
Attachment D:
Night Audit Report for
Green School 5

Prepared for:
The Massachusetts Renewable Energy Trust (MRET)

7/21/2009

**RENEWABLE
ENERGY
TRUST**

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1. Introduction

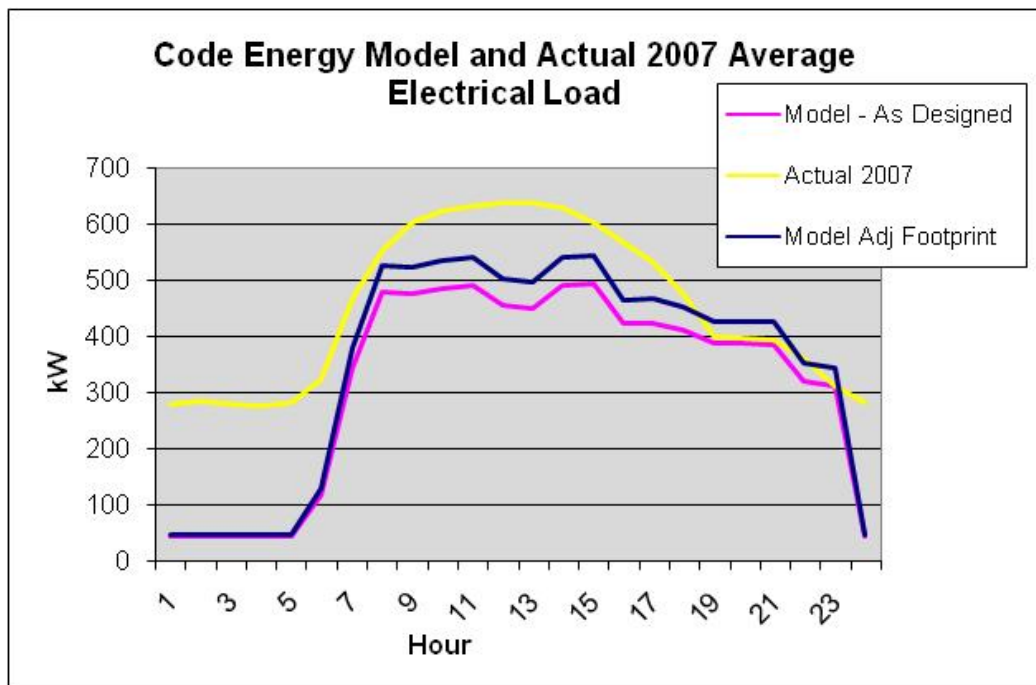
As an extension of Cadmus' Post-Occupancy Green Schools study in Massachusetts, performed on behalf of the Massachusetts Renewable Energy Trust (MRET), Cadmus conducted nighttime audits at two schools to:

1. Better understand the differences between energy simulation models and actual metered loads during unoccupied periods.
2. Assess evening loads and identify any unnecessary loads that could be addressed to save both energy and money.

This report discusses a nighttime audit of GS-5.

Simulation models created before GS-5 was built indicated that nighttime loads could be expected to drop significantly after 11:00 p.m.; however, interval data collected in 2007 showed nighttime electric loads drop only to about 300 kW. As of the writing of this report, 2008 and 2009 records had been requested from NSTAR, but these requests have not been fulfilled.

Figure 1. The Reason for the Difference in Modeled and Actual Energy Demand Was Not Known



This report outlines evening and nighttime energy use and shows where power is consumed. Because the scope of the study was small—a single nighttime audit—only a portion of the

school's roughly 60 electrical panels were metered in detail. Nevertheless, the findings are instructive in determining nighttime loads for this school and in generalizing to other high schools.

2. Methods

Four of the 15 schools in the Green Schools Post-Occupancy Study of Energy Efficiency gave Cadmus access to electric interval data from their utilities. Of these four schools, Cadmus selected the GS-10 to represent elementary schools and GS-5 to represent high schools. Energy data for 2007 provided by NSTAR indicated the 340,000-square-foot high school used 74.11 thousand British thermal units per square foot (kBtu/sf); electric use accounted for 35,100 BTU/sf, and fuel use accounted for 39,000 BTU/sf. Interval electric data indicated that the average daytime electric load at noon was approximately 630 kilowatts (kW), while evening loads dropped to approximately 280 kW.

To determine which building systems use evening electric loads, Cadmus reviewed building plans obtained from the facilities' staffs. Based on our review of GS-5's building plans, we determined that the most efficient use of our site visit would be to first capture spot measurements of the two main switchboards (MSBs) during evening hours and then meter panels downstream that were identified at the MSB as having high loads. Additional panels of interest included panels that had high expected loads: the panels serving stadium lights, parking lights, kitchen loads, and gym lights. These panels were metered individually.

Spot measurements were valuable in assessing which panels had high loads during the evening of the audit; however, in order to gain a thorough picture of electric loads in the building, Cadmus left metering equipment in place at select panels to monitor power over the two-week period of May 7 through May 21, 2009. We also installed meters in the kitchen and in classrooms to monitor plug load usage for 120-volt (120V) equipment such as computers and coolers, and we deployed meters in hallways to log light levels. Panels logged and meters used are shown in Tables 1 and 2.

Table 1: Panels Logged and Spot Measured May 7 to 21, 2009

Panels	Area Served by Panel
DP4E	HVAC, Room Lighting and Transformers
4DP2C	HVAC, Room Lighting and Transformers
LP2B	Gym Lighting
4DP1E	Room Lighting and Transformers
OLP1F	Outdoor Lighting
ATS-LS-1F	Automatic transfer switch that serves panels ELP1F, ESDP, ELTS, ELP2E, ELP3E, ELP4E, which serve emergency and security lighting loads, auditorium lighting, kitchen loads, and other misc. loads tied to emergency backup power
SLP	Stadium Lighting
4DP1E	Room Lighting and Transformers
KPPB1BA	Kitchen

Table 2: Equipment Used During the GS-5 Nighttime Audit of May 7, 2009

Metering Equipment	Number Deployed/ Used in Field	Meter Purpose
Watts Up Pro	7	Logs a time series of kilowatt-hours (kWh) for plug loads such as computers, coolers and printers
Hobo U12	7	Light Levels
Watt Nodes	6	Converts current and voltage readings into true power readings. Pulse output is connected to loggers.
Current transformers (CTs)	18	Used in conjunction with Watt Nodes, Weather Stations and Energy Logger Pros to measure current
Hobo U30, H-21 weather station, H-22 Energy Logger Pro	6	Loggers used to accumulate power readings in a time series
Fluke Power Analyzer 41, 43b	3	Used to spot-measure amps, volts, kilowatts and power factor
Kill-a-watts	5	Used spot measurement of kWh usage of plug load equipment such as computers, coolers and printers

