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FINAL PROJECT REPORT

Electric Plug Load Savings Potential of Commercial Foodservice Equipment

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PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation and bring ideas from the lab to the marketplace. The CEC and the state's three largest investor-owned utilities—Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company—were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The CEC is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Electric Plug Load Savings Potential of Commercial Foodservice Equipment is the final report for the Electric Plug Load Savings Potential of Commercial Foodservice Equipment in Commercial Foodservice project, Contract Number EPC-15-027, conducted by Frontier Energy. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the CEC at ERDD@energy.ca.gov.

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ABSTRACT

Frontier Energy, Inc., the operator of the Food Service Technology Center, worked in conjunction with Pacific Gas and Electric Company and Silicon Valley Power to study the energy load and energy reduction potential of commercial, unhooded electric plug load foodservice equipment.

This project included a market survey, solicitation of test sites, onsite research at a range of commercial foodservice operations to characterize the daily electrical consumption and use of a variety of plug load kitchen equipment, and analysis of collected data. Energy meters were installed at each of 29 test sites to determine electrical consumption. Where opportunities for energy savings appeared present, researchers swapped the baseline plug load equipment with energy efficient replacements.

The results showed that commercial foodservice plug load equipment has a wide range of energy intensity, based on the operation type and hours. Appliance energy use ranged from 20 kilowatt-hours to less than 1 kilowatt-hour. Energy intensive plug load appliances can use more than 7,000 kilowatt-hours per year. Appliances had varying hours of operation, ranging from as little as five hours per day for soup wells to 24 hours per day for espresso machines.

Cumulative energy savings for all plug load equipment can be substantial. The project identified five categories with the highest potential savings as well as several high-energy consuming categories with no energy efficient alternatives available on the market (as of 2019). Restaurant owners were happy with the equipment replacements and often noted better product quality than the previous equipment, but not all categories can generate sufficient savings to justify the cost of early replacement for an individual restaurant owner.

By demonstrating energy saving potential using innovative energy efficient appliance technologies, the data from this project can be used to accelerate the adoption of advanced energy efficient cooking equipment within the commercial foodservice industry.

Keywords: Commercial foodservice equipment, restaurants, conveyor toaster, coffee brewer, cook and hold, cooktop, countertop oven, espresso machine, heat lamp, heated shelf, heat strip, holding cabinet, microwave, panini press, pop-up toaster, rapid cook oven, rectangular heated well, rethermalizer, rice cooker, soda dispenser, soup well, tea brewer, tortilla warmer, waffle iron, baseline, energy-efficiency, energy savings, idle energy use.

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Introduction

Foodservice facilities are the largest energy users in the commercial building sector, consuming as much as five times more energy per square foot than any other type of commercial building. With an estimated 93,300 commercial foodservice facilities operating in California, the total electric load of these establishments approaches 7.36 gigawatt-hours annually.

Electric appliances without dedicated ventilation, commonly referred to as plug load appliances, comprise a substantial portion of commercial foodservice equipment. Though less energy intensive per unit than standard cookline equipment, plug load appliances collectively represent a large energy load in California. However, little is known about the energy use of plug load appliances since they have historically been overlooked during research in favor of larger, more energy-intensive cooking equipment.

With little research into plug load cooking appliance energy usage, there are currently no clear labels to help consumers make educated energy efficient purchasing decisions. Thus, while a few efficient technologies exist, market adoption of them is typically low given the price premiums, lack of research and marketing, and lack of independent confirmation of manufacturer claims. Appliance purchases are driven primarily by initial cost without consideration of potential energy use.

The California Energy Commission funded a comprehensive commercial kitchen plug load equipment study to assess the energy load and energy reduction potential of unventilated commercial plug load foodservice equipment. This study characterizes the energy use of 128 plug load appliances through field monitoring at 29 commercial kitchens in Northern California, demonstrating reduced energy consumption using precommercial appliance designs and control technologies. By demonstrating energy saving potential using innovative energy efficient appliance technologies, the data from this project will be used to accelerate the adoption of advanced energy efficient cooking equipment within the commercial foodservice industry.

Project Purpose

This project quantified the energy use of the various types of commercial foodservice plug load equipment and demonstrated and characterized the energy-savings potential, cost effectiveness, and improved cooking performance of energy efficient plug load equipment when compared with baseline equipment. By sharing this new body of research with manufacturers, utilities, and end users, Frontier Energy aimed to create a business case to expand the creation, incentives, and adoption of energy efficient plug load appliances.

Project Approach

Researchers selected 29 commercial foodservice sites to represent the various facets of the industry: independent quick- and full-service restaurants, quick-service chains, university and corporate dining halls, and hotel restaurants. Researchers established baseline energy consumption by submetering the existing commercial plug load appliances with commercial-grade electric meters. Where energy savings opportunities seemed present, researchers modified or replaced the existing appliances with energy-efficient alternatives. Researchers characterized the resulting plug load energy savings and replacement appliance's effect on restaurant operation, surveying the staff for their thoughts concerning the replacement technology. The research team monitored all appliances for at least two weeks to obtain a reliable energy characterization, and energy data was normalized for hours of operation to mitigate biases from seasonality and fluctuations in business volume. Frontier also conducted laboratory testing to characterize baseline and efficient plug load appliance operation within controlled settings. Findings from this field and laboratory research were integrated with indepth market analyses to determine the strongest energy savings plug load opportunities and total energy savings potential for California.

Project Results

Frontier Energy monitored 91 baseline appliances, analyzed the strongest energy savings opportunities, and made 18 appliance replacements. Some sites were already using energy-efficient appliances, and those were monitored to inform potential savings estimates of baseline appliances. Researchers identified and analyzed 19 of these pre-existing efficient technologies.

The project successfully characterized the energy and operating use of a variety of unhooded commercial plug load appliances, representing a wide range of foodservice applications and use levels. Appliance energy use varied significantly by site and operation type, with hours of operation and appliance settings playing a key role in the energy usage differences across an appliance category. Based on data from direct appliance replacements or extrapolating from efficient equipment data (if no direct replacements were made), researchers estimated savings potential for nine of the 22 appliance categories. The appliances with the strongest energy-saving opportunities were espresso machines, coffee brewers, conveyor toasters, and holding cabinets.

Researchers found that energy-efficient appliances generally produced the same or higher quality food product based on staff interviews. Besides saving energy, efficient appliances increased safety, reduced labor, and sometimes even improved kitchen throughput. Impediments to kitchen productivity and workflow were one of the primary customer concerns around energy-efficient equipment, a concern which this study proved to be nonexistent when the technology is properly applied.

Frontier Energy found that plug load equipment in commercial kitchens demonstrated an average daily energy consumption of 0.6 kWh to 20.4 kWh. The demonstrated appliance savings for efficient replacement ranged from $0 to nearly $600 per unit across the different categories, with the average savings per unit being $200 - $300. The project team recommends additional research to fully explore the energy savings potential of high-opportunity baseline appliances with little or no replacement, such as heat strips and heated wells. Frontier Energy also recommends a dedicated study on rapid cook ovens, which are becoming popular in an evolving foodservice landscape that is trending toward flexible and compact kitchens. Rapid cook ovens are energy-intensive appliances, but their ability to increase throughput and reduce kitchen footprint can create electrical, HVAC, and labor savings when used optimally.

Technology/Knowledge Transfer/Market Adoption

Frontier Energy launched targeted education efforts directed toward foodservice operators/owners, utilities, manufacturers, and equipment vendors. Researchers publicized energy findings and results on the project website, paired with various presentations, classes, and webinars to spread knowledge and direct interested parties to the website for further information. Frontier made key presentations at the Multi-Unit Foodservice Equipment Symposium Conference, the National Restaurant Association show, and in multiple California Energy Wise seminars, among many other efforts. Content for the project has also been publicized through *Foodservice Equipment Reports,* which has run several articles about the project findings and results. The team also created and publicized case studies about the restaurants that featured the best energy-savings stories online.

For consumers, this information is anticipated to generate demand for efficient equipment. By clearly illustrating the potential energy savings, payback periods, and improvements to kitchen quality, Frontier Energy aims to raise awareness and improve customer sentiment toward switching to energy-efficient plug load equipment. For utilities, the goal is to showcase the potential energy savings, spurring them to continue to spread the information and possibly create rebate programs to make energy-efficient replacements more accessible. For manufacturers, researchers aim to provide motivation to increase the supply of energy-efficient equipment and spur market change. This report provides valuable marketing material by which manufacturers can show the potential savings to raise customer demand for their efficient products. This same marketing benefit is directed toward the equipment vendors, to encourage them to stock and promote energy-efficient products more frequently.

Benefits to California

This project demonstrated the energy-savings potential and cost effectiveness of energy-saving technologies in plug load equipment and the behavioral changes necessary to maximize the effectiveness of those technologies. The research will increase the availability of energy-efficient appliances from equipment vendors, drive the creation of more efficient equipment from manufacturers, increase the demand from foodservice operators, and make the replacement opportunities more accessible and enticing with possible rebate incentives from utilities. For ratepayers, this means improved availability, awareness, and possibly better pricing for energy-efficient equipment. These characteristics could save as much as $1,290 in annual energy costs for a single plug load appliance, with savings ranging between -6 percent and 69 percent for replacements. Average payback for the efficient plug load appliances ranged anywhere from immediate to 30 years, varying significantly by use case and appliance category. Frontier Energy projected the total current energy-savings potential of efficient plug loads to be about 51 gigawatt-hours per year given the examined market and energy data, and new technology adoption rates to be between 5 percent and 20 percent.

CHAPTER 1: Introduction

Background

Foodservice facilities are the largest energy users in the commercial building sector, consuming as much as five times more energy per square foot than any other type of commercial building. Foodservice facilities can be found in several commercial building types: large office, restaurant, retail, grocery, school, college, health, and lodging, with an estimated 93,300 commercial foodservice (CFS) facilities operating in California.

Electric appliances without dedicated ventilation, more commonly referred to as plug load appliances, comprise a substantial portion of CFS equipment. Plug load appliances are commonplace, but the individual energy use for these appliances is not always significant enough for a business owner to consider the most energy efficient options. However, small savings from each plug load appliance can add up to a large energy-saving opportunity for the State of California if implemented on a large scale.

CFS is a market sector in which strategic improvements in appliance design could result in significant energy savings and emission reductions. However, heavy competition among manufacturers for market share within a typically frugal industry has emphasized production of inexpensive equipment rather than energy efficient equipment. CFS operators have also been slow to adopt high-efficiency electric foodservice equipment, despite high operating costs and the large number of facilities operating in the state. Appliance purchases are driven primarily by initial cost without consideration of potential energy use. While a few efficient technologies exist, market adoption is typically low given the price premiums and lack of research/marketing to promote advancements in the field. Plug load appliances have historically been overlooked and under-researched in favor of larger, more energy intensive cooking equipment. With little research into plug load cooking appliance energy usage, there are currently no clear labels to help consumers make educated energy efficient purchasing decisions.

The California Energy Commission funded a comprehensive commercial kitchen plug load equipment study to assess the energy load and energy reduction potential of unventilated commercial plug load foodservice equipment. This study characterizes the energy usage of 128 plug load appliances through field monitoring at 29 different commercial kitchens in Northern California, demonstrating reduced energy consumption using pre-commercial appliance designs and control technologies. By demonstrating energy saving potential using innovative energy efficient appliance technologies, the data from this project will be used to accelerate the adoption of advanced energy efficient cooking equipment within the CFS industry.

Objective

The overall goals of this project were to quantify the energy use of the various types of CFS plug load equipment and demonstrate and characterize the energy saving potential, cost effectiveness, and improved cooking performance of energy efficient plug load equipment when compared with baseline equipment. As an under-researched appliance type, the monitoring of unventilated plug loads will guide the creation of a new research database for appliances in this category. With this new body of research, Frontier Energy aims to create a business case for the kitchen design community to overcome the market barriers of energy efficiency measures and provide incentives for the development of new energy efficient equipment. With increasing customer awareness and growing energy efficient inventory, Frontier Energy hopes to facilitate a paradigm shift away from low efficiency equipment purchases toward higher efficiency purchases.

Frontier Energy will provide the results from this study to equipment manufacturers, corporate and independent end users, and utilities. Plug load equipment manufacturers will learn which plug load appliances have the greatest energy-saving potential, along with how their equipment is currently being used. Manufacturers can then determine what improvements they can make to their products to reduce energy without sacrificing performance, thereby increasing the inventory of energy-efficient products. End users will discover new energy-saving solutions they can implement, with a specific cost/benefit analysis that will help them make more informed decisions about their plug load equipment. Utilities will use the findings to determine the energy effect of each appliance category in terms of cumulative kilowatt-hour (kWh) and peak kilowatt (kW) on the grid. The study will recommend ways of reducing plug load energy usage through energy efficient appliance replacement incentives and regulation.

Method

Twenty-nine CFS sites were selected to represent the various facets of the industry: independent quick- and full-service restaurants, quick-service chains, university and corporate dining halls, and hotel restaurants. Researchers established baseline energy consumption by submetering the existing commercial plug load appliances with commercial-grade electric meters. Where there was a potential energy saving opportunity, the existing appliances were replaced with equipment featuring energy saving technologies. Researchers characterized the resulting plug load energy savings and replacement appliance's effect on restaurant operation, surveying the staff for their thoughts concerning the replacement technology. All appliances were monitored for at least two weeks to obtain a reliable energy characterization.

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 (Figure 1). 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 percent measurement accuracy and a measurement resolution of 0.00001 Watt-hour (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 Continental Control Systems 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 (Figure 2). These setups consisted of appropriately sized current transformers paired with either a DENT ELITEpro Energy Meter Data Logger or a Continental

Control Systems Wattnode Pulse Meter and Onset HOBO Pulse Logger combo. Both featured 0.5 percent measurement accuracy, with a resolution minimum of 1.25 Wh.

Figure 1: In-Line Plug Load Meters Installed at Chipotle

Source: Frontier Energy, Inc.

Figure 2: In-Panel Electrical Metering Setup with DENT ElitePro Logger at Mills College

Source: Frontier Energy, Inc.

Researchers collected energy data from the loggers on a bi-weekly 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 graphs 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. Energy data was normalized for hours of operation to mitigate biases from seasonality and fluctuations in business volume. Frontier also conducted laboratory testing to characterize baseline and efficient plug load appliance operation within controlled settings. Findings from this field and laboratory research were integrated with in-depth market analyses to determine the strongest energy saving plug load opportunities and total energy saving potential for California.

A technical advisory committee (TAC) was also formed from various utility heads, energy experts, and key manufacturing and industry figures to support the successful implementation of the project. TAC meetings were held once a year to evaluate the progress of the project, validate methods, scrutinize results, and provide suggestions and feedback.

CHAPTER 2:
Project Approach and Market Evaluation

Project Approach and Verification

Frontier Energy characterized the savings potential of commercial kitchen plug loads via through two main avenues, market analysis and energy data collection. Frontier conducted market analysis by gathering information from existing research databases and conducting an extensive survey effort including both in-person and online surveys. Frontier collected energy data by working with various foodservice operators to monitor the energy use of both baseline and efficient appliances, as used to support the normal foodservice operation. Researchers also worked with equipment manufacturers to conduct energy testing for appliances under standardized laboratory conditions.

Frontier Energy's energy analysis work was verified for accuracy by ADM Associates, Inc (ADM). To confirm the validity of the methods and data of the Frontier Energy team, ADM visited several foodservice sites where Frontier was conducting energy research to verify the operation of the monitoring equipment (Table 1). At these sites, ADM verified the correct installation of the monitoring equipment and quality checked the data collection equipment. During the site visits, ADM conducted one-time power measurements using an AEMC 3910 True RMS power meter to validate the measurements of Frontier's various energy monitoring equipment. ADM confirmed the measurement accuracy of Frontier's monitoring equipment at these various site visits, noting that the readings across ADM's and Frontier's meters were consistent.

ADM also conducted a parallel data analysis to confirm Frontier's data analysis methods (Table 2). ADM requested the baseline and replacement data for four separate appliance replacements and analyzed the resultant savings individually from Frontier Energy. The resultant energy savings between the ADM and Frontier analyses for the same data sets were similar enough to confirm validity.

Table 1: ADM Analyzed Appliances for Data Validation

Site	Appliance Type	Meter Type	Recording Interval	Baseline Monitoring Dates	Replacement Monitoring Dates
Café/Bakery	Toaster	Dent ELITEpro SP Logger	1-Minute	9/16/16 – 11/1/16	3/17/17 – 5/5/17
Mills College	Soup Warmer	HOBO Plug Load Data Logger	1-Minute *	9/2/16 – 12/15/16	9/21/17 – 11/14/17
Caffé 817	Soup Warmer	HOBO Plug Load Data Logger	30-Second	12/13/16 – 1/13/17	10/2/17 – 1/5/18
Caffé 817	Cooktop	WattNode with Hobo Pulse Logger	30-Second	11/16/16 – 12/8/16	3/8/17 – 4/20/17

*** The post-period data were recorded in 30-second intervals.**

Source: Frontier Energy, Inc.

Table 1: Energy Analysis Validation

Calculated Annual Energy Use (kWh)	Café/Bakery (Toaster)		Mills College (Soup Well)		Caffé 817 (Soup Warmer)		Caffé 817 (Hotplate)	
	Base-line	Effi-cient	Base-line	Effi-cient	Base-line	Effi-cient	Base-line	Effi-cient
Frontier Energy	19,022	16,240	332	301	291	161	6,459	2,551
ADM	19,110	16,800	331	303	304	160	6,490	2,577
Difference (%)	0.46%	3.33%	0.30%	0.66%	4.28%	0.63%	0.48%	1.01%

Source: Frontier Energy, Inc.

Plug Load Market Characterization and Potential

To better understand the quantity of plug load cooking and warming appliances installed throughout California, researchers conducted plug load inventory surveys at nearly 200 different foodservice facilities. Surveys focused on identifying the various appliance types, estimating the quantity of the installed base, documenting hours of operation, and establishing customer sentiment regarding preexisting plug load equipment usage and cost and interest in available energy efficient options. Survey respondents were curated to represent the full range of the foodservice industry, with at least 25 respondents each in QSR, full-service restaurant (FSR), institutional dining facility, and commercial cafeteria.

Surveys were conducted via two methods: online and in person. The online surveys conducted by Opinion Dynamics consisted of approximately 30 questions and were designed to take 5 to 10 minutes for operators to complete. Foodservice sites were selectively invited to participate in the survey, with more than 150 total respondents. In-person surveys conducted by Frontier Energy researchers at 50-plus foodservice sites recorded the type and quantity of the various plug load appliances at each facility and included staff interviews about the hours and usage of the different equipment. A portion of the in-person surveys were paired with baseline energy monitoring on sample appliances, providing energy usage data over a period of at least two weeks.

During data analysis, researchers noticed significant discrepancies between the quantitative data gathered from the online surveys and in-person surveys. The average inventory of plug load cooking and warming equipment observed during in-person surveys was 11 appliances per site, which was less than half the estimated quantity from the total aggregate online survey data. This discrepancy indicates the presence of unreliable or overstated quantities from the online surveys. Given the higher level of oversight and expertise associated with the in-person surveys, Frontier Energy researchers concluded that the data collected directly while on site was more representative and should be used as the basis for energy modeling analysis. While the qualitative data gathered from the online surveys provided valuable insights into customer perceptions, the quantitative data is likely inaccurate. Given the lack of consistent terminology used to describe equipment within the foodservice industry, it is possible that the online survey respondents may have had difficulty accurately filling out the equipment inventory numbers without additional guidance.

From the aggregated (online and in-person) survey results, researchers determined several distinct plug load equipment types that were most commonly found in CFS facilities. Survey results were categorized into these different groupings, extrapolating to create an average plug load inventory estimate for CFS facilities in California (Table 3). The estimated number of CFS locations was taken from the *2010 North American Association of Food Equipment Manufacturers (NAFEM) Size and Shape of the Industry Study* and multiplied with the average plug load quantities derived from the market surveys for each appliance type.

Table 3: Plug Load Appliance Inventory Findings

Appliance Type	Average Number of Units per Store	Estimated Total Inventory in California	Percent of Stores with Plug Load Appliance
Toaster (Non-Conveyor)	0.45	42,067	29%
Toaster (Conveyor)	0.29	27,435	29%
Strip Heater	1.13	106,082	39%
Cooktop	0.08	7,316	4%
Rice Cooker	0.33	31,093	18%
Soup Warmer	1.05	98,766	45%
Coffee Brewer	0.88	82,305	71%
Tea Brewer/Hot Water	0.55	51,212	49%
Espresso Machine	0.29	27,435	27%
Holding Cabinet	0.43	40,238	20%
Tortilla Warmer	0.10	9,145	6%
Hot Food (Steam) Well	1.88	175,584	59%
Sandwich Press	0.41	38,409	24%
Waffle Iron	0.20	18,290	16%
Microwave	0.35	32,922	29%
Countertop Oven	0.20	18,290	18%
Miscellaneous (Other)	2.29	213,993	59%
Total		1,020,582	

Source: Frontier Energy, Inc.

The in-person survey results were combined with the energy monitoring results throughout the study to estimate the overall energy load associated with various plug load cooking and warming equipment. The energy load of the miscellaneous equipment found during the kitchen surveys was approximated as the average energy load of the four appliance types (cook and hold, heat lamp, heated shelf, and soda dispenser) monitored during the study that didn't fall under the previously defined largest categories.

Frontier Energy analyzed the in-person survey data results to estimate that more than 1 million plug load appliances are currently in use in the State of California, across more than 93,000 foodservice facilities. Based on the market survey results, the revised estimate of plug-load cooking and warming energy use in California is close to 2.2 terawatt-hour (TWh) per year (Table 4). This research substantiates the significant energy impact of electric plug load appliances.

Table 4: Revised Plug Load Cooking and Warming Equipment Energy Use Estimates

Appliance Type	Average Measured Energy Use (kWh/d)	Estimated Total Inventory in California	Estimated Annual Energy Use (TWh/yr)
Toaster (Pop-Up)	0.6	42,067	0.01
Toaster (Conveyor)	19.6	27,435	0.20
Strip Heater	13.5	106,082	0.52
Cooktop	18.2	7,316	0.05
Rice Cooker	1.7	31,093	0.02
Soup Warmer	0.8	98,766	0.03
Coffee Brewer	9.1	82,305	0.27
Tea Brewer/Hot Water	1.9	51,212	0.04
Espresso Machine	13.1	27,435	0.13
Holding Cabinet	8.1	40,238	0.12
Tortilla Warmer	6.3	9,145	0.02
Hot Food (Steam) Well	5.3	175,584	0.35
Sandwich Press	7.7	38,409	0.11
Waffle Iron	8.7	18,290	0.06
Microwave	3.6	32,922	0.04
Countertop Oven	4.8	18,290	0.03
Miscellaneous (Other)	2.6	213,993	0.20
Total		1,020,582	2.19

Source: Frontier Energy, Inc.

Energy Efficient Equipment and Operator Sentiment

Through Opinion Dynamics, Frontier Energy researchers also conducted an online survey of operator sentiment on various plug load equipment types and energy efficient alternatives. Most operators interviewed expressed interest in the idea of energy efficient plug load equipment, but overall adoption of available technologies has been low for numerous reasons.

The survey results indicated a high need for education on the energy consumption, performance, and benefits of the different types of plug load equipment. Based on the preliminary responses, many operators consider all plug loads appliances to have nearly the same utility costs and will often select an appliance simply based on initial price. Only about 15 percent of the survey respondents noted product quality as a consideration when purchasing plug load cooking and warming equipment, a judgment fueled by the notion that plug load appliances have relatively short life spans and provide interchangeable performance quality. Most respondents believed that the plug load equipment would last less than seven years, with a sizable portion believing the equipment would not even last five years (Table 5).

Table 5: Operator Estimated Equipment Life Expectancy

Plug Load Equipment Type	Life Expectancy		
	Less than 5 years	5 to 7 years	More than 7 Years
Toaster (non-conveyor) (n=138) *	43%	34%	23%
Toaster (conveyor) (n=130)	38%	33%	29%
Strip Heater (n=127)	36%	33%	32%
Cooktop (n=136)	36%	34%	30%
Rice Cooker (n=122)	32%	41%	27%
Soup Warmer (n=138)	32%	39%	29%
Coffee Brewer (n=153)	39%	33%	28%
Tea Brewer/Hot Water (n=143)	34%	35%	30%
Espresso Machine (n=127)	38%	39%	22%
Holding Cabinet (n=135)	30%	34%	36%
Tortilla Warmer (n=118)	41%	28%	32%
Hot Food (Steam) Well (n=123)	29%	40%	31%
Sandwich Press (n=131)	37%	33%	29%

***Note: n = number of surveyed responses**

Source: Frontier Energy, Inc.

About half of the survey respondents were unaware of any energy efficient options within this class of cooking and warming equipment. The most commonly available equipment choices at the foodservice equipment dealers are the standard (baseline) options, with efficient models requiring a special order. Operators commented that their local dealers didn’t offer any different model options when selecting equipment, leaving price and brand as the most important factors (Table 6). Without information on the benefits of selecting more efficient equipment, there is no motivation to learn about different options. Frontier Energy researchers aim to conduct further surveys with foodservice equipment dealers to confirm model selection availability and raise awareness of the possible issues.

Among the operators who were previously aware of energy efficient plug load options, the sentiment is split. About 40 percent of correspondents replied that they would purchase an energy efficient model even without any additional incentives, believing it would still save them money over the lifespan of the purchase. However, about 20 percent of correspondents replied that they wouldn't purchase energy efficient plug load equipment even if there was no additional cost (full rebate), believing their current equipment to be more reliable and of better performance quality than the efficient options. The industry still equates energy efficient equipment with poor performance.

Table 6: Operator Reasons for Not Adopting Energy Efficient Equipment

Issue	Detailed Reasons	% of Respondents*	
		Identified as Barrier	Topic Total
Financial Concerns	Energy efficient equipment is too expensive	32%	78%
	We are not sure if the electric bill savings would justify the higher cost of energy efficient equipment	26%	
	We lack access to financing or capital to fund energy efficient equipment	21%	
Product Awareness & Availability	We are not aware of the energy efficient equipment options	21%	41%
	Energy efficient equipment is not readily available	20%	
Product Performance	We are not sure how well the energy efficient equipment would perform	34%	35%

***Note: percentages do not sum to 100 for multiple response questions**

Source: Frontier Energy, Inc.

While operators expressed interest in energy efficient options, most of the survey respondents first listed cost as being one of the primary barriers to investing in energy efficient plug load equipment. With upfront cost a large deterrent, most respondents stated that they would require payback periods of a year or less to consider purchasing energy efficient plug load equipment. The limit for an acceptable payback period was two years for most operators; less than 10 percent of respondents indicated they would be willing to accept longer payback periods (Table 7).

Table 7: Operator Perceptions on Financial Payback on Investment in Energy Efficient Plug Load Equipment

Minimum Payback Period Necessary	% of Respondents	
	For Replacing Failed Equipment	For Replacing Still Operational Equipment
I would not need a payback on energy savings	9%	12%
6 months or less	31%	25%
6 months to 1 year	35%	40%
1 to 2 years	17%	15%
2 to 3 years	4%	5%
More than 3 years	4%	3%

Source: Frontier Energy, Inc.

Market Conclusions

Research results indicate that plug load cooking and warming equipment represents a significant energy load in California. Across all California's foodservice establishments, there are roughly 1 million plug load cooking and warming appliances operating on CFS facilities, consuming an estimated 2.2 TWh per year in energy. Most plug load cooking and warming equipment is considered a short-term investment with anticipated life expectancies of less than five years. With a general lack of the energy loads and performance benefits of advanced plug load equipment, operators are primarily motivated to purchase the least costly units available.

The initial survey results indicated a tendency among operators to equate the energy effect of different types of equipment, with little regard to actual usage patterns. In the absence of reliable energy consumption and performance information on plug load cooking and warming equipment, it is difficult for operators to ascertain which types of equipment would warrant a higher investment in new technologies. Education on the energy usage and performance benefits of various types of equipment is necessary to affect change in market behavior.

Further research on appliance inventories via in-person surveys is recommended to gather accurate data and improve the energy consumption estimates. This will help to prioritize which equipment offers the greatest energy reduction potential and to focus efforts on highlighting the most promising new technologies by assessing the overall market potential. There are significant opportunities to reduce overall plug load energy consumption using available technologies.

To harness this potential, the primary barriers that need to be overcome are cost and lack of consumer awareness. Nearly half of survey respondents knew little about the energy efficient options available to them, so increased marketing publicity could nearly double the potential market. Equipment distributors should be involved in publicizing energy efficient offerings, since they are often a foodservice facility's primary source of information when making equipment purchasing decisions. To alleviate initial costs and gain widespread adoption, a rebate program offering payback periods of less than two years is necessary, with a payback period of less than one year being preferable.

Appliance Field Analysis

Frontier Energy characterized the energy consumption of 129 plug load appliances across 22 different appliance types and within 29 different CFS sites. The observed plug load appliances fell into three main functional categories: beverage, heating, and holding. This section will primarily discuss the plug load appliances where there exists a point of comparison between an initial and replacement arrangement. The complete appliance data can be found in Appendix C.

Beverage

Beverage equipment that functions to heat or cool drinks is ubiquitous to cafés and restaurants. This study focuses on beverage heating, which is essentially a plug load water heater. All beverage equipment selected for this study has a water heating tank with a resistance element. The primary energy drivers are the volume, temperature, and the duration of the heating period of the heating tank.

Tank volume depends on the number of customers served; it is more efficient to heat one large tank than several small ones of the same combined volume, due to lower surface area to volume ratio. The surface area of the tank is not always insulated, as with espresso machines, and sometimes is poorly insulated in the case of coffee brewers. Quality insulation is relatively inexpensive and can greatly reduce energy usage; however, it reduces service access to certain components for repair.

Water heating temperature depends on the beverage type, with coffee brewer tanks operating close to 200°F (93°C) and espresso machines at 230°F (110°C) with high pressures for steam generation. Tea brewers usually operate at lower temperatures, 160 to 180°F (71 to 82°C), for brewing. Certain models of espresso machines have several tanks kept at different temperatures to keep coffee extraction temperature fluctuations to a minimum throughout a dispensing cycle. Hot water is heated before the coffee is extracted, but post-extraction coffee is usually unheated and is kept in well insulated air-pot containers. In the case of iced tea, the post-extraction hot tea is usually dispensed in a metal container full of ice.

Appliance monitoring efforts were focused on three beverage equipment types: coffee brewers, espresso machines, and tea brewers. Of the three equipment types, espresso machines used the most energy on average (Table 8 and Figures 3 and 4). Researchers found that beverage equipment was often never turned off and left on throughout the night in a constant ready-to-use mode. This wasted nighttime energy could be saved by installing a timer mechanism to turn the equipment on or off at certain time periods or put it into an energy saving mode. Behavioral changes in operation such as having the staff power the equipment on or off when they arrive or leave would greatly reduce energy, but this may not always be an option because of the relatively long preheat time (10 – 30 minutes). The automatic energy saving mode is also typically more effective because it doesn’t rely on operator compliance.

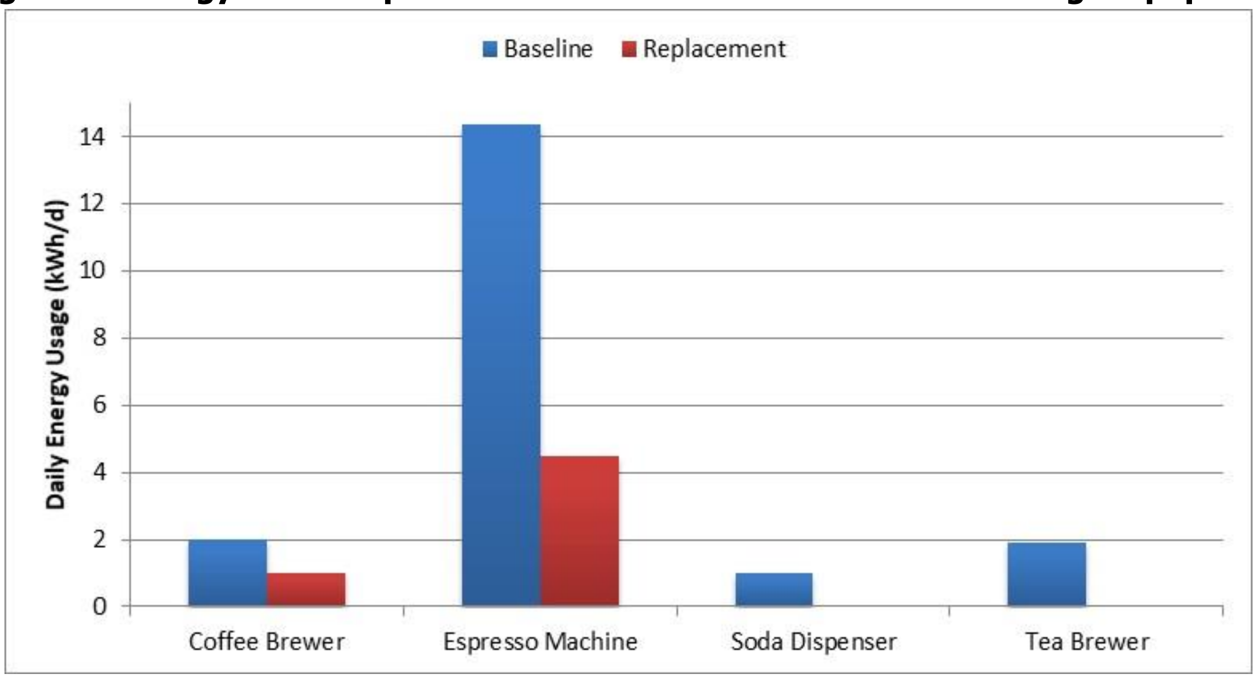
Since coffee brewers and espresso machines have sizeable idle rates, reducing this overnight energy can result in energy reductions of more than 50 percent. Savings are greater for shops with shorter operating hours, since there is more idle energy that can be eliminated. Tea brewers can also reduce their energy use by a significant percentage, but the total savings are lower because they are less energy intensive.

Table 8: Energy Use of Commercial Foodservice Beverage Equipment

Appliance Type	Baseline or Replacement?	Number of Appliances Monitored	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)	Direct Replacement Savings (%)
Coffee Brewer	Baseline	7	9.1	12.7	0.71	55.3
	Replacement	2	1.0	8.0	0.18	
Espresso Machine	Baseline	6	13.1	13.4	0.98	68.7
	Replacement	1	4.5	10.0	0.45	
Tea Brewer	Baseline	3	1.9	13.7	0.14	N/A

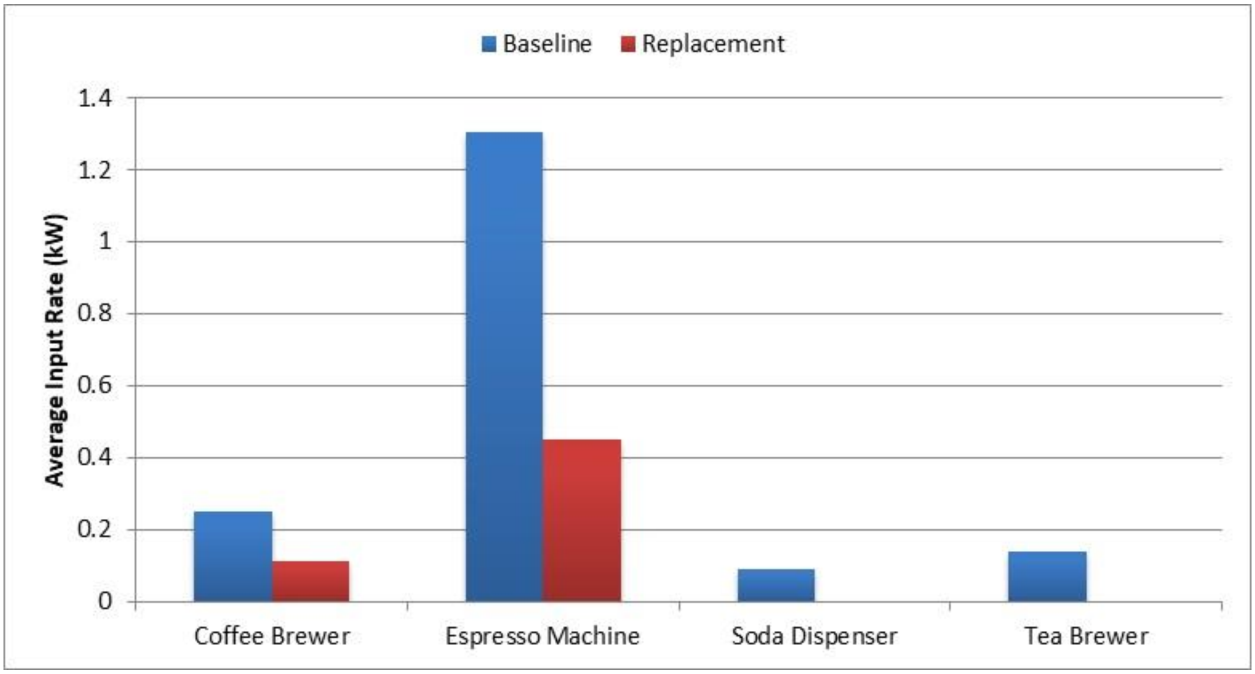
Source: Frontier Energy, Inc.

Figure 3: Energy Use Comparison of Commercial Foodservice Beverage Equipment



Source: Frontier Energy, Inc.

Figure 4: Average Input Rate Comparison of Commercial Foodservice Beverage Equipment



Source: Frontier Energy, Inc.

Coffee Brewer

Coffee brewers are one of the most ubiquitous appliances found in restaurants due to high demand, ease of service, and sizeable profit margin. Researchers monitored coffee brewers at six different sites for a total of seven coffee brewers examined during baseline monitoring. Most of these coffee brewers were 1- or 1.5-gallon machines that operated throughout the day but were used most frequently in the morning. Of the seven baseline coffee brewers, Frontier was able to modify two of them to generate energy savings. The coffee brewer at Rebecca Delight Café was reprogrammed to activate its previously unused energy save mode, while the coffee brewer at the FSTC had an external timer installed to automatically turn the machine on or off to match typical business hours.

Rebecca Delight Café

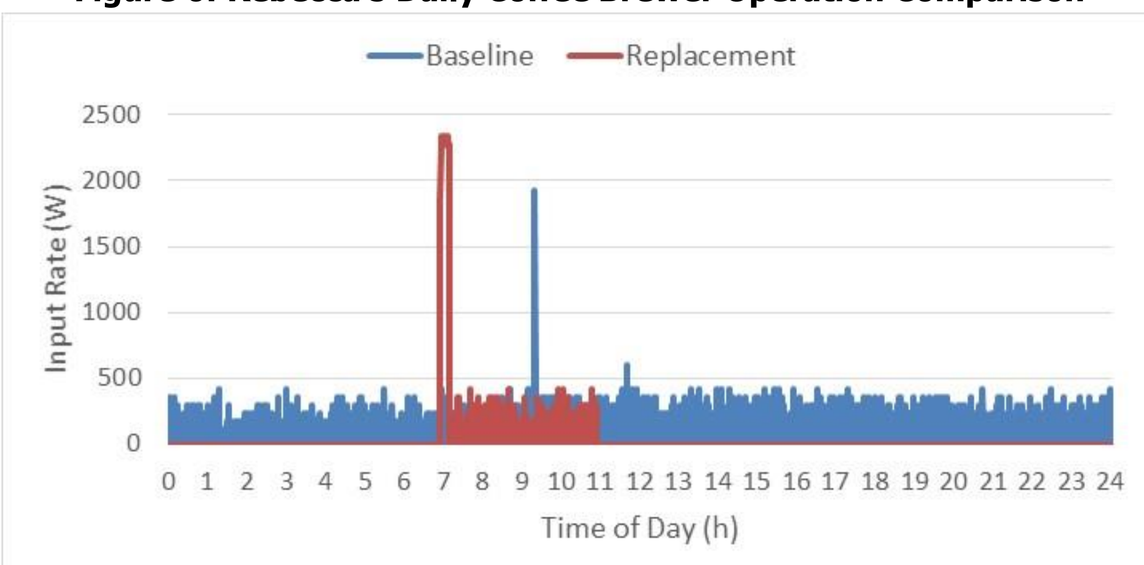
The coffee brewer monitored at Rebecca Delight Café was a Curtis D500GT model, a 120V/1700W single air-pot brewer (Figure 5). For the extent of the café's business, coffee from a single brew cycle usually lasts throughout the day, but the appliance was left on 24/7. The data showed that most of the energy use was due primarily to this idle energy, since the difference between the minimum and maximum daily energy was only about 0.1 kWh (Figure 6). Since the minimum energy use falls on the weekends, when Rebecca's is closed, this indicated that almost all the energy used by the coffee machine was simply idle energy used to keep the coffee brewer in a ready-to-use state. Researchers monitored the coffee brewer for two months and found that the brewer used an average 1.5 kWh per day of electrical energy during an average 8.0 hours of store operation.

Frontier Energy then activated the coffee brewer's previously unused energy save mode. The energy save mode significantly lowered the energy consumption when the brewer was not actively being used, which was most of the time since Rebecca's typically brews just one pot of coffee in the morning and is not open on the weekends. This simple modification, making use of an available but often unused feature of this appliance, reduced energy to an average 0.5 kWh per day, a 67 percent energy reduction. Since the savings were from using a preexisting function within the appliance, there was no payback period.

Figure 5: Rebecca's Curtis ThermoPro 1.5 Gallon Coffee Brewer

Source: Frontier Energy, Inc.

Figure 6: Rebecca's Daily Coffee Brewer Operation Comparison



Source: Frontier Energy, Inc.

Food Service Technology Center

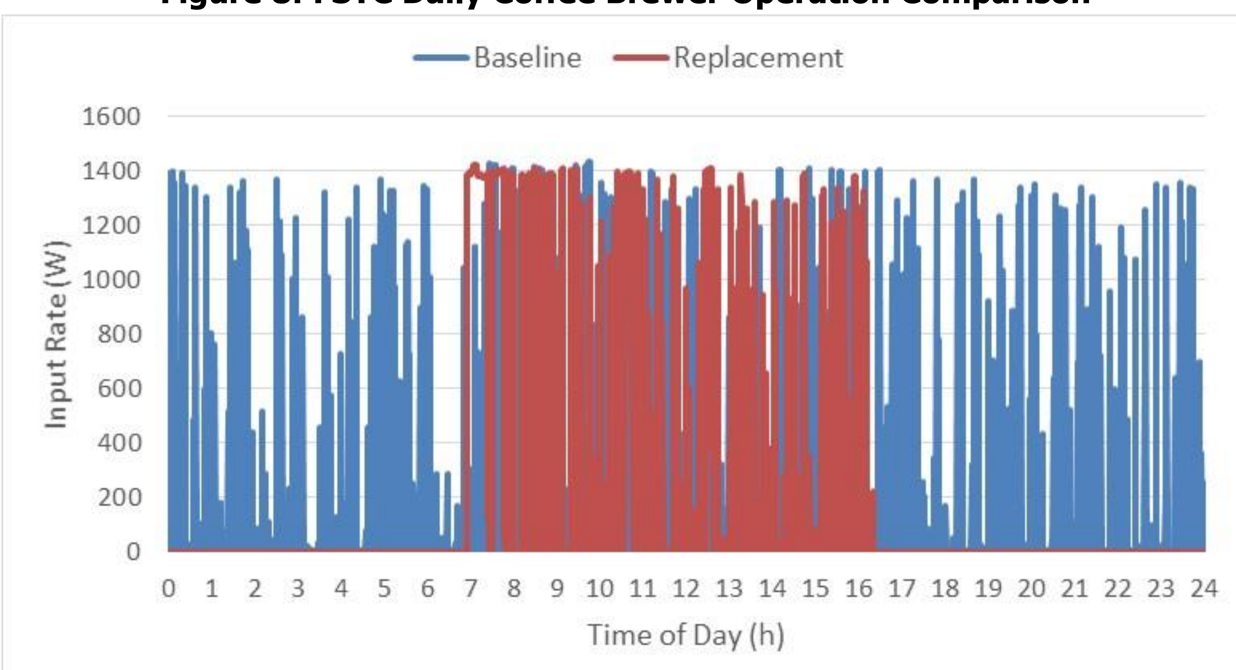
Researchers monitored a Curtis D1000GT model 240V/5050W dual air-pot coffee brewer at the Food Service Technology Center (FSTC) shown in Figure 7. FSTC staff use this coffee brewer to make a single pot of coffee in the morning and sometimes another pot in the afternoon, but it sits relatively untouched for the rest of the workday, used only periodically for hot water dispensing for tea or drip coffee. As such, most of the use is primarily idle energy to keep the dispensed water hot (Figure 8). After analyzing the data, it was clear that the appliance was left on 24/7, even after the workday was over. This includes the weekends, when the FSTC is not open for business, indicating a strong opportunity to save energy during these non-business hours. Monitored for two months, the coffee brewer used an average 2.5 kWh per day of electrical energy, through an average 10.0 hours of facility operation.

