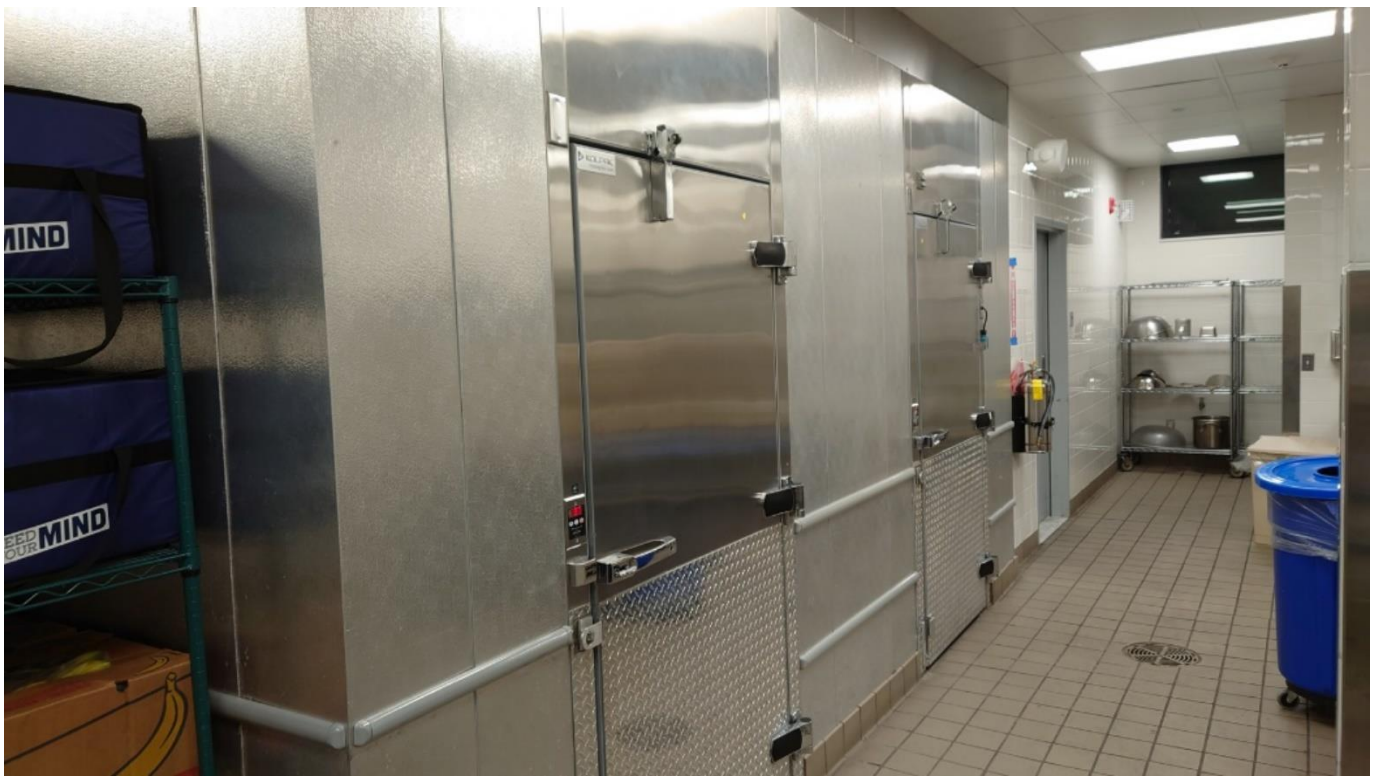
Kitchen Walk-In Refrigeration Load Analysis

April 19, 2024



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1. Executive Summary

Kitchen equipment is one of the largest contributors to energy use intensity (EUI). Most of this energy is consumed by components of the walk-in refrigeration enclosures. The current eQuest energy modeling templates use plug-in equipment inputs and schedules derived from the SCA's *LL31 Feasibility Study: Phase 1* from August 2018. The purpose of this current analysis is to refine the modeling of kitchen walk-in refrigeration enclosure operation given the upgrades to the SCA design standards after the LL31 study such as increased insulation and demand defrost controllers.

The ASHRAE handbooks do not provide operational or energy data for walk-in refrigeration equipment. This is likely because these enclosures are custom built, so there is very little standardization for these items in the industry. The SCA considered it necessary to conduct a field study to understand the real-world operation of walk-in refrigeration equipment typically designed per SCA standards. The study would allow for more accurate energy modeling and a better assessment of the impact on EUI.

SOCOTEC, using its subconsultant Live Building Systems, collected energy data from two schools with walk-in refrigeration equipment (walk-in refrigerators and walk-in freezers). Limited data was collected because certain electrical panel connections were not as indicated in the design. While there were challenges with the wiring of some of the components, much of the data collected was useable. Draft recommendations to the SCA's *eQuest Input Summary for Energy Models* and Appendix A Calculator spreadsheet were made to increase the accuracy of modeling the energy consumption of walk-in refrigeration equipment.

The study has found that revising the schedules results in a 1.7 to 3.4 kBtu/ft^2 reduction in source EUI based on five sample school projects. The EUI savings are inversely proportional to total school size. New schools will see less impact since the current SCA standard enclosure design is more efficient than what was assumed in existing building electrification projects. Refer to Table 1 and 2 for the full results.

2. Equipment Monitoring

2.1 Methodology

SOCOTEC retained Live Building Systems as the licensed electrical sub-contractor to install the monitoring equipment. Energy measurements are collected by installing multi-circuit submeters and current transformers (probes) in circuit breaker boxes that are connected to the walk-in refrigeration equipment as shown in Figure 1. The probes measure current running through wires in the electrical panel. They are wired to the submeter which logs the energy consumption data. The submeters are connected to either a cellular modem or the school's WiFi network which transmits the data. The data can be viewed and downloaded through an online portal hosted by Live Building Systems as shown in Figure 2.

