Plug Load Field Monitoring and Replacement Report

Frontier Energy Report # 50181-R0
June 2019

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Food Service Technology Center Background

The information in this report is based on data generated in the field in commercial foodservice facilities by Frontier Energy who operate the Food Service Technology Center (FSTC). Dedicated to the advancement of the foodservice industry, Frontier Energy is the industry leader in commercial kitchen energy and water efficiency and appliance performance testing for 30 years. They have developed over 35 Standard Test Methods for evaluating commercial kitchen appliance and system performance as well as pioneering lab and field research with cooking appliances, kitchen ventilation systems, hot water systems and dishroom equipment.

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Acknowledgments

Frontier Energy appreciates the funding partners that supported this project including Silicon Valley Power and the California Energy Commission. Frontier also would like to thank all the facilities and their foodservice, maintenance, and engineering staff in accommodating us on our on-site visits and correspondences.

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Revision History

Revision Num.	Date	Description	Author(s)
0	Jun 2019	Final Report	M. Slater, E. Ruan, M. Finck

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Executive Summary

Project Overview

Frontier Energy, Inc. monitored plug load equipment for energy use at ten commercial foodservice facilities in the Silicon Valley Power (SVP) service territory in Santa Clara, California. The project objective was to characterize the energy savings potential of countertop cooking, warming, and dispensing equipment such as conveyor toasters, soup warmers, hot food holding cabinets, and coffee brewers, among others. Researchers established "business as usual" energy use profiles for existing equipment then replaced targeted equipment with new, efficient technologies. Silicon Valley Power (SVP) and the California Energy Commission (CEC) were joint funders of this project. This project is an extension of the CEC *Electric Plug Load Savings Potential of Commercial Foodservice Equipment* (EPC 15-027).

Figure 1: Silicon Valley Power and California Energy Commission Logos

Frontier Energy performed energy use monitoring at two corporate cafeterias, three full-service restaurants, two quick-service restaurants, two cafes, and one hotel kitchen. These sites were selected as they represent a diversity of commercial foodservice operations in SVP service territory.

Background

While small, countertop electric equipment can be responsible for a significant energy load in commercial foodservice operations. This equipment often goes overlooked when identifying energy efficiency opportunities within a facility, particularly with respect to facilities that operate heavy-duty cooking or sanitation equipment such as restaurants, cafeterias, or hotel kitchens. New technologies have become available for this equipment that provide operators with greater control over the energy consumption during both non-peak and peak operating times. This study examined several variations of new technologies including smart controls, better insulating materials, advanced heaters, and induction.

One major barrier to adoption for these technologies is initial purchase cost. Even simple and effective energy-saving technologies such as timer controls have had a low rate of market adoption based on the added cost of the equipment. The in-situ field monitoring presented in this report demonstrates a significant energy savings opportunity for select categories with a reasonable return on investment (ROI). Another barrier to adopting new technology is the notion that if conventional equipment already works, any change invites a risk of failure. The replacements carried out through this project all resulted in positive feedback with the only exception being a faulty appliance, a condition unrelated to the energy saving technology.

The three most impactful appliance categories documented in this study are smart conveyor toasters, induction soup warmers, and modular insulated hot-food holding cabinets. Conveyor toasters are an ideal candidate for smart controls as they are typically turned on at the beginning of service and left operating at maximum temperature for the rest of the day, regardless of their need. Smart toaster controls can start a toasting cycle when product is placed on the belt and drop into a low-power mode after a defined period of inactivity. Warming appliances also have long operating hours and offer opportunities for reducing energy use through advanced heating and insulating technology. Induction technology allows more effective heat transfer to hot soup wells and eliminates the need to use hot water as a heating medium. Holding cabinets have heavy use and long operating hours. A modular design allows operators to have greater functional utilization while minimizing energy losses when staff access the cabinet. This saves energy compared to single-cavity holding cabinets of the same total cavity volume.

Results

The energy savings results are summarized in Table 1, including only the baseline data for equipment that was replaced.

Table 1: Summary of Savings Results

Equipment Type	Baseline or Replacement?	Energy Use (kWh/day)	Operating Span (h)	Energy Savings (kWh/day)	Energy Savings (%)
Conveyor Toaster	Baseline	14.45	9.02	-	-
Conveyor Toaster	Replacement	12.40	8.95	1.95	14%
Soup Well	Baseline	0.89	2.73	-	-
Soup Well	Replacement	0.49	3.23	0.40	44%
Holding Cabinet	Baseline	7.71	7.91	-	-
Holding Cabinet	Replacement	3.43	8.22	4.28	56%

The most favorable savings results came from the conveyor toaster replacements. These replacements yielded an average savings around 2 kWh per day. For a site that operates seven days per week, this translates to $110/year in utility savings when using the average national electrical rate of $0.15 per kWh. Due to the relatively small price point difference between conveyor toasters with setback mode capabilities and conventional models ($1220 vs $820 for 120V and $1390 vs $1280 for 208V), the simple payback time on the incremental cost difference is reasonable. The average payback period would be about four years for a 120V toaster and one year for a 208V toaster, assuming similar energy savings for 208V replacements as exhibited by the project’s 120V replacements. An early retirement program could yield significant energy savings in the commercial foodservice market because of the prevalence of conventional uncontrolled conveyor toasters.

Modular insulated hot-food holding cabinets exhibited the most dramatic reduction—56%, or 4.28 kWh per day—of the equipment categories monitored during the study, but also have the largest dollar cost difference between baseline and replacement models. Energy efficient insulated holding cabinet price points all hover around $4,000, while baseline uninsulated clear door cabinets can cost as low as $1,000.

An early retirement incentive should be offered to customers who want to replace glass door units with the two-door insulated full-size units covered in this study.

The induction soup warmer saved 44% of the energy used by its conventional resistance element counterpart. Most sites have multiple soup warmers, soup warmers can add up to comprise a substantial amount of energy use for sites with long operating hours. However, there is a significant price point difference between electric resistance ($227) and induction soup warmers ($588) – induction units on average cost more than double the price of conventional soup warmers. Due to the increased cost and the relative novelty of the technology, a utility rebate would be needed to realize the potential energy savings for this category. Utility support would have the added benefit of bringing down the cost of induction cooking appliances by generating demand, which could help more people adopt induction cooktops and ranges.

Recommendations

The study demonstrated a high energy savings potential for plug load equipment in commercial foodservice. California utilities can realize these savings by sponsoring rebate and replacement programs aimed at driving market change. The substantial energy savings for hot-food holding cabinets and conveyor toasters justify early retirement programs. Point-of-purchase programs should be considered for induction soup wells. All advanced technologies in this study have been shown to be low-risk options for energy saving programs.

Abstract

Plug loads in commercial foodservice applications are often overlooked pieces of equipment. It has been shown in previous studies that they can consume significant amounts of energy, especially in self-serve cafeteria-type operating scenarios that depend heavily on their use. Because of the low cost and relatively low input rate of this class of equipment, conventional models often lack control technologies, so they consume energy during all hours of operation.

This project documents the baseline energy usage of all plug load equipment found in 10 commercial foodservice sites throughout the Silicon Valley Power service territory. The baseline data was used to identify appropriate replacement strategies to achieve energy savings. The replacement equipment was monitored and the energy savings were documented.

Keywords: Plug load, commercial kitchens, cafeteria, food service, restaurant, energy savings, holding cabinet, cook and hold, induction, soup warmer, rice cooker, holding shelf, toaster, conveyor toaster

Introduction

The role of Frontier Energy as operators of The Food Service Technology Center (FSTC) is to support and educate the foodservice industry to utilize best-available technologies and operating practices to improve performance and productivity while reducing energy use. The ongoing mission is to use nearly forty years of laboratory and field experience to disseminate the latest energy-saving strategies to commercial foodservice operators. This research project characterizes the energy use of plug-load equipment, defined as smaller electrical loads that run auxiliary to the main cooking equipment. These pieces of equipment typically run on 120V service, as opposed to heavy-duty cooking and ventilation equipment, which typically run on 208/240V or 480V service. This study goes further to differentiate between conventional and efficient equipment and to quantify the savings potential associated with efficiency. Refrigeration equipment was excluded in this study. This project was made possible by funds from Silicon Valley Power (SVP) and the California Energy Commission (CEC).

Background

The purpose of the Food Service Technology Center (FSTC) as run by Frontier Energy researchers is to recognize energy efficient technologies germane to the commercial foodservice (CFS) industry. Through significant laboratory and field testing, the FSTC has produced over 40 individual test methods for the energy benchmarking of major kitchen appliances. This includes the main cooking equipment such as steamers, ovens, fryers, and griddles; sanitation equipment such as dishmachines and pre-rinse spray valves; and HVAC equipment such as ventilation hoods and ventilation control strategies. This lab research has been corroborated and refined through field testing, and this body of research is widely accepted in the industry, notably used by the US EPA for their ENERGY STAR® program and by many US energy utilities for rebate and replacement programs. In recent projects, Frontier Energy researchers have realized the need to focus on plug load equipment as a continuation of the existing body of research due to a lack of publicly available literature as well as multiple emerging technologies that promise significant potential energy savings.

Plug load equipment is largely overlooked in energy efficiency discussions. The maximum power draw of these appliances is substantially lower than some major pieces of cooking equipment. On an equipment schedule or a building schematic, the 23 kW combination oven totally overshadows a 1 kW soup well. At a site survey, the room-sized flight-type conveyor dishmachine steals attention from the breadbox-sized conveyor toaster. It becomes less of a priority for the equipment selector or business owner to research and choose efficient plug load equipment. This oversight is inconvenient for the foodservice operator because while plug load input rates are small, their operating hours can easily span the full hours of operation of a foodservice facility. In some operations, plug load energy use can be as high as the electrical energy use from the main cookline because the amount of time these cooking appliances spend at their maximum power draw is substantially less than the plug load equipment. Additionally, some operations, especially cafeteria and employee cantina-style operations, depend on a multitude of plug loads, but only a handful of major cooking and rethermalizing appliances.

CFS facilities are the most energy intensive building types in the commercial sector, and there are an estimated 93,300 CFS facilities in California alone. Almost all those facilities have at least one piece of plug load equipment. Previous efforts to drive market change by promoting energy efficient technologies have experienced issues with a highly frugal industry slow to adopt change. This is largely due to the relatively high cost of new pieces of major CFS equipment and the relatively higher cost of efficient options. The potential for widespread market change is higher with plug load technologies because they have much smaller first costs than heavy-duty equipment. The incremental cost difference for efficient options is also cheaper for plug loads. For this reason, this new body of research will be used to accelerate the adoption of advanced energy efficient cooking equipment in this equipment category.

Technology Descriptions

The pieces of equipment considered in this study are conveyor toasters, soup warmers, rice cookers, holding cabinets, cook and holds ovens, rapid cook ovens, and beverage equipment such as coffee brewers and espresso machines. Figure 2 shows examples of these pieces of equipment.

Figure 2: (Left to Right) Conveyor toaster, soup warmer, holding cabinet, cook and hold oven, and rapid cook oven

The energy efficient options considered in this project were: setback modes for conveyor toasters, induction soup wells, holding cabinets with better insulation, multiple compartments and better door seals, energy efficient cook and hold ovens, and offsetting the energy use of countertop griddles and panini presses by using rapid cook ovens and toasters. Some of these technologies are essentially scaled-down versions of things that already exist for larger pieces of equipment (for example, setback modes have existed in steamers since the early 2000's), but induction cooking is only recently gaining momentum in the market.

For the purposes of this report, it's also necessary to describe how induction cooking works. Induction is dependent on passing a current through a copper coil. This produces a magnetic field, which transfers energy to ferromagnetic metals, which causes them to heat up. Figure 3 is a schematic describing how an induction cooktop works.

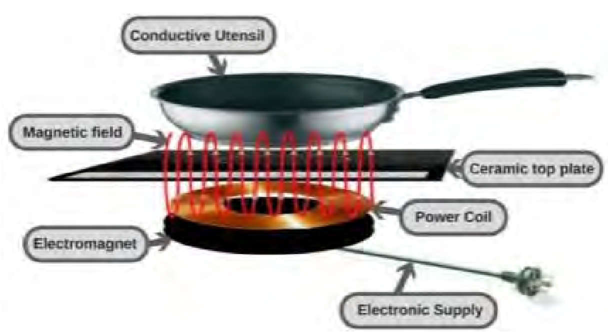

Figure 3: Induction Heat Transfer Schematic

Induction soup warmers work in virtually the same way as induction cooktops, but they have the power coil surrounding the warming vessel and cylinder-shaped ferromagnetic pots as opposed to flat surfaces.

Operating Issues

Similar to the design issues, it's easy for CFS staff to overlook the operation of plug load equipment. Previous monitoring has shown that some pieces of equipment get left running overnight or are left on when not in use. Part of this issue is that conventional plug load equipment doesn't have appropriate control strategies and is heavily dependent on operator input. Another complication is that some plug load equipment in cafeteria environments, especially soup warmers and toasters, are customer-facing, so it is difficult for staff to address any operating issues during meal periods. The staff responsible for maintaining the front of house equipment may also be called to more pressing tasks in the back-of-house, so it's easy to imagine a scenario where the front-of-house equipment gets neglected.

Project Description

The goal of this project was to evaluate and characterize plug load equipment in various operating scenarios to develop an accurate energy use estimate for both conventional and energy-efficient equipment. This information could be used to help energy utilities estimate the savings potential and payback of various replacement programs.

Objective and Scope

The project scope was to select field-testing sites, install instrumentation to monitor and document the baseline plug load energy use, use the baseline data to justify an appropriate replacement, monitor the replacement equipment's energy use, and document energy savings.

Methodology

Ten foodservice facilities were selected for plug load appliance monitoring. Energy monitoring was conducted on individual baseline appliances for a period of at least two weeks or when the energy use was stable and repeatable. Metering packages used for appliance monitoring varied depending on the setup and needs of the facility. Instrumentation packages fell under two main categorizations: in-line and in-panel metering.

For in-line metering, the electrical meter was placed between the electrical source and the appliance, generally tucked somewhere out of sight. The metering instrument most frequently used was the Onset UX120-018 HOBO Plug Load Logger, rated to handle 120V/15A loads. The logger is UL-certified with a 0.5% measurement accuracy and a measurement resolution of 0.00001 Wh, which was programmed to log, process, and store cumulative electrical consumption at 30-second intervals. For appliances with a higher voltage or amperage, a custom metering package was built using a CCS Wattnode Pulse electric meter in either a "Y" or "Delta" configuration with an Onset HOBO Pulse data logger and appropriately sized current transformers (20A or 50A). These electric energy meters had a resolution of 0.5 to 1.25 Wh depending on the size of current transformers used and recorded energy consumption in 30-second intervals.

For in-panel metering, energy metering setups were placed inside the breaker panel to monitor appliances that were either hardwired or in spaces that were too tight or inconvenient to place an in-line meter. These setups consisted of appropriately-sized current transformers paired with either a

DENT ELITEpro Energy Meter Data Logger or a CCS Wattnode Pulse Meter and Onset HOBO Pulse Logger combo. Both featured 0.5% measurement accuracy with a resolution minimum of 1.25 Wh.

Figure 4: Onset Hobo UX120-08 Plug Load Logger Metering Setup

Figure 5: Custom In-Panel 208V Electric

Figure 6: In-Panel Metering with CSS Wattnode

Figure 7: Current Transducer

Energy data from these loggers was collected on a biweekly or monthly basis. Appliance operation hours were determined by calculating an hourly input rate using a five-minute moving average. After reviewing the electrical usage profiles of all appliances, times with input rates higher than the input rates during periods of restaurant non-operation were considered hours that the appliance was operated. When researchers performed replacements, the metering equipment was left in place for an additional monitoring period of at least two weeks to monitor the energy usage of the new appliance. The energy savings were calculated by subtracting the replacement energy usage from the baseline energy usage. Where appropriate, data was also normalized to the facility's hours of operation for a more fair comparison.

Results

1. Site A – Corporate Cafeteria

Site Description

Site A's Signature Building is one of the company's main conference centers in the South Bay. Its cafeteria serves a full campus of office buildings as well as visitor traffic from the company's museum and serves breakfast and lunch five days a week. This kitchen serves an average of 5,500 meals per day with a wide array of cuisines and a menu varying in styles throughout the week.