Frontier Energy installed an external timer on the unit, to turn the coffee machine off when staff normally leaves and an hour before the first person normally arrives in the office. This halved the coffee brewer's total operation time and reduced the average daily energy consumption to 1.5 kWh per day, a 41 percent energy reduction. For this site, the annual energy savings were about $56, the same as the cost of the external timer. The payback period for the timer was thus one year.

Figure 7: FSTC Curtis D1000GT Twin Pot Coffee Brewer

Source: Frontier Energy, Inc.

Figure 8: FSTC Daily Coffee Brewer Operation Comparison



Source: Frontier Energy, Inc.

Results

Coffee brewers exhibited a wide range of energy usage depending on application and coffee consumption (Figure 9). As a large bakery/café chain with long operating hours, Café/Bakery had significantly greater coffee brewer energy use largely due to the high activity demand. This is clearly illustrated in the relatively high average input rate, which shows that the coffee brewers were being actively used (Figure 10). By contrast, Rebecca's and the FSTC used much less energy thanks to significantly less coffee brewing. It is estimated that both operations served less than 50 cups of coffee per day, much less than Café/Bakery or Mills College. In all observed cases however, the coffee brewer was left on 24/7, resulting in a constant energy consumption of about 2 kWh per day of non-operation. The data indicate that leaving coffee brewers constantly on is common, so having a timer to turn the brewer on or off would be a reliable way to save energy. Overall, the baseline coffee brewers had an average energy use of 9.1 kWh per day with 12.7 hours of operation (Table 9).

The replacements were made for the two least-used coffee brewers, which presented the largest opportunity in terms of percent of energy savings (Table 10). Energy savings depend generally on two things: idle rate to keep the coffee brewer in a ready-to-use state and hours idling as opposed to active usage. The higher both factors are, the greater the savings. However, higher idle time tends to mean that the total energy use is not very high. The replacements at Rebecca's and the FSTC had a high percent of savings (67 percent and 40 percent, respectively), but each only reduced overall daily energy consumption by about 1kWh (Figure 9). Normalizing for facilities that are also open on the weekend, this drops the savings down further to 51 percent and 16 percent, respectively. This brings the normalized average energy savings to 33 percent, which serves as a reasonable ceiling for potential energy savings for a simple overnight shutoff. To achieve greater energy savings, coffee brewers would need to be replaced by more efficient or well insulated versions.

Table 9: Coffee Brewer Results

Site	Total Brew Capacity (gal)	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Baseline				
Mills	3.0	8.8	12.0	0.733
Café/Bakery 1	2.0	18.1	18.0	1.006
Café/Bakery 2	3.0	19.5	18.0	1.082
Chromatic Coffee	1.0	11.9	15.0	0.791
Rebecca's	1.5	1.5	6.0	0.245
FSTC	3.0	2.5	10.0	0.252
Average	2.3	9.1	12.7	0.713
Replacement				
Rebecca's	1.5	0.5	6.0	0.075
FSTC	3.0	1.5	10.0	0.148
Average	2.3	1.0	8.0	0.112

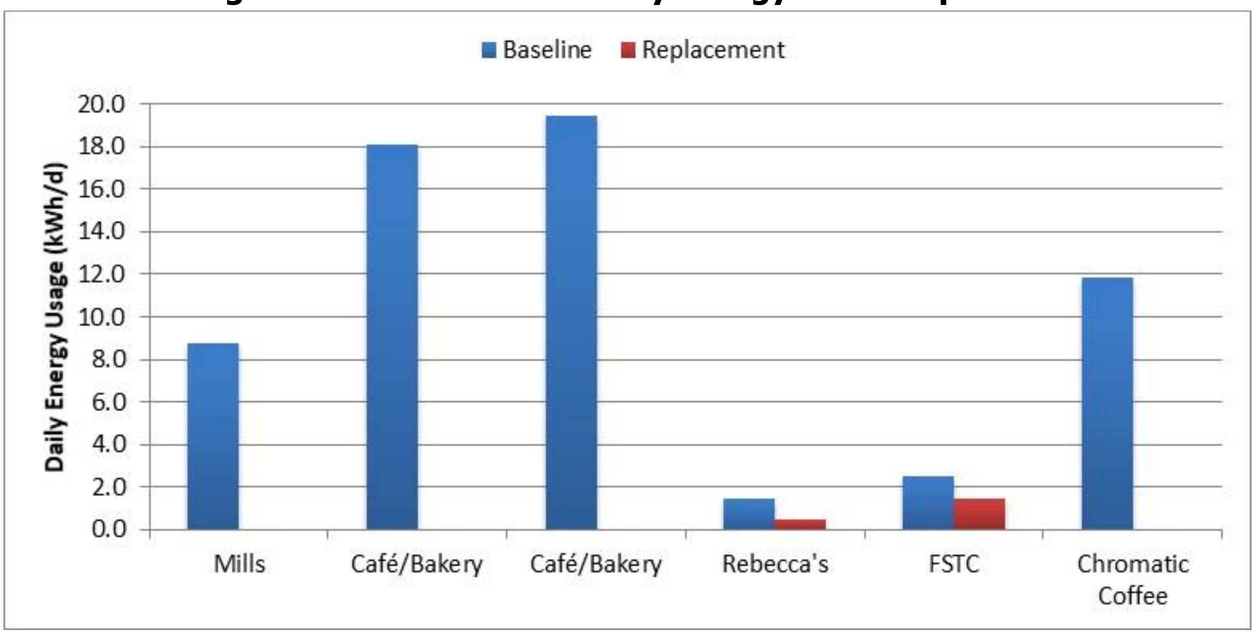
Source: Frontier Energy, Inc.

Table 10: Coffee Brewer Replacement Data Comparison

Site	Baseline or Replacement ?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)	Normalized Savings (%)
Rebecca's	Baseline	1.5	6.0	0.245	69.4
	Replacement	0.5	6.0	0.075	
FSTC	Baseline	2.5	10.0	0.252	41.3
	Replacement	1.5	10.0	0.148	
				Average	55.3

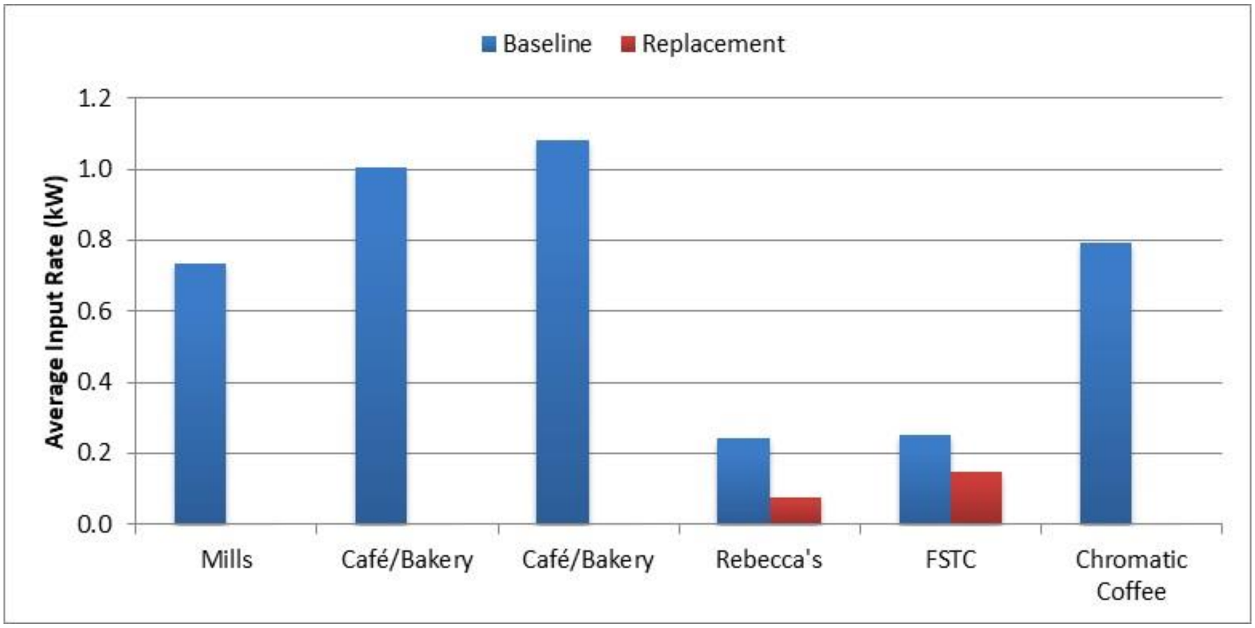
Source: Frontier Energy, Inc.

Figure 9: Coffee Brewer Daily Energy Use Comparison



Source: Frontier Energy, Inc.

Figure 10: Coffee Brewer Average Power Comparison



Source: Frontier Energy, Inc.

Espresso Machine

Espresso machines can be one of the signature pieces of equipment in a café or coffee shop. With prices for high end espresso machines reaching into the tens of thousands, baristas are often very attached to this piece of equipment. Coffee of this genre is just as much an art as food is in a restaurant. As a result, owners are less likely to replace their espresso machine with an energy saving counterpart than other appliances in their operation. Espresso machines maintain water at temperatures higher than 230°F (110°C) under higher pressure inside the boiler and often have additional group-head heating elements. For this project, Frontier Energy explored the full range of espresso machine offerings in varying contexts. Researchers monitored six different espresso machines but could only replace one of them.

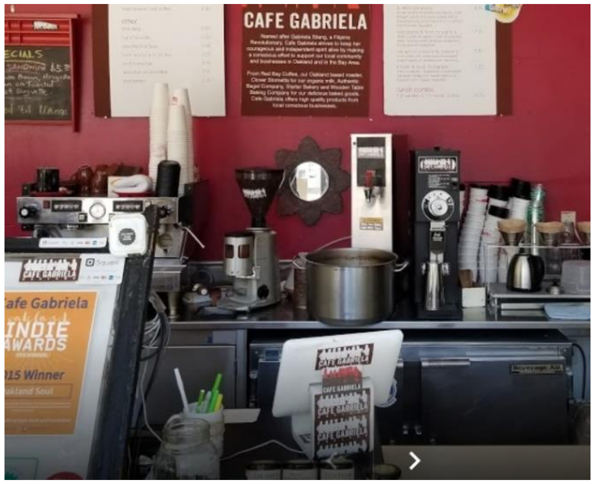
Café Gabriela

Café Gabriela originally had a La Marzocco Linea, a 208V automatic unit with two group heads (Figure 11). After the monitoring period, it was discovered that the espresso machine was left on continuously, despite the café being open for only 10 hours each day and closed during the weekends. This resulted in an average daily energy usage of 14.3 kWh, with the espresso using 14 – 15 kWh during the weekdays and about 13 kWh during the weekends. Since the café isn't open during the weekends, this energy pattern made it clear that much of the energy consumption was due to idle energy rather than active use.

The Linea was replaced by a Nuova Simonelli Aurelia II V unit, featuring an insulated boiler and programmable smart controls that include an automatic shutoff timer (Figure 12). Prior to replacement, Frontier Energy brought in the Café Gabriela staff to train them on the espresso machine usage and programming. The Aurelia was programmed to shut off 30 minutes after service, turn back on an hour before the start of service, and stay off during the weekends. The savings from this customized operation schedule, paired with the lower operating input rate thanks to the insulated boilers, resulted in a reduced average energy use of 4.5 kWh/day. This was a 69 percent reduction in energy, equivalent to about $540 in energy savings per year for the typical $0.15/kWh rate.

Café Gabriela was extremely pleased with both the energy savings experienced and with the quality of the espresso machine itself. No operational changes were necessary to lock in energy savings and create a quality product. The baseline Linea costs about $13,500 while the replacement Aurelia II costs about $12,900, so there was no payback period for this replacement. The $600 purchase savings and the $540 annual energy savings directly benefitted the business, making the replacement an extremely valuable opportunity (Figure 13).

Figure 11: Baseline Automatic Espresso Machine

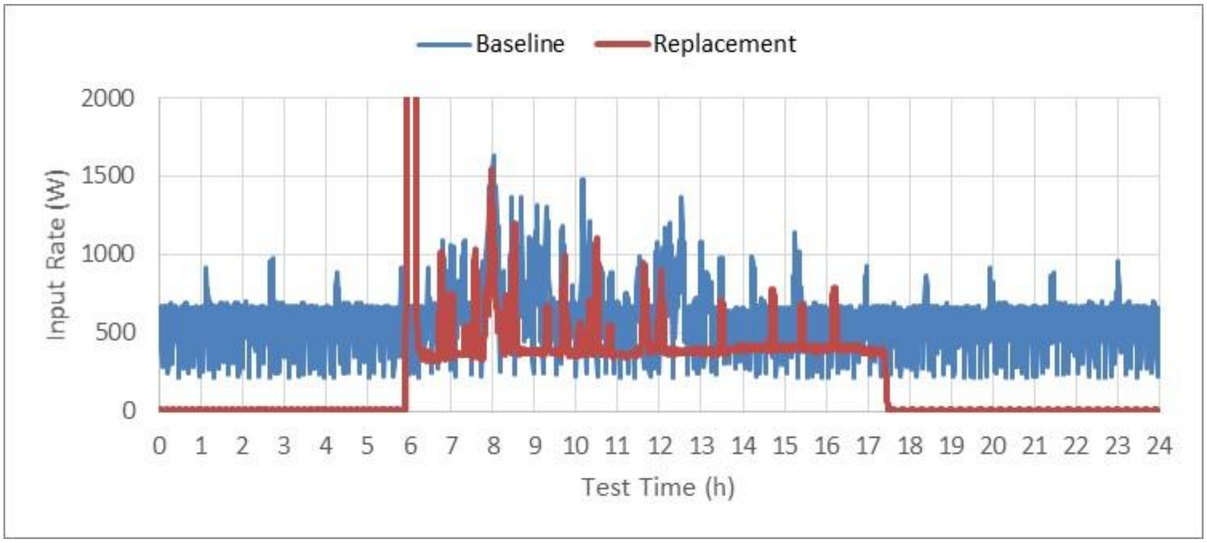


Source: Frontier Energy, Inc.

Figure 12: Nuova Simonelli Aurelia II Replacement Espresso Machine

Source: Frontier Energy, Inc.

Figure 13: Daily Espresso Machine Operation



Source: Frontier Energy, Inc.

Results

The monitored espresso machines exhibited a wide range of energy use, which cannot always be predicted with just operation hours or level of activity (Table 11). The espresso machine at Café/Bakery, a large bakery/café chain with long operating hours and significant product demand, used the least amount of energy because it was a fully automatic espresso machine. Voyager Craft Coffee, with higher active usage but significantly shorter operating hours, had an espresso machine that used more than four times as much energy. Overall, the coffee brewers had an average energy usage of 13.1 kWh per day over 13.4 hours of business operation (Figure 14).

As an appliance that runs constantly, there is significant savings opportunity for the espresso machine, even without having to replace the equipment (Table 12). This can be seen by the comparison of the daily energy usage and the daily active operating hours — the amount of time that the espresso machine is actively being used has a negligible effect on the overall energy use. This implies that the bulk of the energy use is simply because the espresso machine is turned on, which in turn means that significant energy savings can be gained simply by setting a timer for automatic shutoff outside the hours of operation. Operators who do not want to turn off their machine at night may say that heating and cooling of the machine may cause piping to expand, contract, and reduce the lifespan of pipe seals; however, newer machines are built to withstand such thermal fluctuations.

The espresso machine replacement made at Café Gabriela saved 8.6 kWh per day, nearly 69 percent of the baseline energy cost. These savings were thanks to the improved insulation of the unit, which allowed the unit to operate at a lower average input rate (Figure 15), and the automatic timer shutoff, which switched the espresso machine on and off according to the owner's programmed hours of operation. Researchers found through detailed analysis of espresso machine's energy profiles that the start-up energy for the espresso machine is equivalent to about 2 – 3 hours of overnight idling energy. Thus, it is apparent that any foodservice operation that doesn't operate 24/7 could benefit from nighttime espresso machine shutoffs. There was also no payback period for Café Gabriela's espresso machine replacement, so its $540 in annual energy savings were pure profit.

Table 11: Espresso Machine Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Baseline			
Mills	7.9	12.0	0.658
Café/Bakery	4.4	18.0	0.244
Bridges	12.1	11.6	1.047
Chromatic Coffee	19.4	13.0	1.493
Voyager Craft Coffee	20.6	15.0	1.373
Café Gabriela	14.3	11.0	1.304
Average	13.1	13.4	0.978
Replacement			
Café Gabriela	4.5	10.0	0.450
Average	4.5	10.0	0.450

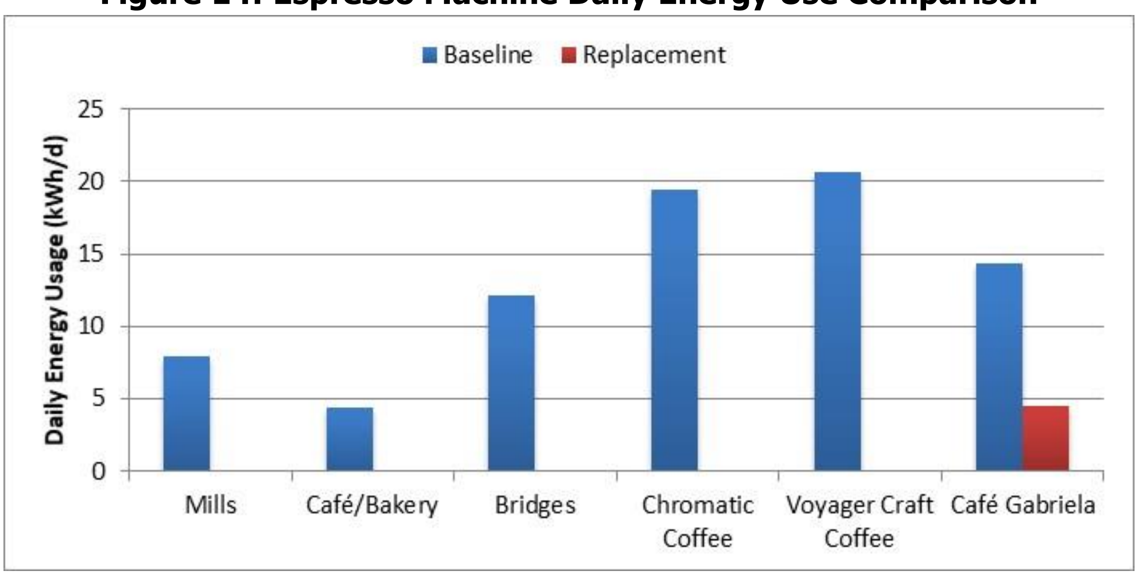
Source: Frontier Energy, Inc.

Table 12: Espresso Machine Replacement Data Comparison

Site	Baseline or Replacement?	Total Average Daily Energy Usage (kWh/day)	Savings (%)	Payback Period (yrs)
Café Gabriela	Baseline	13.1	68.7	None
	Replacement	4.5		

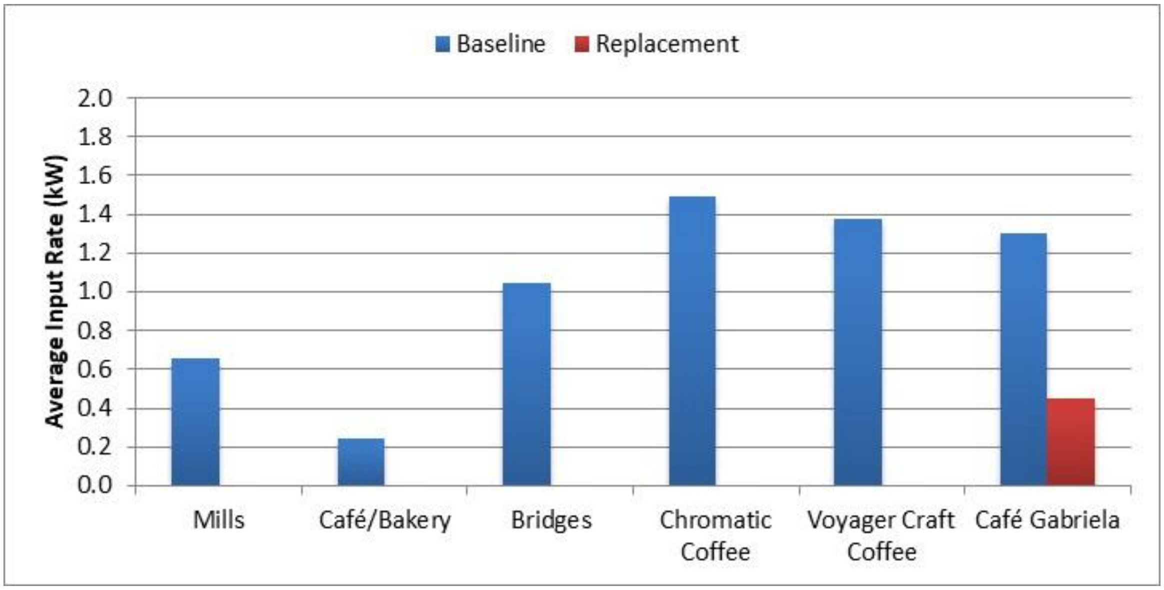
Source: Frontier Energy, Inc.

Figure 14: Espresso Machine Daily Energy Use Comparison



Source: Frontier Energy, Inc.

Figure 15: Espresso Machine Average Power Comparison



Source: Frontier Energy, Inc.

Soda Dispenser

Extremely common in all restaurant types but especially in quick service applications, soda dispensers offer ease of service and sizeable profit margins. Given the ubiquity of the appliance, researchers determined soda dispenser energy use to be worth characterizing, despite it typically being deemed as a low energy appliance. The research team monitored one advanced interface soda dispenser at a large sandwich chain, which was enough to verify the low energy consumption despite 24/7 operation.

Results

Frontier monitored the advanced soda dispenser at Togo's for several days. This soda dispenser was a new electronic model that had a touchscreen interface and could serve tens of different soft drinks and combinations. This soda dispenser was never turned off, but was measured to only use about 1kWh per day on average, with very little difference in energy use between hours of operation and idle time. These machines thus had very repeatable energy use and did not require a long monitoring period to accurately characterize daily energy profiles. Overall, the soda dispenser had an average energy use of 1.0 kWh per day with 11.0 hours of business operation (Table 13). No replacements were made for the soda dispenser because of the lack in suitable replacements and dollar savings available. Operator behavioral change to turn off the machine at night or installing an automatic shutoff timer would likely save less than 0.5 kWh per day.

Table 13: Soda Dispenser Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Togo's	1.0	11.0	0.094
Average	1.0	11.0	0.094

Source: Frontier Energy, Inc.

Tea Brewer

Less ubiquitous than coffee brewers, tea brewers are nonetheless a relatively common appliance found in cafés and full-service restaurants with a variety of drink options. Tea brewers offer ease of service and sizeable profit margins. The research team monitored two tea brewers at two different café sites, one on a college campus and the other at a large bakery chain. Most of the tea brewers operate throughout the day and often are never turned off.

Unlike coffee brewers, tea brewers seem to have relatively little use and do not fluctuate much in daily energy consumption (Table 14). Even Café/Bakery, a large bakery/café chain with long operating hours and elevated levels of activity, averaged only 2 – 3 brew cycles per day. Most of Café/Bakery's tea brewer energy usage stemmed from idle periods with less than 1 kWh difference in energy usage between its busiest and lightest day. As an appliance that is never shut off, there is a definite opportunity to save energy during these idle periods via a timer or an energy saving mode. This could save a significant percentage of the total energy used. Tea brewers do not generally have a constant usage demand, so shutting off the brewer after the brew cycle can greatly reduce standby energy usage. Overall, the tea brewers had an average energy usage of 1.8 kWh per day with 15.0 hours of business operation. No replacements were made for tea brewers because of the lack in suitable replacements and dollar savings available. However, an automatic shutoff timer could likely save about 1 kWh per day if installed.

Table 2: Tea Brewer Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Mills	1.6	12.0	0.133
Cafe/Bakery	1.9	18.0	0.106
Average	1.8	15.0	0.119

Source: Frontier Energy, Inc.

Heating

Foodservice equipment used to heat prepared food tends to be among the more energy intensive plug loads, due to the high temperatures required for these processes. Many of these appliances are constantly left on at a high input rate regardless of usage demands (Figure 17). Heating equipment involves one or two heated surfaces that heat food via conduction, convection, or radiation. Frontier Energy characterized various operation types in this plug load study, monitoring 11 different types of heating equipment.

Cooktops, panini presses, waffle irons, pop-up toasters, rice cookers, and tortilla warmers conduct heat to the food product or cooking vessel through direct contact. Panini presses, waffle irons, and tortilla warmers conduct food using two heated surfaces, whereas the cooktop and rice cooker heat vessels underneath with a single heated surface. The rethermalizer also uses conduction, but through the medium of hot water to heat the product. Countertop ovens meanwhile heat through convection, while conveyor toasters and microwaves cook product through radiation. Rapid cook ovens use a hybrid method of both convection and radiation, which is highly energy intensive but also cooks quickly.

Researchers discovered that baseline conveyor toasters and cooktops used the most energy (Table 15). This was due to a combination of long operation hours, constant high energy input rates, and no thermostatic feedback of the appliance.

Table 15: Energy Use of Commercial Foodservice Warming Equipment

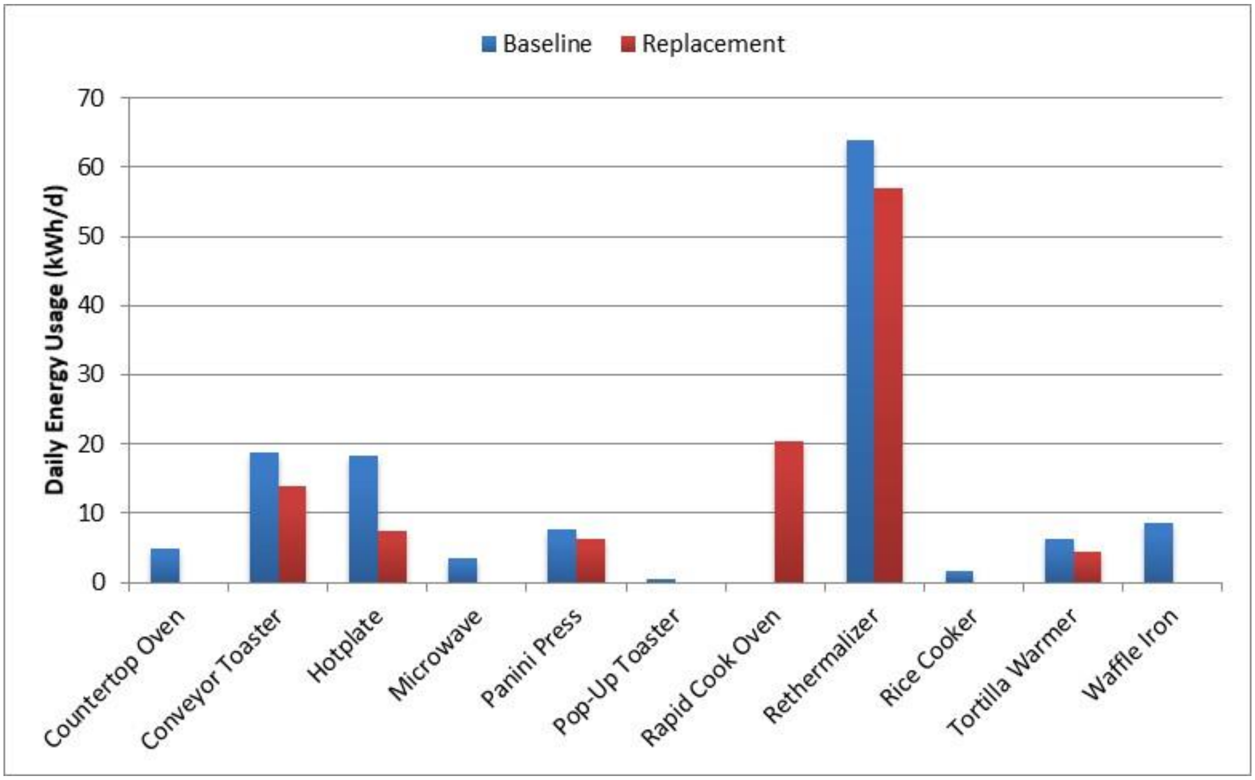
Appliance Type	Baseline or Replacement?	Number of Appliances Monitored	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)	Direct Replacement Savings (%)
Countertop Oven	Baseline	1	4.8	11.2	0.43	N/A
Conveyor Toaster	Baseline	10	19.6	9.5	2.08	21.0
	Replacement	6	14.0	10.4	1.59	
Cooktop	Baseline	1	18.2	8.4	2.17	29.0
	Replacement	4	3.8	4.9	0.76	
Microwave	Replacement	2	3.6	4.1	0.86	N/A
Panini Press	Baseline	7	7.7	7.0	1.07	44.51
	Replacement	4	6.2	10.3	0.59	
Pop-Up Toaster	Baseline	1	0.6	1.3	0.50	N/A
Rapid Cook Oven	Replacement 2	5	20.3	14.6	1.44	N/A
Rethermalizer	Baseline	1	64.0	18.0	3.56	10.9
	Replacement 3	1	57.0	18.0	3.17	
Rice Cooker	Baseline	7	1.7	6.6	0.61	N/A
Tortilla Warmer	Baseline	4	6.3	9.3	0.67	N/A
Waffle Iron	Baseline	2	8.7	9.7	0.90	N/A

[1]Savings not from direct replacement but extrapolated from the comparison of normalized average energy rates for baseline and replacement equipment monitored.
[2]No direct replacements were made using rapid cook ovens, but they are categorized as a replacement technology because of their potential to save energy.
[3]The replacement is the same unit, but with an added lid for less heat loss.

Source: Frontier Energy, Inc.

By contrast, equipment like rice cookers, microwaves, and pop-up toasters used much less energy on average (Figure 16), because the appliance operates on a batch cooking cycle with almost no standby energy. This means the appliance operates at peak energy demand for only a fraction of its total overall operating time, reverting to a zero or low energy setting for the rest of the time.

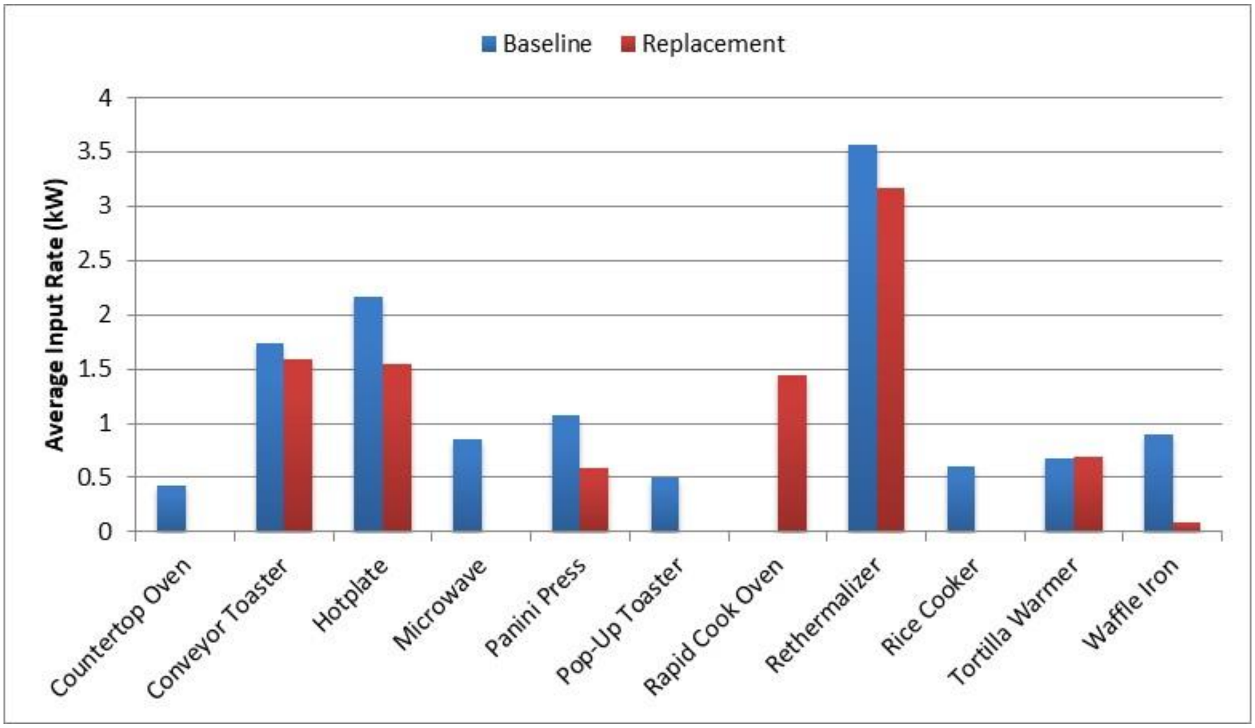
Figure 16: Energy Use Comparison of Commercial Foodservice Heating Equipment



Source: Frontier Energy, Inc.

Only four appliances in this category had energy saving solutions readily available to be tested. The replacement conveyor toasters used sensors to switch the appliance into a reduced input energy saving mode whenever there was a lack of activity, reducing idle energy. Researchers added a lid to the large rethermalizer to measure the effect of a simple solution contingent on behavioral change. The cooktop and panini press replacements used entirely different technologies, induction and hybrid microwave/conduction cooking respectively. These various energy solutions had significantly different levels of success, based on the application and technology.

Figure 17: Input Rate Comparison of Commercial Foodservice Heating Equipment



Source: Frontier Energy, Inc.

Countertop Oven

Countertop ovens are typically found in small bakery/café situations, used to quickly reheat baked goods via convection and optimize taste and texture before serving them to customers. As such, they are typically found at the front of the house, close to the register and the food product display case. To optimize speed of service, these ovens may be left idling somewhere between 300 and 400°F (149 and 204 °C) during peak business hours. However, this appliance is highly visible and thus does not often experience the issue of being left on overnight, as is common with some other plug loads. Among this appliance category, one oven model is particularly common and is both energy efficient and relatively affordable.

Results

Researchers monitored the countertop oven at Kettle'e, an Indian café/bakery. The countertop oven was the common Moffat Turbofan model and was located right behind the pastry case, used to reheat pastries as desired by the customers when they were ordered. This countertop oven operated slightly beyond operating hours, averaging 11.2 hours per day, and was always turned on or off properly. Researchers measured this countertop oven to be consuming 4.8 kWh per day on average (Table 16). The machine was used frequently throughout the day, with more idle operation occurring in the late afternoon. No replacements were made for the countertop because of the lack in suitable replacements; past lab test results on this brand and model have shown it to be quite efficient. In comparison to other plug loads, energy consumption by countertop ovens seems to fall right in the middle.

Table 16: Countertop Oven Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Kettle'e	4.8	11.2	0.432
Average	4.8	11.2	0.432

Source: Frontier Energy, Inc.

Conveyor Toaster

Due to the high constant radiant heat output, conveyor toasters are some of the most energy intensive plug load appliances found in restaurants. Given the popularity of toasted bread, muffins, and bagels, conveyor toasters are commonplace in any restaurant or cafe with a breakfast/lunch service. Conveyor toasters provide higher production capacity and ease of operation, compared to standard pop-up toasters, at a greater energy cost. The research team monitored conveyor toasters at 10 different sites, ranging from campus cafeterias to cafés to full-service restaurants.

The baseline toasters were replaced at six of those sites, with toasters that had smart energy saving technology. Equipped with a sensor, these toasters would activate their energy save mode if there wasn't any product placed into the toaster for a given period of time. The default manufacturer setting for this technology was 30 minutes. Once energy save mode was activated, the toaster would pause the conveyor and significantly lower the electrical input to the heating elements. Once new product was finally placed into the toaster again, the sensor would deactivate the energy save mode and reengage the toaster at full input, slightly extending the cook time of the first batch after resuming cooking operation to maintain the same toasting quality. Thus, these toasters capitalized on reducing idle energy to save energy, which made the savings from replacement vary significantly depending on appliance idle times.

Caffe 817

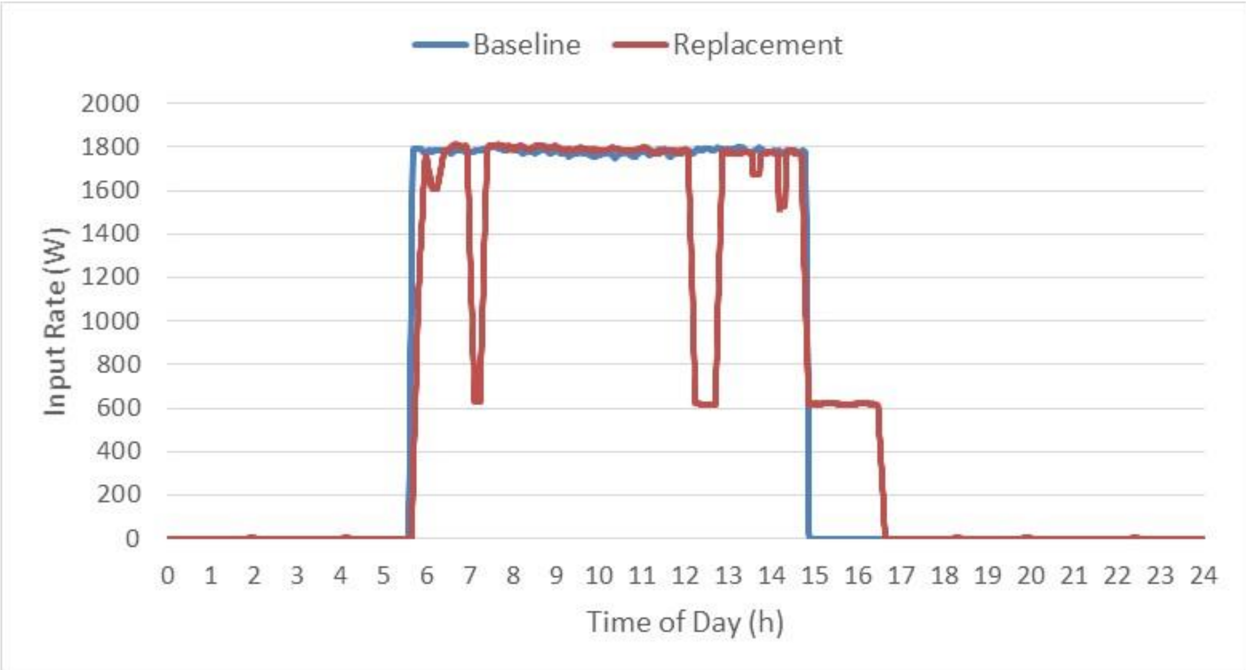
As a European style bakery, Caffé 817 has a constant demand for bread toasting, making their Hatco TQ-10 Toast-Qwik conveyor toaster a perfect candidate for submetering (Figure 18). The conveyor toaster was monitored for three months, resulting in 15.5 kWh per day in electrical consumption, while operating for 8.8 hours per day on average (Figure 19). For most days, the toaster was turned on shortly before café opening and left on at a constant input all day, only being turned off at the close of business.

After baseline monitoring, the Hatco TQ-10 was replaced by a Hatco TQ3-400, which had approximately the same voltage and input ratings but also featured the automatic energy saving mode. This allowed the toaster to significantly reduce its energy rate during low usage periods, typically either immediately after initial preheat or during the afternoon. Caffe 817 was typically busy throughout all its hours of operation, so the replacement toaster still used 15.0 kWh per day, but only an average 9.8 hours of operation per day. Normalizing for hours on, this means the toaster reduced energy consumption by 13 percent, equivalent to about $123 for the average $0.15 per kWh electrical rate. For this site, the energy efficient replacement had a payback period of 3.7 years.

Figure 18: Caffe 817 Baseline Hatco TQ-10 Conveyor Toaster

Source: Frontier Energy, Inc.

Figure 19: Caffe 817 Conveyor Toaster Daily Use Profile



Source: Frontier Energy, Inc.

Mills College (Founders Commons)

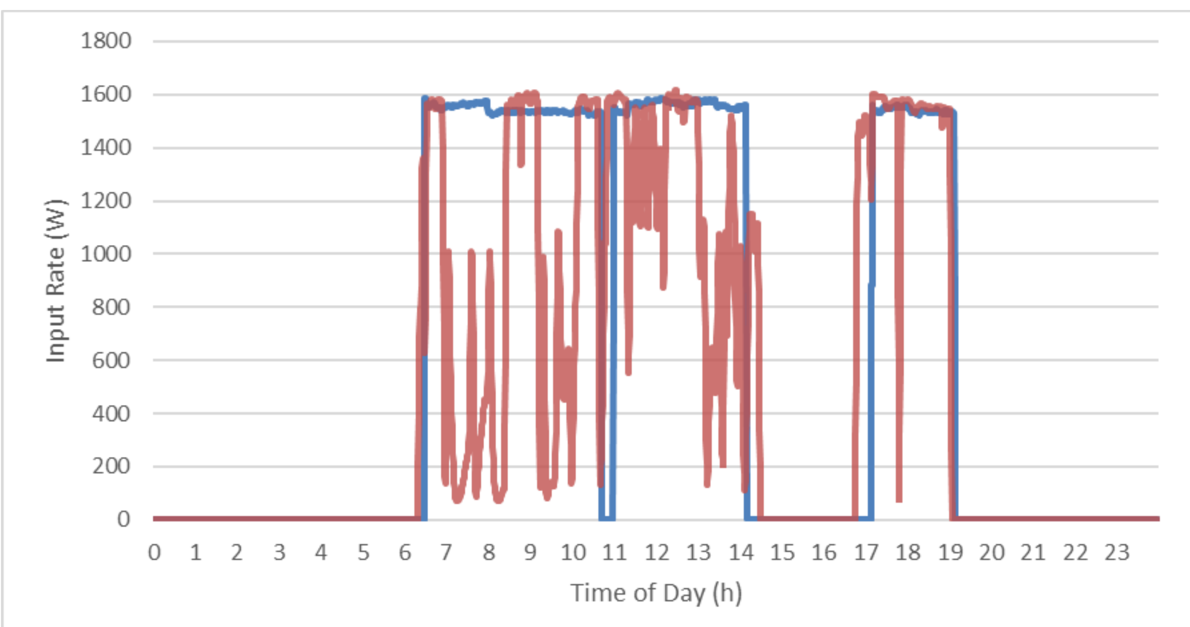
The conveyor toaster monitored at the Mills College Founders Commons dining hall was a 120V Hatco TQ-10 Toast-Qwik (Figure 20).

Figure 20: Mills College Hatco TQ-10 Toast-Qwik Baseline Conveyor Toaster

Source: Frontier Energy, Inc.