Figure 2: Example of Panel Metering



3. Results

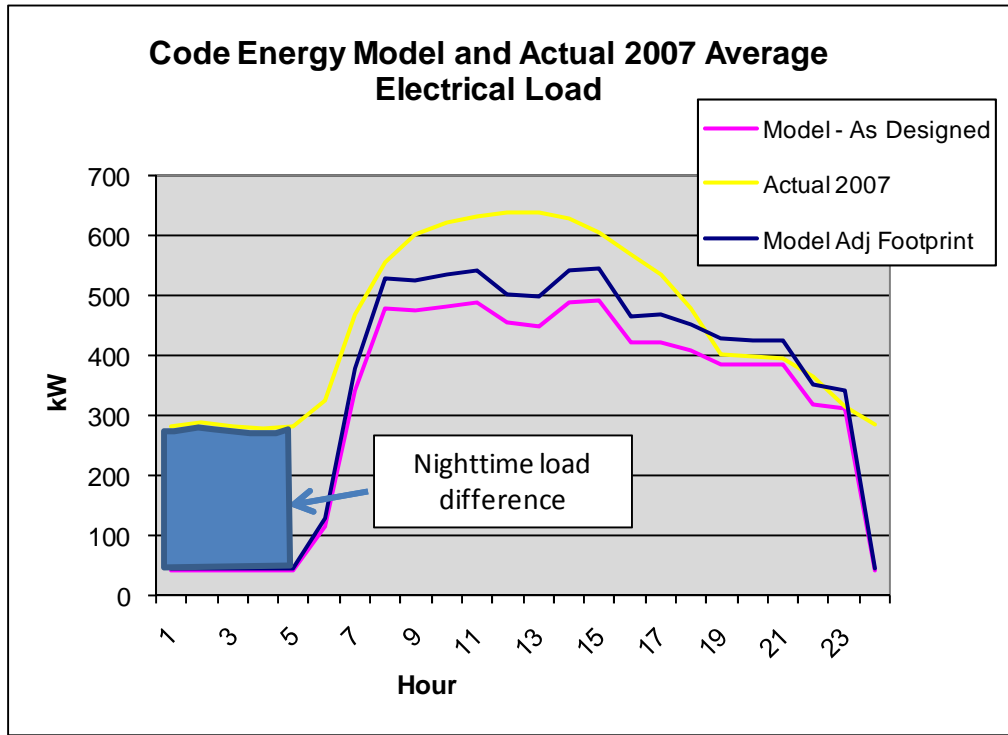
General Observations

During the site visit we noted a high degree of student activity at 6:00 p.m. in the gym and auditorium areas and limited activity in the band rooms. Classroom activity was limited to custodians cleaning. By 8:00 p.m., most student activity had tailed off with some auditorium activity continuing. Lights in all hallways and in the cafeteria were left on mostly un-necessarily. Custodians noted that they didn't know how to switch off hall lights in various floors, so as a result all were left on until they left at approximately 11:00 p.m.

The electrical distribution system feeds individual panels from other larger panels and in some cases from automatic transfer switches that are backed by emergency circuits. As a result, many of the metered loads are mixtures of lighting and plug loads.

Figure 3 shows that the modeled and 2007 interval demand differ most at night, with the actual demand roughly 250 kW higher from 11:00 p.m. to 6:00 a.m.

Figure 3. Modeled Versus 2007 Metered Electrical Demand



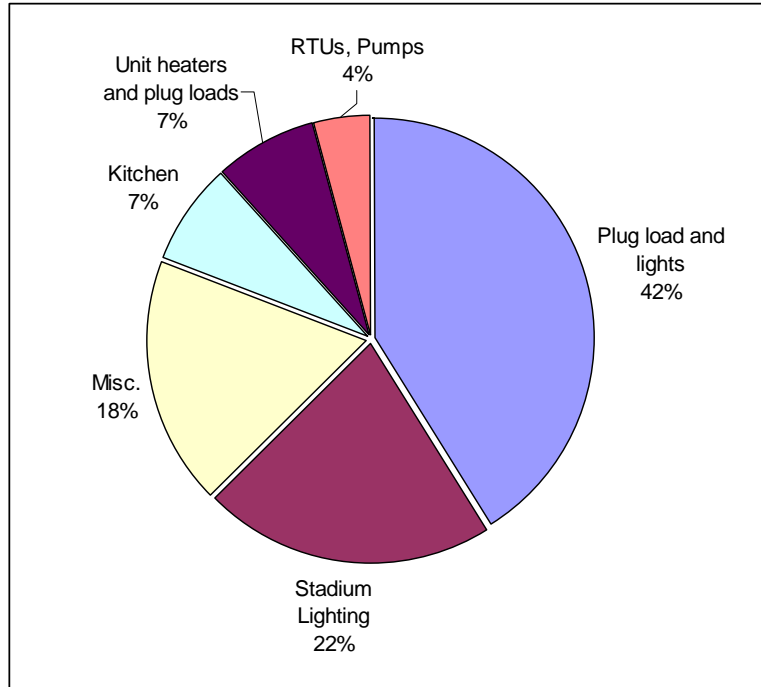
The GS-5 facility manager indicated that the school modified schedules to reduce energy use and expenditures because of the 2008 – 2009 economic downturn. Beginning in January 2009, overnight custodial shifts from 11:00 p.m. to 7:00 a.m. were eliminated and outdoor parking lights, including pole lights and wall packs, were set to come on at sunset and go off at midnight. Previously, these lights stayed on all night. These changes have likely reduced actual loads to well below 300 kW after 11:00 p.m., but they are still substantially above the roughly 40 kW predicted by the model.

Total Spot Measurements

Spot measurements were collected at the main switchboards between 6:00 and 10:00 p.m. on Thursday May 7, 2009, for nearly all circuits except where the wiring was too tight to install a power meter. The total load of about 402 kW was roughly 27 kW higher than the sum of the panels, probably due to one un-metered circuit.

As indicated in Figure 4, lighting, plug loads, stadium lighting panels, and kitchen equipment accounted for over 70% of the observed lighting loads. Because metered panels serve mixed loads, including 277V lighting and 120V transformers that serve plug loads, the precise portion serving lighting versus plugs was not determined.

**Figure 4. Power Use From Spot Measurements
Taken Between 6:00 and 10:00 p.m. on May 7, 2009
Total = 402 kW**



Lighting accounted for a significant portion of the total loads each panel serves. School staff confirmed that hall lights generally stay on until 11:00 p.m., when the evening custodial shift ends. Custodians begin to shut off lights around 10:30 p.m. in preparation to close the school. On May 7, 2009, Cadmus found that afterschool activities including sports practices and band practice wrapped up prior to 9:00 p.m.; however, gym lights, auditorium lights, and hall lights in all wings remained on until the building closed at 11:00 p.m.

