to lowest along with the target time for implementation.

1. Implement unoccupied cooling and heating thermostat setback temperatures. This is to be completed using existing programming thermostats for night and weekend unoccupied periods. This will lower cooling load and reduce cooling energy use during unoccupied periods. Thermostat setback is simply raising cooling setpoints and lowering heating setpoints during scheduled unoccupied periods.
    - FSEC/UCF to schedule and complete ASAP.
2. Repair east building Daikin AHU fan drive to eliminate start-up screech sound of belt slippage. This will eliminate need for continuous fan on operation, which wastes energy when there is no active cooling cycle.
    - FDACS/Cowperthwaite to cover costs and complete ASAP.
3. See if remaining fixtures in West building can have LED change-out before December 31, 2025. Replacement of existing old T8 fluorescent lamps with LED equivalents may reduce light power use by 38%.
    - FDACS/Cowperthwaite to cover costs.
4. Get quotes for installing a high efficiency ductless minisplit AC in the East building lab ASAP. If feasible, implement no later than November 2024.
    - FEIC project can provide up to $5,000 toward this.

Ductless minisplit AC Justification

The east building is cooled by a single central ducted Daikin heat pump system. The cooling setpoint is at 71°F during business hours. This low setpoint is needed to help cool the lab space, which currently runs between 3-12 degrees warmer than the setpoint. The southern side of the lab is about 12 degrees warmer than setpoint due to the heat given off by essential lab equipment in this area. The Daikin central system cools the lab space, a couple offices, and a conference room. There is no zone control on the central ducted system resulting in empty conference room maintained at 68°F and office spaces at 68°F - 72°F. Indoor temperature data recently taken is shown in Figure 6 below illustrating the wide thermal distribution.
A new ductless minisplit AC located on the southern wall of the lab unit would provide zonal control of the lab and also enable the central system setpoint to be raised a few degrees during business hours on the average work day. Figure 7 shows two sets of IR images. One of the hot lab areas and the other of the overcooled conference room cooled by the same central ducted AC system.

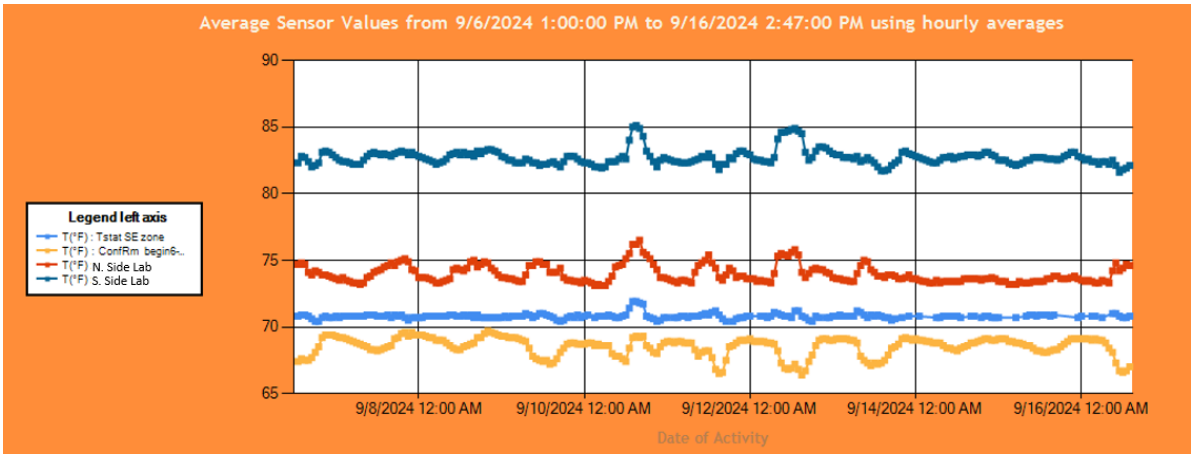
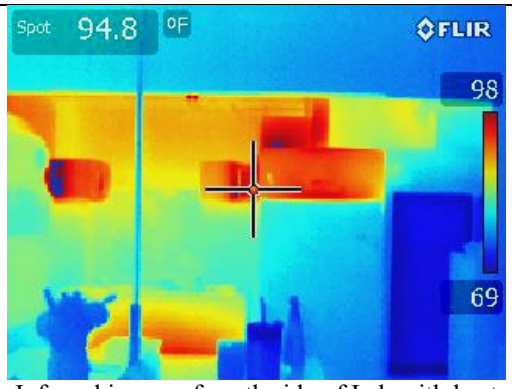


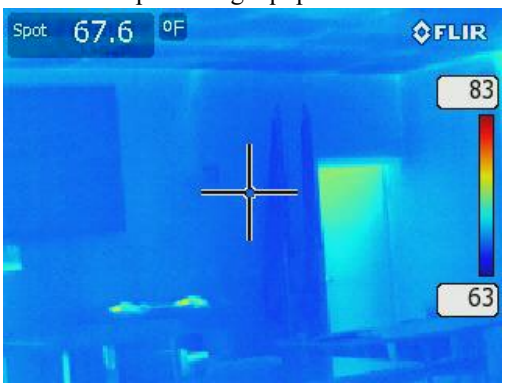
Figure 6. Indoor temperature in East side building (SE zone) over ten summer days with thermostat set at 71°F.



Infrared image of south side of Lab with heat producing equipment.



Photo image of IR shown to the left.



Infrared image of over-cooled conference room.

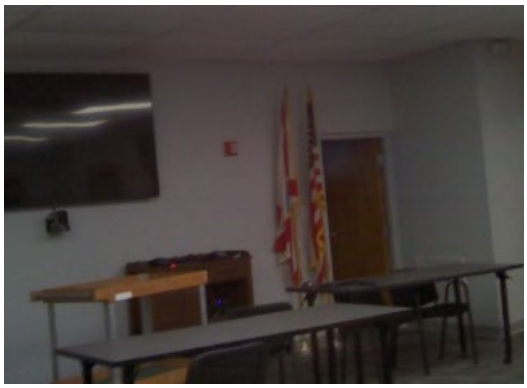


Photo image of IR shown to the left.

Figure 7. Examples of very warm and very cool surfaces in different rooms within the east side of Cowperthwaite building using infrared imaging.

Figure 8 shows the wall outlined in red box where the AC unit may be able to be installed. Raising the central AC setpoint 2 degrees may reduce cooling energy by about 16%. The cooling provided into the lab by the minisplit AC would be about 42% more efficient if it has a seasonal

efficiency SEER2 of at least 20 compared to the approximately SEER 14 rating of the Daikin system.



Figure 8. View of south wall in south side of lab where the indoor unit of a ductless minisplit could be considered for installation.

A cooling system with 12,000 to 18,000 btu/h capacity would be adequate for assisting in meeting the load in the lab space since air from the main central system would still be provided to the lab. The east side main electric service panel currently has two spare 20 amp breakers that could be used to power the ductless minisplit and only one of these may be required if a 115 volt system is installed. There are very high efficiency (SEER2=20) systems with 12,000 btu/h cooling capacity that only require 115 volt service on a 20 amp breaker. It is recommended to stay with a system that does not require changing the breakers given the age of the existing east service panel. Ideally, the whole east building service panel would be upgraded to a modern panel design with more load capacity.

Implemented Energy Saving Measures

Half of the recommended ESM were able to be completed during the monitoring period. The thermostat setback (priority 1), and a small sample of lighting retrofit from fluorescent T8 to LED lamps (priority 3) were able to be implemented. The second highest priority of maintenance on the SE zone AHU fan belt and pulley never occurred. FEIC project staff had been notified that this was scheduled to be taken care of October 1 during a scheduled maintenance on all HVAC units. For unknown reasons, this repair did not occur, the fan continued to remain in ON setting, and Winter Haven site staff did not verify if work was completed. Ongoing monitoring data review demonstrated to FEIC project staff the fan was not in AUTO mode and Winter Haven staff were notified on a few more occasions. Again for unknown reason, Winter Haven facilities never had the fan maintenance completed for the duration of the project.

The zoning efficiency improvement based on installation of a ductless minisplit AC system in the lab (priority 4) was not able to be completed due to high cost. Quotes for this work to install one ductless minisplit unit with 18,000 Btu/h cooling capacity in the lab were too high to justify the cost based on energy savings alone. The total cost was about $7,000 with $5,000 to install the minisplit and another $2,000 to run the electric service to the outdoor unit. If there had

been more time, we may have been able to find a contractor that installs these regularly at a more reasonable cost, however, the old 1950's era electric panel may have played a factor in the elevated electric service cost. There were no complicated runs of refrigerant lines or electric service to explain the elevated cost. The current retail cost for an established brand minisplit including refrigerant line set and condensation line is under $3,000 (not including installation or running electric service to unit).

Thermostat Setback During Unoccupied Periods

Prior to any changes, indoor temperatures were consistently maintained very low between 71°F- 73°F in all three zones regardless of time of day or day of week despite each zone having programmable thermostat capability. All thermostats were located on interior walls as previously shown in Figure 4. The low cooling setpoints are likely to help maintain comfort in the perimeter offices where most occupants work. The window improvements from old jalousie to insulated glass were reported to have improved not only local comfort, but also pest control. However most exterior offices have a relatively high window to office floor area ratio with desks usually within six feet of the window. Thermal shades further improved radiative comfort and reduce monitor screen glare but do not stop thermal transfer of heated window and wall materials to the indoor air temperature. Figure 9 shows an IR image of a typical office space around the west building. This office wall has a northeast facing orientation with image taken during a sunny June afternoon. So thermostat setpoints of about 71°F to 73°F result in perimeter office air temperature around 74°F-76°F during the summer. The occupied temperature setpoints were not changed to avoid comfort complaints.

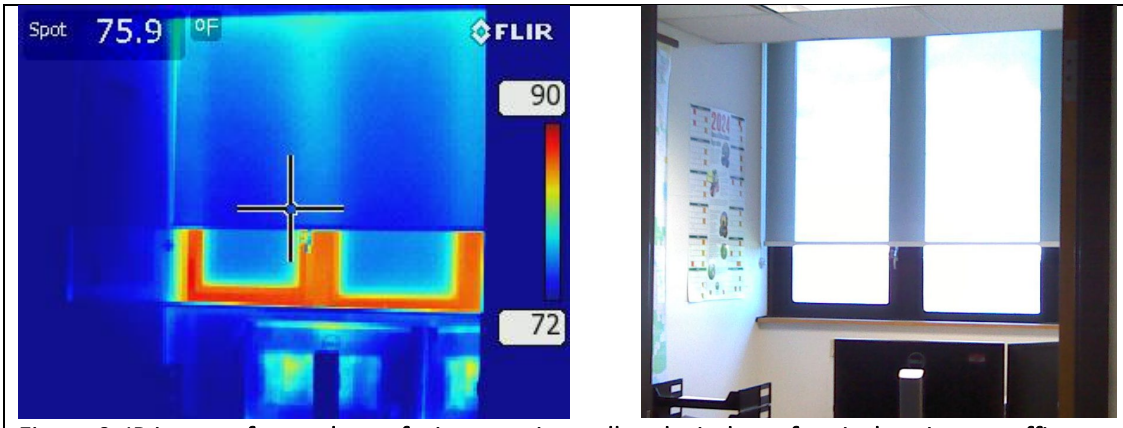


Figure 9. IR image of a northeast facing exterior wall and window of typical perimeter office.

The thermostat setback program initiated is shown in Table 3. Weekday occupied thermostat settings were not changed from what occupants were accustomed to. The greatest setbacks were all weekend long. The thermostats allow a temporary program override if occupants want to adjust comfort. There was no evidence that programs were manually overridden during weekdays or after normal business hours. On weekdays, the temperature was gradually brought down from 78°F to 71°F just prior to occupancy.