This conveyor toaster is located in the communal area for students to use during mealtimes. During meal service, the toaster is left on at a constant setting, used mainly to toast bread for sandwich making (the heat adjustment knob was missing). The staff turns the toaster off between meals as part of their cleanup process. The research team monitored the conveyor toaster for about three months, resulting in an average 10.7 kWh per day of electrical energy during an average 11.5 hours of operation (Figure 21).

Figure 21: Mills College Daily Conveyor Toaster Operation



Source: Frontier Energy, Inc

After baseline monitoring, the Hatco TQ-10 was replaced by a Hatco TQ3-400 (Figure 22). The automatic energy saving mode activated relatively often compared to other sites with the replacement toaster, particularly during the mornings when many students skipped breakfast. The replacement toaster thus used 8.1 kWh per day, an energy reduction of 24 percent. This amounts to about $138 in yearly energy savings, for the average $0.15 per kWh electrical rate. For this site, the energy efficient replacement had a payback period of 3.3 years.

Figure 22: Mills College Hatco TQ3-400 Replacement Conveyor Toaster

Source: Frontier Energy, Inc.

Tech Café A

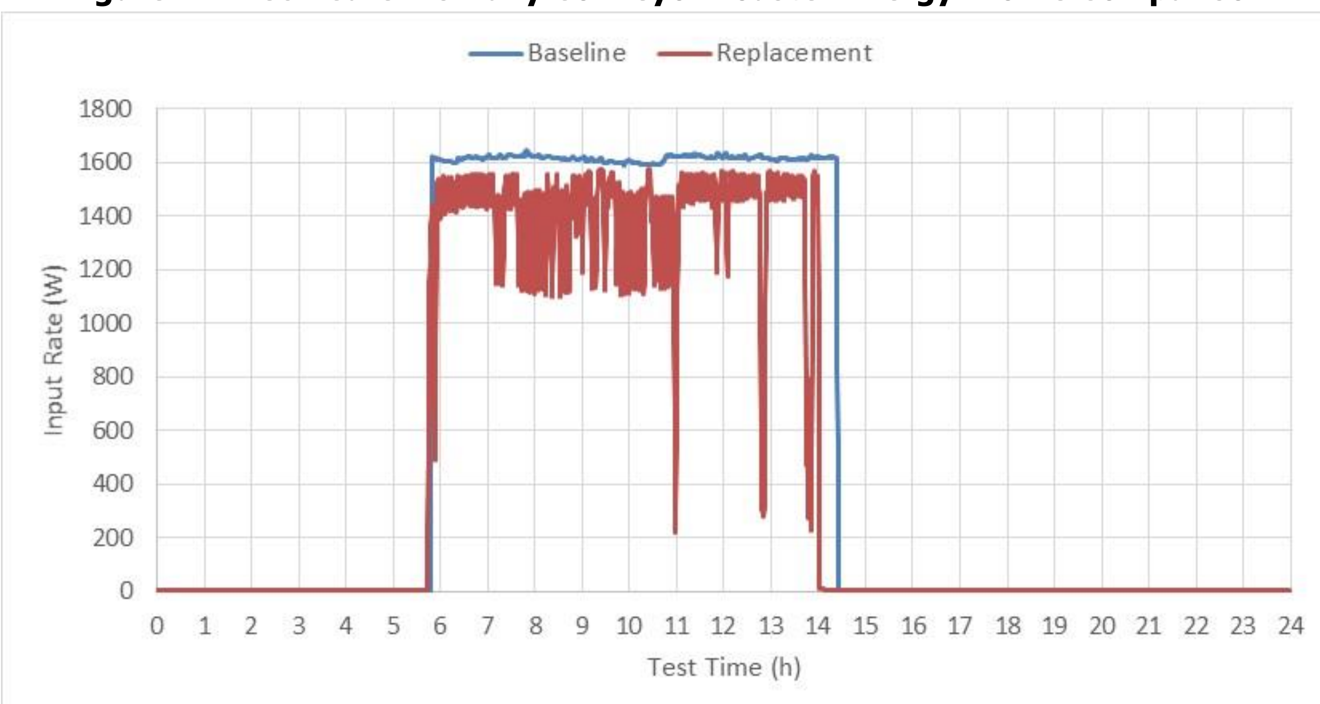
Tech Café A has a corporate cafeteria that operates for breakfast and lunch hours on weekdays, with toast and sandwiches being one of the many options available. Though there is also a sandwich station where employees can order sandwiches, the conveyor toaster is located at the build-your-own sandwich bar, next to a small panini press and popup toaster. Given this bevy of options, the conveyor toaster, the Hatco TQ-10 (Figure 23) is not a particularly high use appliance. However, thanks to constant foot traffic, there is a consistent demand for bread toasting. The baseline conveyor toaster was measured to consume 13.6 kWh per day on average during business days, while operating for 8.5 hours per day on average. For most days, the toaster was turned on shortly before cafeteria opening and left on at a constant input all day, only being turned off at the close of business.

After baseline monitoring, the Hatco TQ-10 was replaced by a Hatco TQ3-400. The automatic energy saving mode activated occasionally, but not often, due to the constant influx of employees. The replacement toaster used 11.0 kWh per day on average during business days, an energy reduction of 15 percent (Figure 24). This amounts to about $83 in yearly energy savings, for the average $0.15 per kWh electrical rate. For this site, the energy efficient replacement had a payback period of 5.4 years.

Figure 23: Tech Café A Hatco TQ-10 Baseline Conveyor Toaster

Source: Frontier Energy, Inc.

Figure 24: Tech Café A's Daily Conveyor Toaster Energy Profile Comparison



Source: Frontier Energy, Inc.

Café/Bakery

The Belleco JT2-B conveyor toaster (Figure 25) in Café/Bakery's San Ramon location was monitored for a month and a half inside the electrical panel. This 208V/20A appliance was usually turned on early in the morning around 3:00 a.m. and left constantly running until the store's closing time around 10:00 p.m. The conveyor toaster also featured an energy saving mode, but this was rarely engaged during the monitoring period; the data showed that the energy saving mode was only engaged three times in over a month of monitoring. This is due both to high customer demand and staff preference for convenience over energy savings. The conveyor toaster at Café/Bakery used significantly more energy than most every monitored location due to much longer operating hours. The toaster averaged 52.4 kWh per day with 18.0 hours of operation.

Figure 25: Café/Bakery Belleco JT2-B Baseline Conveyor Toaster

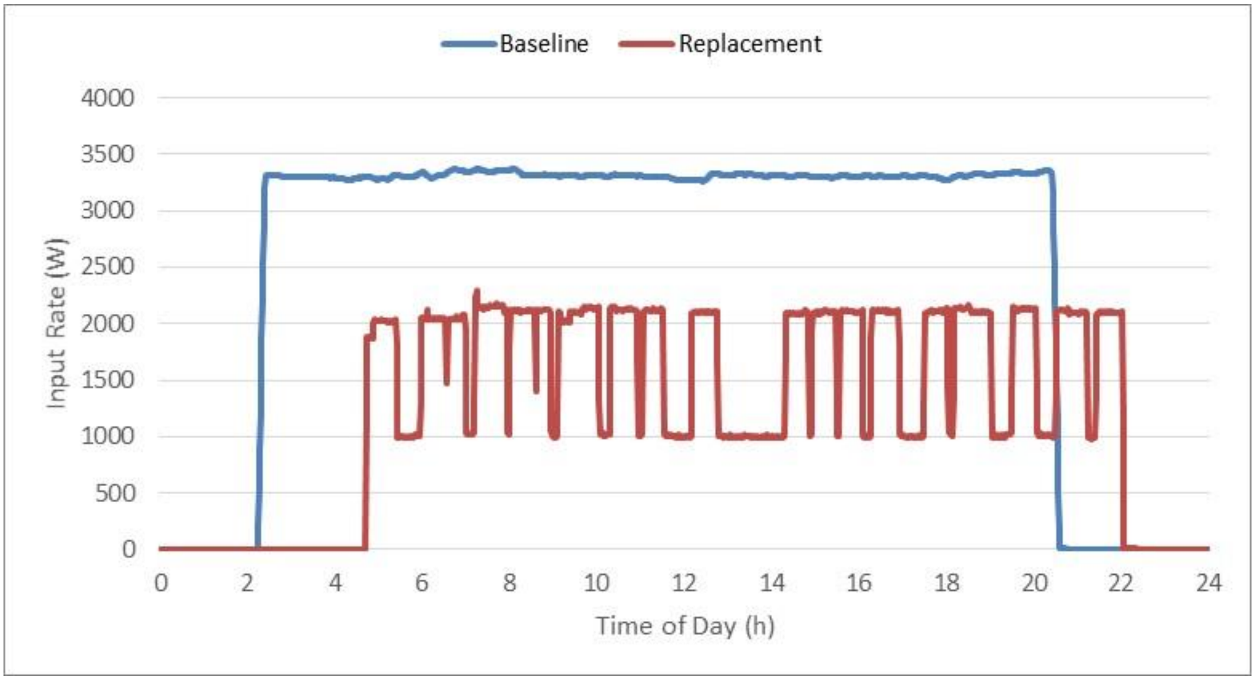
Source: Frontier Energy, Inc.

After baseline monitoring, the Belleco toaster was replaced by a Hatco TQ3-900H, which operated at a lower average input and featured the automatic energy saving mode (Figure 26). The automatic energy saving mode activated often throughout the day. The replacement toaster used 28.5 kWh per day on average during business days, an energy reduction of 46 percent (Figure 27). This amounts to about $1,290 in yearly energy savings, for the average $0.15 per kWh electrical rate. The energy efficient replacement had a payback period of only 3 months for this site, since the long and energy intensive hours of operation created a large energy saving opportunity.

Figure 26: Café/Bakery Hatco TQ3-900H Replacement Conveyor Toaster

Source: Frontier Energy, Inc.

Figure 27: Café/Bakery Daily Conveyor Toaster Energy Profile Comparison



Source: Frontier Energy, Inc.

Spreadz

Spreadz is a sandwich store located in the middle of a business park area, catering mainly to corporate workers looking for a quick lunch. They provide catering and delivery and have been so successful that they recently opened a second store. Frontier monitored the conveyor toaster at the main store, which operates from 10:30 a.m. to 2:30 p.m. every weekday (Figure 28). The conveyor toaster was often turned on significantly earlier, though, to prepare large sandwich orders for delivery. The baseline conveyor toaster averaged 11.4 kWh per day on average during business days, while operating for 7.3 hours per day on average.

After baseline monitoring, the Holman QCS-2-500 was replaced by a Hatco TQ3-400 (Figure 30). Initially, the toaster supplied with the manufacturer default settings of 30 minutes of inactivity before activating the automatic energy saving mode. Under these settings, the mode only activated occasionally, since they had consistent business. The replacement toaster used 10.4 kWh per day on average during business days, an energy reduction of 11 percent (Figure 31). For the average $0.15 per kWh electrical rate, this equates to about $80 per year in annual energy savings.

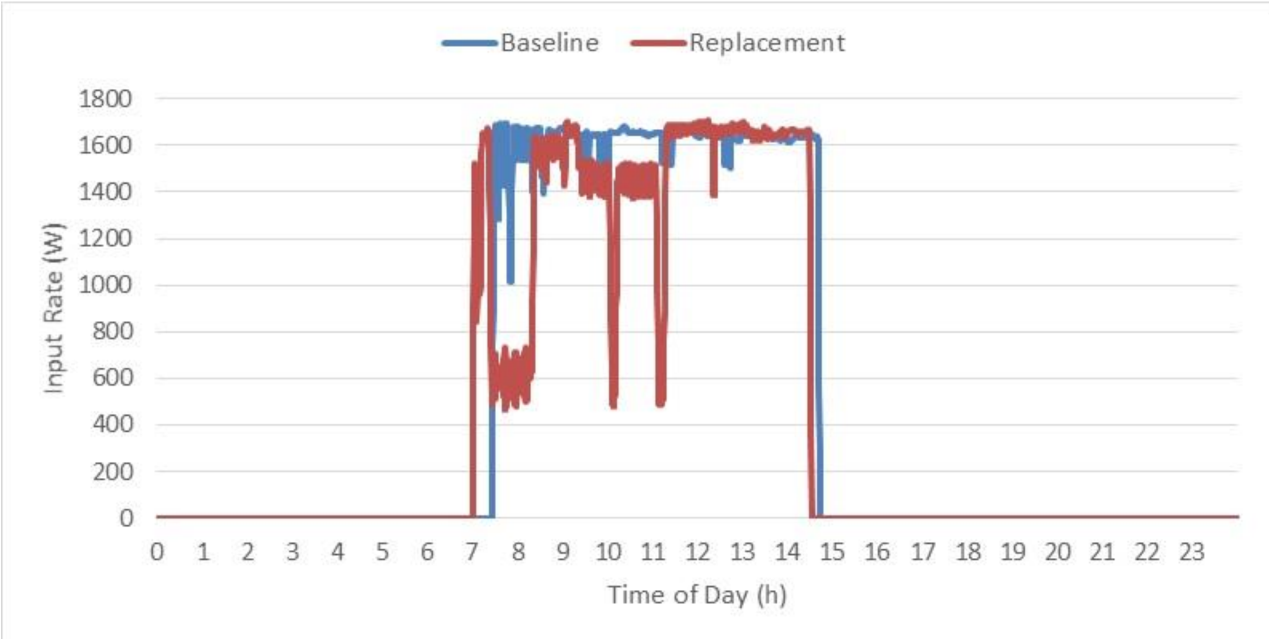
Figure 28: Spreadz Baseline Conveyor Toaster

Source: Frontier Energy, Inc.

Figure 29: Spreadz Replacement Hatco Conveyor Toaster

Source: Frontier Energy, Inc.

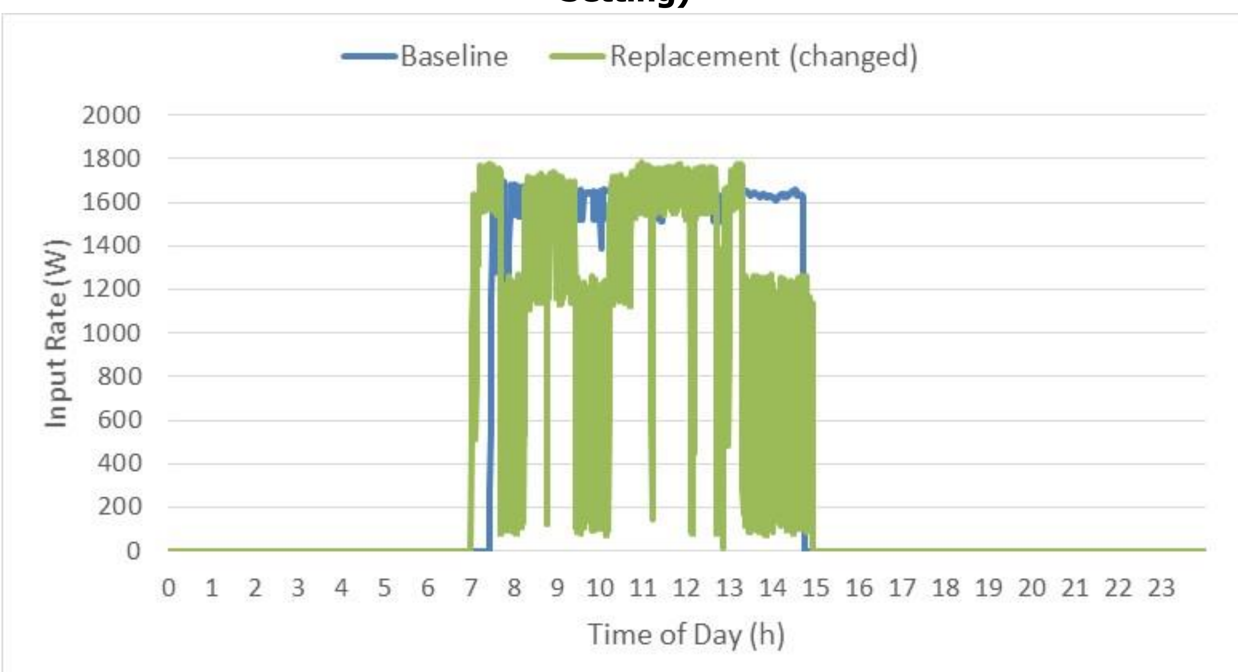
Figure 30: Spreadz Conveyor Toaster Energy Profile Comparison (30 Minute Setting)



Source: Frontier Energy, Inc.

Researchers later changed the settings to activate the energy saving mode after 10 minutes of inactivity (Figure 31).

Figure 31: Spreadz Conveyor Toaster Energy Profile Comparison (10 Minute Setting)



Source: Frontier Energy, Inc.

This allowed the toaster to use the mode more frequently, without affecting the speed of service in any substantial way. Staff did not notice any changes from the previous setting and this shorter activation window setting. This new setting reduced the average daily business day electrical consumption to 9.3 kWh, bringing total energy reduction from their baseline toaster to 19 percent. This amounts to about $80 in yearly energy savings, for the average $0.15 per kWh electrical rate. The energy efficient replacement toaster had a $180 lower purchase price than the baseline unit, so the energy savings for this store was all profit. Overall, Spreadz was pleased with the replacement toaster's speed of service, output product quality, reduced heat and safety hazard, and the eye-catching aesthetic, which matches their logo.

Voyager Craft Coffee

Voyager Craft Coffee is a popular café specializing in espresso and drip coffee beverages, paired with various toast and pastry options for snacking. They are open from 7:00 a.m. to 7:00 p.m. 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. The conveyor toaster is running nearly the entire time, fulfilling toast orders for customers to snack on with their coffee (Figure 32). Researchers measured the baseline conveyor toaster averaged 18.4 kWh per day on average, while operating for 11.2 hours per day on average.

Figure 32: Voyager Craft Coffee Waring Baseline Conveyor Toaster

Source: Frontier Energy, Inc.

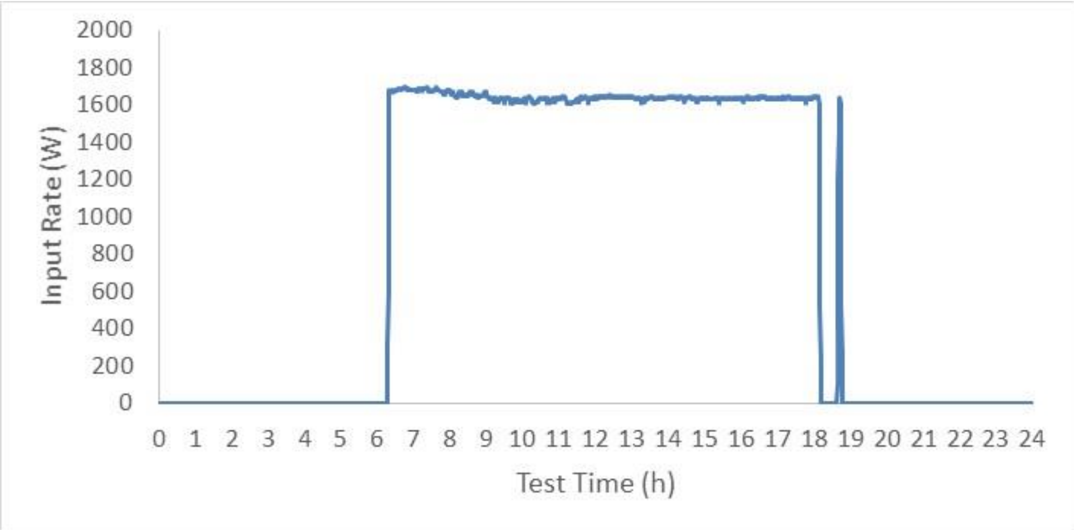
Frontier Energy replaced the baseline Waring toaster with a Hatco TQ3-400 (Figure 33). Initially, there were no savings from the replacement since the coffee shop was so busy that the toaster rarely ever went into its setback mode (Figure 34). After switching the setback mode to trigger at 10 minutes instead of 30 minutes of inactivity (factory setting), however, the replacement toaster reduced the energy use to an average 17.0 kWh/day, a normalized savings of 10 percent compared to the baseline (Figure 35). The decreased activation period did not affect service in any way, and the owners were still very happy with the speed and quality of the output product. The replacement toaster was also less hot to the touch, making it safer to work with. 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 percent of conveyor toaster savings observed at the other sites. The replacement toaster saved about

$98 per year in energy costs, for the average $0.15 per kWh electrical rate. The energy efficient replacement had a payback period of 6.1 years though, since their original unit was very inexpensive.

Figure 33: Voyager Craft Coffee Hatco Replacement Conveyor Toaster

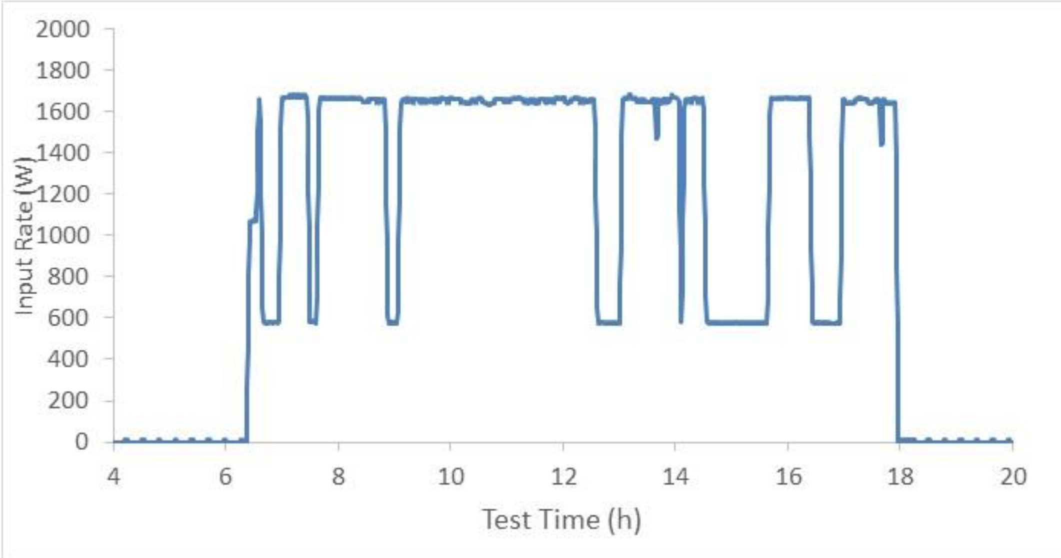
Source: Frontier Energy, Inc.

Figure 34: Voyager Craft Coffee Baseline Conveyor Toaster Operation



Source: Frontier Energy, Inc.

Figure 35: Voyager Craft Coffee Replacement Conveyor Toaster Operation 10-Minute Setback



Source: Frontier Energy, Inc.

Results

Conveyor toasters are one of the strongest candidates for plug load energy reduction due to their high input rates and long hours of operation. Conveyor toasters were often the most energy intensive plug load appliance monitored in the participating sites. The energy saving opportunity varies significantly based on how busy the site is and is often less in terms of percent of savings than other plug loads like holding cabinets or soup warmers. However, the overall high energy use means that even a small percent savings can equate to a sizeable dollar savings.

A 120V conveyor toaster with an energy saving mode can save anywhere from 10 percent for busy restaurants to 25 percent for facilities with longer idling periods, compared to a baseline toaster of the same input rate. Replacements for 208V toasters with 208V toasters with energy saving modes are expected to be even more sizeable, but further research is needed to see whether the increased input rate is offset by the higher usage frequency (Table 17). Energy savings will be highest for facilities that are able to integrate the energy saving mode and size down their toaster, which has the potential to halve energy costs.

Overall, Frontier found that efficient conveyor toasters with automatic energy save modes saved 21 percent, while still creating a quality product and without affecting speed of service (Table 18). Operators found the efficient toasters to output less heat to the space and to be safer since they were not as hot to the touch. Overall, sizeable energy savings and other benefits to the operator make conveyor toasters a strong replacement appliance option (Figures 36). Payback periods ranged anywhere from instantaneous to six years at the very worst, with an average payback of around three years (Figure 37).

Table 17: Conveyor Toaster Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Baseline			
Caffe 817	15.5	8.8	1.766
Mills	10.7	11.5	0.930
Rebecca's	11.9	6.0	1.831
Café/Bakery	52.4	18.0	2.911
Voyager Craft Coffee	18.4	11.2	1.640
Spreadz	8.2	5.2	1.561
Mission City Grill	46.0	14.5	3.166
Tech Café A	8.0	5.0	1.589
Plaza Suites	14.4	11.3	1.280
Café Gabriela	11.3	6.5	1.727
Average	19.6	9.8	2.014
Replacement			
Café/Bakery	28.5	18.0	1.583
Caffe 817	15.0	9.8	1.534
Voyager Craft Coffee	17.0	11.5	1.481
Spreadz	6.4	5.1	1.268
Tech Café A	9.0	6.6	1.356
Mills	8.1	11.5	0.708
Average	14.0	10.4	1.343

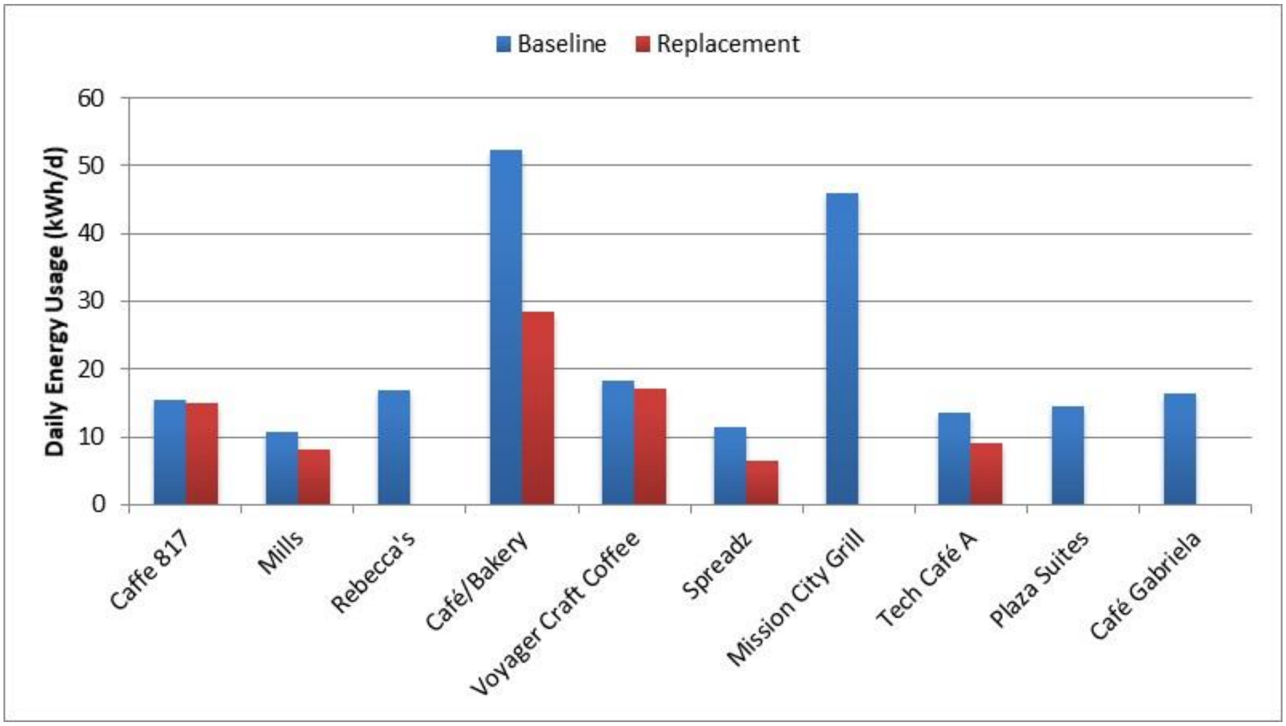
Source: Frontier Energy, Inc.

Table 18: Conveyor Toaster Replacement Data Comparison

Site	Baseline or Replacement?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)	Normalized Savings (%)	Payback Period (yrs)
Café/Bakery	Baseline	52.4	18.0	2.911	45.6	0.2
	Replacement	28.5	18.0	1.583		
Caffe 817	Baseline	15.5	8.8	1.766	13.2	3.7
	Replacement	15.0	9.8	1.583		
Voyager Craft Coffee	Baseline	18.4	11.2	1.640	9.7	6.1
	Replacement	17.0	11.5	1.481		
Spreadz	Baseline	8.2	5.2	1.561	18.8	0 (Instant)
	Replacement	6.4	5.1	1.268		
Tech Café A	Baseline	8.0	5.0	1.589	14.7	5.4
	Replacement	9.0	6.6	1.356		
Mills	Baseline	10.7	11.5	0.930	23.9	3.3
	Replacement	8.1	11.5	0.708		
Average					21.0	3.1

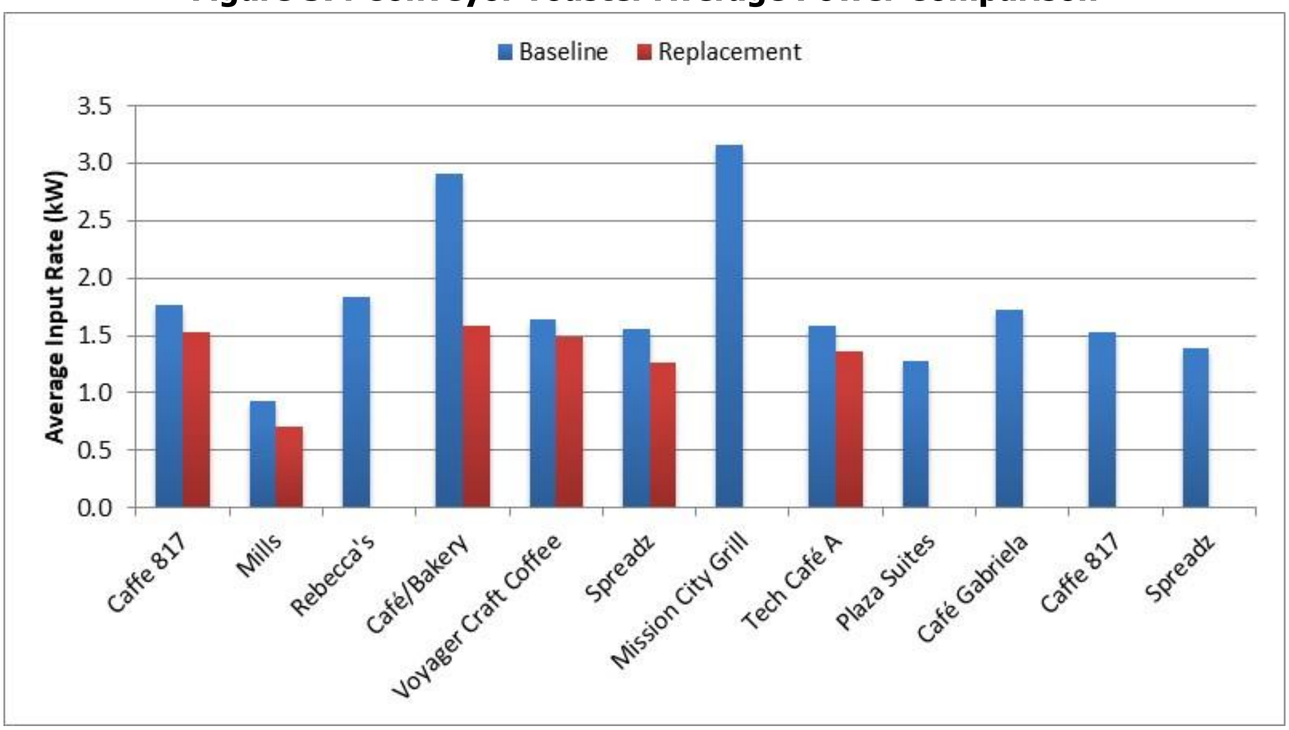
Source: Frontier Energy, Inc.

Figure 36: Conveyor Toaster Daily Energy Usage Comparison



Source: Frontier Energy, Inc.

Figure 37: Conveyor Toaster Average Power Comparison



Source: Frontier Energy, Inc.

Cooktop

Cooktops are commonly found in restaurants and businesses that do not have the need for a full-size six-burner range or prefer the mobility and smaller footprint that a cooktop offers. Like ranges, cooktops tend to have long hours of operation and relatively high energy usage rates required for boiling large amounts of water. While baseline electrical resistance cooktops still exist, efficient induction cooktops are beginning to become more commonplace. The research team found and monitored only one electrical resistance cooktop, but four induction cooktops.

Caffe 817

The only resistance cooktop was found inside Caffe 817's main kitchen area, a Wells W-H70 cooktop with two plates which the café used primarily for cooking their soups (Figure 38). The cooktop was generally turned on in the morning before the restaurant opened to make batches of soup and sometimes later in the afternoon to make replacement batches depending on demand. The cooktop operates for a total of about 8.4 hours per day, with both plates operating simultaneously for about 4.8 hours per day. Over a period of about a month, the cooktop consumed an average of 18.2 kWh per day.

Figure 38: Caffe 817 Wells H-70 Cooktop

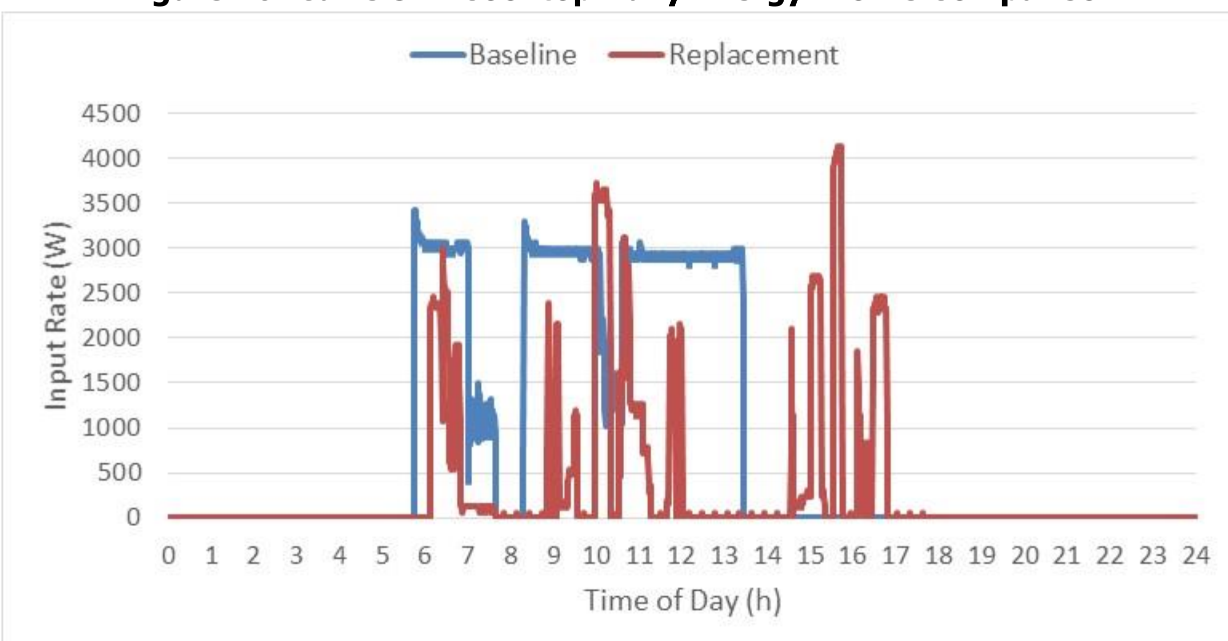
Source: Frontier Energy, Inc.

The Wells cooktop was replaced by a Vollrath induction unit (Figure 39). Replacing with the new induction unit resulted in a quicker heat up time, less heat loss to space, better soup uniformity, and greater safety and ease of cleaning. During the two-month monitoring period, the new induction cooktop averaged 7.4 kWh per day, operating for an average 4.8 hours a day (Figure 40). Normalizing for the seasonal difference in usage, researchers found that the replacement cooktop lowered energy by 29 percent, equivalent to about $164 per year in energy costs for the average $0.15 per kWh electrical rate. The energy efficient replacement had a payback period of 10.4 years despite these significant energy savings, since the baseline unit was significantly less expensive than the induction unit.

Figure 39: Caffe 817 Vollrath Mirage Replacement Induction Cooktop

Source: Frontier Energy, Inc.

Figure 40: Caffe 817 Cooktop Daily Energy Profile Comparison



Source: Frontier Energy, Inc.

Results

Cooktops are one of the strongest candidates for plug load energy reduction (Figure 41) due to their high input rates (Figure 42) and long hours of operation (Table 19), but many of the cooktops currently in service have already been switched to efficient induction technology. Where older resistance cooktops exist, though, substantial energy savings from switching to induction are nearly guaranteed (Table 20). However, the purchase cost of induction units still makes the payback period substantial. The benefits of induction cooktops extend beyond just energy savings, however; they are also safer, easier to clean, and produce quicker and more even heating.

Table 19: Cooktop Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Baseline (Cooktop)			
Caffe 817	18.2	8.4	2.168
Average	18.2	8.4	2.168
Replacement (Induction)			
Caffe 817	7.4	4.8	1.539
Tech Café B	3.0	6.1	0.502
SaltCraft 1	1.7	3.8	0.459
SaltCraft 2	2.9	4.8	0.602
Average	4.5	10.0	0.450

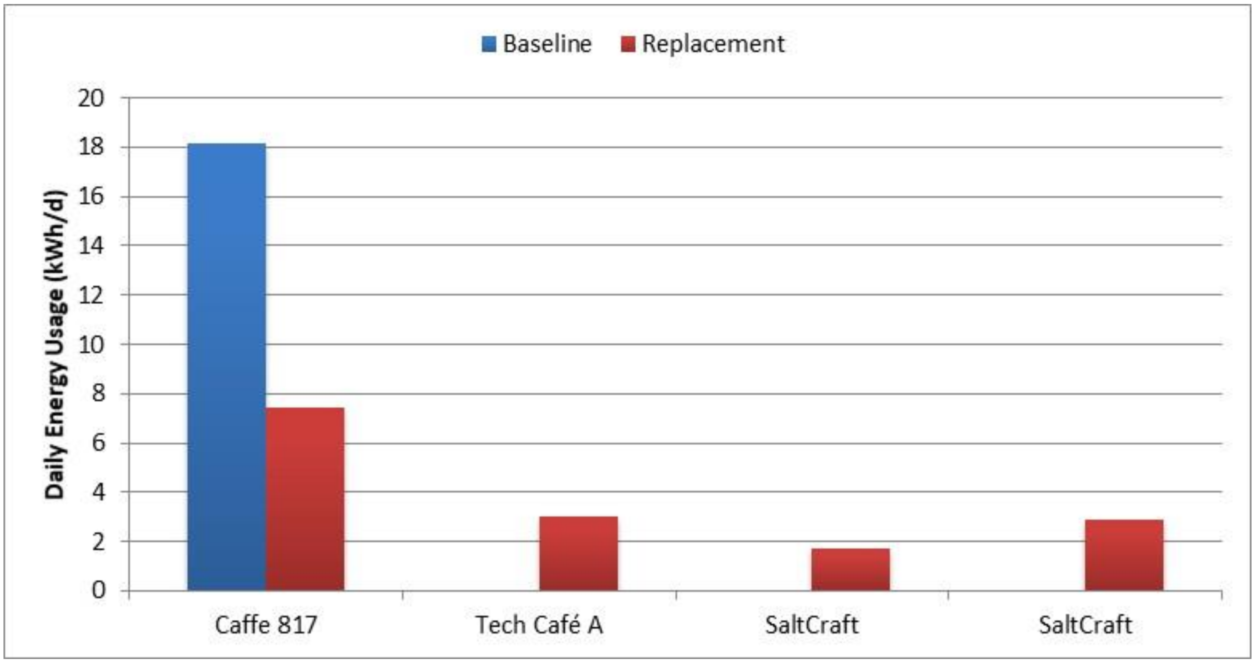
Source: Frontier Energy, Inc.

Table 20: Cooktop Replacement With Induction Data Comparison

Site	Baseline or Replacement?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)	Normalized Savings (%)	Payback Period (yrs)
Caffé 817	Baseline	18.2	8.4	2.168	29.0	10.4
	Replacement	7.4	4.8	1.539		
				Average	29.0	10.4

Source: Frontier Energy, Inc.

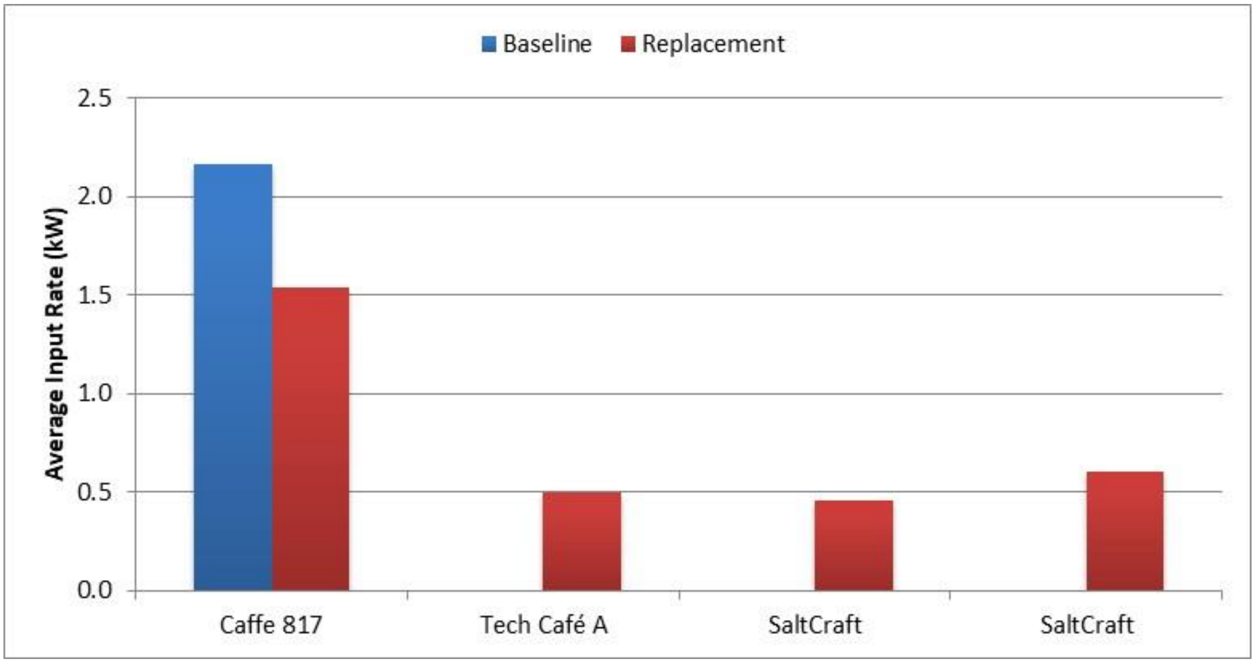
Figure 41: Cooktop Daily Energy Usage Comparison



All replacements are induction.

Source: Frontier Energy, Inc.

Figure 42: Cooktop Average Power Comparison



Source: Frontier Energy, Inc.

Microwave

Extremely common in all restaurant types but especially in quick service applications, microwaves quickly finish either heating products that do not require a crunchy texture or heating the interior of a product that is to be finished off in another appliance. Microwaves are ubiquitous and efficient, only consuming energy when actively operating. Given the commonality of the appliance, researchers determined microwave energy use to be worth characterizing, despite it typically being deemed as a low-energy appliance with minimal energy saving opportunity. The research team monitored two microwaves at a large fast food chain to estimate a baseline energy use of the appliance category.

Results

Frontier monitored the microwaves at two different QSR sites (Table 21). Unlike many other plug load appliances, idle energy is minimal, so the energy consumption for microwaves varied more widely from day to day. Energy consumption mirrored appliance demand much more directly. Researchers found that the microwaves had an average energy usage of 3.6 kWh per day with 24 hours of business operation. The closeness of the input rates from both units indicates that there is minimal idle energy usage. No replacements were made for the microwaves because of the lack in suitable replacements, though a possible replacement could be to replace a microwave and a different appliance with a single rapid cook oven, to reduce labor and streamline processes. Under the right circumstances, this could generate energy savings.