Baseline Monitoring Results

For the baseline phase, many pieces of equipment were monitored including three CresCor H135SUA11 holding cabinets, two Electrolux panini presses with microwave heating, an Unox/Cadco standard panini press, a Hatco TQ-10 Conveyor toaster, two heated pizza shelves, and a rice bowl heated shelf. Table 2 lists the average energy use on days when the appliance was used and the average daily operating time when the heating element was on. Figures 9 through 13 show some of the baseline appliances.

It was found that none of the appliances were used on the weekends, which indicates that this site has a significantly reduced menu on Saturdays and Sundays. For annual usage and savings calculations, it is assumed that the site operates these appliances 250 days per year. The daily energy use listed in Table 2 reflects the average weekday energy consumption.

Table 2: Site A Baseline Monitoring Results

Equipment	Energy Use (kWh/day)	Operating Span (h)
Hatco TQ-10 Conveyor Toaster	13.56	8.53
Popup Toaster	0.86	1.73
Crescor H135SUA11 Holding Cabinet (Front Left)	8.24	8.96
Crescor H135SUA11 Holding Cabinet (Front Right)	10.34	7.83
Crescor H135SUA11 Holding Cabinet (Center)	10.07	7.73
Rice Bowl Heated Shelf	4.35	7.96
Pizza Heated Shelf #1	4.21	8.32
Pizza Heated Shelf #2	2.20	4.48
Electrolux Panini Press (Right)	3.11	4.18
Electrolux Panini Press (Left)	1.43	4.05
UNOX Panini Press	1.01	2.94

Figure 8: Two Heated Shelves with Pizza Stones and Overhead Heat Lamps

Figure 9: Rice Bowl Heated Shelf

The cafeteria had three self-serve heated shelves that were heated underneath by 500-600W resistance elements. The pizza heated sheves were covered with pizza stones to more evenly distribute the holding temperature underneath and had heat strips overhead to keep the cheese warm. One of the pizza shelves was left on for longer during the day using twice as much energy as the other one. The third heated shelf was used to keep prepared rice bowls warm, which were lidded and did not require any overhead heating.

Figure 10: Popup Toaster

Figure 11: Standard Panini Press

Figure 12: Panini Press with Microwave

Given its large scale of operations, the cafeteria also had numerous types of toasters. The self-serve pop-up toaster used the least energy (< 1 kWh per day) since there are no idle energy losses – the heating elements only turn on when the switch is pushed down and the appliance is actively toasting. The standard panini press, also at the self-serve counter, was used rather sparingly, but consumed about 1 kWh/day across its three hours of operation. The most actively used panini presses were at the sandwich station, where staff would create and toast sandwiches to order. These were advanced panini presses with microwave heat, which were operated for 4 hours per day and used 1.5 to 3 kWh per day with the right press being used most frequently. These toasters all used significantly less energy than the conveyor toaster described below.

Figure 13 shows the baseline conveyor toaster. Its associated usage pattern is shown in Figure 14. From the usage pattern, this appliance gets turned on at the beginning of the operating day and is left running at its full input rate until staff shuts the unit off at the end of operation.

Figure 13: Site A Baseline Hatco TQ-10 Conveyor Toaster

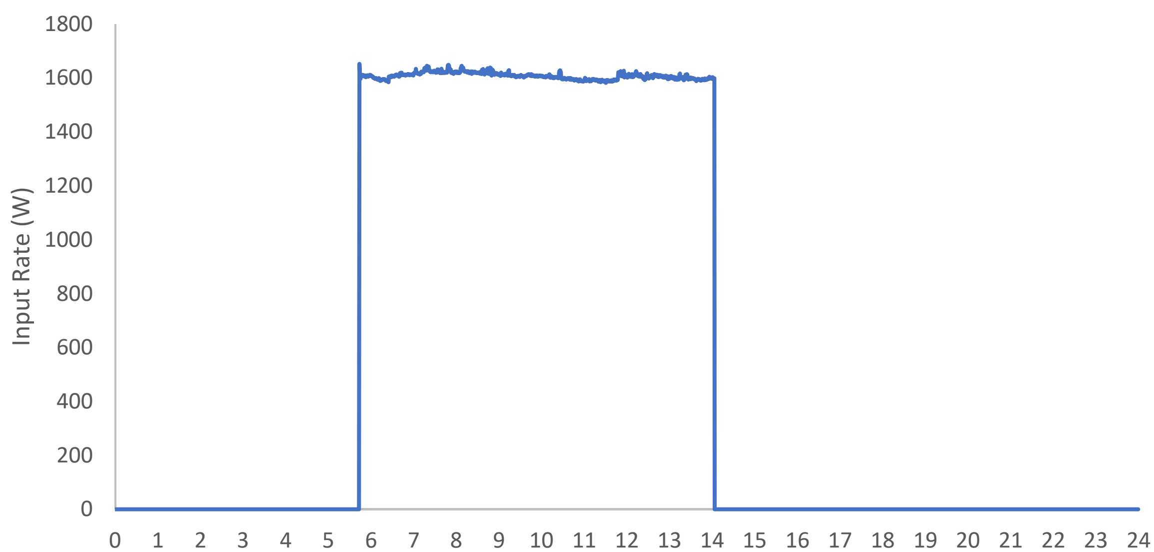

Figure 14: Site A Baseline Conveyor Toaster Usage Pattern

Replacement Monitoring Results and Savings

The only pieces of equipment replaced at this site were the conveyor toaster and one of the holding cabinets. The existing Hatco unit was replaced with a Hatco TQ3-400 and the front left Crescor holding cabinet was replaced with a Cambro PCUHH.

The replacement toaster saved an average of 2.60 kWh per day after its "out-of-the-box" settings were adjusted. This toaster has a setback mode where it can use a fraction of its energy after a user-defined number of minutes of inactivity. The factory settings default threshold setback occurs after 30 minutes of inactivity, but higher savings were realized at an adjusted 10-minute threshold. This unit was customer-facing, located in the front-of-house. The site did not receive any negative feedback about the new toaster even after the setback threshold change. This indicates that the setback mode does not impose any noticeable disturbances to the site. Figure 16 shows the usage pattern for the replacement toaster.

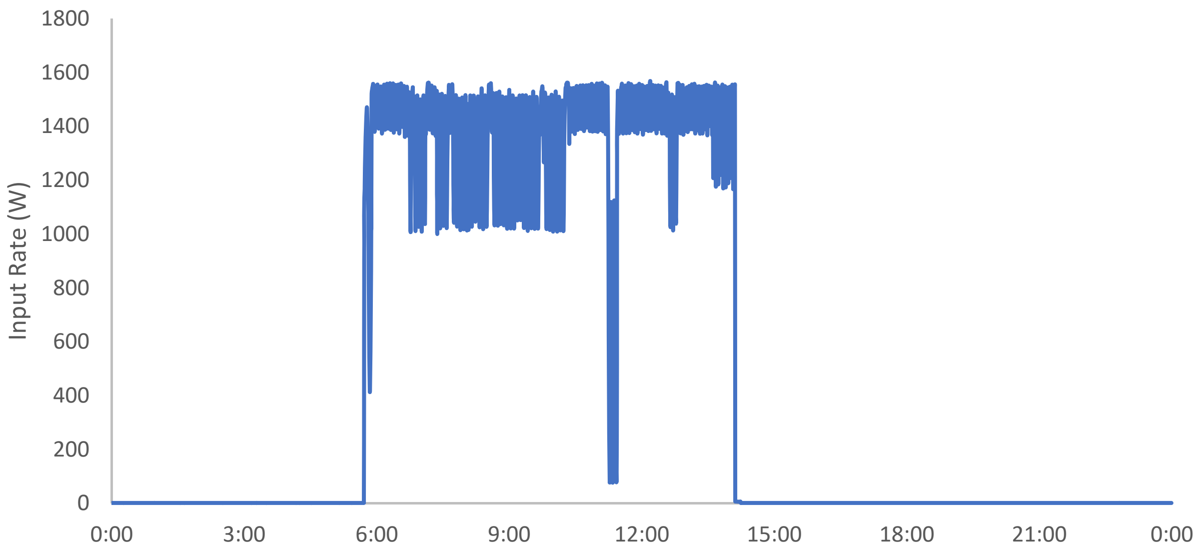

Figure 15: Site A Replacement Conveyor Toaster Usage Pattern

Figure 16: Site A Replacement Conveyor Toaster

The replacement toaster (Figure 16) had similar operating hours and peak input rate as the baseline toaster. The replacement toaster operated between 1,550 and 1,000 Watts, indicating an activation of the toaster's setback mode. Setback mode can be seen from the dips in the input rate throughout the day, which allows it to save energy. The energy savings results are listed in Table 3. The holding cabinet replacement resulted in only 4.31 kWh energy consumption per day for both compartments, a significant reduction compared to the baseline cabinet that used 8.24 kWh/day.

The replacement holding cabinet saved an average 3.93 kWh per day in comparison to the baseline unit, a 48% reduction in electrical energy use. These savings are due in part to the polyurethane foam insulation throughout the unit, which lowered the idle energy rate required to maintain the same holding temperature as the baseline holding cabinet. The replacement cabinet also features separate controls for the upper and lower compartments, allowing for more precise heating and temperature control. This active temperature control is reflected in the increased modulation in the replacement holding cabinet's input rate (Figure 20) as compared to the baseline holding cabinet's input rate (Figure 19), reducing energy usage whenever possible.

Figure 17: Baseline Holding Cabinet

Figure 18: Replacement Holding Cabinet

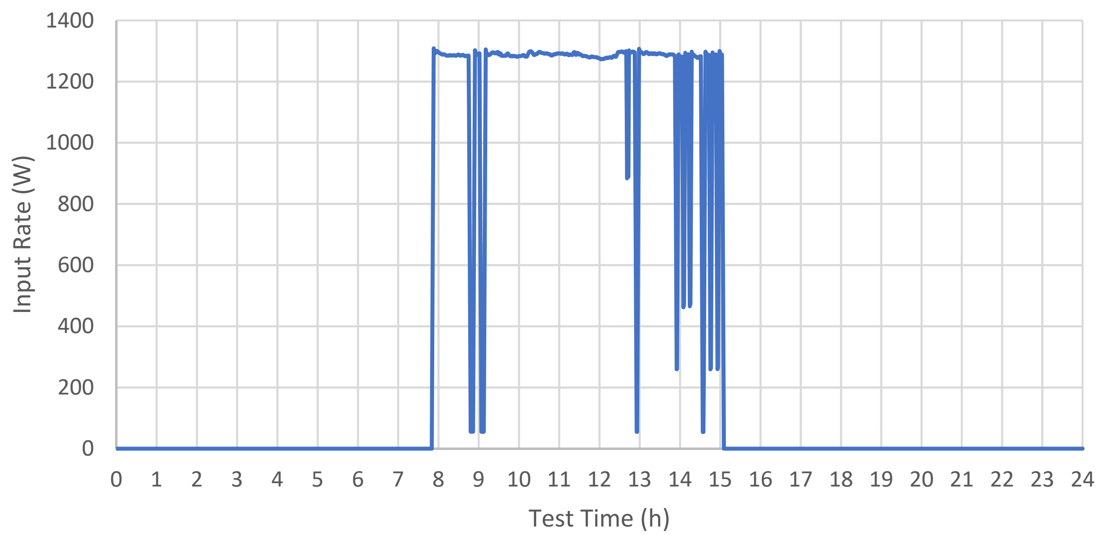

Figure 19: Site A Baseline Holding Cabinet Energy Usage Pattern

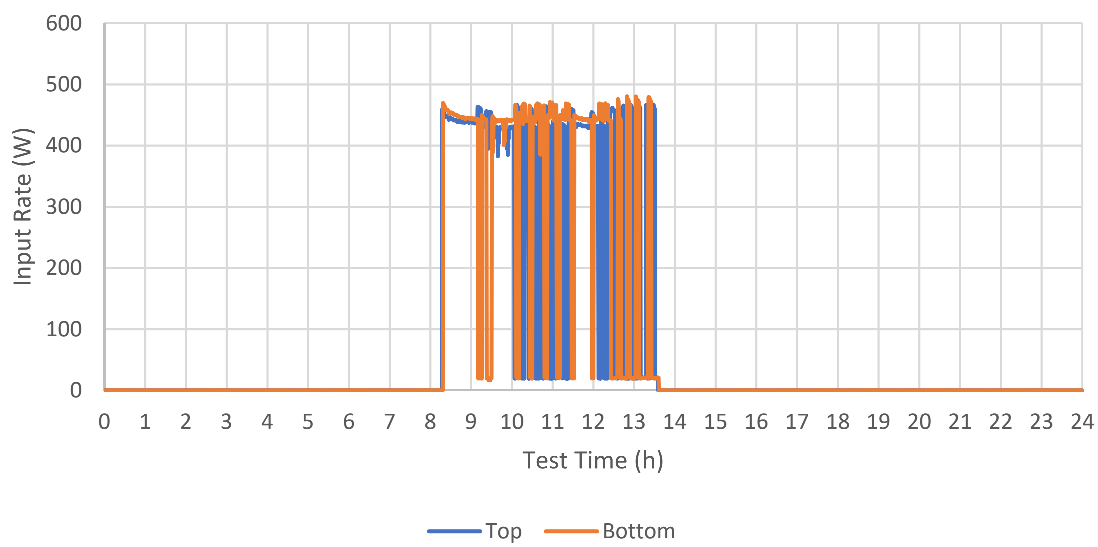

Figure 20: Site A Replacement Holding Cabinet Energy Usage Pattern

Table 3: Site A Toaster and Holding Cabinet Replacement Energy Savings

Equipment	Energy (kWh/day)	Operating Span (h)
(Baseline) Hatco TQ-10	13.56	8.53
(Replacement) Hatco TQ3-400	10.96	8.08
Savings	*2.60*	
(Baseline) Crescor H135SUA11	8.24	8.96
(Replacement) Cambro Pro Cart Ultra (PCUHH)	4.31	8.34
Savings	*3.93*	

Lessons Learned

A 19% energy savings of 2.60 kWh per day translates to a monetary savings of $98 per year when using the average national electrical rate of $0.15 per kWh. The retail price of a TQ3-400 is $1,200, whereas the retail price of a Hatco TQ-10 is $750. The ROI on the incremental cost difference for these units is about 4.5 years. The setback mode saves a substantial amount of energy and can make financial sense, even with the higher first cost.

The holding cabinet replacement saved 3.93 kWh per day, translating to $147 of energy savings per year. The Cambro PCUHH retails for about $4K while the original Cres Cor H135SUA11 retails for about $2.8k, so the payback period for replacement at this site would be about 8 years. This payback period would be too large for most operators to initiate the change, but sites that also have a dinner service or operate on the weekends would experience noticeably shorter payback periods. The holding cabinet saves more energy than the conveyor toaster, but the higher appliance cost makes the replacement not as financially appealing.

2. Site B – Corporate Cafeteria

Site Description

Site B is a manufacturing and engineering facility featuring an employee cantina that serves breakfast and lunch Monday through Friday. Though similar to Site A in function and market sector, Site B has a much smaller footprint and serves less meals due to lower employee foot traffic. The menu varies styles throughout the week.

Baseline Monitoring Results

For the baseline phase, a Hatco heat strip, a Hatco Glo-Ray heated shelf, a Hatco GRN4-66 heat lamp, a Wittco 1000-1S Cook and Hold, a Cadco CPG-10F panini press, a Vollrath Mirage Cadet induction hotplate, and a Turbochef i5 rapid cook oven were monitored. The baseline monitoring results are tabulated in Table 4.

Table 4: Site B Baseline Monitoring Results

Equipment	Energy Use (kWh/day)	Operating Span (h)
Hatco GRN4L-66 Heat Strip	1.42	9.08
Hatco Glo-Ray Heated Shelf	5.39	8.96
Hatco GRN4-66 Heat Lamp	2.18	9.00
Vollrath Mirage Cadet Induction Cooktop	4.50	8.95
Wittco 1000-1S Cook and Hold	8.09	9.69
Cadco CPG-10F Panini Press	2.01	2.51
Turbochef i5 Rapid Cook Oven	18.04	10

The heat strip exhibited the lowest energy usage, averaging only 150 W despite a nameplate input rate of 1,200 W. Unlike the typical heat strip that only turns on and off, the monitored heat strip featured halogen lamp technology, allowing fine adjustments to the heat to match operational needs. The heated shelf averaged 600 W which is consistent with the other two heated shelves at Site A. The panini press was operated for only two hours per day, which limited the unit's daily energy consumption.