Table 3 Thermostat Schedule with Setback for Weekday and Weekends

WEEKDAY Schedule			WEEKEND Schedule		
Time	Cooling setpoint °F	Heating setpoint °F	Time	Cooling setpoint °F	Heating setpoint °F
04:00	75	63	06:00	80	60
05:00	72	63	08:00	80	60
07:00	71	65	18:00	80	60
17:00	78	60	22:00	80	60

Thermostat Setback Measured Temperatures

Figure 10 shows an image of one of the programmable thermostats along with a temperature and relative humidity sensor directly above it. Figure 11 shows daily average indoor temperatures at the thermostat locations of the three zones as well as the outdoor temperature. The upper and lower thermostat programmed cooling settings are noted in Figure 11 with dash blue line and dotted blue line respectively. The temperatures are shown from April 26, 2024 through March 6, 2025. Thermostat setback was first begun at the SW zone September 6, 2024. Setback could not be implemented on the other two thermostats at the same time as they were locked out and the programming feature could not be accessed until later. Setback programs began at the NE and SE zones on October 28, 2024. The highest spikes in temperature, after the setback was implemented, occurred during weekends with cooling setpoints at 80F. There was almost no cooling during weekends by November.



Figure 10. Programmable thermostat with a temperature and humidity monitor sensor.

The building was heavily cooling dominated and had relatively little heating. The SE zone only had four days with any heating cycles. The NE and SW zones had 22 days with any heating at all, but only 11 days (3% of the year) had heating cycles throughout the workday. The SE zone with large internal heat generation in the lab resulted in indoor temperatures approaching the weekend setpoint of 80°F much quicker than the other two office zones as shown in Figure 12. This extra build-up of heat in the SE zone resulted in no weekday energy savings in this specific AC system. The SW zone with good solar exposure during fall through spring had higher weekend daily average temperatures than the NE zone.

The setback programs did not result in any reported occupant complaints since the temperatures occupants were normally accustomed to were maintained during occupied periods. The program also began stages of cooling prior to occupancy so that the occupied temperature was reached by the beginning of each workday.

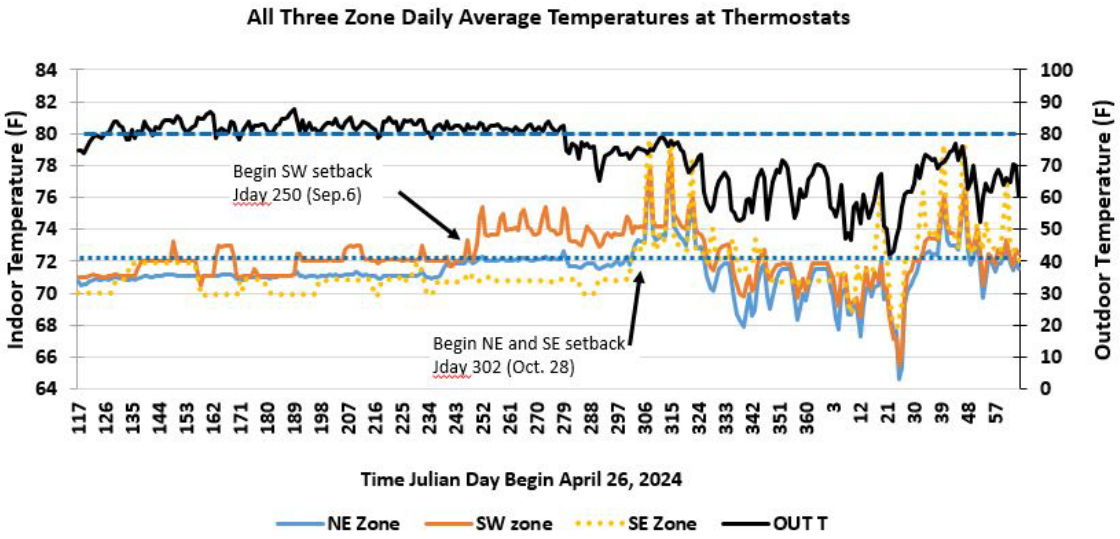


Figure 11. Measured indoor and outdoor temperature from April 2024 to March 2025.

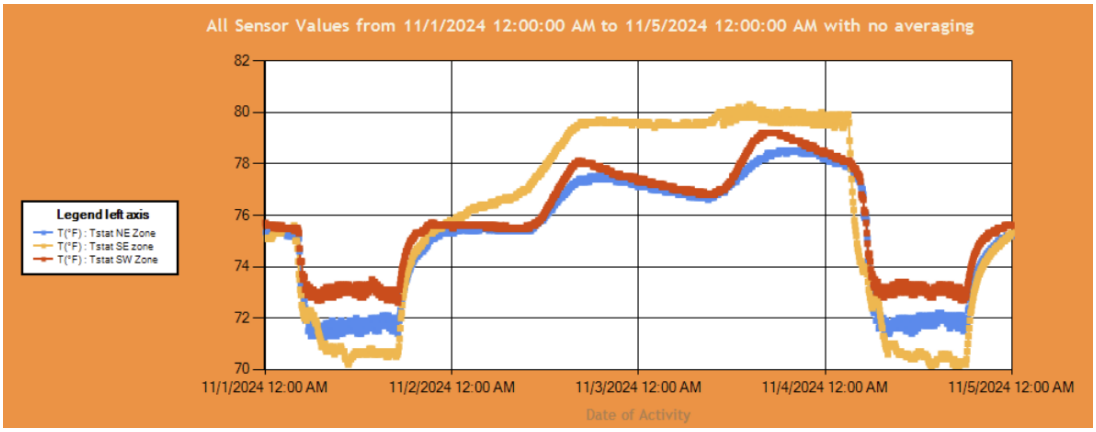


Figure 12. Indoor temperature in three zones with setback. Temperature rise in transition from Friday through the weekend and decline into the following Monday shows SE zone gains more heat over the weekend with all thermostats setback to 80°F during warm weather.

Thermostat Setback Measured Energy Impacts

It would have been ideal to have one year of energy data before and one year after implementing setback to evaluate measured savings so that each condition had similar weather conditions. At the least, it would have been better if changes could have been implemented by mid-summer so that each period had similar shoulder and summer season weather. The data analysis methods took into account the post setback data had some hot weather but not nearly as much as the pre setback period.

Analysis will be presented in two fundamental ways; 1) energy savings solely based upon the sub metered measurements, and 2) energy savings based solely upon monthly energy utility data. The sub metered method is more accurate, but more costly. The billing data method is less accurate, but costs much less and does not require any extra equipment. The billing

method was explored as this may be the only cost-effective option for small commercial buildings.

Setback Energy Savings Summary Based Upon Sub Metered Method

One of the main challenges in comparing energy consumption between the two operating modes was the difference in seasonal conditions during the measurement periods. Most of the no-setback data were collected during the summer and fall period of 2024, while the setback data were recorded during the fall through early spring period of 2024–2025. To determine the HVAC energy savings potential from the thermostat setback strategy, we employed two complementary approaches. The first method involved grouping sets of data only during warmer periods. A method, "k-means clustering" was utilized. This allowed not only a comparison of the cooling energy but also the resulting daily average indoor temperatures during setback during more seasonally warm weather. We were interested in this to determine an average percent savings per degree change in the actual indoor conditions. However, the first analytical method is insufficient for determining annual savings impacts. The second approach involved linear regression least-squares analysis of all available daily space conditioning energy use and daily outdoor temperature data. This enabled simple models to be developed that were used with historical local weather to predict space conditioning energy use for each day of the year. Details on the two sub meter analytical methods can be found in the Sub Meter Analysis section of Appendix A.

Setback Savings per Degree F

Energy savings from thermostat setbacks have been claimed to be 10%-25% energy reduction per degree F change in thermostat change in past study[1]. The FEIC energy study enabled an evaluation of the setback savings in a Florida office and lab building. The aforementioned "k-means clustering" method was used to assemble pre and post data having comparable warm weather. Results of the average daily HVAC energy with and without setback were compared with the corresponding daily average measured indoor air temperature. This was used to calculate the percent energy savings per degree of change in the measured air temperature. The difference between the thermostat settings was not used to calculate the change in temperature since that does not accurately represent the resulting air temperatures. The resulting air temperature depends upon the rate of heat transfer from interior materials to the air as well as the heat transfer between indoors and outdoors. This will vary from zone to zone.

A summary of results is shown for each of the three cooling systems during weekdays and weekends in Tables 4-6. The SE zone, consisting of the east side building including the very warm lab space indicated more energy use during weekdays with the setback. This is believed to be due to the extra heat generated in the lab that gets stored in some materials thereby increasing the cooling load. This demonstrates that it is important to consider internally-generated loads within spaces before implementing thermostat cooling setpoint setbacks. The other two zones NE and SW in the west building represent traditional office space and

[1] Katipamula et al. 2012. "Small- and Medium-Sized Commercial Building Monitoring and Controls Needs: A Scoping Study." PNNL. October 2012.

demonstrated excellent savings for a low-cost improvement. Table 7 shows the combination of all three zones together including the negative savings of the SE zone. Table 8 shows only the combination of the NE and SW zones, which would be more representative of the potential savings for a more traditional office without excessive indoor heat generating equipment. **Table 8 indicates weekday cooling energy savings of 24% and 12.7% cooling energy reduction per daily average degree F the indoor air is raised above the occupied setpoint. The weekend cooling energy savings of 98% and 21.3% cooling energy reduction per daily average degree F.** These results are within the indicated range claimed by Katipamula et al. 2012. However one does not necessarily know what the actual resulting average air temperatures may be after the setback. This makes using the time-weighted average thermostat setting the next best thing in predicting the setback savings. Based on the results in Table 8, the **weekday cooling energy savings of 6.9% cooling energy reduction per daily time-weighted average degree F the indoor air is raised above the occupied setpoint. The weekend cooling energy savings were 10.9% cooling energy reduction per daily time-weighted average degree F.**

Table 4 NE Zone Measured Indoor Air Temperature and Cooling Energy Savings

Thermostat Control	Average daily indoor temperature (ºF)	Average energy use (kWh/day)
Weekday No Setback	71.5	18.2
Weekday With Setback	72.8	14.5
Weekday energy savings		**20.3%**
Weekday average % reduction per indoor ºF raised		**15.6% / ºF**
Weekend No Setback	71.4	20.9
Weekend With Setback	76.5	0.29
Weekend energy savings		**98.6%**
Weekend average % reduction per indoor ºF raised		**19.3% / ºF**

Table 5 SW Zone Measured Indoor Air Temperature and Cooling Energy Savings

Thermostat Control	Average daily indoor temperature (ºF)	Average energy use (kWh/day)
Weekday No Setback	71.4	24.6
Weekday With Setback	73.9	18.0
Weekday energy savings		**26.8%**
Weekday average % reduction per indoor ºF raised		**10.7% / ºF**
Weekend No Setback	71.7	19.4
Weekend With Setback	75.8	0.6
Weekend energy savings		**96.9%**
Weekend average % reduction per indoor ºF raised		**23.6% / ºF**

Table 6 SE Zone Measured Indoor Air Temperature and Cooling Energy Savings

Thermostat Control	Average daily indoor temperature (ºF)	Average energy use (kWh/day)
Weekday No Setback	70.6	60.6
Weekday With Setback	72.9	66.2
Weekday energy savings		**-9.2%**
Weekday average % reduction per indoor ºF raised		**-4.0% / ºF**
Weekend No Setback	70.4	61.5
Weekend With Setback	77.9	25.4
Weekend energy savings		**58.7%**
Weekend average % reduction per indoor ºF raised		**7.8% / ºF**