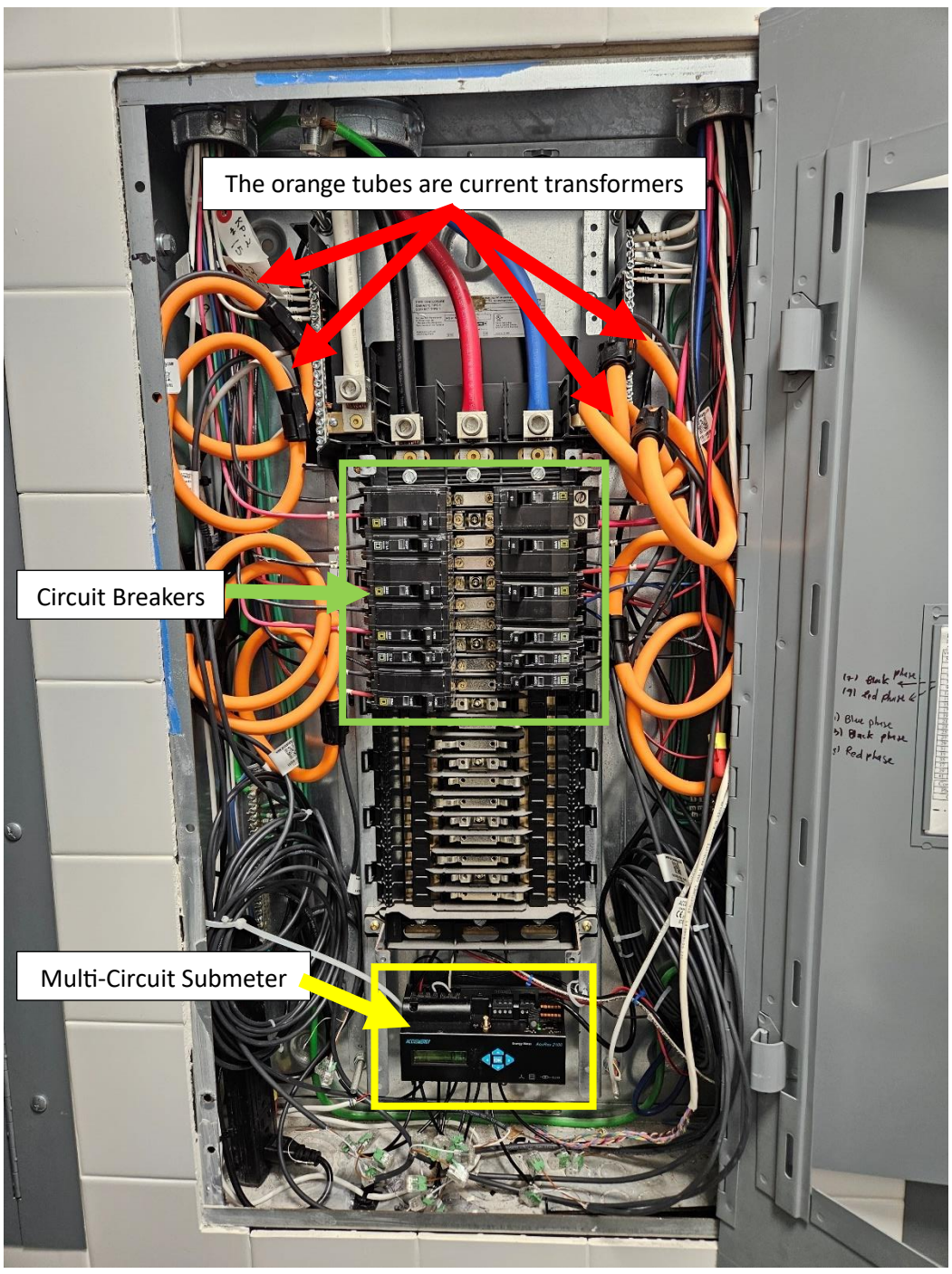

Figure 1: Energy Monitoring Setup at PS School

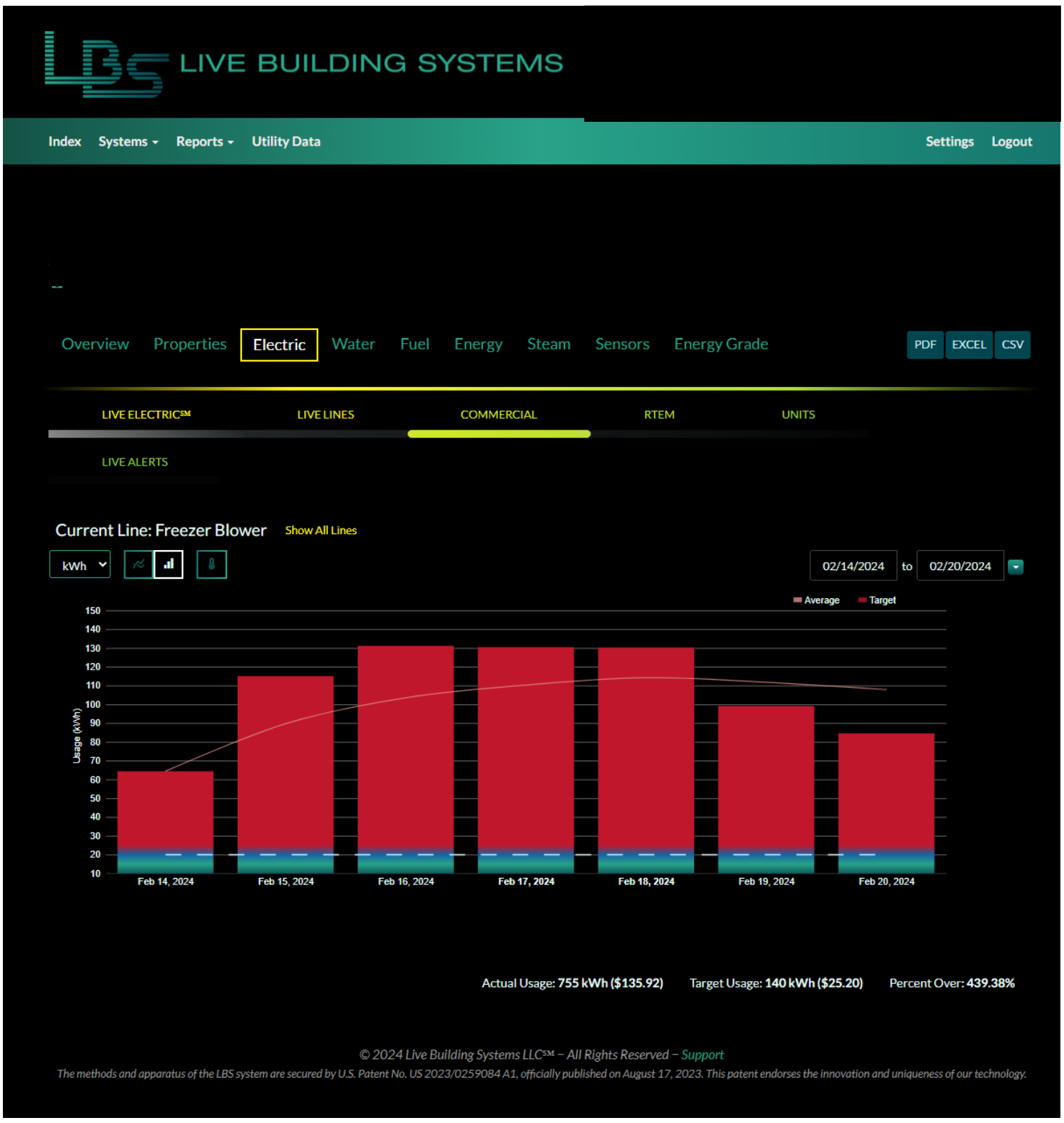

Figure 2: Online Portal for Energy Consumption Data

2.2 Site Conditions

The PS School walk-in enclosure was built completely within the general kitchen area, without any walls exposed to the exterior. This means that it experiences very little seasonal temperature variations.

The typical kitchen equipment schedules found on A-941 of new school projects have generic entries labeled “Walk-In Refrigerator (+35F)” and “Walk-In Freezer (-10F).” Figure 3 is the kitchen equipment schedule for PS School and Figure 4 shows the equipment on the electrical panel. Socotec has observed that the “Walk-In Refrigerator (+35F)” refers to the interior lighting for the enclosure. “Walk-In Freezer (-10F)” refers to both the interior lighting and the defrost system.

