Los Altos School District, Egan Junior High School Post Installation Report

December 23rd, 2019

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Definitions

1. ***Measurement and Verification (M&V):*** The process of monitoring actual building energy performance and system performance before and after the project implementation and verifying building performance relative to project goals. The specific M&V approach is defined in this report.
2. ***Zero Net Energy (ZNE) Source:*** Achieving ZNE will be based on the definition developed on May 19, 2016 for California State Agency Compliance with Executive Order B1812, mandating ZNE for new and existing state buildings. It was developed by a focus group of 20 energy professionals from state agencies, utilities, federal and private sectors, and was accepted by the governor's office as the primary definition for use by state agencies in achieving and reporting on ZNE status for new and existing state buildings, and to be consistent with federally adopted definition. The definition is:
    - **ZNE Source** – Produces as much energy as it consumes over the course of a year, when accounted for at the energy generation source[1]
3. ***The Team****:* The team is composed of Pacific Gas and Electric, Integral Group, the School, and The Cadmus Group.
4. ***Energy Use Index (EUI):*** The amount of annual energy a building uses on a square foot basis, with units of kBtu/ft^2. Site EUI represents the energy used on site, with electricity and natural gas values converted directly to kBtu. Source EUI represents energy accounted for at the source in order to include generation and transmission losses. The conversion rates used in this report are 3.15 for electrical energy, and 1.09 for natural gas energy.
5. ***Coefficient of Performance (COP):*** Coefficient of performance is a unit less energy efficiency metric representing the ratio of heating or cooling delivered to the energy consumed by the unit.
6. ***Lumens (lum):*** Lumens is the SI unit of lighting intensity, or luminous flux, and is equal to the amount of light emitted per second through a solid angle of one steradian by a source of one candela radiating equally in all directions.
7. ***Heating Degree Days (HDD) and Cooling Degree Days (CDD):*** Both HDD and CDD are derived from outside air temperature to represent the relative heating and cooling demands of a building. HDD and CDD are calculated as the difference between the average outside air temperature for a day compared to a base temperature of 65^{o}F.

    Actual Meteorological Year (AMY) and Typical Meteorological Year (TMY) Data: AMY data represents actual outdoor air conditions (temperature, humidity, solar radiation, etc.) for a

[1] White paper: "Definition of Zero Net Energy (ZNE) for California State Agency Compliance with Executive Order B-18-12." May 19.2016.

given time period. TMY data is a collation of multiple years of data, and is frequently used in building simulation software to assess expected heating and cooling conditions without modeling extreme and anomalous weather conditions. Integral used TMY3 data from the Moffett Field station for the energy model referenced in this report.

Introduction

Los Altos Egan Junior High School has renovated its facility in order to achieve zero net energy (ZNE) on a source energy basis, using US Department of Energy site to source multipliers for gas and electricity[2]. This project is enrolled in the Pacific Gas and Electric (PG&E) Proposition 39 ZNE Schools Retrofit Pilot for technical assistance to help the school meet its aggressive ZNE goals. PG&E desired to use one of its technical assistance providers under its existing ZNE Technical Assistance contract to provide measurement and verification (M&V) services for the project during the 2018-2019 school year. The project involved implementing these measures to achieve its ZNE goal:

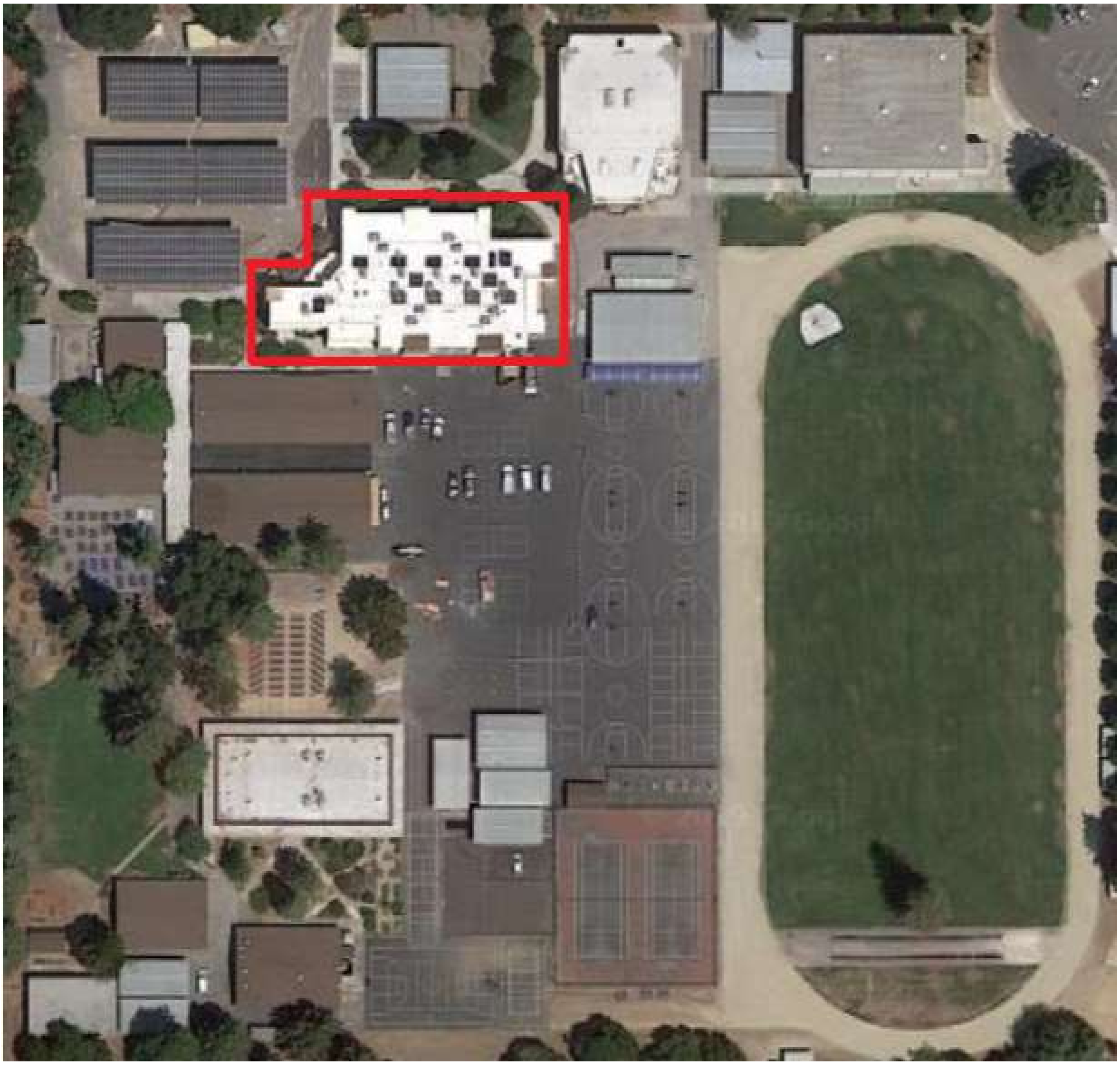
- Replaced the existing combustion heating package air handler units with new heat pump air handling units.
- Retrofitted all lighting in the building to bring the existing lighting power density down from 1.2 W/ft^2 to 0.845 W/ft^2.
- Installed daylighting controls in classrooms to continuously maintain the optimal fixed lighting level setpoint and to supplement electric lighting by utilizing daylight from windows and skylights.
- Replaced the existing prefabricated skylights with new skylights that have improved U-values, solar heat gain coefficients, and visible transmittance values.

The campus consists of several buildings, but the scope of the ZNE project is limited to the main administrative and classroom building (Building K). A satellite image of the campus is shown in Figure 1, with Building K outlined in red. Building K had a modeled baseline EUI of 36.9 kBtu/ft^2-yr and a modeled design ZNE EUI of 19.7 kBtu/ft^2-yr, within the PG&E Pilot's desired ZNE EUI range of about 16-22 kBtu/ft^2-yr.

The renovation project was completed during the summer of 2018. Building K had a metered electrical energy use of 149,842 kWh/yr and a modeled natural gas energy use of 926 therms/yr for the period of November 2018 – November 2019. The post-retrofit measured site Energy Use Intensity (EUI) of Building K is 22.6 kBtu/ft^2-yr. Approximately 645 students are enrolled at Los Altos Egan Junior High School.

[2] DOE 2015. A Common Definition for Zero Energy Buildings. https://www.energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf

Figure 1: Satellite Image of Campus, Building K Outlined in Red



The post-installation monitoring period lasted from November 19th, 2018 through November 19th, 2019. This final report summarizes the results and outcomes of the M&V activities, provides recommendations for improvements and on-going M&V activities, and provides notes on “lessons learned” that may benefit future ZNE and high performing buildings.

Report

The school's energy performance is very efficient, with an EUI that is well below the median K-12 school EUI for the U.S. (48.5 kBtu/ft^2-yr)[3] and California (41 kBtu/ft^2-yr)[4]. This performance is partly due to the aggressive LED lighting implementation and daylighting controls, as well as effective setback temperature controls for the HVAC system. The measured energy consumption was higher than the Integral model mainly due to the parasitic loads from plug equipment, primarily computers for students, consuming energy throughout the evenings, weekends, and summer periods. Additionally, lighting for the corridors and lobby areas often operate long into the evenings, driving up the interior lighting consumption despite the low lighting power density of the site.

The school's current post-retrofit EUI of 22.7 kBtu/ft^2 makes site ZNE readily achievable. However, the solar PV system installed above the parking lot does not provide enough energy to achieve ZNE on either a site or a source basis. Cadmus estimates that an additional 33.6 kW of solar PV panels can be installed on the roof of Building K, which would generate approximately 57,760 kWh/yr of energy and would achieve ZNE source for the building.

Actual Performance During M&V Period

Table 1 shows a comparison of the overall building energy use and EUI values between the Integral ZNE Final Energy Use Model and the metered usage for the period of November 2018 to November 2019. Utility data could not be used, because the scope of the project involved a single building on the campus and the utility meter covers the full campus. The natural gas and solar PV production could not be directly metered during the site visit, but Cadmus found no reason that the modeled values should be changed.

[3] Energy Star Portfolio Manager Technical Reference: U.S. Energy Use Intensity by Property Type, August 2018. https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf

[4] New Buildings Institute, Path to ZNE in K-14 Schools, 2017. Data was taken from CBECS and CEUS surveys.

Table 1: Comparison of Overall Building Energy Use

Category	Integral Post Installation Report Estimated Consumption	2018-2019 Metered Data Verified Consumption
Post Installation Electrical Energy Use (kWh/yr)	127,252	149,842
Post Installation Natural Gas Use (therm/yr)	957	957*
Total Site Energy Use (kBtu/yr)	529,902	606,982
Total Source Energy Use (kBtu/yr)	1,472,048	1,714,852
Post Installation Solar PV Production (kWh/yr)	116,000	116,000*
Site Energy Production (kBtu/yr)	395,808	395,808
Source Equivalent Energy Production (kBtu/yr)	1,246,796	1,246,796
Building Area (ft2)	26,718	26,718
Site EUI (kBtu/ft2-yr)	19.8	22.7
Source EUI (kBtu/ft2-yr)	55.1	64.2

*Could not be directly metered

Figure 2 shows the total building electrical energy use during the post installation period. The data demonstrate a relatively consistent electrical consumption pattern during the school year. Consumption decreases during the summer months (June, July and August) when the facility is less used, and during the winter months (December) when air conditioning demand is lowest. Solar energy production is illustrated with a bell curve that reaches highest production in the summer months (June) and lowest production in the winter months (Nov and Dec), tracking with the relative solar intensity and length of daylight hours throughout the year.

Figure 2: Building Electrical Energy Use During Post Installation Period

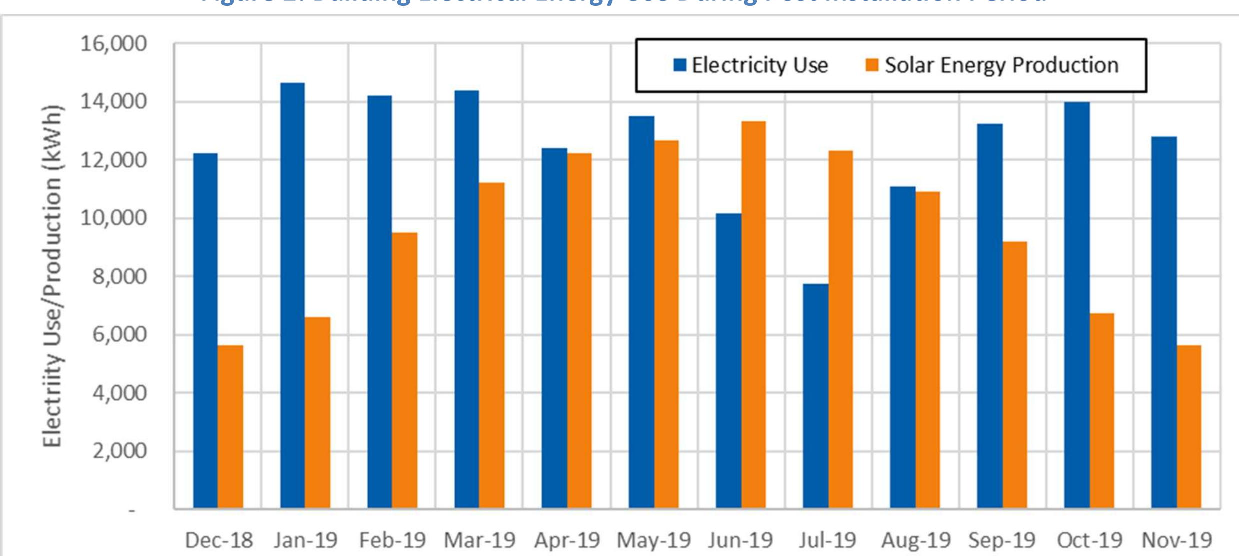


Figure 3 shows the total building natural gas use during the post installation period. Gas consumption remains relatively consistent throughout the school season, demonstrating very little seasonality in the consumption pattern because natural gas is primarily used for domestic hot water.

Figure 3: Building Natural Gas Energy Use During Post Installation Period

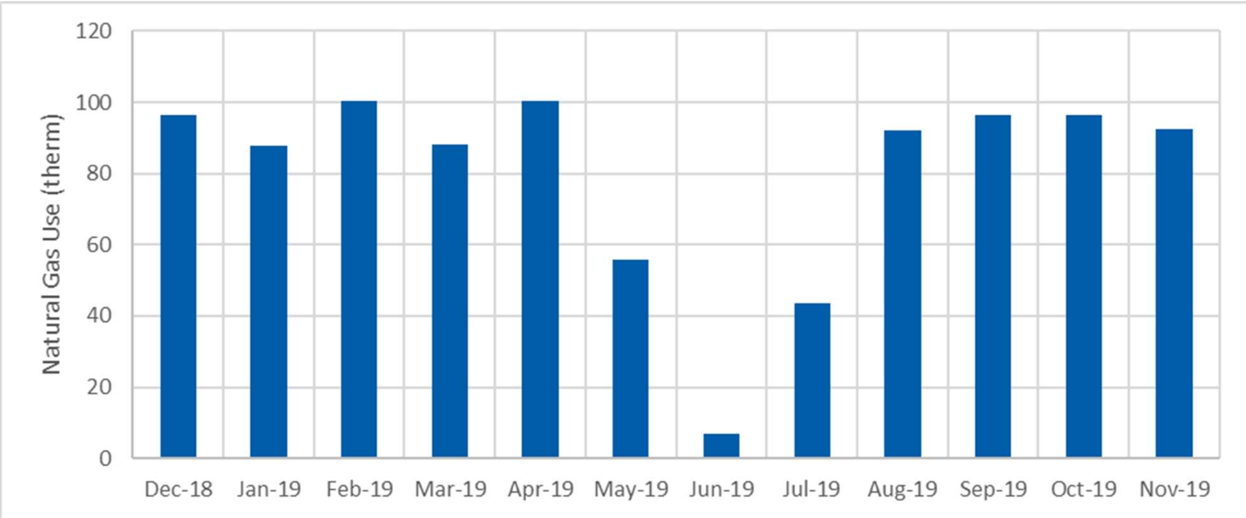


Figure 4 shows the total building energy use during the post installation period. Total energy use shows a pattern of seasonality with total consumption highest in the winter months due to heat pump heating.

Figure 4: Total Building Energy Use During Post-Installation Period

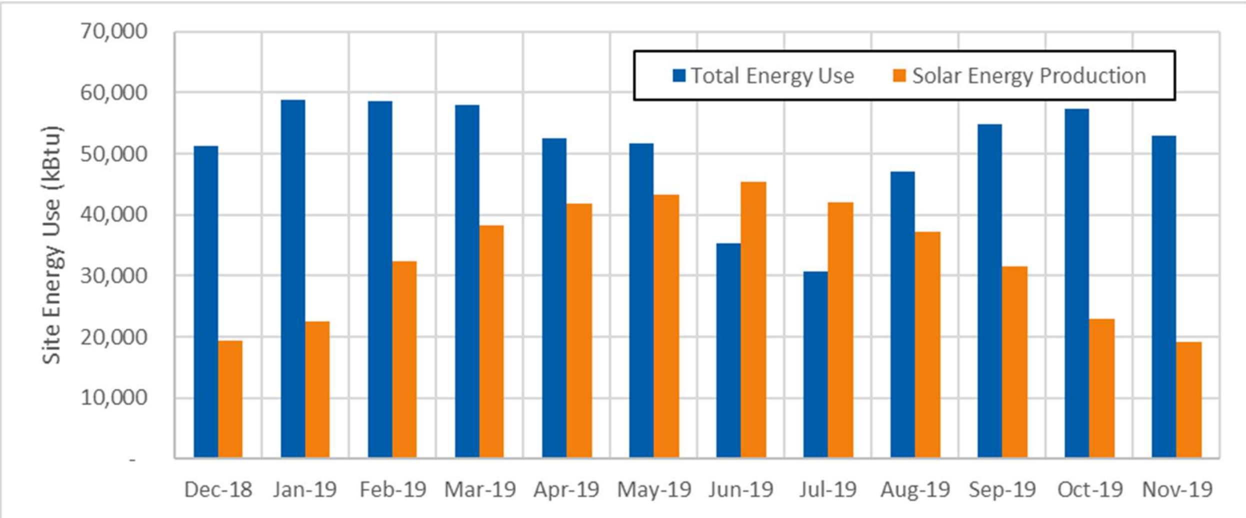
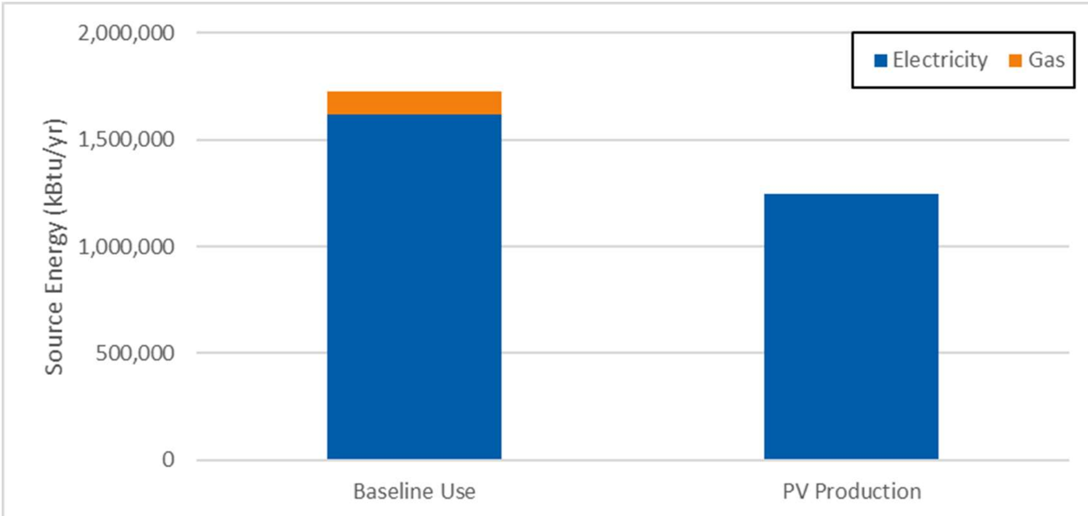


Figure 5 shows the total annual building energy use compared to the total solar PV energy production on a source energy basis. The energy consumption of the building is dominated by electricity usage. PV production currently offsets 72% of the total source energy usage of the building.

Figure 5: Post-Install Usage vs. PV Energy Production, Source Energy



Annual Energy Projections and Energy Model Calibration

Integral developed an energy model for the Los Altos Egan Junior High School using the EnergyPlus platform OpenStudio v.2.7.0 and calibrated the model to the overall energy use for the site.

Table 2 summarizes the annual energy projections and end use breakdowns for the Integral energy model and the metered end uses of the system. The metered energy data demonstrated that the plug load and interior lighting end uses were higher than predicted in the Integral energy model, while the HVAC energy consumption was lower than the Integral energy model.

The plug loads show a very high parasitic load overnight, during the weekends, and during holiday and summer breaks. The Integral model does account for some usage during these periods, approximately 10% of the power of full-load operation. However, metered data shows that the parasitic load can be from 15% up to over 50% of the full load consumption of the plug loads. The majority of the plug loads at Egan Junior High are computer systems, and it is recommended to install plug load management devices on the computer systems to eliminate these parasitic loads when the computers are not being used.

The interior lighting systems were modeled to operate from approximately 6AM to 5PM during the week. The metered data shows that this timeframe correlates well for the classrooms. However, many of the office and lobby areas operate well into the evening, and the corridors are lit continuously. If these areas do not need to be lit for security purposes, it is recommended to install ceiling occupancy sensors to control these fixtures.

The measured HVAC consumption was lower than predicted by the energy model. This is mainly due to a very effective setback strategy on the thermostats; there was very little energy consumption of the HVAC systems during overnight periods and during weekends. The system did still operate during holiday breaks and during summer break, so there is still opportunity for controls savings. However, a building automation system might be required to achieve advanced scheduling control.

Table 2: Comparison of annual performance projections

End Use	Integral Energy Model Site EUI	Integral Energy Model Source EUI	M&V Site EUI	M&V Source EUI	M&V Electrical Energy Consumption (kWh/yr)	M&V Natural Gas Energy (therm/yr)	M&V Total Site kBtu	M&V Total Source kBtu
Heating	1.8	5.8	1.1	3.6	8,958	0	30,566	96,283
Hot Water	3.5	4.0	3.5	4.0	125	957	92,600	105,652
Plug Loads	6.9	22.1	9.7	30.5	75,879	0	258,910	815,566
Exterior Lighting	0.1	1.7	0.3	1.0	2,439	0	8,322	26,215
Lighting	2.5	6.5	5.5	17.3	43,036	0	147,271	462,561
Cooling	1.2	3.7	0.6	1.8	4,490	0	15,321	48,260
Fans	3.6	11.4	1.9	6.0	14,915	0	50,892	160,310
Total	**19.7**	**55.1**	**22.6**	**64.2**	**149,842**	**957**	**603,882**	**1,714,846**

Table 3: Comparison of Actual Meteorological Year (AMY) and Typical Meteorological Year (TMY) Data

Date	AMY		TMY*	
	CDD	HDD	CDD	HDD
Nov-18	5	252	0	375
Dec-18	0	415	0	482
Jan-19	0	373	0	468
Feb-19	0	445	0	380
Mar-19	0	330	5	319
Apr-19	12	156	5	315
May-19	0	175	56	96
Jun-19	118	27	65	44
Jul-19	104	4	113	14
Aug-19	185	0	105	3
Sep-19	123	18	154	6
Oct-19	35	108	7	109
Nov-19	0	287	0	375
Total	**582**	**2590**	**510**	**2986**

*TMY3 data taken from the Mountain View Moffett Field station

Figure 6 shows the site energy end use ratios between the Integral energy model and the M&V data. Figure 7 shows the source energy end use ratios between the Integral energy model and the M&V data.