Table 7 All Zones Combined Measured Air Temperature and Cooling Energy Savings

Thermostat Control	Average daily indoor temperature (ºF)	Average energy use (kWh/day)
Weekday No Setback in all three zones	71.2	34.47
Weekday With Setback in all three zones	73.2	32.90
Weekday energy savings		**4.5%**
Weekday average % reduction per indoor ºF raised		**2.2% / ºF**
Weekend No Setback in all three zones	71.2	33.93
Weekend With Setback in all three zones	76.7	8.76
Weekend energy savings		**74.2%**
Weekend average % reduction per indoor ºF raised		**13.3% / ºF**

Table 8 NE & SW Office Zones Combined Measured Air Temperature and Cooling Energy Savings

Thermostat Control	Average daily indoor temperature (ºF)	Average energy use (kWh/day)
Weekday No Setback in all three zones	71.5	21.40
Weekday With Setback in all three zones	73.4	16.25
Weekday energy savings		**24.1%**
Weekday average % reduction per measured indoor ºF raised		**12.7% / ºF**
Weekday average % reduction per indoor ºF raised based on time-weighted average thermostat setpoint temperature	***Weekday time-weighted setpoint average 74.5***	*24.1% / (74.5-71)=* ***6.9% / ºF***
Weekend No Setback in all three zones	71.6	20.15
Weekend With Setback in all three zones	76.2	0.45
Weekend energy savings		**97.8%**
Weekend average % reduction per measured indoor ºF raised		**21.3% / ºF**
Weekend average % reduction per indoor ºF raised based on time-weighted average thermostat setpoint temperature	***Weekday time-weighted setpoint average 80.0***	*97.8%/ (80-71)F =* ***10.9% / ºF***

Setback Annual Savings

The daily total cooling energy and daily average outdoor temperature were measured for months prior to and after implementing the setback changes on all three cooling systems. A least-squares best fit regression analysis was applied to the cooling energy versus outdoor temperature. Simple models were developed for each test case where local historical weather data for a full year was used to predict the daily cooling energy for every day of the year. An example of the measured data and regression analysis is shown in Figure 13 which features data from the NE zone. In Figure 13, “WD” is weekday and “WE” is weekend. More details on this analysis including the other zones are shown in the Sub Meter Analysis section of Appendix A.

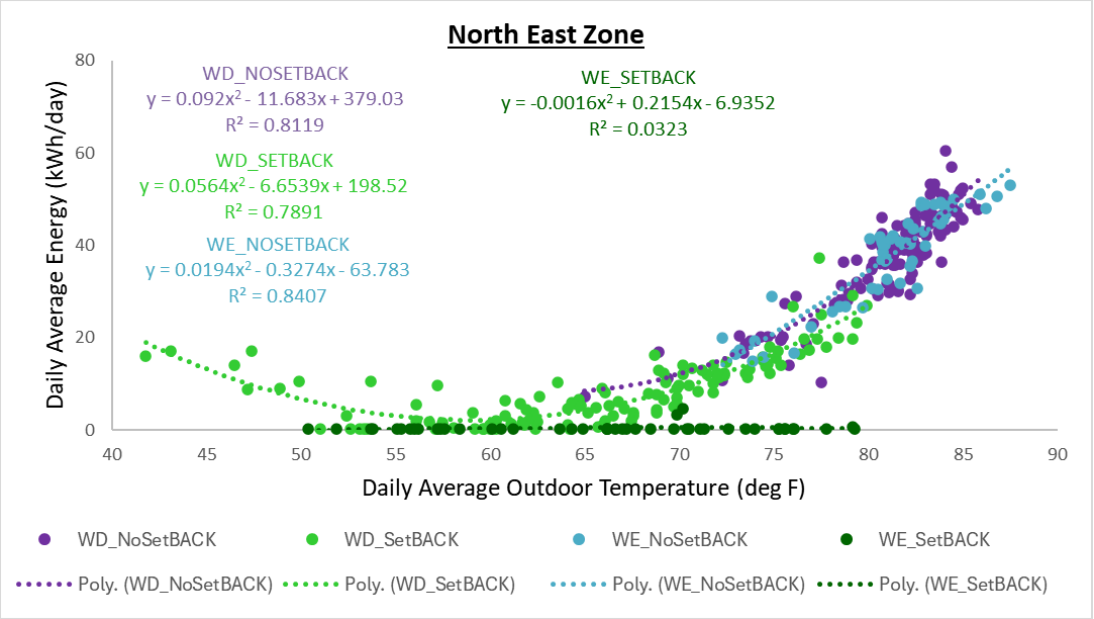


Figure 13. Data measured with and without thermostat setback for NE Zone during weekdays and weekends along with the regression equations and best-fit lines.

The summary of annual predicted energy use for weekdays and weekends with and without setbacks is shown for each zone cooling system in Tables 9-11 respectively. Table 12 shows all zones combined for the whole building which includes the negative weekday savings of the SE zone setbacks. All combined thermostat setback resulted in a total predicted annual cooling energy reduction of 9,363 kWh representing a 24% reduction in total building cooling energy. This came at no cost since all three systems already had programmable thermostats.

Table 9 NE Zone Annual Predicted Cooling Energy Use With and Without Thermostat Setback Including Savings

Thermostat Control	Energy use (kWh/year)
Weekday No Setback	6,316
Weekday With Setback	5,009
Weekday energy savings	**1,307 (20.7%)**
Weekend No Setback	2,355
Weekend With Setback	8
Weekend energy savings	**2,347 (99.7%)**

Table 10 SW Zone Annual Predicted Cooling Energy Use With and Without Thermostat Setback Including Savings

Thermostat Control	Energy use (kWh/year)
Weekday No Setback	5,879
Weekday With Setback	3,784
Weekday energy savings	**2,095 (35.5%)**
Weekend No Setback	2,128
Weekend With Setback	57.8
Weekend energy savings	**2,070 (97.3%)**

Table 11 SE Zone Annual Predicted Cooling Energy Use With and Without Thermostat Setback Including Savings

Thermostat Control	Energy use (kWh/year)
Weekday No Setback	17,005
Weekday With Setback	18,748
Weekday energy savings	**-1,743 (-10.2%)**
Weekend No Setback	5,849
Weekend With Setback	2,562
Weekend energy savings	**3,287 (56.6%)**

Table 12 All Zones Combined Annual Predicted Cooling Energy Use With and Without Thermostat Setback Including Savings

Thermostat Control	Energy use (kWh/year)
Weekday No Setback	29,200
Weekday With Setback	27,541
Weekday energy savings	1,659 (5.7%)
Weekend No Setback	10,332
Weekend With Setback	2,628
Weekend energy savings	7,704 (74.6%)
Full year No Setback	**39,532**
Full year With Setback	**30,169**
Full year cooling energy saved	**9,363 (23.7%)**

Setback Energy Savings Summary Based Upon Utility Energy Billing Method

Since energy improvement retrofits did not occur until the fall of 2024 and the monitoring project concluded in April of 2025, a full year prior and full year after retrofits billing data could not be used. The analysis found significant weather influence on energy. Without post retrofit summer data, the initial analysis only utilized ten electric utility billing statements. The five months before and five months after the energy efficiency measures were installed enabled the most accurate billing data analysis. A revised evaluation is recommended after twelve months of post-retrofit data are available to capture a full year of weather influences on energy use. The analysis methodology is discussed in greater detail in Appendix B. This analysis demonstrated some very important matters that must be considered if M&V solely relies upon energy billing data and no sub metered data. Two very important factors were identified as having a very significant impact upon accuracy.

1. Unequal Billing Periods – Energy use from one month to another is greatly influenced by the number of days in each billing period. For example, some of this building's billing periods were 30 days, others were as long as 35 – a difference of 17%. Seventeen percent may exceed the energy use savings expected from the energy retrofits making energy use differences related to the implemented changes unobservable. Averaging monthly use to the same number of days improves accuracy.
2. Weather Differences – In this building cooling energy use was highly affected by outdoor temperature. Since Central Florida's fall, winter and spring weather varies from one year to

another, comparing the utility bills for the same month(s) but different years can be misleading. For example, energy use savings would be under-represented if the post-retrofit period had warmer summer temperatures than the pre-retrofit period did.

These two factors demonstrated that determining energy savings from utility bills required normalizing the energy use of each period (pre- and post-retrofit) to the same weather data and over the same number of days in this building.

Evaluation solely based upon five months shows that energy use was reduced by 2.2% during the five months following the LED upgrade and thermostat setback measure implementation. The weather data applied to the models and resulting weather-normalized monthly energy use are presented in Table 13.

Table 13 Winter Haven Regional Airport TMYx Degree Days and Predicted Weather-Normalized Monthly Energy Use for Five Months Available During Post Retrofit Data

TMYx Data for Winter Haven Regional Airport[a]			Normalized Energy Use (kWh)		
Month	**HDD**	**CDD**	**Pre-Retrofit**	**Post-Retrofit**	**% Change**
November	7	128	8,690	8,164	6%
December	106	77	7,835	7,806	0%
January	179	33	7,161	7,527	-5%
February	25	82	8,240	7,998	3%
March	43	130	8,538	8,088	5%
Total			40,464	39,582	2.2%

[a]*Weather Data from Climate.onebuilding.org*

The monthly trend results suggest that the energy reduction is tied to cooling as savings increased in warmer months (higher CDD). The monthly trend indicated that the warmer months not available for post-analysis yet, should exceed the 5%-6% observed during the warmer March and November months used in the analysis. The implication is that the total annual savings would be greater than the 2.2% indicated based on the five cooler months available.

Using the models to extrapolate energy use through a whole year predicted the whole building's annual energy use savings may be 13% when late spring and summer monthly periods are considered. Table 14 shows predicted normalized building energy use for a twelve-month period based upon local HDD and CDD data applied to the monthly energy models. This annual prediction was only based upon models created based upon the five cooler months of the year. This analysis should be repeated after the 2025 billing months April through October are available to improve confidence in the results.

Table 14 Annual Predicted Total Billing Energy Use Based Upon Models Developed Using Only Five Cooler Months of the Year.

TMYx Data for Winter Haven Regional Airport [a]			Normalized Energy Use (kWh)		
Month	**HDD**	**CDD**	**Pre**	**Post**	**% Change**
January	179	33	7,161	7,527	-5%
February	25	82	8,240	7,998	3%
March	43	130	8,538	8,088	5%
April	-	275	9,865	8,572	13%
May	-	377	10,669	8,848	17%
June	-	496	11,598	9,166	21%
July	-	513	11,726	9,210	21%
August	-	534	11,890	9,267	22%
September	-	461	11,319	9,071	20%
October	-	314	10,170	8,676	15%
November	7	128	8,690	8,164	6%
December	106	77	7,835	7,806	0%
Annual			117,699	102,392	13%

[a] *Weather Data from Climate.onebuilding.org*

The analytical methodology involves some training to understand where to look for historical Typical Meteorological Year (TMY) weather data and how to normalize the billing data and apply least-squares regression analysis to the data correctly. So while the billing analysis method is less expensive than installing equipment on specific equipment to directly measure energy impacts, skilled labor is required.

Thermostat Setback Summary

The setback program did not result in any complaints because the temperatures occupants were normally accustomed to were maintained during occupied periods. The cooling systems were able to reach desired occupied setpoint temperatures by the beginning of each workday. We learned that typical office spaces could have annual cooling energy reductions of about 24%. However, it is important to consider zones with equipment that give off more heat than typical office spaces which may have increased weekday energy use as demonstrated in the SE zone with the lab.

The percent savings were normalized by how many degrees F the temperature was increased above the normal occupied temperature. This offers some guidance on how much savings a zone may realize based upon different levels of setback. This study demonstrated cooling energy savings of 12.7% / °F of daily average indoor air increase above the occupied cooling

indoor air temperature. But this is based upon the actual measured change in indoor air. Someone planning to implement setback wouldn't know how much the air temperature will change, but would know how much time the zone will be at set temperatures. If estimating the potential energy savings from a typical office cooling setback, one could use the time-weighted thermostat setpoint temperature and subtract the occupied setpoint temperature from this to determine an estimated delta temperature. Then apply 6.9% cooling energy reduction per delta degree F.