Panel Spot Measurements

High loads identified by metering at the MSB were flagged for additional metering at panels downstream (see Table 3, below). “Transformers” are devices that convert 480/277 voltages to 120V suitable for plug loads. The spot measurements accounted for roughly 270 kW or half the building’s entire night load, showing that the load is centered in a few panels and allowing us to understand night loads. In general the loads were dominated by lighting.

Table 3: Panels Spot Measured

Panels	Area Served by Panel	Total Load (kW)
DP4E	HVAC, Room Lighting and Transformers	20.7
4DP2C	HVAC, Room Lighting and Transformers	46.3
LP2B	Gym Lighting	22.8
4DP1E	Room Lighting and Transformers	16.8
OLP1F	Outdoor Lighting	16
SLP	Stadium Lighting	90
2DP1F	Auditorium	60.8

Figure 5. Power Measured at Panel DP4E at 9:00 p.m. on May 7, 2009

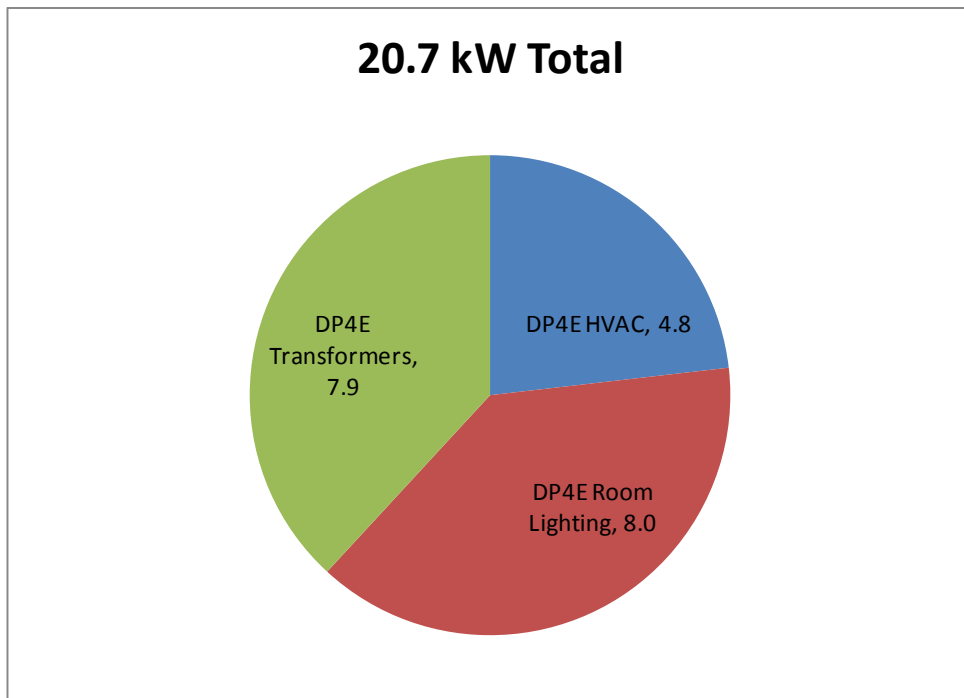


Figure 6. Power Measured at Panel 4DP2C at 7:45 p.m. on May 7, 2009

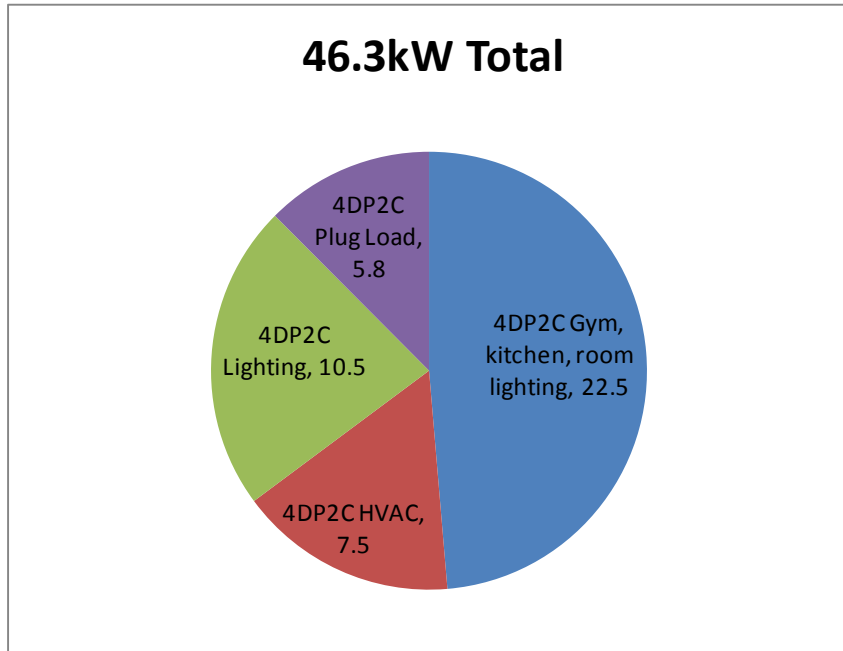


Figure 7. Power Measured at Panel LP2B at 8:40 p.m. on May 7, 2009

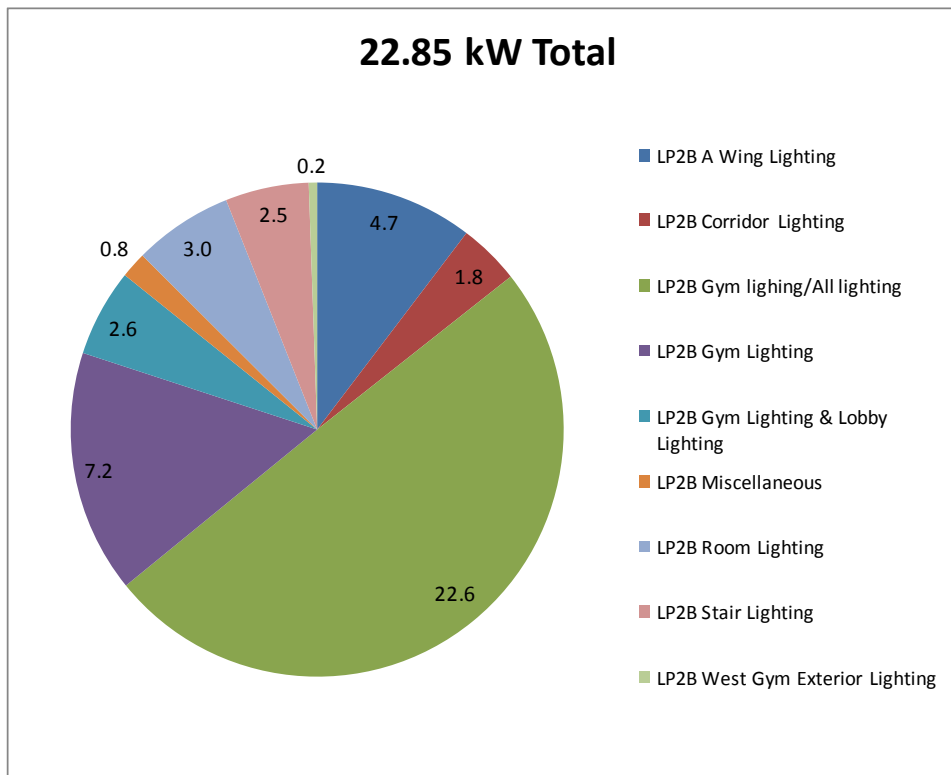
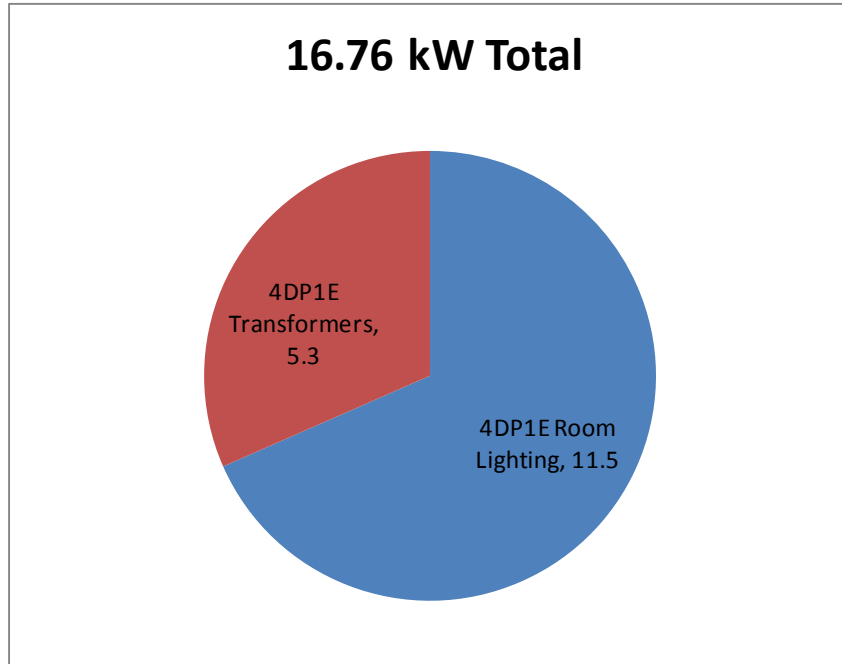


Figure 8. Power Measured at Panel 4DP1E at 8:45 p.m. on May 7, 2009



Panel Monitoring