Table 21: Microwave Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
QSR 1	5.7	6.6	0.870
QSR 2	1.4	1.7	0.822
Average	3.6	4.1	0.846

Source: Frontier Energy, Inc.

Panini Press

Panini presses have a specialized function but are common in foodservice due to the popularity of hot sandwiches. They are typically used on sandwich items to achieve a desired toasted or crunchy texture. To perform in an on-demand situation, these appliances must maintain the contact plates at an execution-ready temperature resulting in high levels of energy consumption. Depending on the type of operation, this constant high heat is not always necessary. Energy could be saved using an energy setback mode or through a different technology. One such existing technology is a hybrid microwave panini press, which cuts down cooking time by using microwaves to cook the inside while searing the outside to still get that proper crisp. Researchers were unable to compare energy through a direct replacement of a baseline panini press, though they were able to estimate possible energy savings by normalizing for hours of usage.

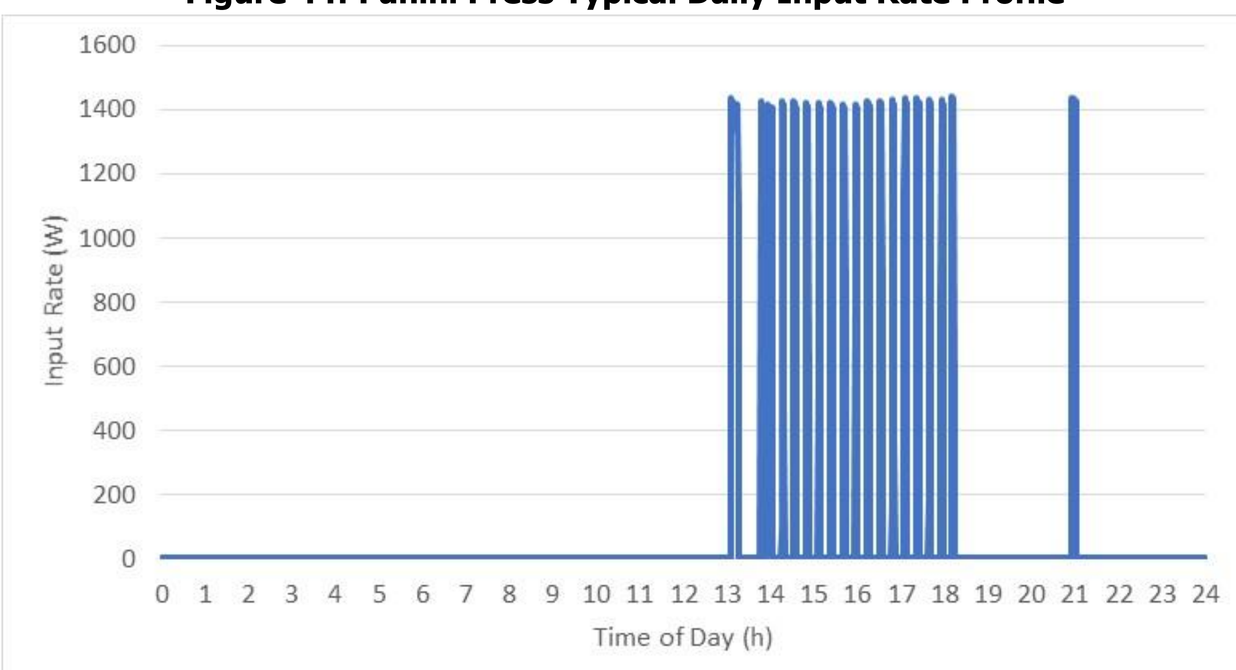
Baseline – University of California, Berkeley

Researchers monitored seven baseline panini presses, one such press being the 120V Star GX10IG model at the UC Berkeley's Crossroads dining hall (Figure 43). The panini press is located in the communal area near the bread/sandwich counter for students to use during mealtimes. It is normally turned on during the transition to lunch service and left on until the end of the dinner service since the dining hall operates continuously. During meal service, the panini press is left on at a constant setting, normally in an open position while idling. The exact time the staff turns the panini press off varies, and it was observed in the data that once the students forgot to turn off the unit overnight. Much of the energy usage stems from the press idling and keeping the grill plates hot rather than heating actual food product. This is particularly true when the grill plates are left open, which students do frequently during usage periods. During the energy monitoring period, the panini press used an average 2.5 kWh per day of electrical energy during an average 1.9 hours of operation (Figure 44). Averaging only the days of usage, the panini press used 5.3 kWh per day of electrical energy across 4.0 hours of operation.

Figure 43: UC Berkeley Star GX10IG Panini Press

Source: Frontier Energy, Inc.

Figure 44: Panini Press Typical Daily Input Rate Profile



Source: Frontier Energy, Inc.

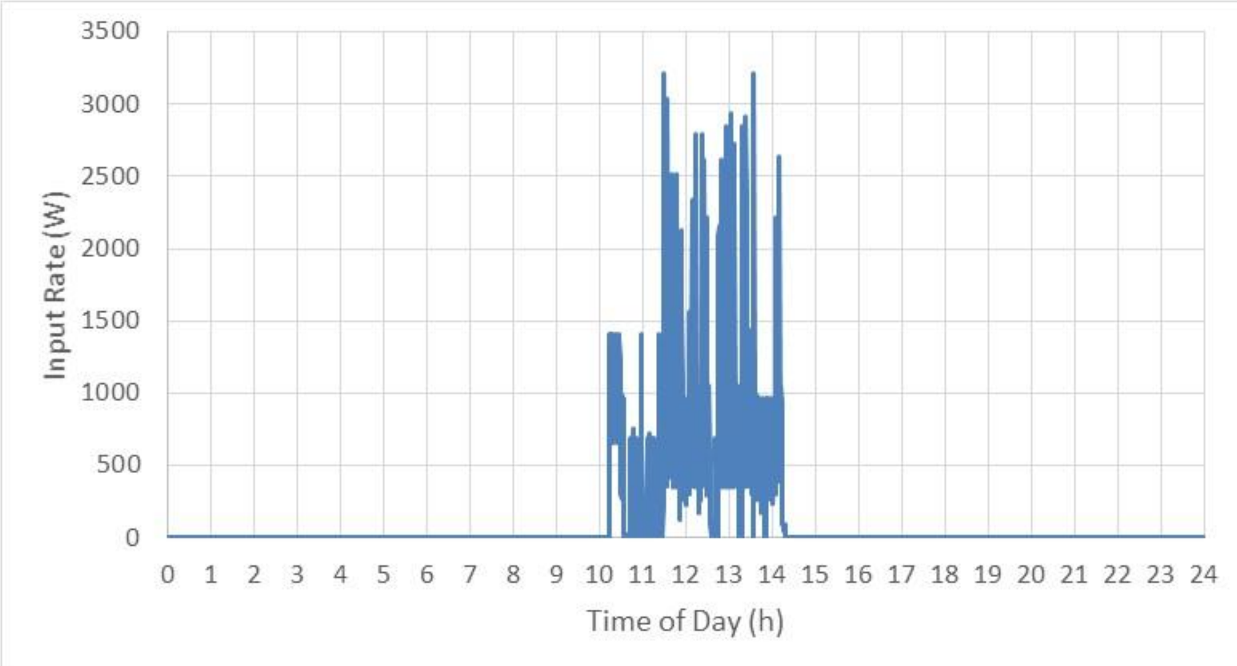
Replacement – Tech Café A

Researchers monitored two 208V Electrolux panini presses at the sandwich station at Tech Café A's dining hall (Figure 45). The panini press is located behind the counter and is used by the staff to toast sandwiches ordered by the employees. One panini press was used slightly more than the other, given the proximity to the counter where the staff constructed the sandwiches. The presses were turned on right before service and off immediately after service, for an average four hours of operation per day. During the energy monitoring period, one panini press used an average 3.1 kWh per day of operation while the other used an average 1.4 kWh per day of operation (Figure 46). These two presses serve as a benchmark for what the energy consumption of advanced panini presses can be like for high and low volume operations.

Figure 45: Tech Café Advanced Panini Press

Source: Frontier Energy, Inc.

Figure 46: High Speed Microwave Panini Press Daily Energy Profile



Source: Frontier Energy, Inc.

Results

Panini presses generally operate continuously at large electrical input rate, since they must maintain very hot surfaces to create the proper texture whenever used. This appliance usage behavior means that total energy use corresponds strongly with the hours of equipment on-time, a conclusion that is confirmed by the baseline energy data. However, researchers discovered that the advanced microwave panini presses fluctuate much more in average input rate, since the microwave technology means that more energy is used in specifically heating food product than simply keeping the crisping surfaces hot. Energy use for these efficient panini presses thus track active production usage much more than simply on-time, which resulted in a 45 percent lower measured average input rate (Table 22).

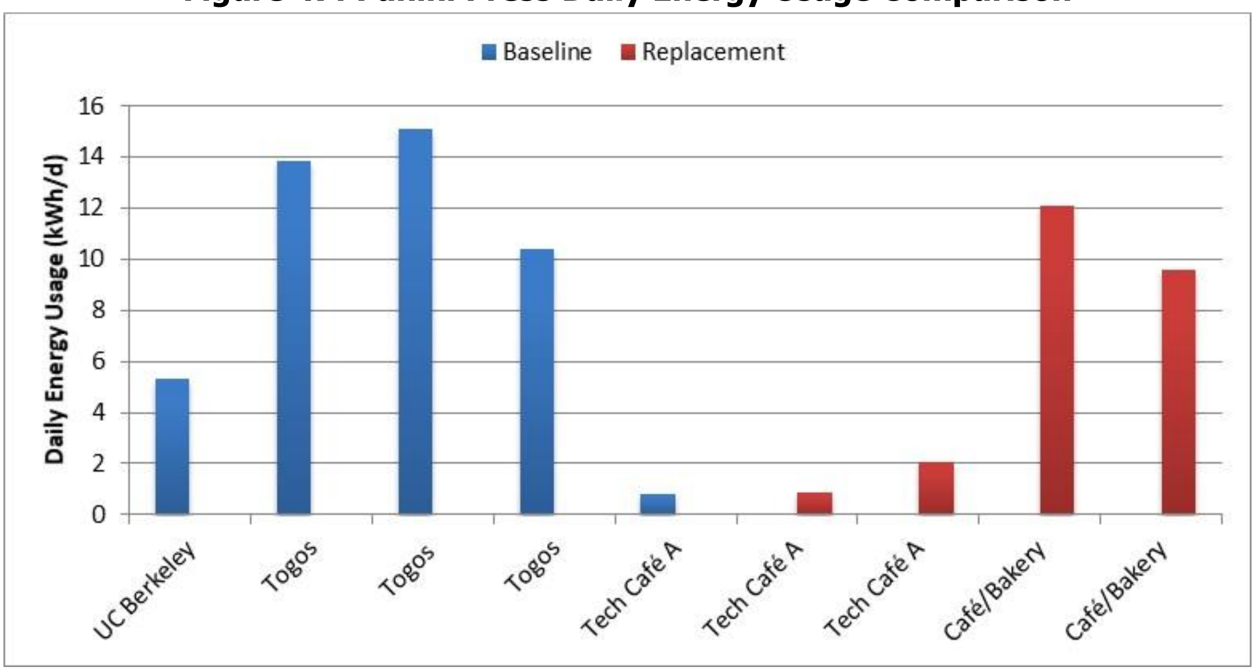
Thus, even though researchers could not do any direct panini press replacements, Frontier concluded that switching to the advanced microwave panini press would reduce energy costs by 45 percent on average (Figures 47 and 48).These savings could be significantly higher or lower depending on how actively the panini press is being used. As shown in Tech Café A's cafeteria, increased usage can make an advanced panini press use double the energy of the same unit, despite being used for the same application and having the same hours of operation. This type of demand-driven energy use is ideal, and is a natural energy saving upgrade from the on-time-driven energy use of the baseline models.

Table 22: Panini Press Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Baseline			
UC Berkeley	5.3	4.1	1.306
Togo's North Livermore	13.9	11.6	1.193
Togo's Livermore	15.1	12.5	1.206
Togo's Santa Clara	10.4	8.9	1.170
Tech Café A	0.8	2.4	0.342
Average	7.7	7.0	1.069
Replacement			
Tech Café A 1	0.9	2.5	0.352
Tech Café A 2	2.0	2.7	0.744
Café/Bakery 1	12.1	18.0	0.672
Café/Bakery 2	9.6	18.0	0.533
Average	6.2	10.3	0.593

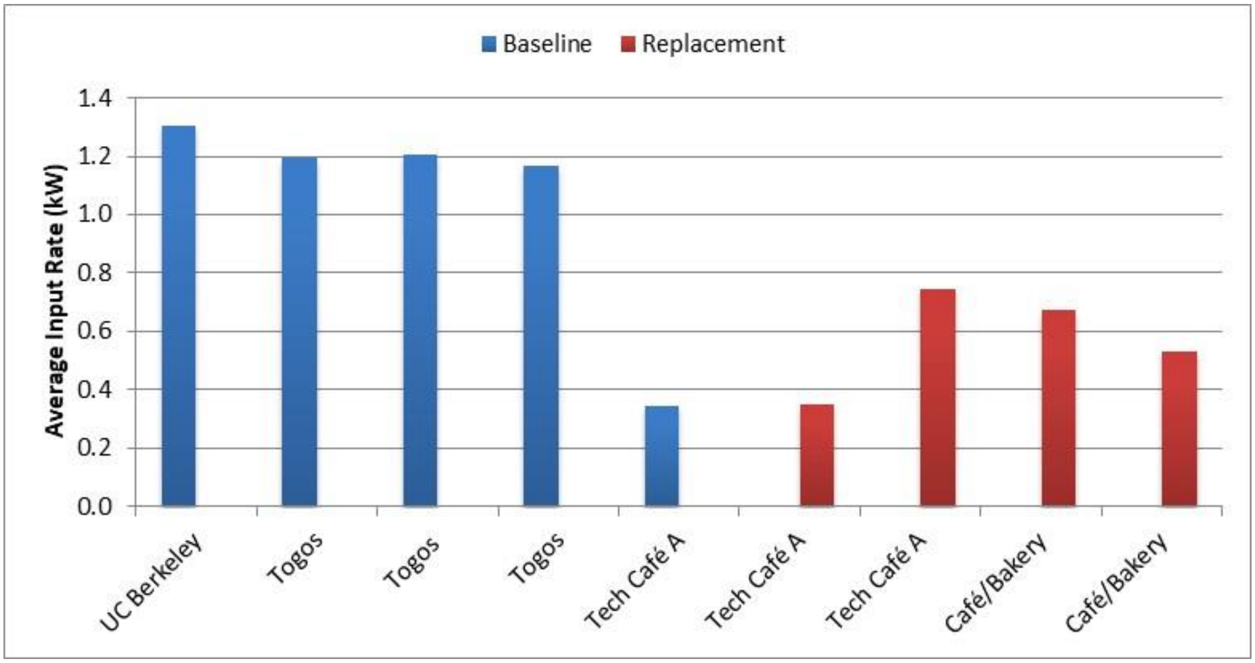
Source: Frontier Energy, Inc.

Figure 47: Panini Press Daily Energy Usage Comparison



Source: Frontier Energy, Inc.

Figure 48: Panini Press Average Power Comparison



Source: Frontier Energy, Inc.

Pop-Up Toaster

Pop-up toasters are a common toasting appliance for low volume usages, thanks to the low equipment costs and ease of use. These are generally used in self-serve areas of dining halls or cafeterias, where customers can toast their own bread. Energy usage is entirely demand driven, since the heating elements only engage when a customer is toasting. Given the ubiquity of the appliance, researchers determined pop-up toaster energy use to be worth characterizing, despite it typically being deemed as a low energy appliance. The research team monitored one pop-up toaster at a corporate cafeteria, which was enough to ballpark the energy consumption.

Results

Frontier monitored the pop-up toaster at Tech Company's corporate cafeteria and found that it used only 0.6 kWh on average per day (Table 23). On business days, the pop-up toaster averaged 0.86 kWh, operating for 1.73 hours out of the approximate four hours of cafeteria operation. No replacements were made for the pop-up toaster because of the lack in suitable replacements and dollar savings available. Extrapolated for a whole year, the pop-up toaster itself only costs about $34 in annual energy costs, using the typical $0.15/kWh electrical rate.

Table 23: Pop-Up Toaster Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Tech Café A	0.6	1.3	0.474
Average	0.6	1.3	0.474

Source: Frontier Energy, Inc.

Rapid Cook Oven

Rapid cook ovens are a new advanced technology that is quickly gaining popularity. They are comprised of a high temperature countertop oven with embedded microwave technology for quick cooking. This hybrid appliance allows for flexible and high-speed cooking, all with a small kitchen footprint. Rapid cook ovens are thus being used to replace older ovens, toasters, and microwaves as part of full menu process changes. Rapid cook ovens have potential to consolidate multiple pieces of equipment in the kitchen, reducing overall energy use. The rapid cook oven operated at a 500 – 600°F (260 – 316°C) cavity temperature resulting in high energy usage. As an expanding appliance category with potential for energy saving replacement, Frontier conducted extensive research to characterize the field usage of rapid cook ovens across a variety of applications. The research team monitored five rapid cook ovens in total, across four different facilities.

Results

Frontier monitored the rapid cook oven at two quick service chains, an independent coffee shop and a corporate cafeteria. All rapid cook ovens monitored consumed double-digit kWh daily, even ovens that only operated for about six hours per day. The two lowest energy using units, at Tech Café B (Figure 49) and Togo's (Figure 50), had the highest average input rate. This indicates that rapid cook oven energy use is strongly driven by volume of product cooked. The units with concentrated periods of usage had an average input rate about twice that of the rapid cook ovens found in the Quick Service Restaurant open 24 hours. Daily profile graphs shown in Figure **Error! Reference source not found.** and 53 indicate that energy input can vary widely throughout the day, but that idling rates to keep the oven hot and ready typically fall between 1– 2 kW. Cooking rates can be three to four times higher, depending on the exact recipe settings. Daily energy consumption was found to be as high as 27.5 kWh per day.

It is difficult to estimate the potential savings from rapid cook ovens, since the upgrade would need to replace multiple appliances and involve process changes. This affects the costs of cooling, space, and even labor, making the replacement analysis more complex than a traditional like-for-like replacement. However, an example case study can be made of the replacement at Togo's. The owner replaced their two-platen panini press with a rapid cook oven, which expanded their menu capabilities to offer six new menu items (Figure 54). Togo's found it also allowed them to turn off one of the wells of their steam holding table, since the increased speed meant that they could prepare the ingredients fresh rather than precooking and holding. Though the rapid cook oven consumed a sizeable 12.8 kWh/day, being able to replace both the panini press and the steam well meant that the appliance energy before and after replacement was essentially unchanged (Table 24). Togo's had approximately the same energy cost before and after rapid cook oven replacement, but gained an expanded menu and a higher quality product to deliver to the customer (Figures 55 and 56).

Figure 49: Tech Cafe B TurboChef i5 Rapid Cook Oven

Source: Frontier Energy, Inc.

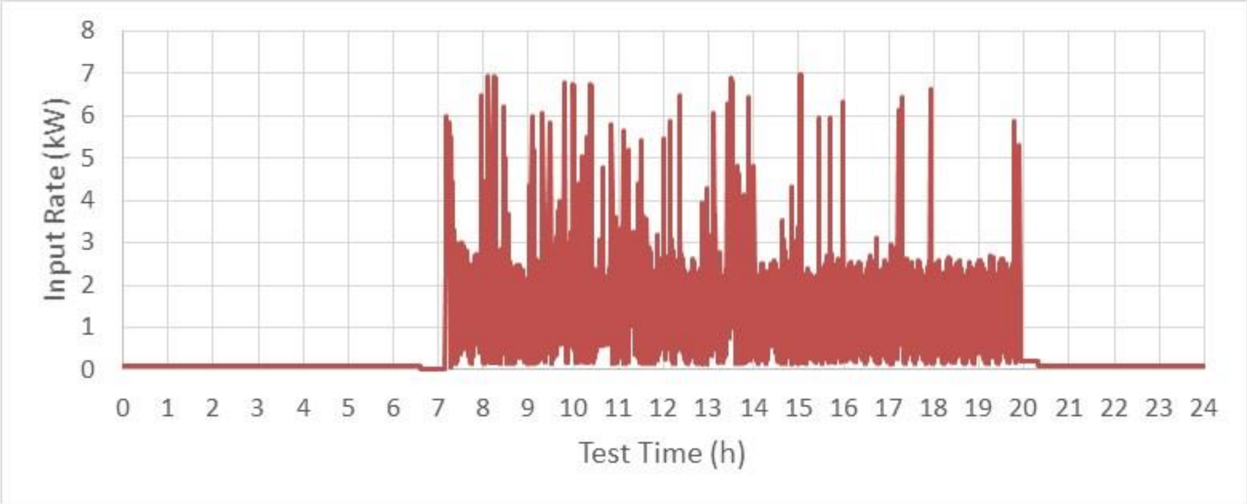
Figure 50: Togo's Amana ACE19V Rapid Cook Oven

Source: Frontier Energy, Inc.

Figure 51: Chromatic Coffee TurboChef i3 Rapid Cook Oven

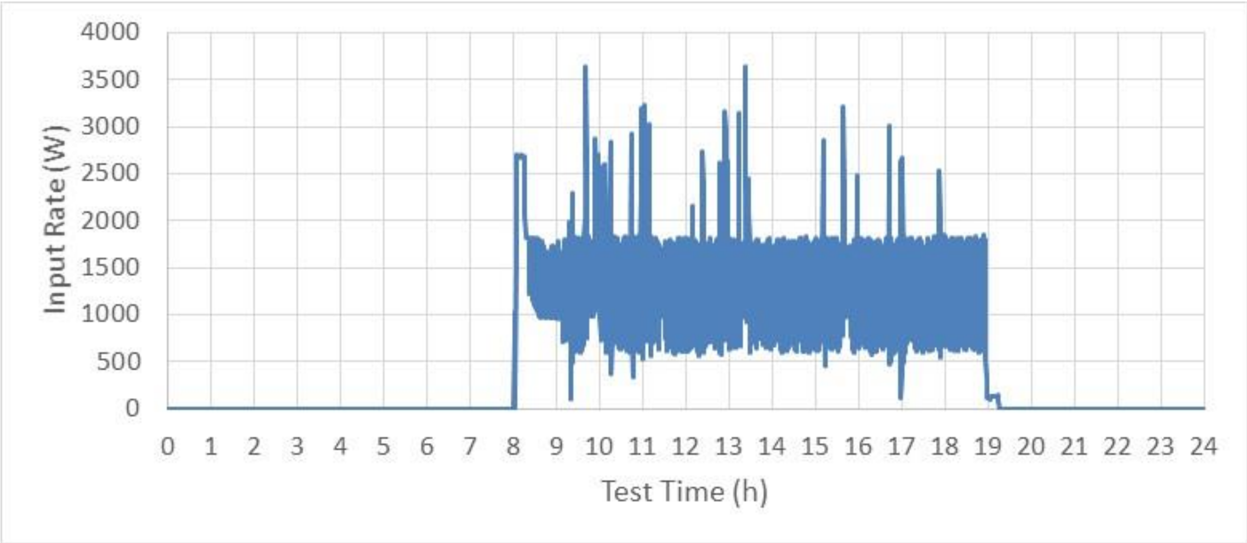
Source: Frontier Energy, Inc.

Figure 52: Chromatic Coffee Rapid Cook Oven Daily Energy Profile



Source: Frontier Energy, Inc.

Figure 53: Togo's Rapid Cook Oven Daily Energy Profile



Source: Frontier Energy, Inc.

Figure 54: Togo's Amana ACE19V Rapid Cook Oven

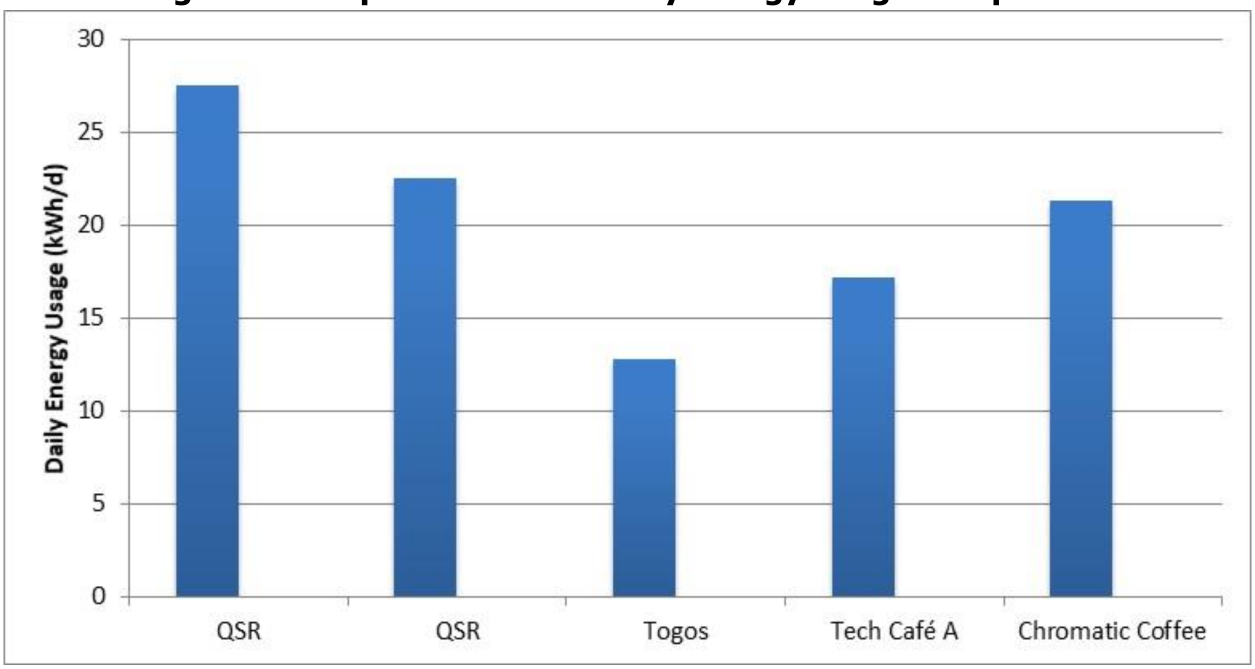
Source: Frontier Energy, Inc.

Table 24: Rapid Cook Oven Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
QSR#1	27.5	23.5	1.173
QSR#2	22.6	24.0	0.942
Togo's	12.8	6.2	2.066
Tech Café B	17.2	6.3	2.740
Chromatic Coffee	21.3	13.1	1.626
Average	20.3	14.6	1.439

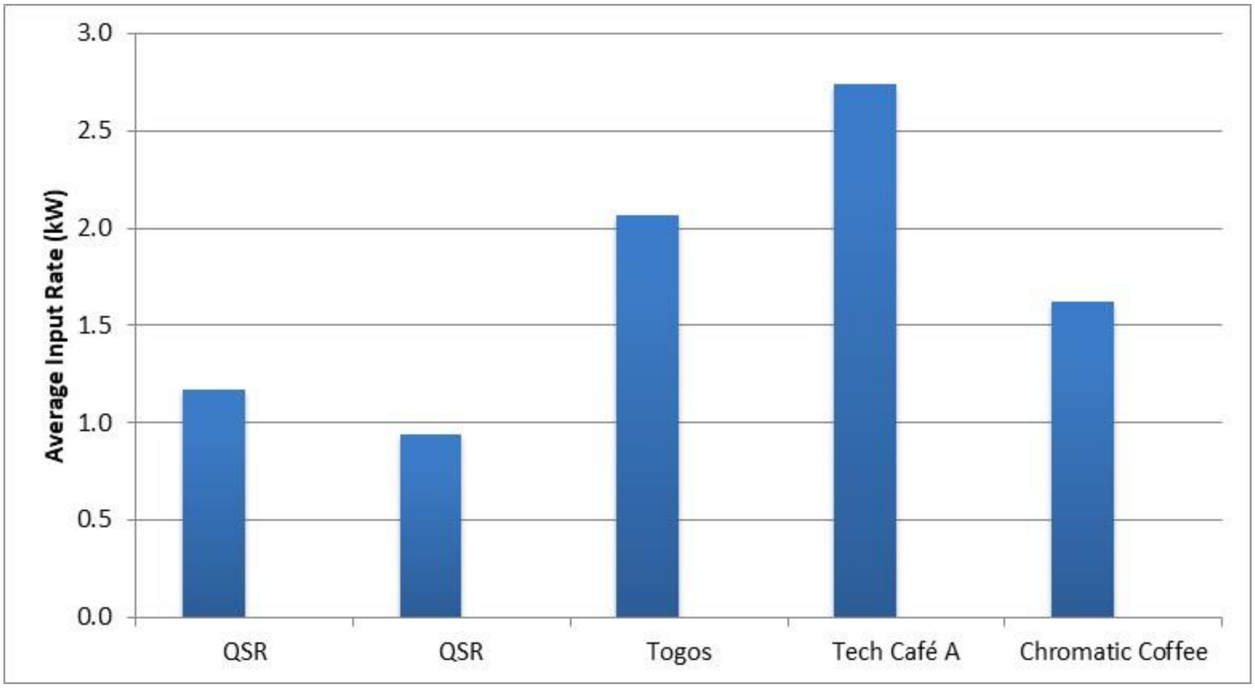
Source: Frontier Energy, Inc.

Figure 55: Rapid Cook Oven Daily Energy Usage Comparison



Source: Frontier Energy, Inc.

Figure 56: Rapid Cook Oven Average Power Comparison



Source: Frontier Energy, Inc.

Rethermalizer

The rethermalizer is a specialty piece of equipment that heats up prepared product for service. It essentially consists of a high temperature circulating water bath, in which packaged goods can be submerged for reheating. This appliance is fairly rare because of its large volume and specialized purpose and only one was found among the 29 sites monitored.

Results

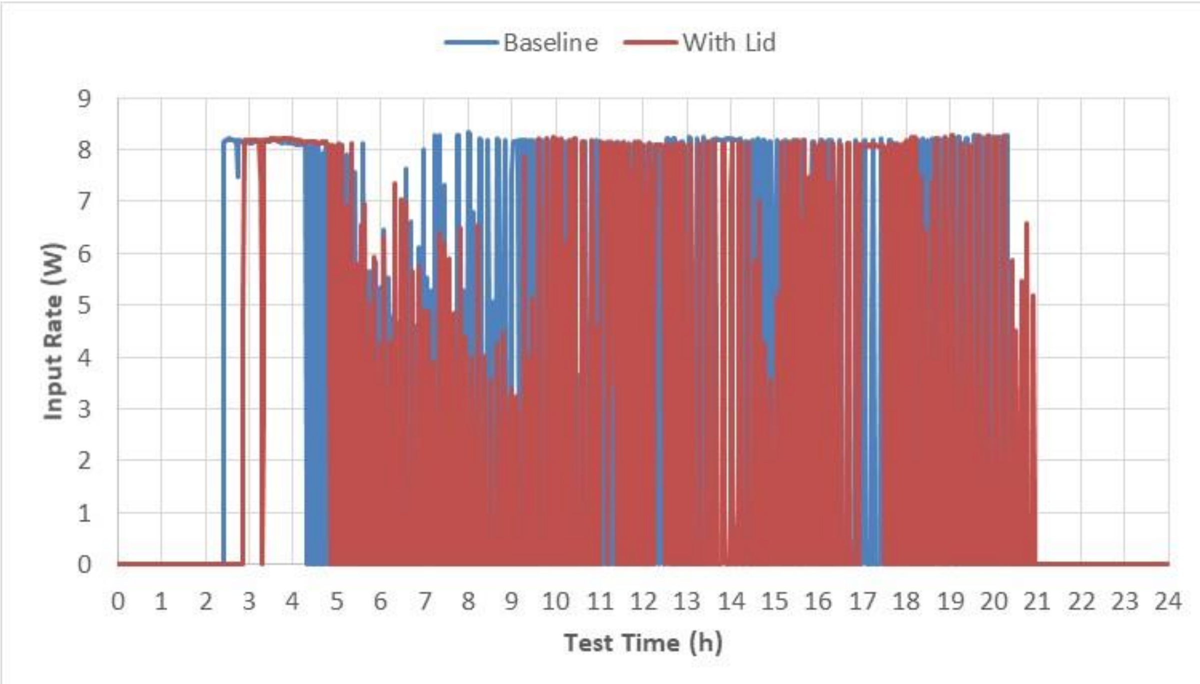
Frontier monitored the rethermalizer found at Café/Bakery (Figure 57), which was being used to heat up large quantities of packaged soup.

Figure 57: Café/Bakery Rethermalizer

Source: Frontier Energy, Inc.

Daily operation consisted of a long preheat of more than an hour to get the large volume of water to the proper temperature, followed by continual but varied usage all through the store's long hours of operation. Energy use generally started picking up slightly before lunchtime, when the store starts shifting from a more breakfast-oriented service. The baseline rethermalizer consumed a sizeable 64 kWh/day (Figure 58).

Figure 58: Café/Bakery Rethermalizer Energy Profile Comparison



Source: Frontier Energy, Inc.

Researchers noticed that the unit had no insulation and that much of the heat energy was escaping out into the work environment rather than going into the soup. Frontier suggested covering the rethermalizer with a lid when not actively taking product in/out, as a simple and cost-effective solution to save energy. With the added lid to retain the heat, the rethermalizer reduced its energy consumption from 64 kWh/day to 57 kWh/day (Table 25). For the average $0.15 per kWh rate, the addition of a lid amounts to approximately $380 in annual energy savings for the site.

Table 25: Rethermalizer Replacement Data Comparison

Site	Baseline or Replacement	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)	Normalized Savings (%)
Café/Bakery	Baseline	64.0	18.0	3.556	10.9
	Replacement	57.0	18.0	3.167	
				Average	10.9

Source: Frontier Energy, Inc.

Rice Cooker

Rice cookers are common in any operation that serves rice and a staple in kitchens serving Asian cuisine. Large-scale kitchens specializing in different cuisines may prepare the rice in steamers instead of rice cookers with their high throughput and versatility to cook other products. Rice cookers are inherently a batch cooking appliance with most of the energy expended during the cooking process and less energy during the keep-warm period that follows. Restaurants typically have multiple rice cookers due to the limited capacity of a single cooker to produce a quality and uniform product. Researchers monitored seven rice cookers at four different sites, three of which were Asian fusion restaurants with multiple rice cookers.

Lin Jia Asian Kitchen

As an Asian fusion restaurant focusing on Chinese food, Lin Jia has an absolute necessity for rice. They operate two rice cookers, a Zojirushi NYC-36 (Figure 59) and a Tiger JNO-A36U (Figure 60), both were monitored for energy usage for about one month. Both appliances are 120V, 20-cup commercial cookers from reputable Asian brands that have a long history of rice cooker manufacturing. Lin Jia uses both cookers throughout the day to supply fresh rice for lunch and dinner services, typically cooking anywhere from one to four batches daily depending on demand. Across the monitoring period, the Zojirushi had an average energy consumption of 2.2 kWh per day, operating for about 6.0 hours per day (Figure 61). The Tiger had an average energy consumption of 1.7 kWh per day, operating for about 8.4 hours per day (Figure 62).

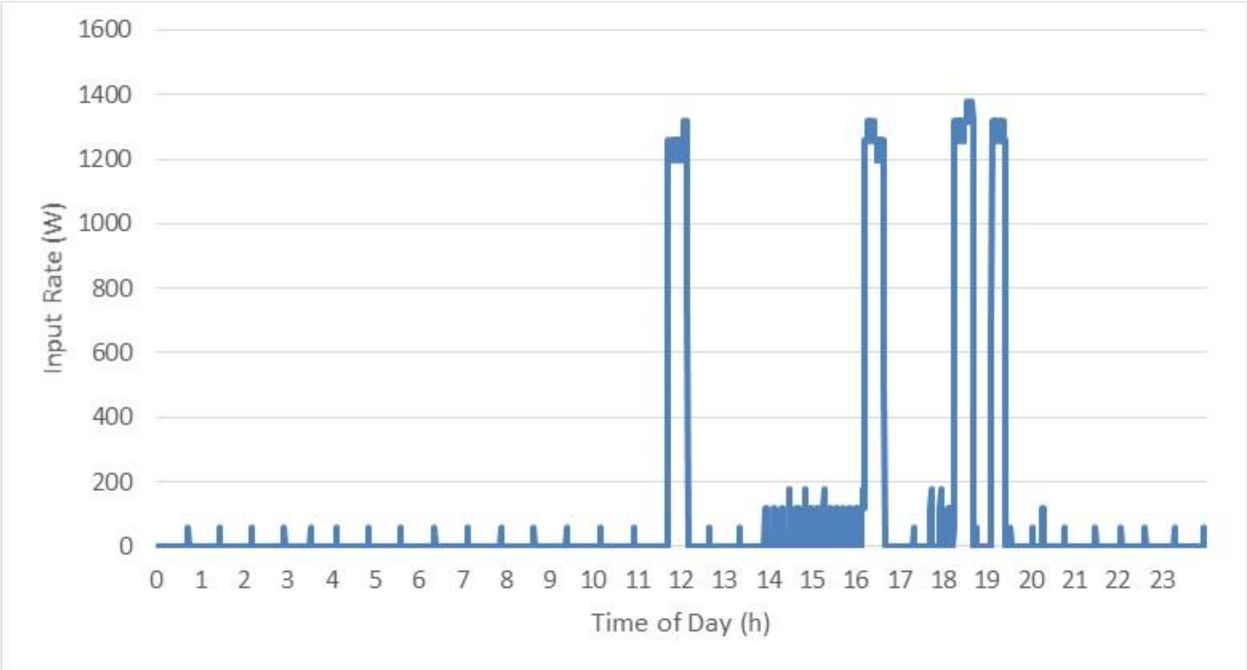
Figure 59: Lin Jia Zojirushi NYC-36 Commercial Rice Cooker and Warmer

Source: Frontier Energy, Inc.

Figure 60: Lin Jia Tiger JNO-A36U Commercial Rice Cooker and Warmer

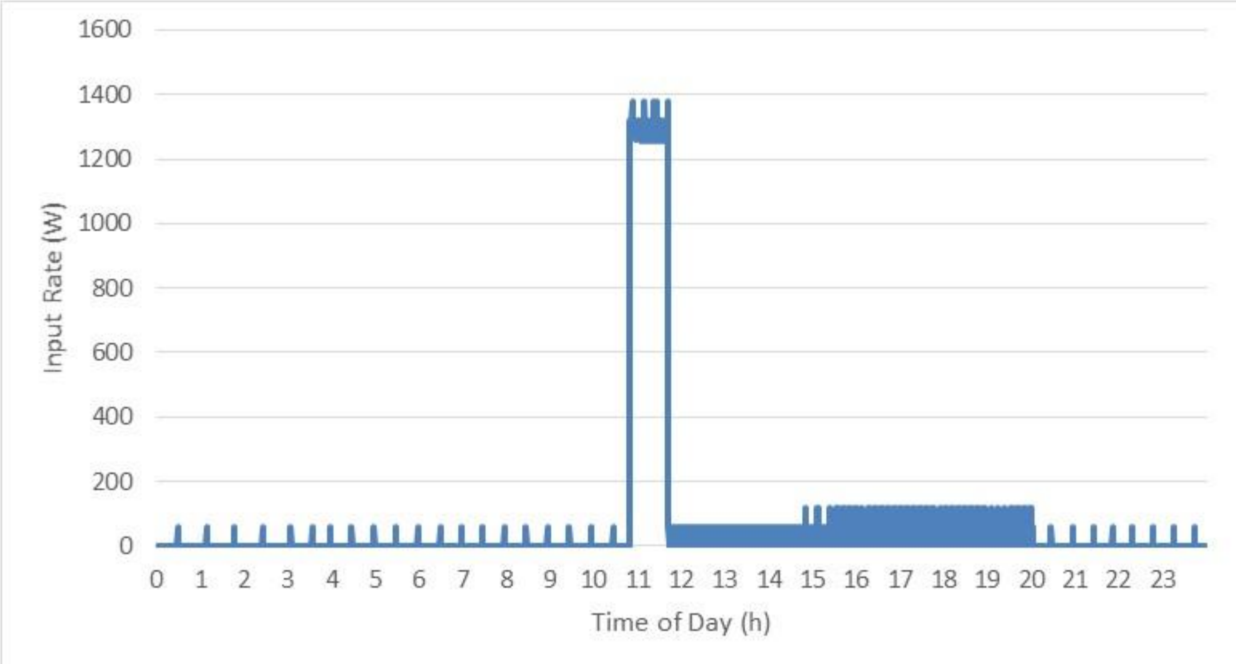
Source: Frontier Energy, Inc.

Figure 60: Zojirushi Rice Cooker Typical Daily Input Rate Profile



Source: Frontier Energy, Inc.

Figure 61: Tiger Rice Cooker Typical Daily Input Rate Profile



Source: Frontier Energy, Inc.

Dabba

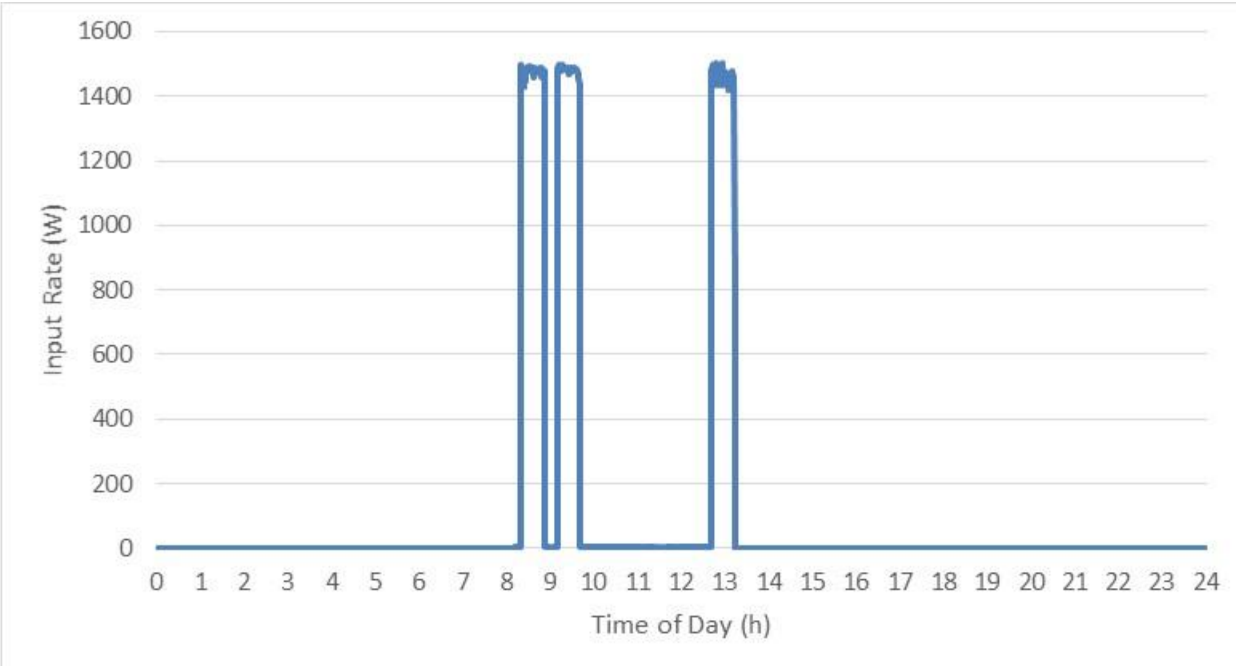
Dabba features two large Town 57137 37-cup rice cookers (Figure 63), which it uses to prepare large batches of rice ahead of the daily lunch service.