The large increase in temperature over the weekend during warm weather did result in more stored thermal energy that had to be removed on Monday. This was observed as higher cooling energy use on Mondays compared to other days of the week. The equipment in the lab space was a significant contributor to internal heat build-up in the SE zone as was previously discussed. Spaces with large internal cooling loads may have negative savings as was demonstrated in the weekday SE zone system. Energy savings could be maximized by not having any weekday setback and only using weekend setback on this one system.

Overall annual savings using setback on all three systems resulted in an annual predicted energy savings of 9,363 kWh representing a 24% reduction of the total building cooling energy use. This included the negative weekday savings of the SE system. If the weekday setback was removed from the SE system, total annual energy savings could be reduced by about 11,106 kWh (28 % of total annual cooling energy).

Comparison Between Utility Energy Bill and Sub Metered Data Analysis

The bill analysis solely based upon using five cooler months that occurred during the post retrofit determined 2.2% total building energy reduction. Extrapolating the trend of increased savings during warmer months to estimate an annual savings projected a total building energy reduction of 13%. The sub metered-based analysis annual predicted energy reduction of 9,363 kWh represents 7.9% of the total annual (normalized) building energy use of 119,173 kWh. A small lighting retrofit did occur during the utility billing analysis and will be discussed in further detail in this report. Only twenty lamps were replaced which would only have an annual energy reduction of 875 kWh. If the setback savings and LED lamp savings are combined, the annual energy reduction is 10,238 kWh representing an 8.6% decrease in the whole building energy use. The billing analysis method underestimated the percent reduction by about 74% based on five month limited evaluation and overestimated the percent reduction by about 55% based on the extrapolated 12 month evaluation. As previously discussed, the monthly billing analysis should be repeated after bill months April – October can be obtained.

Predicted Savings from Preventative Maintenance on SE AHU

The second energy monitoring recommendation was to maintain the SE zone AHU fan belt and pulley alignment to eliminate the cycle start-up screech sound. This would enable the thermostat fan control to be moved from the ON mode back into the AUTO mode. Occupants preferred to run in the on mode to avoid hearing a loud brief belt screech noise during each

cooling cycle start. Figure 14 shows the thermostat with fan set to on. The condenser unit and AHU fan energy were being measured and the amount of fan energy waste from remaining on instead of energy used when in AUTO mode was still able to be calculated. The daily cooling cycle runtime was calculated and then correlated to the condensing unit energy measured at 1 minute intervals. The remaining condenser off-cycle time was equated to hours per day the AHU fan ran wastefully. The AHU fan wattage multiplied by hours per day that the fan was not needed was used to determine the fan "waste" energy per day. This was correlated against the outdoor temperature as shown in Figure 15. The reduction in waste during hotter weather is expected since the active cooling cycles are longer and there is less "off" time between active cooling cycles. Cooling cycles are particularly longer during warmer weather since this system had two-stages of capacity. This evaluation includes the period before the thermostat setpoint setback and after setback was implemented. The data points circled in red having more energy waste than the predicted least-squares best-fit regression line are warm weekends when the thermostat setting was higher than weekdays resulting in much more actual fan wasted energy than weekdays with thermostats at lower setpoints on average. If the AHU fan was turned to AUTO instead of ON mode it was predicted to save 2,677 kWh per year (11.5% reduction in SE zone annual cooling energy).



Figure 14. SE zone thermostat with fan set to ON instead of AUTO mode.

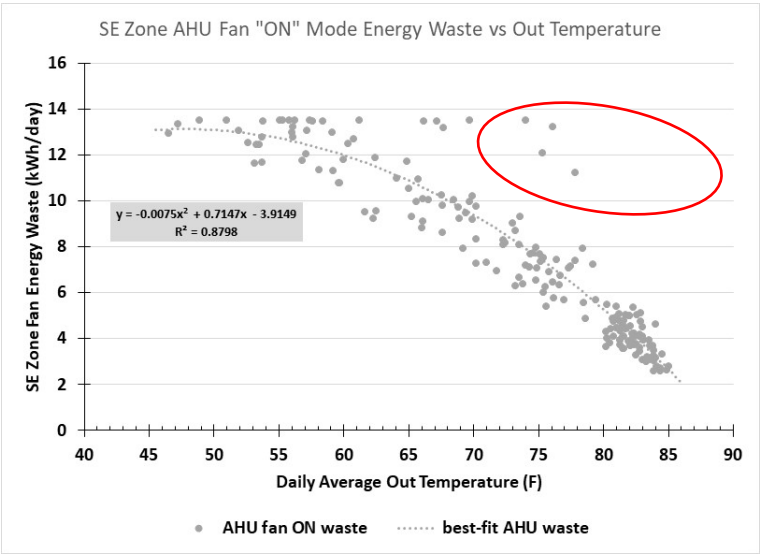


Figure 15. SE Zone AHU fan "ON" mode energy waste per day compared to average outdoor temperature shows more waste during cooler weather and weekends with thermostat setback.

Energy Impact of Small Sample of Indoor Lighting Retrofit to LED

The remaining fluorescent lamps on the west side of the building had been recommended to be replaced with LED lamps just as had already been completed on the east side of the building. The recommended LED retrofit was not able to be completed during the energy study monitoring period. However, a small sample of old fluorescent lamps was able to be replaced with LED lamps on August 19, 2024. Figure 16 shows three of the five hallway fixtures where lamps were changed out with LED. The existing lighting ballasts that served the fluorescent lights were disconnected from power. This is known as ballast bypass in LED retrofits. Figure 17 shows the end connection of one of the LED replacement lamps that plug directly into the existing T8 sockets. The T8 fluorescent lamps were four foot long and installed into 2 feet by 4 feet ceiling troffer fixtures. Each fixture held 4 lamps. A total of twenty lamps were replaced into five fixtures located at the west end central hallway. An occupancy sensor was also installed to replace a manually controlled switch for the hall lights. The average light illuminance in the hall section under three fixtures after LED replacement increased from 52 foot candles to 103 foot candles. Figure 18 shows an image of lighting illuminance being measured.

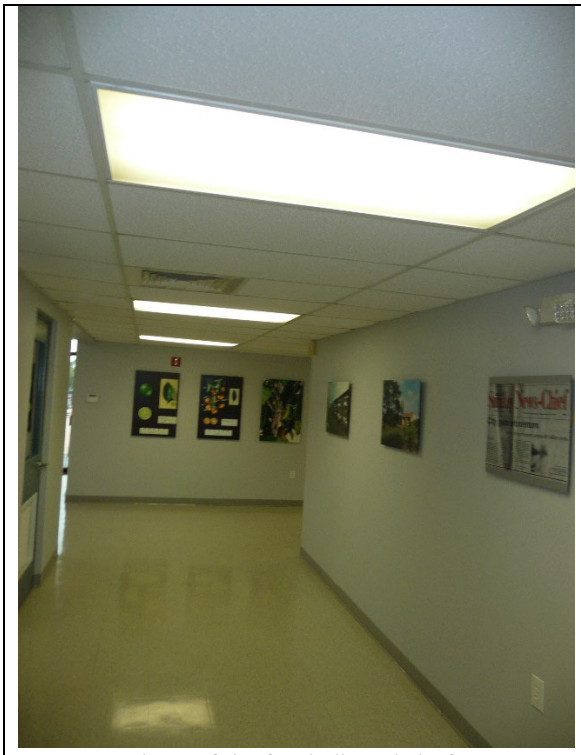


Figure 16. Three of the five hallway light fixtures prior to when LED lamps replaced T8 32 watt fluorescent lamps in the existing fixtures.



Figure 17. LED T8 replacement lamp in existing fixture.

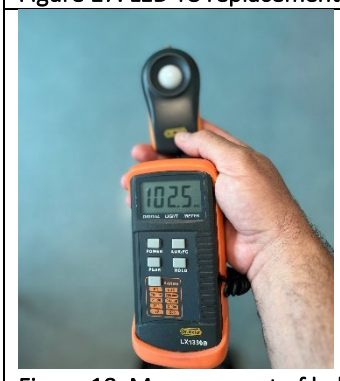


Figure 18. Measurement of hall lighting illuminance under LED lamps.

The daily total lighting energy in the west side building before and after the small LED retrofit was completed is shown in a chronological time-series graph in Figure 19. The weekday variability is a little more noticeable in the post LED measurements and likely due in-part to the

occupancy control. One weekday Monday during the post-period was a holiday and had the same energy use as weekend days as expected.

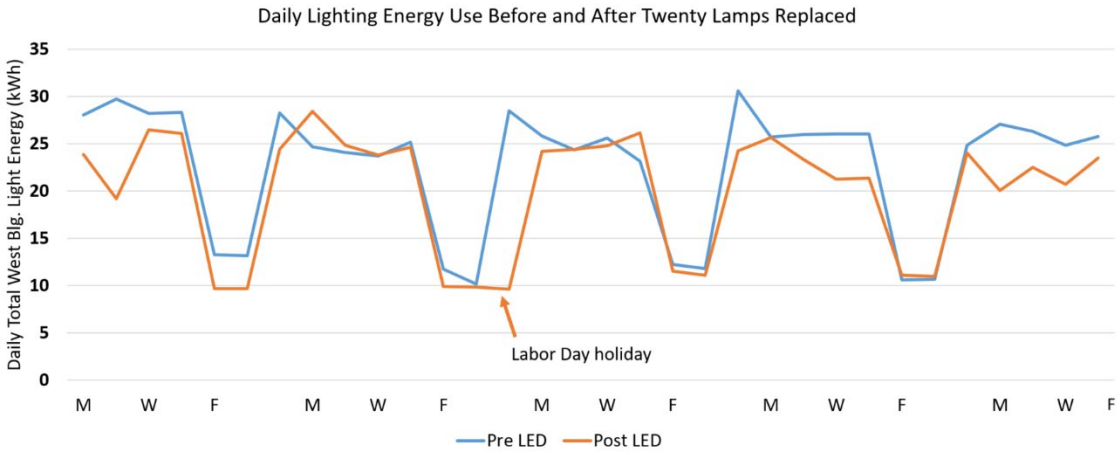


Figure 19. Time series of daily total lighting energy in west side building before and after small sample of LED retrofit was completed.

The five weeks prior to and following the LED retrofit were evaluated to determine energy savings. Labor Day Holiday was not included in the weekday analysis. Monitoring lighting energy throughout the year demonstrated very consistent time of use of lighting, therefore a long period of analysis was not needed for the lighting. A summary of the lighting energy is shown in Table 15. The weekday energy was reduced by 2.5 kWh/day and the weekend dropped 2.2 kWh/day on average. This may be due to the reduction of standby power from eliminated lighting ballasts and possibly some lighting occasionally left on during the pre-period compared to the post-period.

Based on the rated power difference between the fluorescent lamp and LED lamp over nine-hour operation per day an energy reduction of about 0.0945 kWh/day per lamp could be expected. The measured daily average energy reduction per lamp was 0.1247 kWh/day and included re-lamping and the occupancy control impacts.
Assuming the difference in energy reduction per lamp is due to occupancy control the breakdown would be as follows:

0.1247 Wh/day – 0.0945 Wh/day = 0.0302 Wh/day per lamp

The occupancy control may be providing 0.0302 Wh/day reduction representing 24% of the total daily reduction.

Table 15 West Building Total Lighting Daily Average Energy Use Before and After Limited LED Retrofit On Weekdays and Weekends

Thermostat Control	Energy use (kWh/day)
Pre LED Weekday	26.3
Post LED Weekday	23.8
Weekday energy savings	**2.5 (9.5%)**
Pre LED Weekend	12.3
Post LED Weekend	10.2
Weekend energy savings	**2.2 (17.1%)**

Based on 261 weekdays and 104 weekend days per year, the total annual reduction from replacing 20 lamps and adding occupancy control to them equates to 875 kWh (10.7% of west building total light energy use).