Figure 21: Heated Shelf Turned to Maximum Setting

The largest energy users at this site were the Turbochef rapid cook oven and the cook and hold oven. The rapid cook oven operated at a 500-600°F cavity temperature resulting in high energy usage; FSTC lab testing showed 1.8 kW idle rate and 5.8 kW cooking rate for a similar model. The cook and hold usually operates at lower temperatures (< 200°F), however, has higher operating hours with protein cook cycles exceeding 6 hours. Figure 22 shows the rapid cook oven on top of the cook and hold, and Figure 23 shows a typical daily operating profile for the cook and hold.

Figure 22: Site B Winco Cook and Hold and Turbochef i5 Rapid Cook Oven

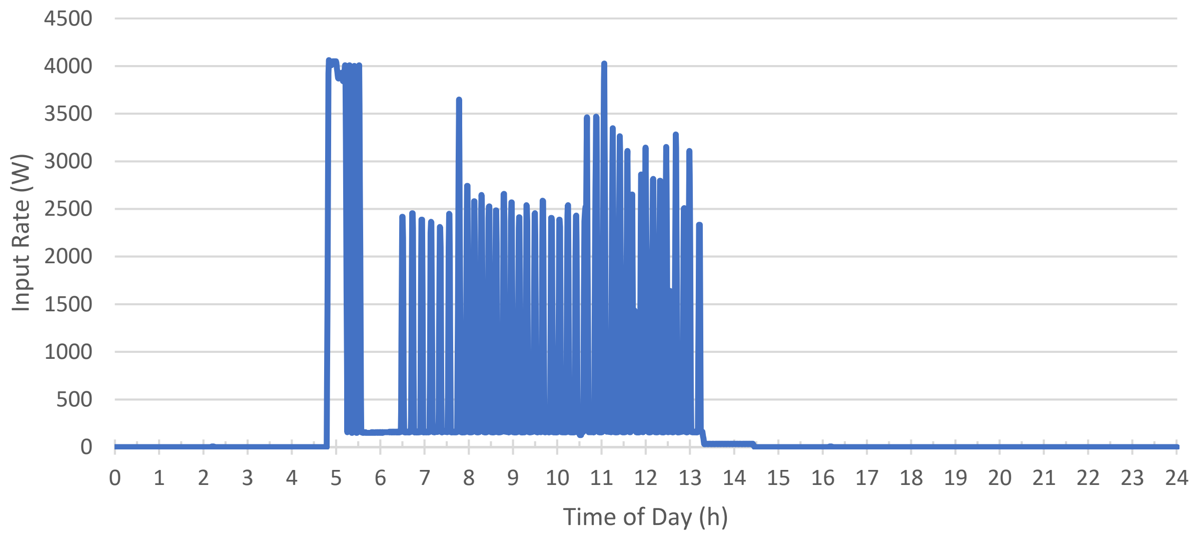

Figure 23: Site B Baseline Cook and Hold Typical Daily Energy Profile

Replacement Monitoring Results and Savings

For the replacement phase, the Wittco cook and hold oven was replaced with a Cres Cor CO-151-HUA-6DX. This has a total input rate of 4.7 kW including its convection heater and fan. It also has digital temperature controls that allow the operator to easily control the cooking parameters and therefore the energy use of the unit. Although the maximum input was over 4 kW, the baseline unit averaged less than 1 kW during its cooking and holding cycle which was on average 10 hours per day as seen in Figure 25. The energy profile for replacement cook and hold very closely mirrored that of the baseline, meaning it operated very similarly and did not modify user behavior. Thus, the replacement cook and hold had a similar energy usage of 8.5 kWh per day and did not save any energy over the baseline.

Figure 24: Site B Replacement Cook and Hold Oven

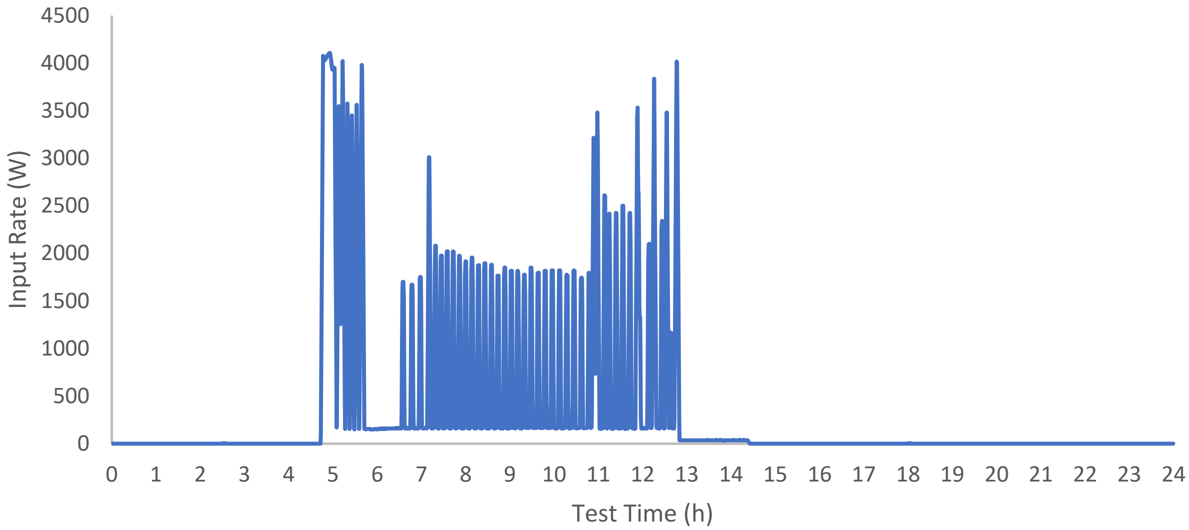

Figure 25: Site B Replacement Cook and Hold Typical Daily Energy Profile

Lessons Learned

Site B was the only instance of a cook and hold oven replacement in this project. Through this replacement, researchers found that higher- and lower-end cook and hold ovens do not have any significant differences in energy use. Unlike other plug load appliances, the technology has yet to stratify into meaningfully different tiers, though some advanced cook and hold units do also offer humidity controls. Since baseline units don't offer such features though, these controls do not make the advanced units any more energy efficient.

The halogen heat strip used much less energy than a traditional cal rod heat strip would have in that situation. Since heat strips with smart sensing technologies don't currently exist, halogen heat strips may be the best technology currently available for generating energy savings. More research should be done to determine the payback period and cost/benefit analysis on halogen heat lamps.

3. Spreadz

Site Description

Spreadz is a counter-serve deli. It serves deli-style sandwiches, soups, and salads between 10:30 AM and 2:30 PM from Monday to Friday. It is in the middle of a business park, so it mostly functions as a lunch spot for a small community of office workers.

Figure 26: Spreadz Sandwiches Front Counter

Baseline Monitoring Results

Spreadz was using four Nemco conventional resistance element electric soup warmers, three of which held 7 quarts and one which held 11 quarts of soup. It was also using a Holman QCS-2-500 conveyor toaster with a rated input rate of 1.7 kW. Table 5 contains the results of the baseline monitoring.

Table 5: Spreadz Baseline Monitoring Results

Equipment	Energy Use (kWh/day)	Operating Span (h)
Nemco 7 qt soup warmer (right)	0.75	2.94
Nemco 7 qt soup warmer (left)	0.61	2.94
Nemco 11 qt soup warmer	1.04	2.52
Holman QCS-2-500 conveyor toaster	11.43	7.32

The conveyor toaster and the 11-quart soup warmer were, as expected, the biggest energy users at the site. The conveyor toaster had an operating profile similar to the other non-setback mode toasters, where it ran at its maximum input rate during the site's hours of operation. This is reflected in the long average operating span of 7 hours, 20 minutes. The toaster operating hours were longer than the facility's regular open hours, because staff showed up to the site to handle catering/delivery orders. The 11-quart soup warmer shown in Figure 27 had a simple on/off control strategy, reflected in Figure 28. At the beginning of the day, there is a long period of energy usage which corresponds to heating up cold soup from a refrigerated temperature to a ready-to-serve state. It then cycles about 10 times per hour at about a 50% duty cycle until someone shuts it off. This is typical for a heating element controlled by a simple on and off temperature controller. The baseline soup warmer did not even have a temperature setpoint, only a low-hi rotary dial.

Figure 27: Spreadz Baseline 11-quart Soup Warmer

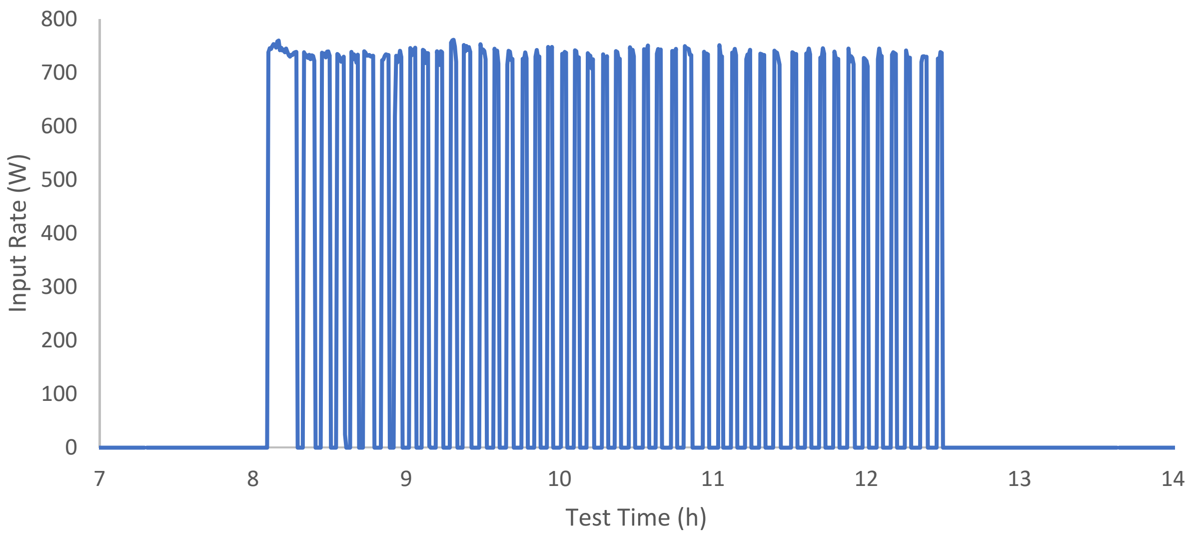

Figure 28: Spreadz Baseline 11-quart Soup Warmer Operating Profile

Replacement Monitoring Results and Savings

Figure 29: Spreadz Replacement Induction Soup Warmer

Figure 30: Spreadz Replacement Toaster

For the replacement phase, the 11-quart and one of the 7-quart soup warmers were replaced with a CookTek SinAqua Souper induction soup well of a corresponding size. The conveyor toaster was replaced with a Hatco TQ3-400 pictured in Figure 30 with a maximum input rate of 1.78 kW. Compared to their baseline units, the replacements resulted in 24% energy savings for the 7-quart soup warmer, 60% energy savings for the 11-quart soup warmer, and 19% energy savings for the conveyor toaster. The input rate profile for the 11-quart induction soup warmer is shown in Figure 31. The operating profile is very different from the baseline. It has extended usage at the beginning of the operation for the initial soup fill, but the induction heating is done in short bursts which appears to be lower energy than the baseline unit. From Figure 31, the site sold most of its soup in between 11 and 12 pm. The induction element cycled on more frequently to reheat the soup during the dispensing period. There is a relatively stable idle period between about 12:15 and the store’s closing when no soup was dispensed. The 7-quart induction soup warmer’s energy profile followed very similarly.

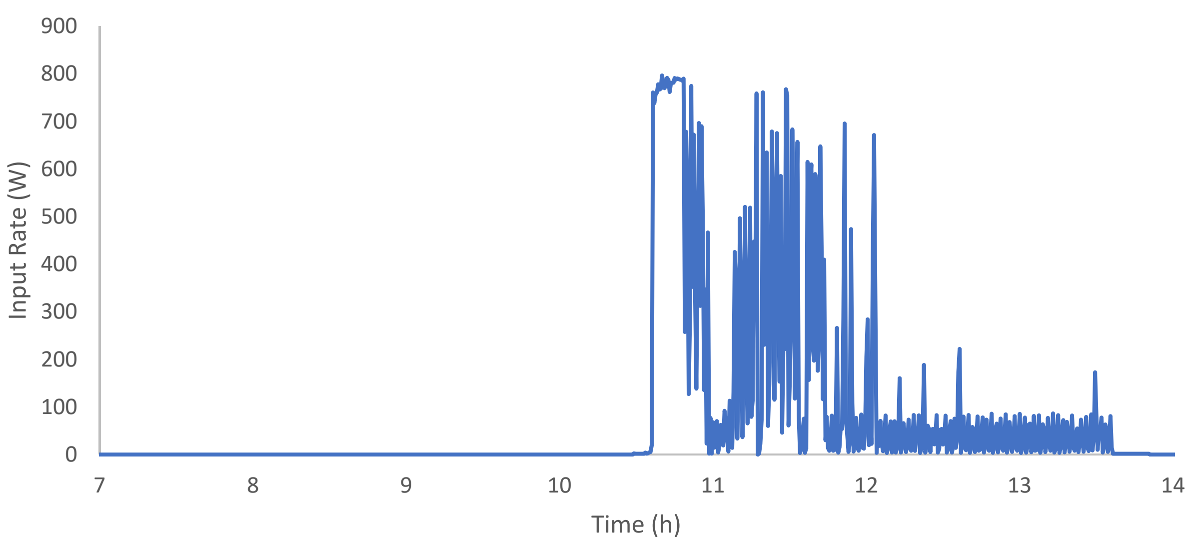

Figure 31: Spreadz Replacement Induction 11-quart Soup Warmer Operating Profile

As for the toaster replacement at Site A, both the baseline and replacement toasters operated at nearly the same input rate, so all savings can be attributed to the setback mode activation. For Spreadz, this was most prominent immediately after the initial toaster preheat in the relative lull before the lunch hour rush. The toaster replacement was originally done with the default 30-minute setback trigger, but data showed that the setback mode had few opportunities other than the morning lull to engage under those conditions. This resulted in only 9% energy savings. Once the setback trigger was adjusted to 10-minutes, however, those savings jumped to 19%, equivalent to about $85 in annual energy savings when using the average national electrical rate of $0.15 per kWh. The setback adjustment had no noticeable effect on speed of service. The full savings results from the replacements at Spreadz are summarized in Table 6.