Figure 62: Dabba Town 57137 37 Cup Rice Cookers

Source: Frontier Energy, Inc.

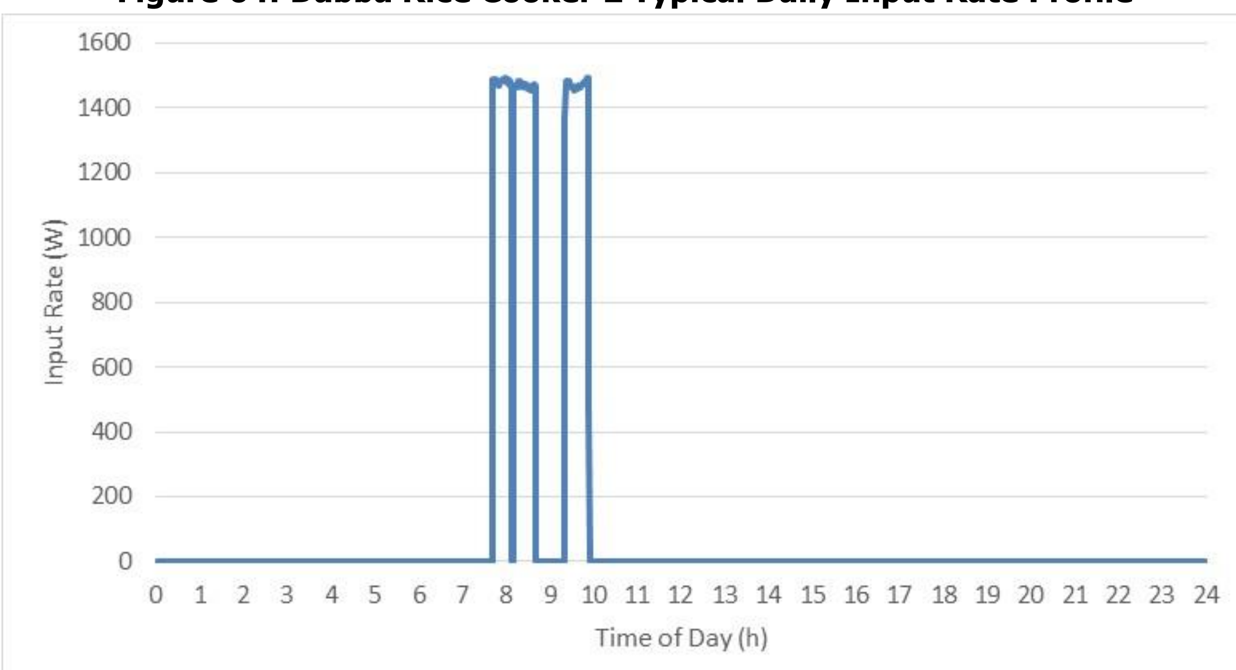
Typically, the cookers produce a total of three batches of rice in the morning with an extra batch being cooked if heavy business volume requires it. The batches of rice are emptied immediately after cooking so the rice can be seasoned and placed on the service line for a create-your-own style lunch. As such, the rice cooker is never in a warming state for any substantial period of time. Sometimes a single rice cooker may be used and the other left unused, since they are interchangeable. Researchers monitored both 120V rice cookers for several months. Throughout the monitoring period, one rice cooker averaged 1.6 kWh per day, operating for about 1.4 hours per day (Figure 64). The other rice cooker had an average energy consumption of 1.2 kWh per day, operating for about 1.1 hours per day (Figure 65). Both cookers are the same model and the normalized energy usage by hours of operation is nearly identical.

Figure 63: Dabba Rice Cooker 1 Typical Daily Input Rate Profile



Source: Frontier Energy, Inc.

Figure 64: Dabba Rice Cooker 2 Typical Daily Input Rate Profile



Source: Frontier Energy, Inc.

Results

Rice cookers have relatively low energy usage compared to other plug load appliances. Based on monitoring results at all four sites, rice cookers are not an appliance generally left on when not in use (Table 26). Different restaurants use rice cookers in different ways. Lin Jia used the warming function as needed and then unplugged it, whereas Dabba unplugged the rice cooker right after every cook cycle because they needed the rice for additional preparation.

Table 26: Rice Cooker Results

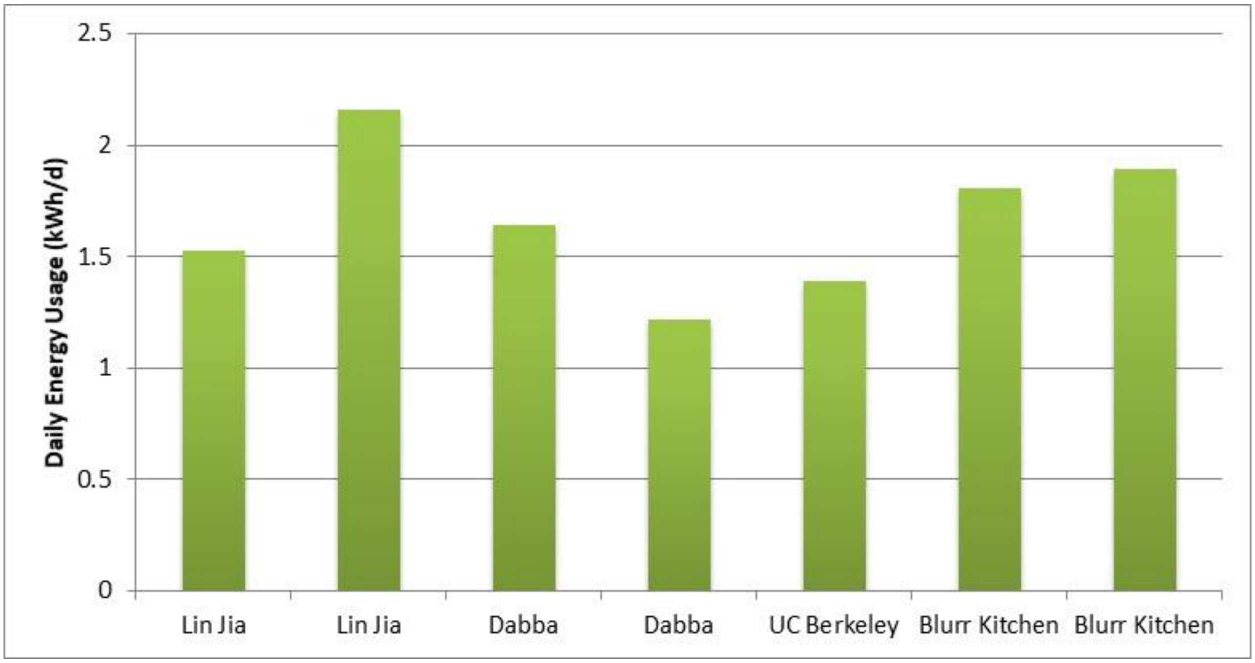
Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Lin Jia	1.5	8.9	0.172
Lin Jia	2.2	6.0	0.358
Dabba	1.6	2.8	0.596
Dabba	1.2	1.9	0.632
UC Berkeley	1.4	7.2	0.194
Blurr Kitchen	1.8	9.5	0.191
Blurr Kitchen	1.9	10.3	0.183
Average	1.7	6.6	0.332

Source: Frontier Energy, Inc.

The input rate differences may seem to indicate that some rice cookers are more efficient, but this is due much more to usage behavior than rice cooker efficiency. For example, the Dabba input rates look particularly high because they only capture cooking usage and never warming usage. Rice cooker energy usage doesn't always correlate completely with the number of operating hours because the number of cook cycles (which are more energy intensive) have the largest effect on energy usage. A good example is the comparison between the two rice cookers monitored at Lin Jia. At initial glance, the Zojirushi seems more inefficient in terms of energy usage and input rate (Figure 66). However, a closer look at the data shows that this is primarily because the Zojirushi usage had a significantly higher proportion of cooking to warming activity than the Tiger rice cooker.

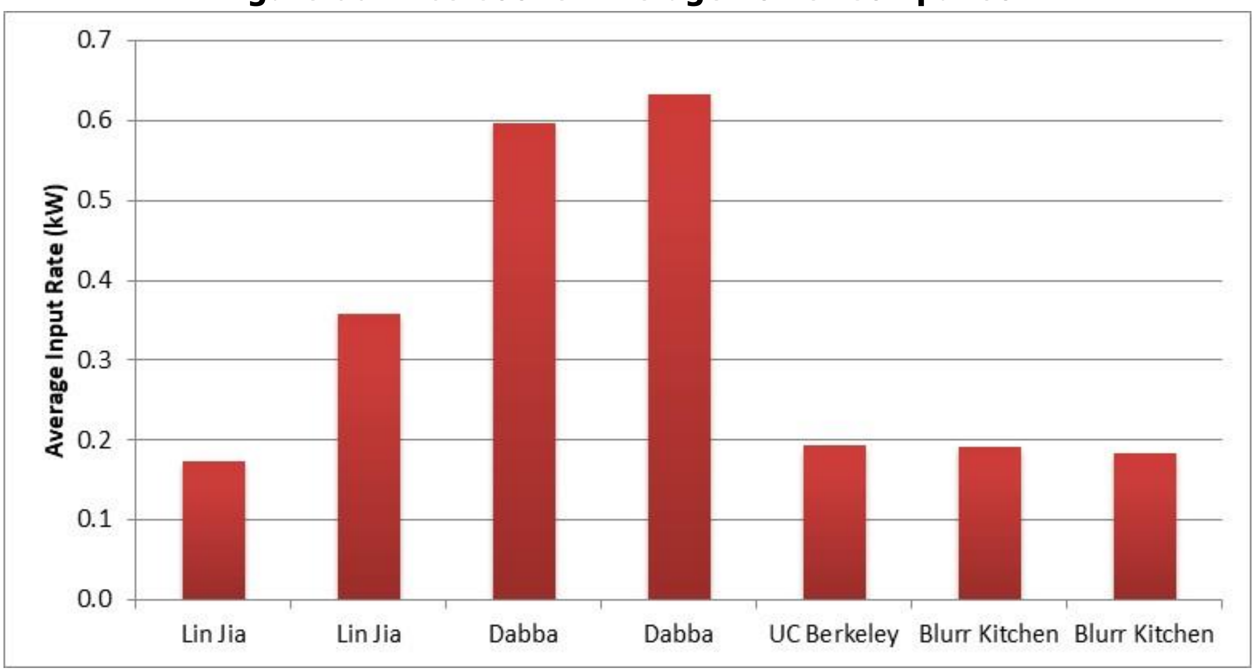
Rice cookers don't have significant distinctions between them, and it is difficult to save much energy simply by switching rice cooker models. Induction technology could possibly provide energy savings, but no commercial induction rice cookers exist that are National Science Foundation (NSF) certified. Currently, the largest sized induction rice cooker has a capacity of only 8 cups, which isn't nearly enough for a foodservice operation. Overall, the rice cookers had an average energy usage of 1.7 kWh per day, throughout 6.6 hours of operation (Figure 67).

Figure 65: Rice Cooker Daily Energy Usage Comparison



Source: Frontier Energy, Inc.

Figure 66: Rice Cooker Average Power Comparison



Source: Frontier Energy, Inc.

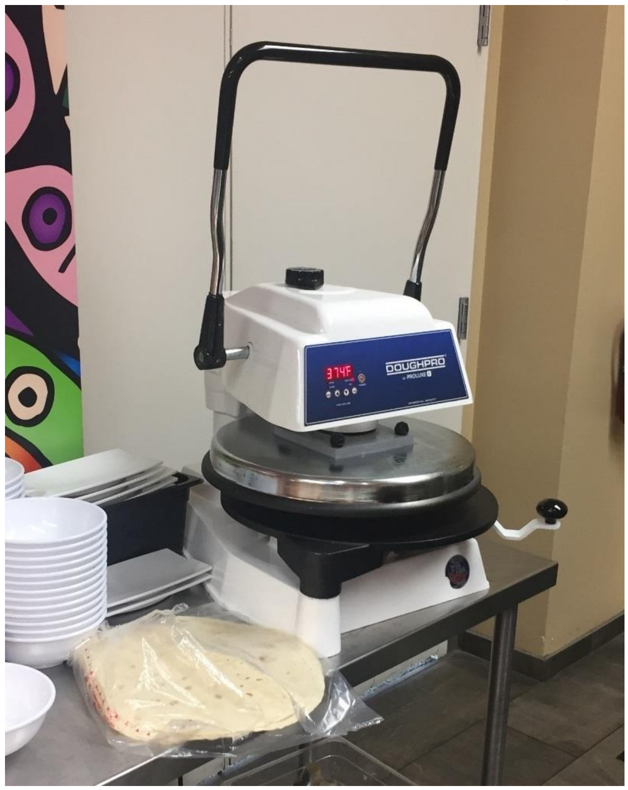
Tortilla Warmer

Tortilla warmers are essential for any restaurant that serves tortillas without a griddle. They are necessary to properly prepare tortillas for clientele by heating them from top and bottom for a short period of time. Depending on business volume, a restaurant may have multiple warmers. Five tortilla warmers from three separate locations were evaluated throughout the baseline monitoring period.

San Ramon Valley Conference Center

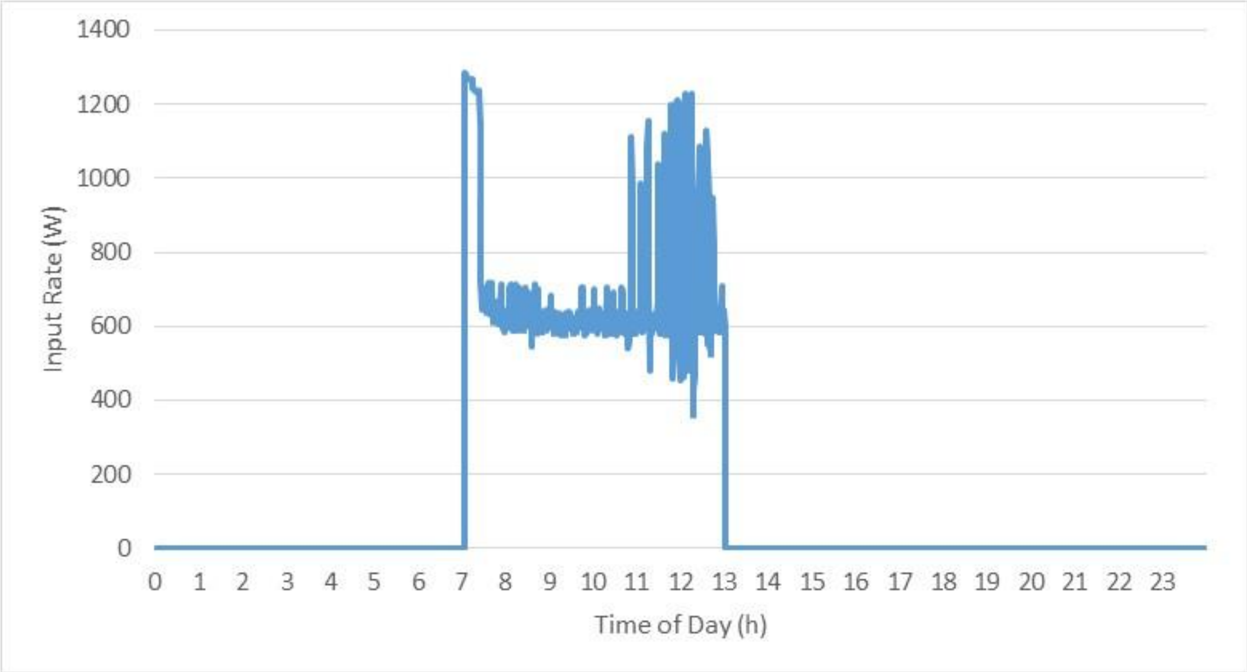
The San Ramon Valley Conference Center (SRVCC) features a taqueria open for weekday lunch, which receives a steady stream of business from the conference center employees and attendees. The taqueria uses a 120V Doughpro tortilla warmer, which was selected for energy monitoring (Figure 68). Over two months, the tortilla warmer used an average of 2.2 kWh per day, operating for 3.2 hours per day (Figure 69). Accounting only for days of operation, the tortilla warmer used an average of 4.0 kWh per day, operating for 5.8 hours per day. The taqueria's short operating hours made the tortilla press an unlikely candidate for replacement, but there is an opportunity to save energy by turning the tortilla press on closer to the start of lunch service to reduce the appliance operating hours even more.

Figure 67: San Ramon Valley Conference Center Doughpro Tortilla Warmer



Source: Frontier Energy, Inc.

Figure 68: San Ramon Valley Conference Center Daily Doughpro Tortilla Warmer Operation



Source: Frontier Energy, Inc.

Chipotle

Chipotle has two tortilla warmers (Figures 70 and 71) on its front service line that it uses constantly throughout the day, due to high demand. The tortilla warmers are turned on in the morning about an hour before the restaurant opens and left on all day until closing. Both tortilla warmers were monitored for more than a month. The left tortilla warmer had some fluctuations in daily energy usage, averaging 7.3 kWh per day with 13.3 hours of operation per day (Figure 72). By comparison, the right tortilla warmer had more consistent daily energy usage, averaging 8.8 kWh per day with 13.3 hours of operation per day (Figure 73).

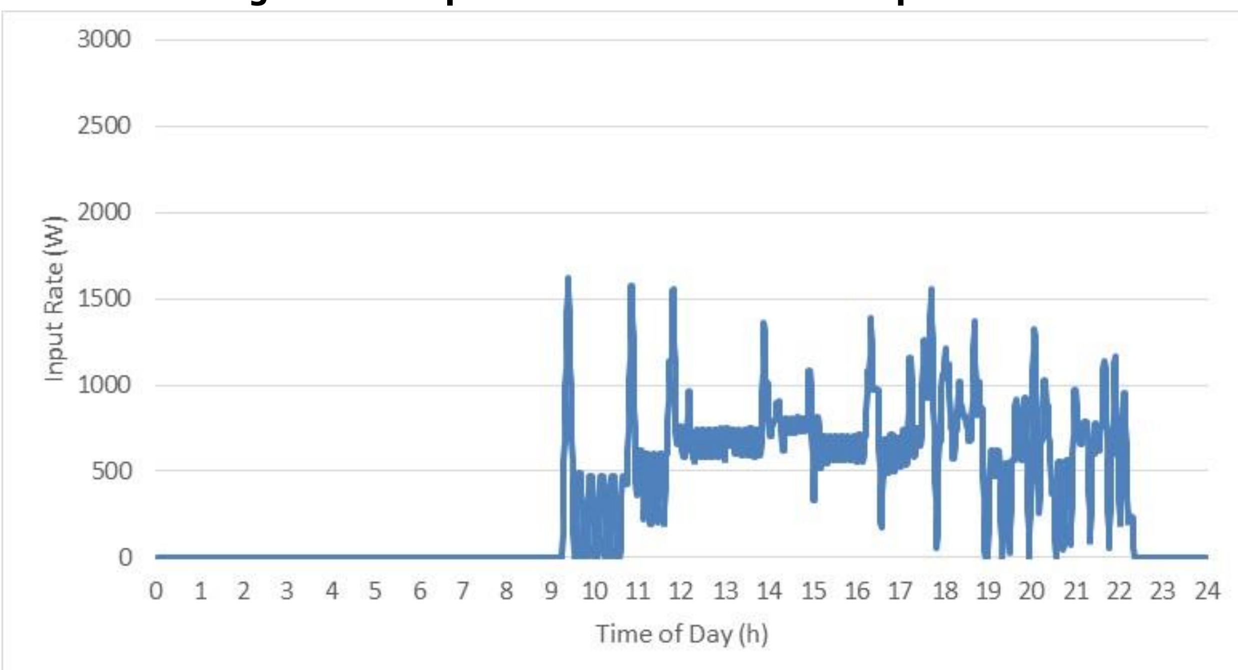
Figure 70: Chipotle Left Tortilla Warmer

Source: Frontier Energy, Inc.

Figure 69: Chipotle Right Tortilla Warmer

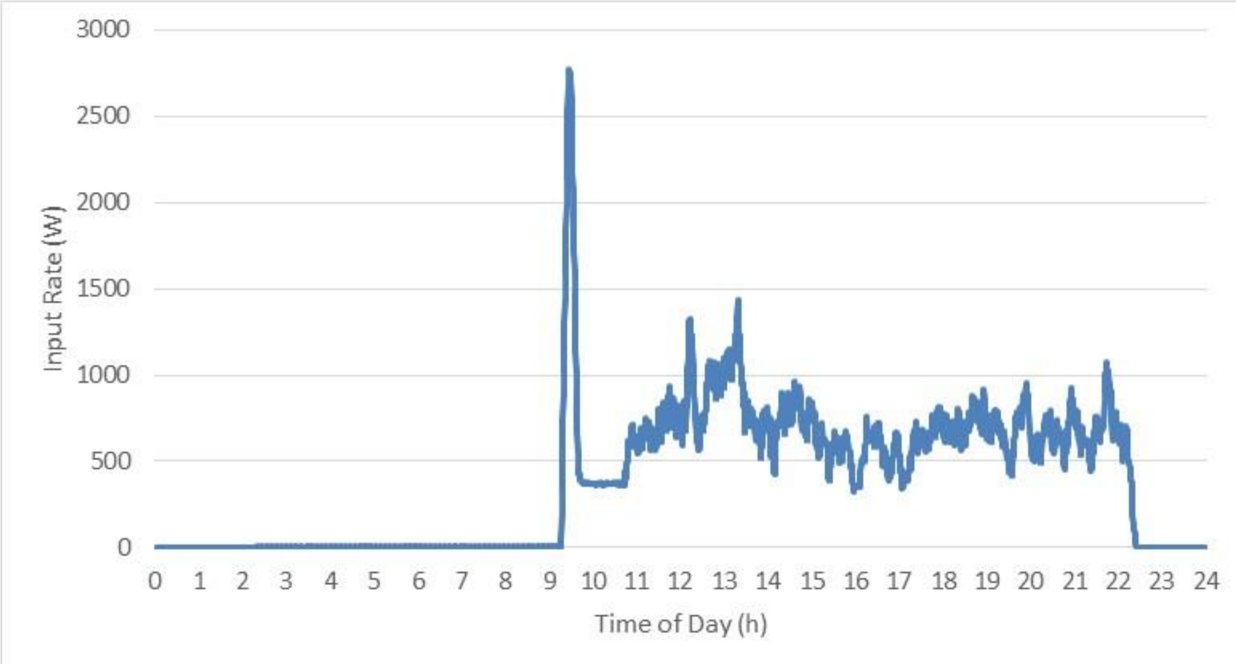
Source: Frontier Energy, Inc.

Figure 70: Chipotle Left Tortilla Warmer Operation



Source: Frontier Energy, Inc.

Figure 71: Chipotle Right Tortilla Warmer Operation



Source: Frontier Energy, Inc.

Results

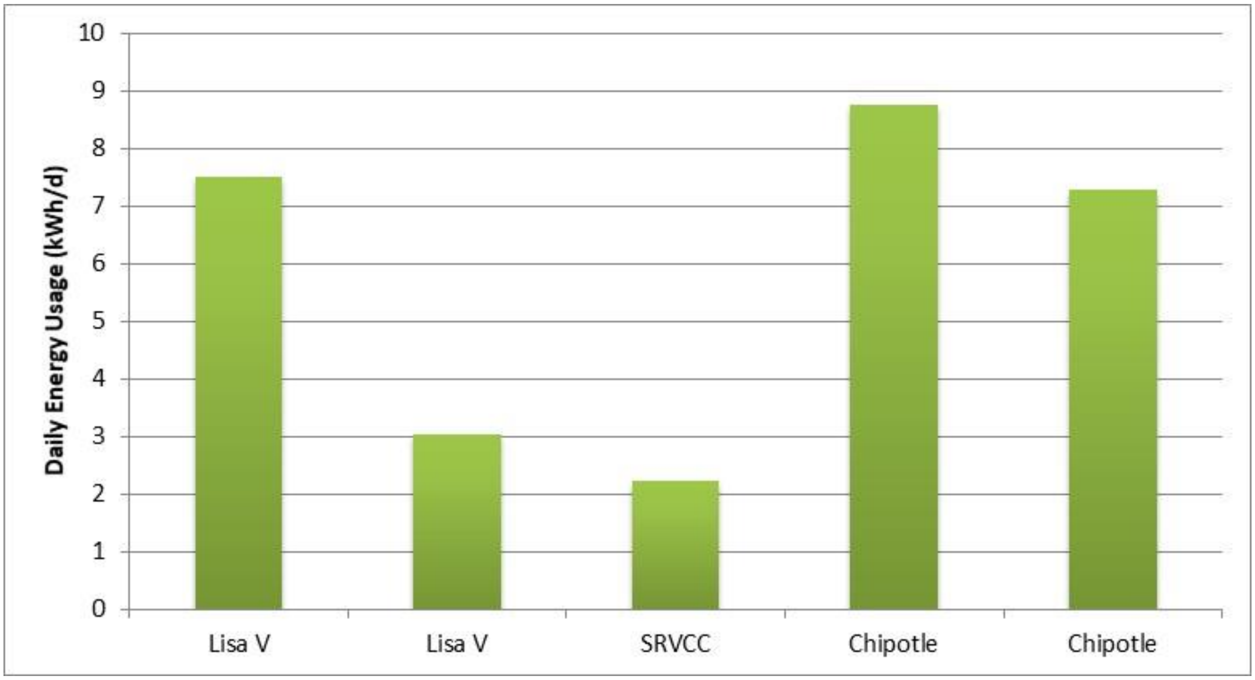
Tortilla warmers operate by heating two metal plates with energy usage dependent on plate area, temperature, and operation time. Plate temperature and diameter are often standard at 350°F (177°C) and 14”, respectively, to accommodate a burrito-sized tortilla. As such, the largest factor in energy consumption is operation time (Table 27). Tortilla warmers had an average energy usage of 5.8 kWh per day with 9.4 hours of operation (Figure 74). No suitable replacement technologies for tortilla warmers were found currently on the market. Thus, the current best method to reduce tortilla warmer energy would be to leave the warmers in a closed position when not in use and to reduce their operation time by turning them on a half hour before usage and off immediately after the end of service, lowering the average power (Figure 75).

Table 27: Tortilla Warmer Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Operating Energy (kWh/d)	Average Operating Hours (h)	Average Input Rate (kW)
Lisa V	7.5	9.5	7.5	9.5	0.789
Lisa V	3.0	7.7	3.0	7.7	0.396
SRVCC	2.2	3.2	4.0	5.8	0.700
Chipotle Right	8.8	13.3	8.8	13.3	0.661
Chipotle Left	7.3	13.3	7.3	13.3	0.549
Average	5.8	9.4	6.1	9.9	0.619

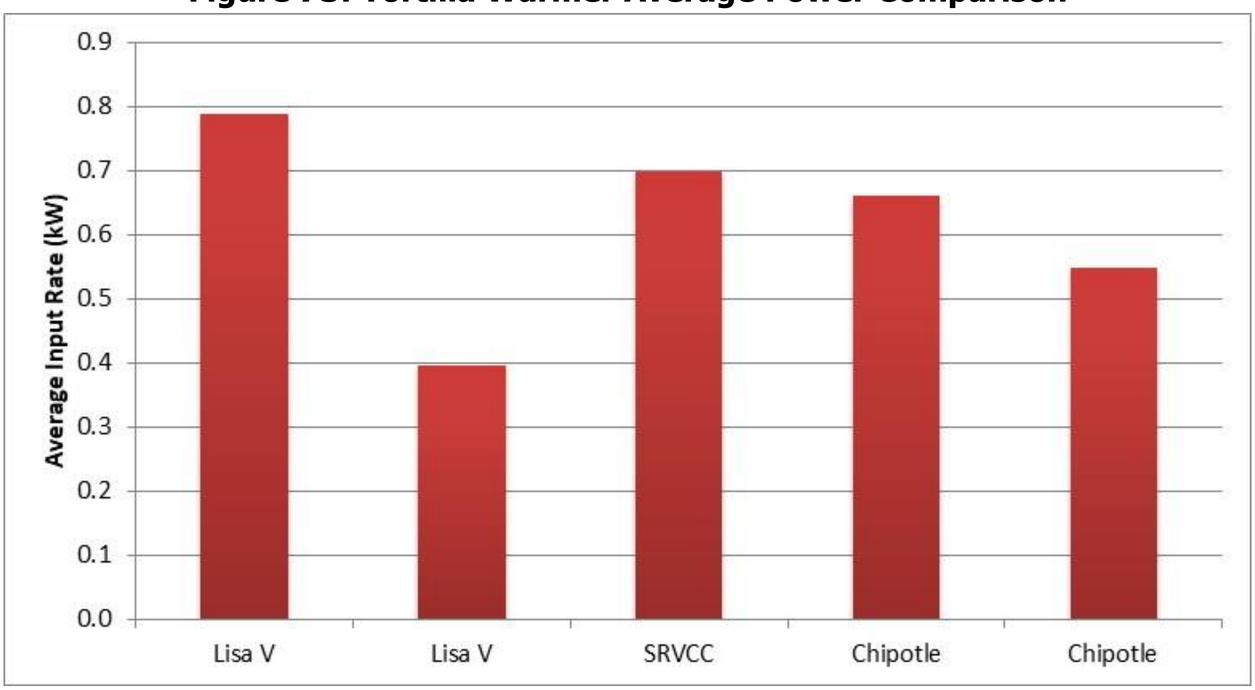
Source: Frontier Energy, Inc.

Figure 72: Tortilla Warmer Daily Energy Usage Comparison



Source: Frontier Energy, Inc.

Figure 73: Tortilla Warmer Average Power Comparison



Source: Frontier Energy, Inc.

Waffle Iron

Waffle irons are a unique appliance in that they are present in all restaurants that serve waffles, and none of the restaurants that do not. They are an extremely specialized appliance that often finds a place into the kitchens of breakfast restaurants, diners, corporate cafeterias, and school dining halls. To get the proper crisp on the waffle exterior, these appliances must keep the contact plates at a high temperature resulting in high levels of energy consumption.

Waffle irons were measured at an American diner and a hotel self-service dining area, to gauge waffle iron energy consumption.

Results

The waffle iron energy data illustrate how the same piece of equipment can have very different energy usage depending on application and hours of operation (Table 28).

Table 28: Waffle Iron Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Mission City Grill	13.9	14.9	0.932
Plaza Suites	3.6	4.5	0.794
Average	8.7	9.7	0.863

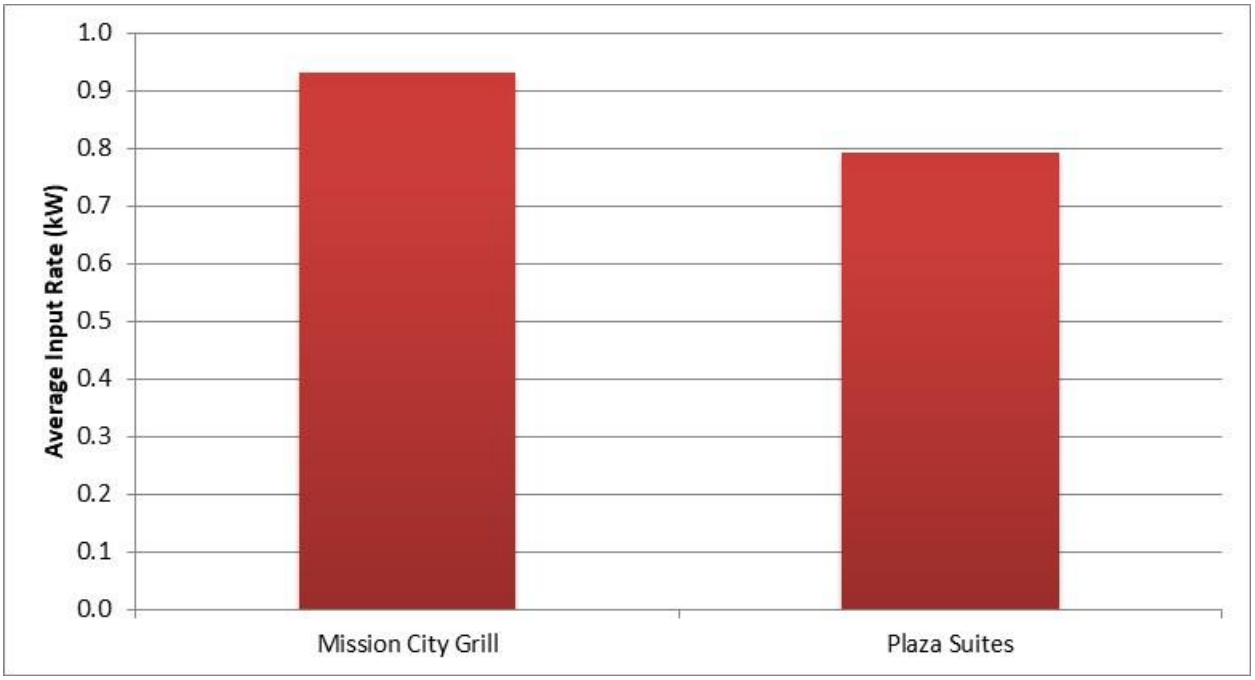
Source: Frontier Energy, Inc.

Though the waffle irons at Mission City Grill and Plaza Suites were the same model and obtained from the same company, the difference in average energy usage between the two units was more than 10 kWh/day (Figure 76). This was due mainly to the differences in hours of operation, as the waffle iron at Mission City Grill was operating for much longer each day than at Plaza Suites. The two waffle irons used an average 8.7 kWh/day on 9.7 hours of operation. Despite the highly varied energy use, the waffle irons at the diner and hotel had similar average input rates (Figure 77). Waffle iron energy use can thus be estimated from hours of operation relatively accurately.

Figure 74: Waffle Iron Daily Energy Usage Comparison

Source: Frontier Energy, Inc.

Figure 75: Waffle Iron Average Power Comparison



Source: Frontier Energy, Inc.

No energy efficient alternatives currently exist for waffle irons, and energy save mode technologies used in other appliances may not be effective for traditional waffle irons due to the high thermal mass of the plates. Additionally, most waffle irons already have an on-demand energy feature built in, where the waffle iron only enters high input when closed and turned on. Currently, the best method to reduce waffle iron energy would be to keep the plates closed when not in operation and reduce their operation time by turning them on a half hour before usage and off immediately after the end of service.

Holding

Holding equipment is found in many foodservice operations since it provides added flexibility in food preparation. Holding equipment allows the operator to prepare food ahead of time and have it ready to be served at a moment's notice. Complex dishes involve cooking different ingredients at different times, which requires the ingredients cooked first to be held warm until the last ingredient is plated. This time difference could be a matter of seconds or minutes, using heat lamps or heat strips for holding, or several hours, in the case of holding cabinets or heated shelves. The added flexibility allows restaurants to do time intensive batch cooking processes, or to prepare ahead of time for large influxes of business during busy hours. Frontier Energy evaluated the energy usage characteristics of seven different food holding appliances: cook and holds, heat lamps, heat strips, heated shelves, holding cabinets, rectangular heated wells, and soup warmers (Table 29).

Table 29: Energy Usage of Commercial Foodservice Holding Equipment

Appliance Type	Baseline or Replacement?	Number of Appliances Monitored	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)	Direct Replacement Savings (%)
Cook and Hold	Baseline	1	5.0	5.3	0.94	-6.5
	Replacement	1	5.7	5.7	1.00	
Heat Lamp	Baseline	1	1.4	5.6	0.24	N/A
Heat Strip	Baseline	3	9.3	12.7	0.59	N/A
Heated Shelf	Baseline	5	2.8	7.3	0.43	N/A
Holding Cabinet	Baseline	9	8.1	7.2	1.15	58.5
	Replacement	3	2.9	7.2	0.42	
Rectangular Heated Well	Baseline	8	5.1	7.4	0.72	33.81
	Replacement	1	5.2	10.9	0.48	
Soup Warmer	Baseline	7	0.8	5.9	0.16	49.1
	Replacement	9	0.6	5.1	0.11	

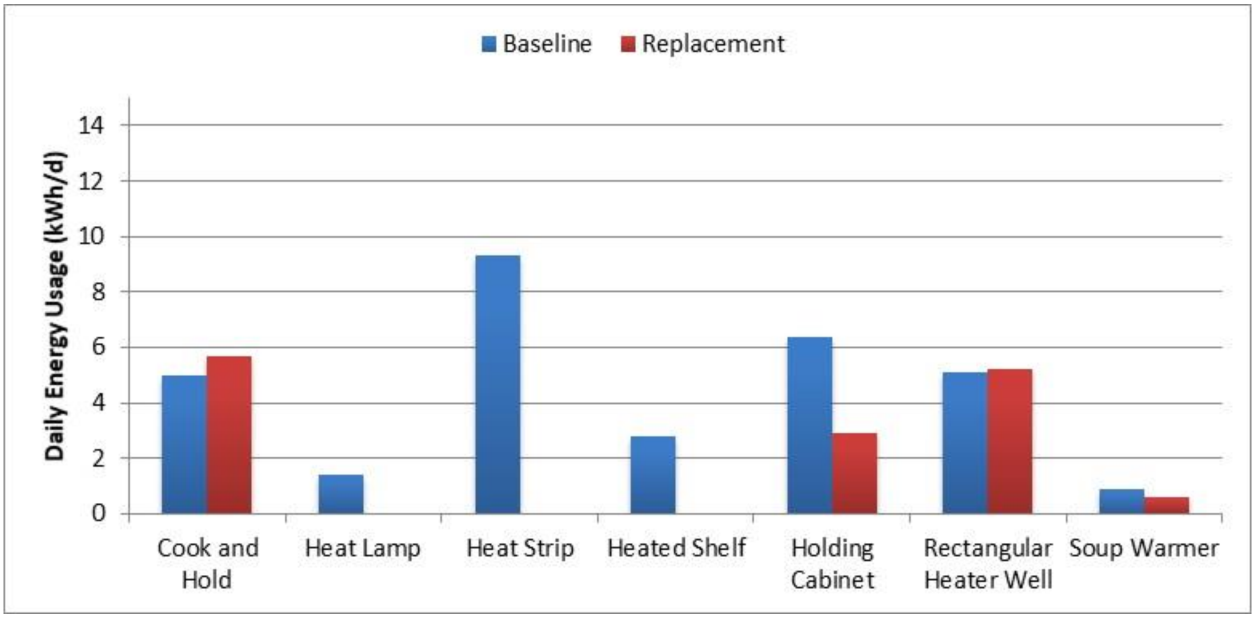
[1]Savings not from direct replacement but extrapolated from the comparison of normalized average energy rates for baseline and replacement equipment monitored.

Source: Frontier Energy, Inc.

Frontier Energy found that heat strips and holding cabinets used the most energy throughout baseline monitoring (Figure 78). Heat strips used a lot of energy because of their long hours of operation and steady input rate throughout the day, which is relatively high for holding equipment. Since heat strips must heat food product from a distance away rather than through direct contact, higher input rates are necessary to deliver the same amount of heat to the product. Their inherent inefficiency is that the heat source is directed downward at the food without any enclosure to contain the heat, which rises naturally. Heat lamps operate under a similar concept but cover a smaller area and thus have a lower input rate. Heated shelves exhibited the same inefficiency with heat coming from the bottom instead of the top.

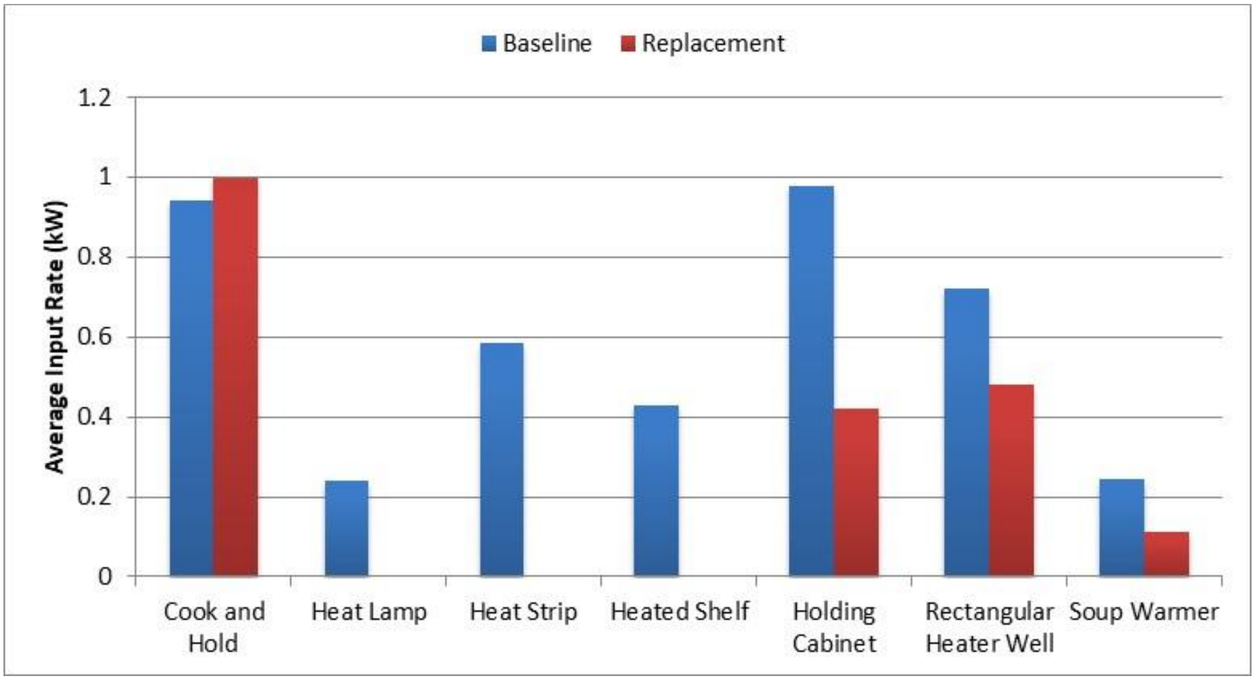
The high energy consumption of holding cabinets was also due to long hours of operation and high input rate, but this high input rate was due more to volume to be heated than design (Figure 79). Holding cabinets were the largest appliance explored in the holding category, and larger amounts of food product naturally require more energy to hold around 140°F (60°C). Glass and solid door holding cabinets were monitored. Primary energy saving solutions for this appliance category seem to be product-sensing technology for demand driven energy usage systems and appliance design improvements, such as better insulation and more efficient heating technologies like induction.

Figure 78: Energy Usage Comparison of Commercial Foodservice Holding Equipment



Source: Frontier Energy, Inc.

Figure 79: Input Rate Comparison of Commercial Foodservice Holding Equipment



Source: Frontier Energy, Inc.

Cook and Holds

Cook and holds are hybrid appliances that can do heating and holding. They are commonly found in restaurants and businesses that have dishes with long preparation times, since they can be cooked slowly in the oven overnight and held at a ready-to-serve temperature throughout the rest of the next business day, all in the same appliance. Cook and holds can help to optimize certain kitchen processes, helping to save time and labor at critical busy periods throughout the day. A single baseline cook-and hold was monitored at Tech Café B's corporate cafeteria kitchen, which was later replaced by a new high-end cook and hold model.

Tech Café B

Tech Café B is a manufacturing and engineering facility featuring an employee cantina that serves breakfast and lunch Monday through Friday. The menu varies styles throughout the week, but the cook and hold is typically used to prepare and hold various foods during breakfast. During lunch, the appliance transitions toward primarily holding prepared foods for replenishing the service stations during the lunch rush. The baseline Wittco 1000-IS cook and hold was measured to consume 5.0 kWh/day while operating for a total of about 5.3 hours per day.

For the replacement phase, the Wittco cook and hold oven (Figure 80) was replaced with a Cres Cor CO-151-HUA-6DX (Figure 81). 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 more than 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 82. 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. 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.