Figure 6: Comparison of site energy end-use between the Integral energy model (left) and the M&V data (right)

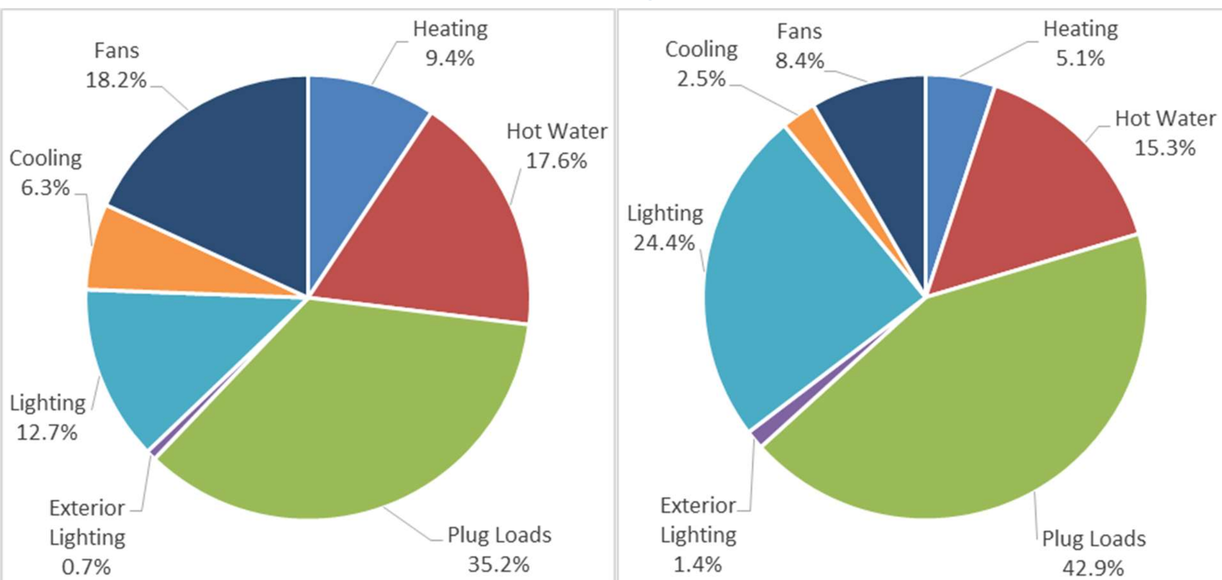
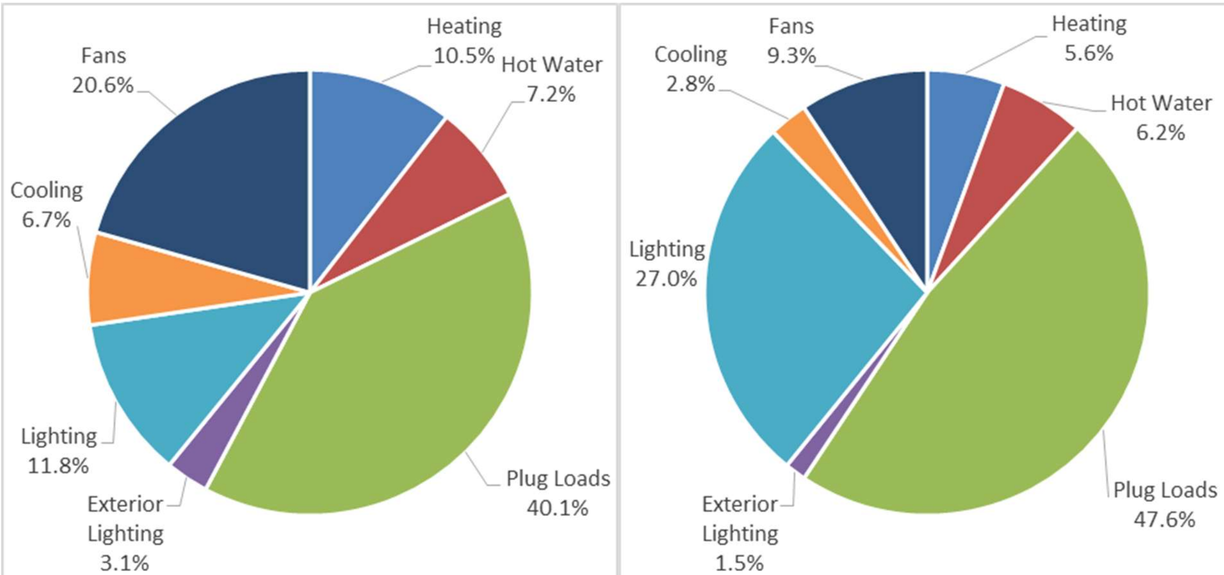


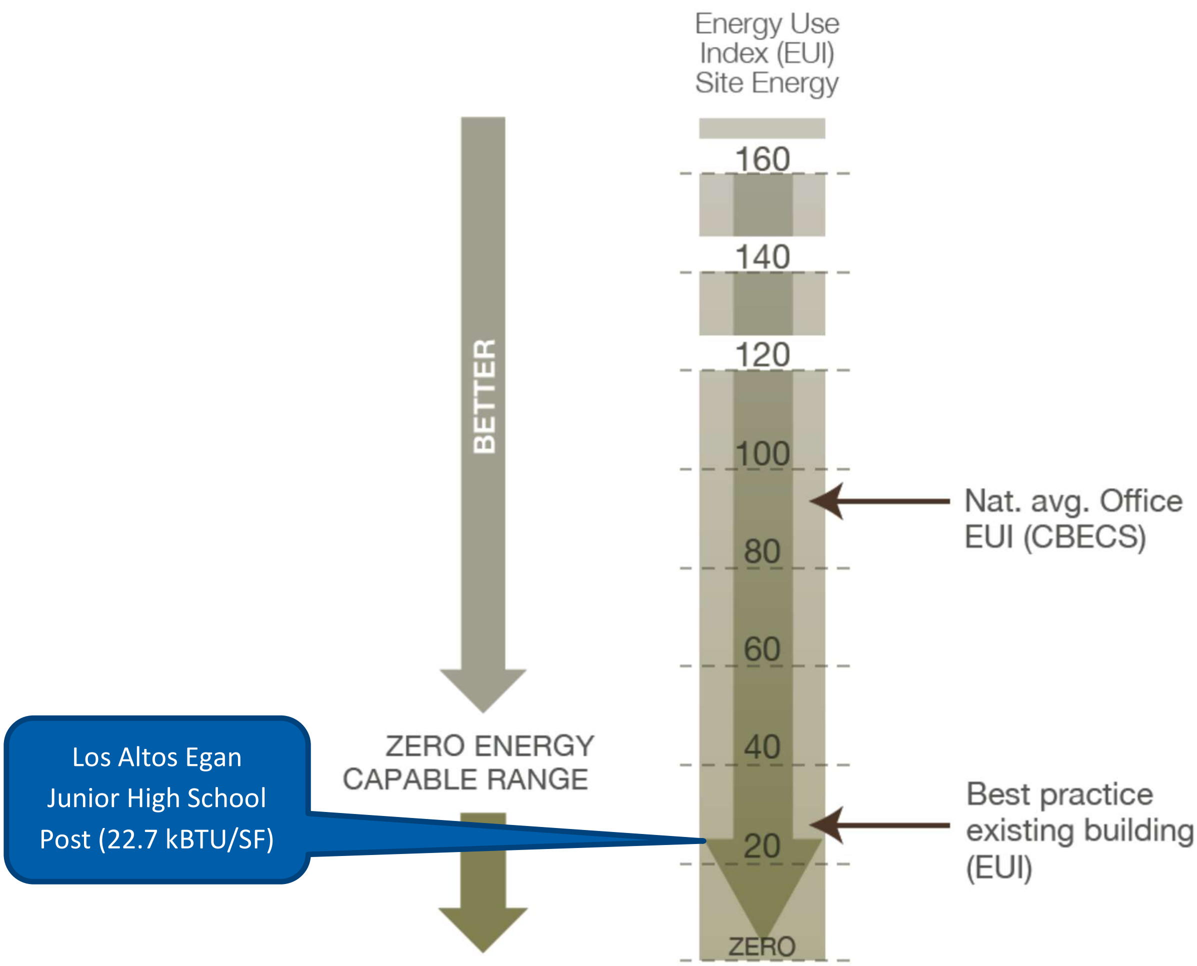
Figure 7: Comparison of Source energy end-use between the Integral energy model (left) and the M&V data (right)



Benchmarked Performance

Figure 8 shows the adapted EUI scale from the New Building Institute (NBI)'s "Getting to Zero" Report[5] with the school's EUI overlain. NBI defines "ZNE Capable" buildings as those with EUIs ≤ 35 kBTU/ft^2/year. This is the upper limit of actual ZNE building's energy use (excluding renewables generation) that are in the NBI's database. Egan Junior High School's post-installation EUI of 22.7 kBTU/ft^2/year before renewables, and a post-installation site EUI of 7.90 kBTU/ft^2/year with renewables included, makes ZNE easily achievable with additional solar PV capacity installed at the campus.

Figure 8: Adapted EUI Scale from "Getting to Zero" report from the New Buildings Institute showing Los Altos Egan Junior High School EUI



[5] New Buildings Institute. "Getting to Zero 2012 Status Update: A First Look at the Costs and Features of Zero Energy Commercial Buildings." March 2012.
http://newbuildings.org/sites/default/files/GettingtoZeroReport_0.pdf

Lessons Learned, Recommendations, and Opportunities

It is a simple process to verify the overall EUI of the building using utility bills, and it is recommended to install a submeter on the future photovoltaic system to easily determine the impacts of renewable energy on the site EUI and source EUI. The scope of this project limited the use of utility data; since only one building was targeted for ZNE performance, utility bills for the entire campus could not be used. Cadmus installed electrical power meters on every panel in the building in order to determine the annual electrical energy consumption of the building. A single power meter would have been installed on the switchgear feeding the building, but there was not enough space between the conductors to fit the sensors. Natural gas was determined through the energy model; there are no non-invasive sensors that can be used to measure natural gas flow.

Short term metering of lighting, HVAC, and other loads at this site was can be challenging. This is because electrical panels are distributed throughout the buildings, and multiple electrical rooms would need to be metered to collect enough relevant data. Additionally, because of renovations and poor circuit labeling, it is difficult to establish if we were monitoring a circuit that was actually loaded, or had been decommissioned at some point during the building’s life. This is evident with the computer receptacle plug load circuits we monitored; only two of the six measured circuits had any significant load. Additionally, with generic labeling it was impossible to determine which room a circuit labeled “lighting” was serving. Egan had panels that were dedicated to specific purposes (HVAC panels, lighting panels, and plug load panels), which made it easier to determine the overall end uses of the electrical energy consumption. At many other buildings, the panels have mixed end uses, and reduces the ease of panel-level metering.

Sub Metering

Metering problems have been a common issue for several recent ZNE buildings, including other projects in the PG&E Pilot. Metering is a specialty field that, depending on the metering equipment involved, can require special expertise to install and calibrate. It is recommended that all metering/submetering equipment in ZNE and high performing buildings receive appropriate commissioning/verification to ensure they are providing accurate data. During the duration of metering at Egan Junior High, several meters were removed or went missing during the data collection process. The meters we used wirelessly provide data to Cadmus every day, and these issues were quickly diagnosed and corrected to minimize loss of data.

Plug Loads

Plug loads comprise an increasingly large percentage of the total building energy use as HVAC and other regulated loads are reduced. It is not uncommon for plug loads to represent 25% - 50% of a building’s total load. Egan’s plug loads are relatively high compared to typical commercial buildings, accounting for 42.9% of the total building energy use. The energy model estimated plug load energy at 35.2%.

There is difficulty in metering individual plug load circuits, due to the diversity in usage between different plug loads throughout a school campus. At Egan, there were 5 panels specifically dedicated to plug loads and one panel specifically dedicated to the elevator, which made monitoring the plug load energy usage much easier than other schools. The data shows that for the panels dedicated to computer circuits, there was a significant amount of energy dedicated to maintaining sleep mode on the computers overnight, over the weekends, and during holiday and summer breaks. The elevator panel shows that there is also a significant amount of energy usage during these periods; it is estimated that the elevator control system would automatically switch floors every 2-3 hours.

The key lessons learned are that plug loads represent a large portion of building use, and focusing on opportunities to reduce these loads will be important for future ZNE buildings. There may be opportunities for PG&E and other organizations to support projects to improve the modeling of plug loads. As a starting point, it would be useful to document how well plug loads are currently being modeled (e.g., a study comparing LEED building energy modeled data vs. actual plug loads).

Measures

The energy efficiency measure package implemented by Egan Junior High includes:

Measure 1

- The 20 existing package air handler units were replaced with new Carrier heat pump air handling units.
- The SEER values of the new heat pump units varied from 15.0 – 15.8 Btu/W-hr based on model number.
- The COP values of the new heat pump units varied from 3.66 – 3.70 based on model number.

Measure 2

- The school retrofitted all lighting in the building, reducing the installed lighting power density from 1.2 W/ft^2 to 0.845 W/ft^2.

Measure 3

- Installation of daylighting controls in all classrooms to continuously dim based on lighting from windows and skylights.

Measure 4

- The existing prefabricated skylights were replaced with Kalwall skylights.
- The new skylights have a U-Value of 0.53, a solar heat gain coefficient of 0.38, and a visible transmittance of 0.2.

Appendices

These appendices outline all the metered data collected from November 2018 through November 2019. The sections are organized by lighting power, HVAC power, space temperature, space lighting intensity, and plug load power. Table 4 summarizes the electrical panels on site, as well as the types of circuits that are wired to the panels.

Table 4: Summary of Electrical Panels and Circuit Loads

System	Description
Panel HCP1	31 receptacle and appliance circuits
	3 miscellaneous circuits
Panel HCP2	33 receptacle circuits
	1 miscellaneous circuit
Panel HCPR	32 receptacle circuits
	2 miscellaneous circuits
Panel HAC1	8 receptacle circuits
	3 domestic hot water circuits
	2 miscellaneous circuits
Panel HAC2	14 receptacle circuits
Panel HL1	20 indoor lighting circuits, 1 exterior circuit
	1 miscellaneous circuit
Panel HL2	13 indoor lighting circuits
Panel HACR	39 HVAC circuits
Panel HACR2	1 receptacle circuit
	21 HVAC circuits
	3 miscellaneous circuits

Logged Data – Lighting Power

- The following figures discuss the logged lighting power averaged by hour for weekdays, holidays, weekends, and summer days.
  - Figure 9 shows the average logged lighting power for Panel HL1. Panel HL1 routes power for the computer room, lobby, conference room, office, and work room lighting circuits. The lighting in these rooms often continues operating late into the evening.
  - Figure 10 shows the average logged lighting power for Panel HL2. Panel HL2 routes power for all the classroom lighting circuits.
  - Figure 11Figure 11 shows the average logged lighting power for the exterior lighting. Exterior lighting generally ramps up at 4PM to full load at 8PM-11PM, shuts off from 8PM-11PM, turns on at full load from 5AM-6AM and ramps to off by 8AM.
  - Figure 12 shows the average logged lighting power for 2nd floor Classroom 1. This room does not appear to be affected by daylighting control, and this may be due to northern-facing skylights.
  - Figure 13 shows the average logged lighting power for 2nd floor Classroom 2. Compared to the previous classroom lighting, the power in this classroom more effectively tapers off during the afternoon, and it is possible this is due to a more effective daylight control.
  - Figure 14 shows the average logged lighting power for 2nd floor Classroom 3. The lighting in this room rarely operated, it is unclear if this room wasn't used or there was an error with the sensor.
  - Figure 15 shows the average logged lighting power for 2nd floor Classroom 4.
  - Figure 16 shows the average logged lighting power for Computer Room K125.
  - Figure 17 shows the average logged lighting power for the 2nd Floor corridor. This graph shows that corridor lighting operates continuously, and is not shut off during weekends, holidays, or during the summer.
  - Figure 18 shows the average logged lighting power for the 1st Floor corridor. Similar to the previous graph, this shows the corridor operating continuously. There is likely another room connected to this lighting circuit that drives up the load during typical classroom hours.
  - Figure 19 shows the average logged lighting power for the library.
  - Figure 20 shows the average logged lighting power for the main lobby.
  - Figure 21 shows the average logged lighting power for an office, supply room, and toilet on the 1st floor.
  - Figure 22 shows the average logged lighting power for the 2nd floor restrooms and mechanical room.
  - Figure 23 shows the daily energy consumption of both lighting panels for the entire monitoring period. Generally, the classroom lighting will only operate on weekdays, but many of the support areas operate on weekends and throughout the summer.
  - Figure 24 shows the daily energy consumption of both lighting panels for the month of January 2019.
  - Figure 25 shows the daily energy consumption of both lighting panels for the month of September 2019.

Figure 9: Logged Lighting Power for Panel HL1

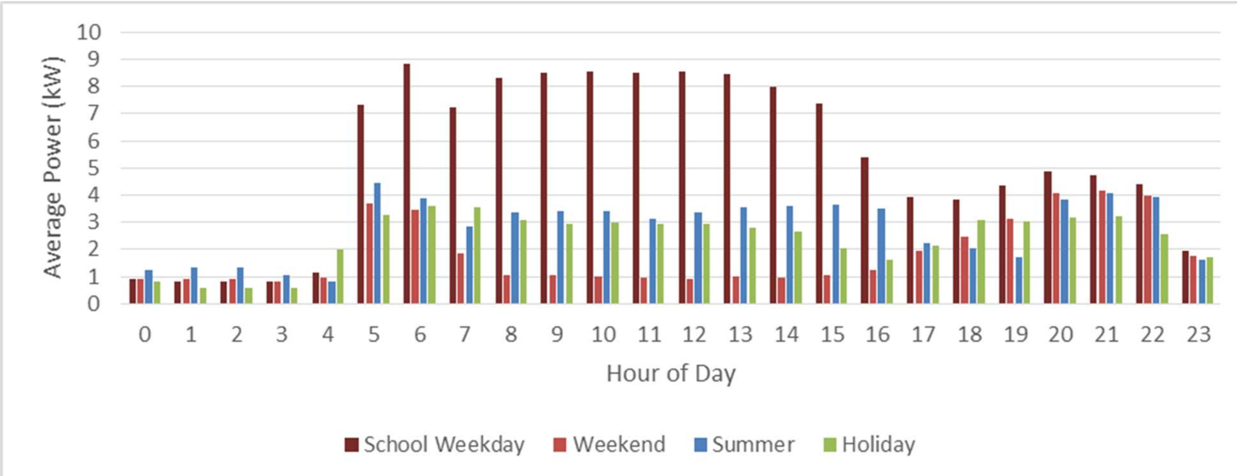


Figure 10: Logged Lighting Power for Panel HL2

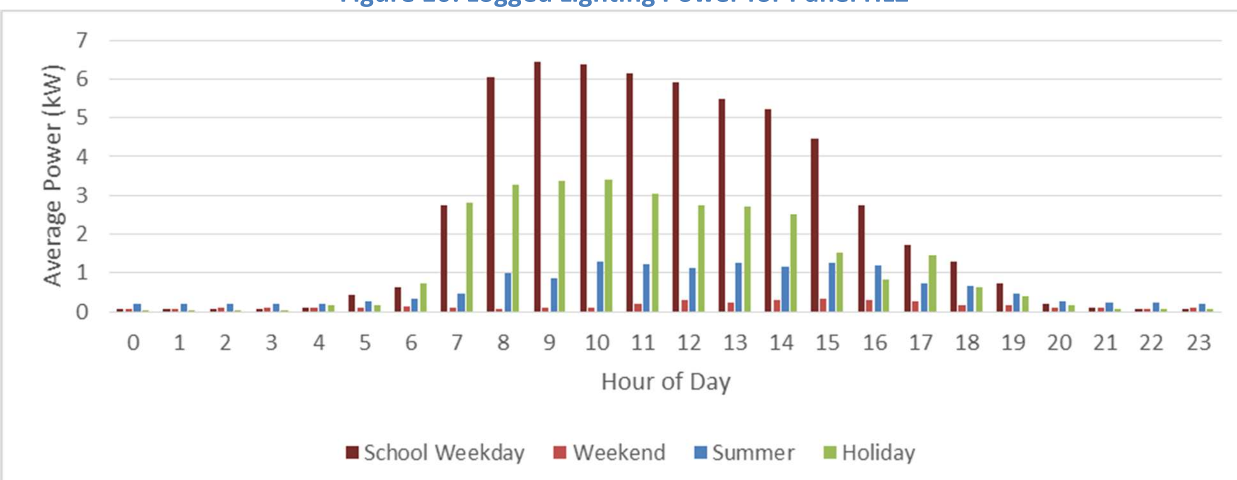


Figure 11: Logged Lighting Power for Exterior Lighting Circuit

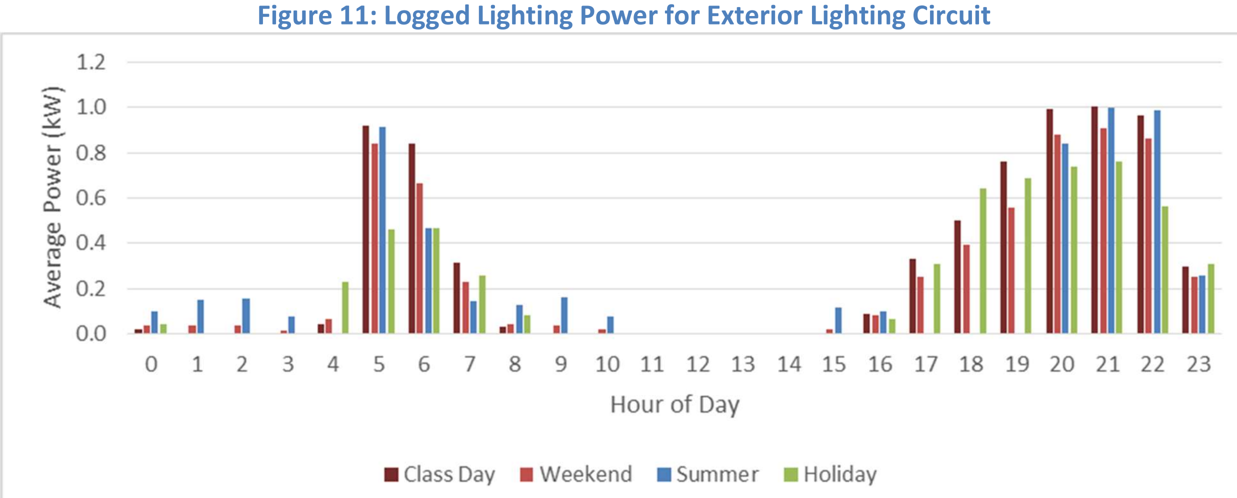


Figure 12: Logged Lighting Power for 2nd Floor Classroom 1 (Unknown Class Number)

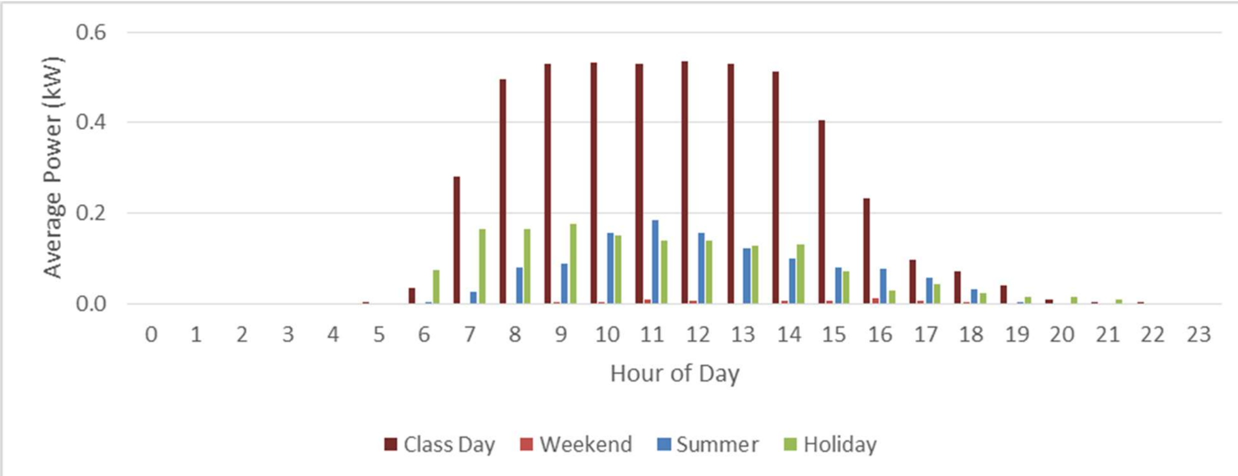


Figure 13: Logged Lighting Power for 2nd Floor Classroom 2 (Unknown Class Number)

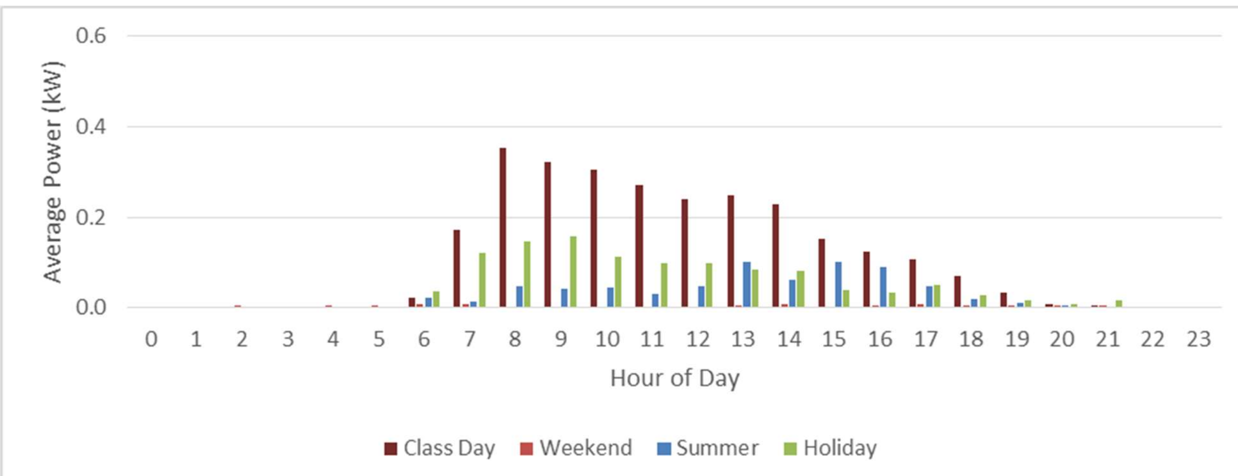


Figure 14: Logged Lighting Power for 2nd Floor Classroom 3 (Unknown Class Number)