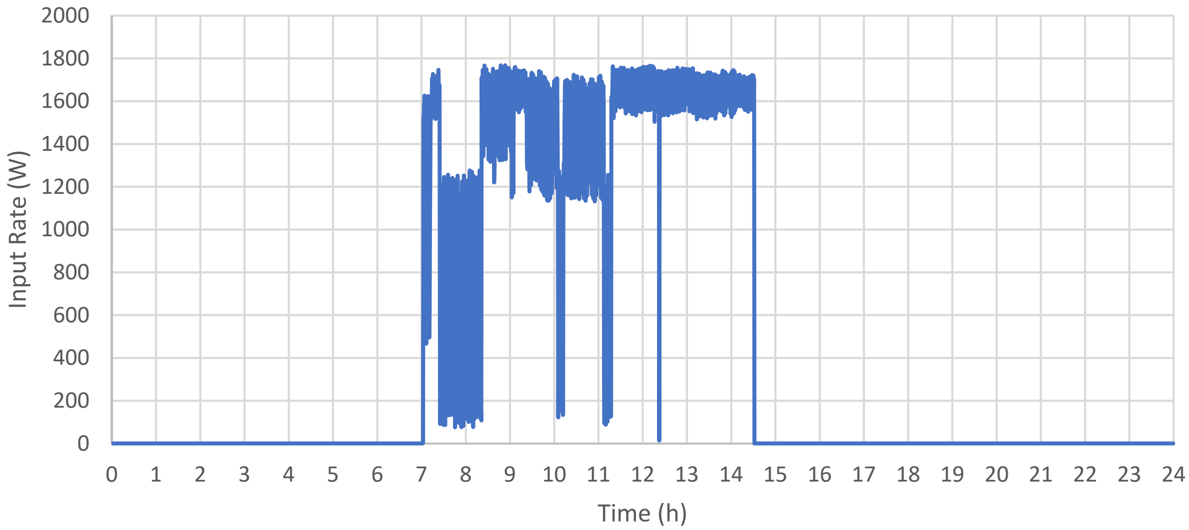

Figure 32: Spreadz Replacement Toaster Daily Energy Profile at 30 Minute Setback

Table 6: Spreadz Energy Savings

Equipment	Energy (kWh/day)	Operating Span (h)
(Baseline) Holman QCS-2-500	11.43	7.32
(Replacement) Hatco TQ3-400	9.26	7.30
	Savings: 2.17	
(Baseline) Nemco 7-qt soup warmer	0.75	2.94
(Replacement) CookTek 7-qt soup well	0.57	3.85
	Savings: 0.18	
(Baseline) Nemco 11-qt soup warmer	1.04	2.52
(Replacement) CookTek 11-qt soup well	0.41	2.61
	Savings: 0.63	

Lessons Learned

The monitoring at this site backs up the result observed at Site A – the setback mode on the conveyor toaster saved around 20% of the energy of a conventional conveyor toaster with the same input rate. Soup warmers are divided into two categories: warmers and rethermalizers. This unit was a rethermalizer which has higher input rate than a warmer and can reheat soup from refrigerated temperature and then hold it, whereas the warmer is only design to hold warm soup. The CookTek SinAqua Souper used retails for about $675, whereas a conventional soup warmer retails for about $150. The CookTek SinAqua Souper saved Spreadz $23.60 per year in electricity costs when using the average national electrical rate of $0.15 per kWh, which would work out to a 22-year simple payback time. This is almost certainly longer than the lifetime of a soup well. There are other advantages to induction soup warmers besides energy savings, however. The CookTek SinAqua has digital temperature control and much more precise temperature holding bandwidth than a conventional resistance soup warmer. This improves holding product quality and may reduce the scorching of soup residue during temperature stratification. By minimizing product loss, the induction soup well may have a shorter actual payback period than indicated through energy savings alone.

4. Site C – Bakery/Cafe

Site Description

Site C is an Indian café and bakery that serves drinks, pastries, and café food with an Indian twist. This restaurant typically has coffee/breakfast, lunch, and dinner rushes; they also deliver via an online ordering service. Site C is open from 8AM to 9PM from Tuesday to Sunday, typically serving around 2,000 orders per day.

Baseline Monitoring Results

For the baseline phase, a Moffatt Turbofan E22M3 countertop convection oven with an input rate of 1.5 kW, a Waring WPG250 Panini Supreme with an input rate of 1.8 kW, and an APW Wyott CW-2A wet well with an input rate of 1.5 kW were monitored. Both the panini press and wet well used significant amounts of energy when on, averaging more than 9 kWh per day. The monitored equipment is pictured in Figure 33.

Figure 33: (Left to Right) Site C's Countertop Oven, Panini Press and Wet Well

The monitoring results are shown in Table 7.

Table 7: Site C Energy Monitoring Results

Equipment	Energy (kWh/day)	Operating Span (h)
Countertop Oven	5.55	12.84
Panini Press	9.38	10.82
Wet Well	9.15	12.78

Replacement Monitoring Results and Savings

There were no pieces of equipment replaced at this site since there were no suitable energy efficient alternatives.

Lessons Learned

There was some significant plug load energy use at this site, but no appropriate equipment replacements were viable given the Site C's equipment requirements and the currently available technology. It would be possible in other applications to swap out a panini press with a rapid cook oven, but given Site C's method of preparing their popular empanadas, this change would have required an adjustment to the menu. Rapid cook ovens are also energy intensive appliances that generally only save energy when consolidating a cookline and replacing multiple pieces of equipment, which would not be the case for Site C. During the baseline monitoring period, researchers expected to replace the conventional countertop wet well with an induction unit. However, at the time of the project's replacement phase, the induction wet well manufacturer only had induction units in a floor standing configuration. According to the manufacturer, there is a countertop model in development, but it is not yet field-ready or commercially available.

5. Site D – Quick Service Restaurant

Site Description

Site D is open from 9 AM to 7 PM Monday through Friday and 10AM to 3 PM on Saturday and Sunday. They also deliver to the surrounding office buildings during their normal business hours. This location is surrounded by large office buildings and is close to the Santa Clara Convention Center, so they typically serve a high number of meals per day.

Baseline Monitoring Results

Site D was in the middle of a cooking process change and used a panini press and a microwave to cook its sandwiches. A Duo MOD400DM Panini Press and a 4-pan hot holding table were monitored for the baseline phase at this site. The baseline microwave was not monitored. The energy usage results are shown in Table 8, the panini press is pictured in Figure 34, the microwave is pictured in Figure 35, and Figure 36 shows the holding table. Figure 37 and Figure 38 show operating profiles of the panini press and the holding table, respectively.

Figure 34: Site D Baseline Panini Press

Figure 35: Site D Baseline Microwave

Figure 36: Site D Hot Holding Table

Table 8: Site D Baseline Monitoring Results

Equipment	Energy (kWh/day)	Operating Span (h)
Duo MOD400DM Panini Press	10.40	8.89
Hot Holding Table (4 pan)	7.93	7.69

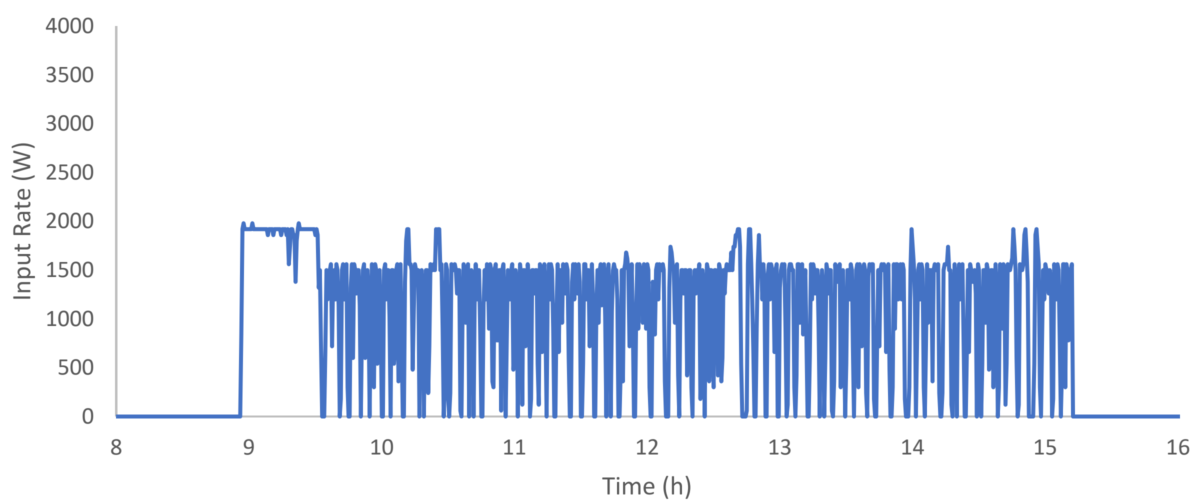

Figure 37: Site D Baseline Panini Press Operating Profile

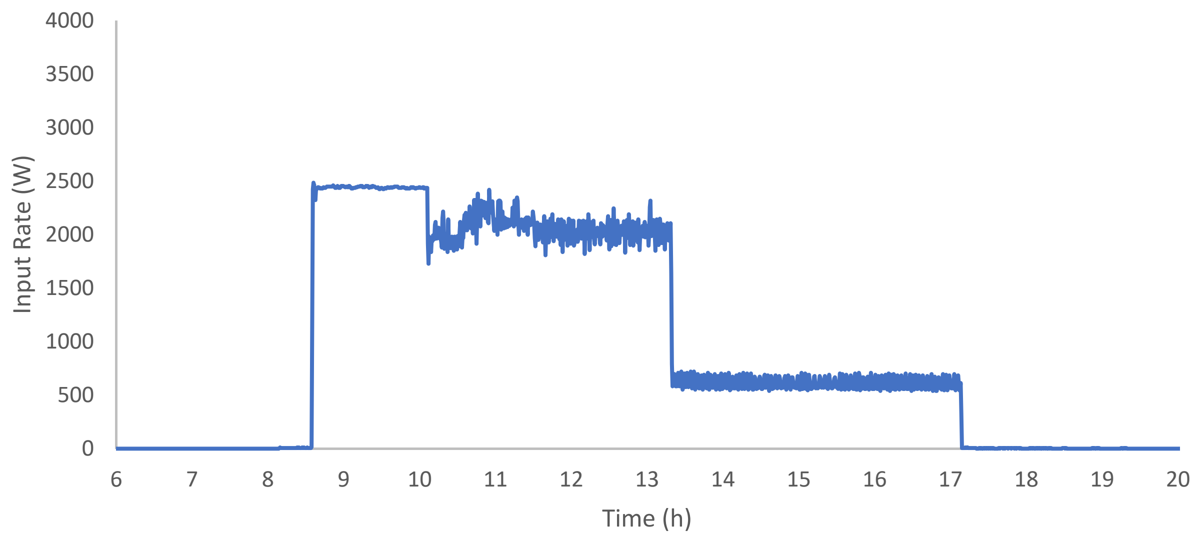

Figure 38: Site D Baseline Hot Holding Table Operating Profile

Site D used the panini press virtually all day. There was an initial start-up/preheat period roughly from 9 to 9:30 AM where its heating elements were operating at full capacity. It cycled for the rest of the day at about 80% of its capacity because the staff primarily used one of the two platens at a time. The spikes to 2 kW throughout the day are moments when both platens needed to be used simultaneously, which typically happened during rush periods. The hot holding table was preheated at 2.5 kW in the beginning of the day for an hour, then operated thermostatically until after lunch. Then, only two of the four pans were heated resulting in a lower idle energy.

Replacement Monitoring Results and Savings

The panini press was replaced with an Amana ACE19V rapid-cook oven pictured in Figure 39. This change was of interest to engineers from the Site D corporate office who are considering a company-wide rollout of replacements. Site D does not have the same menu constraints as Site C did, which made the change feasible at this site from a menu standpoint. Table 9 shows the replacement monitoring results. Figure 40 and Figure 41 show operating profiles of the rapid cook and microwave ovens, respectively.

Figure 39: Site D Amana ACE19V Rapid Cook Oven

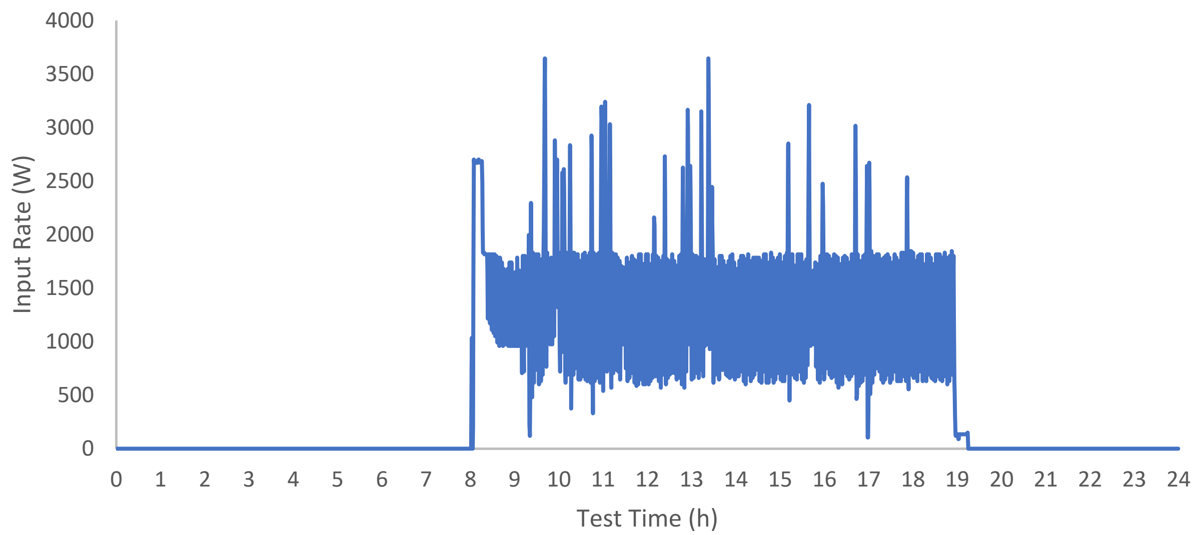

Figure 40: Site D Amana ACE19V Oven Energy Profile

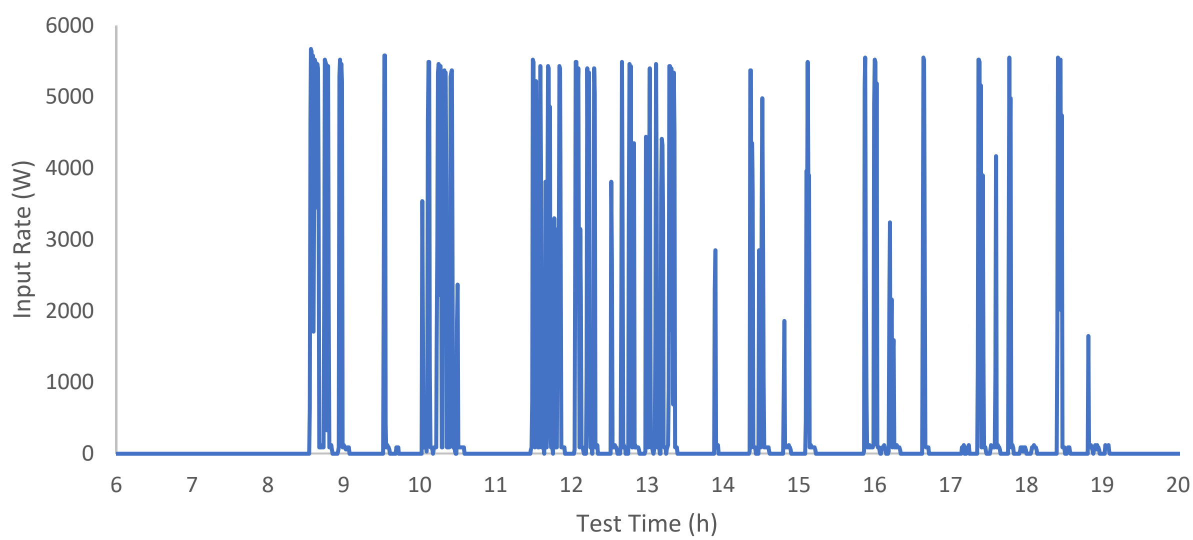

Figure 41: Site D Amana AMSO Microwave Oven Energy Profile

The rapid cook oven was used in conjunction with a new microwave. As shown in the two profiles above, the microwave has higher maximum power, however it comes in short bursts with no idle energy associated with the rapid cook oven. The new microwave used 4.3 kWh per day which is three times less than the rapid cook oven. Since the old microwave was not monitored, the old microwave is assumed to have used the same energy as the new microwave, making it a non-factor in energy use comparison. Though the rapid cook oven used more energy than the panini press it replaced, the staff at Togo's later found that the expanded flexibility provided by the rapid cook oven allowed one of the wells at the hot holding table to be shut off. This procedural change was implemented too late to quantify the resulting energy savings, but it is estimated to have set the energy difference of the full panini press to the rapid cook oven replacement to approximately zero. The holding table was not replaced because of the potential difficulties to install an energy efficient built-in induction unit.