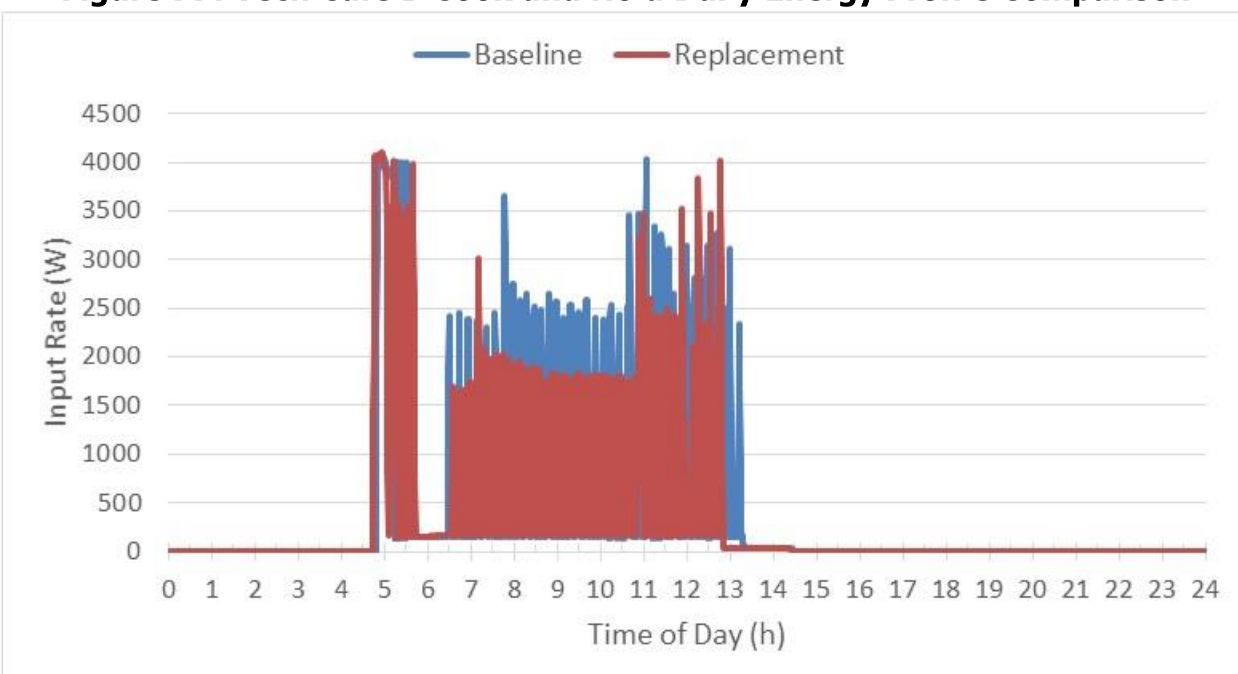
Figure 80: Tech Café B Baseline Wittco Cook and Hold

Source: Frontier Energy, Inc.

Figure 76: Tech Café B Replacement CresCor Cook and Hold

Source: Frontier Energy, Inc.

Figure 77: Tech Café B Cook and Hold Daily Energy Profile Comparison



Source: Frontier Energy, Inc.

Results

The replacement cook-and hold operated at a slightly lower input rate than the baseline unit while holding, but cycled more frequently (Table 30). Normalizing for hours of operation, both units used similar amounts of energy per day, with the replacement cook and hold even using slightly more. This indicates that the disparity between the energy consumption of average and high-end models is negligible, and energy saving opportunities are not currently present within the appliance category given the current offerings. The heating technology and insulation differences between both models are not significant, and more advances need to be made towards producing more efficient units.

Table 30: Cook and Hold Replacement Data Comparison

Site	Baseline or Replacement ?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)	Normalized Savings (%)
Tech Café B	Baseline	5.0	5.3	0.939	-6.4
	Replacement	5.7	5.7	0.999	
				Average	-6.4

Source: Frontier Energy, Inc.

Heat Lamp

Though heat strips are typically more common given the volume of food passing through foodservice establishments, heat lamps are sometimes used instead for holding singular or display types of food product. Often this is a large piece of protein, such as found at carving stations at buffet restaurants. Heat lamps energy usage typically follows the hours of operation, since heat lamps are generally in highly visible locations and can be seen to be either on or off. During operation, heat lamps generally are held at a constant input rate, with no modulation throughout service. Frontier monitored a single Hatco GRN4-66 heat lamp at a Tech Café B corporate cafeteria (Figure 83).

Figure 78: Tech Café B Heat Lamp

Source: Frontier Energy, Inc.

Results

The Hatco GRN4-66 heat lamp at Tech Café B was measured to use an average of 1.4 kWh/day on an average 5.6 hours of operation. (Table 31) The heat lamp operated at a steady input rate throughout the operating period, with no potential for input modulation —

the unit is operated by a simple switch and is either on or off. No replacements were made for the countertop because of the lack of suitable replacements.

Table 31: Heat Lamp Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Tech Café B	1.4	5.6	0.243
Average	1.4	5.6	0.243

Source: Frontier Energy, Inc.

Heat Strip

Heat strips are commonly found in cook-to-order restaurants, installed to keep food warm for short periods of time while awaiting pickup by a server or customer. As an appliance that constantly radiates heat to an open, uninsulated environment, energy usage of heat lamps can be high. Heat strips require enough power to transfer enough heat to food product as far as two feet below it and are typically left on constantly during hours of restaurant operation. The team monitored heat strips at three locations: two baseline resistance heat strips and one efficient halogen heat strip.

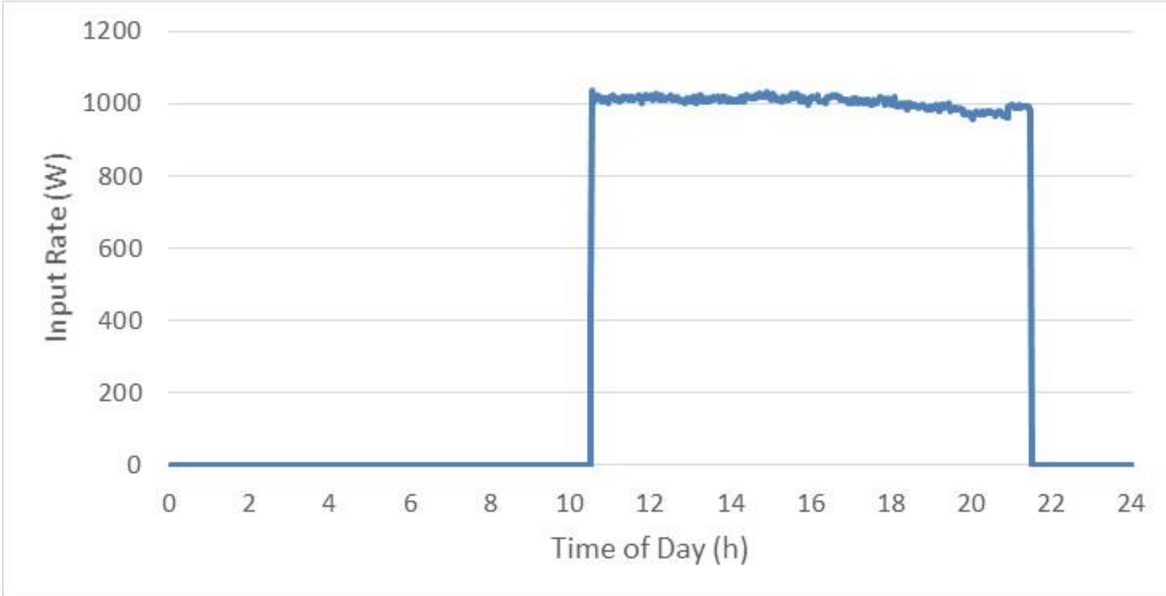
Baseline (Average Case) - Mills College (Tea Shop)

The Mills College Tea Shop features a 120V, 9A Vollrath Cayenne strip heater in its grill area (Figure 84), to keep the cooked-to-order food warm while waiting for students to pick up their orders. This strip heater is turned on at the beginning of service and left on at a constant setting until the close of service, regardless of whether there is any food being kept warm. Monitored for three months, the heater used a total average 6.5 kWh per day of electrical energy (including off days) during an average 12.0 hours of operation, though it averaged 9.8 kWh per day, when it was on during the weekdays (Figure 85). The staff always turned off the heat lamp after the end of service and the strip heater was not operational on weekends.

Figure 79: Vollrath Cayenne 4-Foot Strip Heater

Source: Frontier Energy, Inc.

Figure 80: Mills College Daily Heat Strip Operation



Source: Frontier Energy, Inc.

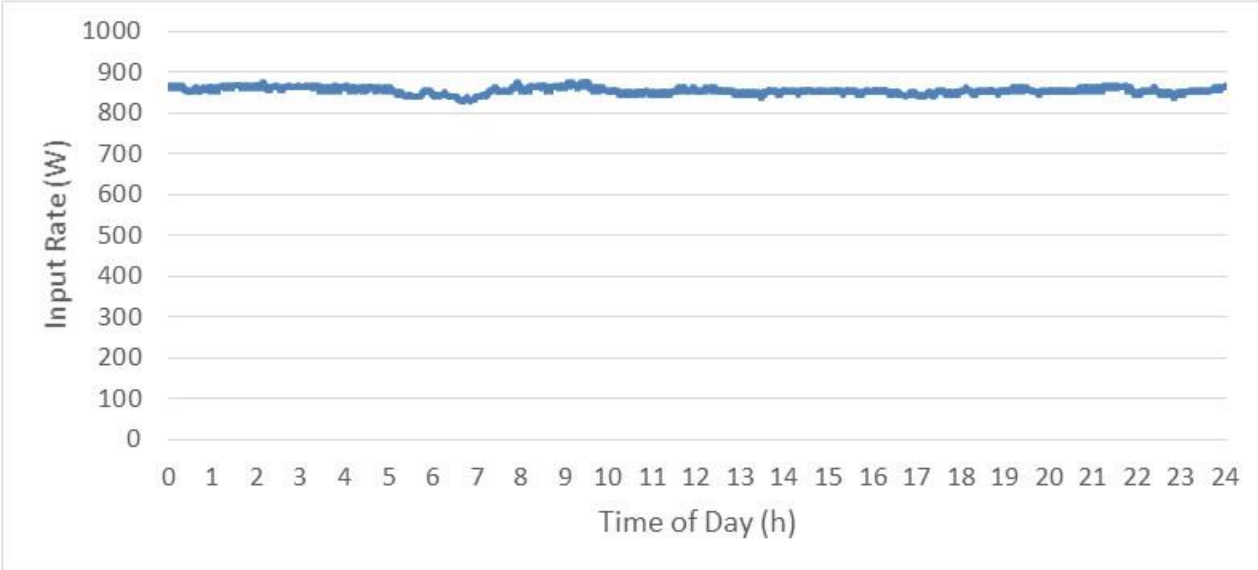
Baseline (Worst Case) - Doubletree Hotel

The Doubletree Hotel kitchen features a line of three 4-foot Hatco Glo-Ray infrared stainless-steel strip heaters on its front line (Figure 86). All heaters are kept on constantly, keeping cooked-to-order food warm until the server comes to pick it up for delivery. The heat strips are constantly left on despite not warming any food underneath. This results in a major loss of energy, especially with three heat lamps together. Researchers monitored the heat lamps for three months, resulting in a total average 20.4 kWh per day of electrical energy while being on for a full 24 hours per day (Figure 87). The hotel does not serve room service past midnight so there is no reason for the heat lamps to be on at night.

Figure 81: Doubletree 4-Foot Hatco Glo-Ray Heat Strip

Source: Frontier Energy, Inc.

Figure 82: Doubletree Hotel Daily Heat Strip Operation



Source: Frontier Energy, Inc.

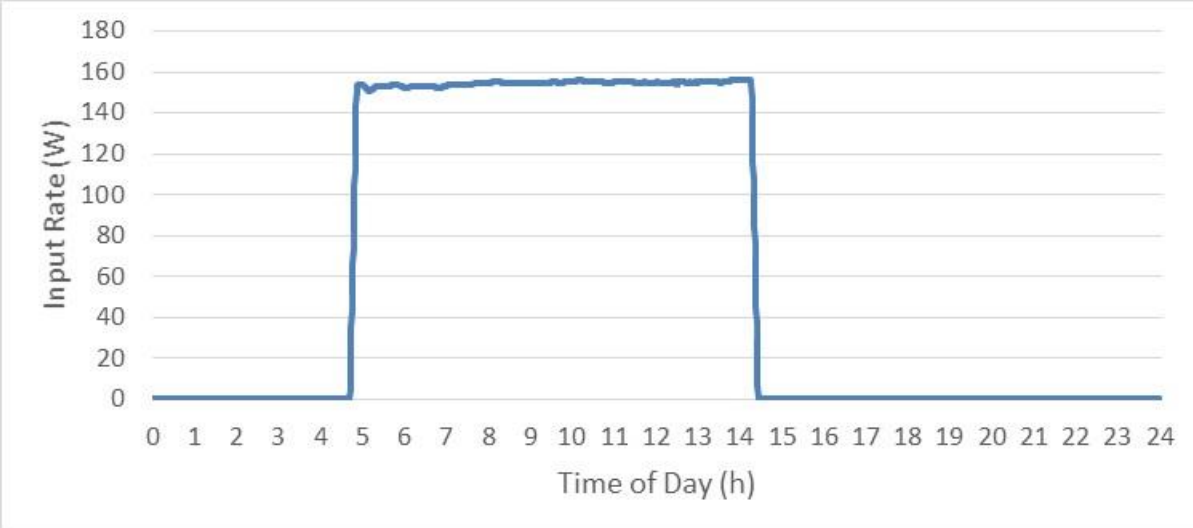
Baseline (Best Case) - Tech Café B

Tech Café B features a 120V, 10A Hatco GRN4L-66 strip heater (Figure 88) in its serving area to keep the cooked-to-order food warm while waiting for customers to pick up their orders. This strip heater is turned on at the beginning of service and left on at a constant low setting until the close of service, averaging only 150W despite a nameplate input rate of 1,200W. 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. Due to the low warming requirements of this application, staff could keep the heat strip at this low input rate and still deliver the product to their customer as desired. The heat strip was measured to consume 0.9 kWh per day of electrical energy (including off days) during an average 5.5 hours of operation, though it averaged 1.4 kWh per day, when it was on during the weekdays (Figure 89).

Figure 83: Tech Café B 4-Foot Hatco Glo-Ray Heat Strip

Source: Frontier Energy, Inc.

Figure 89: Tech Café B Halogen Heat Strip Daily Energy Profile



Source: Frontier Energy, Inc.

Results

Based on the project findings, it is clear that heat strips are a strong candidate for energy saving opportunities. Heat strips are energy intensive appliances that operate at a constant and relatively high input rate without any thermostatic feedback. Heat strips are frequently forgotten by staff and not powered off since it is difficult to tell if they are on or off; oftentimes the only way to tell if they are on is to feel underneath for emitted heat. This problem is clearly demonstrated by the results found at the Doubletree Hotel, where the heat strips were found to never be turned off (Table 32). With a simple, automatic timer or sensing technology, there is potential to save a sizeable amount of energy on the magnitude of 10 kWh/day (equivalent to 12 hours off) for a site like Doubletree.

Though sensing technology for heat strips is not currently available on the market, another solution could be to switch to halogen heat strips, which allow for temperature adjustment to match the required levels of heating demand. Paired with proper staff training, this could significantly reduce the energy consumption of the heat strip. Though no direct heat strip replacements were done, this type of replacement could theoretically save up to 81.4 percent of the operating energy, comparing the baseline resistance and halogen heat strip results.

Table 32: Heat Strip Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Doubletree	20.4	24.0	0.850
Mills College	6.5	8.6	0.756
Tech Café B	0.9	5.5	0.156
Average	9.3	12.7	0.587

Source: Frontier Energy, Inc.

Heated Shelf

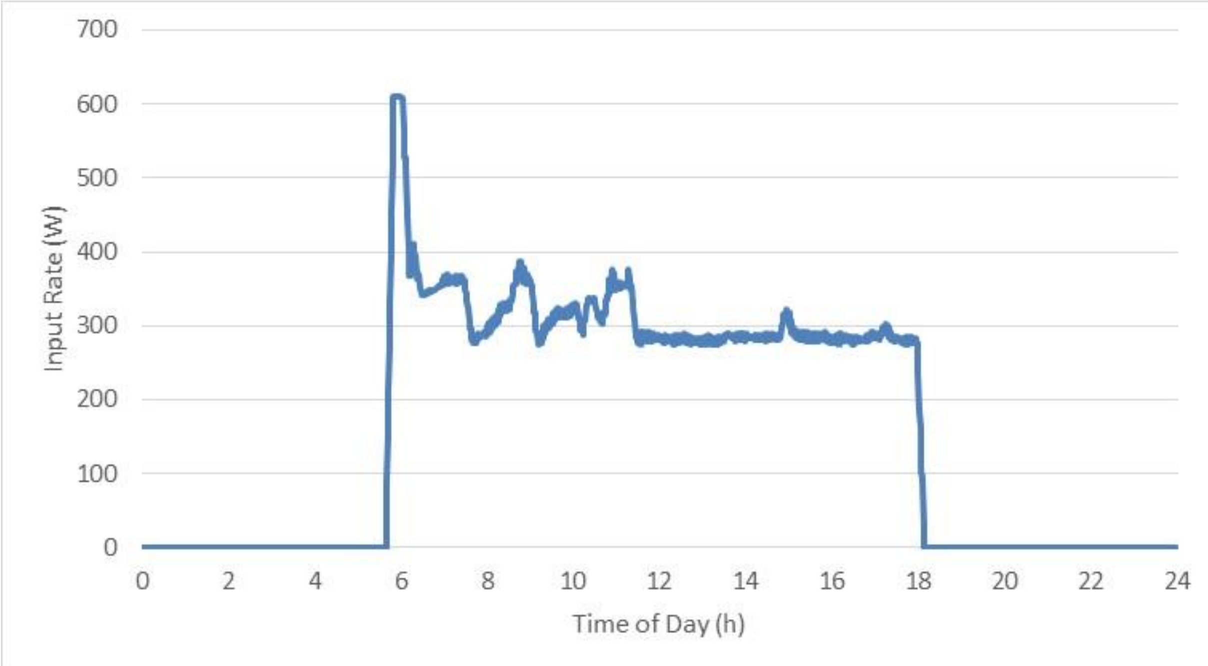
Unlike other holding equipment that is meant to use in the back of the kitchen, heated shelves prioritize the visually attractive display of food over the effectiveness with which it can keep food warm. Heated shelves leave food product exposed to open air and heat product underneath, making the heat transfer to the held product relatively inefficient. Rather than keeping the product at a true state of warmth, the appliance instead capitalizes on the psychological image of freshness formed when a customer feels the initial warmth of the product's exterior. Heated shelves are less common appliances, found more frequently in bakeries and catering/self-serve restaurants. Researchers monitored several heated shelves throughout the period of this study, at a bakery/café chain restaurant and across corporate cafeterias.

Results

Compared to the other plug load appliances in this project, the heated shelf is a weaker candidate for energy saving opportunities. There is some variation in energy usage based on the heating requirements of the application, but overall the heated shelf operates at a relatively low average input rate, approximately less than 600W for all five monitored instances (Figure 90). This low input requirement is because the appliance is designed simply to keep the product warm to the touch, rather than keeping the whole product warm. Due to the exposed nature of the appliance, heated shelves are by nature inefficient, exposing the heated surface to ambient air and sacrificing heat retention for visibility and aesthetic. Enclosing the heated shelf would reduce the energy usage, but the appliance would then technically be more of a display cabinet than a heated shelf.

To save energy, the heated shelf would either have to compartmentalize its heating or have smart optical/weight sensors to heat only the areas that need to be heated. One such option might be to have smaller induction-compatible coasters or shelves on a low power induction warming surface, so the heating element is removed when the product is removed. Currently however, smart technologies for heated shelves are not on the market, and energy savings are based more on operator behavior. Given the low energy usage of heated shelves, manufacturers may not have found potential energy savings worth the investment of new technologies. Overall, the heated shelf had an average energy usage of 2.8 kWh per day during 7.3 hours of operation (Table 33). Average energy use and input rate varied significantly across the different sites (Figure 91 and Figure 92).

Figure 90: Café/Bakery Daily Heated Shelf Operation



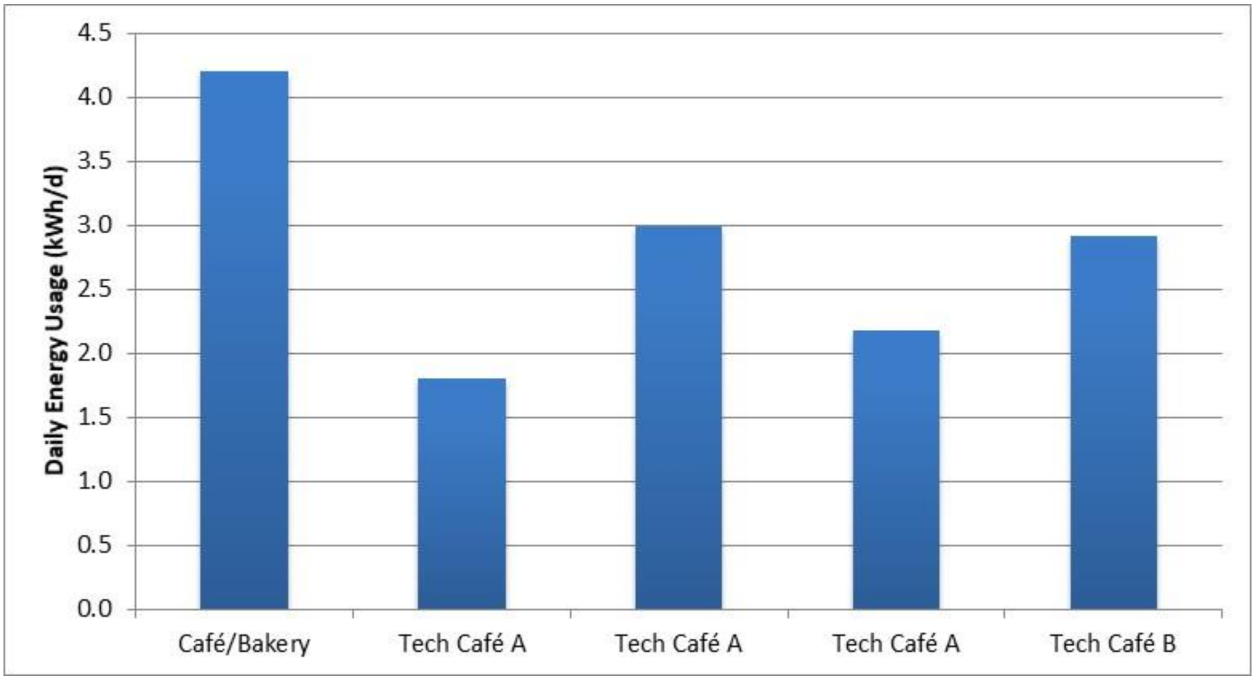
Source: Frontier Energy, Inc.

Table 33: Heated Shelf Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Café/Bakery	4.2	18.0	0.233
Tech Café A	1.8	3.7	0.492
Tech Café A	3.0	5.5	0.547
Tech Café A	2.2	4.5	0.489
Tech Café B	2.9	4.9	0.601
Average	2.8	7.3	0.427

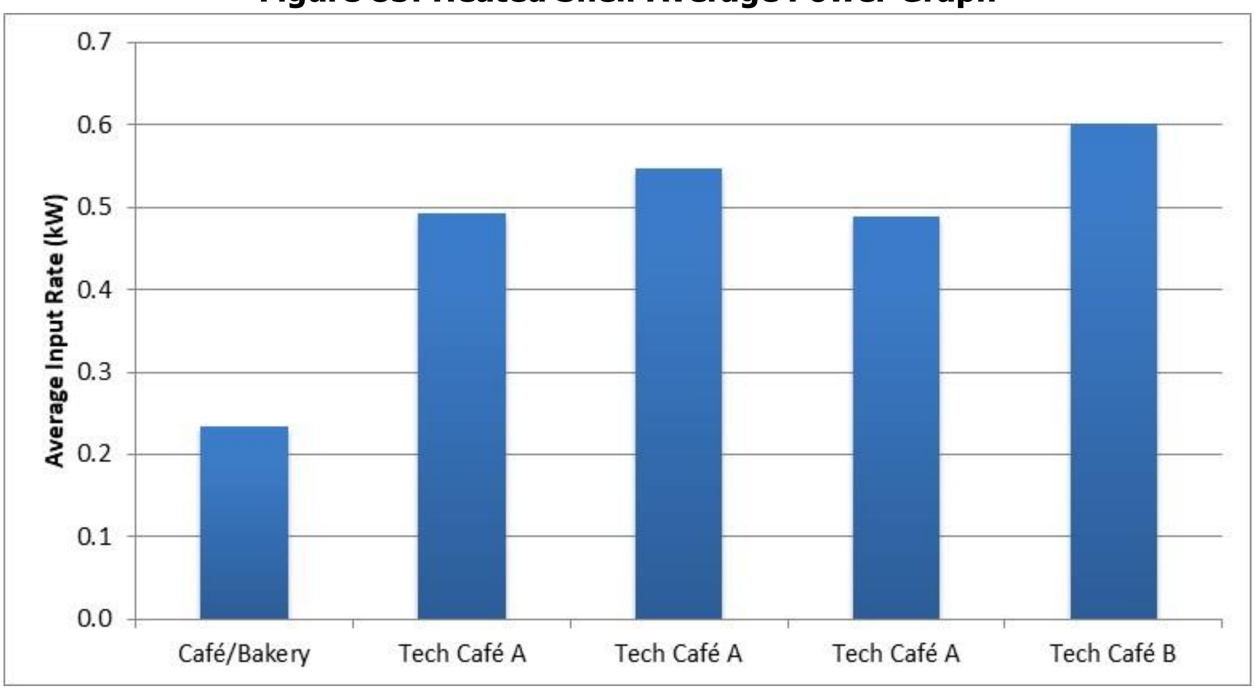
Source: Frontier Energy, Inc.

Figure 84: Heated Shelf Daily Energy Usage Graph



Source: Frontier Energy, Inc.

Figure 85: Heated Shelf Average Power Graph



Source: Frontier Energy, Inc.

Holding Cabinet

Holding cabinets are commonly found in restaurants and businesses that use batch cooking to prepare food ahead of time for product that requires a long cook time or in preparation for heavy business traffic. These appliances typically have long hours of operation and relatively consistent energy usage rates throughout each day, though day-to-day variations can be significant if used for catering operations. Holding cabinets are usually designed to hold their contents between 140 and 160°F (60 and 71°C) and can be either dry or humidified. The research team monitored a total of five holding cabinets at three different locations: fast/casual chain restaurant, a conference center kitchen, and a college dining hall.

Plaza Suites

The holding cabinet monitored at Plaza Suites was a 120V Carter-Hoffman PH1830 (Figure 93). The menu had shifted so the holding cabinet was now primarily used just to hold and warm plates, despite being a full-sized unit. The baseline holding cabinet consumed 3.9 kWh/day on average, over 3.8 hours of breakfast/brunch operation.

Since the baseline holding cabinet was clearly oversized for the purposes it was being used for, Frontier replaced the baseline cabinet with an insulated Cambro PCUHH dual compartment unit (Figure 94). This allowed for compartmentalized heating, meaning Plaza Suites could downsize to use only one of the compartments for plate warming/holding for normal day to day operations, with the option to use the other compartment for heated holding if demand was particularly high. Otherwise, the other compartment could function as passive holding, effectively halving the holding cabinet's energy use. Figure 95 shows an input rate of 500 watts instead of the unit's manufacturer-specified total input rate of 1 kW.

The replacement holding cabinet was also well insulated with polyurethane foam, so the input energy rate to maintain a desired holding temperature was lowered. These two advantages compared to the baseline unit allowed the replacement holding cabinet to reduce energy to an average 1.2 kWh/day over 3.8 hours of operation. Overall, the new holding cabinet saved 70 percent of the energy consumed by the baseline unit. Because this site operates seven days a week, this translates to $145 per year in utility bill savings (assuming $0.15/kWh). Both baseline and replacement cabinets are similar in retail price, so replacement could result in immediate savings with no payback period. The $145 per year in energy savings was pure profit. 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 four hours per day.

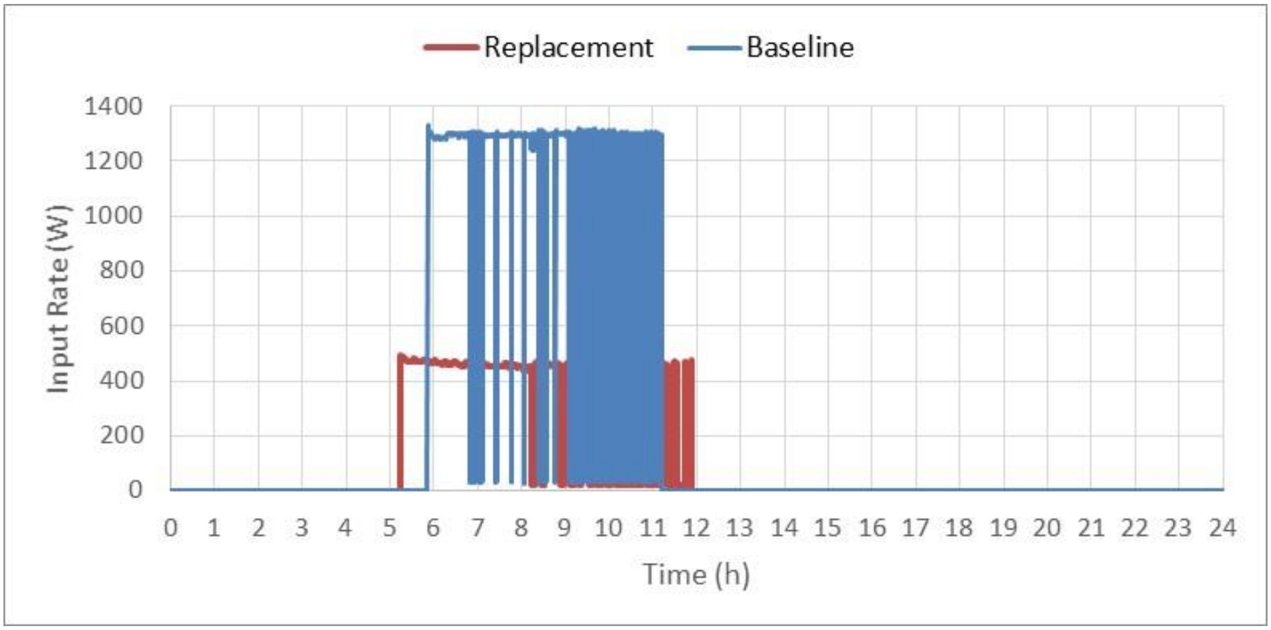
Figure 86: Plaza Suites Baseline Carter-Hoffman PH1830 Holding Cabinet

Source: Frontier Energy, Inc.

Figure 87: Plaza Suites Replacement PCUHH Holding Cabinet

Source: Frontier Energy, Inc.

Figure 88: Plaza Suites Holding Cabinet Daily Energy Profile Comparison



Source: Frontier Energy, Inc.

Tech Café A

Tech Café A has a cafeteria that serves a full campus of office buildings as well as visitor traffic from the company's museum, operating for 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. The kitchen features several 120V Crescor H135SUA11 holding cabinets since the high customer traffic at their corporate cafeteria requires the staff to do much of the meal preparation before the actual service (Figure 96). Frontier monitored several of their baseline holding cabinets and replaced one of them with a solid-door, well insulated Cambro PCUHH holding cabinet (Figure 97).

The original baseline Crescor cabinet used 8.2 kWh/day on weekdays, operating for 9.0 hours on average. In comparison, the replacement Cambro holding cabinet consumed only 4.3 kWh of energy per day for both compartments. The replacement holding cabinet saved an average 3.9 kWh per day in comparison to the baseline unit, a 48 percent 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 as compared to the baseline holding cabinet's input rate, reducing energy usage whenever possible.

The holding cabinet replacement saved 3.9 kWh per day, translating to $115 of energy savings per year for the average $0.15 per kWh electrical rate (Figure 98). The Cambro PCUHH retails for about $4,400 while the original Cres Cor H135SUA11 retails for about $3,000, so the payback period for replacement at this site would be about 12.6 years. This long payback period is a result of only operating during weekday lunch period. Sites that also have a dinner service or operate on the weekends would experience noticeably shorter payback periods.

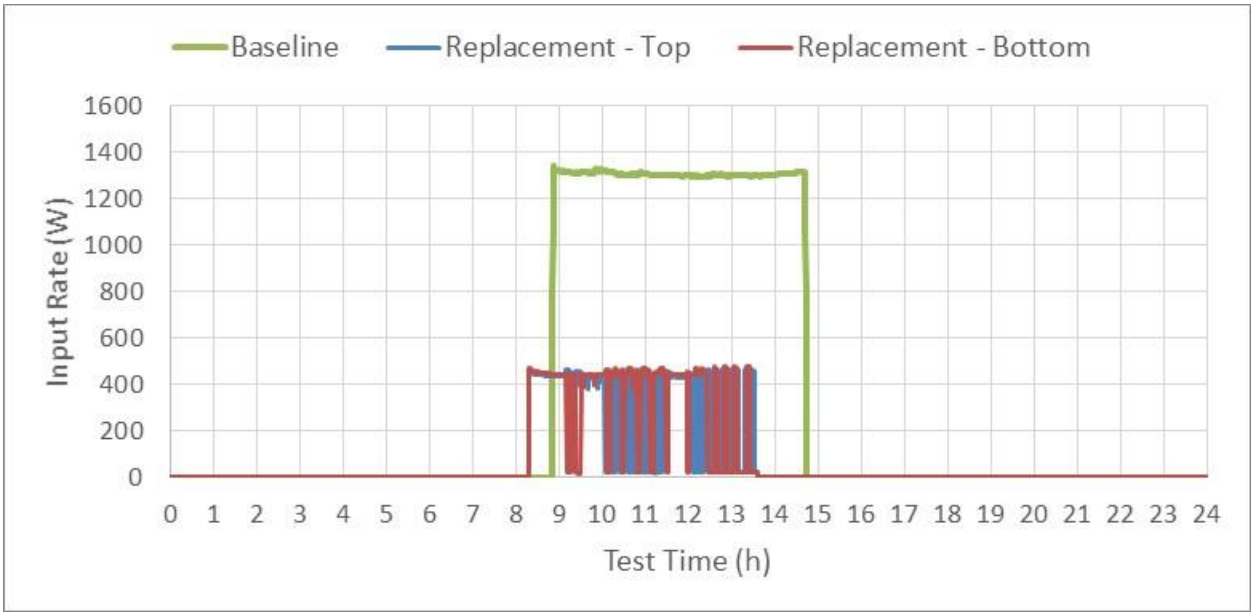
Figure 89: Tech Café A Baseline CresCor H135SUA11 Holding Cabinet

Source: Frontier Energy, Inc.

Figure 90: Tech Café A Replacement Cambro PCUHH Holding Cabinet

Source: Frontier Energy, Inc.

Figure 91: Tech Café A Holding Cabinet Daily Energy Profile Comparison



Source: Frontier Energy, Inc.

Blurr Kitchen

Blurr Kitchen is a quick service restaurant specializing in Vietnamese bahn mi sandwiches and southeast Asian small plates, open from 11:00 a.m. to 9:00 p.m. daily. Among its kitchen equipment was a Winholt INHPL-1836 holding/proofing cabinet (Figure 99), which was used only for holding rather than proofing. This holding cabinet was measured to consume 11.0 kWh/day on average, over 11.0 hours of daily operation. This high energy use was because 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.

Figure 92: Blurr Kitchen Baseline Winholt INHPL-1836 Holding/Proofing Cabinet

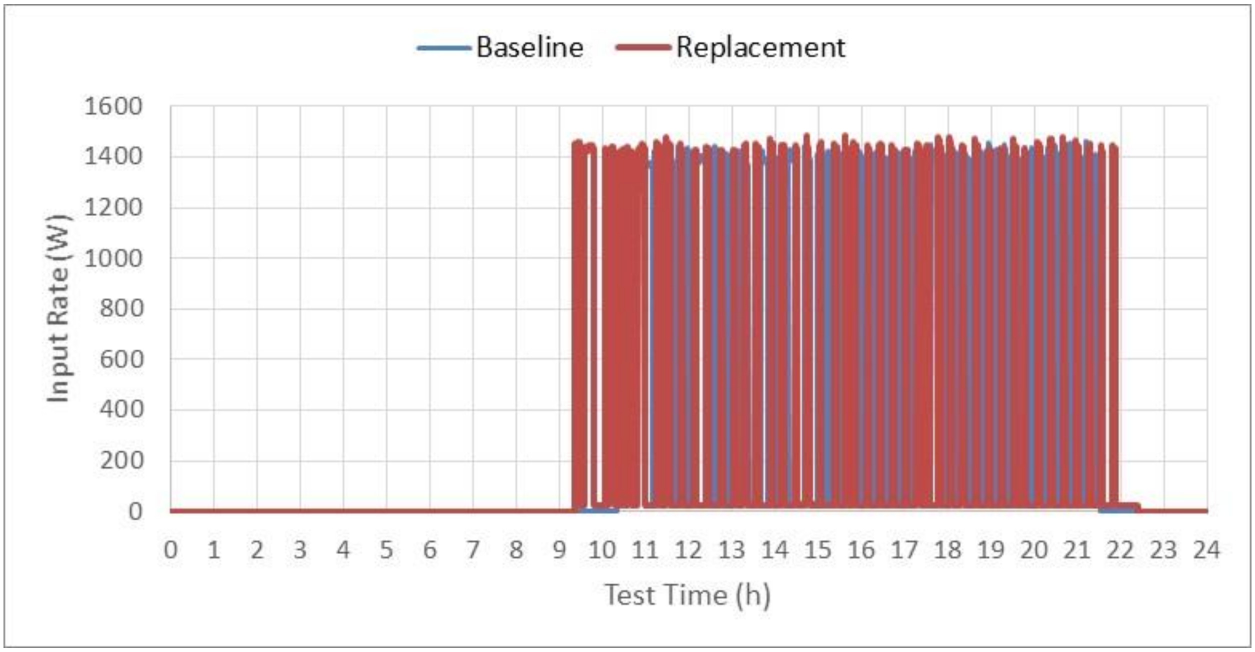
Source: Frontier Energy, Inc.

The baseline holding cabinet was replaced with a Vulcan VBP18 solid door insulated holding cabinet (Figure 100), which cut the energy usage by more than half and used only 4.8 kWh/day on average, over 12.5 average daily hours of operation (Figure 101).

Figure 100: Blurr Kitchen Replacement Vulcan Holding Cabinet

Source: Frontier Energy, Inc.

Figure 93: Blurr Kitchen Holding Cabinet Daily Energy Profile Comparison



Source: Frontier Energy, Inc.

These energy savings were due primarily to the insulation, allowing the replacement cabinet to cycle the heat on much less frequently despite having a nearly identical maximum input rate. Whereas the baseline cabinet spent most of its time on its heating cycle and periodically cycled off when the temperature was high enough, the replacement cabinet 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 62 percent reduction in normalized energy use. Since the restaurant operates seven days a week, this is equivalent to about $419 in yearly energy savings for the average $0.15 per kWh electrical rate. The Vulcan VBP18 sells for about $5,700 while the original Winholt INHPL-1836 sells for about $1,500, so the payback period for replacement at this site is nearly 10 years, despite the large energy savings.

Results

Given the success of the three holding cabinet replacements and the high energy demand exhibited across all nine observed baseline units, holding cabinets are clearly a promising appliance category for generating energy savings (Table 34). Energy savings from holding cabinet replacement were the most consistently strong across all explored equipment categories, with three replacements all resulting in savings more than 40 percent and even as high as 70 percent (Table 35). Energy savings could potentially be even higher, since there were several holding cabinets had higher daily energy consumption than any of those replaced (Figure 102).

The savings can be attributed to several key factors. 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 extremely important, especially 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 (Figure 103). The payback period for holding cabinets can vary significantly depending on purchase price though, despite their high energy savings. The purchase prices of the baseline holding cabinets varied anywhere from $1,500 to $4,700, making the payback period anywhere from instantaneous to 12.6 years.

Table 34: Holding Cabinet Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Baseline			
SRVCC	9.6	6.5	1.766
UC Berkeley	12.6	12.9	0.930
UC Berkeley	13.1	10.9	1.831
UC Berkeley	5.9	5.7	2.911
Tech Café A	5.9	4. 5	1.640
Tech Café A	6.9	5.3	1.561
Tech Café A	4.3	4.7	3.166
Plaza Suites	3.9	3.8	1.589
Blurr Kitchen	11.0	11.0	1.280
Average	8.1	7.2	1.151
Replacement			
Tech Café A	2.7	5.3	0.516
Plaza Suites	1.2	3.8	0.305
Blurr Kitchen	4.8	12.5	0.386
Average	2.9	7.2	0.418

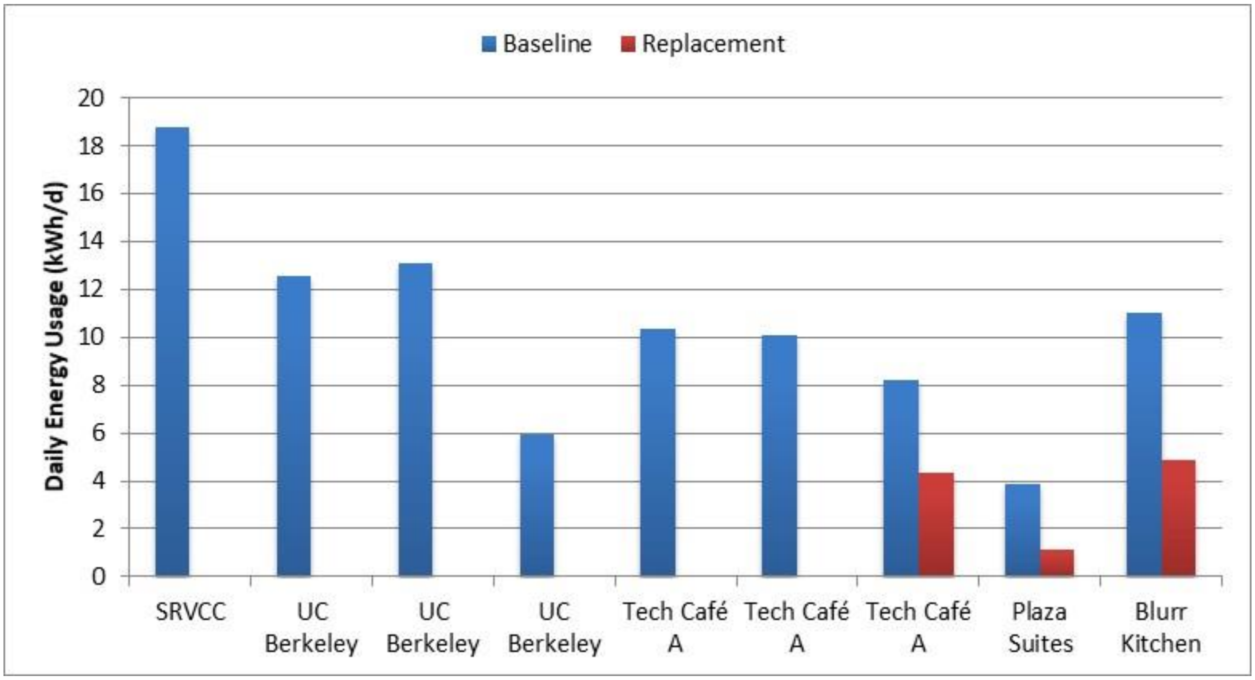
Source: Frontier Energy, Inc.