SCHEDULE OF EQUIPMENT

	ITEM NO.	QTY	DESCRIPTION	PLUMBING							ELECTRICAL							MANUFACTURER	REMARKS	SCA SPEC SECTION 11400
				HW	CW	W	IW	FD/FS	G	MBTU	HP	KW	Amps	EO	DR/ SR	Vlts	Ph			
			KITCHEN																	
	AK-1	1	Scale															Ametek/Chatillon BP15-100-T		4.22
	AK-2	1	Receiving Table															Fabricated		4.07A
	AK-3	1	Mobile Steam Cleaner										15.0		DR	120	1	SprayMasterTechSMT600PEW		4.08
	AK-4	3	Hose Bib		3/4"								15.0		DR			BY OTHERS		
	AK-5	1	Mop Rack															Rubbermaid 1993		4.27A
	AK-6	1	Can Wash/Mop Sink	2)1/2"	2)1/2"		X	FS										IMC/Teddy DL-20-1		4.12
	AK-7	1	Dunnage Rack															Eagle MDR2430-E	30"x24"	4.06B
	AK-8	1	Worktable															Fabricated		4.07A
	AK-9	1	Can Crusher															Edlund CM-1000SS		4.23
	AK-10		Spare No.																	
	AK-11	2	Speed Rack															CresCor 207-1820		4.14A
**	AK-12	1	Walk-in Freezer					FD					8.7	EO		120	1	Kolpak		4.15
	AK-13	1 Lot	Refrig. Shelving															Metro MetroSeal		4.16
**	AK-14	1	Walk-in Refrigerator					FD					1.0	EO		120	1	Kolpak		4.15
	AK-15	3	Handwash Sink w/soap	1/2"	1/2"	1-1/2"												Eagle HSA-10-FAW	B-2111 Soap	4.30ABCD

Figure 3: Kitchen Equipment Schedule for PS School

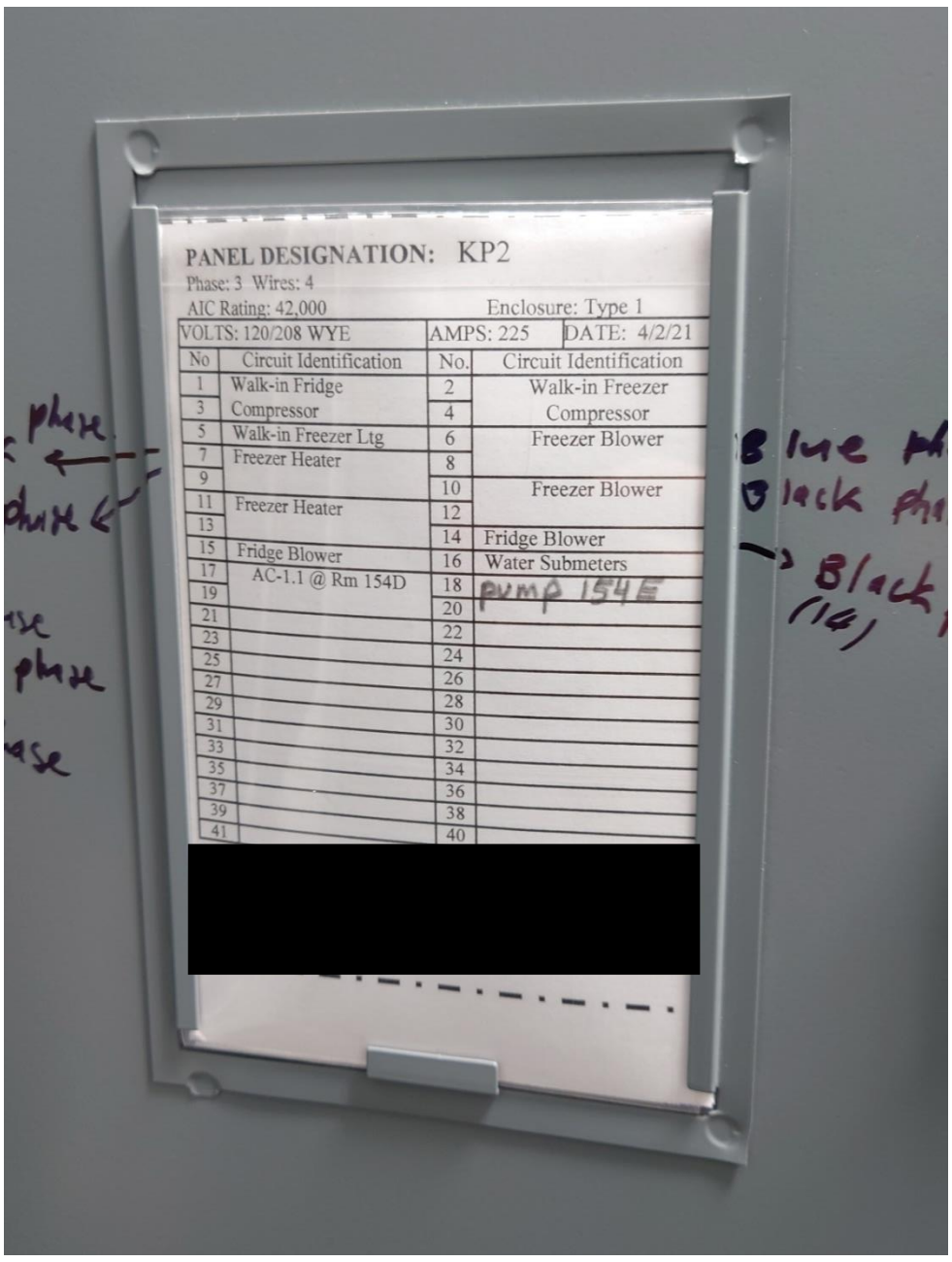

Figure 4: Kitchen Electrical Panel at PS School

3. Data Analysis

The process outlined below was used to calculate the hourly usage schedules that are entered into the Appendix A Calculator and energy model template:

a. Hourly electricity use data is downloaded from the online portal for each piece of equipment being monitored.

b. The meters have been collecting data between 2/22/2023 and 2/21/2024 for PS School and between 2/16/2023 and 2/21/2024 for the High School. Not all of the downloaded data is valid for use. There were periods when the submeters were unable to log information. The invalid data is presented as blank entries. These entries are filtered out and are not used in calculating the hourly usage schedules.

c. Schedules with average values for each hour in a typical day were created. For example, an equipment's energy usage at 4PM on a weekday in May is an average of all of its energy use at 4PM on weekdays in May from the hourly data. Schedule values are calculated by dividing the energy use by the rated power for that equipment. A weekday schedule for May is shown in Figure 5. Operating schedules are created for each piece of equipment and are different between weekdays vs. weekends and holidays.