Table 4 shows panels logged with high-accuracy recording power meters for two weeks. The panels were chosen because they showed substantial power draw during MSB and panel spot metering. In addition, the kitchen was metered because experience has shown that kitchens contribute to high nighttime loads.

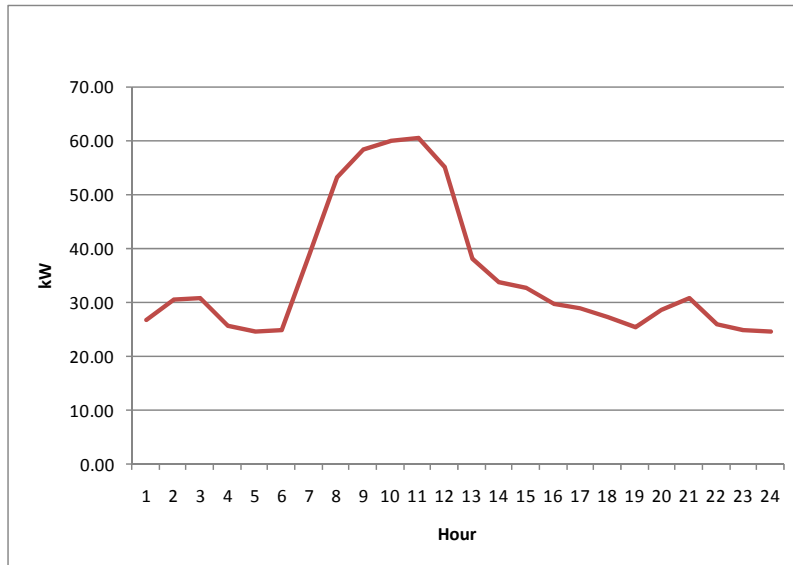
Table 4. Panels Logged with Recording Power Meters

Panels	Area Served by Panel	Average Night Load (kW)
KPPB1BA	Kitchen	30
ATS-LS-1F	Automatic transfer switch that serves panels ELP1F, ESDP, ELTS, ELP2E, ELP3E, ELP4E, which serve emergency and security lighting loads, auditorium lighting, kitchen loads, and other misc. loads tied to emergency backup power	10
4DP1E	Room Lighting and Transformers	2
OLP1F	Outdoor Lighting	16 (off at midnight)
SLP	Stadium Lighting	90 (peak—off by 10:00 p.m.)

Figure 9 shows the kitchen power draw metered at electrical panel KPPB1BA over the two-week monitoring period. Kitchen equipment nighttime loads averaged 25 to 30 kW, nearly as much as the total modeled nighttime load. A separate panel not metered during the study serves an ice machine and some other additional kitchen loads. The load increases to about 60 kW between

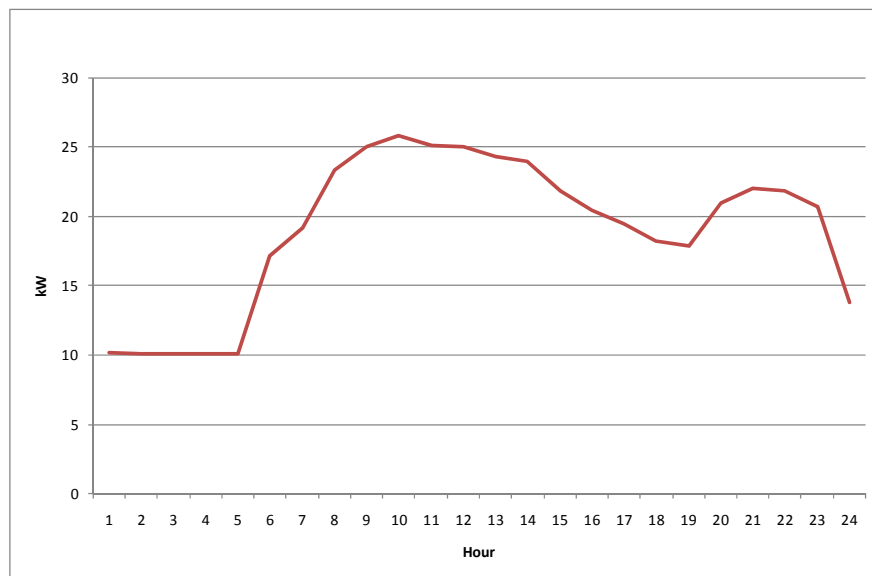
8:00 a.m. and 1:00 p.m., then returns to the 30 kW baseline. The load during peak periods is about 300 kilowatt-hours per day (kWh/day), and the unoccupied load is about 570 kWh/day.