The total invoiced cost of this lighting retrofit was $521. Based on a simplified cost of electricity for this building at $0.134 / kWh and annual savings projected to be 875 kWh, $117.25 is saved annually resulting in a 4.4 year simple payback.

Energy Retrofit Summary

Only two energy retrofits were completed during the energy study. The results of both are shown in Table 16. The thermostat setback had no cost since programmable thermostats having weekday and weekend schedule capability were already installed. The small lighting retrofit with one occupancy sensor control for 5 hallway light fixtures proved to be very cost effective with a simple payback of 4.4 years.

Table 16 Energy Savings from Thermostat Setback, Lighting Fixture Upgrade from Fluorescent to LED, and Maintenance on One AHU

	Thermostat setback	20 LED lamp with occupancy sensor control	Combined retrofits
Pre Energy (KWh/y)	39,532	8,145	47677
Post Energy (kWh/y)	30,169	7,270	37439
Energy Savings (KWh/y)	9,363	875	10238
Energy Savings as % of system (s) evaluated	23.7%	10.7%	21.5%
%Energy Savings as % of total building energy use (119,173 kWh/y)*	7.9%	0.7%	8.6%
Annual savings value @ $0.134 / kWh saved	$1,255 / year	$117 / year	$1,372 / year
Cost of retrofit ($) and payback (years)	$0** Instant payback	$521 4.4 year simple payback	$521 0.4 years

*Baseline energy 119,173 kWh/y based upon most recent prior calendar year electric billing data normalized by 30-day billing periods, HDD & CDD 2024.

** No cost since programmable thermostats were already installed but not programmed.

It is recommended to re-evaluate the building EUI after the whole billing energy data can be obtained for April through October 2025.

These simple ESM are applicable to any office building and demonstrate high priority cost-effective building improvements that can reduce building operating costs and improve energy sustainability using public resources responsibly.

Appendix A Sub Metered Data Analytical Methodology

Sub Meter Analysis

One of the main challenges in comparing energy consumption between the two operating modes was the difference in seasonal conditions during the measurement periods. Most of the no-setback data were collected during the summer and fall period of 2024, while the setback data were recorded during the fall through early spring period of 2024–2025. To determine the HVAC energy savings potential from the thermostat setback strategy, we employed two complementary approaches. The first method involved clustering groups of data only during warmer periods. This allowed not only a comparison of the cooling energy but also the resulting daily average indoor temperatures during setback during more seasonally warm weather. We were interested in this to determine an average percent savings per degree change in the actual indoor conditions. However, the first analytical method is insufficient for determining annual savings impacts. The second approach involved linear regression least-squares analysis of all available data. This enabled simple models to be developed that were used with historical local weather to predict energy use for each day of the year.

These two approaches allowed for a comprehensive evaluation of the energy savings associated with the thermostat setback strategy in all three zones of the building. The clustering-based comparison approach provided insight into actual daily performance under similar warm weather conditions, while the regression-based approach offered a broader perspective on potential energy savings more applicable for predicting annual energy use. For both approaches, the data were separated into weekdays and weekends, and the analyses were conducted accordingly. There was no significant heating during winter so only cooling energy impacts are reported here.

K-means clustering method for predicting summer impacts- involved comparing the measured daily average energy consumption (kWh/day) between days with and without the thermostat setback during the warmer periods of available data. For a meaningful comparison, it is important to identify days with similar daily average outdoor temperatures and manually selecting similar days for comparison was challenging. To achieve this, we applied “k-means clustering”, an unsupervised machine learning algorithm. *K-means clustering* is one of the most widely used clustering techniques in data mining, which groups data points into clusters such that items within each cluster are similar to one another and dissimilar to those in other clusters. The algorithm relies on *Euclidean distance* to measure the distance between each data point and the centroid (i.e., the average of all data points within that cluster). A critical step in this process is determining the appropriate number of clusters, as the outcome of the clustering analysis is highly sensitive to this parameter. To address this, we utilized the elbow method, a commonly used technique for identifying the optimal number of clusters.
Based on the clustering results, we identified groups of days with similar daily average outdoor temperatures, separately for weekdays and weekends. We then compared the average daily HVAC energy consumption between the setback and no-setback scenarios within each group. This clustering analysis was performed independently for the NE, SE, and SW zones and the

results were analyzed accordingly. This method enables a direct comparison of actual HVAC energy use before and after implementing the thermostat setback. This method is not suitable for predicting annual energy.

Least-squares regression method for annual prediction- involved developing a regression model based on measured data to project the annual energy consumption of the air conditioning system with and without the thermostat setback. The daily total space conditioning energy of each system was plotted against the daily average outdoor temperature. Least-squares, best-fit regression analysis was performed. The resulting simple model from this analysis was used with daily outdoor average temperature acquired from local historical weather data to predict the daily total cooling energy use for each day of the year when there was no thermostat setback and when there was thermostat setback implemented. The resulting energy use over the whole year was calculated and annual energy savings based upon the difference between the predicted energy before and after the setback was implemented.

Thermostat Setback Energy Saving Potential – Based on Clustering Results

For illustration, Figures A1 (weekdays) and A2 (weekends) are presented to depict the daily average HVAC energy consumption for the corresponding daily average outdoor temperature for the NE Zone. The respective energy savings results for weekdays and weekends are presented in Table A1 and Table A2, respectively. The selection of days with the thermostat setback and NO setback was based on the clustering results.
In the NE Zone, data collection began on April 25, 2024. From that date until October 27, 2024, the HVAC system operated **without** the thermostat setback. From October 28, 2024, to April 10, 2025, the thermostat setback strategy was implemented.
Despite these seasonal differences, as mentioned earlier, the use of the clustering algorithm enabled the identification of days with similar daily average outdoor temperatures across both operating periods, allowing for a reasonable comparison of HVAC energy consumption under the two thermostat strategies.

As shown in Tables A1 and A2, for both weekdays and weekends, the days with and without thermostat setbacks had similar outdoor temperatures, while energy consumption was lower on the setback days. **For the selected days, the HVAC energy savings in the NE zone for weekdays and weekends were ~20% and ~99%, respectively.** The significantly higher savings observed during weekends can be attributed to the use of a constant cooling setpoint temperature of 80°F. In contrast, a varying cooling setpoint schedule[2] was maintained during weekdays to ensure that building occupants did not experience noticeable changes in thermal comfort due to the thermostat setback strategy. Accordingly, from Table A1, it can be seen that the variation in the indoor temperature in the NE Zone during thermostat setback and no setback was less than 1.5°F.
It is important to note that the energy savings presented in the tables are based on the selected days. The energy savings may differ if another cluster with a different range of daily average outdoor temperatures were selected for the analysis.

[2] 75°F from 04:01 to 05:00; 72°F from 05:01 to 07:00; 71°F from 07:01 to 17:00; 78°F from 17:01 to 04:00;

It was also observed that the constant setpoint of 80°F maintained over the weekend led to relatively higher HVAC energy consumption on Mondays. This increase is due to the air conditioning system operating for an extended period to bring the indoor temperature down to the lower weekday setpoint. An example of this effect is highlighted by the red circle in Figure A1, which shows elevated energy use on a Monday despite a similar daily average outdoor temperature in the NE Zone.

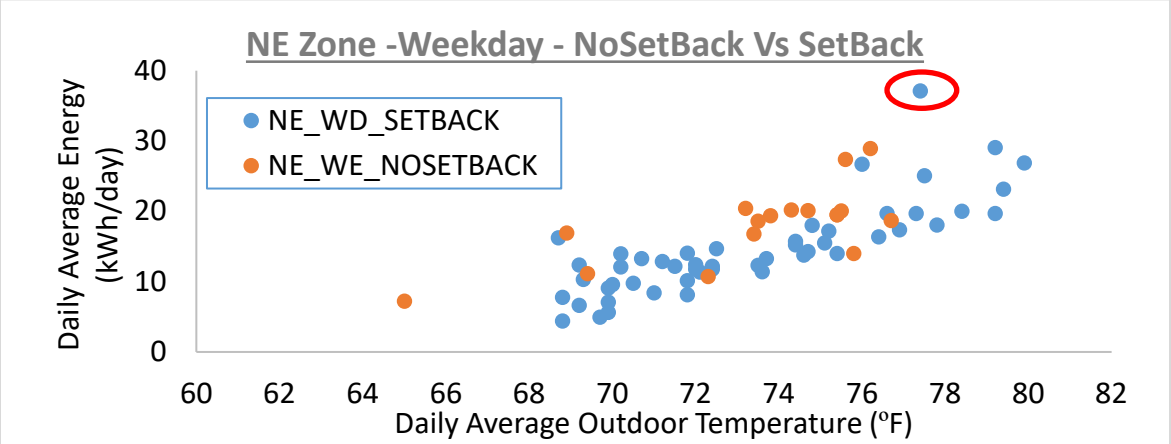


Figure A1. Energy use comparison for NE Zone during weekdays with and without thermostat setpoint setback

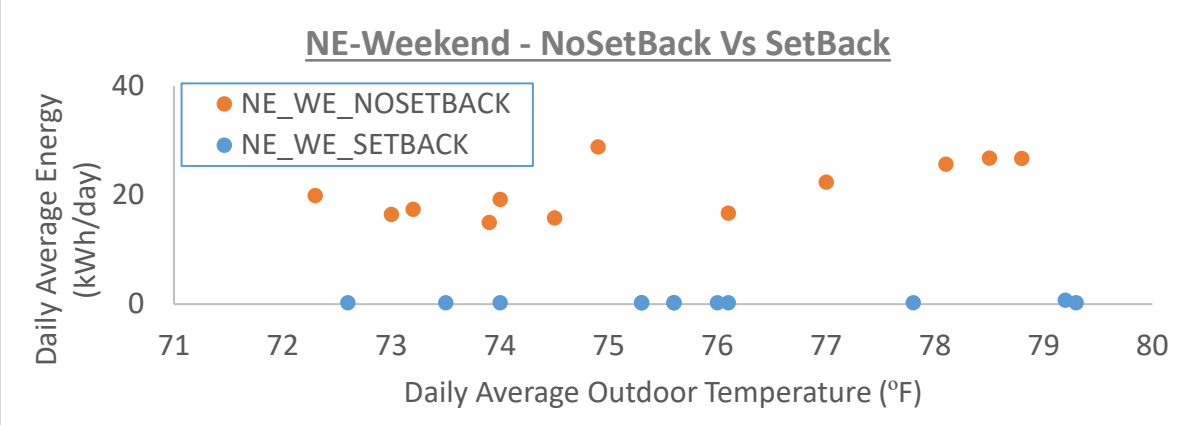


Figure A2. Energy use comparison for NE Zone during the weekend with and without thermostat setpoint setback

Table A1 NE Zone – Weekday Energy Savings on Selected Days Based on Measured Data

Thermostat strategy	Number of days	Daily average outdoor temperature (°F)	Average daily indoor temperature (°F)	Average Daily HVAC energy consumption (kWh/day)
Weekday_NoSetBack	19	73.5	71.5	18.2
Weekday_SetBack	51	73.3	72.8	14.5
Energy Savings				**20.3%**
Average % reduction per indoor degree raised				**15.6% / °F**

Table A2 NE Zone – Weekend Energy Savings on Selected Days

Thermostat strategy	Number of days	Daily average outdoor temperature (°F)	Average daily indoor temperature (°F)	Average Daily HVAC energy consumption (kWh/day)
Weekend_NoSetBack	13	75.4	71.4	20.9
Weekend_SetBack	13	75.9	76.5	0.29
Energy Savings				**98.6%**
Average % reduction per indoor degree raised				**19.3% / °F**

Tables A3 and A4 present similar results for the SW zone. For the selected days, the HVAC energy savings in the SW zone for weekdays and weekends was ~27% and ~99%, respectively.