Table 9: Site D Energy Savings Results

Equipment	Energy (kWh/day)	Operating Span (h)
(Baseline) Duo Panini Press	10.40	8.89
(Replacement) Amana ACE19V	12.81	6.20
Savings	*-2.41*	

Lessons Learned

Rapid cook ovens are relatively expensive with costs exceeding $4,000; however, the menu expansion capabilities and ease-of-use of a rapid cook oven can justify the initial investment. Items previously heated in a microwave, then toasted in a panini press as a two-step process can be cooked in the rapid cook oven in a single step. This is achieved through high temperatures and a microwave magnetron integrated into a single oven. Rapid cook ovens are very energy intensive on their own, but they can take the place of multiple pieces of equipment and streamline various processes. Energy savings were not achieved at this site, but the evolution of the equipment use practices following the replacement indicates that there is further potential for custom energy savings solutions. The replacement also increased workplace safety, since it is significantly more likely for a staff member to burn themselves on a panini press than on an oven.

As more multiunit operators are moving toward adoption of rapid cook oven technologies, they should be aware of the high energy consumption associated with installing high temperature ovens. When done simply in a one-for-one replacement, it will likely raise energy costs. However, taking advantage of the speed and flexibility of rapid cook ovens to consolidate kitchens and redesign process flows could result in improvements in energy use, kitchen workflow, and throughput. More extensive research needs to be done to better quantify the savings potential and learn the optimal replacement use cases for rapid cook ovens.

6. Plaza Suites

Site Description

The Plaza Suites is an upscale hotel with a restaurant that has daily self-serve breakfast buffet, as well as lunch and dinner service. The back-of-house for this restaurant is virtually always operating due to its in-suite dining service, but its front-of-house is only used for breakfast. The breakfast line was monitored as a part of this project.

Figure 42: Plaza Suites Front of House Equipment

Baseline Monitoring Results

Plaza Suites had three important pieces of plug load equipment that were monitored. These were a Carter-Hoffman FH90-00 holding cabinet that was used primarily to hold and warm plates, a Belleco JT-1 conveyor toaster, and a Carbon's Golden Malted RT-P waffle iron. Both the waffle iron and the holding cabinet were used for less than five hours a day on average, but the conveyor toaster experienced more than twice the usage. Table 10 summarizes the baseline energy monitoring results.

Table 10: Plaza Suites Baseline Monitoring Results

Equipment	Energy (kWh/day)	Operating Span (h)
Carter-Hoffman FH90-00 Holding Cabinet	3.85	3.79
Vollrath Belleco JT-1 Conveyor Toaster	14.41	11.26
Carbon's Golden Malted RT-P Waffle Iron	3.58	4.51

Replacement Monitoring Results and Savings

Although the conveyor toaster used the most energy, it could not be replaced by an energy efficient alternative due to the site's requirements for toasting cavity opening size. There were no energy efficient options that could accommodate the thicker toast cooked at the hotel. Meanwhile, the waffle iron was part of a package deal with the hotel's syrup supplier, so they were unwilling to replace it. The only appliance that ended up being replaced was the holding cabinet. The Carter-Hoffman FH90-00 baseline holding cabinet (Figure 43) was replaced by an insulated Cambro PCUHH holding cabinet (Figure 44), resulting in a 2.70 kWh/day energy savings.

Figure 43: Plaza Suites Baseline Holding Cabinet

Figure 44: Plaza Suites Replacement Holding Cabinet

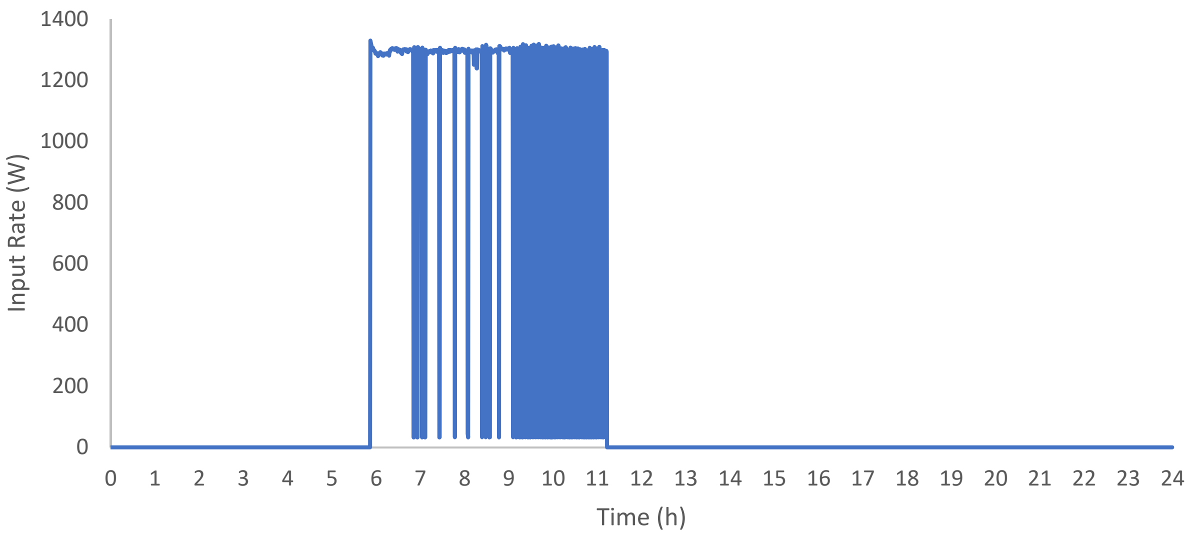

Figure 45: Plaza Suites Baseline Holding Cabinet Energy Profile

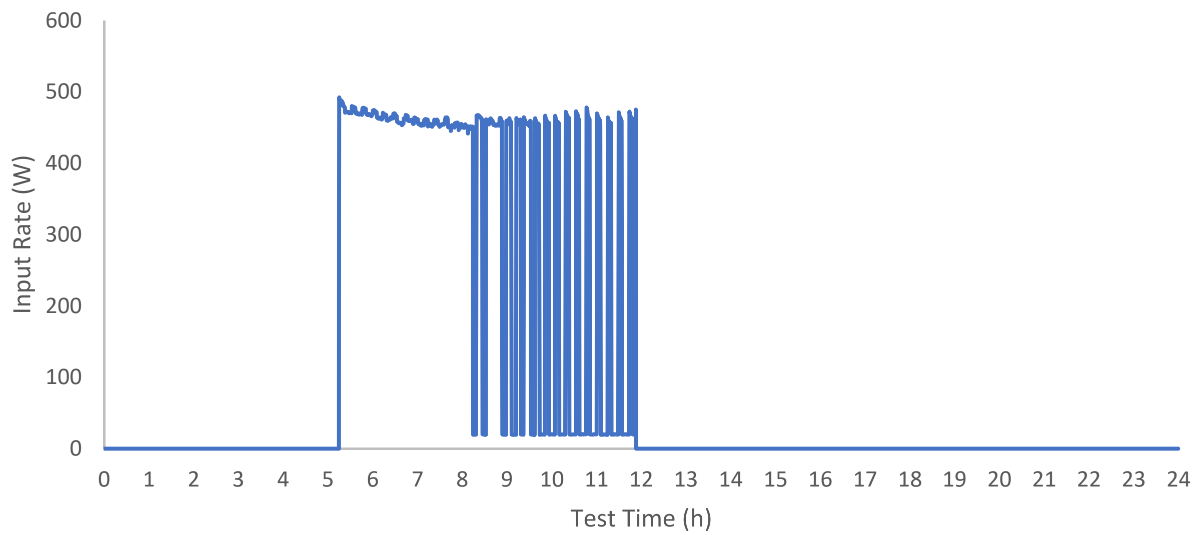

Figure 46: Plaza Suites Replacement Holding Cabinet Energy Profile

Overall, the new holding cabinet saved 70% of the energy consumed by the baseline unit. Because this site operates seven days a week, this translates to $147 per year in utility bill savings (assuming $0.15/kWh). These savings are thanks in part to the polyurethane foam insulation throughout the unit that lowered the idle energy rate required to maintain the same holding temperature as the baseline holding cabinet. More significantly, the replacement holding cabinet allowed the staff to reduce their heating load, since the replacement holding cabinet has separate heating elements for each of its cavities as opposed to the baseline unit's larger heating element that services the whole unit. This allowed staff to customize their holding cabinet usage to fit the needs of the kitchen, using only the top half for active heating and the bottom for passive holding. This is also why Figure 46 shows an input rate of 500 watts instead of the unit's manufacturer-specified total input rate of 1 kW. Table 11 summarizes the savings results.

Table 11: Plaza Suites Energy Savings Results

Equipment	Energy (kWh/day)	Operating Span (h)
(Baseline) Carter Hoffman FH90-00	3.85	3.79
(Replacement) Cambro PCUHH	1.15	3.77
Savings	*2.70*	

Lessons Learned

Compartmentalization can be extremely useful for operations with large variances in demand, since it offers the flexibility to adapt to those large swings. Insulation is also a key factor for an appliance whose main purpose is to maintain temperature. Whereas most holding cabinets operate at 1,200 W, the Cambro PCUHH can operate at only 500 W per cabinet and still cycle less often to maintain proper holding set temperature. Both baseline and replacement cabinets are similar in retail price, so replacement could result in immediate savings with no payback period. In a case with higher hours of operation, the savings could be even larger – the holding cabinet at the Plaza Suites was only operated for an average of less than 4 hours per day.

7. Site E – Full Service Restaurant

Site Description

Site E is a medium-sized full-service restaurant and bar specializing in American diner fare. This site is open from 7 AM to 9 PM daily and typically serves breakfast, lunch, and dinner.

Baseline Monitoring Results

At this site, a Carbon's Golden Malted RT-P waffle iron, a Holman QCS-3-100 conveyor toaster, and a Vollrath Cayenne T43R heated well were monitored for their energy usage. Figure 47 shows the baseline conveyor toaster and Figure 48 shows the countertop heated well.

Figure 47: Site E Holman QCS-3-1000 Conveyor Toaster

Figure 48: Site E Countertop Heated Well

Table 12 is a summary of the baseline monitoring results. The conveyor toaster was the clear "energy hog" at the site. This was by far the most energy intensive conveyor toaster monitored in this project, with an estimated yearly energy cost of over $1,700 using the average national electrical rate of $0.15 per kWh.

Table 12: Site E Baseline Monitoring Results

Equipment	Energy (kWh/day)	Operating Span (h)
Carbon's Golden Malted RT-P Waffle Iron	13.85	14.87
Holman QCS-3-1000 Conveyor Toaster	46.04	14.54
Vollrath Cayenne T43R Heated Well	9.63	9.90

Replacement Monitoring Results and Lessons Learned

Figure 49: Site E Hatco Replacement Conveyor Toaster

The toaster was replaced by a Hatco TQ3-400 model. The research team later discovered that the site staff switched back to the baseline model almost immediately, well before any meaningful energy data could be obtained. The staff cited power malfunctions as the reason for replacement, stating that the toaster automatically restarted several times. This model has a 10-minute preheat period that cannot be bypassed, so these resets caused too many delays for the staff to give the toaster a second chance. The replacement toaster was later brought into the laboratory for extensive error testing, but the issue could not be recreated. The toaster has since been given to Voyager Craft Coffee, which reported that the toaster has been working well.

Based on the other toaster replacements in this project, it is estimated that the new machine should have generated at least 20% energy savings for a yearly cost savings around $350 when using the average national electrical rate of $0.15 per kWh. However, because of the long operating span and high input rate of the baseline toaster, it is likely that the savings would have been higher. The baseline Holman toaster retails at $1.7K, so there would have been no payback period and the restaurant would have been able to pocket any energy savings. Unfortunately, the unknown errors caused a lack of faith in the equipment, so the savings could not be realized. Advanced energy saving equipment still needs to shed its finicky image, which stands in contrast to the perceived reliability of energy intensive heavy-duty models.

Neither the waffle iron or the heated well were replaced. The waffle iron was the same model used in the Plaza Suites, but used significantly more energy at Site E due to longer operating hours. However, Site E had the same syrup package deal with the manufacturer and was not willing to replace the appliance. Waffle irons seem to offer a significant energy savings opportunity though, if a quick-heating or well-insulated version was available. The heated wet well was not replaced because there were no available induction countertop warming well alternatives – at the time of the study, this technology was still only in development.

8. Site F – Quick Service Restaurant

Site Description

Site F specializes in Vietnamese bahn mi sandwiches and southeast Asian small plates. They are open from 11 AM to 9 PM daily.

Baseline Monitoring Results

The only pieces of equipment monitored at this site were a pair of Proctor Silex electric rice cookers and a Winholt INHPL-1836 holding cabinet. Table 13 lists the monitoring results and Figure 50 shows one of the identical rice cookers and the holding cabinet.

Figure 50: Site F Proctor Silex Rice Cooker and Winholt Holding Cabinet

Table 13: Site F Energy Monitoring Results

Equipment	Energy (kWh/day)	Operating Span (h)
Winholt INHPL-1836 Holding/Proofing Cabinet	11.03	10.98
Proctor Silex 37560R Rice Cooker (right)	1.81	9.46
Proctor Silex 37560R Rice Cooker (left)	1.89	10.31

Given the long hours of operation, the rice cookers used relatively small amounts of energy. Most of the time they were simply keeping cooked rice warm, which can take little energy given the appliance's insulation. The holding cabinet was a much more energy intensive piece of plug load equipment, though its operating profile (Figure 51) is typical of conventional holding cabinets. Part of the reason the energy use is so high is that the door was made of glass as opposed to a more insulating material. The glass allows heat to escape into the ambient air faster than plastic or insulated stainless steel, so more energy input is required to maintain the proper cabinet temperature. There are a few instances in Figure 51 where the cabinet cycles onto its maximum input rate for a long period of time – at approximately 10 AM, 12:30 PM, and 6:30 PM. The first is when the holding cabinet is preheating. The remaining two occurred when the door is either left open for a long time or there is a lot of door opening and closing happening in a given period. This is the heating element trying to compensate for hot air escaping from the holding cabinet's cavity. These are all instances where a more insulative cabinet would not make a difference. The insulation makes a difference the period in when the heater cycles normally however, which comprises a much larger bulk of the daily energy use.