Figure 9. Kitchen Panel Average kW (May 7 to May 21, 2009)



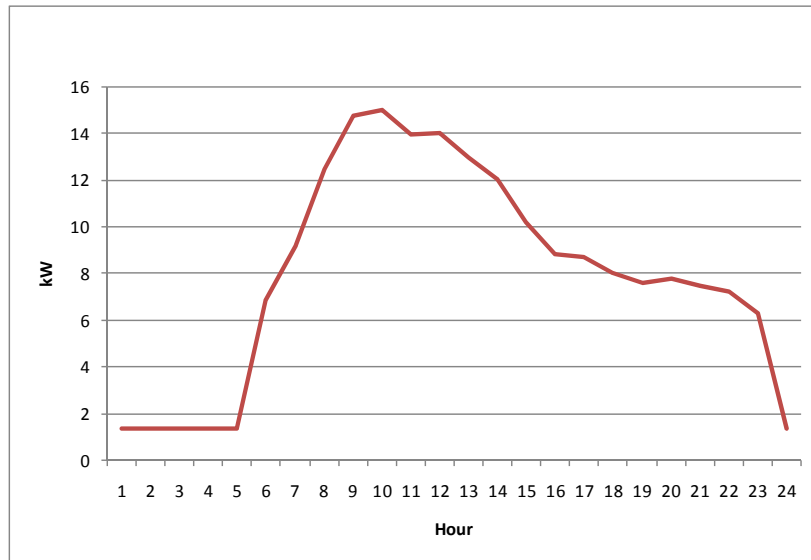
The ATS-LS-1F is an automatic transfer switch that serves panels ELP1F, ESDP, ELTS, ELP2E, ELP3E and ELP4E, which serve emergency and security lighting loads, auditorium lighting, and other miscellaneous loads tied to emergency backup power. Its base load is 10 kW (Figure 10); maximum power of 31.85 kW occurred at 9:39 a.m. on May 11, 2009. This base load contributes to overall nighttime electric demand, and models used to predict energy use should take this fact into account. There were two panels dedicated to emergency loads alone, with other subpanels serving some additional emergency/safety equipment throughout the building.

Figure 10. Panel ATS-LS-1F (Emergency Equipment) Average kW (May 7 to May 21, 2009)



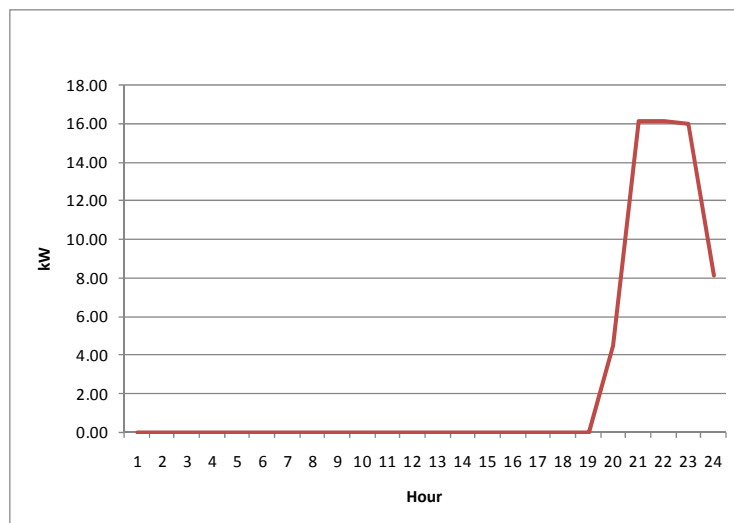
In Figure 11, the base load for panel 4DP1E, which serves room lighting, transformers, and other miscellaneous loads, is approximately 1.8 kW. From midnight until 5:00 a.m., loads are at their lowest. Maximum power for this panel occurred at 8:35 a.m. on May 13, 2009, and measured 20.78 kW. Even though the base load for this panel is relatively low, the base loads at each of GS-5's more than 100 panels accumulate to represent a portion of the building's nighttime load.

Figure 11. Panel 4DP1E Average kW (May 7 to May 21, 2009)



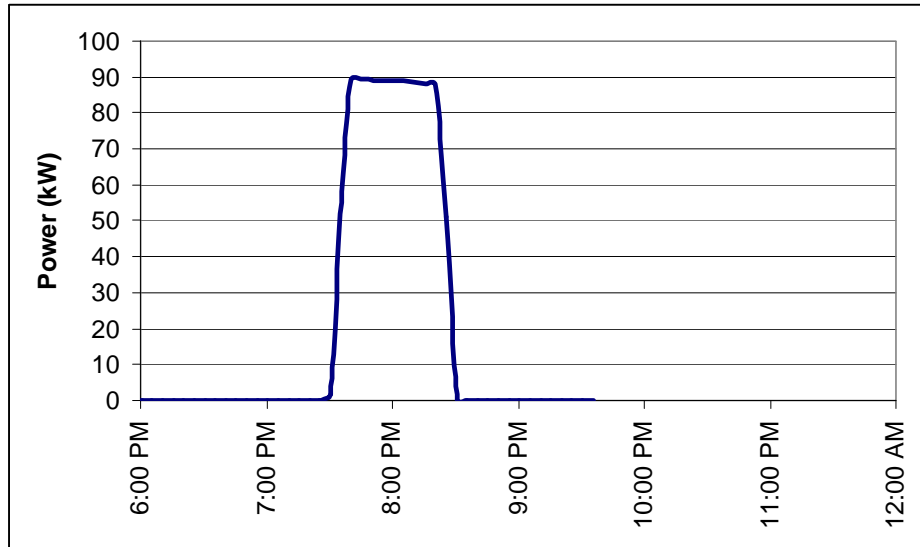
The outdoor lighting panels (Figure 12) indicate that outdoor parking lights (excluding field lights) come on at half power at 7:00 p.m. and reach full power by about 8:00 p.m., where they remain until 11:00 p.m. Base loads when the lights are off are zero. Previously, these lights had been left on until dawn. Shutting them off at 11:00 p.m. reduces operating time by about 2,400 hours per year and saves roughly 40,000 kWh or over \$4,000.

Figure 12. Outdoor Lighting: Average Power Demand



Stadium lighting consists of four large pole lights, each housing 16 to 18 1,500-watt lamps to light the field with a total of about 90 kW of lights. Figure 13 shows a typical power curve when the lights are in use. Because the lights are not used every day, the average daily usage is much lower. The lights use about 90 kilowatts per hour of use, which costs about \$14.