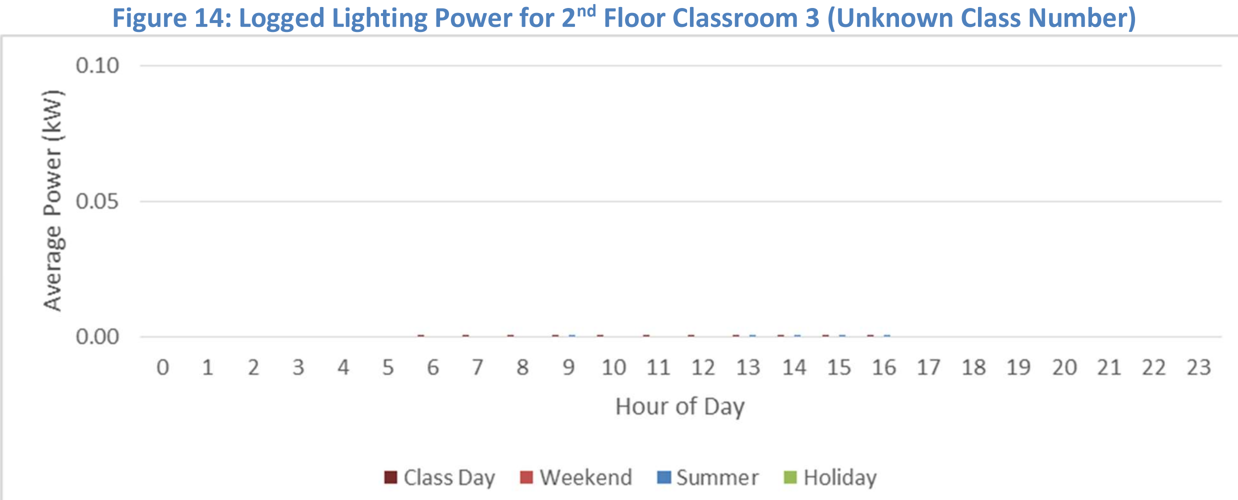


Figure 15: Logged Lighting Power for 2nd Floor Classroom 4 (Unknown Class Number)

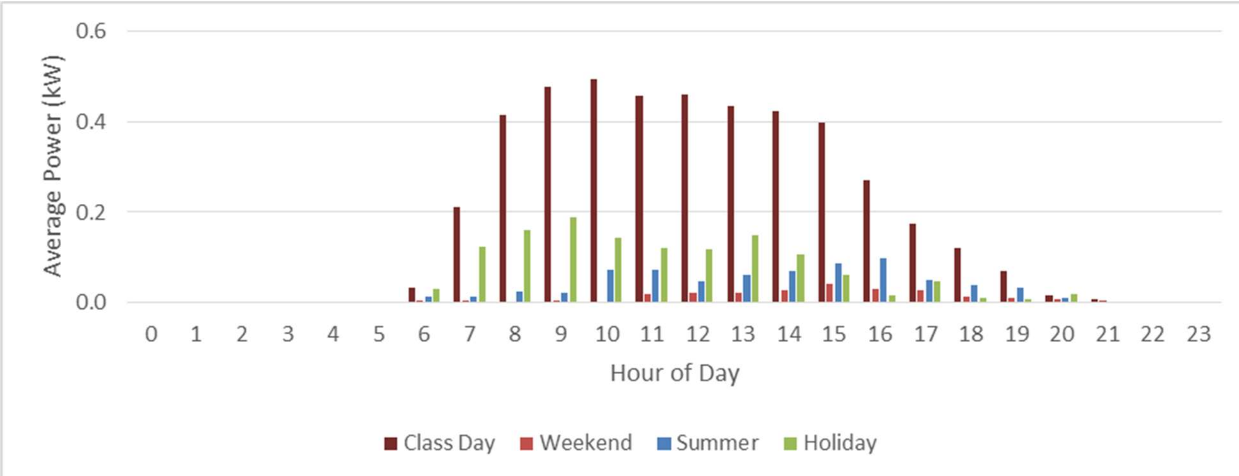


Figure 16: Logged Lighting Power for Computer Room K125

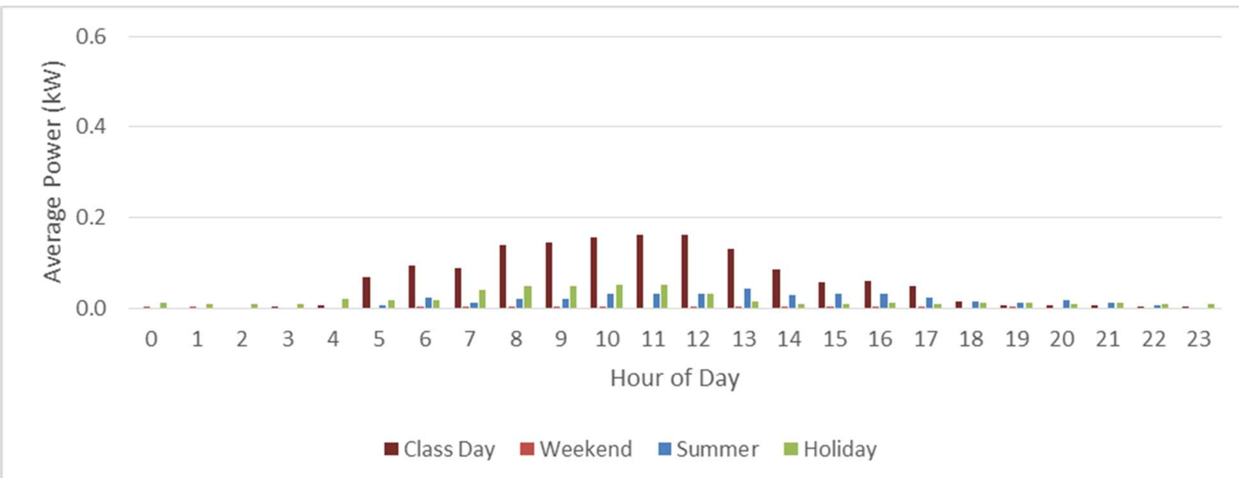


Figure 17: Logged Lighting Power for Second Floor Corridor

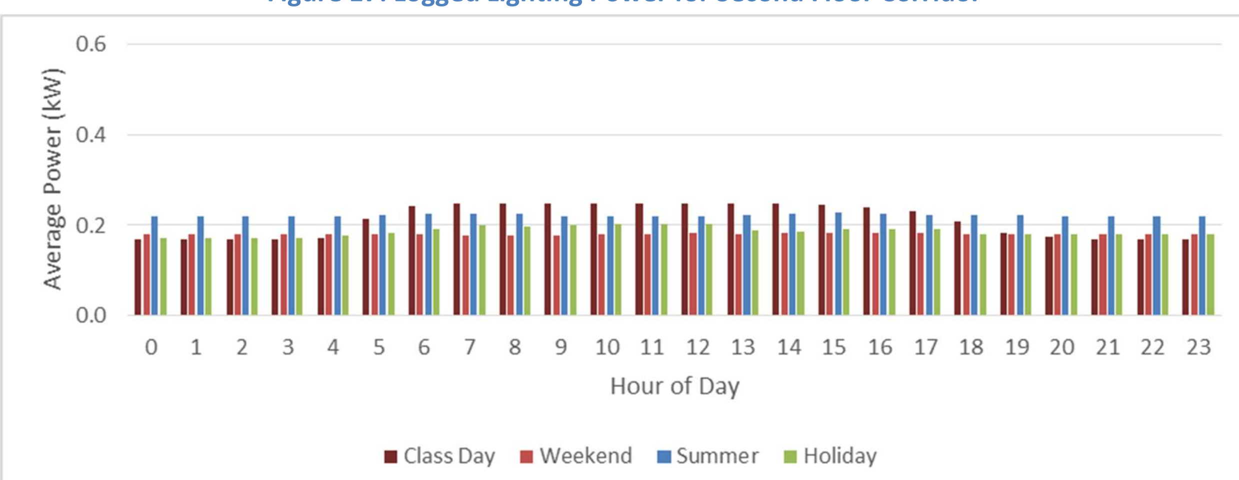


Figure 18: Logged Lighting Power for First Floor Corridor

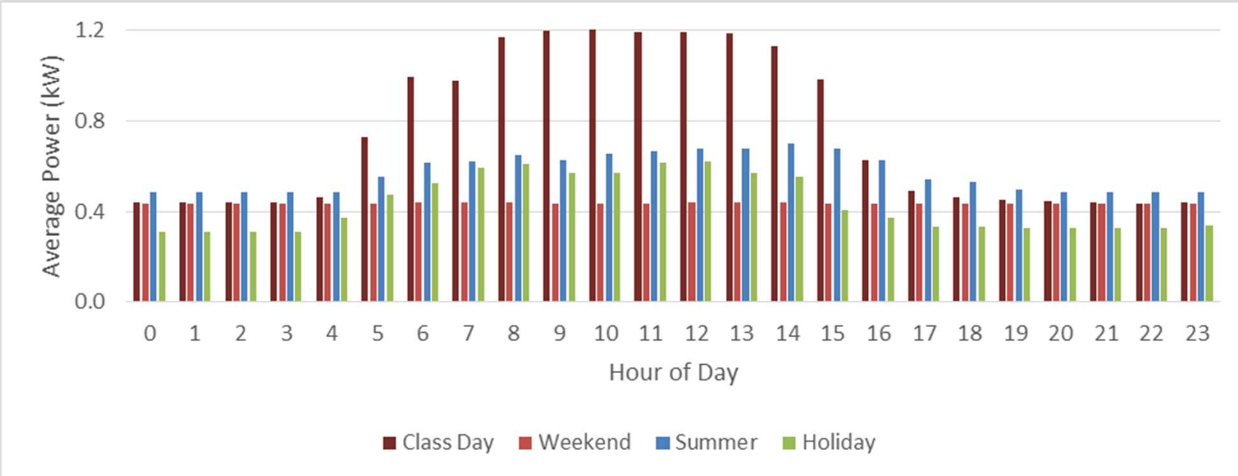


Figure 19: Logged Lighting Power for Library

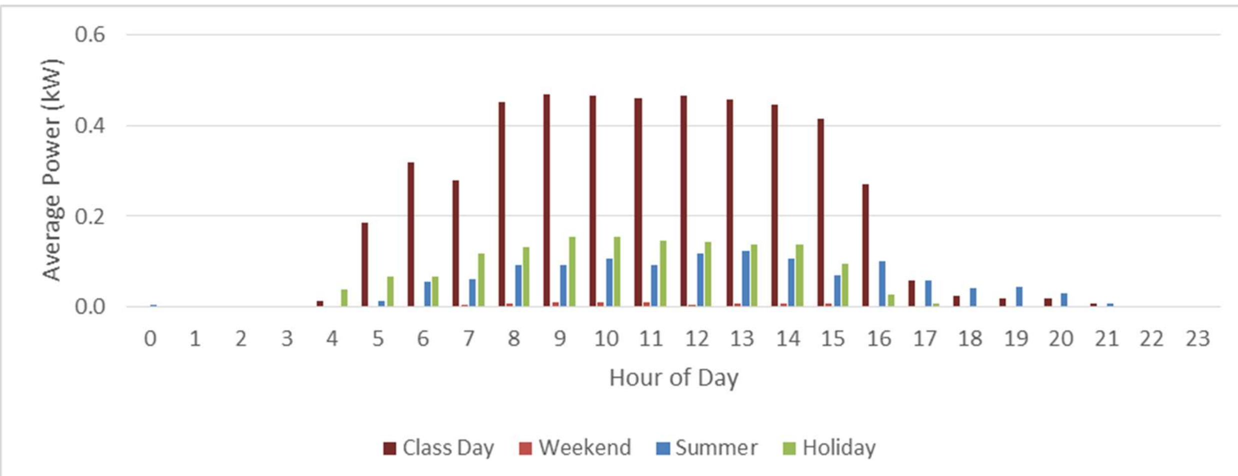


Figure 20: Logged Lighting Power for Main Lobby

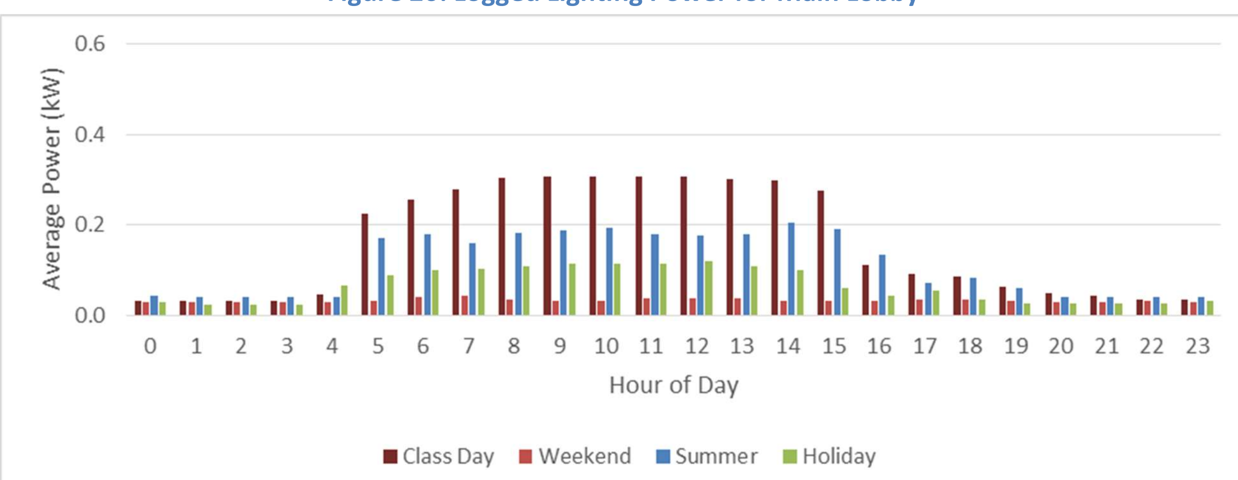


Figure 21: Logged Lighting Power for an Office, Supply Room, and Toilets

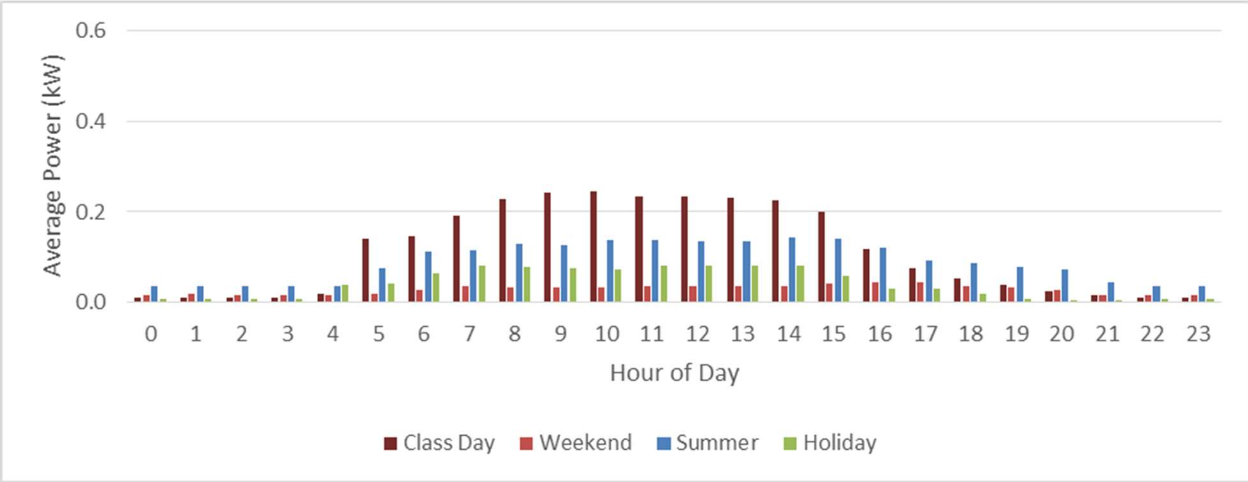


Figure 22: Logged Lighting Power for Second Floor Restrooms and Mechanical Room

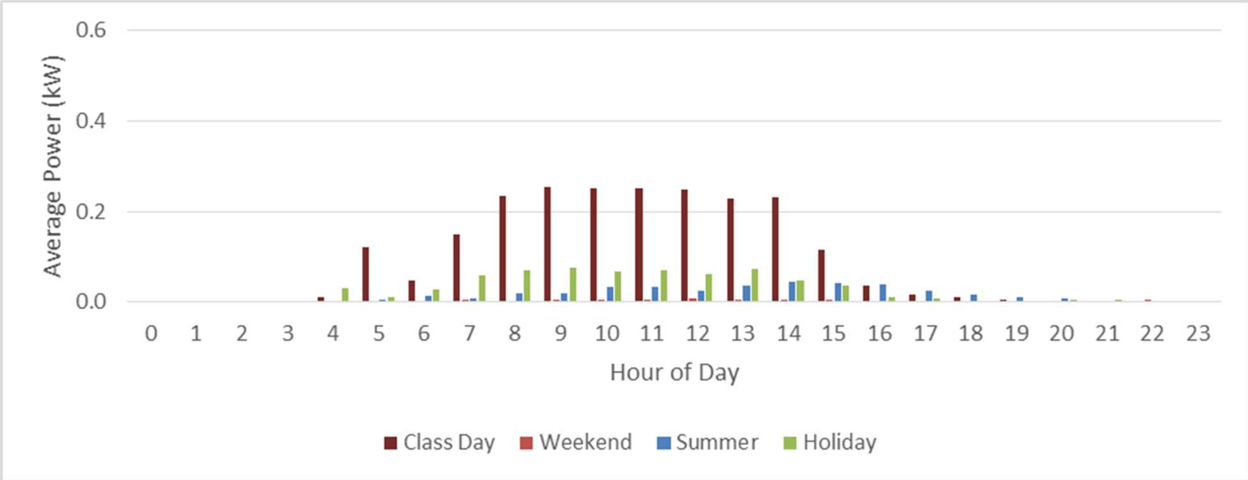


Figure 23: Daily kWh of Metered Lighting Panels, Entire Period

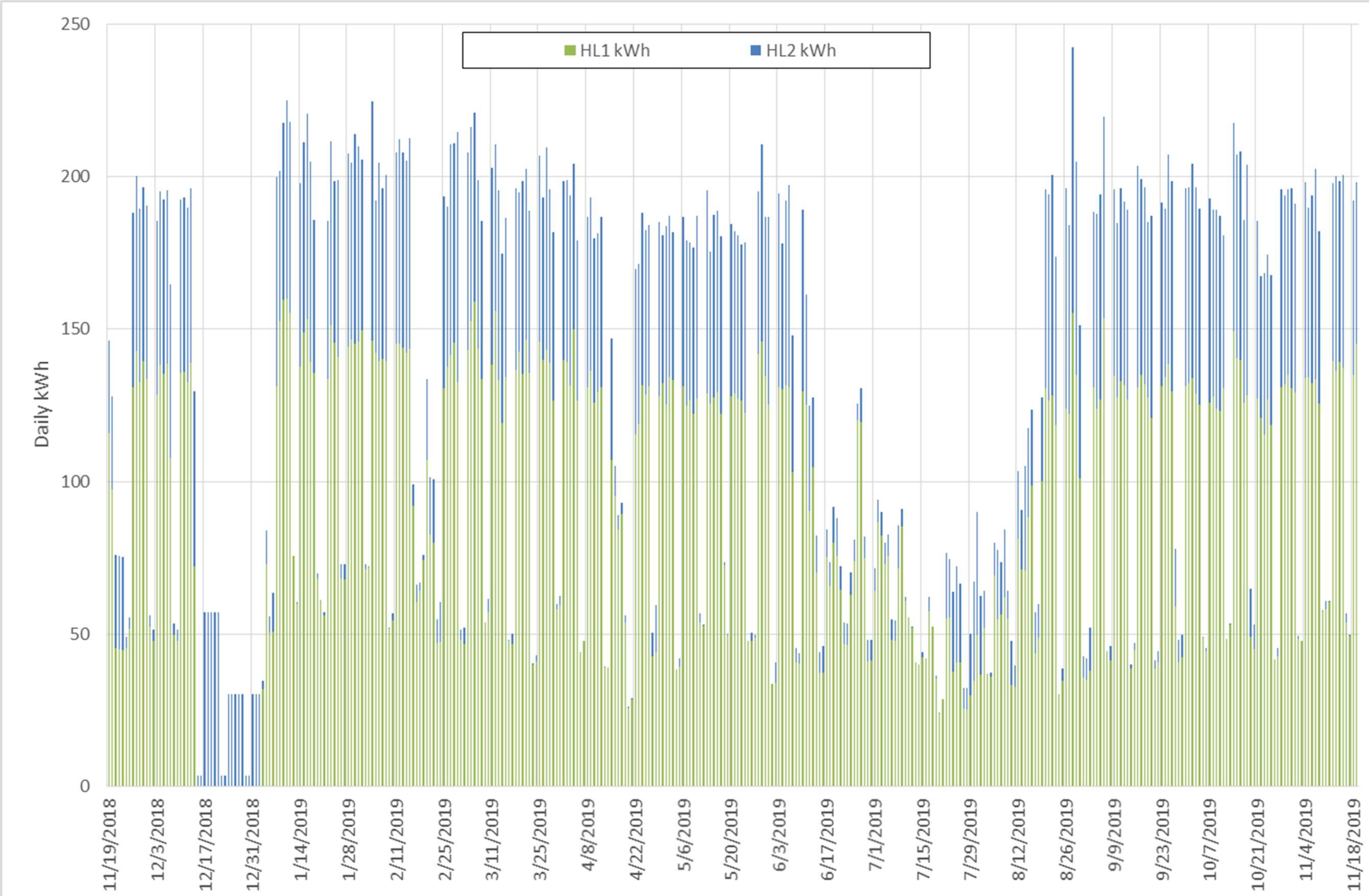


Figure 24: Daily kWh of all Metered Lighting Circuits, One Month (January 2019)

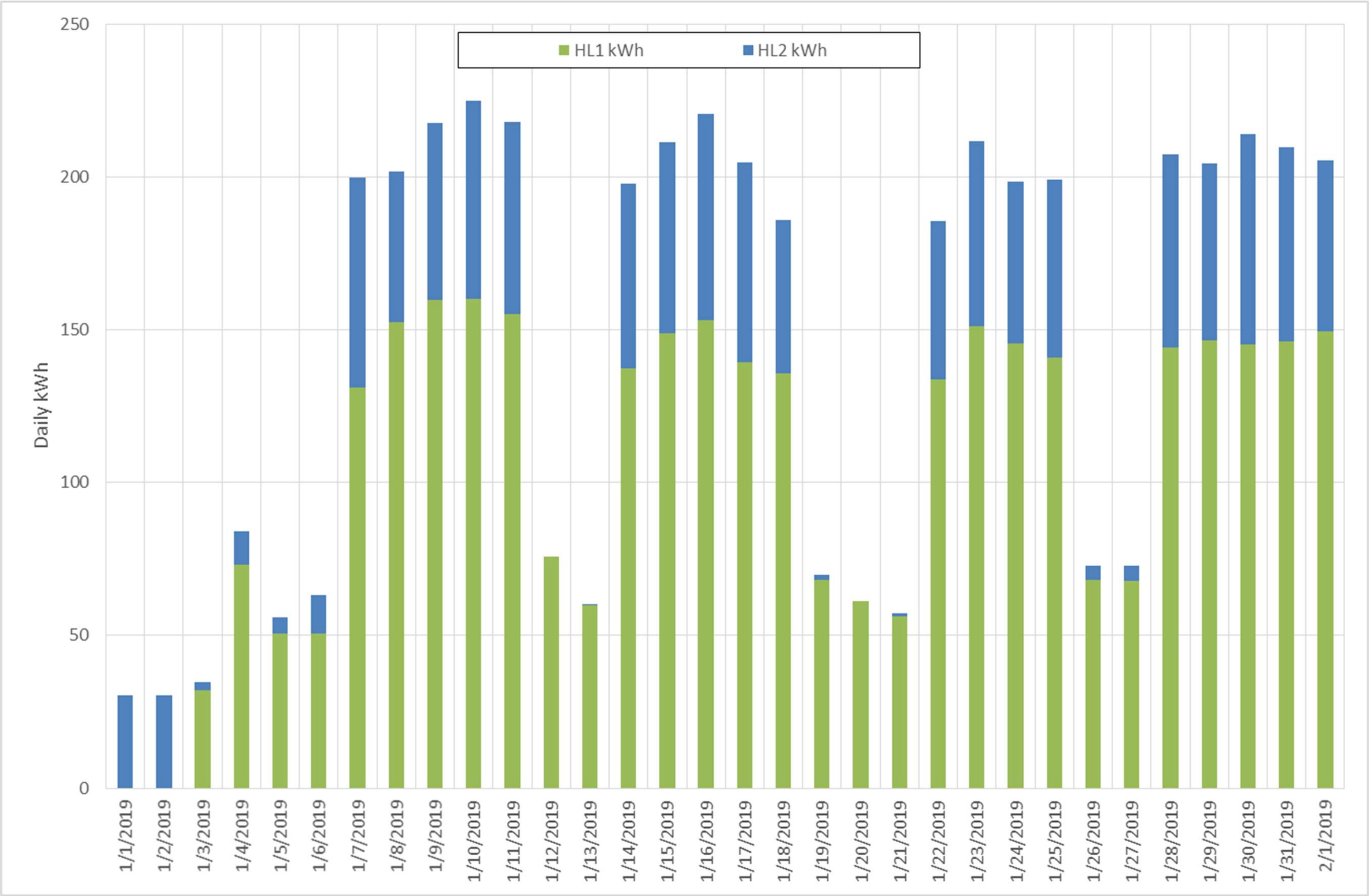
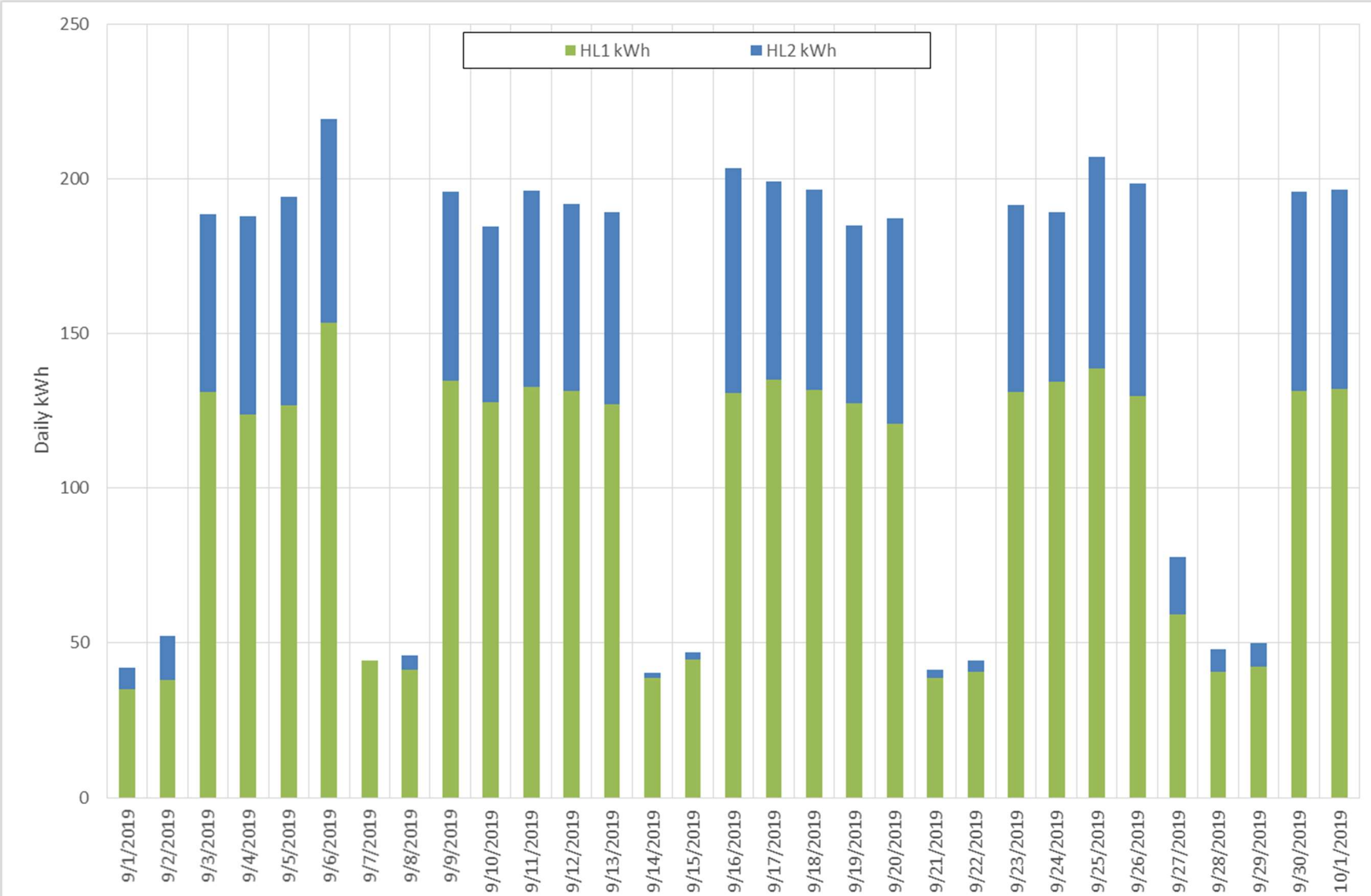