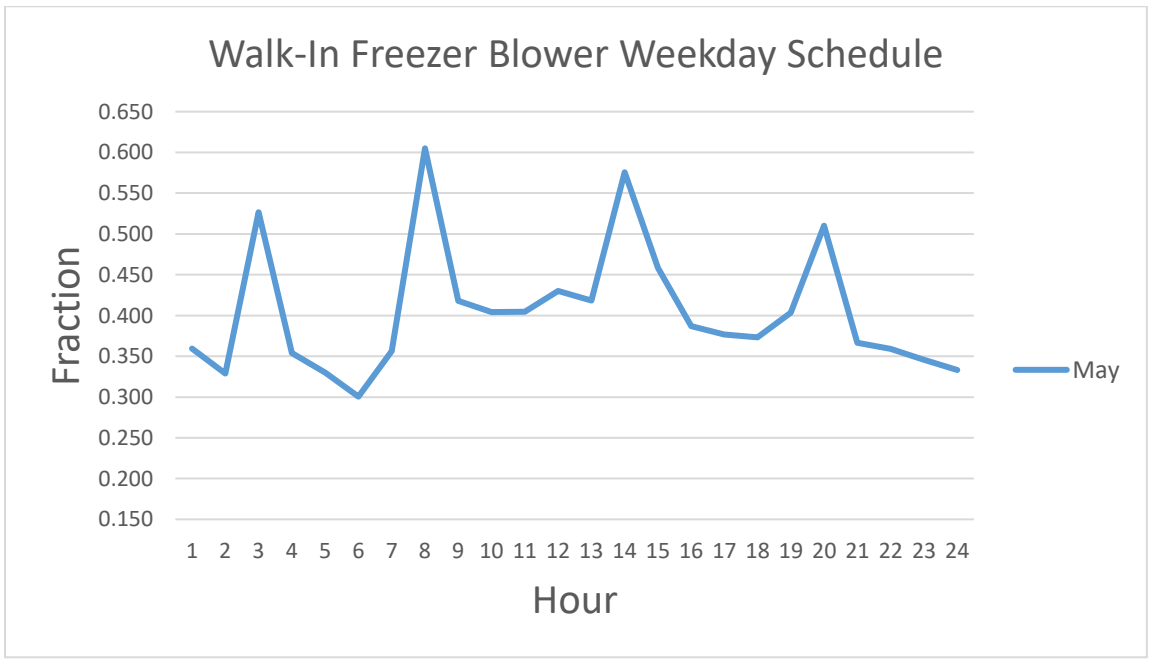

Figure 5: Walk-In Freezer Blower Weekday Schedule in May

d. The operating schedules were examined after calculation to determine if they conform with the expected operating hours. As maintenance staff has performed work on the units at several occasions to remediate equipment faults, the operating patterns are not fully consistent across the entire monitoring interval.

   The weekday schedule for a freezer blower in January and February was compared to the weekday schedules for months March through December in Figure 6. The January and February schedules generally show higher usage and peaks at different hours compared to the schedules for other months. Based on the equipment schedules, the rated power for the freezer blower is 3.85 kW. There are data points that show hourly energy consumption ranging between 3.88 to 5.71 kWh. This is higher than expected based on the rated power for the freezer blower.

   The walk-in refrigeration equipment is expected to operate mostly the same for all months of the year with very slight seasonal variation. This is due to the relatively constant environmental conditions of the kitchen. About 20% of the data for January and February shows energy consumption that is higher than expected. For these reasons, the December schedule for the freezer blower was used for both January and February.

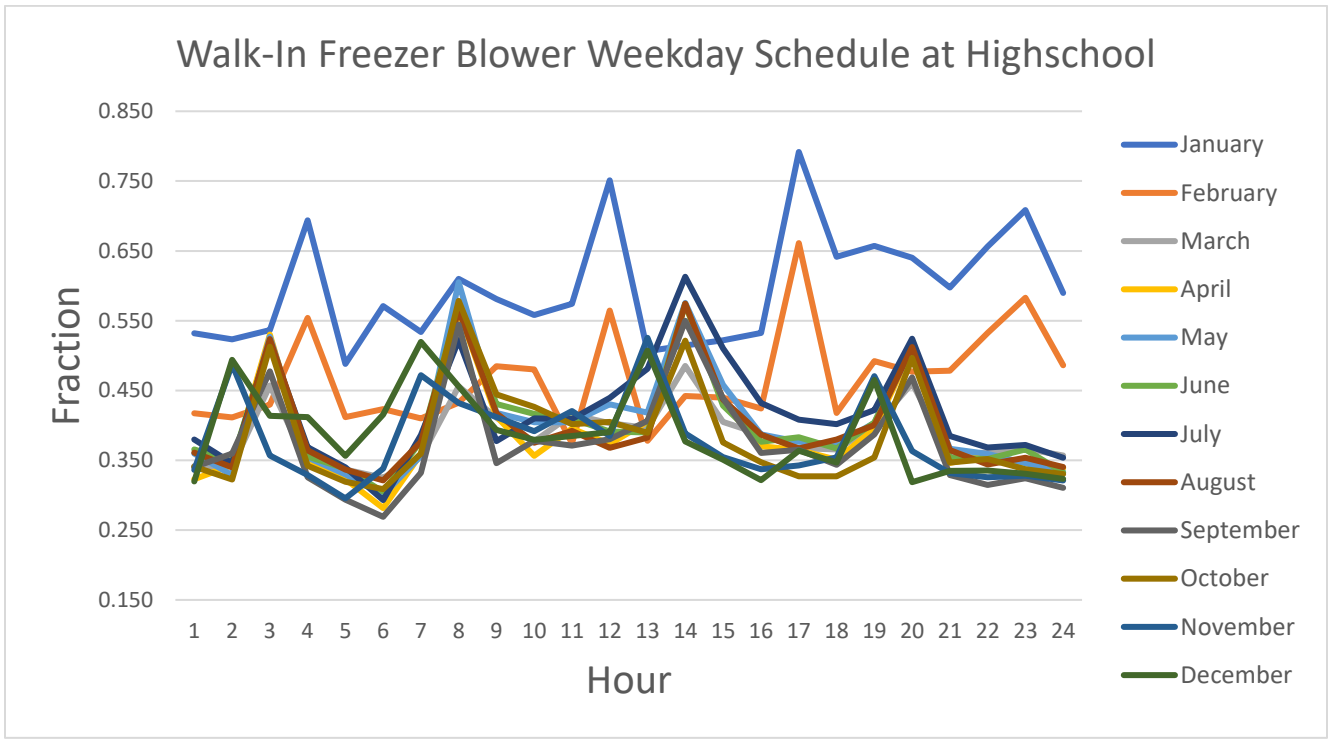

Figure 6: Walk-In Freezer Blower Weekday Schedules for each Month

e. The average weekday schedule were calculated by weighting the hourly load fractions for each month by the number of weekdays in each month. The average weekend/holiday schedule was calculated the same way, except by weighting with the number of weekends and holidays in each month.

4. Proposed Changes to the eQuest Input Summary and Appendix A Calculator

4.1 Schedule Comparisons

Figure 7 through 12 compare the new calculated schedules to the currently used inputs. All of them, except the weekday schedule for the freezer blower, show less runtime. Socotec proposes to apply the new schedules to the Appendix A Calculator. All kitchen walk-in refrigeration equipment will be modeled as a direct load in combination with the KIT-WALKIN-YR schedule.