Figure 13. Power Used by Stadium Lights (Example Night)



Plug Load Monitoring

While on site, Cadmus monitored selected computers and other miscellaneous plug loads. Watts Up Pro meters, which monitor power over time, were installed in the library and the kitchen. Figure 14 shows a representative student computer in the library. The computer is used mornings and either shut off or in sleep mode when not in use. Power usage on May 8 began at about 8:00 a.m. when the school day started and ended around 2:00 p.m. when the computer was shut down. Weekend use (May 9 and 10, 2009) showed standby power of 2.3 watts. This pattern held true for the entire two-week monitoring period.

Figure 14. Student Computer Power Use (Library Computer)

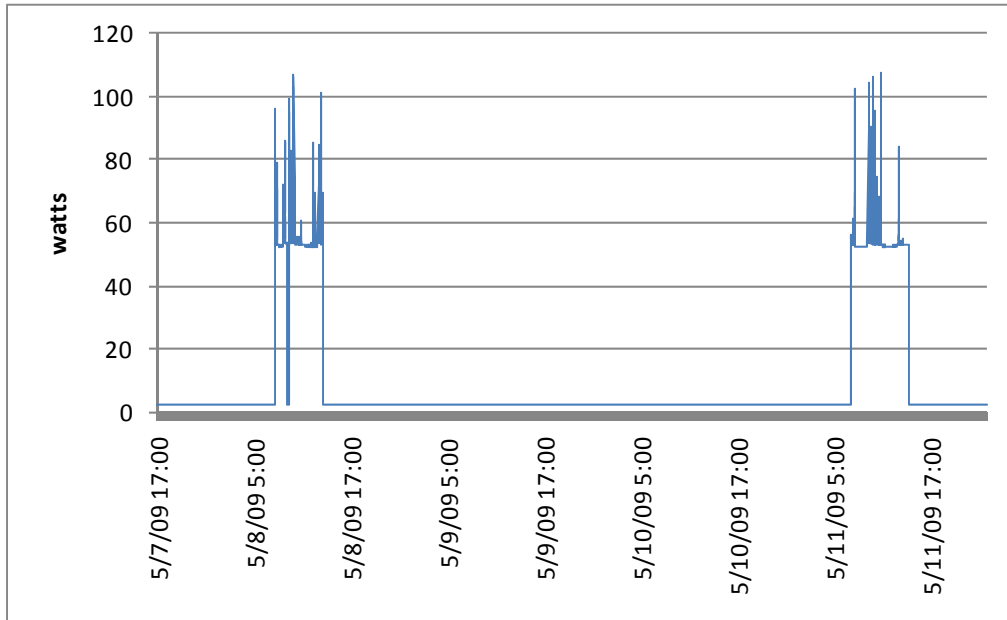
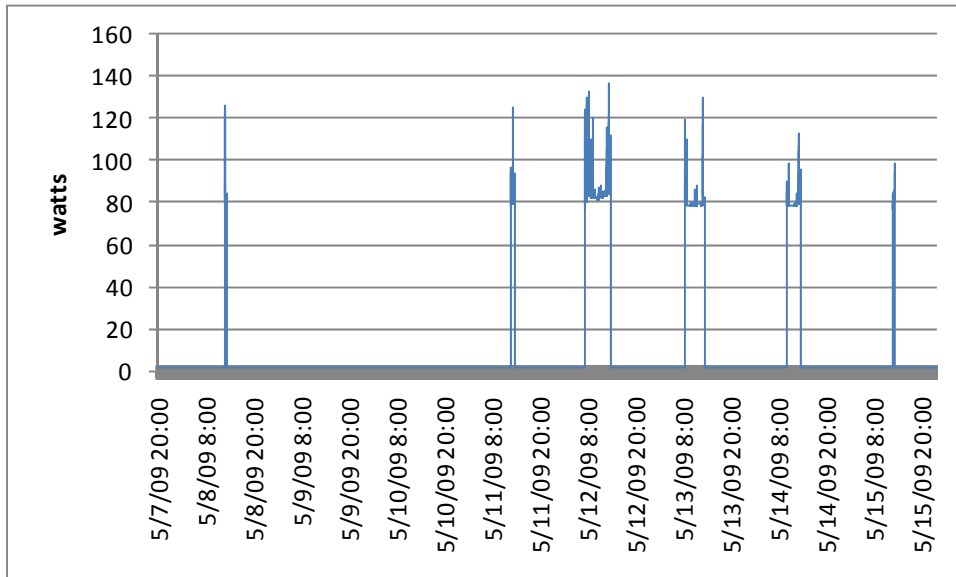


Figure 15. Library Administrator Computer Power Use



The library administrator's Dell Optiplex Gx520 computer showed minimal use during the monitoring period. Sleep settings appeared to be in place; power consumption during periods of non-use was measured at 2W, while power consumption during use was found to be approximately 80W, spiking to 140W at times.

Figure 16 shows power data for a pass-through refrigerator in the kitchen. More power is used during the school day, probably due to opening and closing the refrigerator for food preparation, lunch and cleanup. Average power use is 367 W, with standby use of 104 – 110 W. Commercial refrigerators such as this one typically are inefficient; this refrigerator uses roughly as much power as four full-size residential refrigerators.