Figure 25: Daily kWh of all Metered HVAC Units, One Month (September 2019)



Logged Data - HVAC

- The following figures illustrate the logged HVAC power for the school.
    - Figure 26 shows the average daily kW of the metered HVAC panel vs. the heating degree days for in-session weekdays.
    - Figure 27 shows the average daily kW of the metered HVAC panel vs. the cooling degree days for in-session weekdays.
    - Figure 28 shows the average daily kW of the metered HVAC panel vs. the heating degree days for in-session weekends.
    - Figure 29 shows the average daily kW of the metered HVAC panel vs. the cooling degree days for in-session weekends.
    - Figure 30 shows the average daily kW of the metered HVAC panel vs. the heating degree days for holidays.
    - Figure 31 shows the average daily kW of the metered HVAC panel vs. the cooling degree days for holidays.
    - Figure 32 shows the average daily kW of the metered HVAC panel vs. the heating degree days for the summer.
    - Figure 33 shows the average daily kW of the metered HVAC panel vs. the cooling degree days for the summer.
    - Figure 34 shows the average hourly kW of the metered HVAC panel. This figure shows that the HVAC system is very effective at setting back the units during unoccupied hours overnight and on unoccupied days over the weekend, but does not shut down the system during unoccupied days during holidays, extended holiday breaks, and over the summer.
    - Figure 35 shows the daily energy consumption of the metered HVAC panel for the entire monitoring period.
    - Figure 36 shows the daily energy consumption of the metered HVAC panel for the month of January 2019.
    - Figure 37 shows the daily energy consumption of the metered HVAC panel for the month of September 2019.

Figure 26: Average Daily kW of all Metered HVAC Units vs. Heating Degree Days, In-Session Weekdays

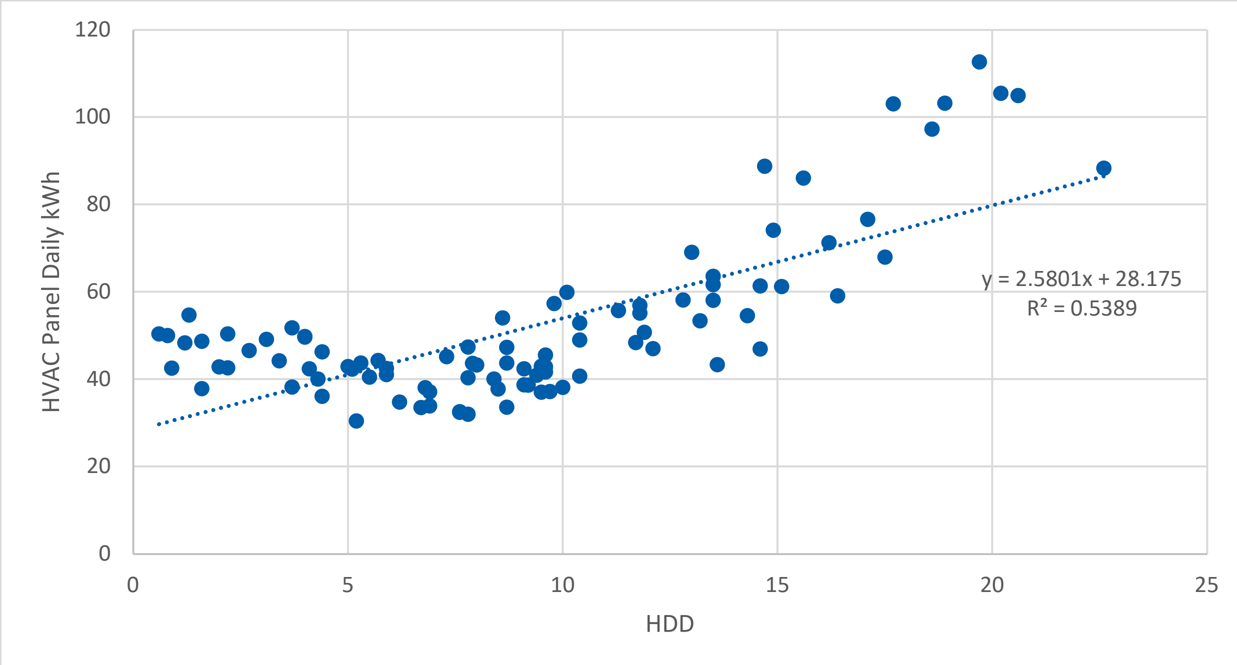


Figure 27: Average Daily kW of all Metered HVAC Units vs. Cooling Degree Days, In-Session Weekdays

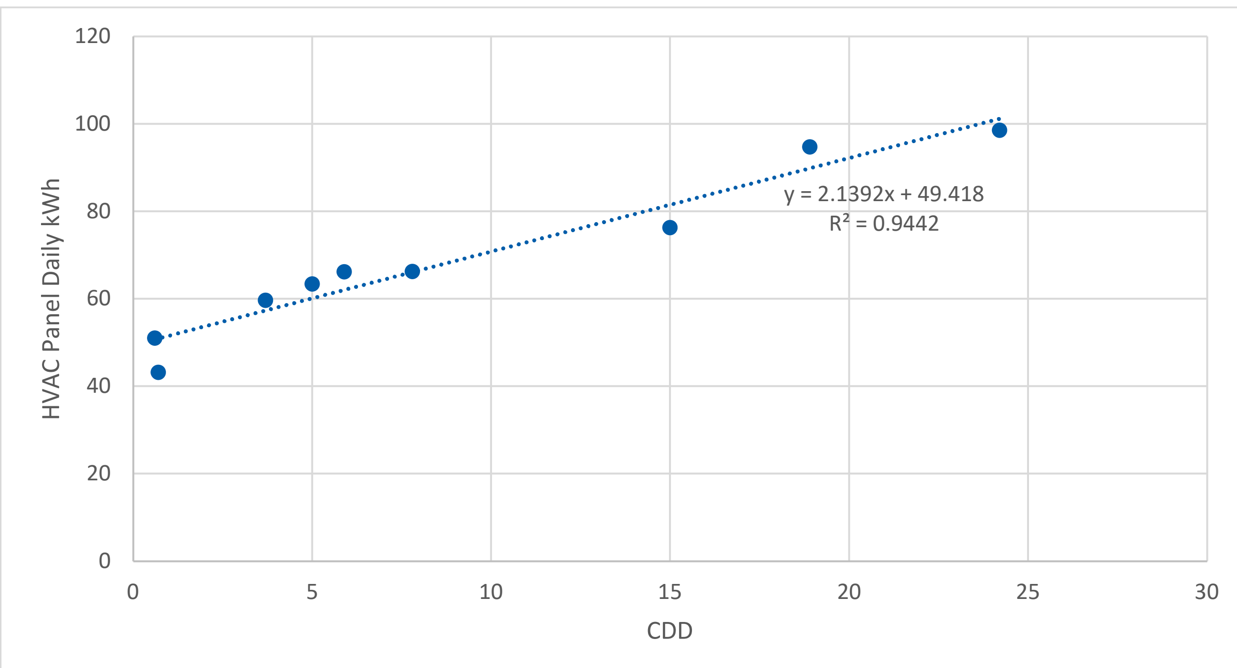


Figure 28: Average Daily kW of all Metered HVAC Units vs. Heating Degree Days, Weekends

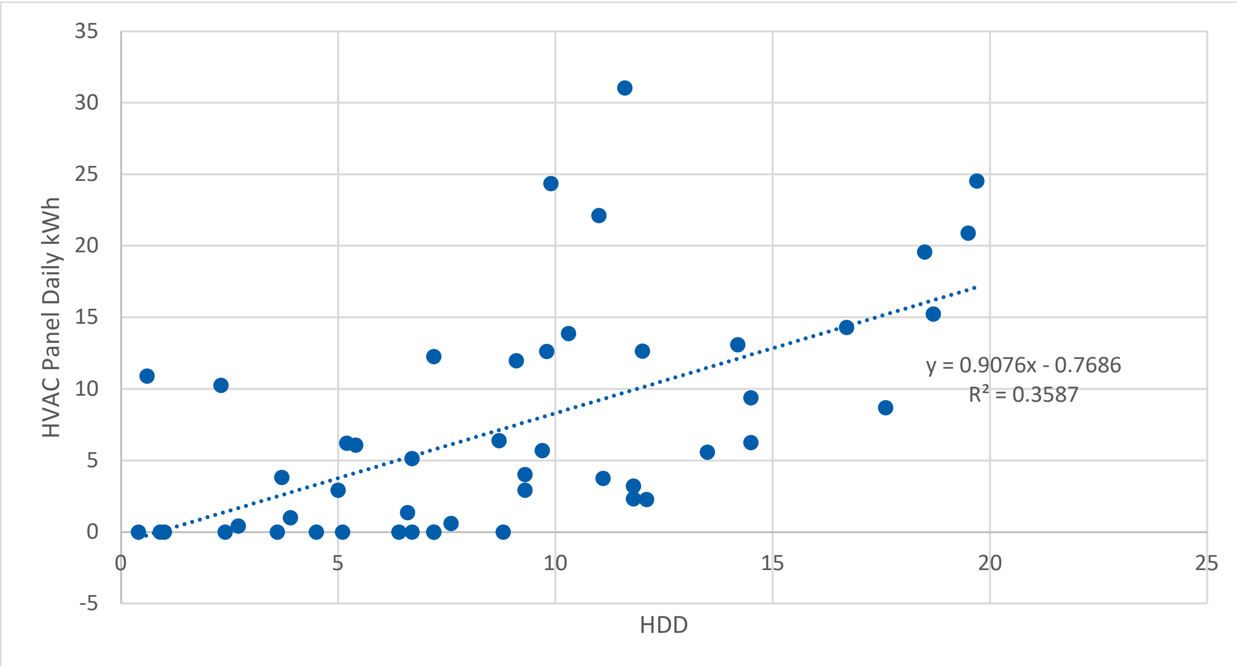


Figure 29: Average Daily kW of all Metered HVAC Units vs. Cooling Degree Days, In-Session Weekends

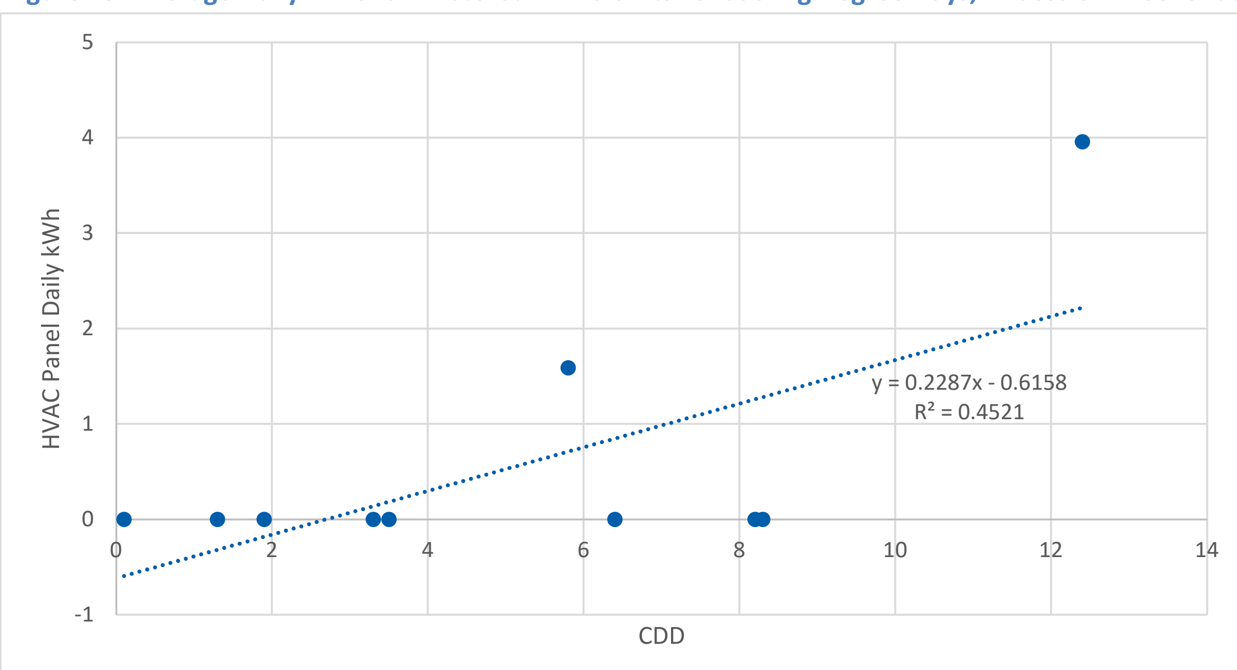


Figure 30: Average Daily kW of all Metered HVAC Units vs. Heating Degree Days, Holidays

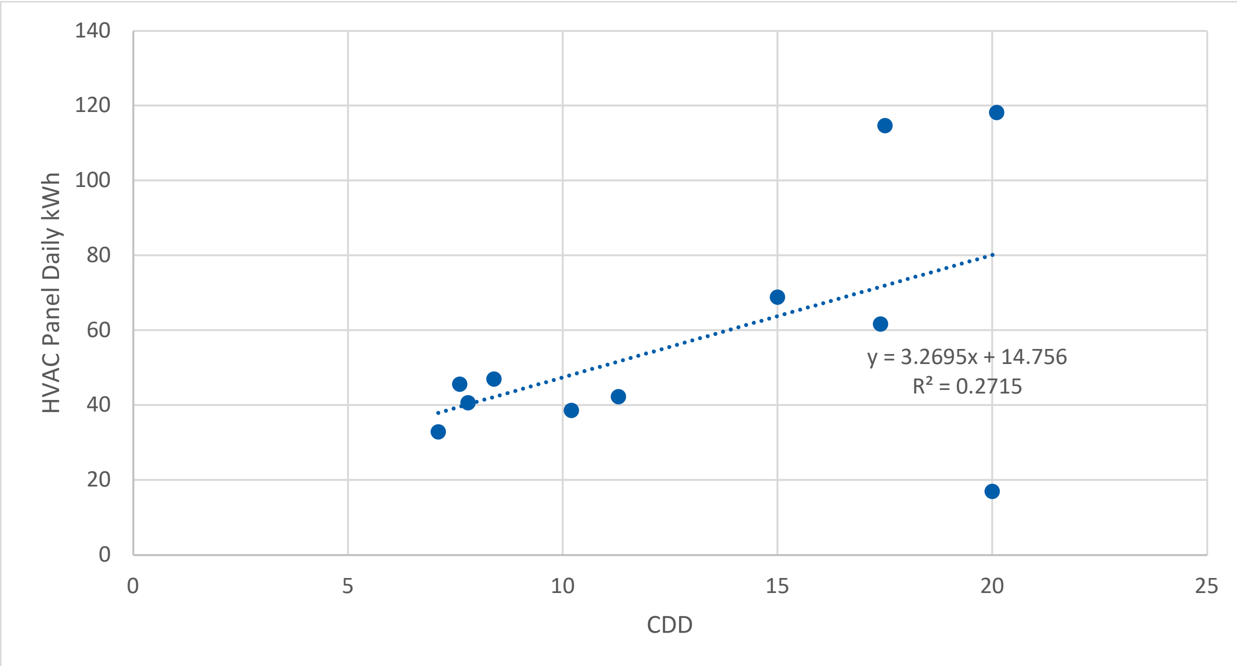


Figure 31: Average Daily kW of all Metered HVAC Units vs. Cooling Degree Days, Holidays

No data recorded for this situation.

Figure 32: Average Daily kW of all Metered HVAC Units vs. Heating Degree Days, Summer

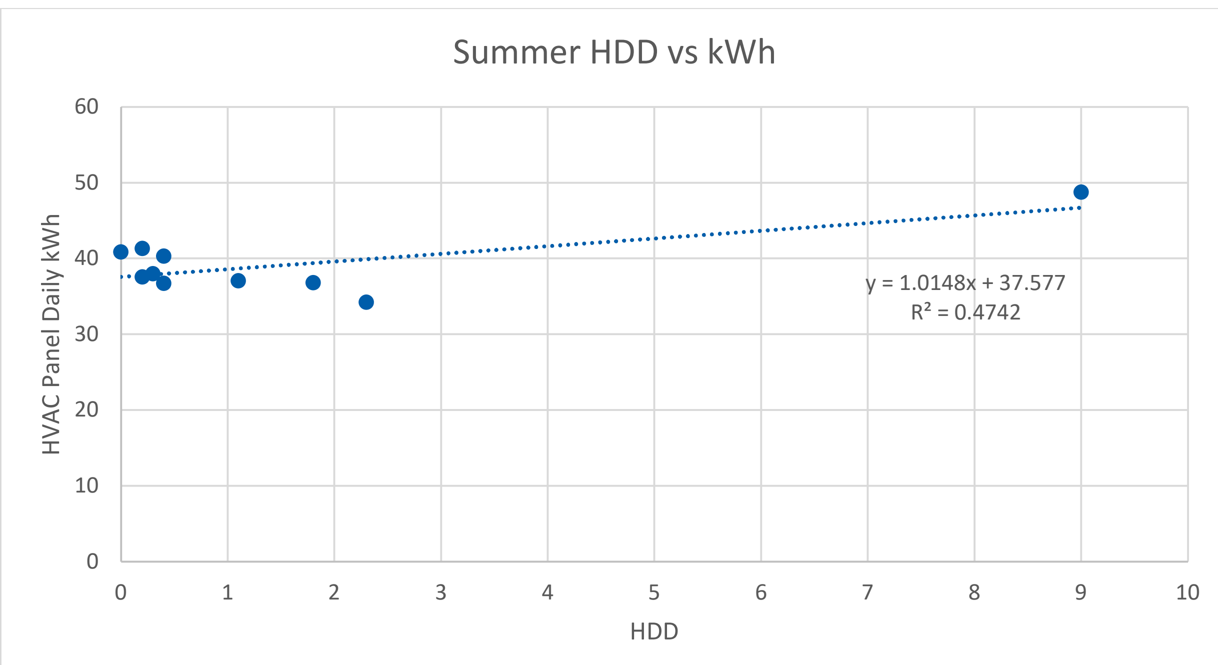


Figure 33: Average Daily kW of all Metered HVAC Units vs. Cooling Degree Days, Summer