Table A3 SW Zone – Weekday Energy Savings on Selected Days

Thermostat strategy	Number of days	Daily average outdoor temperature (°F)	Average daily indoor temperature (°F)	Average Daily HVAC energy consumption (kWh/day)
Weekday_NoSetBack	14	77.8	71.4	24.6
Weekday_SetBack	50	77.8	73.9	18.0
Energy Savings				**27.3%**
Average % reduction per indoor degree raised				**10.9% / °F**

Table A4 SW Zone – Weekend Energy Savings on Selected Days

Thermostat strategy	Number of days	Daily average outdoor temperature (°F)	Average daily indoor temperature (°F)	Average Daily HVAC energy consumption (kWh/day)
Weekend_NoSetBack	15	79.4	71.7	19.4
Weekend_SetBack	13	79.9	75.8	0.6
Energy Savings				**99.5%**
Average % reduction per indoor degree raised				**24.3% / °F**

Tables A5 and A6 represent the energy savings calculated for the SE zone and it can be seen that the presented results vary from the other two (NE and SW) zones. In the SE Zone, negative energy savings during weekdays were observed with the thermostat setback strategy. This outcome is attributed to the presence of lab equipment in the SE zone, which generated relatively higher internal heat gains compared to the other zones. In contrast, the NE and SW Zones are typical office spaces, primarily occupied by personnel and equipped with lighting and office equipment, resulting in lower internal loads. On the other hand, for the selected weekend days, approximately 59% HVAC energy savings were achieved.

Table A5 SE Zone – Weekday Energy Savings on Selected Days

Thermostat strategy	Number of days	Daily average outdoor temperature (°F)	Average daily indoor temperature (°F)	Average Daily HVAC energy consumption (kWh/day)
Weekday_NoSetBack	15	73.5	70.6	60.6
Weekday_SetBack	62	73.0	72.9	66.2
Energy Savings				**-9.2%**
Average % reduction per indoor degree raised				**-NA-**

Table A6 SE Zone – Weekend Energy Savings on Selected Days

Thermostat strategy	Number of days	Daily average outdoor temperature (°F)	Average daily indoor temperature (°F)	Average Daily HVAC energy consumption (kWh/day)
Weekend_NoSetBack	6	75.5	70.4	61.5
Weekend_SetBack	5	75.6	77.9	25.4
Energy Savings				**58.7%**
Average % reduction per indoor degree raised				**7.8% / °F**

Thermostat Setback Energy Saving Potential – Based on Least-Squares Regression

The daily total cooling energy and daily average outdoor temperature was measured for months prior to and after implementing the setback changes on all three cooling systems. A least-squares best fit regression analysis was applied to the cooling energy versus outdoor temperature. Simple models were developed for each test case where local historical weather data for a full year was used to predict the daily cooling energy for every day of the year. Regression models were developed to estimate the annual energy savings (from January 1 to December 31, 2024) resulting from the thermostat setback strategy in each zone. Figure A3 illustrates the data distribution for the full data collection period (spanning from April 25, 2024, to April 10, 2025) in the NE Zone. In this figure, the data are grouped based on the day of the week and thermostat setback status.

Based on the observed data distribution within each group, a second-order polynomial regression model was selected for energy use projection. The corresponding regression equations, as shown in Figure A3, were developed to characterize the relationship between daily average outdoor temperature and daily total HVAC energy consumption. These models were then applied to a full year of weather data (daily average outdoor temperature) to estimate the annual HVAC energy consumption under both thermostat setback and no-setback scenarios. Historical daily average outdoor temperature data representing an entire year was obtained from a local weather station near the Winter Haven monitoring site.

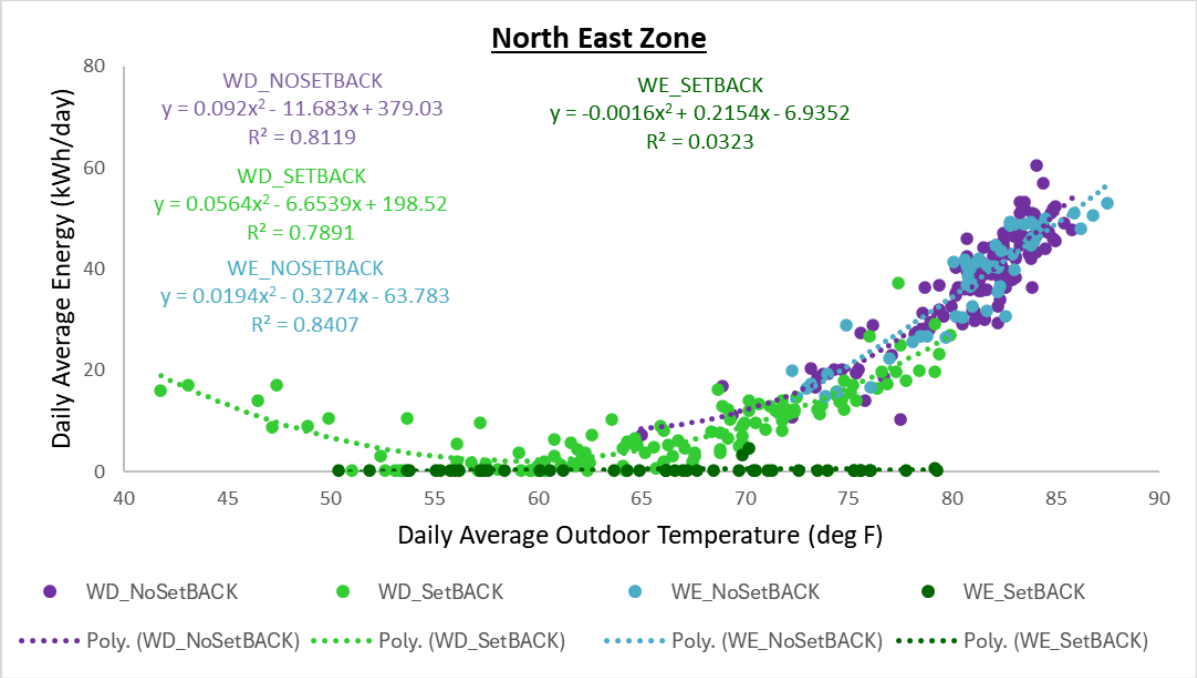


Figure A3. Data distribution with and without thermostat setback for NE Zone during weekdays and weekends, with the information of regression equations.

To ensure the credibility of the prediction results, it is good practice to validate the regression model by comparing its output with actual measured data. Accordingly, for selected days, we compared the regression-based estimates with the measured HVAC energy consumption in the NE Zone. The results are shown in Figures A4 (weekdays without setbacks) and A5 (weekdays with setbacks). As seen from the figures, the regression results show reasonably good agreement with the measured values with negligible variations.

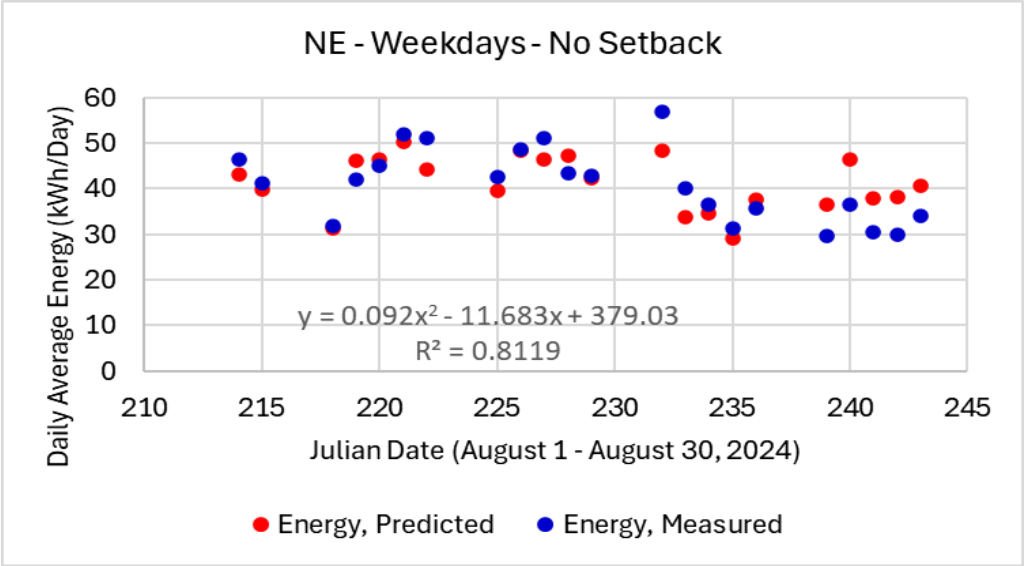


Figure A4. Comparison of regression results with actual measured data for selected weekdays with NO thermostat setback in NE Zone.

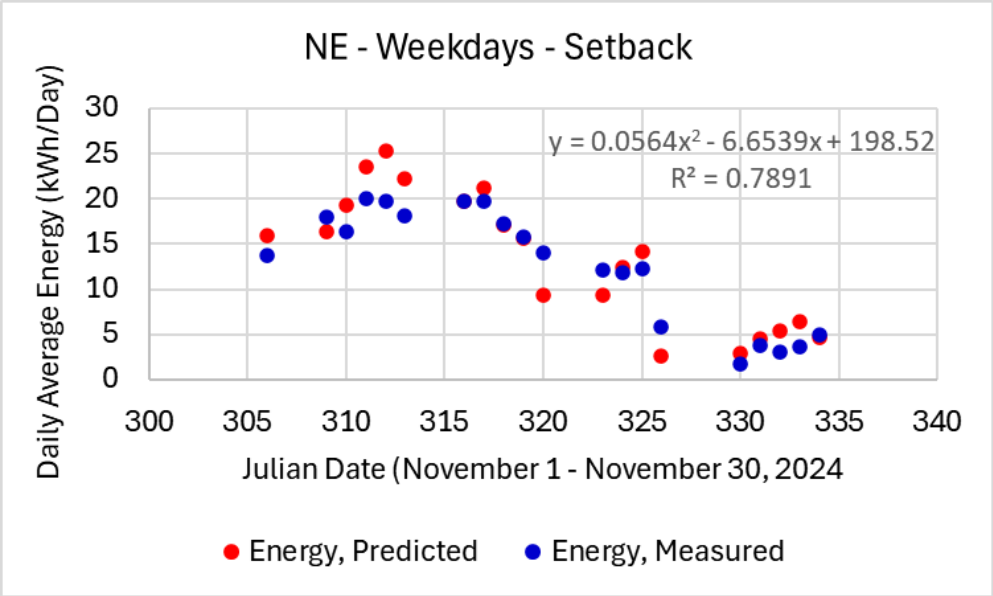


Figure A5. Comparison of regression results with actual measured data for selected weekdays with thermostat setback in NE Zone.

Tables A7 and A8 present the regression results for the NE Zone, corresponding to weekdays and weekends, respectively. It can be seen from Figure A3 that for the weekdays, the balance point between heating and cooling appears to occur at approximately 60°F. Hence, for the weekday analysis, **only days with outdoor temperatures greater than 60°F were included**. Thus, the regression-based cooling energy estimates for weekdays were limited to days when the outdoor temperature exceeded this threshold.
In contrast, for the weekend analysis, data points without thermostat setbacks were limited for outdoor temperatures below 66.5°F. As a result, **a threshold of 66.5°F was adopted for weekends**, and only days with outdoor temperatures above this value were used to estimate cooling energy consumption.

As shown in Tables A7 and A8 below, the estimated annual HVAC energy savings in the NE Zone due to the thermostat setback strategy are approximately 21% (1,307 kWh) for weekdays and 99% (2,344 kWh) for weekends.