Figure 16. Pass-through Refrigerator Power Use

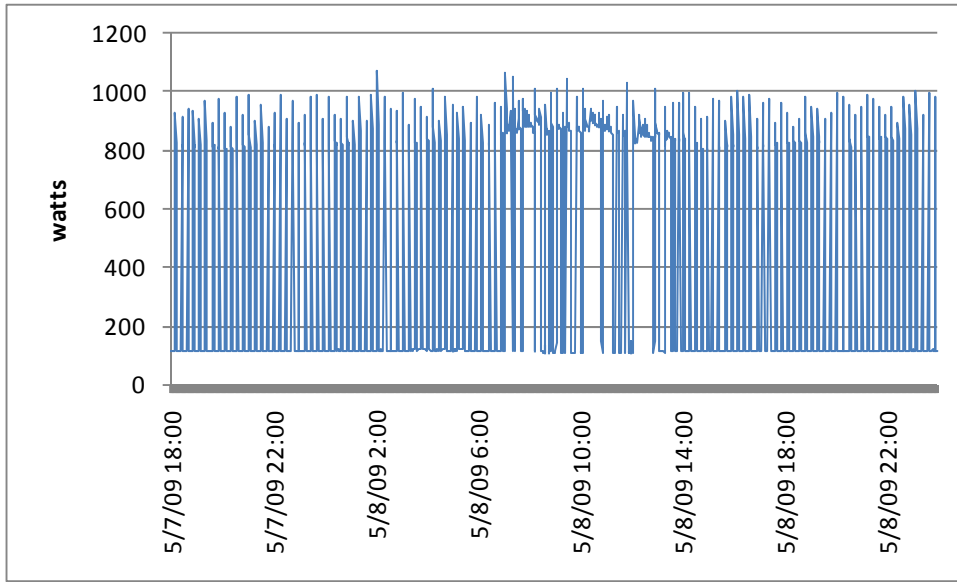
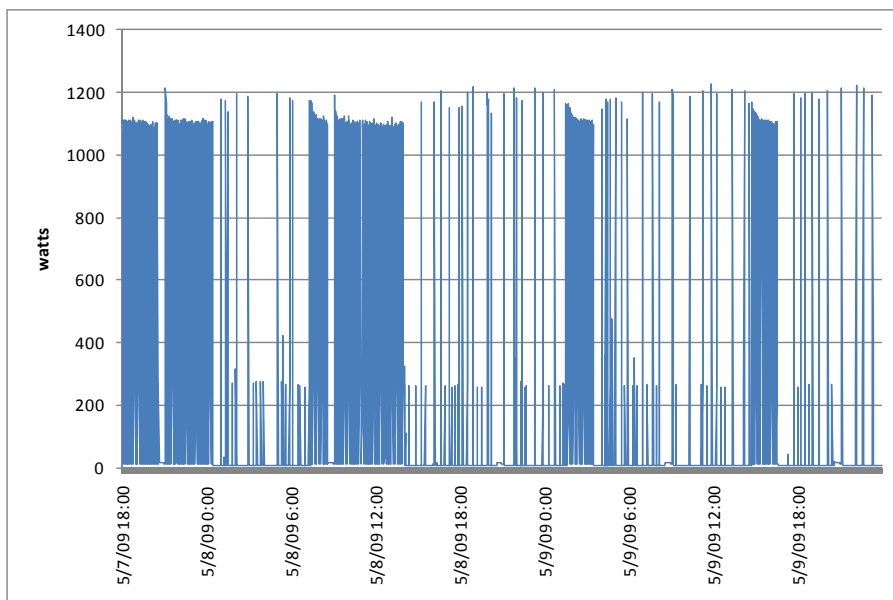


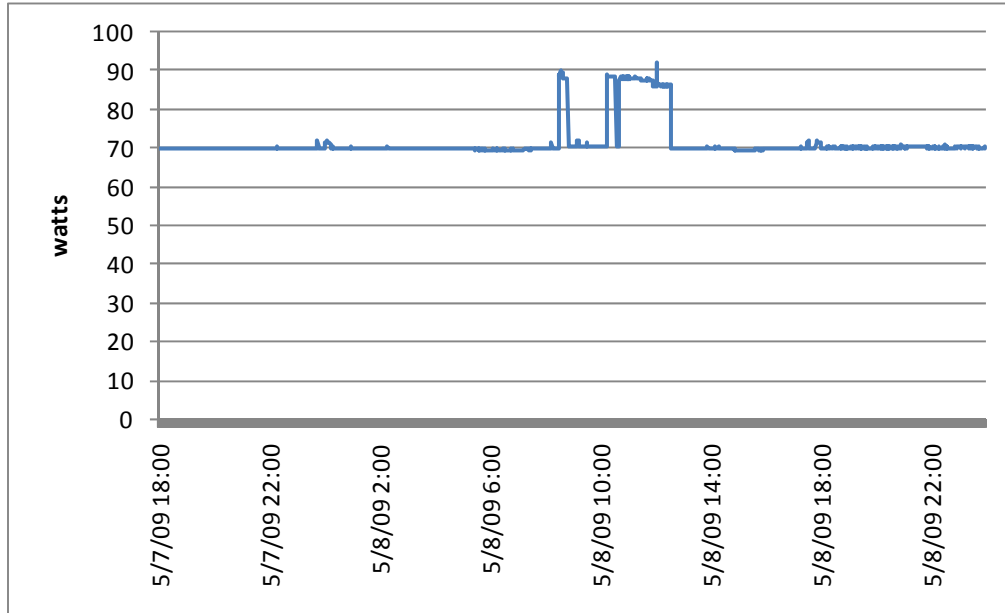
Figure 17 shows ice maker power use from May 7 to 9, 2009. Power use over the two-week monitoring period appeared to be higher during school hours and averaged approximately 227 W.

Figure 17. Ice Maker Power Use



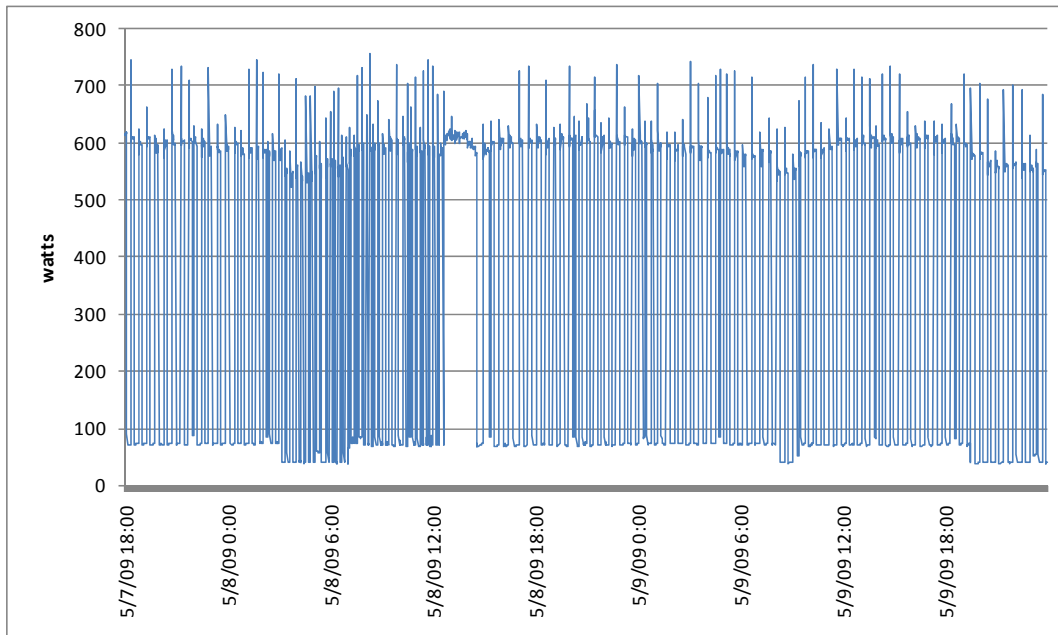
As shown in Figure 18, below, the cash register cart uses an average of 72 W (70 W when standing by). We recommend unplugging the cash register when it is not in use.