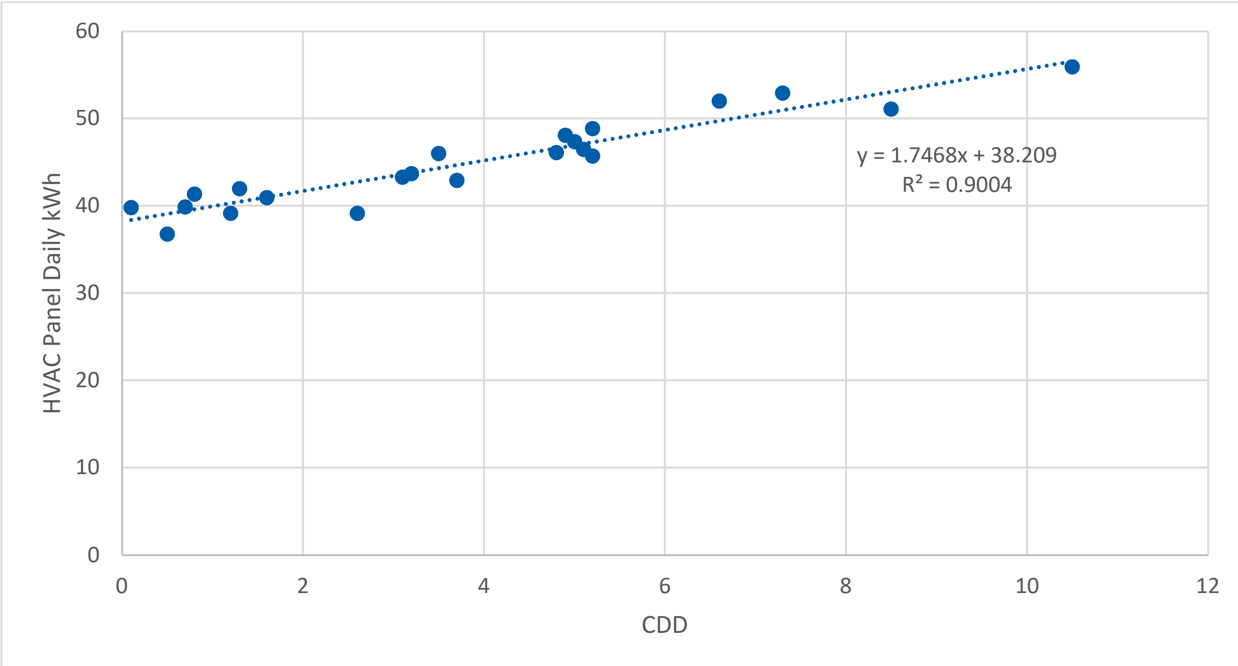


Figure 34: Logged kW for HVAC Panel HACR2

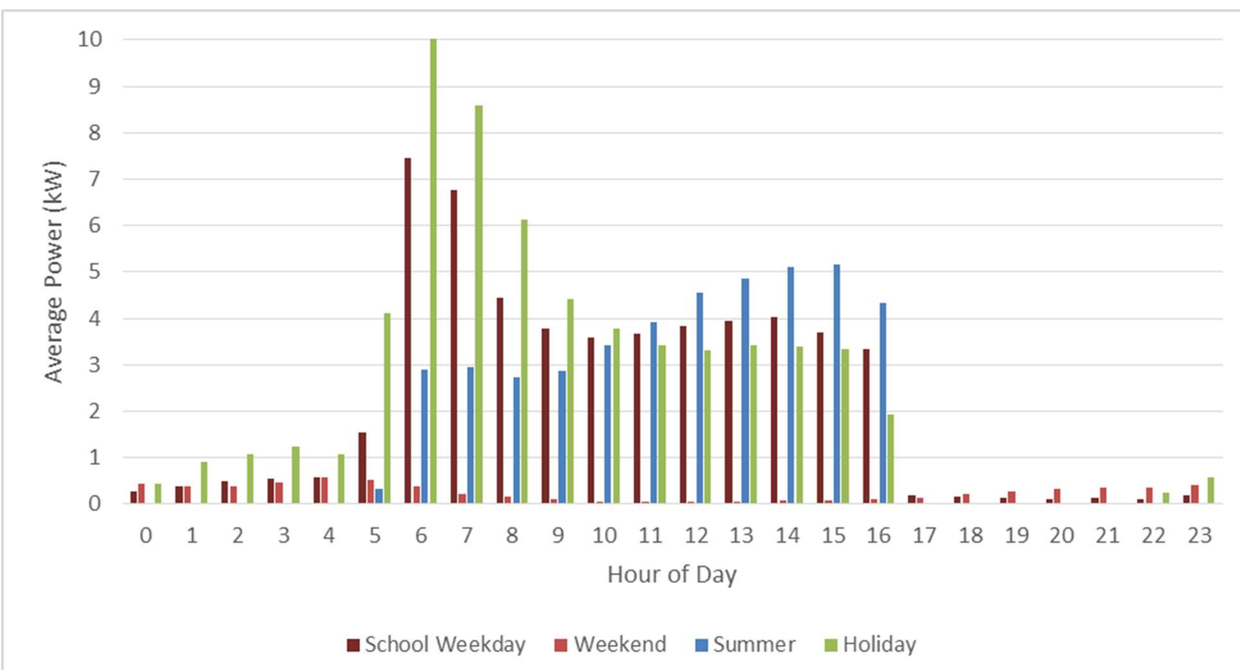


Figure 35: Daily kWh of all Metered HVAC Units, Entire Period

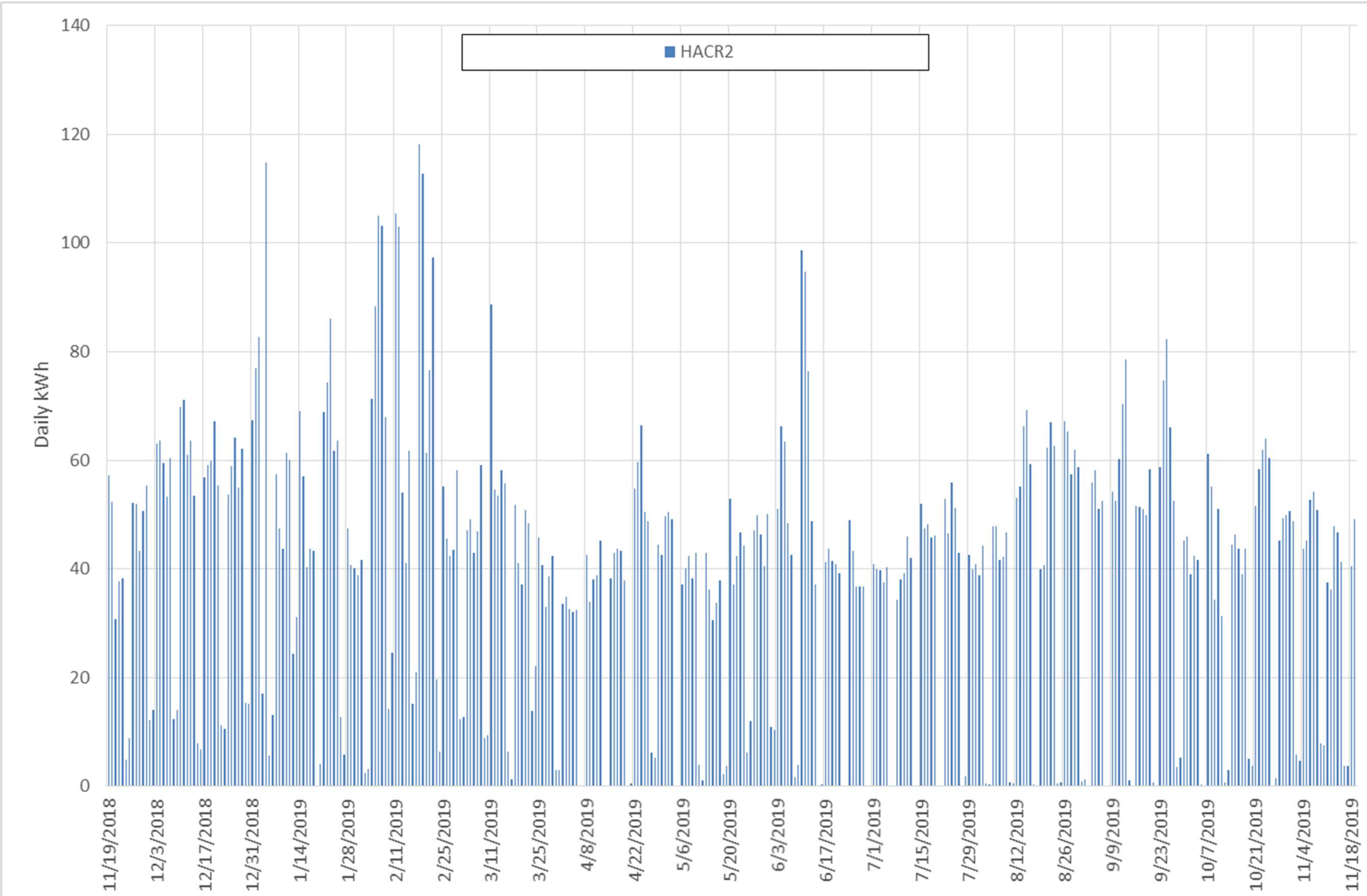


Figure 36: Daily kWh of all Metered HVAC Units, One Month (January 2019)

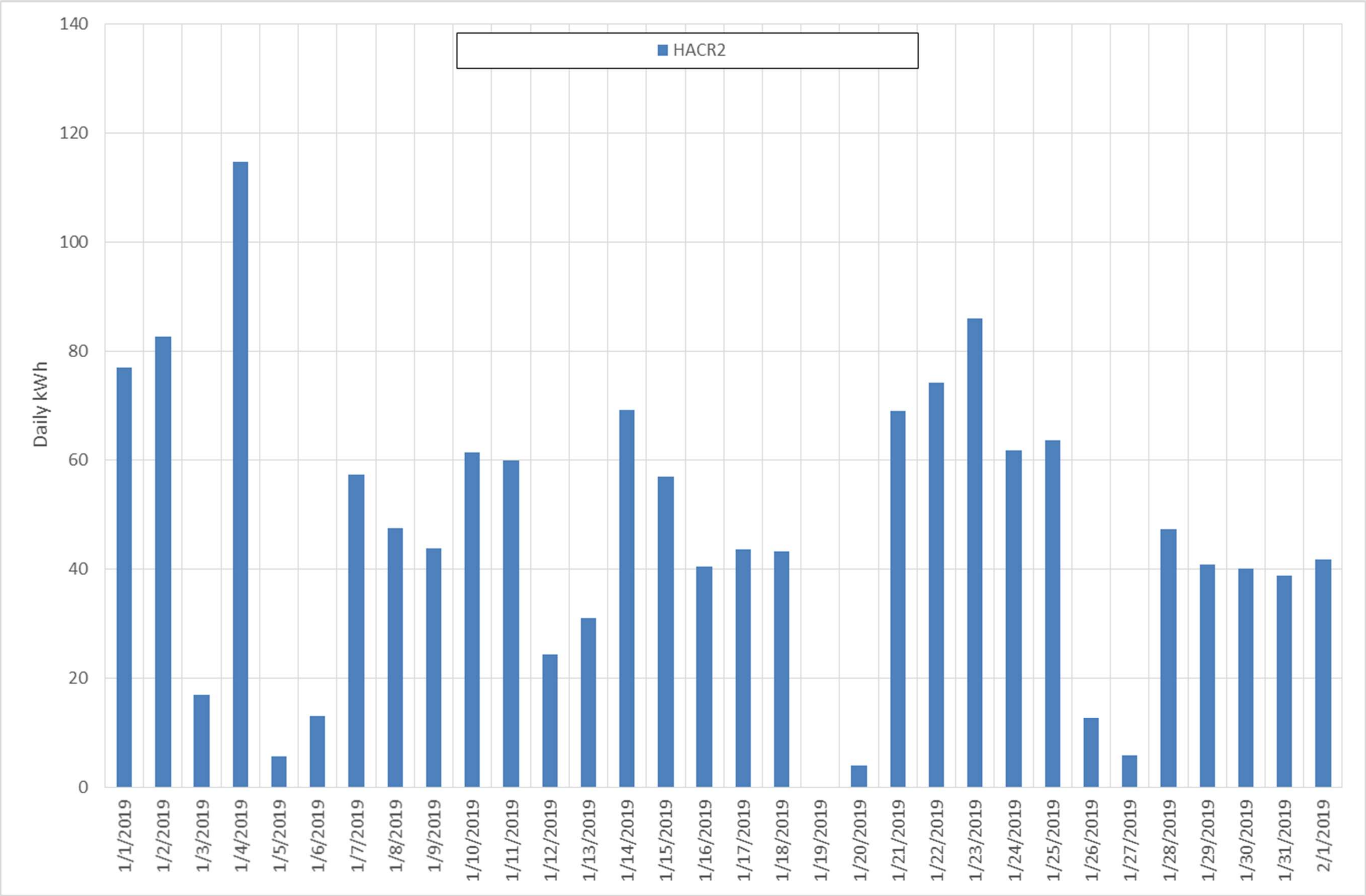
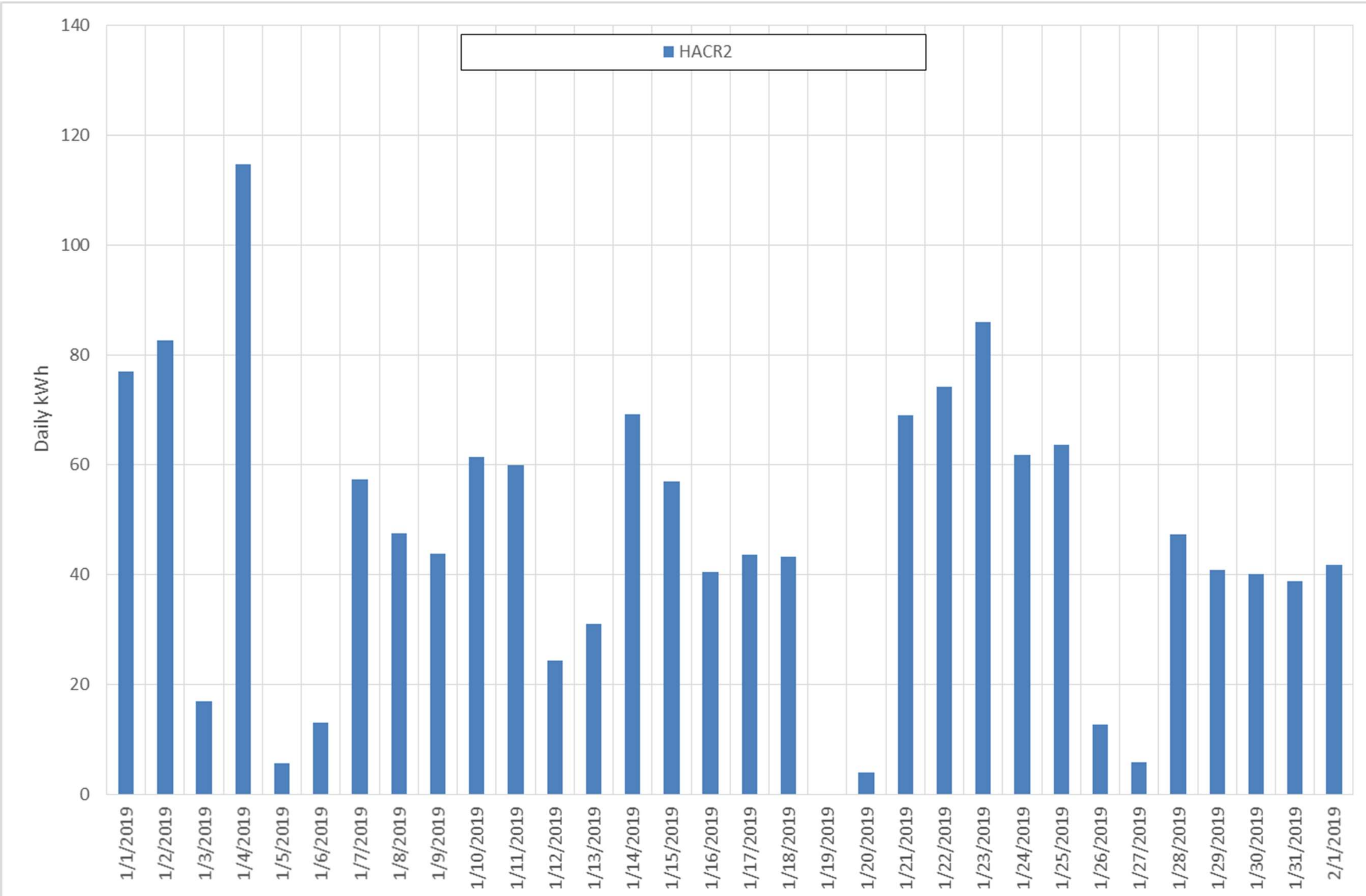


Figure 37: Daily kWh of all Metered HVAC Units, One Month (September 2019)



Logged Data - Temperature

- The following figures illustrate the logged temperature averaged by hour for weekdays, holidays, weekends, and summer days.
  - Figure 38 shows the average room temperature for Classroom 206.
  - Figure 39 shows the average room temperature for Classroom 207.
  - Figure 40 shows the average room temperature for Classroom 212.
  - Figure 41 shows the average room temperature for the Principal's Office.
  - Figure 42 shows the average room temperature for the library.
  - Figure 43 shows the average room temperature for Conference Room 2.
- Figure 44 shows the room temperature of the classrooms for the entire monitoring period.
- Figure 45 shows the room temperature of the classrooms for a typical week (12/2/2018).
- Figure 46 shows the room temperature of the classrooms for a typical week (6/2/2019).
- Figure 47 shows the room temperature of the support rooms for the entire monitoring period.
- Figure 48 shows the room temperature of the support rooms for a typical week (12/2/2018).
- Figure 49 shows the room temperature of the support rooms for a typical week (6/2/2019).

Please note that several temperature and light loggers were missing when the loggers were collected. As a result, no data was available for those areas.