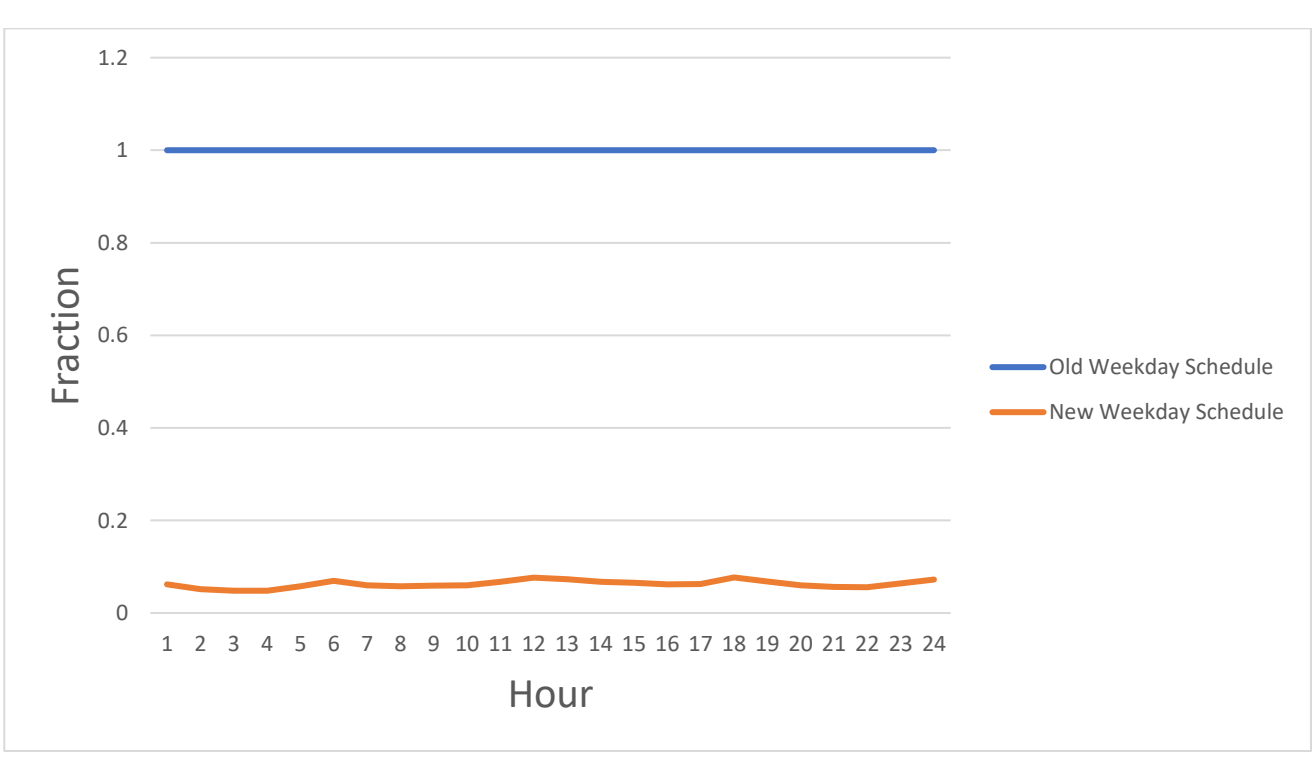

Figure 7: Walk-In Freezer and Fridge Compressors Weekday Schedules

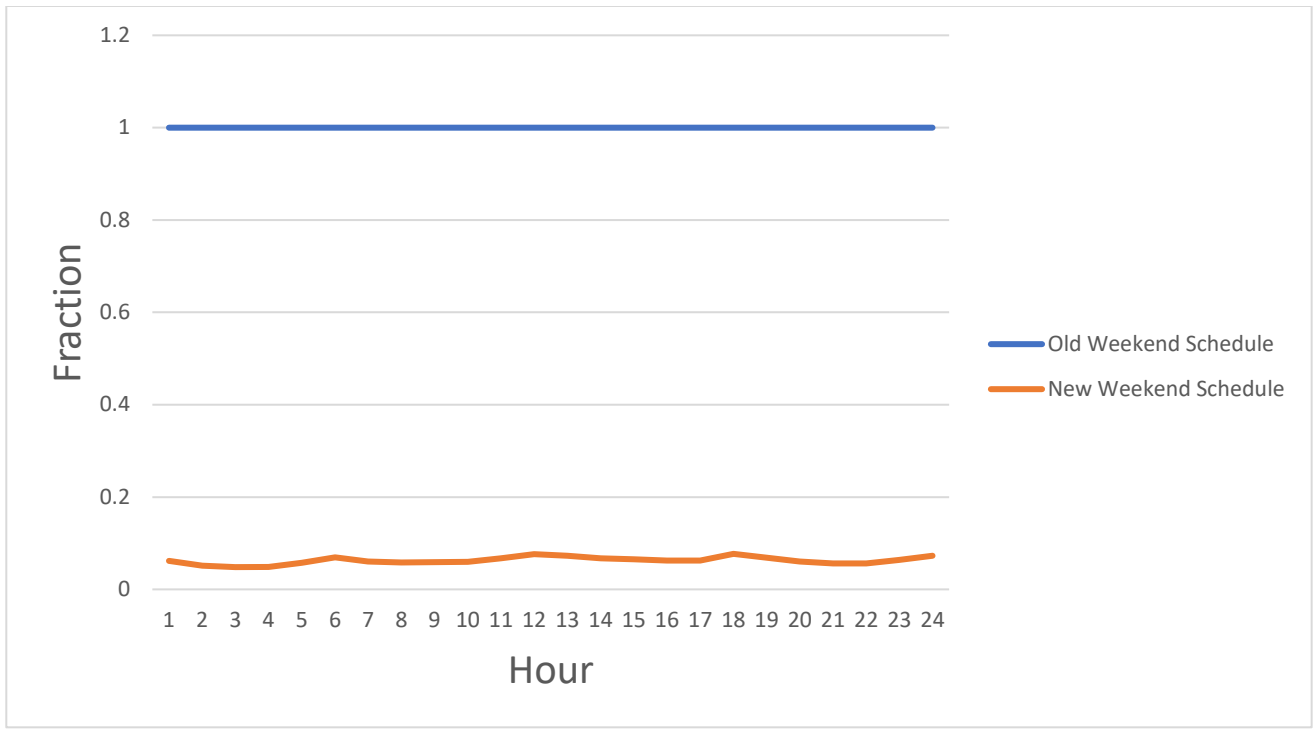

Figure 8: Walk-In Freezer and Fridge Compressors Weekend Schedules

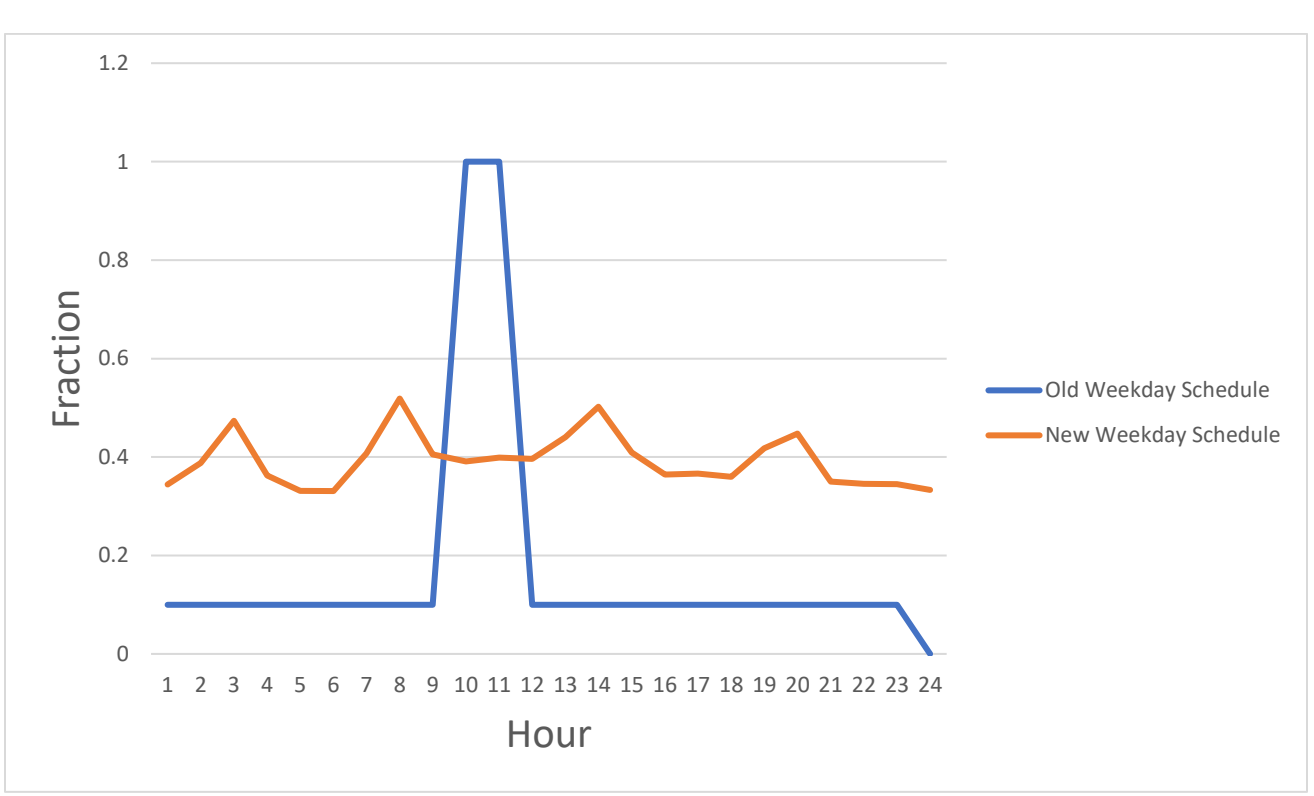

Figure 9: Walk-In Freezer Blower Weekday Schedules

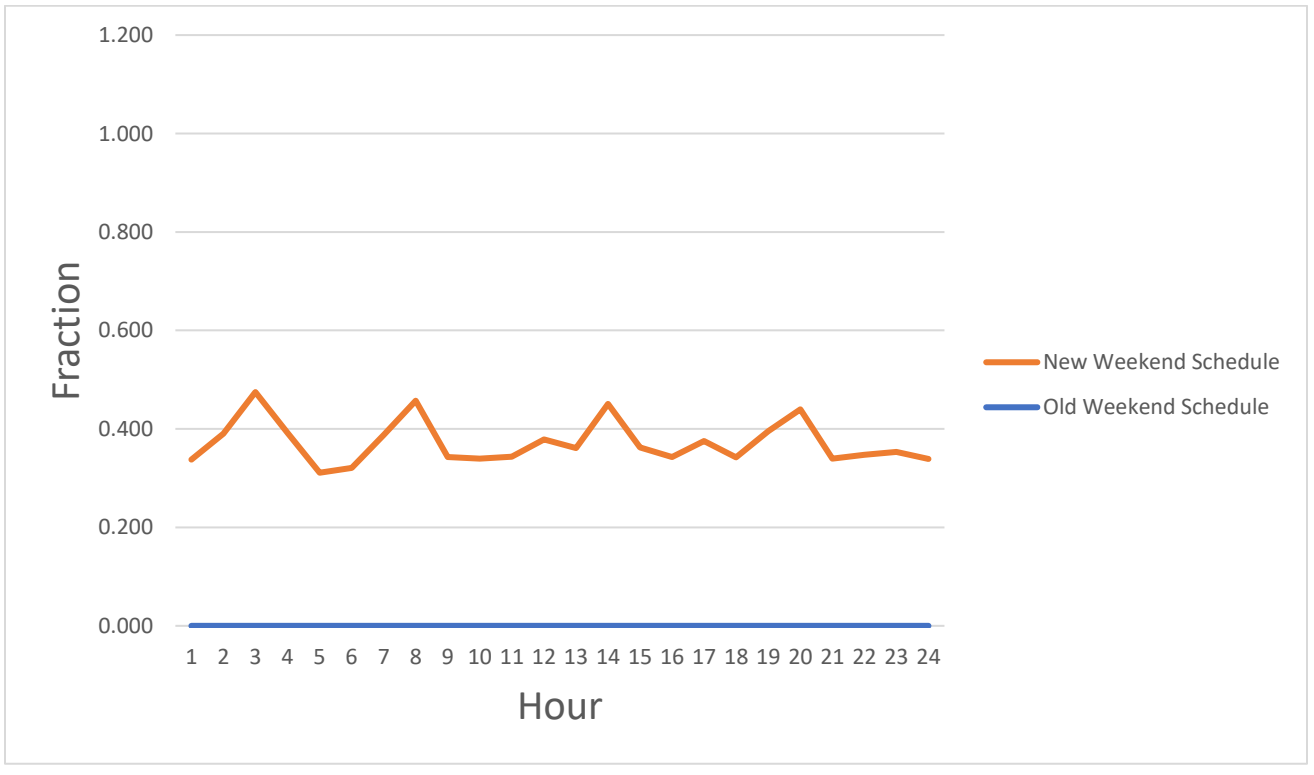

Figure 10: Walk-In Freezer Blower Weekend Schedule