Table 35: Holding Cabinet Replacement Data Comparison

Site	Baseline or Replacement?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)	Normalized Savings (%)	Payback Period (yrs)
Tech Café A	Baseline	4.3	4.7	3.166	43.9	12.6
	Replacement	2.7	5.3	0.516		
Plaza Suites	Baseline	3.9	3.8	1.589	70.0	0 (Instant)
	Replacement	1.2	3.8	0.305		
Blurr Kitchen	Baseline	4.3	4.7	3.166	61.6	10.0
	Replacement	4.8	12.5	0.386		
				Average	58.5	7.5

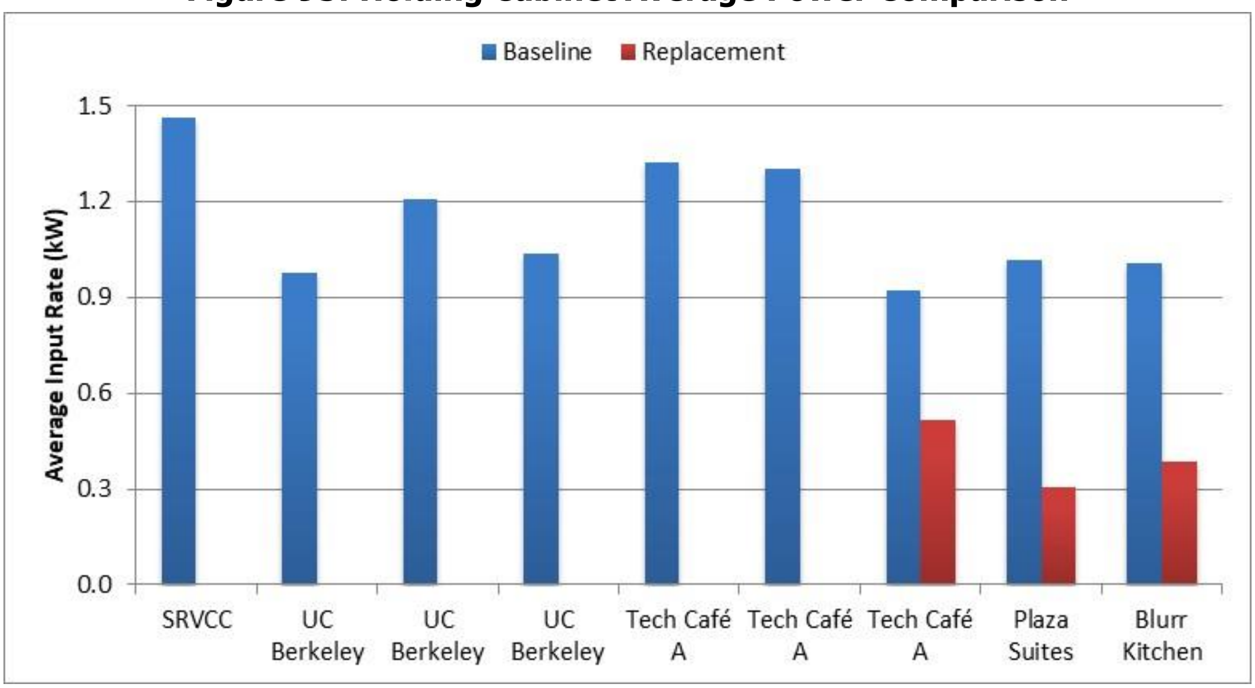
Source: Frontier Energy, Inc.

Figure 94: Holding Cabinet Daily Energy Usage Comparison



Source: Frontier Energy, Inc.

Figure 95: Holding Cabinet Average Power Comparison



Source: Frontier Energy, Inc.

Rectangular Heated Well (12” x 20”)

Rectangular heated wells are common appliances for batch cooking operations and are typically used to keep prepared food warm. These appliances heat a water bath to more than 200°F (93°C) until steam forms. Operators place a pan of food directly over the water bath, so the hot steam directly contacts the pan, keeping food warm. The well can be subdivided by rails to fit differently sized pans, but the water bath should always be fully covered to prevent any energy waste through escaped steam. The heated wells are designed to heat the most common pan size of 12″x20″ with depths ranging from 2″ to 4″ (Figure 104). Eight baseline rectangular heated wells were monitored for the project, along with one larger induction well.

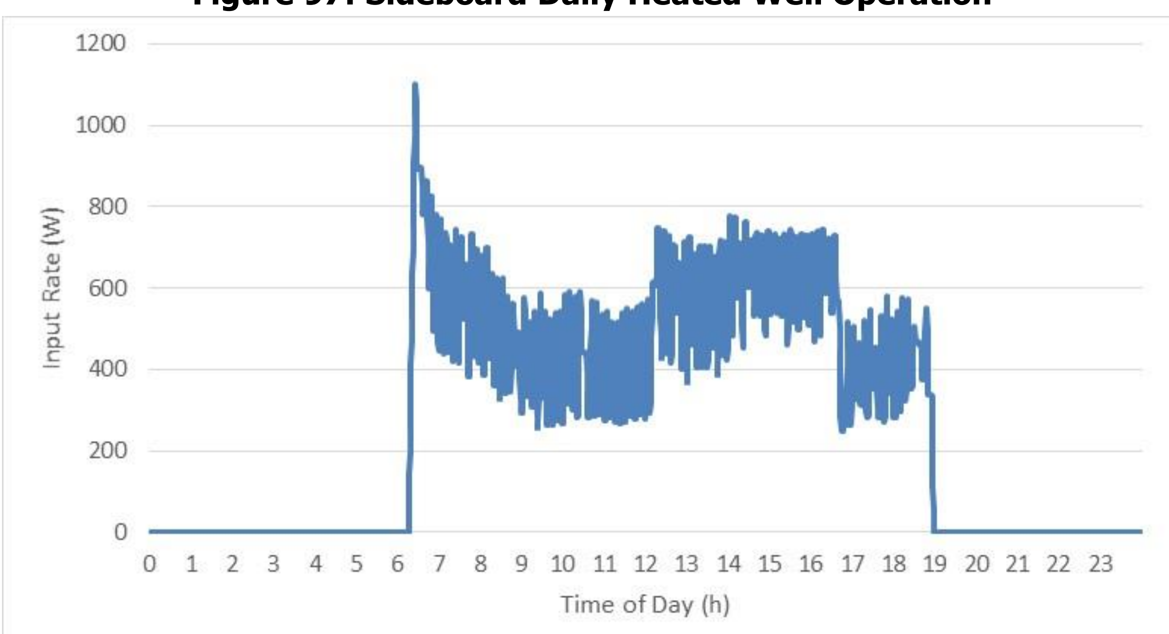
Baseline: Sideboard Danville

The heated well monitored at Sideboard was fairly representative of the average restaurant usage patterns (Figure 105). As a restaurant running 12-plus hours per day, Sideboard batch cooks several of its carefully crafted sauces and keeps them warm in a Nemco 12″x20″ rectangular heated well for quick use and service. The first batch of these sauces is created early in the morning before the restaurant opens, so the heated well typically runs from about 7:00 a.m. to 7:00 p.m. daily. During the monitoring period, the heated well used about 6.4 kWh per day while operating for 11.3 hours per day on average.

Figure 96: Nemco 12″x20″ Rectangular Heated Well at Sideboard

Source: Frontier Energy, Inc.

Figure 97: Sideboard Daily Heated Well Operation



Source: Frontier Energy, Inc.

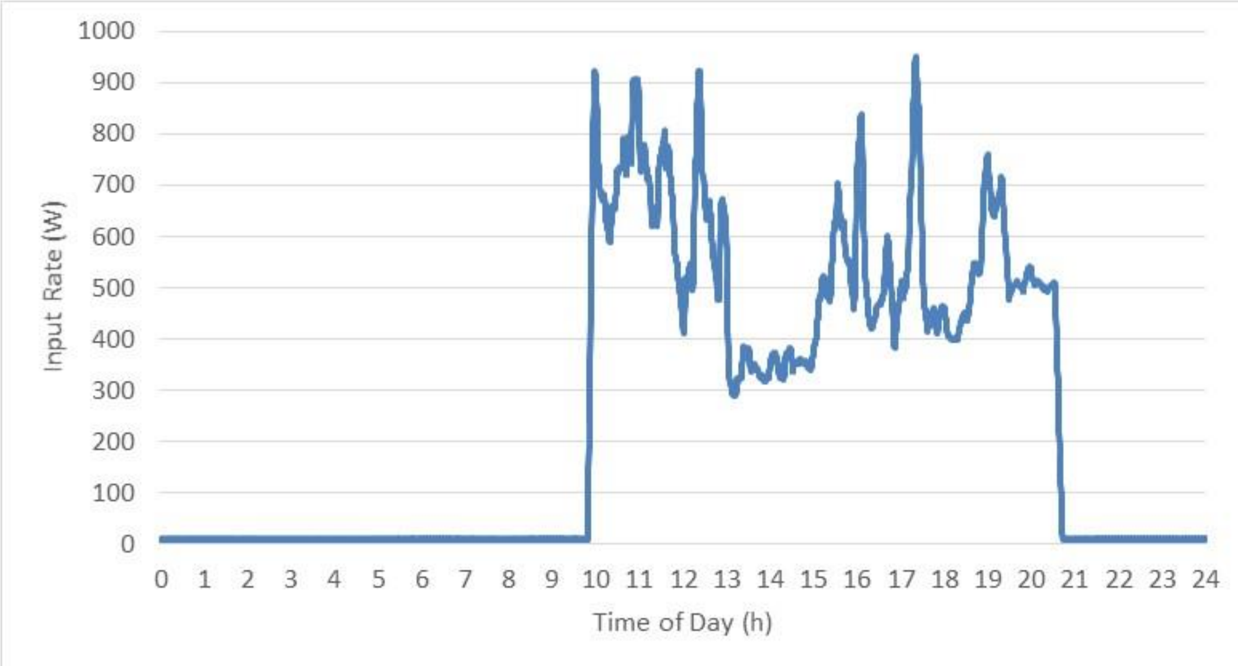
Replacement: Claremont Hotel

Though no stand-alone 12″x20″ induction wells are currently available in the market, larger units are being prototyped for development and release. Frontier Energy researchers had the opportunity to monitor one such prototype at Claremont Hotel, where a four-well induction unit was installed in the employee breakroom (Figure 106). This induction well was used to hold staple foods such as rice, vegetables, and proteins for the staff to have for lunch or dinner while on break. Over the course of the monitoring period, the induction well used about 5.2 kWh/day while operating for 10.9 hours per day on average (Figure 107). This was for all four units, so the equivalent energy use for a singular well would be only about 1.3 kWh/day. However, the induction unit had issues with maintaining the proper holding temperature, and thus had to be supplemented with a heat strip. This heat strip used 9.6 kWh/day while operating for 9.6 hours per day on average (Figure 108), making the added heat strip energy about 2.4 kWh/day per 12″x20″ well equivalent. Thus, the total theoretical 12″x20″ heated well replacement was about 3.7 kWh/day. This is significantly less that the 5.2 kWh/day total energy use measured just for the four-well induction unit itself, but the full four-well induction energy will be used for the theoretical savings comparison for a more conservative estimate of possible savings. Since the induction well is still an unfinished technology and there is reduced energy per given area with larger appliances, the more conservative estimate can illustrate the savings even in low savings scenarios.

Figure 98: Claremont Hotel Vollrath Prototype Induction Heated Well

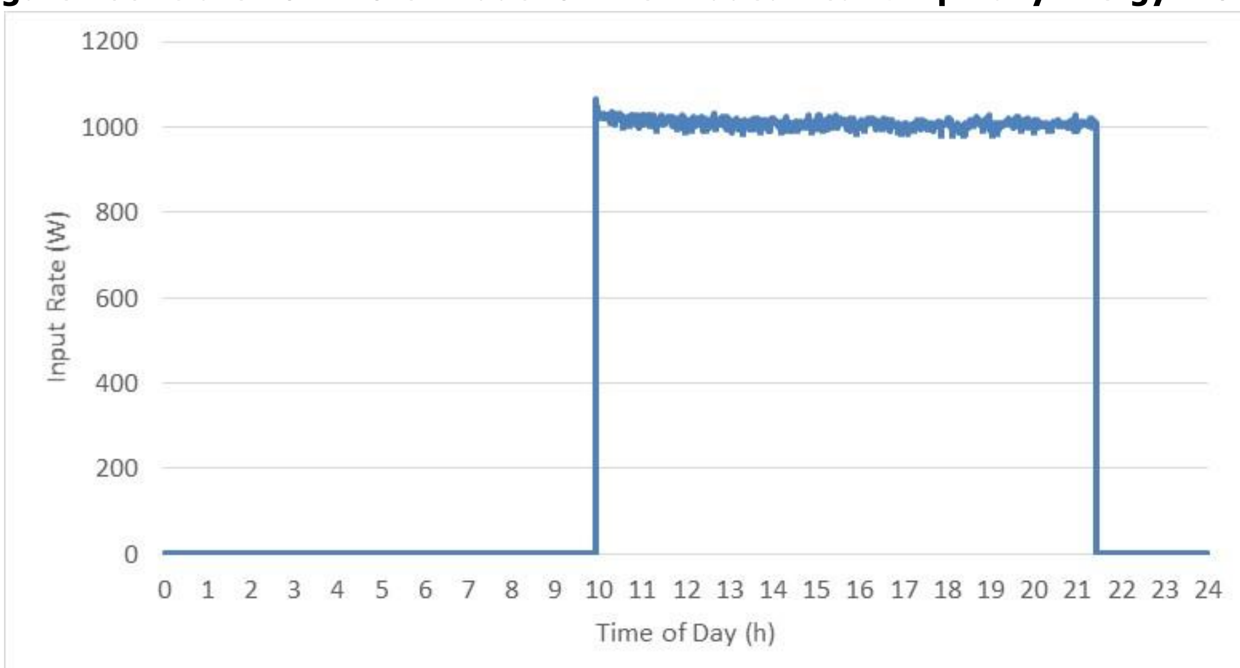
Source: Frontier Energy, Inc.

Figure 99: Claremont Hotel Induction Heated Well Daily Energy Profile



Source: Frontier Energy, Inc.

Figure 100: Claremont Hotel Induction Well Added Heat Strip Daily Energy Profile



Source: Frontier Energy, Inc.

Results

Rectangular heated wells operate at a low input rate and, unlike other plug load appliances discussed in this project, wells are rarely left on without doing useful heating. Since the wells operate by heating a water bath to create steam to heat pans, they have a clear visual cue for wasted energy when the appliance is on without a pan to be heated. This helps signal operators to turn off the appliance if not needed, unless there is an empty pan blocking the steam. This lack of idle energy usage combined with low input rates make the heated wells a weaker candidate for plug load energy savings.

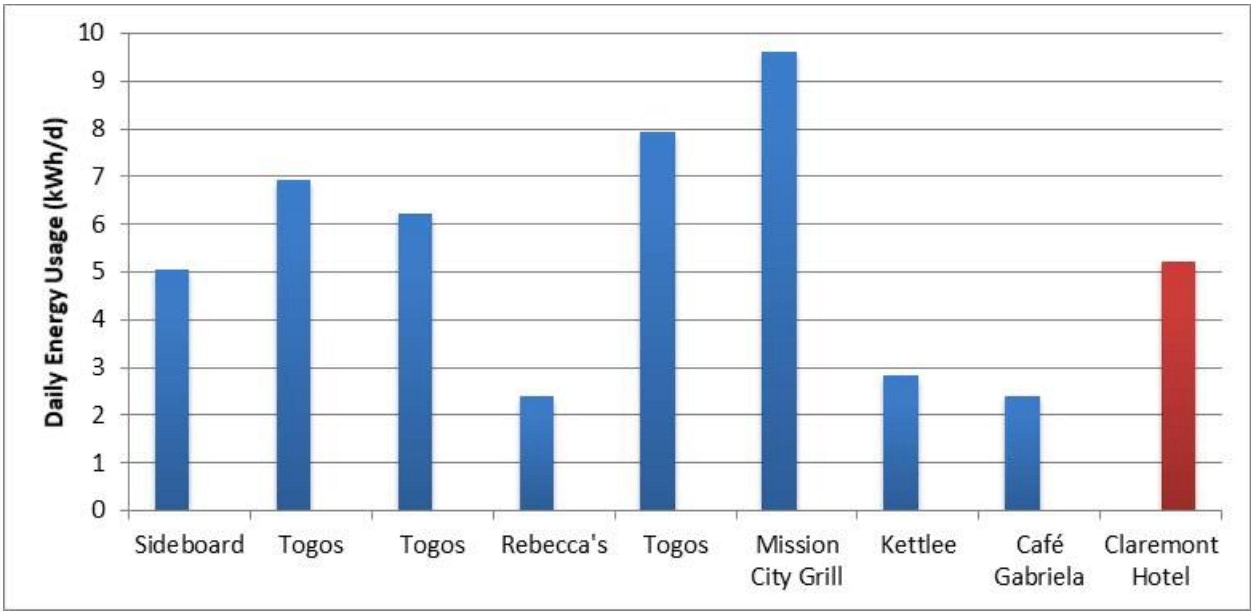
Although there is little idle energy usage, there are several points of inefficiency that could result in energy waste. If the space is not partitioned and used properly, heat might be wasted on empty pans if there is no insulated lid. Many heated wells are wet wells, which is a relatively inefficient technology. It may be possible to produce energy savings with dry well technology, better insulation/partitioning, or induction wells. The baseline heated wells had an average energy usage of 5.4 kWh per day with 7.4 hours of operation (Table 36. The prototype induction heated four-well unit had an average energy usage of 5.2 kWh per day with 10.9 hours of operation. Normalizing for hours of operation, one might then be able to reasonably expect induction wells to have a savings potential of about 34 percent, which is a more conservative estimate than the more direct induction and heat strip single pan equivalent (Figures 109 and 110). Thus, though the technology is still in development, the savings potential seems substantial.

Table 36: Rectangular Heated Well Results

Site	Pan Capacity	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Baseline				
Sideboard	1	5.04	8.61	0.585
Togo’s North Livermore	4	6.93	8.11	0.855
Togo’s North Livermore	4	6.2	11.2	0.557
Rebecca's	1	2.4	4.4	0.545
Togo’s	4	7.9	7.7	1.031
Mission City Grill	2	9.6	9.9	0.972
Kettle’e	1	2.9	4.0	0.716
Café Gabriela	1	2.4	5.5	0.439
Average		5.4	7.4	0.721
Replacement				
Claremont Hotel	4	5.2	10.9	0.477
Average		5.2	10.9	0.477

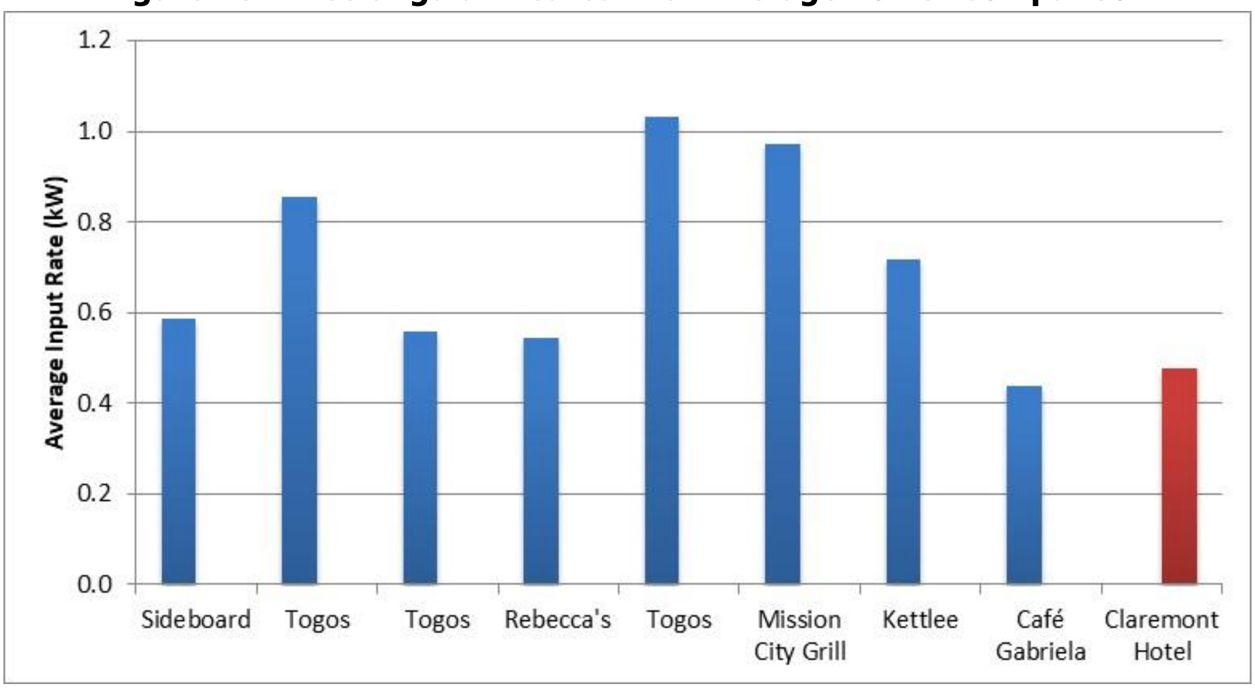
Source: Frontier Energy, Inc.

Figure 101: Rectangular Heated Well Daily Energy Usage Comparison



Source: Frontier Energy, Inc.

Figure 102: Rectangular Heated Well Average Power Comparison



Source: Frontier Energy, Inc.

Soup Warmer

Soup warmers are found in any businesses that sell soup, as soups are a labor and time intensive product often cooked in batches. Multiple soup warmers are often used in the same location to sell a variety of different soups. These usually operate at a low input rate and typically do their warming via heated water bath. The water bath is heated to create steam, which comes in contact with a soup container placed inside and keeps it warm.

Soup warmers using induction technology for holding are becoming more common, however. These heat the soup pot directly, removing the need for water and often creating a more even heating throughout the soup itself. The research team monitored seven baseline soup warmers and nine induction soup warmers, across six different locations.

Caffe 817

Caffe 817 is a small local café that serves breakfast and lunch fare, including two daily types of soup. The restaurant featured two 120V LiteLine LLW-7 7-quart soup warmers in its front service area, near the register for quick and easy service (Figure 111). After the soups come off the cooktop, they get transferred into one of two soup warmers. Researchers monitored the soup warmer that the operator stated had the higher usage. The data showed that the soup warmer operated for an average of 7.7 hours per day resulting in an average energy consumption of 0.9 kWh per day.

Figure 103: Caffe 817 LiteLine LLW-7 7-Quart Soup Warmer

Source: Frontier Energy, Inc.

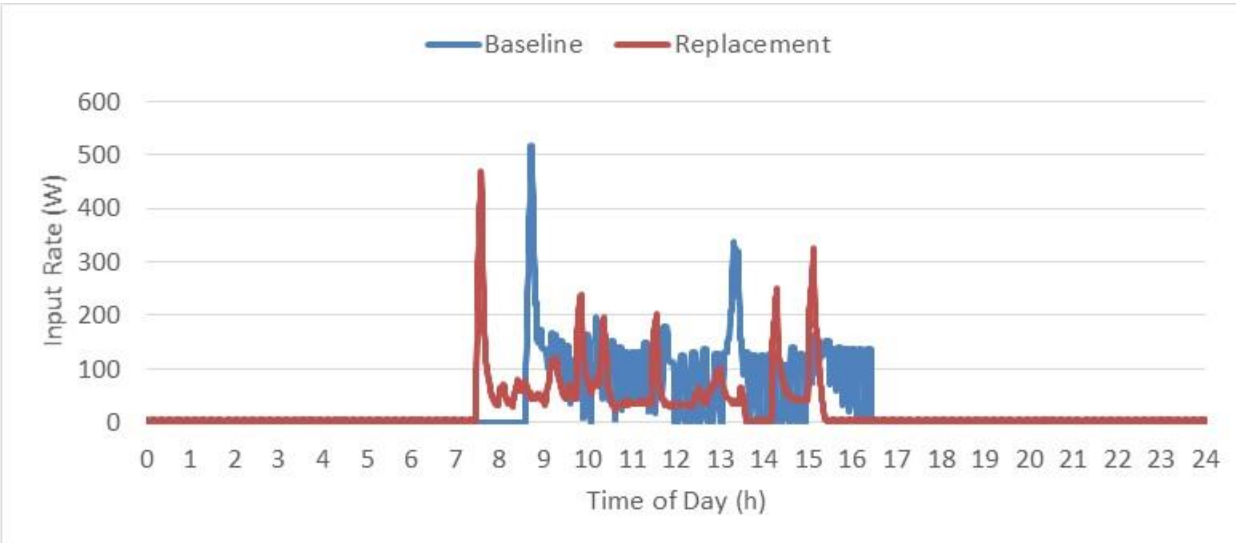
Frontier replaced the soup warmer with a Vollrath 7-quart induction model (Figure 112).

Figure 104: Caffe 817 Vollrath Induction 7-Quart Soup Warmer

Source: Frontier Energy, Inc.

The replacement required no additional staff training thanks to the simple digital controls, and the setup and cleanup were simplified since there was no water involved. The increased temperature modulation from the induction technology saved energy by reducing the holding energy to match the decreasing soup volume throughout the day. Over a monitoring period of several months, the induction soup warmer averaged less than 0.5 kWh per day, on an average 5.1 hours of operation (Figure 113). Normalizing for the usage, the soup warmer reduced energy use by 22 percent as compared to the baseline. For the average $0.15 per kWh cost of electricity, this is equivalent to an annual energy savings of about $7. For this site, the energy efficient replacement had a payback period of 65.7 years, not including the cost savings from the induction warmer's lower product loss. The staff was also very happy with the ease of use and food product quality.

Figure 105: Caffe 817 Soup Warmer Energy Profile Comparison



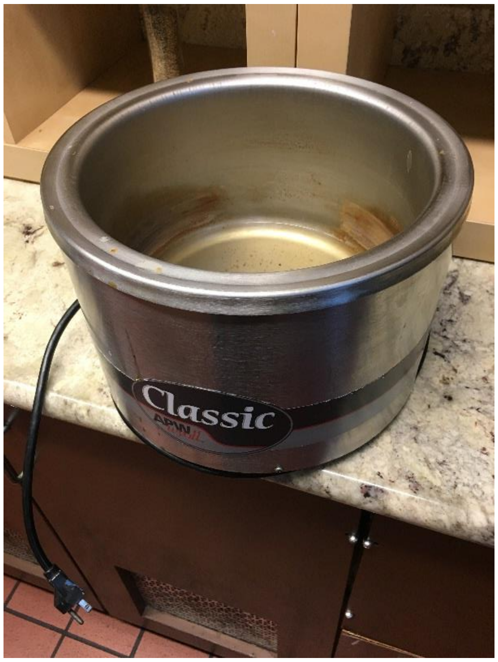
Source: Frontier Energy, Inc.

Mills College (Founders Commons)

The Mills College Founders Commons dining hall features two soup warmers used every day during its lunch and dinner services — a 7-quart APW Wyott RW-1V and an 11-quart APW Wyott RW-2V (Figure 114). Both are 120V plugins that keep the self-serve soup warm as students browse the dining options and pick out which items they want. Depending on the menu for the day, either one or both soup warmers may be used. When meal services are over, the soup warmers are turned off and unplugged. Over a three-month monitoring period, the 7-quart soup warmer used an average 0.6 kWh per day and the 11-quart soup warmer used an average 1.5 kWh per day with an average 8.0 hours of operation (Figure 115)

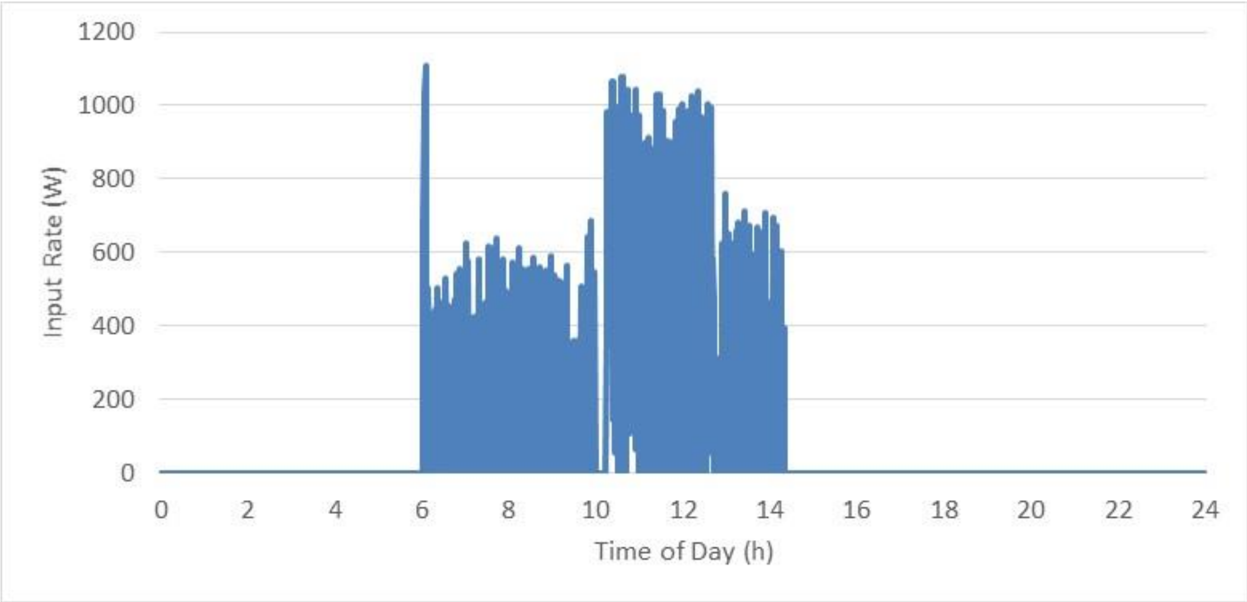
Frontier replaced the 11-qt soup warmer with a Vollrath 11-quart induction model (Figure 116). The replacement required no additional staff training thanks to the simple digital controls, and the setup and cleanup were simplified since there was no water involved. The increased temperature modulation from the induction technology saved energy by reducing the holding energy to match the decreasing soup volume throughout the day. Over a monitoring period of several months, the induction soup warmer averaged slightly more than 0.5 kWh per day, on an average 7.9 hours of operation (Figure 117). Normalizing for the usage, the soup warmer reduced energy use by 63 percent as compared to the baseline. For the average $0.15 per kWh cost of electricity, this is equivalent to an annual energy savings of about $50. For this site, the energy efficient replacement had a payback period of 7.8 years, not including the cost savings from the induction warmer's lower product loss. The staff was very happy with the ease of use and food product quality.

Figure 106: Mills College APW Wyott RW-2V Baseline 11-Quart Soup Warmer



Source: Frontier Energy, Inc.

Figure 107: Mills College Baseline 11-Quart Soup Warmer Operation

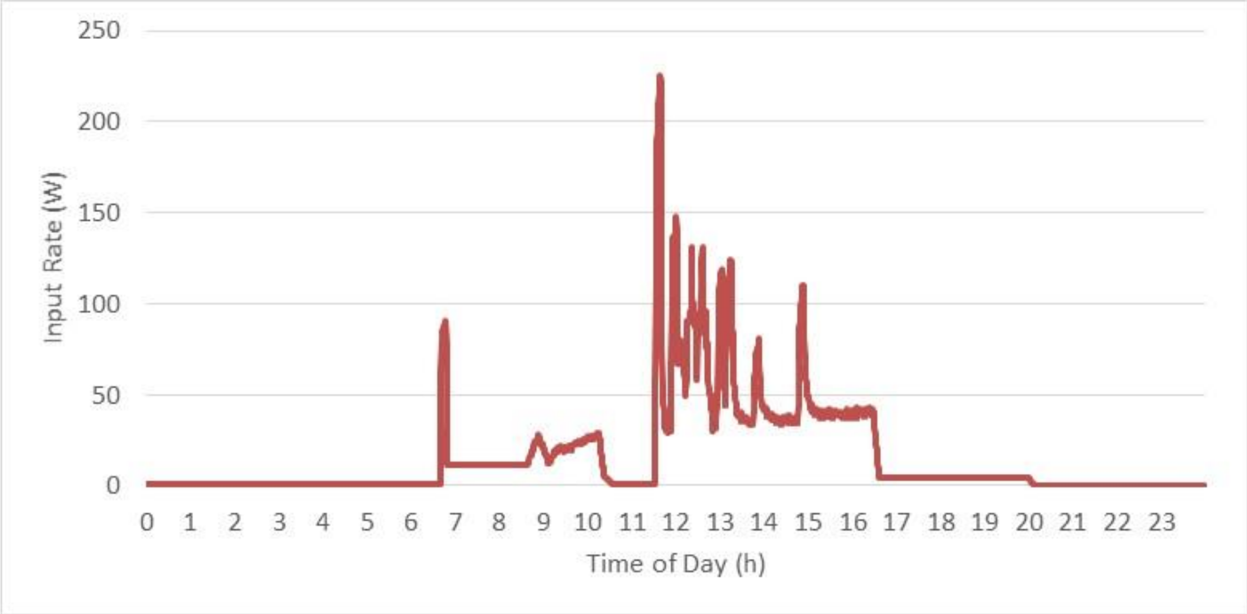


Source: Frontier Energy, Inc.

Figure 108: Mills College Vollrath Induction 11-Quart Soup Warmer

Source: Frontier Energy, Inc.

Figure 109: Mills College Replacement 11-Quart Soup Warmer Operation



Source: Frontier Energy, Inc.

Spreadz

Spreadz is a specialty sandwich shop that also offers a variety of soups to pair with the meal. It has three 7-quart soup warmers and one 11-quart soup warmer (Figure 118) in its front service area, near the register for quick and easy service. These soups are prepared early in the morning and transferred to the soup warmers for holding until ordered. Researchers monitored the 11-quart and two of the 7-quart soup warmers to get a baseline energy consumption. The 7-quart soup warmers averaged 0.5 kWh/day on 1.9 hours of operation per day, while the 11-quart soup warmers averaged 0.7 kWh/day on 1.7 hours of operation per day.

Frontier replaced both a 7-quart and an 11-quart baseline soup warmer with corresponding Vollrath 7-quart induction model (Figure 119). The replacements required no additional staff training thanks to the simple digital controls, and the setup and cleanup were simplified since there was no water involved. The increased temperature modulation from the induction technology saved energy by reducing the holding energy to match the decreasing soup volume throughout the day. Compared to their baseline units, the replacements resulted in 42 percent energy savings for the 7-quart soup warmer and 69 percent energy savings for the 11-quart soup warmer (Figures 120). For the average $0.15 per kWh cost of electricity, this is equivalent to an annual energy savings of about $15 and $50 respectively. For this site, the energy efficient replacement had a payback period of 37.5 and 11.9 years respectively, not including the cost savings from the induction warmer's lower product loss. The staff was very happy with the ease of use and food product quality, and the bright red aesthetic also represented their brand well.

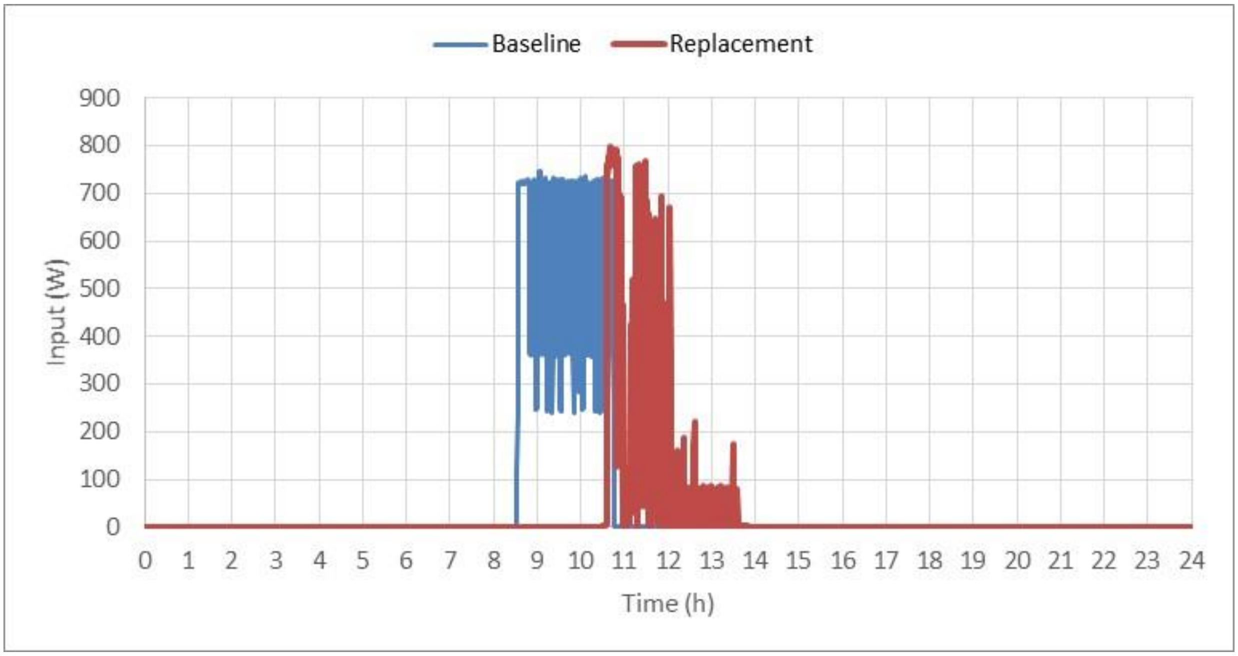
Figure 110: Spreadz Baseline Nemco 11-Quart Soup Warmer

Source: Frontier Energy, Inc.

Figure 111: Spreadz CookTek SinAqua Induction 11-Quart Soup Warmer

Source: Frontier Energy, Inc.

Figure 112: Spreadz 11 Qt Soup Warmer Energy Profile Comparison



Source: Frontier Energy, Inc.

Results

All the monitored soup warmers used a relatively small amount of energy compared to other plug load appliances (Table 37). Despite the low energy consumption, soup warmers are represented in a significant number of restaurants with an estimated 39,000 units being sold every year. Together, they account for a large volume of energy usage. Induction soup wells are also on the rise, which promise sizeable energy reduction. For these reasons, soup warmers represent a good plug load energy saving opportunity despite the relatively low usage. Overall, the soup warmers had an average energy usage of 0.8 kWh per day with 5.0 hours of operation (Figure 121). Energy savings from induction replacements varied from 20 – 70% (Table 38), but total savings were low because of the low average input rate soup warmers operate at (Figure 122). The savings analysis resulted in a very high payback period of just more than 30 years, but an extended analysis of product loss differences between the baseline and induction units is needed to determine the true cost differential. Regardless of the dollar savings though, the operators all preferred the induction warmers due to their ease of use and high product holding quality.

Table 37: Soup Warmer Results

Site	Total Average Energy (kWh/d)	Total Average Hours (h)	Average Input Rate (kW)
Baseline (Resistance)			
Caffe 817	0.9	7.7	0.117
Mills	0.9	12.0	0.075
Mills	0.6	8.0	0.075
Mills	1.5	8.0	0.188
Spreadz	0.7	1.7	0.411
Spreadz	0.5	2.0	0.255
Spreadz	0.4	1.9	0.217
Average	0.8	5.9	0.117
Replacement (Induction)			
Dabba	0.3	4.6	0.061
Dabba	0.3	5.3	0.060
Dabba	0.3	4.1	0.073
Dabba	0.2	4.1	0.055
Caffe 817	0.4	4.9	0.092
Mills	0.5	7.9	0.069
Togo's*	2.3	9.0	0.251
Spreadz	0.4	3.2	0.126
Spreadz	0.4	2.7	0.149
Average	0.6	5.1	0.107

*** High energy consumption may be due to use as rethermalizer, as a different location had a 3-compartment steam table for holding that consumed 8 kWh per day**

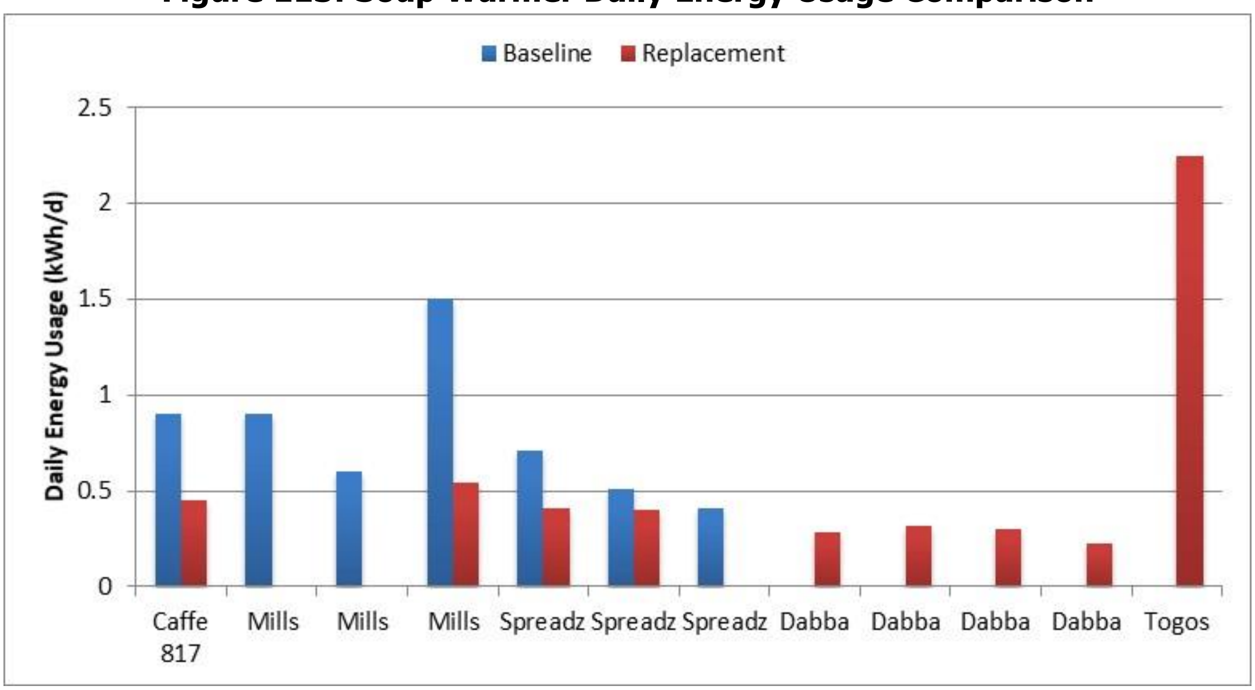
Source: Frontier Energy, Inc.