Figure 38: Average Room Temperature for Classroom 206

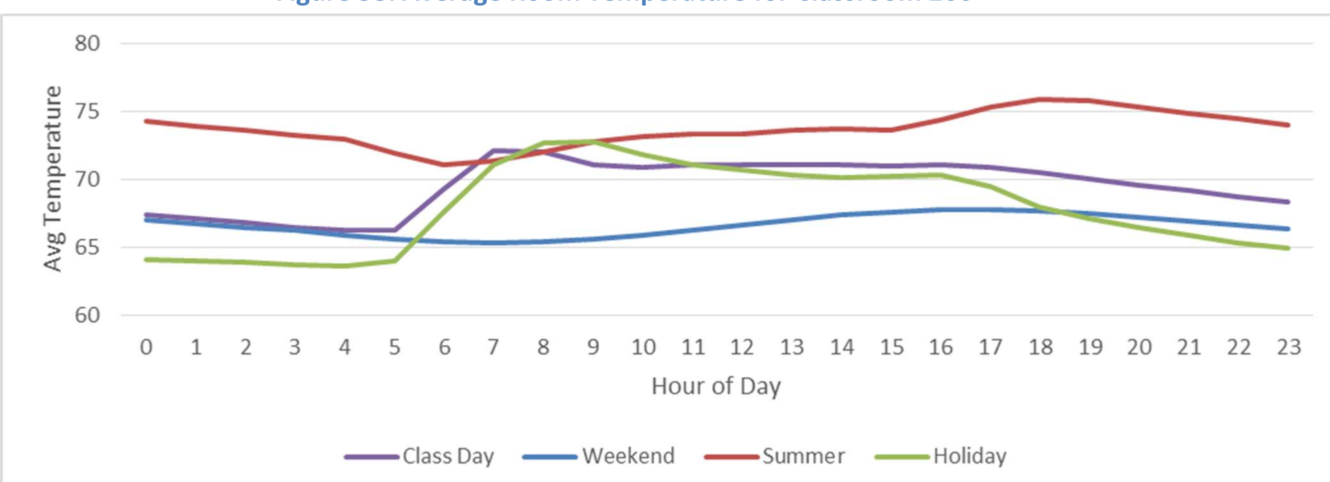


Figure 39: Average Room Temperature for Classroom 207

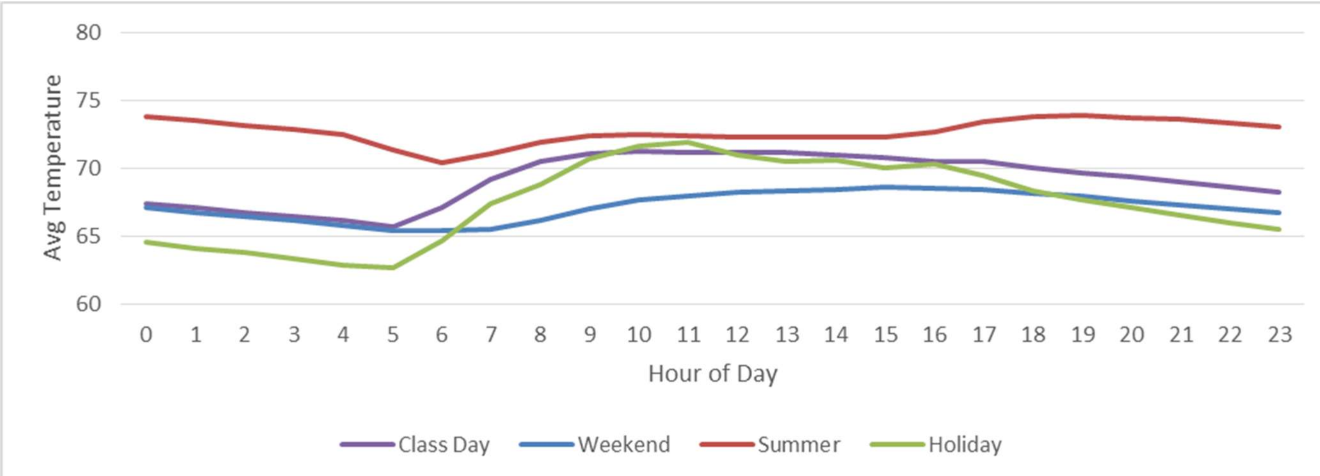


Figure 40: Average Room Temperature for Classroom 211

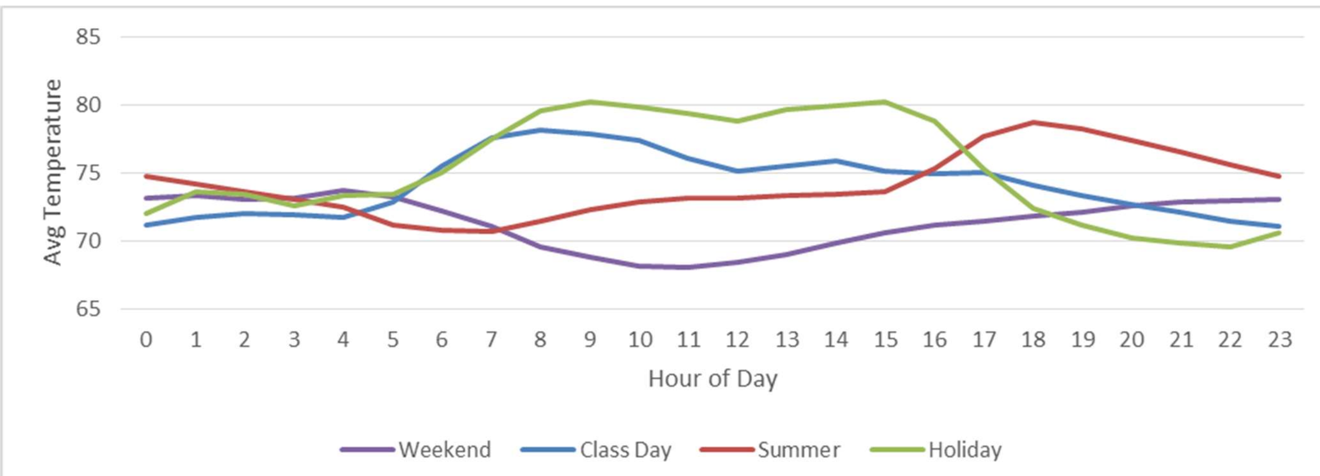


Figure 41: Average Room Temperature for the Principal's Office

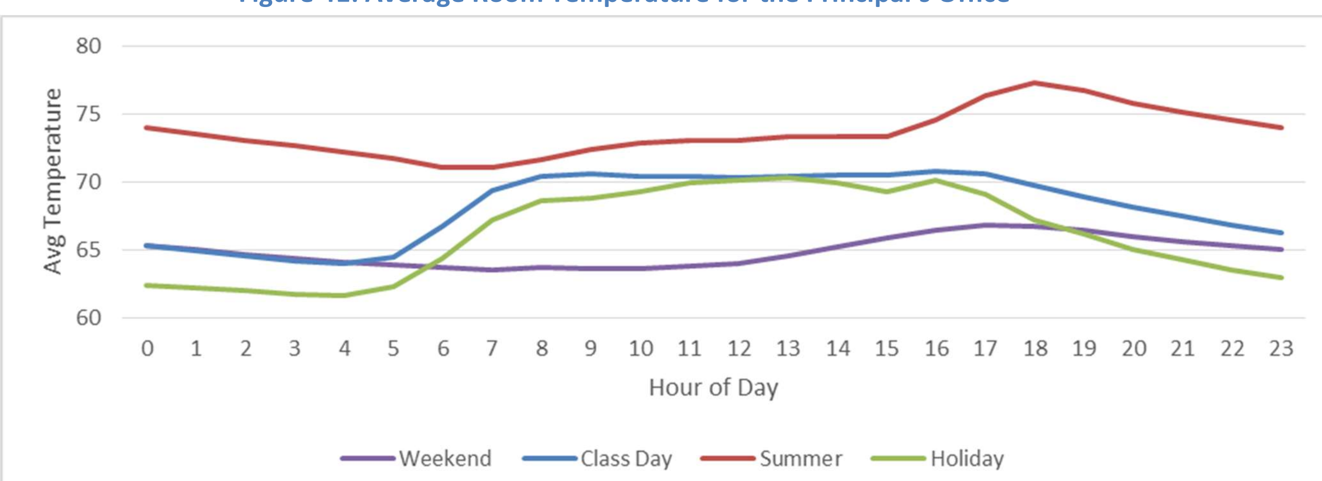


Figure 42: Average Room Temperature for the Library

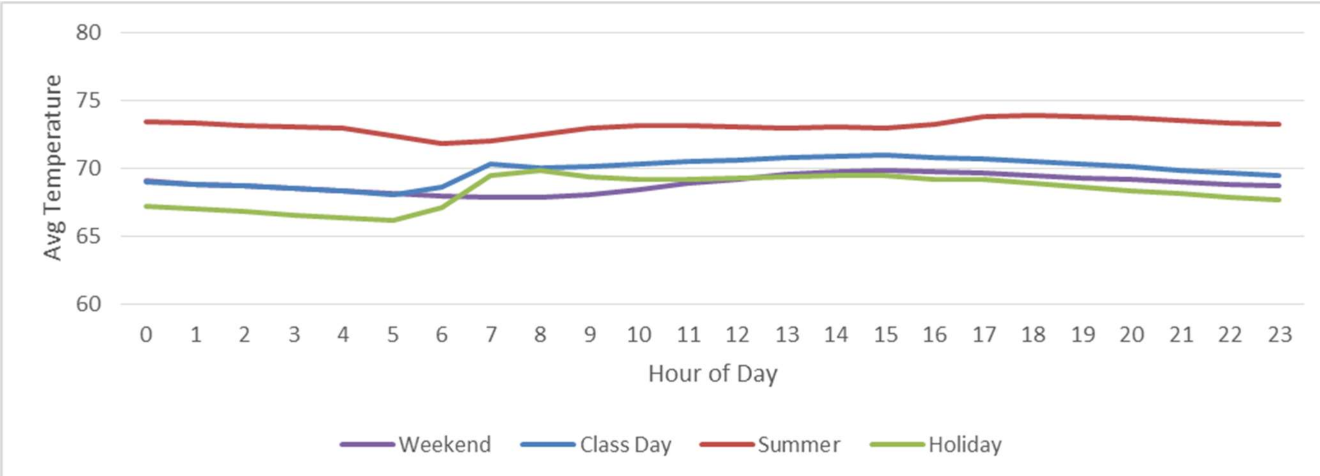


Figure 43: Average Room Temperature for Conference Room 2

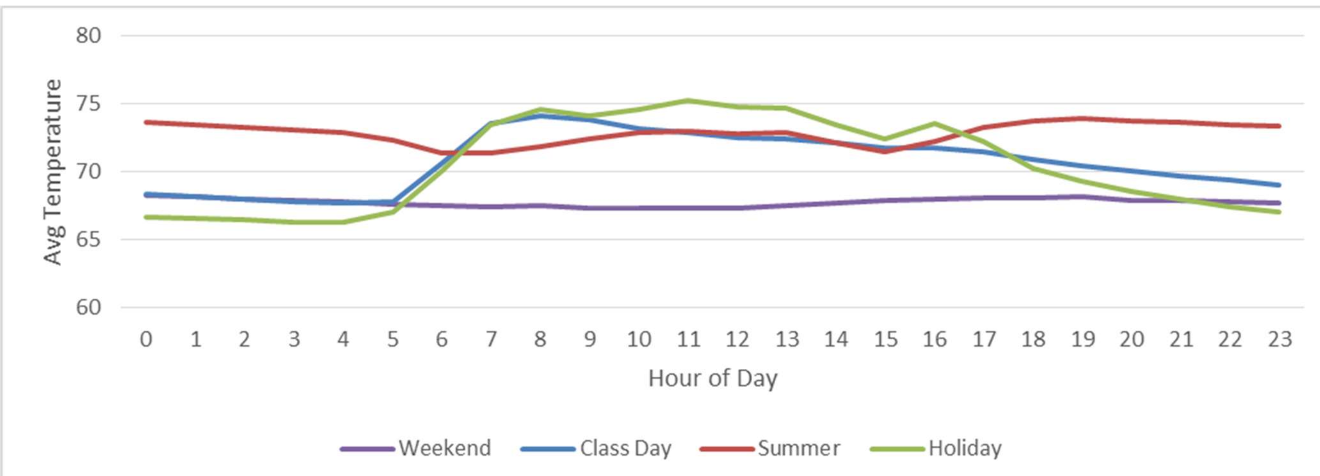


Figure 44: Room Temperature for Classrooms, Entire Period

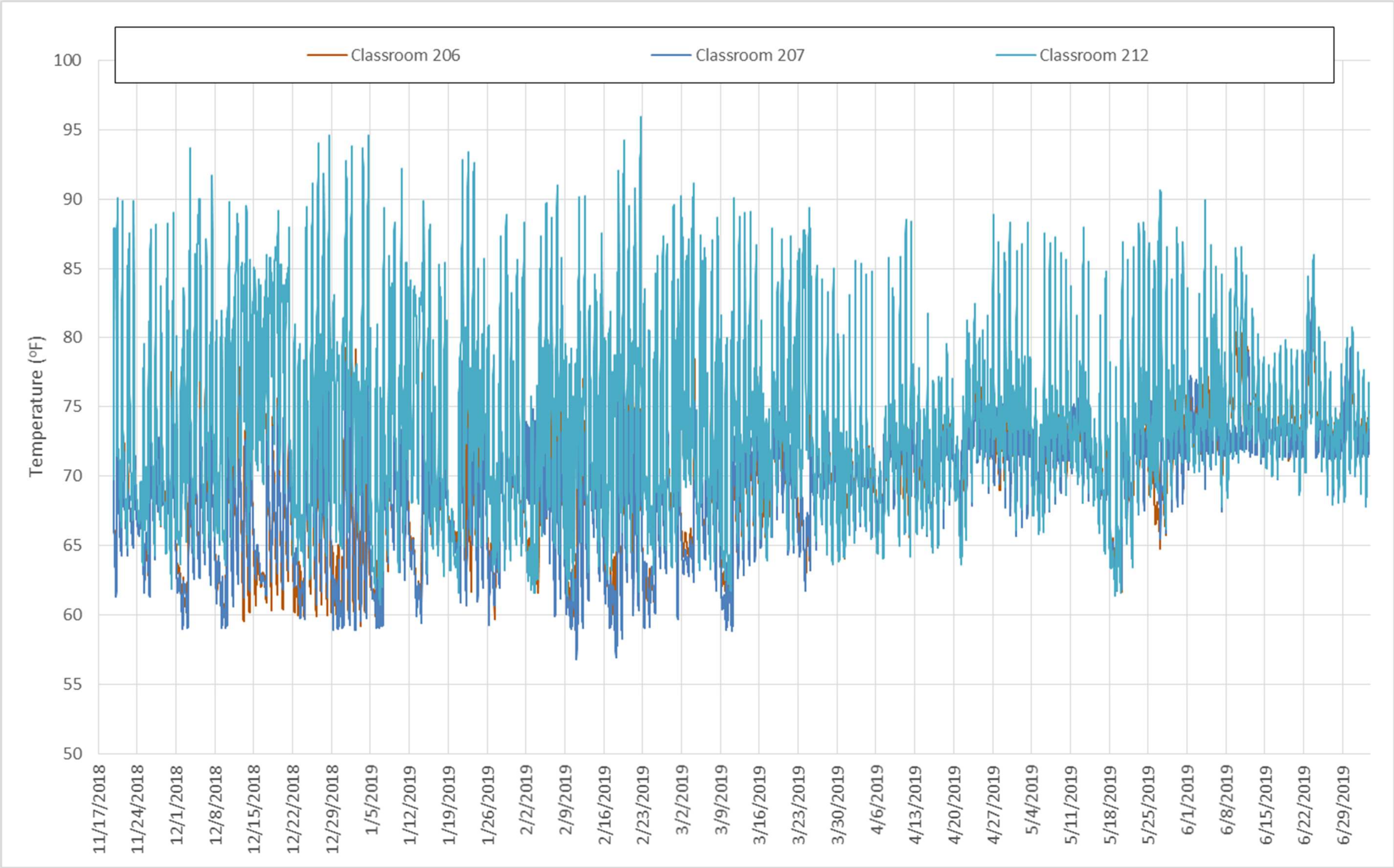


Figure 45: Room Temperature for Classrooms, One Week (12/2/2018)

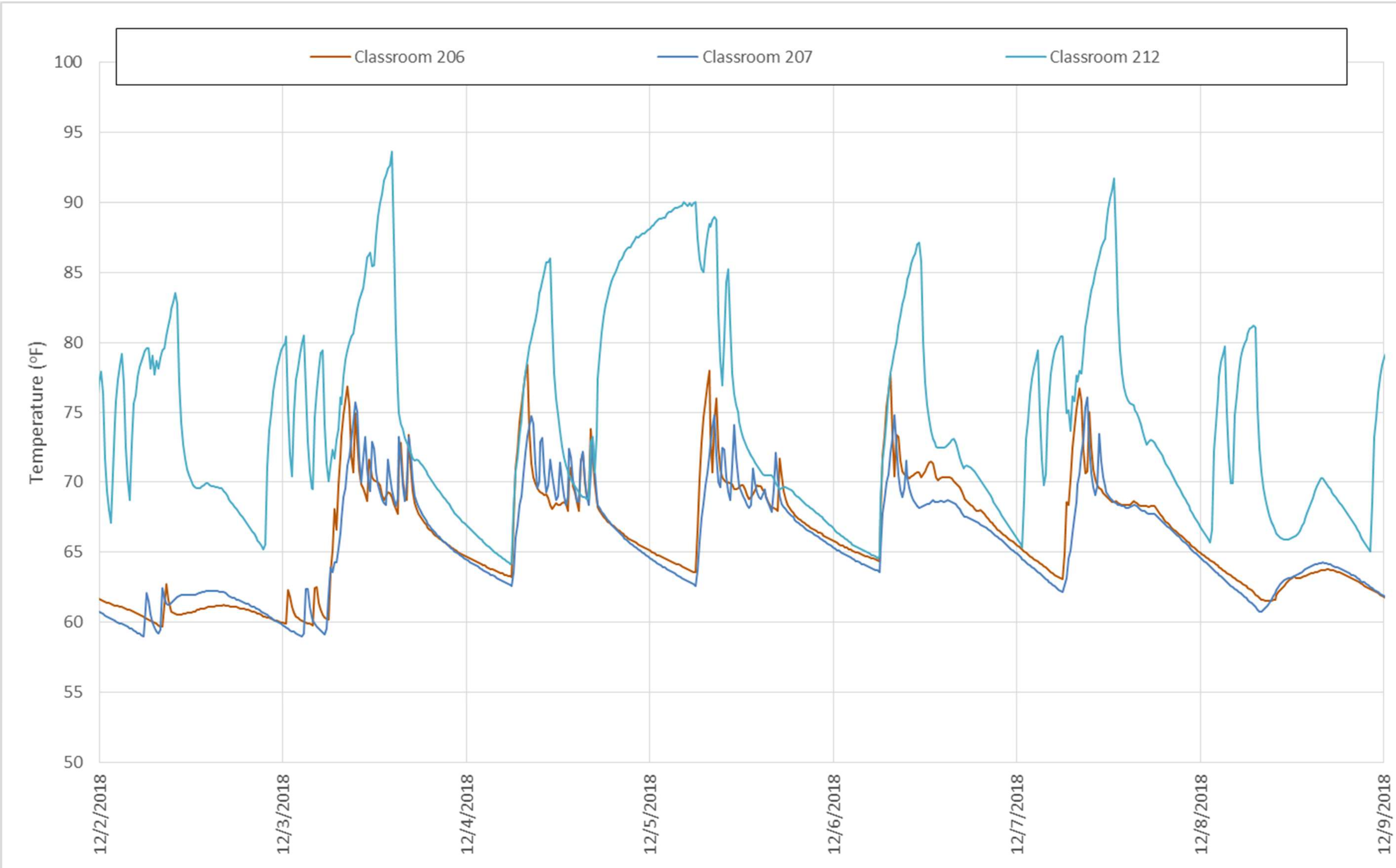


Figure 46: Room Temperature for Classrooms, One Week (6/2/2019)

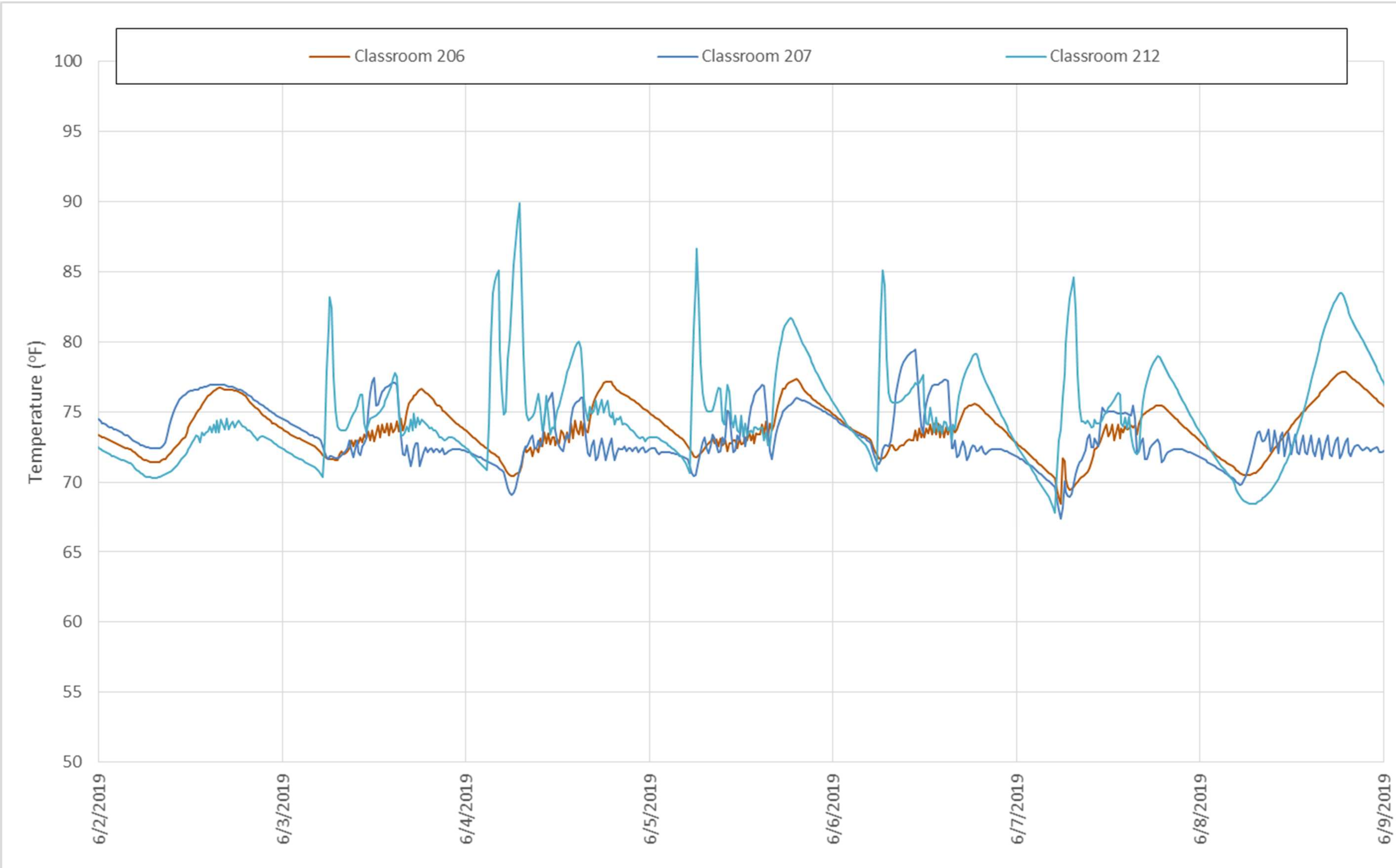


Figure 47: Room Temperature for Support Areas, Entire Period

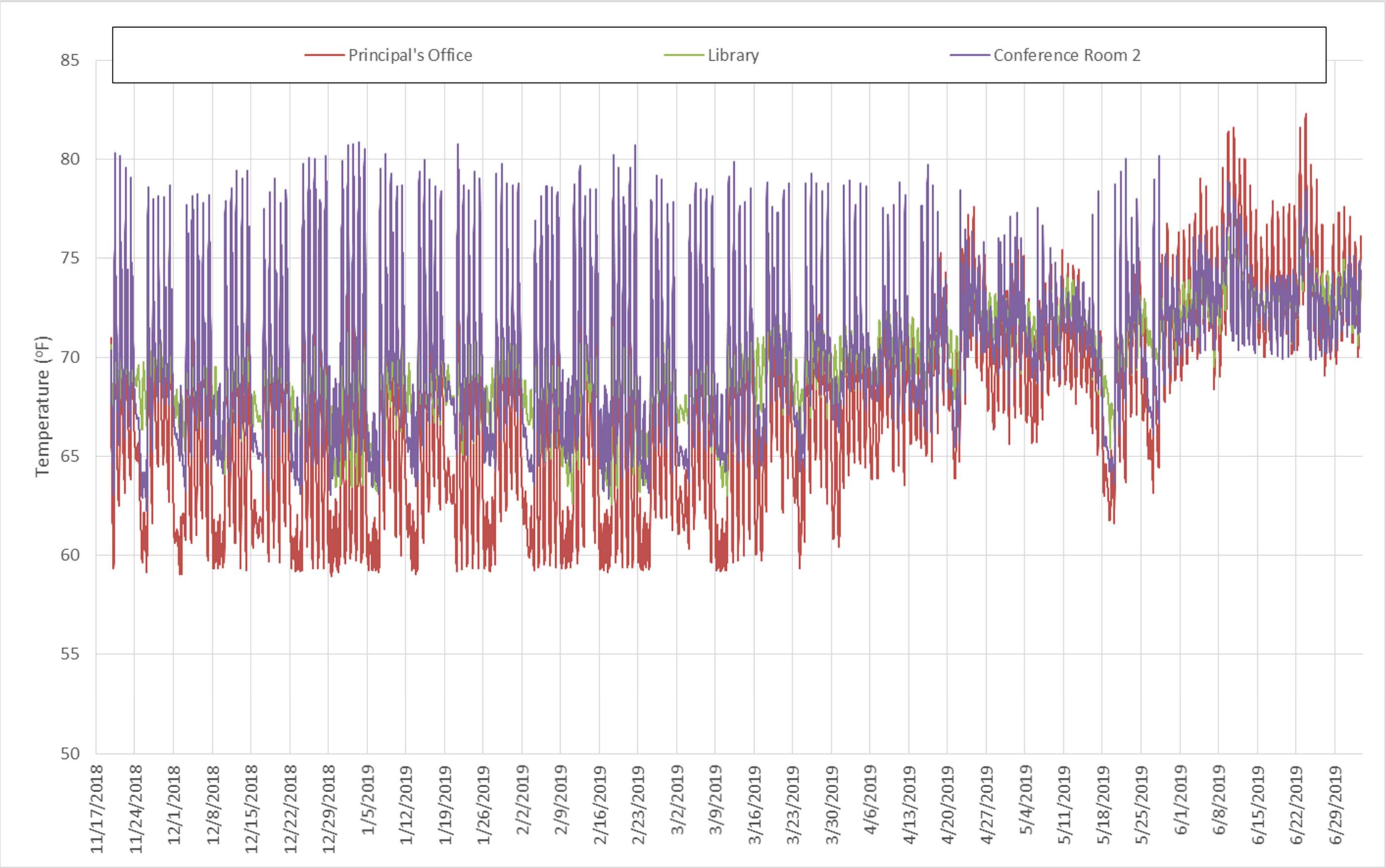


Figure 48: Room Temperature for Support Areas, One Week (12/2/2018)

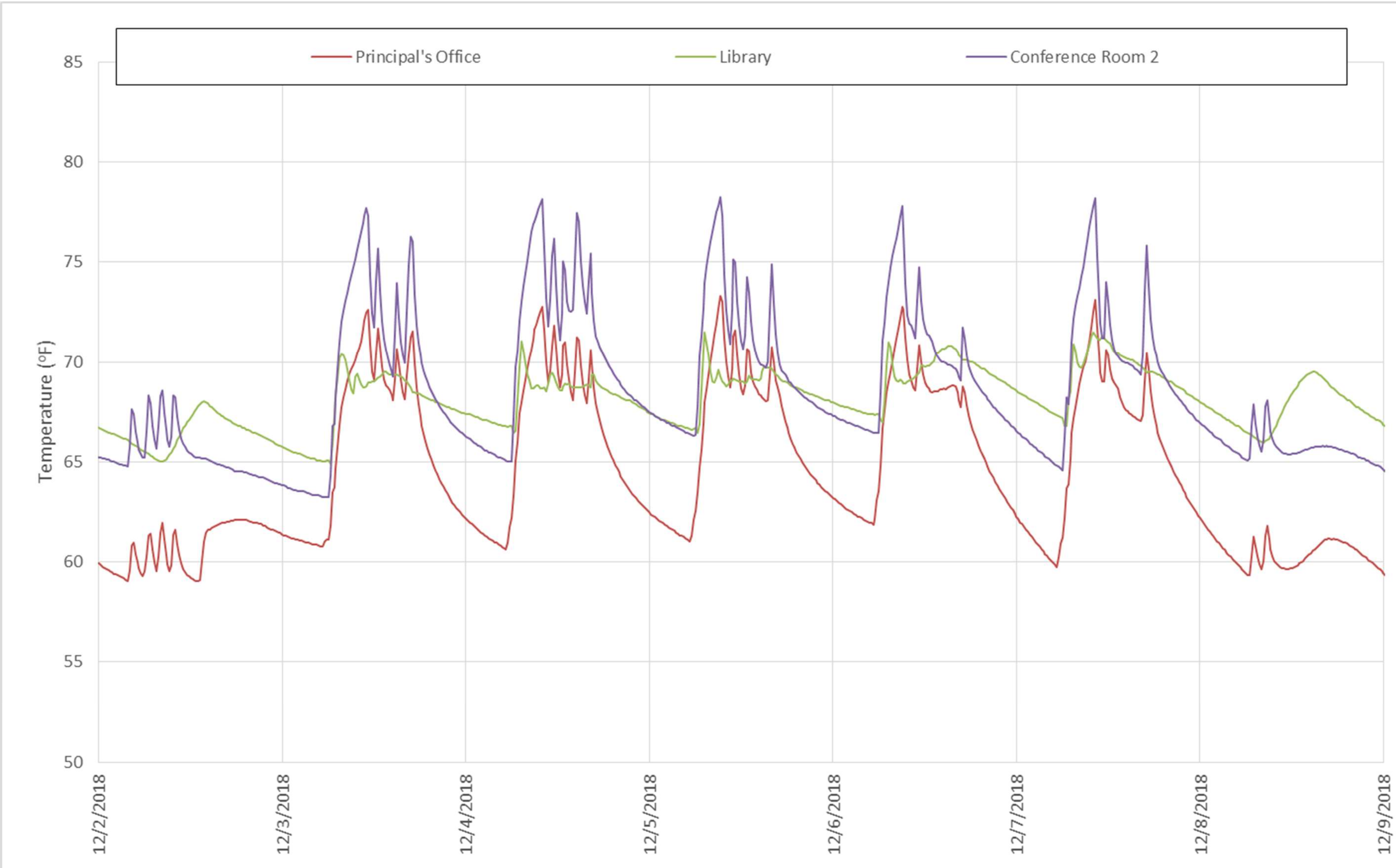
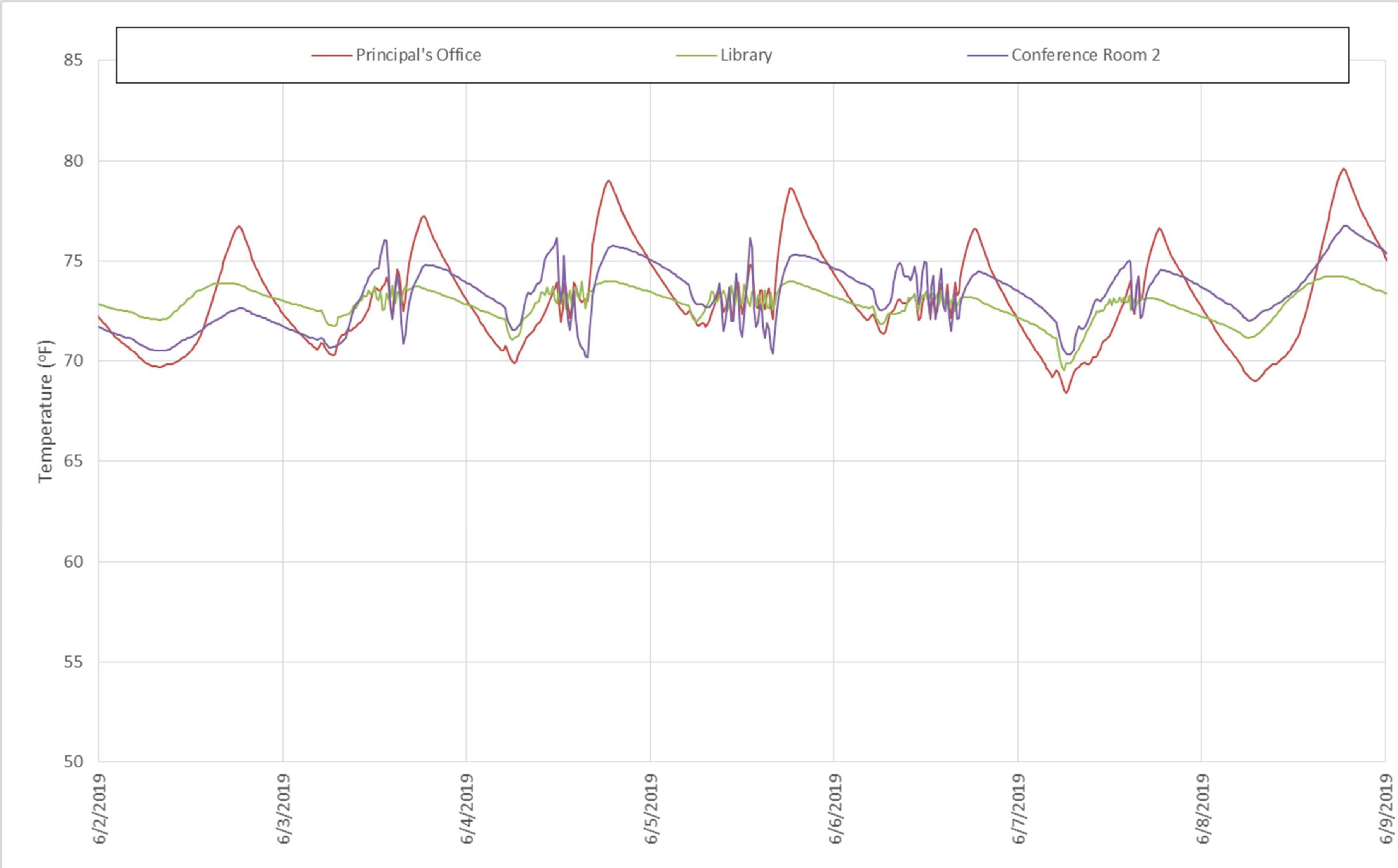


Figure 49: Room Temperature for Support Areas, One Week (6/2/2019)



Logged Data – Lighting Intensity

- The following figures illustrate the logged lighting intensity for the school.
    - Figure 50 shows the room lighting intensity of the classrooms for the entire monitoring period.
    - Figure 51 shows the room lighting intensity of the classrooms for a typical week (12/2/2018).
    - Figure 52 shows the room lighting intensity of the classrooms for a typical week (6/2/2019).
    - Figure 53 shows the room lighting intensity of the support rooms for the entire monitoring period.
    - Figure 54 shows the room lighting intensity of the support rooms for a typical week (12/2/2018).
    - Figure 55 shows the room lighting intensity of the support rooms for a typical week (6/2/2019).