Table A7 NE – Weekday Annual Cooling Energy Savings Based on Regression Analysis

Thermostat strategy	Number of days	Average daily outdoor Temperature °F	Average daily HVAC energy use kWh/day (Predicted)	Total HVAC Energy (kWh)
Weekday_NoSetBack	230	76.3	27.5	6,316
Weekday_SetBack			21.8	5,009
Energy Savings % and kWh			**20.7%**	**1,307kWh**

Table A8 NE – Weekend Annual Cooling Energy Savings Based on Regression Analysis

Thermostat strategy	Number of days	Average daily outdoor Temperature °F	Average daily HVAC energy use kWh/day (Predicted)	Total HVAC Energy (kWh)
Weekend_NoSetBack	83	77.6	28.37	2,355
Weekend_SetBack			0.09	8
Energy Savings % and kWh			**99.7%**	**2,347 kWh**

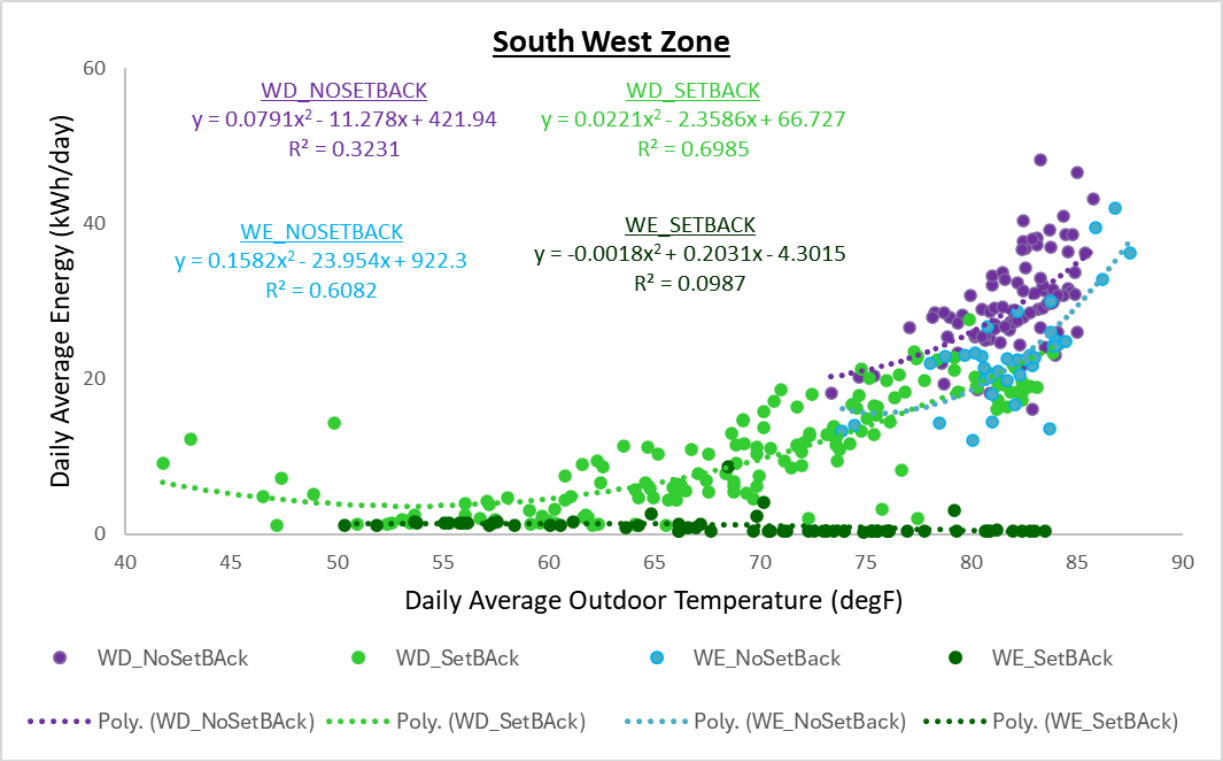


Figure A6. Data distribution with and without thermostat setback for SW Zone during weekdays and weekends, with the information of regression equations.

Figure A6 shows the data distribution and the corresponding regression models for SW zone. Tables A9 and A10 show the estimates of annual HVAC energy savings in the SW Zone. Due to similar zone office activity, **the same thresholds (as balance point) considered for NE for the outdoor temperature to determine the cooling period were followed for the SW zone as well**. Using the regression equations derived using the data collected in the SW zone, the HVAC energy savings due to the thermostat setback strategy are approximately 36% (2,095 kWh) for weekdays and 97% (2,070 kWh) for weekends.

Table A9 SW – Weekday Annual Cooling Energy Savings Based on Regression Analysis

Thermostat strategy	Number of days	Average outdoor Temperature °F	Average daily HVAC energy use kWh/day (Predicted)	Total HVAC Energy (kWh)
Weekday_NoSetBack	230	76.3	25.6	5,879
Weekday_SetBack			16.5	3,784
Energy Savings % and kWh			**35.5%**	**2,095kWh**

Table A10 SW – Weekend Annual Cooling Energy Savings Based on Regression Analysis

Thermostat strategy	Number of days	Average outdoor Temperature °F	Average daily HVAC energy use kWh/day (Predicted)	Total HVAC Energy (kWh)
Weekend_NoSetBack	92	76.2	23.13	2,128
Weekend_SetBack			0.63	57.8
Energy Savings % and kWh			**97.3%**	**2,070kWh**

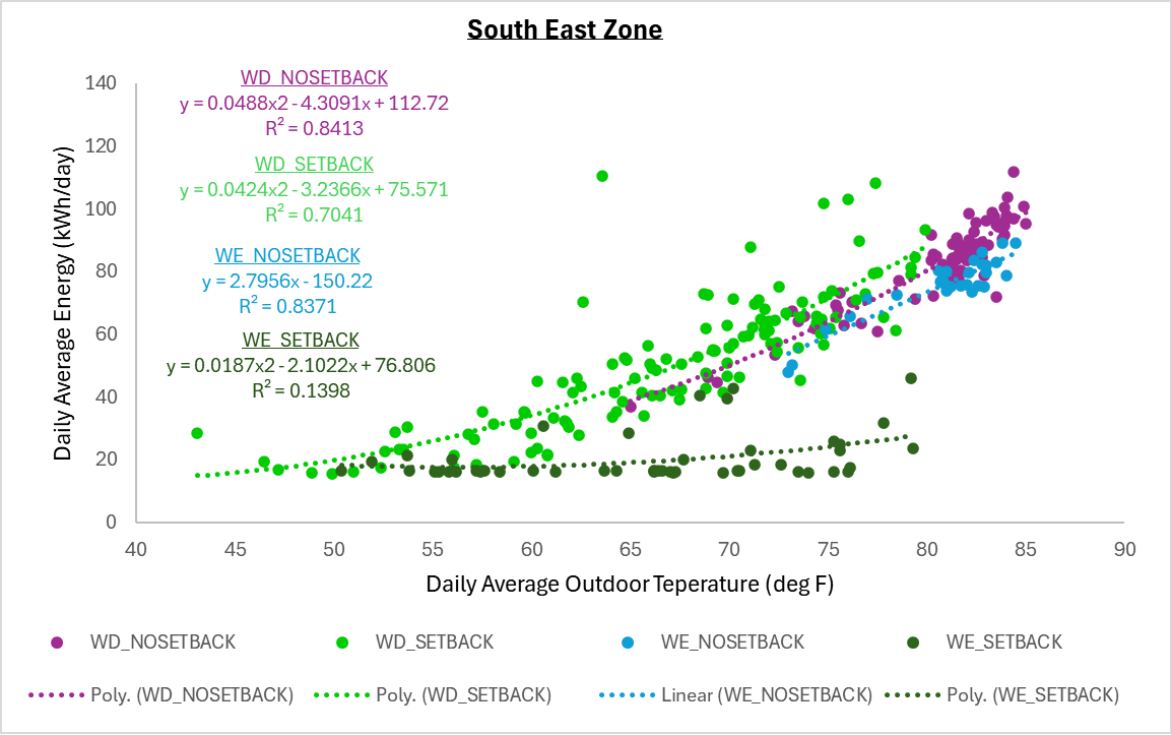


Figure A7. Data distribution with and without thermostat setback for SE Zone during weekdays and weekends, with the information of regression equations.

Figure A7 shows the data distribution and the corresponding regression models for the SE zone. Note that the balance point (to determine cooling) for weekdays and weekends for the SE Zone is considered to be 50°F. It is understood that the presence of lab equipment in the SE Zone required the HVAC system to provide the cool energy to maintain the thermostat setpoint

temperature, even when the average daily temperature was at 50°F. Thus, a threshold of 50ºF was considered for the regression analysis during both the weekdays and weekends. Tables A11 and A12 present the estimated annual HVAC energy savings in the SE Zone. No energy savings were achieved during weekdays with the thermostat setback strategy. There was approximately a 10% increase in weekday cooling energy consumption. This increase is consistent with the explanation provided regarding Table A5 related to high internal heat gains within this zone. On the other hand, the annual energy savings during weekends for SE is projected to be 57% (3,287kWh).

Table A11 SE – Weekday Annual Cooling Energy Savings Based on Regression Analysis

Thermostat strategy	Number of days	Average outdoor Temperature °F	Average daily HVAC energy use kWh/day (Predicted)	Total HVAC Energy (kWh)
Weekday_NoSetBack	262	73.9	64.9	17,005
Weekday_SetBack			71.5	18,748
Energy Savings % and kWh			**-10%**	**-1,743kWh**

Table A12 SE – Weekend Annual Cooling Energy Savings Based on Regression Analysis

Thermostat strategy	Number of days	Average outdoor Temperature °F	Average daily HVAC energy use kWh/day (Predicted)	Total HVAC Energy (kWh)
Weekend_NoSetBack	100	74.7	58.5	5,849
Weekend_SetBack			25.4	2,562
Energy Savings % and kWh			**56.6%**	**3,287kWh**

Table A13 presents the summary of energy savings in terms of each zone and the total building, respectively. Note that the energy savings presented below include both weekdays and weekends and represent a full year based on 2024 outdoor historical weather data. From the regression analysis results, it is inferred that the energy savings in the total building due to the thermostat setback strategy is estimated as 23.7%.

Table A13 Annual Total Building Cooling Energy Use and Savings Based on Regression Analysis Results Summary Including Weekday and Weekend With and Without Setback

	kWh/y	% kWh/y saved
NE pre-setback	8,671	
NE post-setback	5,017	
NE saved	**3,654**	**42.1%**
SW pre-setback	8,007	
SW post-setback	3,842	
SW saved	**4,165**	**52.0%**
SE pre-setback	22,854	
SE post-setback	21,310	
SE saved	**1,544**	**6.8%**
Total building pre-setback	39,532	
Total building post-setback	30,169	
Total building saved	**9,363**	**23.7%**

Thermostat Setback Summary

The setback program did not result in any complaints because the temperatures occupants were normally accustomed to were maintained during occupied periods. The cooling systems were able to reach the desired occupied setpoint temperatures by the beginning of each workday. We learned that typical office spaces had measured cooling energy reductions of 12.7% / °F of daily average indoor air increase above the occupied cooling indoor air temperature. If estimating the potential energy savings from a typical office cooling setback, one could use the time-weighted thermostat setpoint temperature and subtract the occupied setpoint temperature from this to determine an estimated delta temperature. Then apply 6.9% cooling energy reduction per delta degree F.

The large increase in temperature over the weekend during warm weather did result in more stored thermal energy as was observed in cooling energy operation on Mondays compared to other days of the week. The equipment in the lab space was a significant contributor to internal heat build-up in the SE zone as was previously discussed. Spaces with large internal cooling loads may have negative savings as was demonstrated in the weekday SE zone system. Energy savings could be maximized by not having any weekday setback and only using weekend setback on this one system.