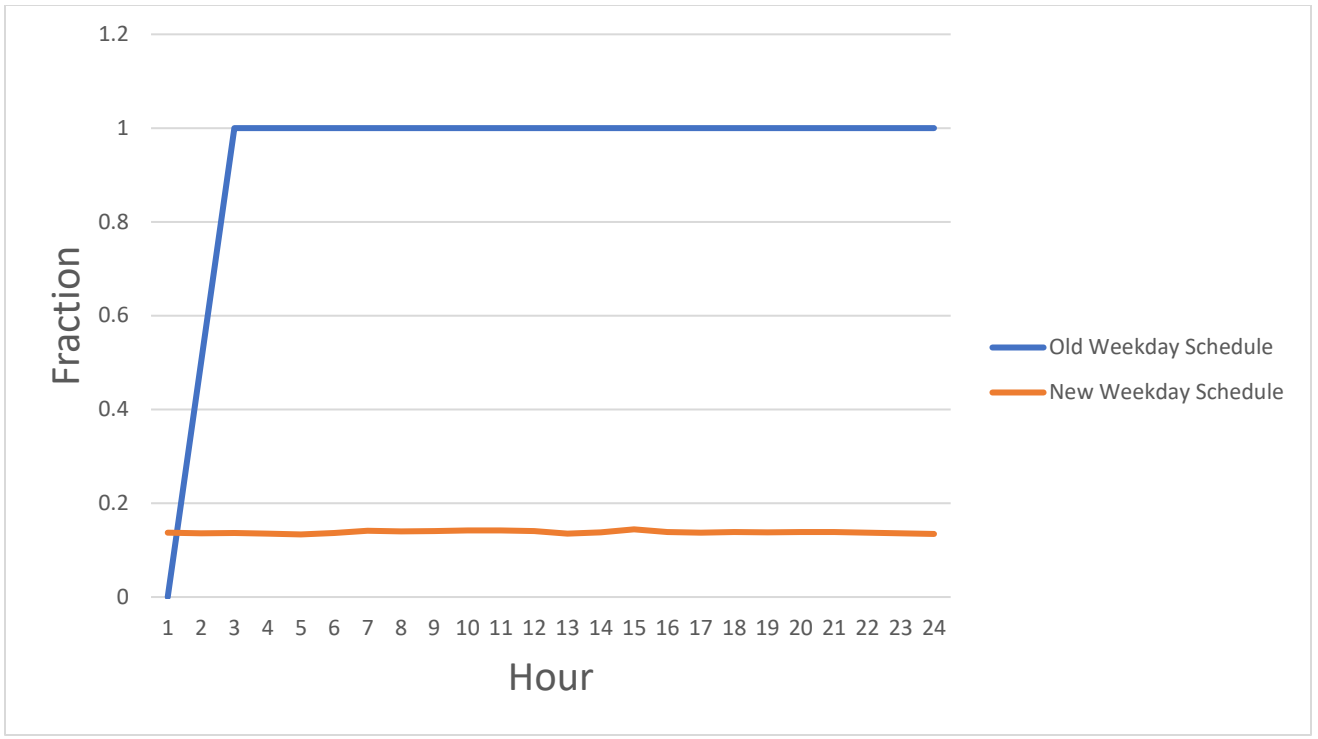

Figure 11: Walk-In Fridge Blower Weekday Schedules

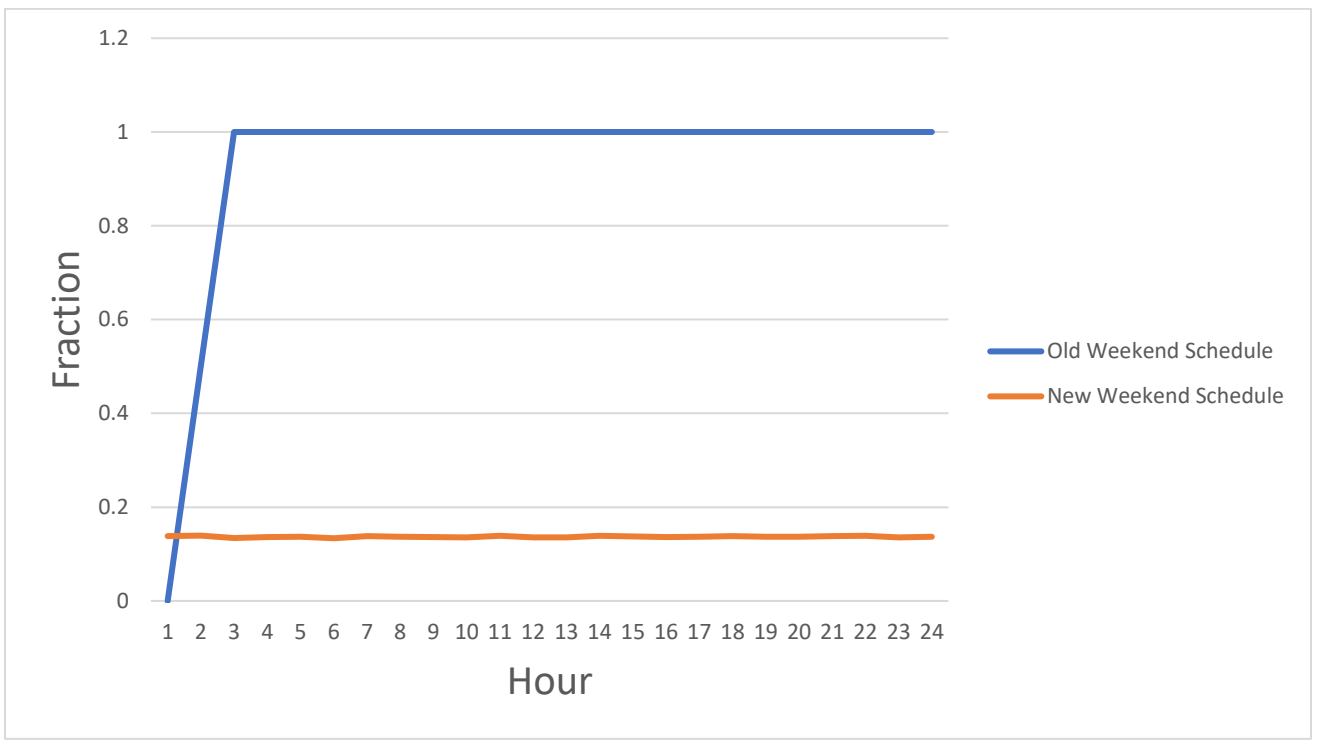

Figure 12: Walk-In Fridge Blower Weekend Schedules

Figure 13 and 14 compare the new schedules to the current inputs for the “Walk-In Freezer (-10F)” and “Walk-In Refrigerator (+35F)” items in the Appendix A Calculator. Those items represent the freezer heater and lighting. The enclosure lighting was not monitored but its behavior has been observed on site, as it is only on when the enclosure door is opened during kitchen operating hours. The December freezer-heater data was used, due to the heater being located entirely within the refrigerated enclosure at a constant temperature. These schedules will be applied to the Appendix A Calculator.