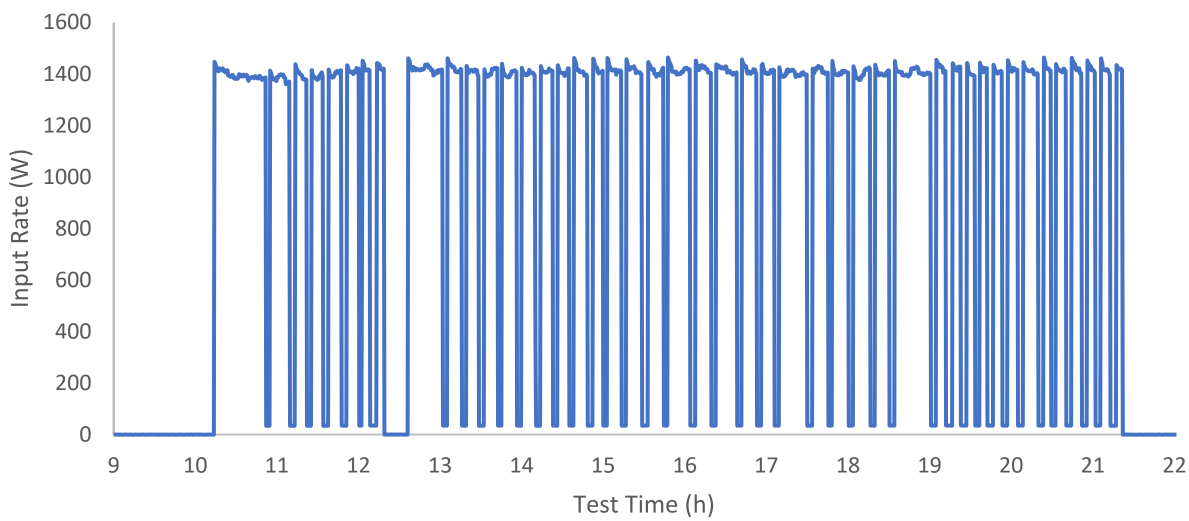

Figure 51: Site F Holding/Proofing Cabinet Baseline Operating Profile

Replacement Monitoring Results

The baseline holding cabinet was replaced with a Vulcan VBP18 solid door insulated holding cabinet, which cut the energy usage by more than half. This was due primarily to the insulation, allowing the replacement cabinet to cycle the heat on much less frequently. Looking at the daily energy profiles, the baseline cabinet (Figure 51) spent most of its time on its heating cycle, periodically cycling off when the temperature was high enough. By contrast, the replacement cabinet (

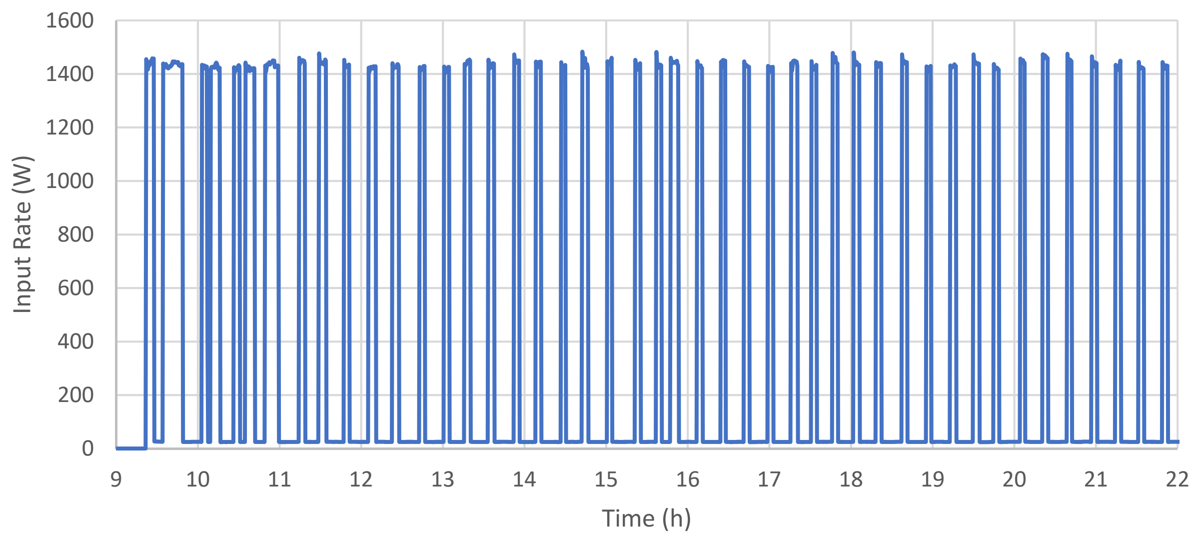

Figure 53) spent most of its time off its heating cycle, only periodically pumping more heat in to bring the holding cabinet back to temperature. This illustrates the significantly reduced heat loss from the replacement cabinet's insulation, resulting in a 6.19 kWh/day (56%) reduction in total energy use despite slightly longer average daily hours of operation. Since the restaurant operates 7 days a week, this is equivalent to about $330 in yearly energy savings.

Figure 52: Site F Replacement Holding Cabinet

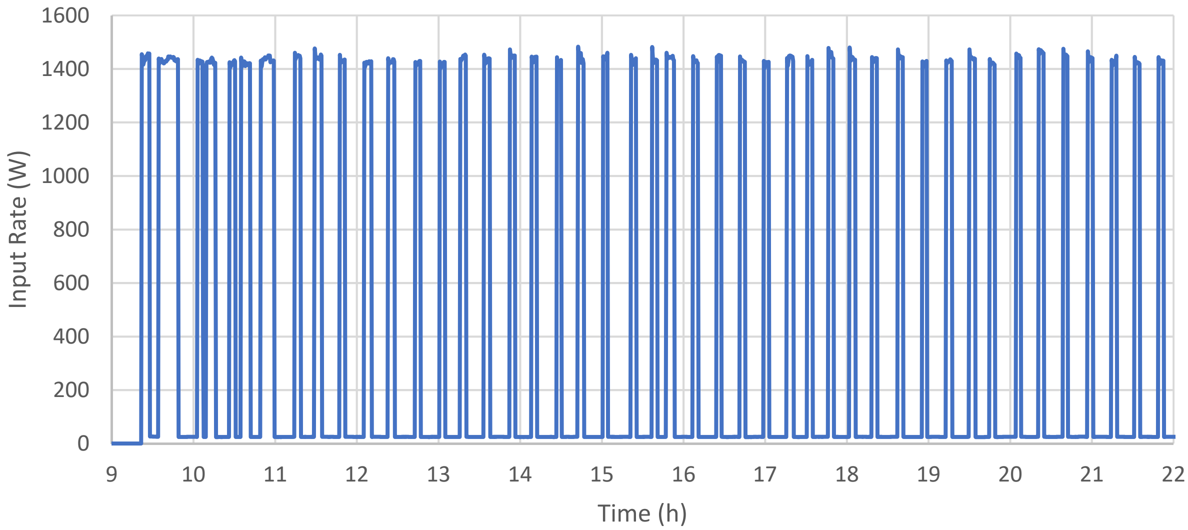

Figure 53: Site F Holding/Proofing Cabinet Replacement Operating Profile

Table 14: Site F Energy Savings Results

Equipment	Energy (kWh/day)	Operating Span (h)
(Baseline) Winholt INHPL-1836 Glass Door	11.03	10.98
(Replacement) Vulcan VBP18 Solid Door	4.84	12.54
Savings	*6.19*	

Lessons Learned

Unlike the holding cabinet replacement at Plaza Suites, the operator did not change the way they used the new equipment – all energy savings were purely from the appliance itself. In conjunction with the findings from Site A, the results show that insulation is clearly an integral part in determining the energy usage of holding cabinets. When it is an option, solid doors will generally be preferable to glass doors from an energy perspective. Switching to a unit with two doors may also have helped cut down on heat loss from door openings.

9. Site G – Café

Site Description

Site G is a craft coffee shop and roastery in Santa Clara that specializes in roasting ethically-sourced coffee. It is open from 7 AM to 9 PM daily.

Baseline Monitoring Results

The pieces of equipment monitored at this site were a drip coffee brewer, rapid cook oven, and espresso machine, all pictured in Figure 54. Table 15 summarizes the baseline monitoring results.

Figure 54: (Left to Right) Site G Espresso Machine, Rapid Cook Oven and Coffee Brewer

Table 15: Site G Baseline Monitoring Results

Equipment	Energy (kWh/day)	Operating Span (h)
La Marzocco Strada Espresso Machine	20.6	24.0
Turbochef i3 Rapid Cook Oven	21.3	13.1
Fetco CBS-2132-XTS Coffee Brewer	11.9	24.0

All three appliances monitored used significant amounts of energy due in part to the long hours of operation. The Turbochef i3 was the most energy intensive of the three despite being the only one turned off at night. However, given the versatility and speed of the rapid cook oven, it can be difficult to replace. Replacing a rapid cook oven may require multiple pieces of equipment to perform the same functions for a set of menu items. A replacement would also require more counter space and electrical connections, which is why the rapid cook oven was not replaced at this site.

The espresso machine and the coffee brewer are both left operating throughout all hours of operation and overnight. There is a misconception in the coffee making industry that these machines will sustain damage if turned off and turned back on. This is a vestigial historical holdover from the original espresso machines when this technology first came on the market. They used to be put together with paper gaskets, which would warp, shrink, and eventually break if the unit was turned off. Modern machines are put together with rubber gaskets and can be turned off without a problem. Modern espresso machine manufacturers are also aware of this widely-held misconception and install controls for a significantly lower overnight idle rate to achieve energy savings. This is reflected in Figure 56. Based on a review of the operating profiles, the idle losses for both the coffee brewer and the espresso machine are not enough to justify replacement. Also, it is worth noting that espresso machines are very expensive, in the $20,000 range, which makes this equipment category the exception to the generalization that plug load equipment is cheap enough for most restaurant owners to replace. Luckily, the high price tag of espresso machines allows manufacturers to "bake in" energy-saving control schemes so all these units can essentially be omitted from utility replacement programs.

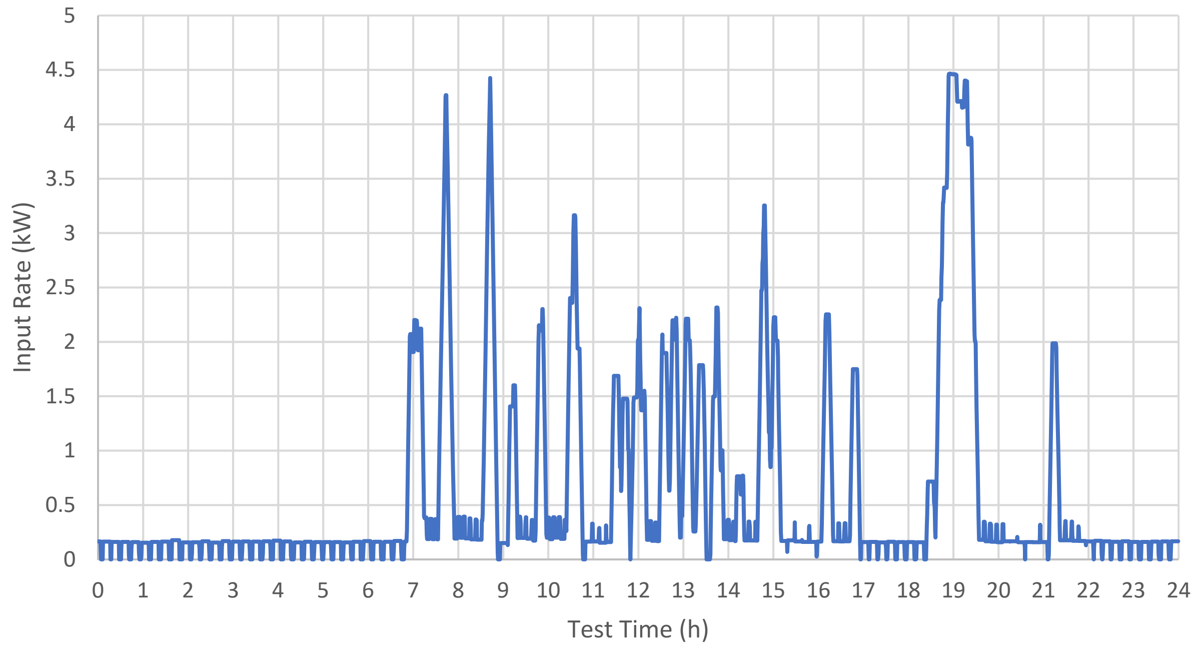

Figure 55: Site G Coffee Brewer Daily Energy Profile

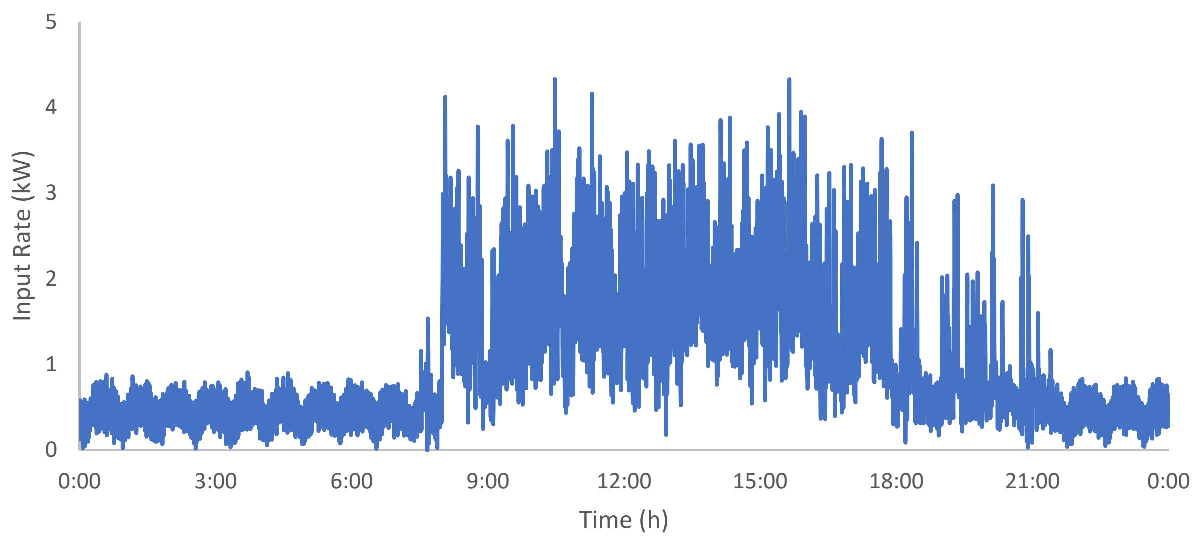

Figure 56: Site G La Marzocco Strada Espresso Machine Operating Profile

Replacement Monitoring Results and Savings

There were no pieces of equipment replaced at this site since there were no suitable energy efficient alternatives.

Lessons Learned

Higher-end equipment can be difficult to replace due to their functionality and features. The high energy usage of espresso machines and coffee brewers is strongly linked to the 24-hour operation of the machine. This energy can be lowered significantly if the machine can be programmed to turn off at night, but significant barriers in public perception still exist. The potential energy savings in each individual case may not be enough to overcome those barriers.

10. Voyager Craft Coffee

Site Description

Voyager Craft Coffee is a popular cafe specializing in espresso and drip coffee beverages, which they pair with various toast and pastry options for snacking. They are open from 7 AM to 7 PM daily and are well known for their creative and aesthetic signature drinks, themed after various cities around the world. Business is a constant flow of take-out orders and customers who sit inside the café to chat or work while enjoying their coffee. Figure 57 shows the site exterior.

Figure 57: Voyager Craft Coffee Site Exterior

Baseline Monitoring Results

The only two pieces of equipment monitored at this site were the espresso machine and the conveyor toaster. The conveyor toaster is depicted in Figure 58 and its operating profile in Figure 59, and the baseline monitoring results are shown in Table 16.

Figure 58: Voyager Craft Coffee Baseline Conveyor Toaster

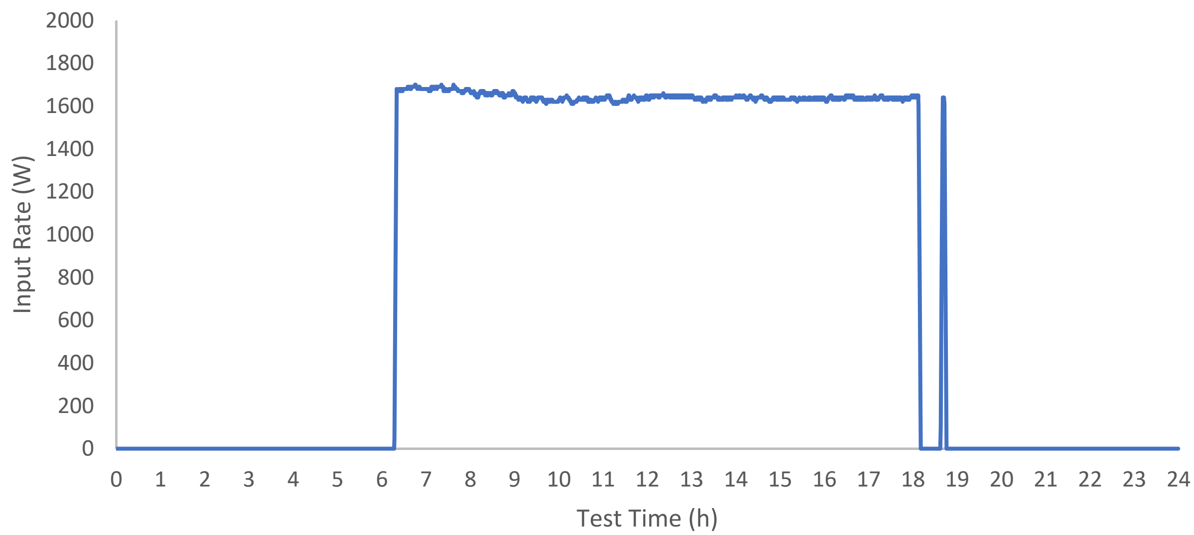

Figure 59 Voyager Craft Coffee Baseline Toaster Energy Profile

Table 16: Voyager Craft Coffee Baseline Results

Equipment	Energy (kWh/day)	Operating Span (h)
La Marzocco Strada Espresso Machine	19.41	24.0
Waring CTS1000 Conveyor Toaster	18.37	11.20

Like the espresso machine monitored at Site G, the espresso machine at Voyager Craft Coffee used about 20 kWh per day and was left on overnight. It had almost the same usage pattern with a slight variation in the hours of operation. The conveyor toaster was in use for most of the operating day and used its maximum energy input rate whenever the facility's doors were open.