Figure 18. Cash Register Cart Power Use



Vending machine power use cycles regularly, with some periods of greater use, probably when the machine is filled and water must be cooled. The average power draw was 320 W.

Figure 19. Vending Machine Power Use



Light Level Monitoring

Cadmus deployed seven Hobo U12s throughout the third floor D and E wings to sample light levels over the two-week study period. As is evident in the figures shown below, the seven monitored lights in wings D and E perform identically, coming on at 5:00 a.m. and shutting off at 11:00 p.m. on weekdays. Weekend use is minimal; the lights come on for less than three hours. Variation in light levels is not meaningful because it simply indicates how close the light meter was to the nearest fixture.

Figure 20. D Wing Light Levels

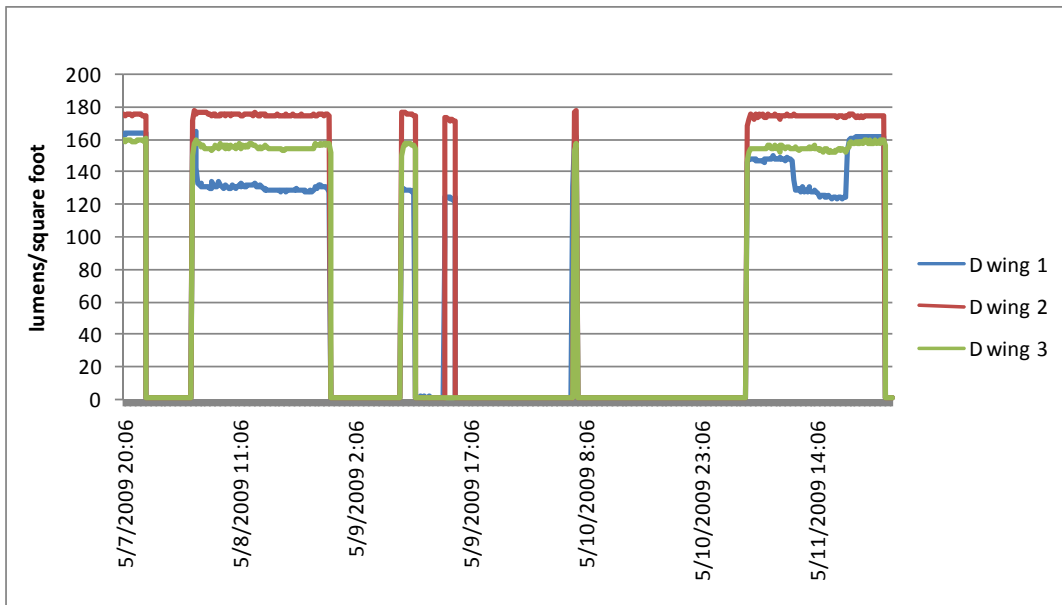
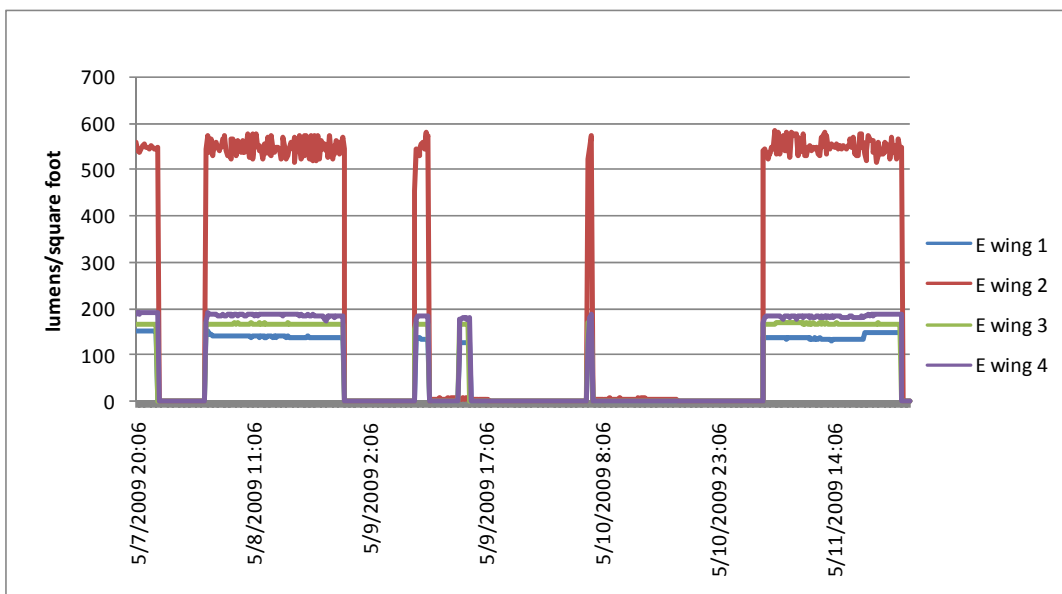


Figure 21. E Wing Light Levels



4. Conclusions and Recommendations

One of the purposes of this nighttime audit was to better understand the differences between energy simulation models and actual metered loads during unoccupied periods. We saw that substantial loads at GS-5 included lighting and plug loads and a nearly continuous 30 kW load from kitchens. Two selected panels have minimum loads totaling about 12 kW, and we believe most other panels have similar minimum loads. Although not metered separately, the school has over 30 transformers that transform 480/277V power to 120V. The transformation process has some unavoidable losses. Based on transformer manufacturers' data, these transformers alone have standby losses of nearly 10 kW.

The primary purpose of energy modeling for new construction is not to predict annual energy expenses for the future owner, but rather to confirm that building specifications meet not only the current building code but also the Massachusetts Collaborative for High Performance Schools (MA-CHPS) criterion of electricity savings in excess of 20% over a school built to code. That said, there is no reason not to use studies such as this one to inform future modeling practices. We recommend that modelers calculate cafeteria loads, transformer losses, and security light power use and adjust modeled schedules to anticipated actual use.

Another purpose of this report was to assess evening loads and identify any unnecessary loads that could be reduced to save energy and money. GS-5 has already taken a number of steps to reduce evening and night loads at the high school. This progress could have been assessed had NSTAR provided data in a timely manner. The high school has eliminated night cleaning and now turns off interior and exterior lights by 11:00 p.m. Computers appear to be well managed and either shut off or put into sleep mode when not in use. The main opportunity for savings appears to be in lighting. Audited lights in hallways, the gym and the cafeteria were on during evenings when no activity was taking place. Architects and engineers use the term dark school to refer to schools that turn off all lights—even security lighting—when a school is unoccupied. Doing so can reduce standby power use.

When pursuing new opportunities for savings, the savings must be balanced with the effort required to achieve them. Reducing night and weekend loads by 20 kW, for example, could save roughly 120,000 kWh per year (which costs about \$16,000 per year) based on 6,000 unoccupied hours.