Overall annual savings using setback on all three systems resulted in an annual predicted energy savings of 9,363 kWh representing a 24% reduction of the total building cooling energy use. This included the negative weekday savings of the SE system. If the weekday setback was removed from the SE system, total annual energy savings could be reduced by about 11,106 kWh (28 % of total annual cooling energy).

Appendix B Monthly Energy Utility Bill Analysis Methodology

At the end of energy monitoring, two years previous energy utility bills were collected and analyzed for the Winter Haven Plant Industry Cowperthwaite office and lab buildings. Since energy improvement retrofits did not occur until the fall of 2024 and the monitoring project concluded in April of 2025, a full year prior could not be compared to a full year after retrofits using billing data. The analysis found significant weather influence on energy. Without post retrofit summer data, the initial analysis only utilized ten electric utility billing statements. The five months before and five months after the energy efficiency measures were installed enabled the most accurate billing data analysis. A revised evaluation is recommended after twelve months of post-retrofit data are available to capture a full year of weather influences on energy use.

A weather-normalized utility data evaluation was conducted to determine how effectively utility bill statements could detect changes in energy use following the efficiency measures implemented at the Winter Haven Plant Industry facility. During the available monitoring period, two energy reduction efforts were implemented: thermostat setpoint setback during unoccupied periods and replacement of twenty fluorescent lamps to LED ballast by-pass lamps. The utility billing energy analysis indicated that total building energy use was only reduced by 2.2% over the five relatively cool months evaluated following implementation of the LED upgrade and thermostat setback measures. However, the evaluation also suggests that annual energy use savings could be 10% of total building use if able to use a full year of data with warmer months included as will be demonstrated in this analysis.

The “pre-retrofit” period is approximately represented from November 2023 through March 2024 and the “post-retrofit”, is approximately November 2024 through March 2025. The monthly utility electricity measured use indicated in billing statements is summarized in Table B1. This data is intentionally presented without any account for the number of billing days in each month to point out inherent impacts that can affect the accuracy of calculating energy savings from such raw data.

Table B1 Pre and Post-Retrofit Utility Monthly Energy Use Without Normalization

	Energy Use Bills (kWh)	
Representative Month	Pre-Retrofit 10/25/2023 - 3/26/2024	Post-Retrofit 10/24/2024 - 3/26/2025
November	9,760	8,880
December	7,720	8,000
January	7,120	7,360
February	7,920	7,920
March	9,000	8,120

* Billing data period dates; Billing data not consistently collected on same date every month.

Challenges in Using Utility Energy Use Billing Data

Table B1 demonstrated that year-over-year monthly energy use sometimes decreased, but at other times it increased. Two influences that can obscure energy use changes related to energy improvement interventions are 1. unequal billing periods and 2. weather differences between periods. These influences are described below.

1. Unequal Billing Periods – Energy use from one month to another is greatly influenced by the number of days in each billing period. For example, some of this building billing periods were 30 days, others were as long as 35 days – a difference of 17%. Seventeen percent may exceed the energy use savings expected from the energy retrofits making energy use differences related to the implemented changes unobservable. Averaging monthly use to the same number of days improves accuracy.
2. Weather Differences – In this building cooling energy use was highly affected by outdoor temperature. Since Central Florida's fall, winter and spring weather varies from one year to another, comparing the utility bills for the same month(s) but different years can be misleading. For example, energy use savings would be under-represented if the post-retrofit period had warmer summer temperatures than the pre-retrofit period did.

For these reasons, determining energy savings from utility bills requires normalizing the energy use of each period (pre- and post-retrofit) to the same weather data and over the same number of days.

Regression Modeling Using Energy Billing Data

To ensure accurate comparisons between pre- and post-retrofit, we applied a regression modeling technique which can be used to predict energy consumption based on weather, allowing us to compare data from different periods. Regression modeling was used to estimate the relationships between energy use and weather.

We used regression modeling to conduct a weather-normalized energy use evaluation using Plant Industry's billing data. A simple linear regression can optimize for the best fit between total monthly energy consumption and corresponding weather data by separating energy usage into components related to heating, cooling, and all other energy use demands (referred to as the baseload) for both the pre and post-retrofit periods[3]. The model outcomes include an intercept, which represents the baseload energy consumption, and coefficients assigned to each independent variable in the model.

Example results using this technique are graphed in Figure B1 using the Plant Industry building electricity use for the full year of 2022 when no building modifications occurred. The plot shows the baseload energy (green), heating (red), cooling (blue), and total energy use (purple) over the year. The utility billing data is also represented here (dashed purple), to demonstrate how well the prediction aligns with actual energy use. As expected, we observe high cooling needs in

[3] Agnew, K., and M. Goldberg. 2013. Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol (Subcontractor Report, NREL/SR-7A30-53827).

the summer and a little heating needed between December and March. Relative to other Florida Department of Agriculture and Consumer Services buildings we evaluated, the Plant Industry building's total consumption was comprised of greater baseload energy. One implication of higher baseload use relative to heating and cooling is that energy efficiency measures targeting heating and cooling energy reductions are more likely to have less impact on the overall building energy savings.

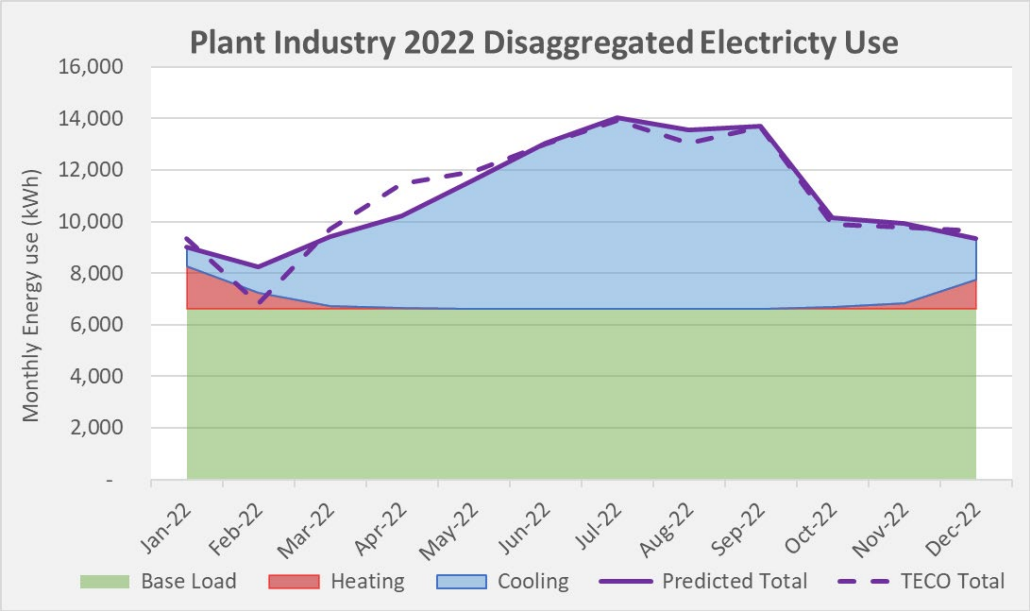


Figure *B1.* Winter Haven energy use disaggregation. Monthly baseload energy in green, heating in red, cooling in blue, total energy use in purple, and utility provider billing data in dashed purple.

The regression model applied variables known as heating and cooling *degree days* as a proxy for the reported local weather for each corresponding billing period to predict that month's known energy use. Degree days are the difference between the daily average temperature and a temperature when minimal heating or cooling is needed for occupants to feel comfortable. This is often somewhere around 65°F. [4] Heating degree days (HDD) and cooling degree days (CDD) – calculated from the daily average dry bulb temperatures observed in Winter Haven and reported by the National Oceanic and Atmospheric Administration (NOAA) – were summed for each billing period and used in our models as the independent weather variables to predict energy use.

Regressions were made for both the pre- and post-retrofit periods, using the applicable five months of data. Ideally, this approach uses at least twelve months of data to capture the full seasonal swing and nuances between a building's heating and cooling needs. While the models

[4] According to the National Oceanic and Atmospheric Administration, "Degree days are the difference between the daily temperature mean, (high temperature plus low temperature divided by two) and 65°F. If the temperature mean is above 65°F, we subtract 65 from the mean and the result is Cooling Degree Days. If the temperature mean is below 65°F, we subtract the mean from 65 and the result is Heating Degree Days."

we ran used only five months of data and undervalued heating use, the overall results of this modeling were strong. Regression results are summarized as:
Pre-retrofit: 7715 + (-4.56*HDD) + (7.82*CDD); R^2 = 0.978, F(2,2) = 21.65, p = 0.012

Post-retrofit: 7834 + (-2.22 *HDD) + (2.69*CDD); R^2 = 0.955, F(2,2) = 10.35, p = 0.001

These model outcomes can be applied to the same weather (HDD and CDD) to predict the pre- and post-retrofit energy use for direct comparison. The weather data we used for this pre-post-retrofit comparison is the latest Typical Meteorological Years (TMY) data, called TMYx, available through Climate.OneBuilding.org and derived from hourly weather data through 2023 in the NOAA Integrated Surface Database for the Winter Haven Regional Airport - Gilbert Field.[5]

Key Findings and Implications of Energy Bill Analysis

Evaluation results show that energy use was reduced by 2.2% during the five months following the LED upgrade and thermostat setback measure implementation. The weather data applied to the models and resulting weather-normalized monthly energy use are presented in Table B2.

Table B2 Winter Haven Regional Airport TMYx Degree Days and Predicted Weather-Normalized Monthly Energy Use for Five Months Available During Post Retrofit Data

TMYx Data for Winter Haven Regional Airport[a]			Normalized Energy Use		
Month	**HDD**	**CDD**	**Pre-Retrofit**	**Post-Retrofit**	**Change**
November	7	128	8,690	8,164	6%
December	106	77	7,835	7,806	0%
January	179	33	7,161	7,527	-5%
February	25	82	8,240	7,998	3%
March	43	130	8,538	8,088	5%
Total			40,464	39,582	2.2%

[a]*Weather Data from Climate.onebuilding.org*

The monthly results suggest that the energy reduction is tied to cooling because the months with the highest cooling needs, November and March, show the greatest savings. The monthly trend indicates that the warmer months not available for post-analysis yet, should exceed the 5%-6% observed during the warmer March and November months used in the analysis. The implication is that the total annual savings would be greater than the 2.2% indicated based on five cooler months available.

Using the models to extrapolate energy use through a whole year suggests the whole building annual energy use savings may be 13% when late spring and summer monthly periods are considered. Table B3 shows predicted normalized building energy use for a twelve-month period based upon local HDD and CDD data applied to the monthly energy models. This annual prediction was only based upon models created based upon the five cooler months of the year.

[5] https://climate.onebuilding.org/

This analysis should be repeated after the 2025 billing months April through October are available to improve confidence in the results.

Table B3 Annual Predicted Total Billing Energy Use Based Upon Models Developed Using Only Five Cooler Months of the Year

TMYx Data for Winter Haven Regional Airport [a]			Normalized Energy Use (kWh)		
Month	**HDD**	**CDD**	**Pre**	**Post**	**% Change**
January	179	33	7,161	7,527	-5%
February	25	82	8,240	7,998	3%
March	43	130	8,538	8,088	5%
April	-	275	9,865	8,572	13%
May	-	377	10,669	8,848	17%
June	-	496	11,598	9,166	21%
July	-	513	11,726	9,210	21%
August	-	534	11,890	9,267	22%
September	-	461	11,319	9,071	20%
October	-	314	10,170	8,676	15%
November	7	128	8,690	8,164	6%
December	106	77	7,835	7,806	0%
Annual			117,699	102,392	13%

[a] *Weather Data from Climate.onebuilding.org*