Replacement Monitoring Results and Savings

Table 17 lists the energy savings from replacing the baseline toaster with a Hatco TQ3-400, pictured in Figure 60. Initially, there were no savings from the replacement, since the coffee shop was so busy that the toaster rarely ever went into its setback mode. After switching the setback mode to trigger at 10 minutes instead of 30 minutes of inactivity (factory setting), however, the replacement toaster reduced the energy use by 9% compared to the baseline. Figure 61 (30-min) and Figure 62 (10-min) illustrate the difference in setback mode activation. The increased activation did not affect service in any way. However, the setback mode activation was still infrequent due to the shop's constant toaster orders, so the energy savings were less than the 20% conveyor toaster savings observed at the other sites.

Figure 60: Voyager Craft Coffee Replacement Conveyor Toaster

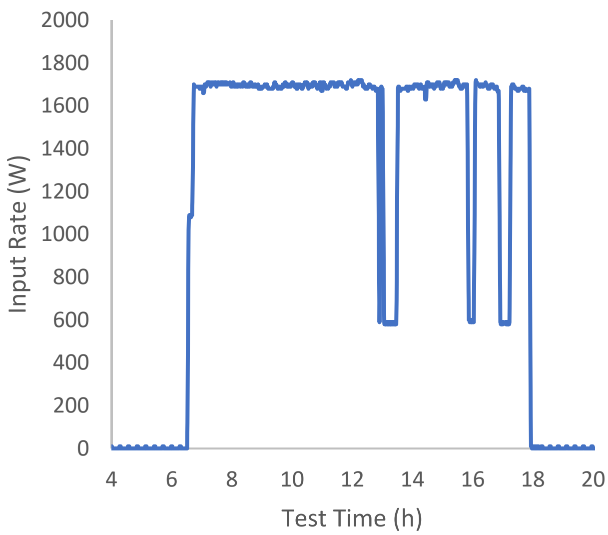

Figure 61: Voyager Craft Coffee Replacement Toaster 30 min setback trigger

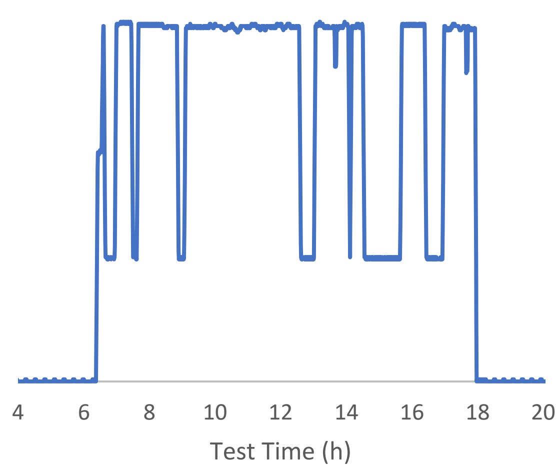

Figure 62: Voyager Craft Coffee Replacement Toaster 10 min setback trigger

Table 17: Voyager Craft Coffee Energy Savings Results

Equipment	Energy (kWh/day)	Operating Span (h)
(Baseline) Waring CTS1000	18.37	11.20
(Replacement) Hatco TQ3-400	16.99	11.47
Savings	*1.38*	

Lessons Learned

The conveyor toaster replacement did not save as much energy as the other sites in this study. This is an important data point because it shows the limitations of a setback mode. If a site is constantly using an appliance, a setback mode won't be activated and therefore won't achieve any energy savings. When this happens, it's more of a measure that the baseline technology is appropriately sized and operates at an appropriate schedule for the site rather than a failure of the replacement technology. With that said, a setback mode cannot make an appliance use more energy, so it is a very low-risk technology to design rebate and replacement programs around. It is especially suitable for sites that have higher variability in customer demand.

Equipment Comparison Analysis

1. Conveyor Toasters

Table 18 summarizes the monitoring completed on conveyor toasters at various sites. The baseline toasters (excluding the unit at Site E since it's an outlier) used an average of 1.6 kWh per hour of facility operation with little variation, which is unsurprising given their constant input rate operating profiles. The Site E toaster was an outlier because it was a 208V toaster while the rest of the toasters were 120V, 15A appliances. The 1.6 kW figure is the maximum input rate that can be achieved using a standard household plug (120V, 15A).

It is possible to accurately estimate the daily energy usage of a baseline conveyor toaster given its specification sheet (or even plug configuration) and an operating schedule because there is no turndown ratio or duty cycle involved. These units consume electricity at their specified input rates whenever the power switch is turned on. The TQ3-400 toasters save energy by use of their setback mode, which automatically engages to reduce the heating input rate and pause conveyor movement when the sensors fail to detect any cooking activity for the user's set length of time. Setback mode automatically disengages when product is put into the toaster and the toast time is extended for the first product cooked after the setback period to achieve toast quality consistency.

For this entire chapter, green highlighted rows in tables represent an energy-efficient replacement model installed by Frontier Energy.

Table 18: Conveyor Toaster Monitoring Results Summary

Site	Facility Type	Equipment	Setback?	Energy Use (kWh/day)	Operating Span (h)
Site A	Corp. Cafeteria	Hatco TQ-10	No	13.56	8.53
Site A	Corp. Cafeteria	Hatco TQ3-400	Yes‡	10.96	8.09
Spreadz	Quick Service Rest.	Holman QCS-2-500	No	11.43	7.32
Spreadz	Quick Service Rest.	Hatco TQ3-400	Yes†	10.37	7.44
Spreadz	Quick Service Rest.	Hatco TQ3-400	Yes‡	9.26	7.30
Site E	Full Service Rest.	Holman QCS-3-1000	No	46.04	14.54
Site E	Full Service Rest.	Hatco TQ3-400	Yes‡	N/A	N/A
Voyager Craft Coffee	Café	Warring CTS-1000	No	18.08	11.20
Voyager Craft Coffee	Café	Hatco TQ3-400	Yes†	18.43	11.82
Voyager Craft Coffee	Café	Hatco TQ3-400	Yes‡	16.99	11.47
Plaza Suites	Hotel	Vollrath Belleco JT-1	Yes (Manual)	14.41	11.26

†indicates the setback mode was set to activate after 30 minutes of inactivity.
‡indicates that the setback mode was set to activate after 10 minutes of inactivity.

The user definition of the setback mode settings directly controls how much energy these units can save compared to the baseline. For the first set of replacements, the factory preset was used. These settings reduced heater energy usage by 35% after 30-minutes of inactivity. This relatively conservative setting was chosen because the setback mode inherently reduces the operating temperature of the toaster, and researchers were concerned about the unit's ability to recover quickly after setback mode is engaged.

This was also the default factory setting, meaning that many users would achieve the energy savings resulting from this setting (unless they actively changed the settings themselves).

After the first round of testing at the Voyager Craft Coffee and Spreadz sites, it was realized that more aggressive setback settings (setback engagement after a shorter period of inactivity) would be needed to achieve a significant impact. The replacement toaster at Voyager Craft Coffee used slightly more energy than the baseline with the conservative setback settings, which was an unacceptable result for this study. This is likely due to the consistent toasting time intervals of the site that did not allow the toaster to go into setback. The settings were adjusted to turn down the heaters after 10 minutes of inactivity (factory default was 30-min). These more aggressive settings produced more favorable energy savings without affecting service – none of the sites seemed to even notice the change. Table 19 summarizes the savings achieved by the replacement toaster with the 10-minute setting at each site. Unfortunately, the toaster replacement data from Site E was not successful despite its large energy savings opportunity.

Table 19: Conveyor Toaster Replacement Savings

Site	Energy Savings (kWh/day)	Energy Savings (%)	Annual Utility Savings ($/y)*	Simple Payback Time (y)
Site A	2.60	19%	$101	2.5
Spreadz	2.17	19%	$84	3.0
Voyager Craft Coffee	1.38	8%	$75	3.2

* when using the average national electrical rate of $0.15 per kWh

Site A and Spreadz exhibited similar savings. This is due to the comparable operating hours and energy usage of their baseline and replacement toaster models at the two sites. The energy savings at Voyager Craft Coffee were about half of the savings at Site A and Spreadz, even though the operating span was longer at Voyager Craft Coffee. This was due to the more frequent toasting demand at Voyager Craft Coffee than at the other sites, resulting in less opportunity to operate in setback mode. Site A and Spreadz had a more varied range of food products and a larger assortment of preparation equipment, whereas Voyager Craft Coffee had a limited menu and fewer appliances. Most of the foodstuffs that Voyager Craft Coffee heated onsite were warmed in the conveyor toaster. The toaster doesn't spend any significant time idling, so there was less savings to be achieved with setback mode. The most savings would be achieved using setback mode in a site with long operating hours, well-defined meal periods and long breaks of inactivity between them (as seen in corporate cafeterias). No sites where replacements were carried out reported any operating issues with the new toasters.

It was expected that the energy savings at Site E would be much higher than the savings achieved at the other sites as their baseline toaster was substantially oversized for their needs and had a much larger idle window. The replacement toaster at Site E was smaller with about half the energy input rate as the baseline toaster. Even without the setback mode savings, the operating energy use of the replacement toaster should have been significantly less than the baseline while actively toasting. This underlines the importance of sizing equipment appropriately based on the customer demand. Of all the sites, it was also anticipated that Site E's operation had the operating schedule most conducive to achieving savings through the implementation of a setback mode. This diner has three distinct meal services with little carry over between periods, which would have provided plenty of downtime. However, equipment malfunctions and a lack of trust in the technology resulted in an unsuccessful replacement, so no real energy savings data on this best-case real scenario could be obtained. Though the error could not be replicated, the research team will notify Hatco of this occurrence and recommend the mandatory 10-minute preheat period be modified or removed. This feature is what made the restarts such an issue, since the toaster could not be used for the following 10 minutes even if the cavity had already reached proper toasting temperature.

The study showed that most conveyor toasters are 120V with maximum input rates of 1.6kW. Although 208V toasters are less common, their energy savings potential is much higher because they operate at 3 kW. Site E showed an oversized 208V toaster that could be replaced with a lower input 120V TQ3-400 toaster, however, a TQ3-900 model is available for higher power applications utilizing similar setback strategies for facilities that require a higher level of throughput. The figures below show the setback energy profiles from one of the monitored sites. Toasters are one of the most energy intensive plug load appliances in the commercial kitchen and an automatic setback mode is an effective method of saving energy without significant operation disturbances. Among all the sites that had the toaster replacement, none of them noted any impact on operations caused by the setback mode. Toasters with digital setback controls cost more than conventional manual thermostat toasters, and it is recommended that the extra cost should be offset with an energy incentive. Tables 20 and 21 give average price points for conveyor toasters.

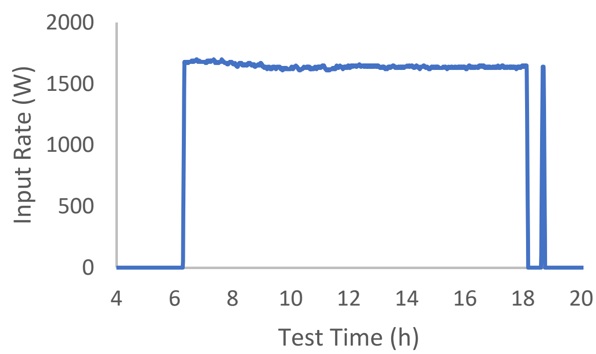

Figure 63: Baseline Toaster Constant Input

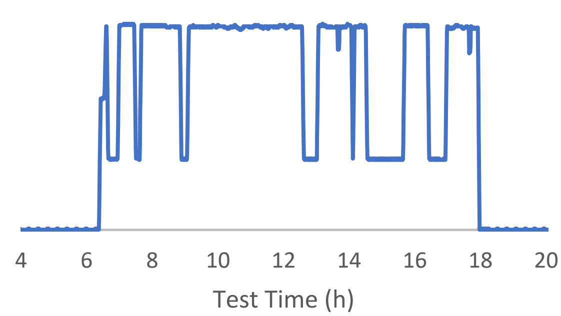

Figure 64: Replacement Toaster With 10 min setback trigger

Table 20: Cost of Various 120V Toasters

120V toasters	Baseline Toaster Cost	Automatic Setback Toaster Cost
Waring CTS1000	$571	-
Hatco TQ-10	$767	-
Star QCS2-500	$1370	-
Vollrath CT2-120350	$560	-
Hatco TQ3-400	-	$1219
Average	$817	$1219
Difference		*$402*

Table 21: Cost of Various 208V Toasters

208V toasters	Baseline Toaster Cost	Automatic Setback Toaster Cost
Star QCS3-1000	$1752	-
Beleco JT4-SBS	$1708	-
Vollrath JT4-208550	$996	-
Hatco TQ-400H	$1191	-
Avatoast T3600B 14	$749	-
Hatco TQ3-900	-	$1390
Average	$1279	$1390
Difference		*$111*

2. Soup Warmers

Table 22 summarizes the monitoring completed on induction soup warmers at Spreadz. The site had limited operating hours and relatively low demand for the soup warmers. The number of soup warmers a site needs does not necessarily map directly with its total soup volume demand, but rather the number of different kinds of soup sold at the same time. This leads to a relatively low usage baseline scenario, where the largest soup warmer was only using about 1 kWh per day. When it was replaced with an induction soup warmer, 60% energy savings were achieved for a total 630 Wh per day of savings. The savings from replacing the larger soup well were greater than for the smaller soup well – the 7-quart replacement only saved 24% energy in comparison. Both saved a significant percentage of energy though, even despite having slightly longer operating hours than their baseline counterparts.

Table 22: Conventional and Induction Soup Warmer Monitoring Summary

Site	Facility Type	Equipment	Capacity (qt)	Induction?	Energy Use (kWh/day)	Operating Span (h)
Spreadz	Quick Service Rest.	Nemco	7	No	0.75	2.94
Spreadz	Quick Service Rest.	Nemco	7	No	0.61	2.94
Spreadz	Quick Service Rest.	Nemco	11	No	1.04	2.52
Spreadz	Quick Service Rest.	CookTek	7	Yes	0.57	3.84
Spreadz	Quick Service Rest.	CookTek	11	Yes	0.41	4.53

While Spreadz was not an ideal candidate for showcasing the savings potential of an induction soup warmer because of its lower operating hours, it was an opportunity to provide a real-world comparison between the two warming technologies. The induction warmers reduced the energy required to keep the same volume of soup warm by up to 60%. In a different operating scenario such as a cafeteria or a grocery store where a conventional soup warmer would run for 10 to 12 hours a day, a 60% energy savings could translate to around 2 kWh per day of savings. Also, although the kWh savings are relatively small per warmer, most facilities that have soup warmers have multiple units. With relatively low purchase price compared to other foodservice appliances, this is a product category where a point-of-purchase rebate would be extremely helpful to drive market-wide adoption.

Figure 65: Countertop Baseline Soup Wells

Figure 66: Built-In Baseline Soup Wells

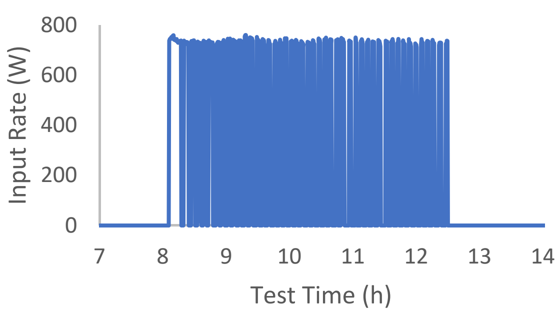

Figure 67: Baseline Resistance Soup Warmer Energy Profile

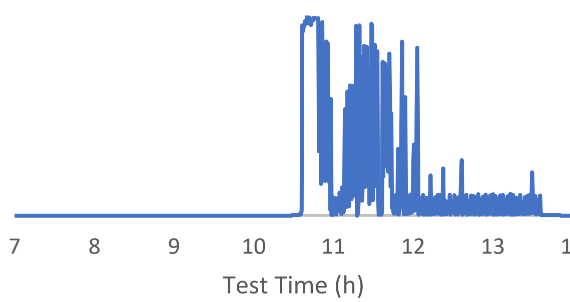

Figure 68: Energy Efficient Induction Soup Warmer Energy Profile

Some induction soup warmers are almost $500 more expensive than conventional models and operators are largely unaware of the benefits associated with induction technology. To achieve a 5-year simple payback time, a soup warmer would need to save 1.8 kWh per day, the potential for which is supported by the results seen from Spreadz. Based on concurrent research being conducted under the scope of the California Energy Commission's *Electric Plug Load Savings Potential of Commercial Foodservice Equipment* (EPC 15-027), an average induction soup well saves 50% of the energy of its conventional counterpart. Thus, soup wells that use more than 3.6 kWh per day can generally be replaced and achieve savings. For 11-quart soup wells, this would mean an average unit operating time of at least 9 hours per day, and for a 7-quart soup well, this would mean an average unit operating time of at least 14 hours per day, using the data from Spreadz as a reference. For sites with long operating hours, significant energy savings are achievable through replacement. Utility-sponsored rebate and early retirement programs would be an effective means for transforming the soup well market. More studies should also be done to quantify how the increase in yield from soup holding in induction wells may shorten the payback period for replacing conventional soup wells.