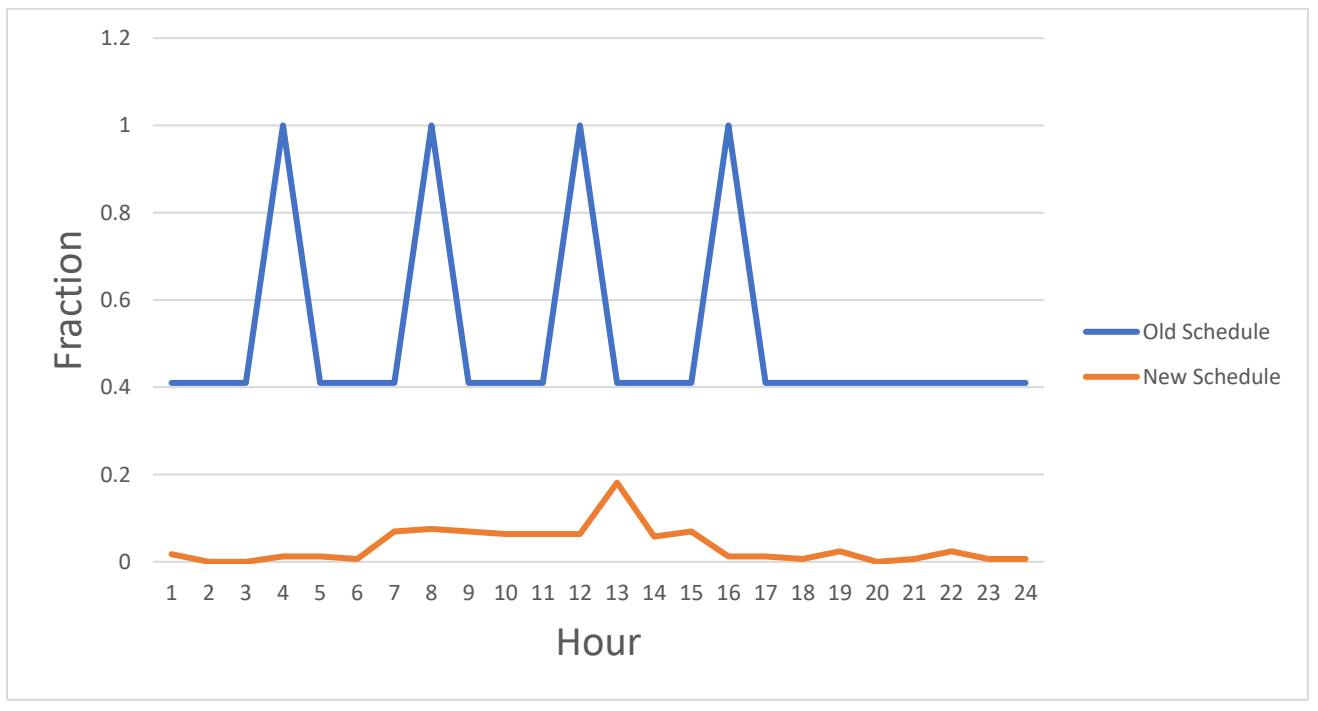

Figure 13: General Walk-In Freezer Schedule

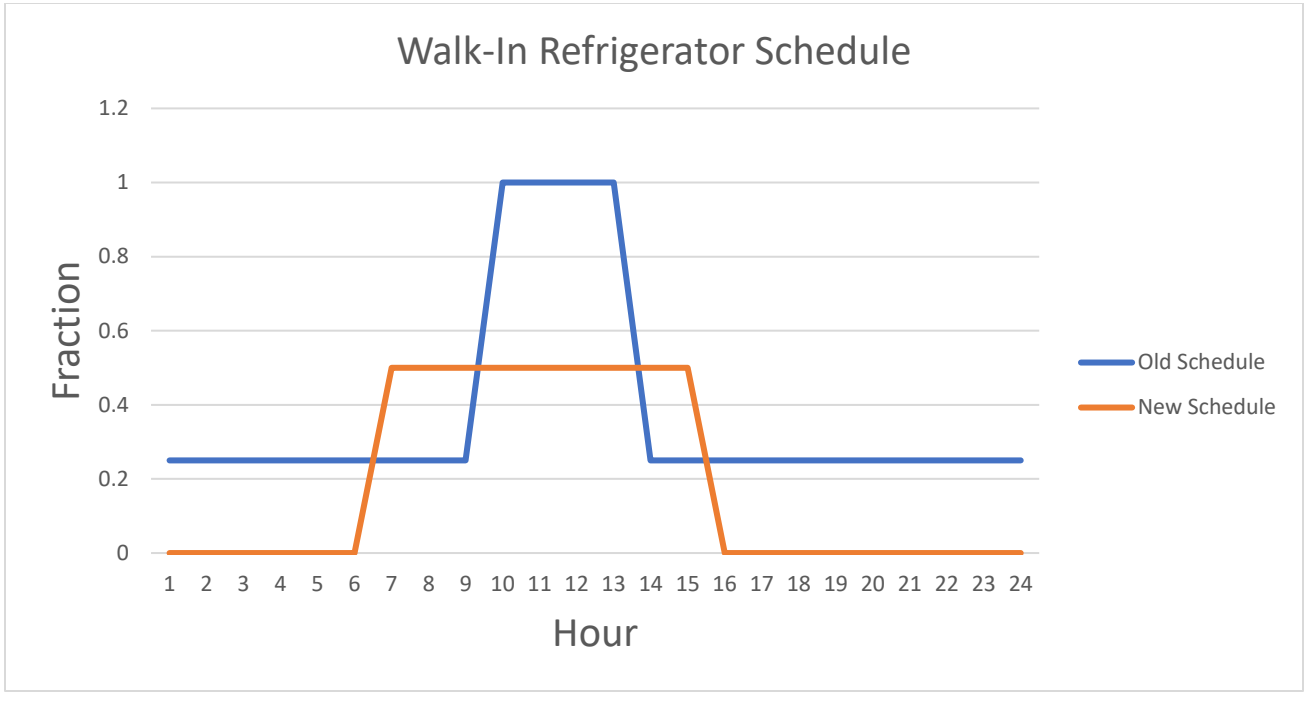

Figure 14: General Walk-In Refrigerator Schedule

5. Reduction in Energy Use Intensity

The proposed operating schedules were tested on five sample school projects to assess their impact on energy usage.

Table 1 shows the energy savings for each school after implementing the schedules. Table 2 shows the decrease in source EUI ranges between 1.7 to 3.4 kBtu/ft^2.

The EUI savings decrease with larger schools. This is because the energy savings do not scale with school size, as the walk-in refrigeration equipment is not directly proportional to the student population. For existing schools the rated power for existing walk-in freezer and refrigerator compressors is higher than that of compressors for a GSG project. This is per the proposed walk-in refrigerator/freezer energy usage for the SCA's *eQuest Modeling Guide for Existing Building Electrification* as shown in Table 3. This results in higher energy savings when applying the new schedules and leads to higher EUI savings compared to newly constructed schools of a similar size.

School	Project Type	Building Area (sqft)	Old Site Energy (MMBtu)	New Site Energy (MMBtu)	Site Energy Savings (MMBtu)	Old Source Energy (MMBtu)	New Source Energy (MMBtu)	Source Energy Savings (MMBtu)
PS School 1	Addition	54026	1464	1393	71	3733	3552	180
PS School 2	GSG Renovation	68931	1776	1706	70	4529	4349	180
IS School 3	GSG New Construction	75238	1688	1622	66	4303	4135	168
PS School 4	GSG New Construction (Natural Gas)	97841	3973	3907	66	6785	6622	163
PS School 5	Electrification	117648	3532	3375	157	9007	8606	401

Table 1: Energy Savings per School

School	Building Area (ft^2)	Old Site EUI (kBtu/sqft)	New Site EUI (kBtu/sqft)	Old Source EUI (kBtu/sqft)	New Source EUI (kBtu/sqft)	EUI Savings (kBtu/sqft)
PS School 1	54,026	27.1	25.8	69.1	65.8	3.3
PS School 2	68,931	25.8	24.7	65.7	63.1	2.6
IS School 3	75,238	22.4	21.6	57.2	55.0	2.2
PS School 4	97,841	40.6	39.9	69.3	67.7	1.7
PS School 5	117,648	30.0	28.7	76.6	73.2	3.4

Table 2: EUI per School

Case	Meter	Load	Schedule	End Use
Existing baseline	KIT-MISC-METER	28.886	KIT-WALK-IN-YR	MISC-EQUIP
Demand defrost only		26.888		
Additional enclosure insulation only		26.946		
Demand defrost + enclosure insulation (same as new GSG unit)		25.004		

Table 3: Walk-In Refrigerator/Freezer Energy Use – Existing Building Baseline