Figure 50: Lighting Intensity Classrooms, Entire Period

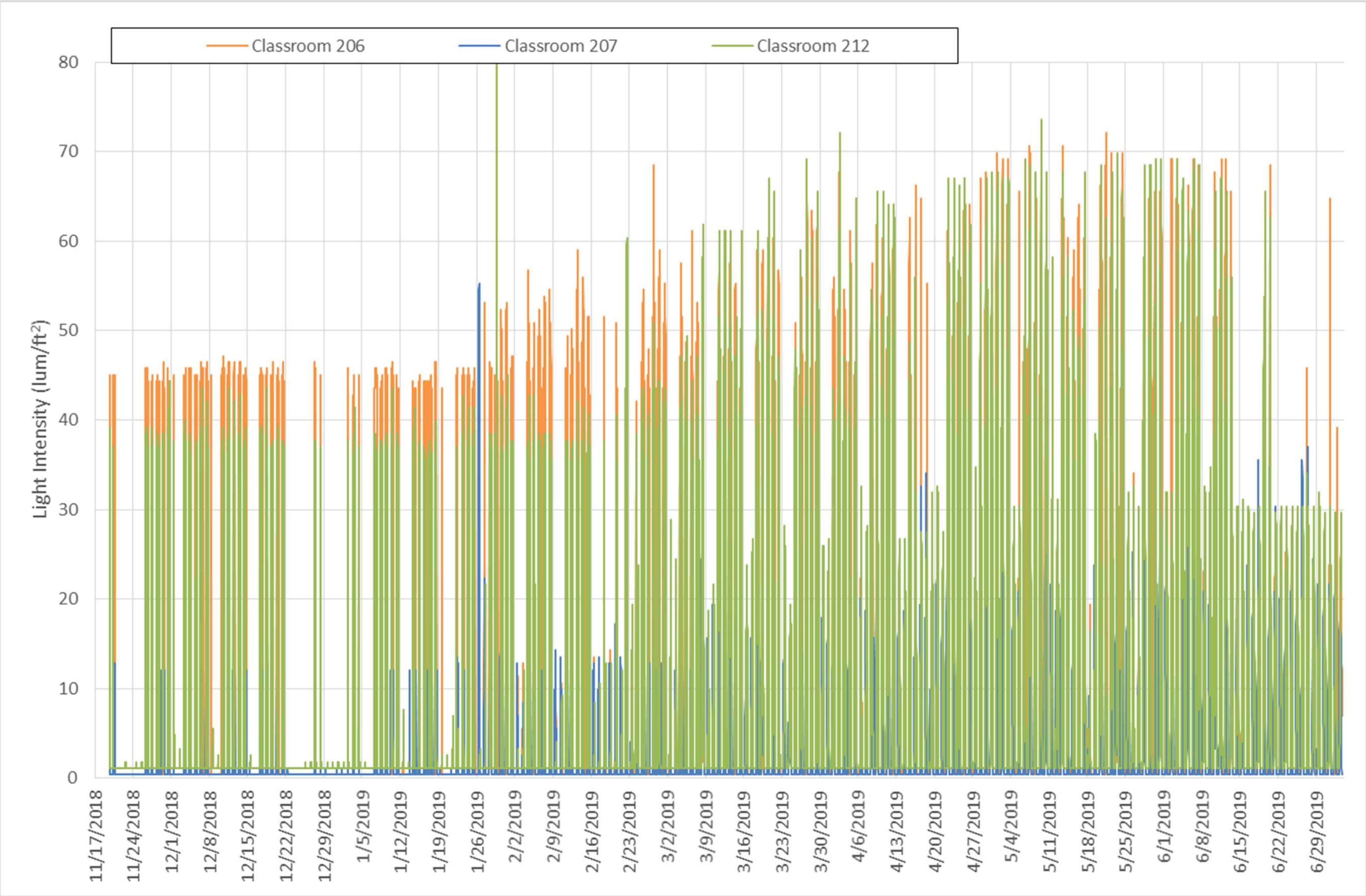


Figure 51: Lighting Intensity Classrooms, One Week (12/2/2018)

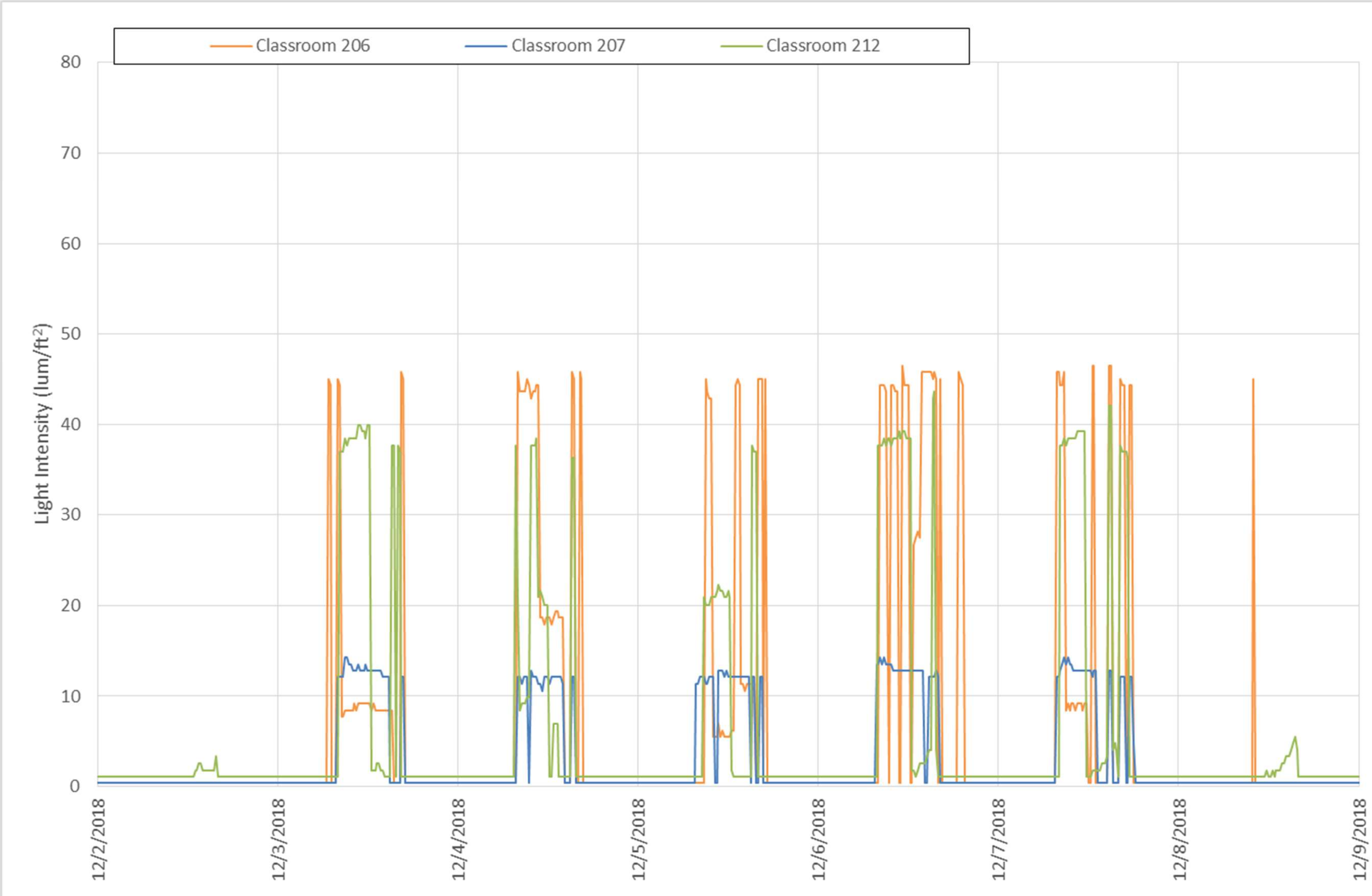


Figure 52: Lighting Intensity Classrooms, One Week (6/2/2019)

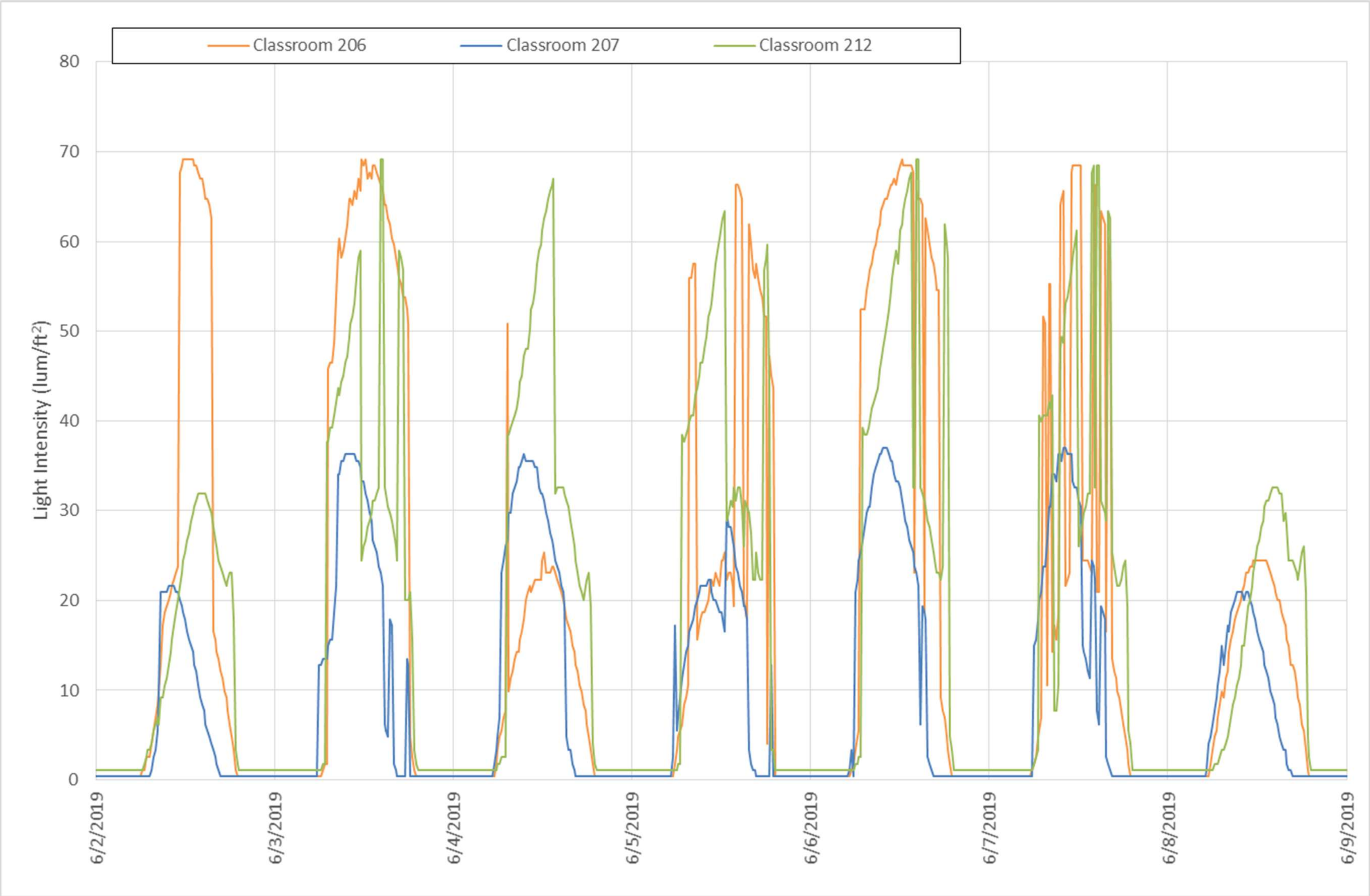


Figure 53: Lighting Intensity Support Rooms, Entire Period

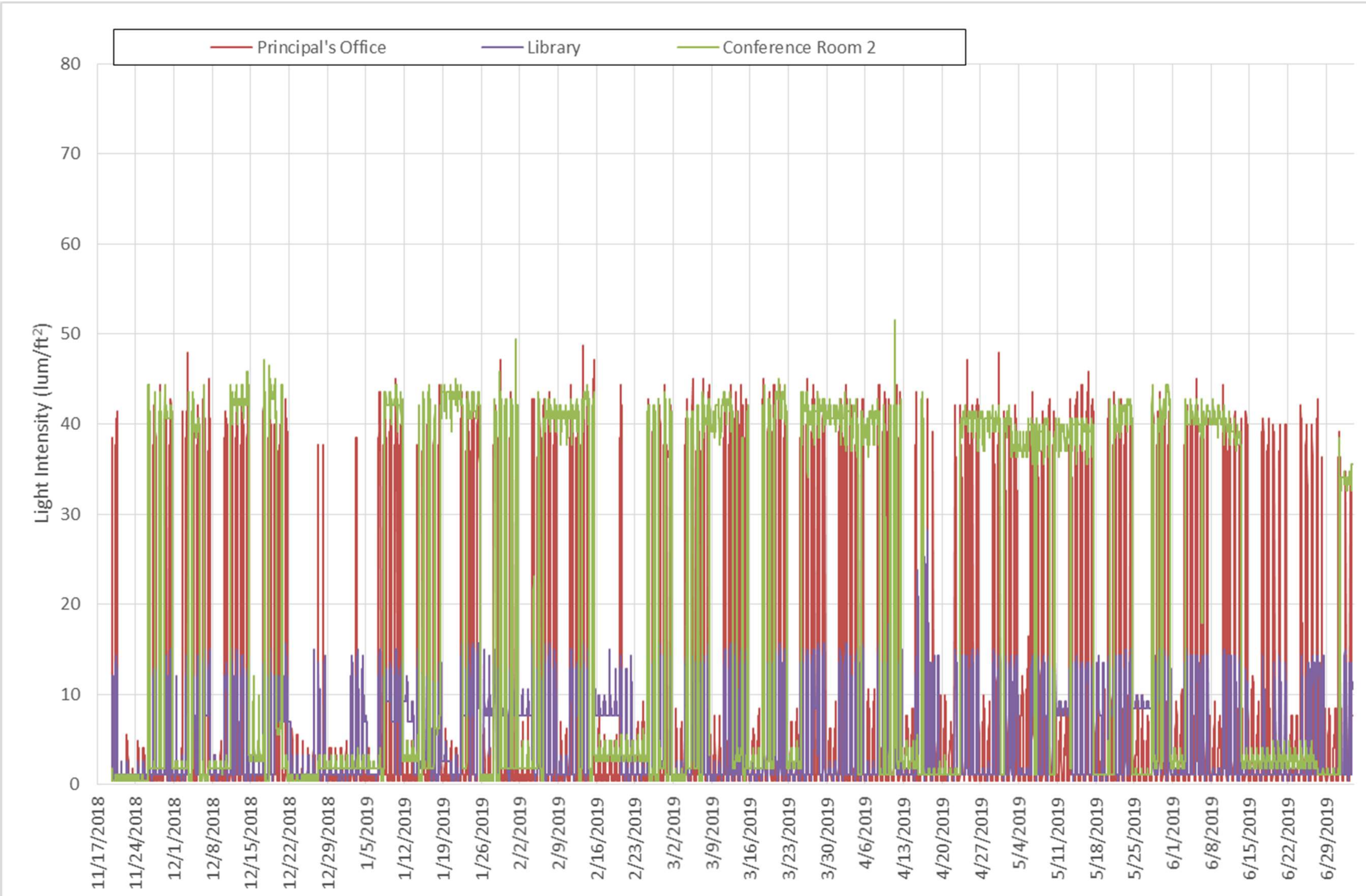
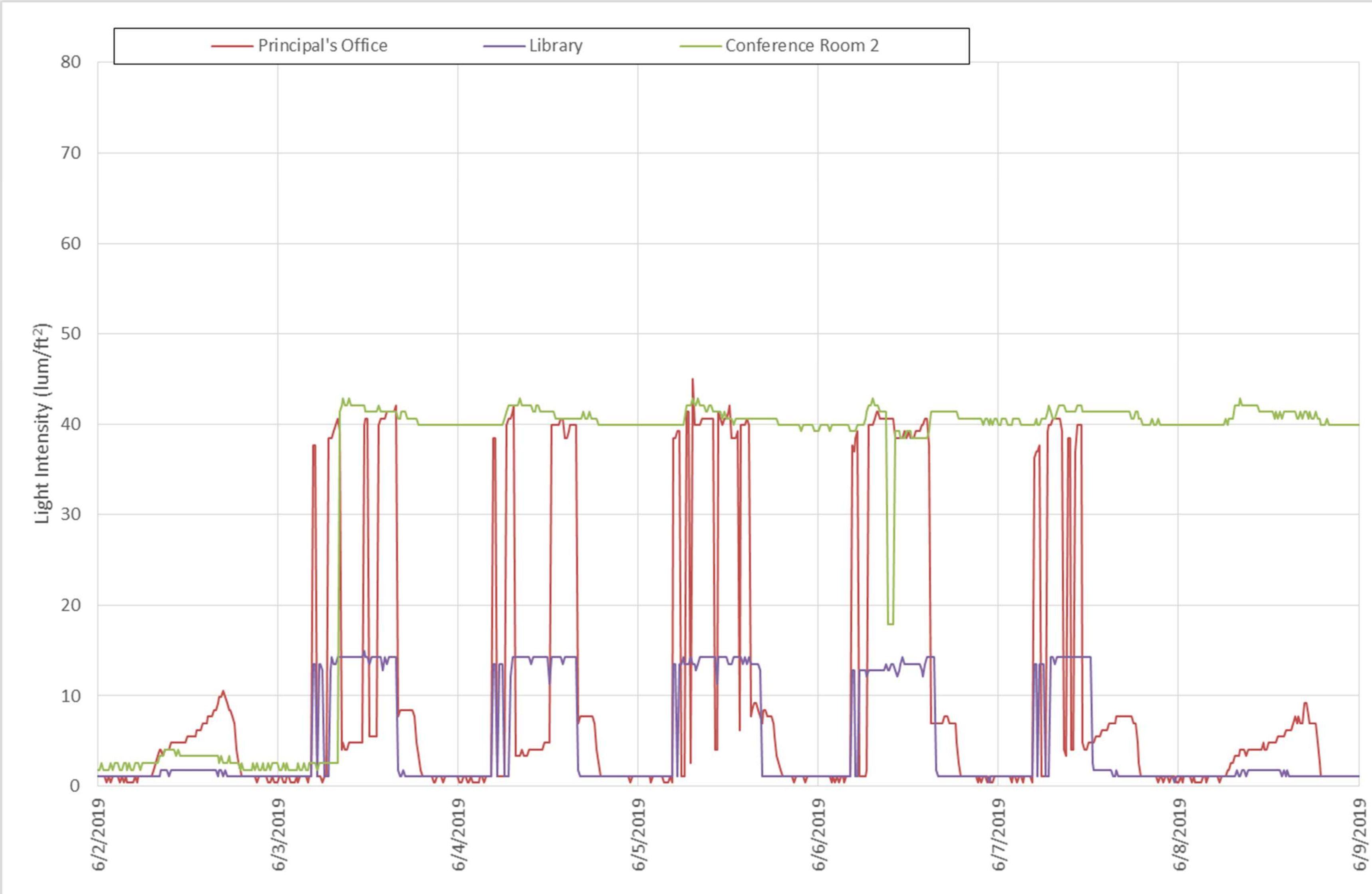


Figure 54: Lighting Intensity Support Rooms, One Week (12/2/2018)

Figure 55: Lighting Intensity Support Rooms, One Week (6/2/2019)



Logged Data – Plug Loads

- Figure 56 shows the average logged plug load power for Panel HAC1. This panel controls computer receptacles and all of the floor boxes in the library.
- Figure 57 shows the average logged plug load power for Panel HAC2. This panel is dedicated entirely to computer receptacles.
- Figure 58 shows the average logged plug load power for Panel HCP1. This panel controls most of the appliances in the office area, including the copier, microwave, refrigerator, and dishwasher.
- Figure 59 shows the average logged plug load power for Panel HCP2. This panel is dedicated entirely to computer receptacles.
- Figure 60 shows the average logged plug load power for Panel HCPR. This panel is dedicated entirely to computer receptacles and one fan.
- Figure 61 shows the average logged plug load power for the Elevator panel. It is estimated that overnight energy usage of the elevator is due to the elevator cycling between floors once every 2-3 hours.
- Figure 62 shows the average logged plug load power for Computer Receptacle Circuit 1.
- Figure 63 shows the average logged plug load power for Computer Receptacle Circuit 2.
- Figure 64 shows the average logged plug load power for Computer Receptacle Circuit 3. This circuit, along with the following 3 circuits, show very minimal energy usage. This highlights the difficulty in monitoring energy use of plug loads at the circuit level; it is impossible to tell which circuits will bear the majority of the energy load until data collection has already begun.
- Figure 65 shows the average logged plug load power for Computer Receptacle Circuit 4.
- Figure 66 shows the average logged plug load power for Computer Receptacle Circuit 5.
- Figure 67 shows the average logged plug load power for Computer Receptacle Circuit 6.
- Figure 68 shows the daily energy consumption of each of the metered plug load panels for the entire monitoring period.
- Figure 69 shows the daily energy consumption of each of the metered plug load panels for the month of September 2017.
- Figure 70 shows the daily energy consumption of each of the metered plug load panels for the month of March 2018.

In general, the plug loads show a very high parasitic load during the off hours and during holidays, weekends, and summer break. Plug load management will be an increasingly important energy efficiency measure as other systems in schools become more efficient.