Table 23: Prices of Various Soup Warmers

Soup Warmers 11-qt	Resistance Coil	Induction
Nemco 6101A	$103	-
Avantco W800	$85	-
APW Wyott RCW-11	$160	-
Wells LLSC11WA-120	$324	-
Vollrath 72009 Cayenne	$255	-
Hatco RHW-1	$437	-
CookTek 676101 Sinaqua	-	$688
Vollrath 74110110 Mirage	-	$487
Average	$227	$588
Difference		*$360*

3. Holding Cabinets

Table 24 summarizes the monitoring completed on holding cabinets at all sites. Holding cabinet replacements have shown promising results with an average energy reduction of 56%. Even the lowest energy saving replacement (at Site A) reduced holding cabinet energy by 48%. Meanwhile, the best performing replacement was at the Plaza Suites, where the switch from the single-door to the double-door insulated unit resulted in 70% energy savings. This replacement was more atypical, since the configuration change allowed the site to significantly alter their holding cabinet usage. The replacement done at Site F was more standard and involved no changes in operator behavior, but still resulted in a substantial 56% reduction in energy. Cook and hold units unfortunately do not seem to have the same energy saving potential, as the replacement with the top-of-the-line Cres Cor unit did not yield any energy savings.

Table 24: Holding Cabinet Monitoring Summary

Site	Facility Type	Equipment	Door Type	Energy Use (kWh/day)	Operating Span (h)
Site A	Corporate Cafeteria	Cres Cor H135S	solid	8.24	8.96
Site A	Corporate Cafeteria	Cambro PCUH	solid	4.31	8.34
Site F	Full Service Rest.	WinHolt INHPL	glass	11.03	10.98
Site F	Full Service Rest.	Vulcan VBP18	solid	4.84	12.54
Site B	Corporate Cafeteria	Wittco 1000-IS*	solid	8.09	9.69
Site B	Corporate Cafeteria	Cres Cor CO-151*	solid	8.49	8.49
Plaza Suites	Hotel	Carter Hoffman FH90	solid	3.85	3.79
Plaza Suites	Hotel	Cambro PCUH	solid	1.15	3.77

*Cook and Hold unit used mostly in holding mode.

While glass doors offer visibility and convenience for staff, it is a poor insulator. Glass-door holding cabinets typically use 80 to 105% more energy than solid door holding cabinets.

Table 25: Energy Usage Comparison of Baseline and ENERGY STAR Holding Cabinets

Holding Cabinets (23-ft^3)	Solid Door	Glass Door
Baseline Energy Usage (W)	387	711*
ENERGY STAR Energy Usage (W)	264	477**

*https://fishnick.com/publications/appliancereports/holdingcabinets/Vulcan_VHFA18-1_Holding_Cabinet_sr.pdf
**Out of 117 holding cabinets listed in ENERGY STAR, only 1 had glass doors (249W, 12-ft^3) normalized per 23-ft^3

Kitchen staff generally appreciate the ability to view inside a holding cabinet without having to open the door. A common misconception is that the energy difference would be mitigated by more frequent door openings of solid-door units. However, the insulative difference between glass and solid doors is commonly underestimated. Field testing confirms the energy penalty associated with glass-door holding cabinets overshadows the energy associated with more frequent door openings of solid door units. Plastic is also a better insulating material than insulated stainless steel, giving the Cambro units an advantage over the stainless holding cabinets at Site A and Plaza Suites.

One strategy that helped reduce the energy consumption was to utilize stacked half-size cabinets in place of a single full-size unit. Having separate cavities allows operators to designate a primary and peak-use cavity and a secondary back up cavity. The primary cavity was used most of the day and the secondary cavity was turned on during busy periods that required additional capacity. This strategy is expected to work well at the other sites that conduct catering activity with effective staff training that reinforces turning off the secondary cabinets during slow periods. Furthermore, it is often seen that staff uses holding cabinets for cookware storage, so having one compartment that is not actively heated allows them to do so without wasting energy.

Figure 69: Baseline Single Compartment Holding Cabinet

Figure 70: Replacement Dual Compartment Holding Cabinet, Only Top Compartment Heated

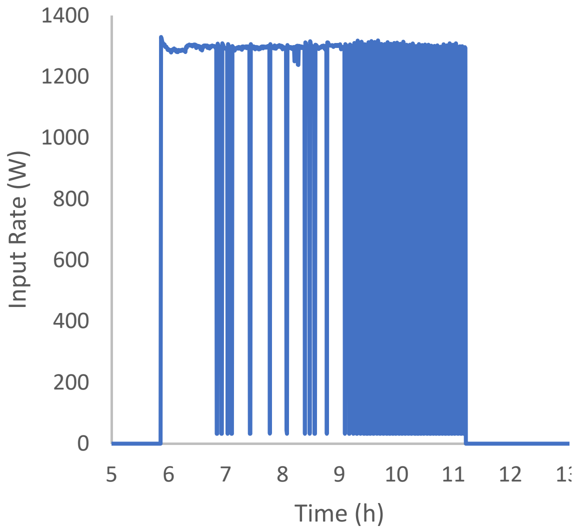

Figure 71: Baseline Holding Cabinet Single Door Full Size

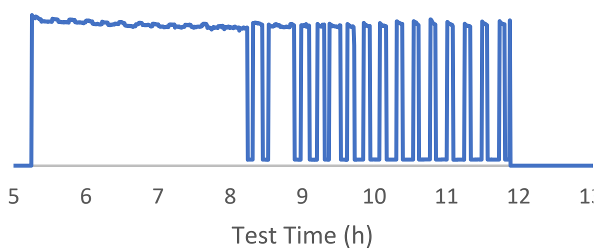

Figure 72: Replacement Plastic Insulated Holding Cabinet Top Compartment

Table 26: Prices of Various Holding Cabinets

Full Size Holding Cabinets	Baseline	Efficient
Avantco HEAT-1836 Glass Door	$849	-
Avantco HPI-1836 Glass Door	$1149	-
Vulcan VHFA18 Glass Door	$2777	-
Winholt NHPL-1836 Glass Door	$1049	-
Winholt INHPL-1836 Glass Door	$1359	-
Metro C549 Dutch Door	-	$3399
Metro C569 Dutch Door	-	$4099
Cres Cor H-137 Dutch Door	-	$4499
Cres Cor H-339 Double Stacked	-	$3979
Cambro PCUHH615	-	$4420
Vulcan VBP15	-	$4035
Average	$1,437	$4,072
Difference		*$2,635*

Conclusions and Recommendations

The research team monitored 52 individual pieces of equipment representing 19 different appliance types at 10 site locations. The locations provided a diverse cross-section of the foodservice market section, each site with their own unique set of operating characteristics ranging from small cafes to large cafeterias. Equipment replacements were carried out for 12 pieces of baseline equipment. Energy savings were achieved for all replacements except for the cook and hold oven and the rapid cook oven, though the latter at least provided the opportunity for menu expansion.

The most significant and repeatable energy savings came from the holding cabinet replacements, where improved insulation reduced heat loss and significantly lowered the energy required to maintain holding temperature. Conveyor toaster replacements also resulted in significant kWh/day savings despite only reducing baseline energy use by 14%, since conveyor toasters are such energy intensive appliances. The energy savings can vary substantially depending on the conveyor toaster's idle time, since the energy reduction is proportional to the time the toaster can spend in its setback mode. In contrast, the soup warmer replacements reduced energy use by a large percentage, but the total energy savings in terms of kWh/day were still low. Though a standalone soup well does not use a large amount of energy on its own, most facilities utilize multiple units to offer a wide variety of soups. Large quantities of soup wells can cause potential savings for the product category to add up significantly. Frontier Energy recommends an early-retirement program for conveyor toasters to be replaced with automatic setback mode toasters as well as point-of-purchase incentives for induction soup wells and efficient hot-food holding cabinets.

Table 27 presents the average baseline and replacement energy usage and hours of operation of each appliance type. Please note that the replacement data presented is the average savings across all replacements in comparison to their baselines, but not every baseline unit was replaced. Also, the oversized baseline conveyor toaster from Site E was omitted from the average.

Table 27: Average Energy Used Per Day by Appliance Type

Equipment Type	Baseline or Replacement?	Number Monitored	Energy Use (kWh/day)	Operating Span (h)	Energy Savings (kWh/day)**	Energy Savings (%)**
Conveyor Toaster	Baseline	4	14.45	9.02		
Conveyor Toaster	Replacement	3	12.40	8.95	1.95	14%
Soup Well	Baseline	3	0.80	2.80		
Soup Well	Replacement	2	0.49	3.23	0.40	44%
Holding Cabinet	Baseline	5	8.71	7.86		
Holding Cabinet	Replacement	3	3.43	8.22	4.28	56%
Panini Press	Baseline	6	4.56	5.57		
Rapid Cook Oven	Baseline / Replacement*	1	12.81	6.2	N/A	N/A
Rapid Cook Oven	Baseline	2	19.67	11.55		
Cook and Hold	Baseline	1	8.09	8.62		
Cook and Hold	Replacement	1	8.49	8.49	N/A	N/A
Countertop Oven	Baseline	1	5.55	12.84		
Induction Cooktop	Baseline	1	4.50	8.95		

Espresso Machine	Baseline	2	20.01	24	
Coffee Brewer	Baseline	1	11.87	24	
Heat Lamp	Baseline	1	2.18	9.00	
Heat Strip	Baseline	1	1.42	9.08	
Heated Shelf	Baseline	4	4.04	7.43	
Hot Well	Baseline	3	8.90	10.12	
Pop-Up Toaster	Baseline	1	0.86	1.73	
Waffle Iron	Baseline	2	8.72	9.69	
Rice Cooker	Baseline	2	1.85	9.89	

*Process change, see Site D Section

**Energy savings calculated using average baseline energy from replacement sites only

The most energy-intensive appliance category in this study was the espresso machine, followed closely by the rapid cook oven, both consuming approximately 20 kWh per day. These appliances exhibited significantly higher usage through the day than the other plug load appliances selected for the study, representing strong energy saving opportunities.

The two espresso machines monitored were the main appliance used at the coffee shop sites – virtually every customer who entered the store purchased a beverage that was prepared using the espresso machine. Even though the machines had long operating hours, the idle energy rates of the baseline machines were comparatively low, offering little opportunity for energy reduction from replacement alone. Replacements are also less feasible for specialty coffee shops like the ones monitored, since the espresso machine is often a centerpiece that is specifically chosen to meet the needs of the store. The best energy solution is to instead install a timer control which would automatically turn the machine off at night and back on before the start of service, eliminating overnight energy use and potentially saving up to 30% of total energy use. However, end users are reluctant to install aftermarket controls on their expensive coffee equipment and dissuaded by the persistent myth that turning espresso machines on and off may decrease their lifespan. Despite conversations about the lack of evidence supporting this myth, both coffee shops monitored decided not to install the automatic timer controls. More research needs to be done to quantify the energy savings from nightly shutoffs for espresso machines, paired with research on how the practice affects equipment longevity.

The baseline rapid cook oven monitored had similarly high energy use and throughput. Rapid cook ovens represent a unique appliance that offers flexibility and speed in a small footprint. This is achieved at the cost of a higher energy intensity. There is currently no feasible alternative that offers the same combination of speed and versatility at a significantly lower energy footprint. The rapid cook oven that replaced the panini press used almost 25% more energy than the baseline appliance. However, the rapid cook oven allowed the site to offer five new products that they had not been able to produce with their previous equipment. This added versatility suggests that a rapid cook oven could potentially replace multiple pieces, reducing kitchen footprint and saving energy in select replacement situations. Additional research in this area is highly recommended, especially with the recent trend towards smaller and more flexible kitchens. Situations in which rapid cook ovens can be used to save energy are more complex and may involve integrating process changes to maximize the energy savings potential of the technology. In a simple one-for-one replacement, a rapid cook oven will not likely save energy.

The most favorable, utility-actionable savings results came from the conveyor toaster replacements. These replacements yielded an average savings around 2 kWh per day. For a site that operates seven days per week, this translates to $110/year in utility savings when using the average national electrical rate of $0.15 per kWh. Due to the relatively small price point difference between conveyor toasters with setback mode capabilities and conventional models($1220 vs $820 for 120V and $1390 vs $1280 for 208V), the simple payback time on the incremental cost difference is reasonable. The average payback period would be about four years for a 120V toaster and one year for a 208V toaster, assuming similar energy savings for 208V replacements as exhibited by the project's 120V replacements. The savings for 208V toasters are likely much higher, as exhibited by the 208V toaster energy usage (46.0 kWh/day) at Site E in comparison to the average measured 120V toaster energy usage (14.5 kWh/day). Conveyor toasters have an average working life of about five years, so midlife equipment replacements can make sense for both 120V and 208V toasters. An early retirement program could yield significant energy savings in the commercial foodservice market because of the prevalence of conventional uncontrolled conveyor toasters. Additional research should be conducted to confirm the payback period for 208V conveyor toasters, which represent a strong energy savings opportunity at less than a year.

The holding cabinet replacements also produced favorable savings results, reducing baseline energy use by 56% on average. This is the highest per unit savings of all the equipment categories explored, with replacements saving 4.28 kWh/day on average. However, energy efficient insulated holding cabinet price points all hover around $4,000, while baseline uninsulated clear door cabinets can cost as low as $1,000. Energy savings are possible with utility programs which promote the two-door insulated full-size units monitored in this study. An early retirement incentive should be offered to customers who want to replace glass door units with the more efficient units covered in this study.

While the induction soup warmers showed the least kWh savings per unit in the current study, the results could be more significant for sites with multiple units and longer operating hours. The induction soup warmer saved 44% of the energy used by its conventional resistance element counterpart, but the total energy savings was only a fraction of a kWh per day due to the short operating span of the test site. There is a significant price point difference between electric resistance ($227) and induction soup warmers ($588) – induction units on average cost more than double the price of conventional soup warmers. Sites with longer operating hours could theoretically achieve more favorable paybacks. Due to the increased cost and the relative novelty of the technology, a utility rebate would be needed to realize the potential energy savings for this category. Like conveyor toasters, soup warmers are almost ubiquitous to commercial foodservice facilities in general – full- and quick-service restaurants, cafeterias, grocery stores, and even cafes and delis typically operate multiple soup warmers simultaneously. Utility support would have the added benefit of bringing down the cost of induction cooking appliances by generating demand, which could help more people adopt induction cooktops and ranges.

An important result from the study that supports any replacement programs with the technologies listed above is that there was no negative feedback from any of the sites where replacements were performed, except for the site that received the faulty unit. Operators are typically sensitive to change, and if there's a deviation from what they understand as 'normal' operation, they are usually quick to voice an opinion. From an operator's perspective, the changes to day-to-day operation associated with conveyor toasters with setback modes, modular holding cabinets, and induction soup warmers are not significant, making these technologies low-risk for replacement.

Among the remaining less explored equipment categories in this study, waffle irons and hot wells also exhibited high energy use. Any new energy saving technologies that develop for these product categories should be explored and field tested once available. Induction hot well replacements seem to be currently in development, but new waffle iron technology is still nonexistent.