Figure 56: Logged Plug Load Power for Panel HAC1

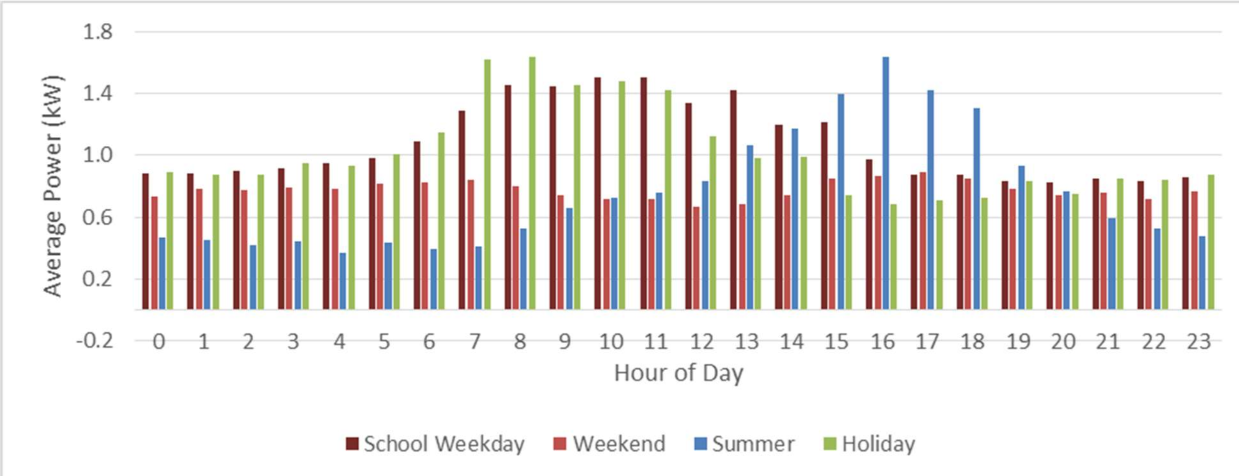


Figure 57: Logged Plug Load Power for Panel HAC2

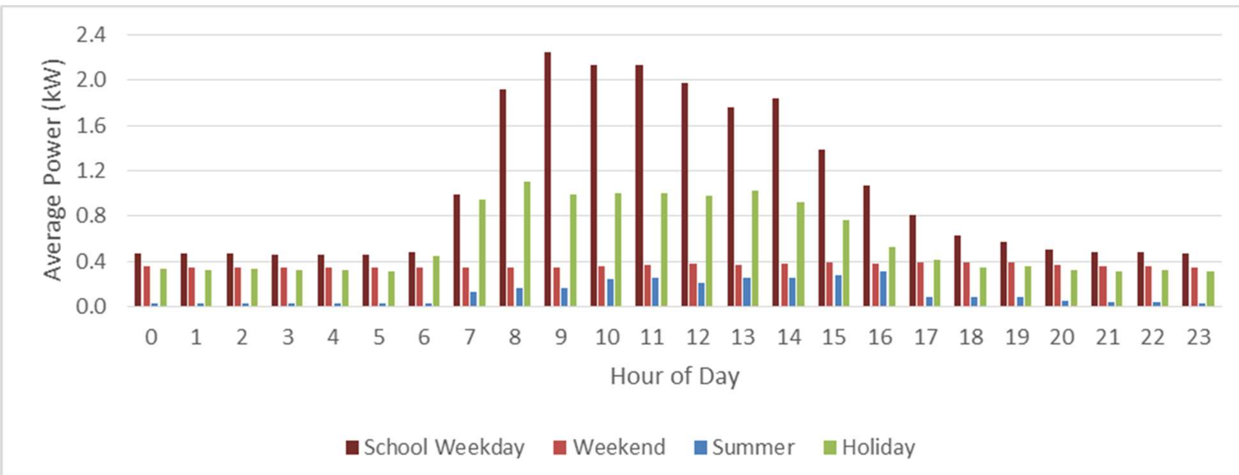


Figure 58: Logged Plug Load Power for Panel HCP1

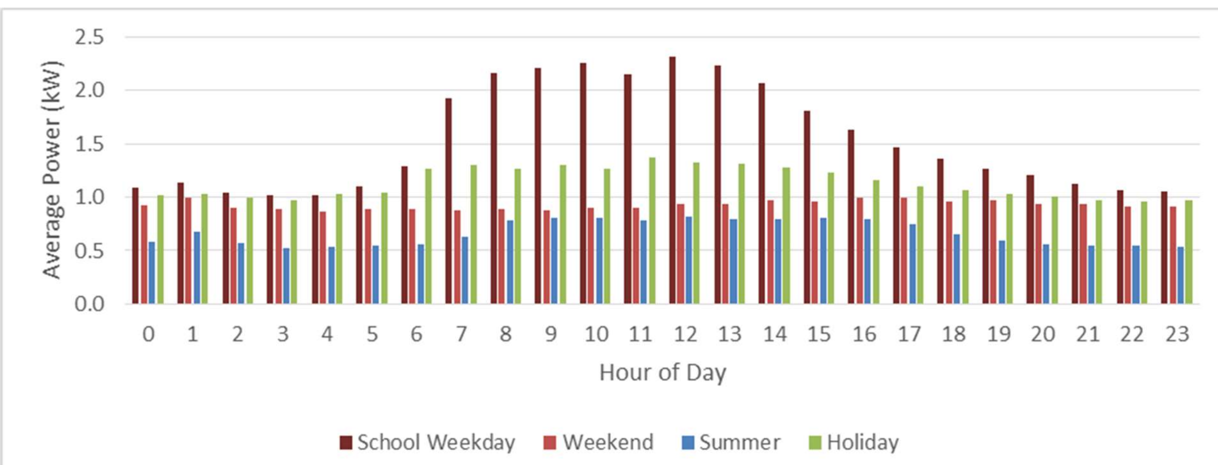


Figure 59: Logged Plug Load Power for Panel HCP2

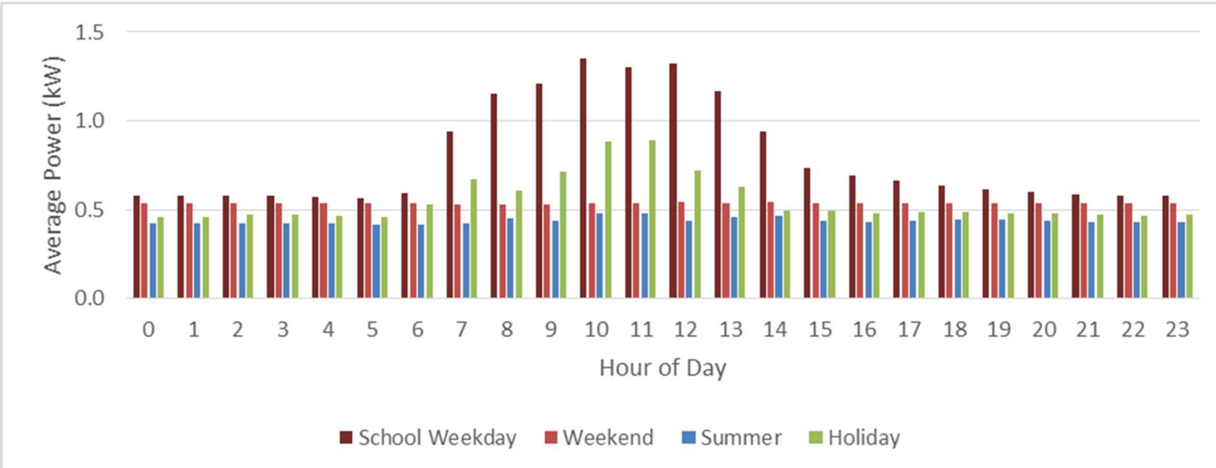


Figure 60: Logged Plug Load Power for Panel HCPR

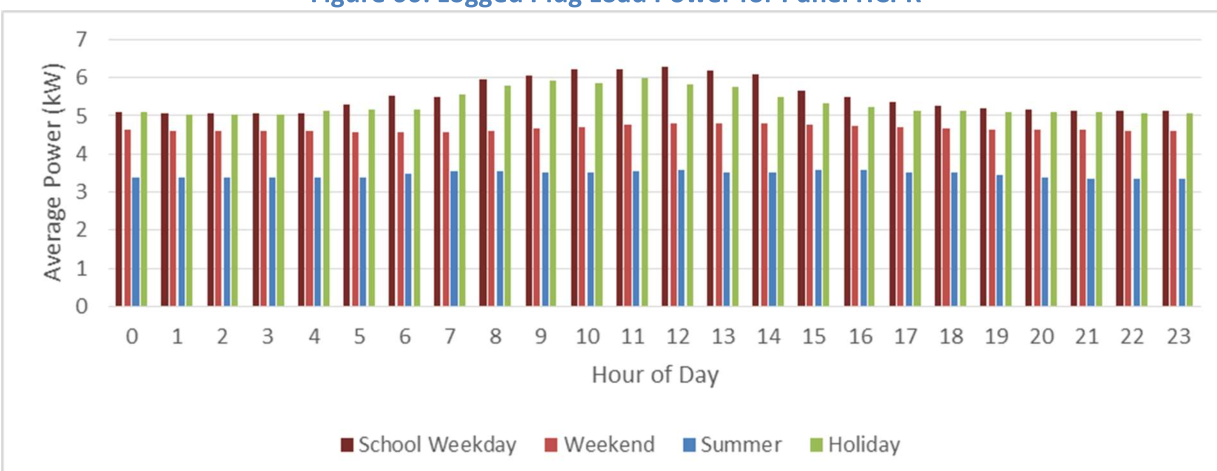


Figure 61: Logged Plug Load Power for Elevator Panel

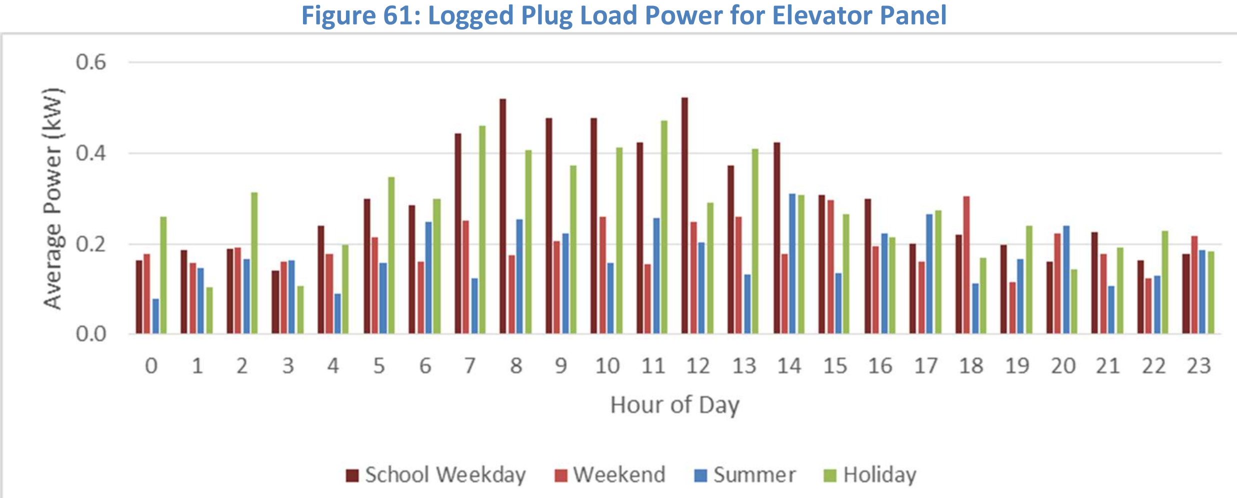


Figure 62: Logged Plug Load Power for Computer Receptacle Circuit 1

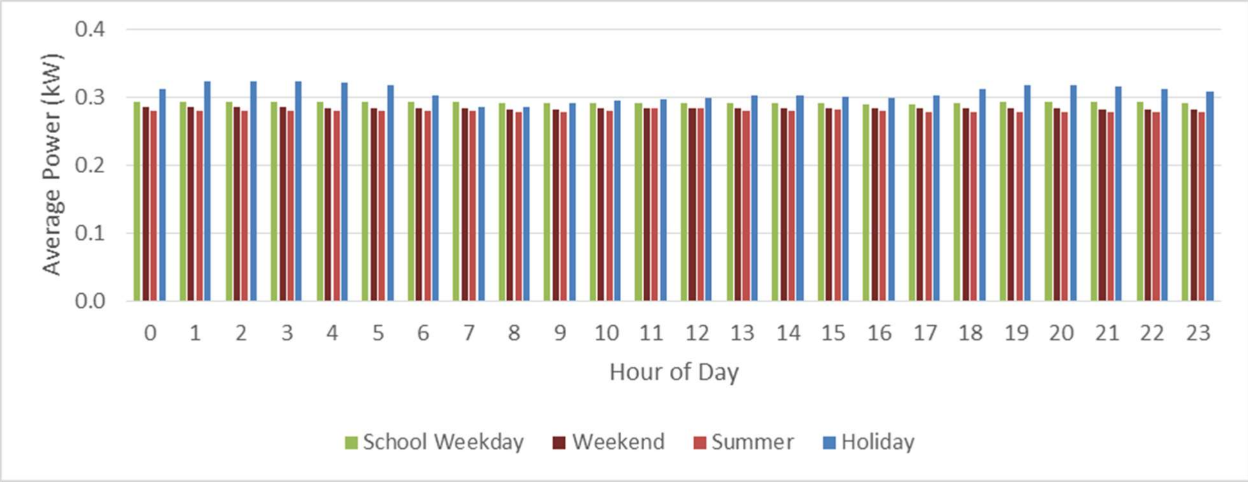


Figure 63: Logged Plug Load Power for Computer Receptacle Circuit 2

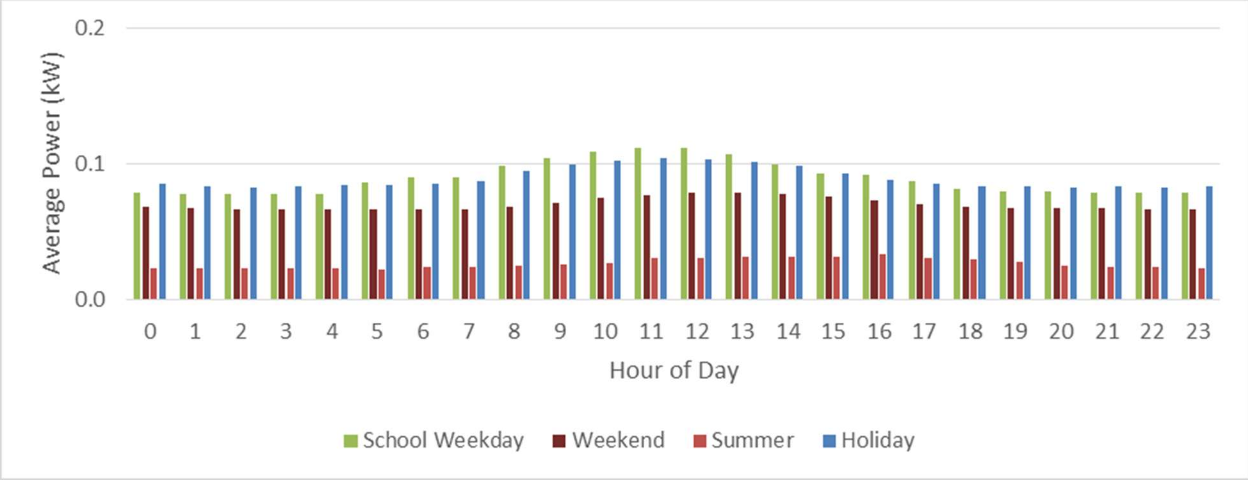


Figure 64: Logged Plug Load Power for Computer Receptacle Circuit 3

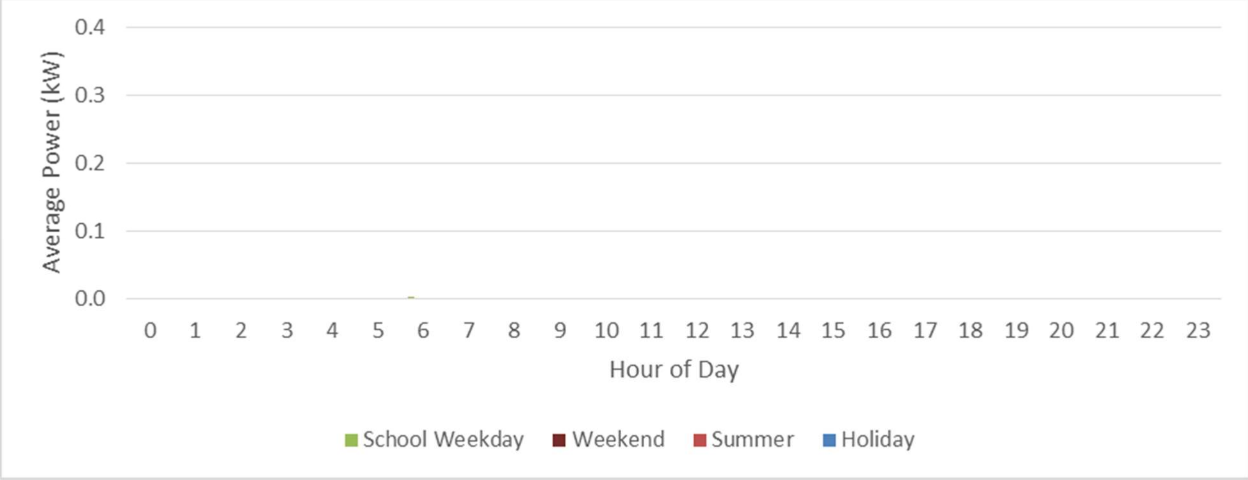


Figure 65: Logged Plug Load Power for Computer Receptacle Circuit 4

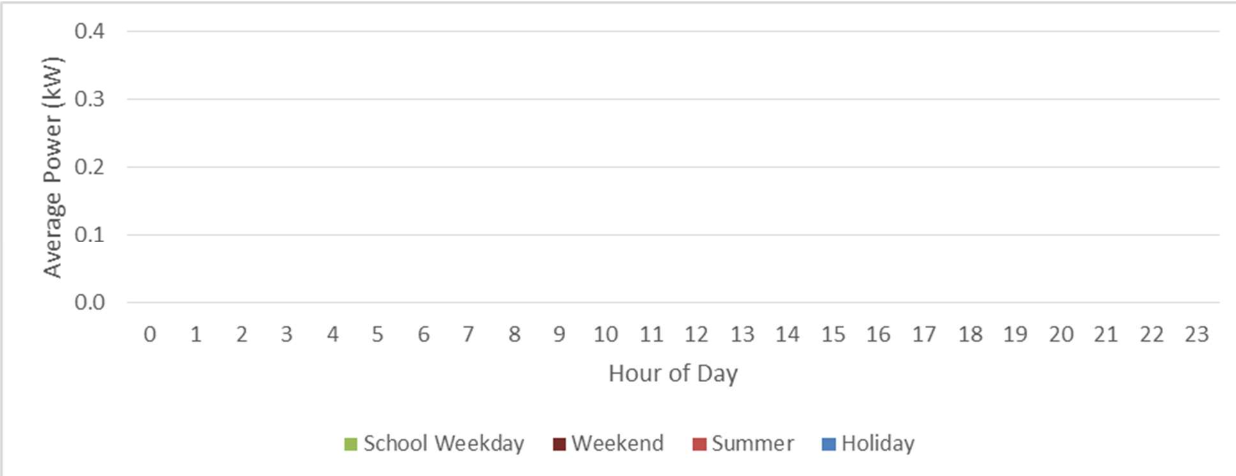


Figure 66: Logged Plug Load Power for Computer Receptacle Circuit 5

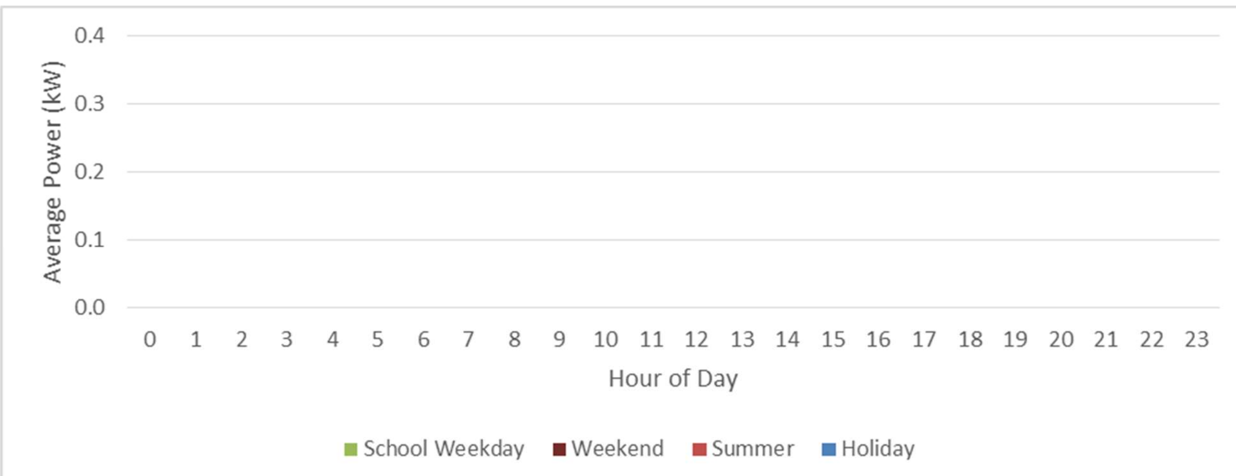


Figure 67: Logged Plug Load Power for Computer Receptacle Circuit 6

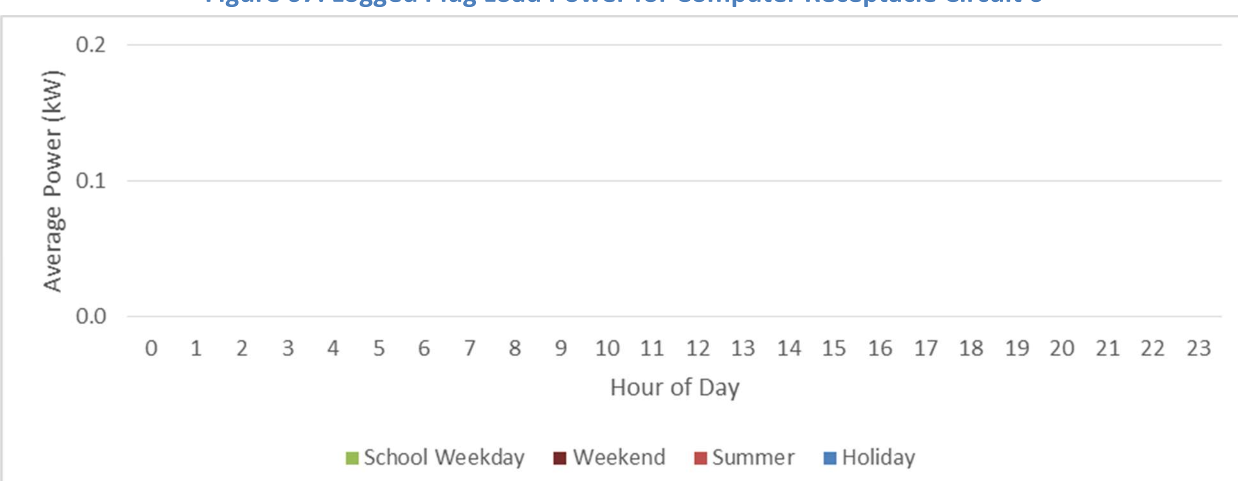


Figure 68: Daily kWh of all Metered Plug Load Panels, Entire Period

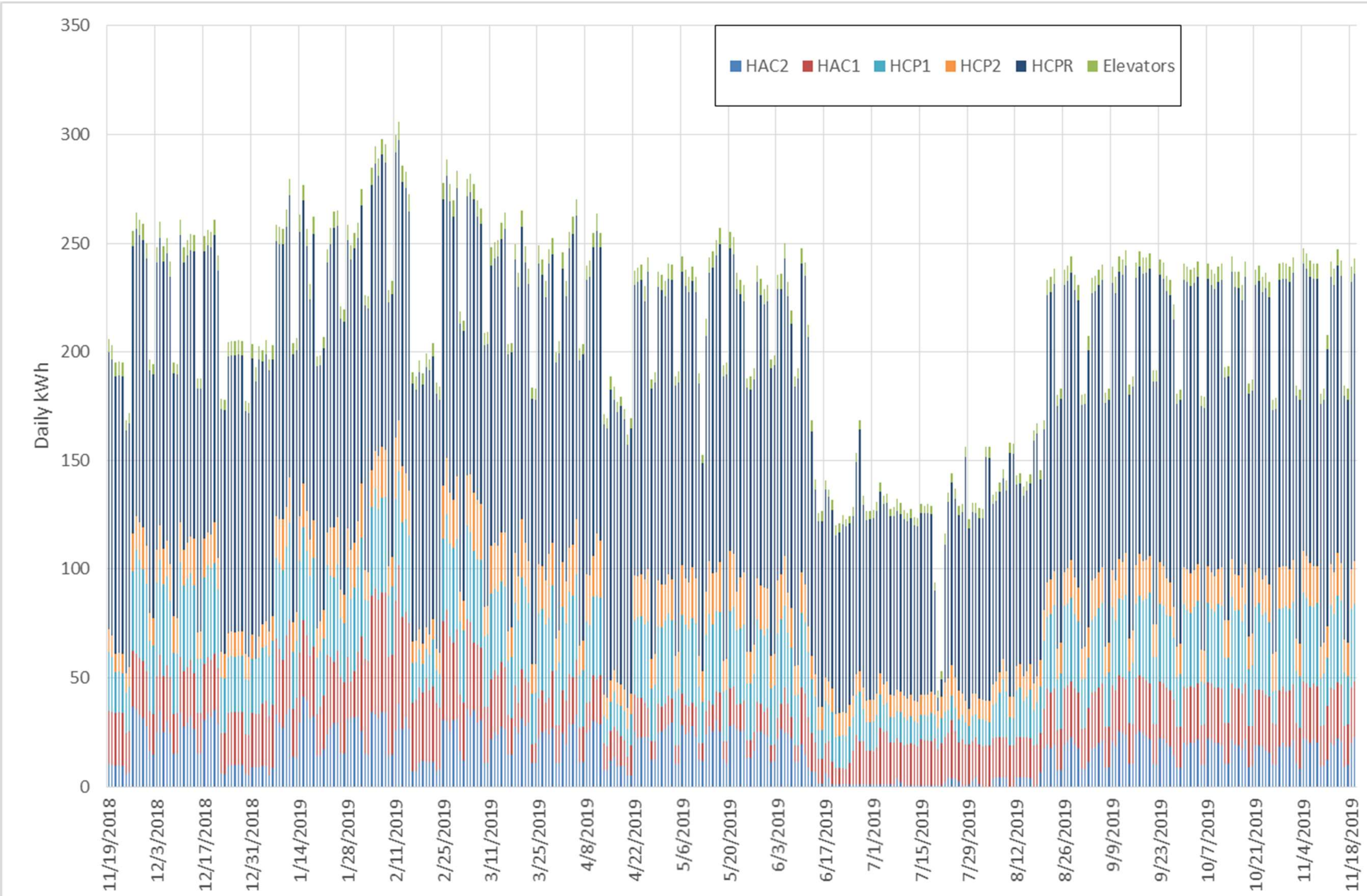


Figure 69: Daily kWh of all Metered Plug Load Panels, One Month (January 2019)

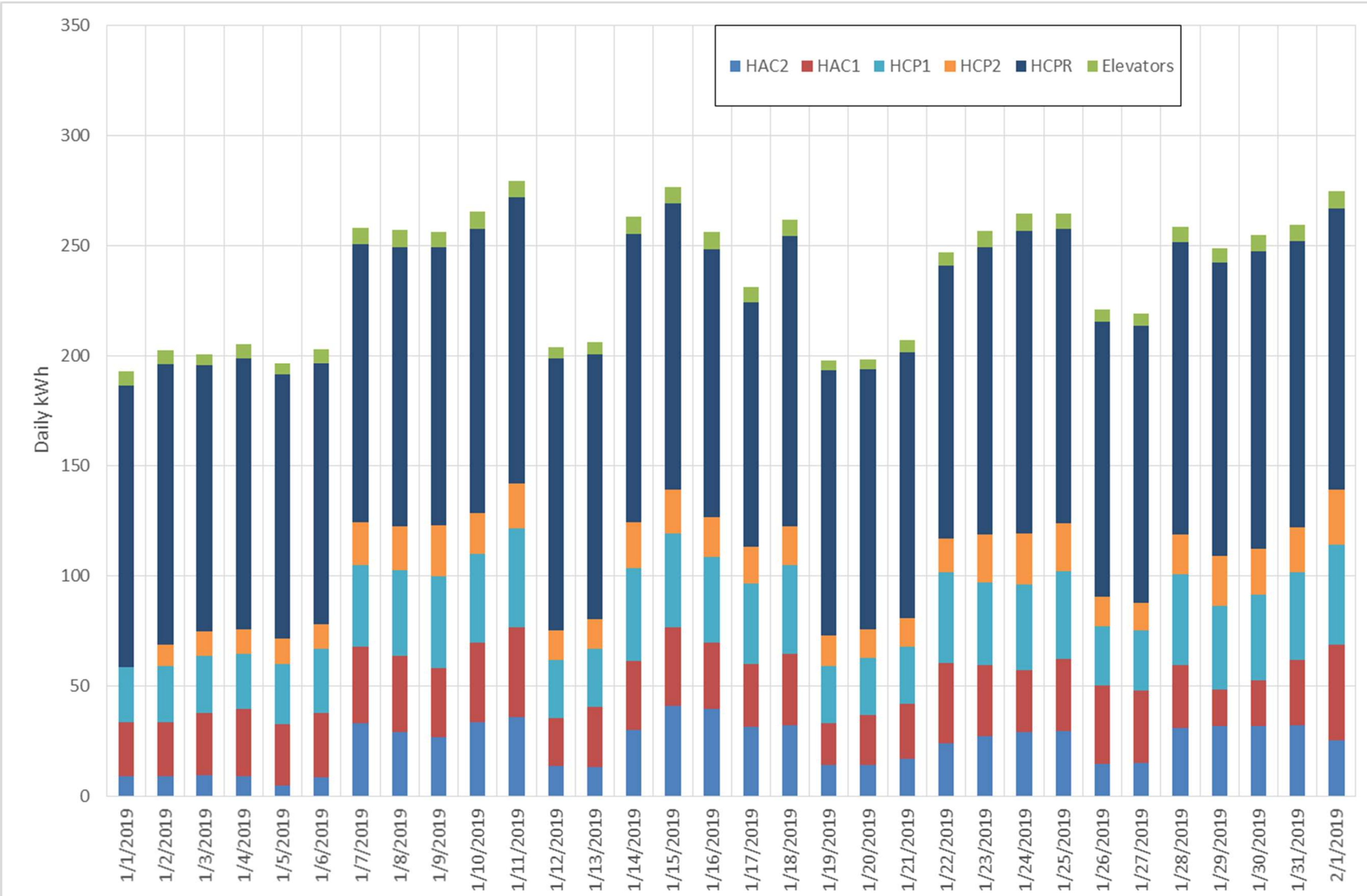


Figure 70: Daily kWh of all Metered Plug Load Panels, One Month (September 2019)