Table 38: Soup Warmer Replacement Data Comparison

Site	Baseline or Replacement?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)	Normalized Savings (%)	Payback Period (yrs)
Caffe 817	Baseline	0.9	7.7	0.117	22.1	65.7
	Replacement	0.4	4.9	0.092		
Mill College	Baseline	1.5	8.0	0.188	63.2	7.8
	Replacement	0.5	7.9	0.069		
Spreadz (11qt)	Baseline	0.7	1.7	0.411	69.4	11.9
	Replacement	0.4	3.2	0.126		
Spreadz (7qt)	Baseline	0.5	2.0	0.255	41.6	37.5
	Replacement	0.4	2.7	0.149		
				Average	49.1	30.7

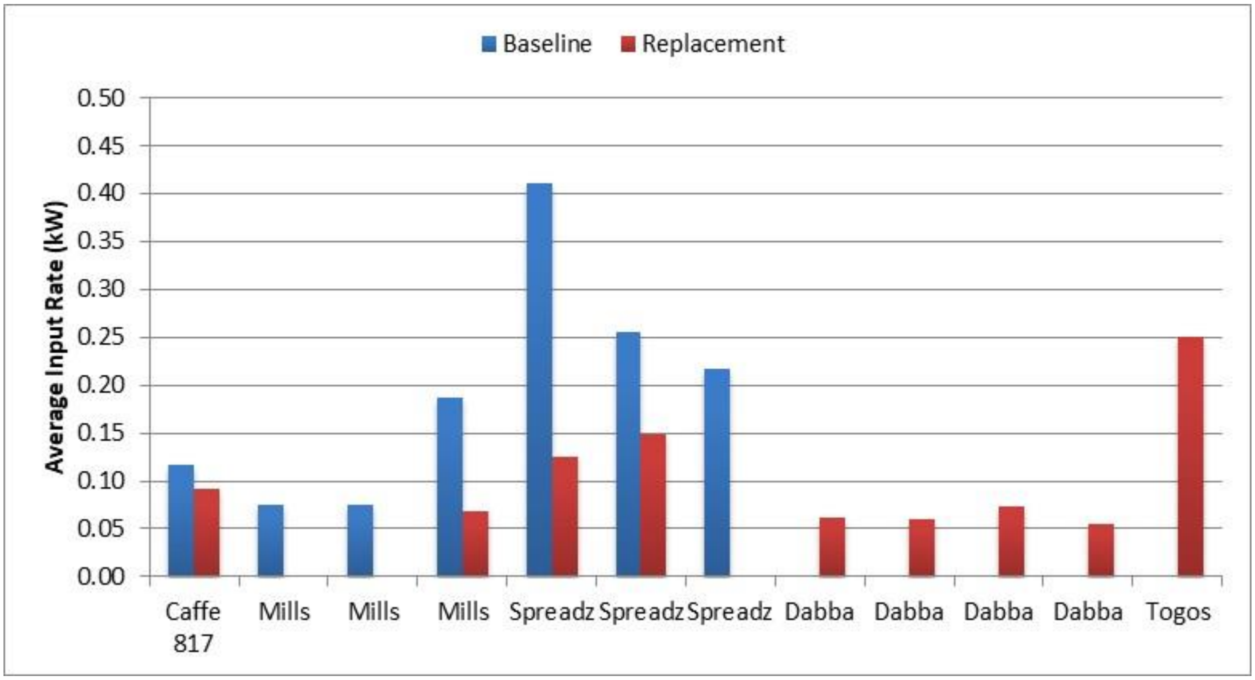
Source: Frontier Energy, Inc.

Figure 113: Soup Warmer Daily Energy Usage Comparison



Source: Frontier Energy, Inc.

Figure 114: Soup Warmer Average Power Comparison



Source: Frontier Energy, Inc.

Appliance Laboratory Analysis

Frontier Energy supplemented the field analysis with additional laboratory data to expand the characterization of the energy efficient new technologies beyond the limited replacement opportunities found at the monitored site. Testing the efficient appliance technologies under controlled laboratory settings increased the breadth of data and allowed for comparison across different models and input rates. This in-depth data can also be combined with the collected field data to create more accurate energy models for estimating energy savings across various projected use cases.

Induction

Induction cooktops have become increasingly accepted in commercial foodservice as replacement for the encumbered gas cooktops, but many obstacles still exist. Many still believe that electric cooktops are inferior to gas cooktops, given the lackluster performance of electric resistance cooktops. Electric resistance cooktops are slow to heat up, cool down, and modulate temperatures for precision cooking. Induction cooktops, however, have cool down time and temperature modulation capabilities like that of traditional gas cooktops and the heat up time can be considerably faster.

Induction cooktops are also easier to clean, have better temperature control, reduce burn hazards, reduce radiant heat to space, and have modular designs that can flexibly adapt to demand. However, chefs are reluctant to give up the visual feedback that an open flame provides and that they are used to. There are also concerns of whether the benefits of induction can offset the higher initial cost and shorter expected lifetime.

Frontier Energy conducted an in-depth laboratory analysis on various induction cooktop models to better characterize the operation and energy efficiency of commercially available units (Table 39). Application of the regimented American Society for Testing and Materials (ASTM) test method as well as the additional simmer and sauté tests provides clear evidence

that not only are induction cooktops highly energy efficient when compared to traditional heating methods, but far more productive as well. Extended data and discussion of induction cooktops can be found in APPENDIX D:
Appliance Laboratory Analysis - Induction.

Table 39: Induction Cooktop Testing Data Summary

	Model B	Model D	Model E	Model G	Model H
Voltage	120V	208V	208V	208V	208V
Power Per HOB (kW)	1.4	2.5	3.5	5.0	5.0
Boil Efficiency (%)	82.7	87.8	87.0	83.5	90.4
20lb Boil Time* (min)	42.1	22.2	17.2	13.9	10.5
Average Simmering Power (kW)	0.94	0.88	1.10	0.98	0.95
Cooking Efficiency (%)	42.5	39.5	38.3	34.8	39.5
Burger Cook Time (min)	5.96	5.28	5.75	5.24	5.48
Pan Preheat Time (min)	1.46	1.66	1.54	0.71	0.63
Average Cooking Power (kW)	0.67	0.78	0.77	1.36	0.87

Source: Frontier Energy, Inc.

Conduction

As a component of the plug load study, Frontier Energy characterized the performance and energy use of the new Condeco electric conduction cooktop in a controlled laboratory environment. The cooktop's energy saving features include smart controls that adjust input rate based on temperature sensor feedback, insulation that captures and directs heat energy for minimal losses, and durable, precisely flat surfaces for maximum heat transfer efficiency. The specialized paired cookware also features double walls on both the sides and the lid to minimize heat loss to ambient air. The conduction cooktop was tested in conjunction with a residential induction range, representative of the most energy efficient option currently available in residential kitchens.

The conduction and induction cooktops demonstrated similar heat-up energy requirements, though the lower input rate resulting from the smart controls resulted in the conduction cooking system taking about a minute and a half longer to reach boiling temperature. The simmer and sauté tests showed that the conduction cooking system operated significantly more efficiently than induction when cooking. This difference in energy efficiency is particularly apparent when requiring precision — the conduction system allows for more exact temperature control with its temperature feedback system than an induction system with a smaller number of discrete power settings. The energy efficiency of the conduction system is maximized when paired with the conduction cookware; energy savings are theoretically still possible when using the conduction cooktop with a normal induction pot, but the effect of the pot on the smart controls makes the heating too slow to be practical.

The conduction system also currently operates slightly slower than induction due to its lower input rate and smart control algorithms, though the control algorithms could possibly be modified to increase input rate to make boiling time on par with induction. The current algorithms programmed to promote healthy cooking make the duty cycles of the conduction cooktop significantly lower. The double-walled construction of the conduction cookware also reduces external pot temperature in comparison to induction by about 25°F (14°C) for the sides of the pot and 60°F (33°C) for the lid. This results in safer and more efficient cooking, but the specific savings per household will vary depending on usage. Overall, researchers found that the conduction cooktop offers significant energy savings, particularly for households that do extensive simmer cooking (Table 40). Extended data and discussion on the conduction cooktops can be found in Appendix E.

Table 40: Conduction Versus Induction Cooktop Test Results Summary

Cooktop	Conduction Cooking System	Induction Range*
Heat-Up Input Rate (W)	1.8 kW	2.2 kW
5-lb Water Heat-Up Time (min)	8.0	6.5
5-lb Water Heat-Up Energy (Wh)	236	244
5-lb Water Heat-Up Efficiency (%)	90.5	84.8
Production Capacity (lb/h)	37.7	45.9
5-lb Water Simmer Energy Rate (W)	48	683
Simmering Pot Exterior Temperature (°F)	179	210
Simmering Pot Lid Temperature (°F)	139	208
Cooking Heat-Up Time (min)	1.33	2.44
Cooking Heat-Up Energy (Wh)	45	30
Sauté Time (min)	9.17	7.05
Sauté Energy (Wh)	38	61
Sauté Input Rate (W)	245	515
Sauté Duty Cycle	9.6%	22.3%
Sauté Efficiency	92.7%	54.0%

***Heat-Up done with Power Boil setting, Simmer done on Medium setting (5th setting) and Sauté done on 4th setting**

Source: Frontier Energy, Inc.

Rapid Cook Ovens

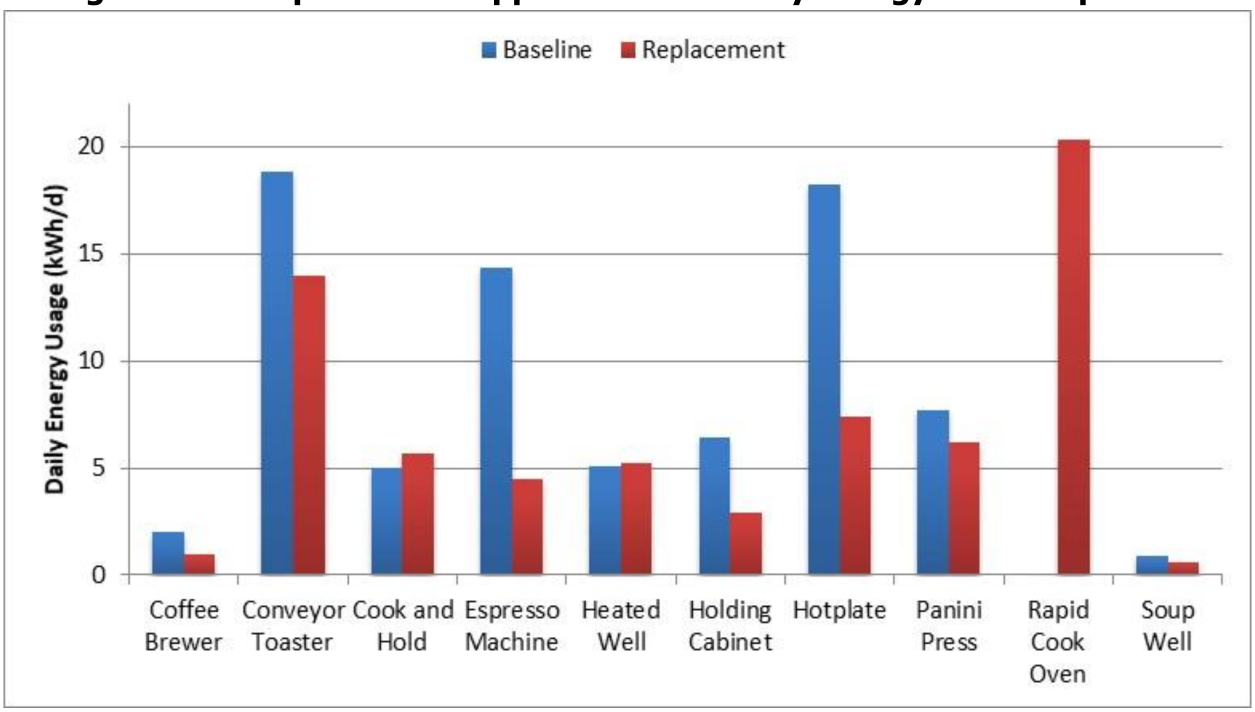
Frontier Energy conducted additional laboratory testing on rapid cook ovens given the recent increased interest in the technology, particularly from larger chain accounts. Many foodservice operators are shifting their process from batch cooking-and-holding to rapid cooking. Frontier

Energy conducted an analysis on the current state of the market, characterizing the different rapid cook technologies currently available and benchmarking their comparative energy consumption and production capacities through controlled laboratory testing. Frontier also analyzed the energy cost of units monitored at active foodservice operations. More detailed information on rapid cook ovens can be found in Appendix F.

CHAPTER 3: Project Results

More than 91 different pieces of equipment were evaluated throughout the baseline energy monitoring period, spanning 22 distinct appliance types across 29 different site locations. Eighteen of those baseline appliances were directly replaced with energy-efficient alternatives, with effects on energy and service closely monitored. Additionally, 19 efficient technology appliances already present at the sites were monitored and characterized for theoretical replacement savings. The test sites included a variety of independent quick and full-service restaurants, several quick service chains, university and corporate dining halls, and hotel restaurants. Researchers averaged and normalized energy usage across each appliance type to generate representative baseline energy estimates for each appliance category (Figure 123). For appliance categories with efficient technologies currently available on the market, energy data from direct or theoretical equipment replacements was analyzed to characterize the estimated energy saving opportunity.

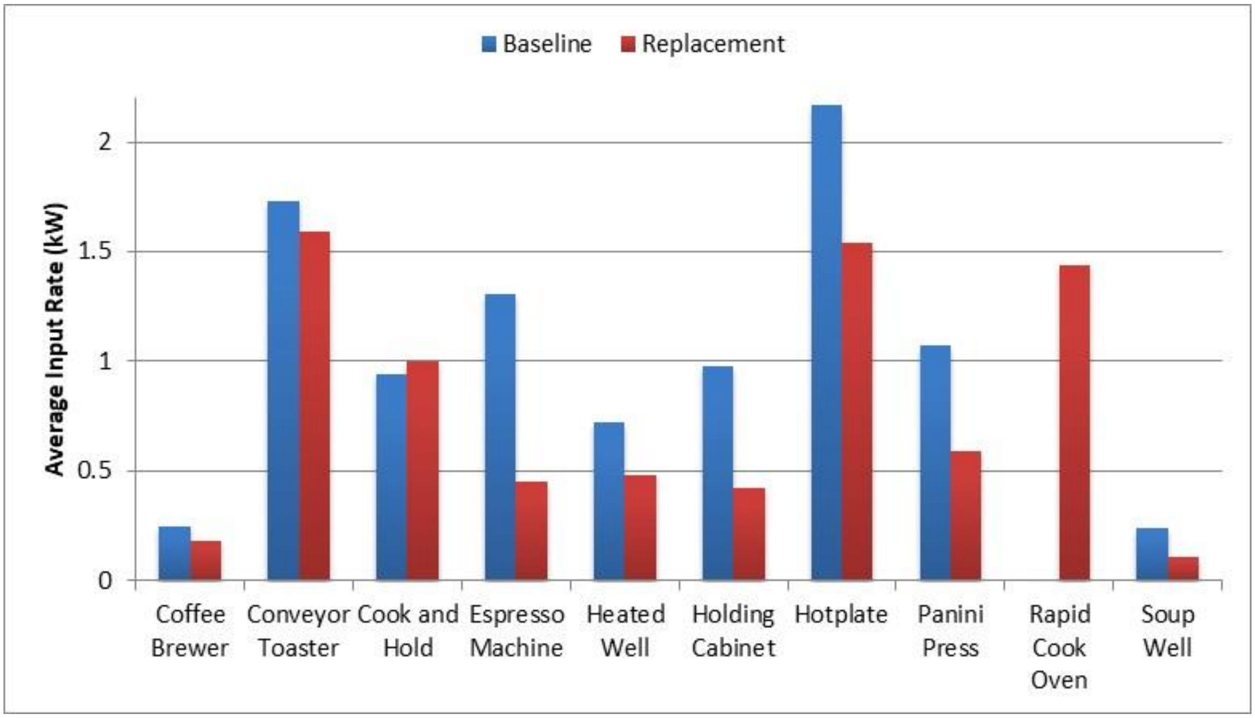
Figure 115: Replacement Appliance Total Daily Energy Use Comparison



Source: Frontier Energy, Inc.

Suitable replacement technologies could only be found for nine of the 22 plug load appliance types. Direct replacements of baseline equipment were only done for seven of these categories: coffee brewers, conveyor toasters, cook and holds, cooktops, espresso machines, holding cabinets, and soup warmers (Figure 124). Data from direct appliance replacements serve as the most accurate estimate of potential energy savings for replacement scenarios.

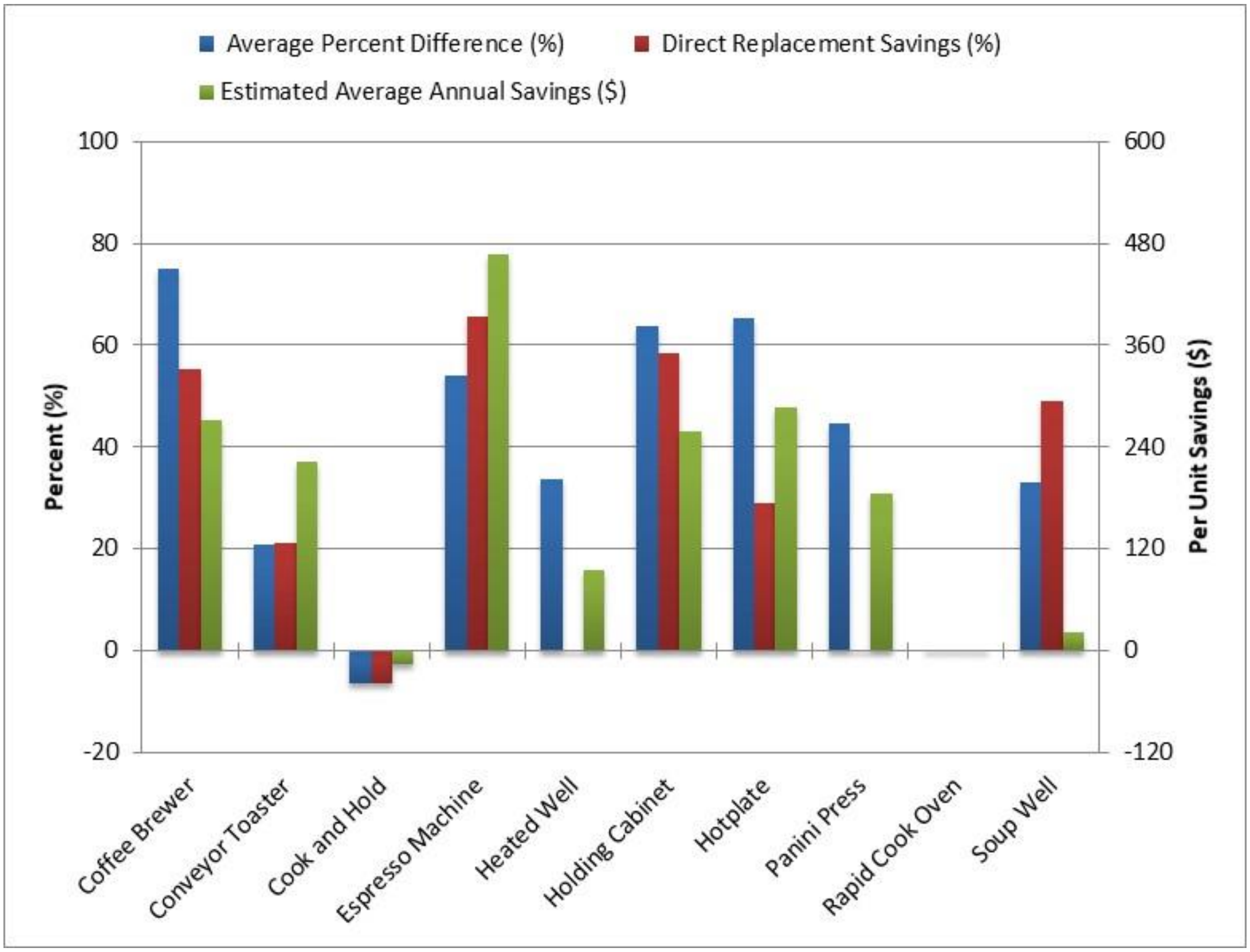
Figure 116: Replacement Appliance Input Rate Comparison



Source: Frontier Energy, Inc.

The replacement data found that in terms of annual cost savings, espresso machines, cooktops, and holding cabinet replacements yielded the best results (Figure 125). In terms of highest percent energy reduction, espresso machines, coffee brewers, holding cabinets, and soup warmers yielded the best results. When factoring in equipment costs to determine payback periods, espresso machines, coffee brewers, and conveyor toasters came out on top. Given the variation within appliance categories in key factors such as daily operation energy profiles and operator willingness to engage in best energy practices, however, it is difficult to determine in isolation the most promising plug load energy opportunities. Results across the different energy savings metrics varied substantially within each product category and more research is advised to create conclusive comparisons. The project illustrates the range of savings possibilities, which can vary from nonexistent to $1,290 in annual energy cost savings with a payback period of nearly zero.

Figure 117: Replacement Savings Comparison



Source: Frontier Energy, Inc.

Frontier Energy considers the most favorable, actionable energy saving opportunity to come from conveyor toaster replacements. These replacements yielded an estimated average in utility savings of about $223 per year 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, the simple payback time on the incremental cost difference is reasonable. The average payback period was about three years for a 120V toaster and three months for a 208V toaster. The payback period for 208V toasters is significantly shorter because energy consumption is much higher. From the data collected, the average measured energy consumption was nearly four times as large for 208V toasters than for 120V toasters, or 49 kWh/day to 12 kWh/day. However, the cost difference between 208V and 120V toasters isn't nearly as large, with the 208V units only costing one-and-a-half to two times more than 120V units. 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 CFS 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 represents a strong energy saving opportunity within only a few months.

Espresso machines are also very promising, based on the results of the replacement done in Café Gabriela. They typically run 24/7, so by implementing an automatic timer shutoff for nonbusiness hours and switching to a unit with an insulated boiler, the store lowered its energy by a substantial 69 percent. This is equivalent to $540 in annual savings. The payback period can be low or even nonexistent; in the case of Café Gabriela, the energy-efficient machine was $600 less expensive. That means choosing the efficient espresso machine over the baseline model would have saved the café more than $1,000 by the first year, and more than $500 every year after that. This makes specifying an insulated efficient espresso machine when making a new purchase an obvious choice. However, replacing an existing espresso machine can be problematic since the machines are quite expensive, and operators are often hesitant to modify their espresso machine because it serves as the centerpiece for a coffee shop. For owners who don't want to switch machines, significant savings can still be realized by implementing the automatic timer shutoff. Turning the espresso machine off overnight should reduce energy costs by at least 20 percent, but unfortunately very few owners take advantage of this feature, due partly to an unsubstantiated industry rumor about frequent shutoffs reducing equipment lifespan. Education initiatives are recommended to help owners learn about the effectiveness of overnight shutoffs, which should save them at minimum $150 per year in energy costs. A study to investigate the effect of shutoffs on equipment lifespan would also be fruitful, given the widespread rumor. For owners purchasing a new espresso machine, increased awareness of the long-term savings of efficient espresso machines would be effective at the point of purchase to increase adoption.

Coffee brewers fall into a category similar to espresso machines, where the bulk of the energy savings would come from eliminating long standby periods. By eliminating overnight and sometimes weekend operation, coffee brewers can save around half of their total operating energy with minimal operational changes or expenses. Many coffee brewers have a seldom-used energy save mode that can be easily programmed — this is a free source of energy savings that requires just a few minutes to set up. Using this method, there is no payback period and all savings go directly to the owner. For Rebecca's, this equated to $55 a year back to the owner's pocket. However, the energy save mode requires some start-up time when the coffee brewer moves from idling to active. For coffee brewer owners without energy save modes or with requirements for coffee first thing in the morning, an external timer is a simple solution that only costs about $56. The payback period for this was only about a year for the site monitored, with zero disturbance to daily operation habits. Frontier recommends educational outreach as the best way to capitalize on these energy savings, since many coffee brewers already have energy save modes, and external timers are relatively inexpensive.

Holding cabinets also exhibited favorable savings opportunities. With three different replacements, all showing energy savings of greater than 40 percent, it has proven to be the most reliable energy saving opportunity even across different applications. The benefits from enhanced insulation and compartmentalization would result in an estimated $286 in annual energy savings, and replacements would require little to no behavioral change. However, energy efficient insulated holding cabinet price points all hover around $4,000, while baseline uninsulated clear door cabinets can cost as little as $1,000. This caused payback periods for the holding cabinets to range anywhere from instantaneous to 12 years. It is clear, however, that energy savings are possible with utility programs that 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.

Cooktops are a strong candidate for plug load energy reduction due to their high input rates and long hours of operation, but many of the cooktops currently in service have already been switched to efficient induction technology. Where older resistance cooktops exist though, substantial energy savings from switching to induction are nearly guaranteed, on the range of $286 per year based on the data. Induction cooktops are also safer, easy to clean, and produce quicker and more even heating. Though induction cooktops are significantly more expensive than resistance cooktops, the industry's steady shift toward induction indicates that the benefits in safety and labor cost makes the switch to induction worth more than just the energy savings. A utility rebate to reduce the upfront cost of replacement would effectively accelerate the conversion to induction cooktops.

Induction soup warmers saved 49 percent of the energy used by its conventional resistance element counterpart but showed the lowest cost savings per unit among the direct replacement categories. Savings could be more significant for sites with multiple units and longer operating hours, but there is also a significant price point difference between electric resistance and induction soup warmers that makes the payback period substantial. 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 CFS facilities in general; full- and quick-service restaurants, cafeterias, grocery stores, and even cafés 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. Induction soup warmers are also easier to use and have better holding uniformity, so there is less product loss from crusting. Additional research is advised to quantify the value of this product loss, to more accurately determine the potential savings of induction soup warmers.

Among appliance categories where direct replacements were not available, heat strips show the most promise. Heat strips are energy-intensive appliances that operate at a high constant input rate without any thermostatic feedback and are frequently forgotten by staff and not powered off. With an automatic timer or sensing technology to lower or turn off the heating elements when they are not actively in use, energy savings can be substantial. However, sensing technology for heat strips isn't currently available on the market. At this point, switching to halogen heat strips and implementing proper staff training is the best option for capturing energy savings. This practice could save just as much energy but is significantly more difficult to implement.

Rapid cook ovens also represent a unique opportunity, since they offer flexibility and speed in a small footprint, though at the cost of a higher energy intensity. Rapid cook oven can potentially replace multiple appliances to reduce kitchen footprint and save energy in select replacement situations. Additional research in this area is highly recommended, especially with the recent trend toward 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 saving potential of the technology. In a simple one-for-one replacement, a rapid cook oven will not likely save energy.

An important result from the study that supports any replacement programs with the technologies listed is that there was no negative feedback from any of the sites where replacements were performed, except for a site that received a faulty unit. Operators are typically sensitive to change, and if there is 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 the efficient technologies for the appliances discussed are minimal, making these technologies low risk for replacement.

Table 41 summarizes the energy data for all appliance categories currently with replacement potential. When available, the average percent of savings found when replacing a baseline appliance with an energy-efficient appliance was transposed onto the total average baseline energy of the appliance category to estimate the expected annual savings for appliances in the category. This may be different from the average savings found at sites where appliance replacements occurred, but better illustrates the potential savings across sites with various use cases. When there was data for efficient appliance alternatives but no direct replacements done with an appliance category, the average percent of difference was substituted to provide a best estimate for savings. The largest projected dollar energy savings were found in espresso machines, cooktops, coffee brewers, holding cabinets, and conveyor toasters.

Table 41: Potential Savings from Efficient Plug Load Replacements

Appliance Type	Baseline Number Tested	Baseline Total Average Daily Energy Usage (kWh/day)	Baseline Normalized Input Rate (kW)	Efficient Number Tested	Efficient Total Average Daily Energy Usage (kWh/day)	Efficient	Average Percent Difference (%)	Direct Replacement Savings (%)	Average Annual Savings ($/unit)	Average Shown Payback Period (years)
Coffee Brewer	7	9.1	0.71	2	1.0	0.18	75.0	55.3	272	0.5
Conveyor Toaster	10	19.6	2.08	6	14.0	1.59	20.8	21.0	223	3.1
Cook and Hold	1	5.0	0.94	1	5.7	1.00	-6.5	-6.4	-17	∞
Cooktop	1	18.2	2.17	4	3.8	0.76	65.2	29.0	286	10.4
Espresso Machine	6	13.1	0.98	2	4.5	0.45	53.9	**68.7**	467	None
Heat Strip	2	13.5	0.84	1	0.9	0.16	81.4	N/A	594*	N/A
Heated Well	8	5.1	0.72	1	5.2	0.48	33.8	N/A	94*	N/A
Holding Cabinet	9	8.1	1.15	3	2.9	0.42	63.7	58.5	258	7.5

Appliance Type	Baseline Number Tested	Baseline Total Average Daily Energy Usage (kWh/day)	Baseline Normalized Input Rate (kW)	Efficient Number Tested	Efficient Total Average Daily Energy Usage (kWh/day)	Efficient	Average Percent Difference (%)	Direct Replacement Savings (%)	Average Annual Savings ($/unit)	Average Shown Payback Period (years)
Panini Press	7	7.7	1.07	4	6.2	0.59	44.5	N/A	185*	N/A
Rapid Cook Oven	N/A	N/A	N/A	5	20.3	1.44	N/A	N/A	N/A	N/A
Soup Well	7	0.8	0.16	9	0.6	0.11	32.9	49.1	21	30.7

***Savings not from direct replacement but extrapolated from the comparison of normalized average energy rates for baseline and replacement equipment monitored.**

Source: Frontier Energy, Inc.

CHAPTER 4: Technology/Knowledge/Market Transfer Plan

Technology/Knowledge Transfer Activities

The Frontier Energy Food Service Technology Center (FSTC) Outreach Team successfully implemented the technology/knowledge transfer activities outlined in the Technology/Knowledge Transfer Plan that was submitted to the CEC as a requirement of the project workplan in June 2018.

Frontier Energy disseminated technical information and knowledge gained from this demonstration project by leveraging the FSTC's long-standing workforce education and training and information-outreach program (www.fishnick.com) for foodservice as well as the strategic industry partnerships it has forged over the past three decades. The objective of the education and outreach was to communicate the benefits of high efficiency, electric, commercial grade cooking and holding equipment from both an energy/carbon reduction and a performance standpoint. The technology transfer program used a variety of teaching and demonstration formats to highlight the various energy-efficient equipment options available with an end goal to overcome traditional market barriers and accelerate the adoption and implementation of energy efficient electric cooking and holding equipment in the CFS marketplace. In addition to sharing information specific to the appliances studied in the project, the education and training included best design practices that are necessary to create the right economic and performance environment for the successful integration of high efficiency electric appliances into current commercial kitchen operations.

Pacific Gas and Electric Company's (PG&E) Workforce Education and Training (WE&T) is an ongoing program offered to the foodservice sector by California's four investor-owned utilities (IOUs) through the statewide California Energy Wise (CAEnergyWise.com) seminar program. Energy efficiency seminars, workshops, and webinars provide a forum in which a group of market actors is delivered extensive information on energy-efficient technology and/or the application of energy-efficient technology. The Frontier Energy Outreach Team leveraged data and information gleaned from the CEC demonstration project to enhance existing seminar sessions and develop fresh seminars and webinars built around the new-found knowledge, information, and tools. Frontier Energy coordinated development, promotion, and delivery of these seminars. Many of the education and outreach events were facilitated using the Frontier Energy Food Service Technology Center in collaboration with PG&E's WE&T program. Other seminars and workshops were offered in Southern California in collaboration with the San Diego Gas & Electric Company, Southern California Edison, and SoCalGas foodservice energy efficiency training centers.

Frontier Energy also leveraged its partnerships with established industry professional and trade entities, regional and national conferences, and media organizations to share the lessons learned from the CEC research to the wider foodservice and design industry including kitchen designers, equipment specifiers, architects, engineers, energy efficiency consultants, utility professionals, policy makers, and other high-level market actors. Information outreach was delivered through various modes and venues including seminars, demonstrations, poster sessions, webinars, articles, papers, and interviews.

Additionally, the data filtered through to CFS industry actors via design consultations; energy efficiency site audits for local restauranteurs; routine interface with manufacturers and their representatives; and the Frontier Energy FSTC website at www.fishnick.com. Three representative case studies were developed to highlight key findings and promote market acceleration for the most promising technologies. The case studies were distributed through existing FSTC and CEC outreach channels.

The targeted audience for the technology transfer activities included engineers, facility designers/consultants, equipment manufacturers, equipment dealers and representatives, equipment service agents, contractors and installers, commercial foodservice operators of large and small chains, franchisees, and independent owner/operators of non-commercial (institutional) foodservice operators such as hotel, hospital, business, commissary kitchens, and campus kitchen/dining facilities. The technology transfer audience also included professional/trade organizations, associations, and societies; industry media through articles, technical features and/or interviews; government entities such as correctional, military kitchen/dining facilities; codes and standards bodies/advocates; utilities — energy centers, California statewide IOU advisory council meetings, codes and standards, incentives, and emerging technologies groups; and other research organizations.

Technology transfer was executed via the following activities:

- Project Webpage: Developed a comprehensive project webpage unique to the research project: https://fishnick.com/cecplug/.
- Project Case Studies: Developed three case studies showcasing the successes and lessons learned at monitored sites.
- Project Fact Sheets: Developed two fact sheets summarizing the project — an initial fact sheet prior to the start of the project and a final fact sheet at the completion of the project.
- California Energy Wise Seminars: Conducted numerous two-hour seminars highlighting results from the demonstration project.
- Industry Outreach: Consistently disseminated plug load information via short, quick-time frame seminars (typically 20 to 60 minutes); webinars; articles; papers; interviews; social media including Facebook, LinkedIn, Twitter, Instagram, and the fishnick.com website. These events are primarily delivered to targeted audiences at the request or invitation of industry hosts.
- Media / Media Events: Collaborated with Foodservice Equipment Reports magazine to create industry articles covering status updates and findings from project sites.
- Project Showcases: Hosted a Project Showcase event to highlight the key successes and lessons learned from the appliance field analysis. The information was shared with a wide cross-section of the industry via presentations and hands-on demonstrations of equipment featured in the research project.

The full technology/knowledge transfer report is in Appendix G.

Lessons Learned

Technology transfer activities indicated strong interest in the foodservice industry in plug load learnings, given the growing influx of induction and rapid cook technologies and the trend toward faster and more flexible kitchens. Seminar attendees found much of the knowledge to be new to them and were often surprised to learn the extent of energy savings that could be garnered with simple actions like activating built-in energy saving modes. Manufacturers were receptive to seeing how their advanced technology equipment might expand in sales and seemed open to developing further innovations if the demand is sufficient.

The largest strides that can be made in advancing these energy-efficient technologies come in consumer awareness/education programs and incentive programs to reduce initial purchase cost. Market surveys found that many of the plug load appliances were thought of as secondary, lower cost pieces, and bought on the basis of lowest initial cost. Efforts to lower initial purchase cost or shift consumer mindset to lifetime cost of ownership are projected to be the most effective to capitalize on the energy-savings opportunity efficient plug loads represent.

CHAPTER 5: Benefits to Ratepayers

Evaluation of Project Benefits

This project demonstrated the energy saving potential and cost effectiveness of energy-efficient technologies in non-hooded plug load foodservice equipment. Efficient plug load technologies were shown to reduce energy consumption by up to 69 percent, equaling up to $1,290 in annual energy savings for a single plug load appliance. Frontier Energy projected the current total energy saving potential of efficient plug loads to be about 51 GWh per year for the State of California, given the examined market and energy data and projected technology adoption rates between 5 percent and 20 percent.

Frontier Energy also demonstrated that efficient plug load appliances can have various advantages beyond energy savings. Efficient appliances are often safer than their cheaper counterparts — efficiency generally means less wasted heat, meaning fewer hot surfaces and burn risks for workers. Induction technologies especially reduce operator scalding risks, since the appliance will only operate when paired with the appropriate cooking vessel and heats the vessel directly rather than through an intermediate heat transfer medium like flame or steam. Insulated equipment such as efficient holding cabinets and conveyor toasters also have much cooler outer surfaces; many of the operators who received these replacement technologies noted the difference to be substantial.

Energy reduction for plug load appliances also results in overall heat load reduction in the kitchen, which results in more comfortable working conditions for staff. Commercial kitchens are typically among the hottest working environments, with hot appliances and often poor ventilation. Any reduction in heat output can be vital to worker health, while also saving on air conditioning costs.

Sites have also noted increased cooking uniformity and overall higher product quality from the efficient plug load appliances. Technologies like induction have more evenly distributed heating than gas or electric resistance heating, and many of the advanced technologies also feature programmable cooking controls with more user feedback than conventional models. The programmable recipes on these models ensure that each product is created to the same specifications, which can also lower labor costs, especially for large chain establishments.

Cost savings, safer working spaces, higher product quality, and ease of use all make energy-efficient plug load technologies appealing. The movement toward sustainability also has widespread consumer appeal, and efficient plug loads may provide good marketing opportunities, since they are more customer-facing and not as expensive as ventilated cookline equipment.

Frontier Energy has educated its clients and audiences about the large potential of plug load savings, which is very often overlooked. Frontier Energy’s market research has shown that most facilities are open to energy-saving technologies and that the largest barrier to adoption is simply education on the matter. The findings from this project expand this education and create a gateway into the world of foodservice energy efficiency. Frontier Energy’s seminars have shown many examples of the leading technology, and several attendees have voiced their decisions to switch to energy-efficient plug loads to capitalize on the savings and advantages they have to offer.

Project-Specific Benefits

Frontier Energy has generated new research on many emerging technologies like induction, conduction, rapid cook ovens, and demand-based controls. The findings from the project have substantiated the energy savings from various applications of these technologies and will heighten awareness of efficient plug load equipment as an avenue for energy-saving technology for end users, manufacturers, and utilities.

The research will increase the availability of energy-efficient appliances from equipment vendors, drive the creation of more efficient equipment from manufacturers, increase the demand from foodservice operators, and make the replacement opportunities more accessible and enticing with possible rebate incentives from utilities. For ratepayers, this means improved availability, awareness, and possibly better pricing for energy-efficient equipment.

Throughout the course of the project, local foodservice establishments received 18 total efficient plug loads at zero cost, as part of research to characterize plug load savings potential in real-world application. These donated appliances will save their new owners up to $1,290 in annual energy cost, with savings hovering between -6 percent and 69 percent for replacements. Small but promising manufacturers such as Condeco received invaluable third-party research data that they can use as marketing material to validate their efficient technologies and increase market presence. Public entities will also gain a substantial database of new data, which can be used to create new rebate measures or other programs to facilitate energy savings.

Scalable Project Benefits

The energy saving technologies evaluated in this project would benefit greatly from an incentive program to reduce the payback period and increase market adoption. Individual rebates for each appliance would be relatively small, given the lower price of plug load appliances, but would mitigate the cost difference between baseline and efficient appliances to encourage participation.

The energy saving potential found for the various appliance categories was combined with the analysis from the market evaluation to estimate the total plug load energy saving potential in California. This projection includes the theoretical savings that would result from energy saving measures/replacements that could not be directly confirmed by direct appliance replacement during the project. Since these replacements are still developing traction, they were assigned a lower predicted rate of adoption. This energy model projects 51.3 GWh per year in plug load savings, with additional potential available as public awareness grows and perception of these technologies becomes more mainstream (Table 42).

Table 42: Energy Consumption and Savings Opportunity for Various Plug Load Categories

Appliance Type	Estimated Annual Energy Use (TWh/yr)	Energy Savings From Efficient Alternative (%)	Energy Savings Measure Adoption Rate (%)	Energy Saving Potential (GWh/yr)
Toaster (Pop-Up)	0.01	N/A	N/A	N/A
Toaster (Conveyor)	0.20	21.0%	10%	4.1
Strip Heater	0.52	N/A	N/A	N/A
Cooktop	0.05	29.0%	20%	2.8
Rice Cooker	0.02	N/A	N/A	N/A
Soup Warmer	0.03	49.1%	20%	2.8
Coffee Brewer	0.27	55.3%	10%	15.1
Tea Brewer/Hot Water	0.04	50.0%	10%	1.8
Espresso Machine	0.13	68.7%	10%	9.0
Holding Cabinet	0.12	58.5%	10%	7.0
Tortilla Warmer	0.02	N/A	N/A	N/A
Hot Food (Steam) Well	0.35	33.8%	5%	5.9
Sandwich Press	0.11	44.5%	5%	2.4
Waffle Iron	0.06	N/A	N/A	N/A
Microwave	0.04	N/A	N/A	N/A
Countertop Oven	0.03	N/A	N/A	N/A
Miscellaneous (Other)	0.20	2.3%	10%	0.5
Total	2.19			51.3

Source: Frontier Energy, Inc.

CHAPTER 6: Conclusions and Recommendations

Recommendations

The project successfully characterized the energy and operating use of a variety of unhooded commercial plug load appliances, representing a wide range of foodservice applications and use levels. Appliance energy usage varied significantly by site and operation type, with hours of operation and appliance settings playing a key role in the energy usage differences across an appliance category. Based on data from direct appliance replacements or extrapolating from efficient equipment data (if no direct replacements were made), researchers estimated savings potential for nine of the 22 appliance categories. The appliances with the strongest energy saving opportunities were determined to be espresso machines, coffee brewers, conveyor toasters, and holding cabinets.

Researchers found that the energy-efficient appliances generally produced the same or higher-level quality food product, as determined by staff interviews. Besides saving energy, the efficient appliances also increased safety, reduced labor, and sometimes even improved kitchen throughput. Impediments to kitchen productivity/workflow were one of the primary customer concerns around energy-efficient equipment, which this study proved to be nonexistent when the technology is properly applied.

Additional research is recommended to more completely explore the energy saving potential of high opportunity baseline appliances with little or no replacement alternatives, such as heat strips and heated wells. Frontier Energy also recommends a dedicated study on rapid cook ovens, which are becoming popular in an evolving foodservice landscape that is trending toward flexible and compact kitchens. Rapid cook ovens are energy-intensive electric appliances, but their ability to increase throughput and reduce kitchen footprint can create electrical, HVAC, and labor savings when used optimally. Additional research should also be conducted to confirm the payback period for 208V conveyor toasters, which represent a strong energy saving opportunity within only a few months. Induction soup warmers reduced energy consumption by 49 percent, but additional research is advised to quantify the value of induction's reduced product loss, to more accurately determine the potential savings of induction soup warmers. Lastly, a study to investigate the effect of shutoffs on espresso machine lifespan could finally dispel the old preconception that is preventing owners from turning machines off overnight, thereby easily reducing their espresso machine energy consumption by 20 percent.

Suggestions for Policy Makers and Government Agencies

Frontier Energy determined several of the monitored plug load appliance categories to present actionable opportunities for energy savings. Conveyor toaster replacements, which yielded an estimated average energy savings of about $223 per year, are extremely common and would benefit from an early retirement program. Espresso machine replacements, which can be significantly more expensive but generated $540 in annual energy savings, would benefit from education initiatives to help owners learn about the effectiveness of overnight shutoffs. Turning the espresso machine off overnight should reduce energy costs by at least 20 percent, but unfortunately very few owners take advantage of this feature, due partly to an unsubstantiated industry rumor about frequent shutoffs reducing equipment lifespan. Coffee brewer owners would benefit from a similar educational message and many coffee brewers already have energy save modes that could be easily activated.

Holding cabinet replacements all exhibited energy savings of greater than 40 percent, and Frontier suggests implementing an early retirement incentive program for customers who want to replace glass door units with insulated, solid double-door units.

The industry's steady shift toward induction cooktops is indicative of the benefits in not only energy, but safety and labor costs. A utility rebate to reduce the upfront cost of replacement would effectively accelerate the conversion to induction cooktops, though electric infrastructure upgrade costs may still prove to be a barrier for gas to electric conversions.

Induction soup warmers saved 49 percent of the energy used by its conventional resistance element counterpart, but 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. The adoption of induction technology is pivotal to the potential for electrification in CFS, since induction cooktops can match the responsive performance of gas ranges in a way that electric resistance cannot.

LIST OF ACRONYMS

Term	Definition
˚C	Degrees Celsius
˚F	Degrees Fahrenheit
A	Amp
ADM	ADM Associates, Inc.
ASTM	American Society for Testing and Materials
CEC	California Energy Commission
CFS	Commercial foodservice
EPIC	Electric Program Investment Charge
FSR	Full-service restaurant
FSTC	Food Service Technology Center
GWh	Gigawatt-hour
HVAC	Heating, ventilation, and air conditioning
IOU	Investor-owned utility
kW	Kilowatt
kWh	Kilowatt-hour
LLC	Limited liability corporation
MUFES	Multi-Unit Foodservice Equipment Symposium
NAEFM	North American Association of Food Equipment Manufacturers
NRA	National Restaurant Association
NSF	National Science Foundation
NSF	National Science Foundation
PG&E	Pacific Gas and Electric Company
SRVCC	San Ramon Valley Conference Center
TAC	Technical Advisory Committee
TWh	terawatt-hour, a unit of energy equivalent to 10^{12} watt-hours
V	Volt
W	Watt

Term	Definition
WE&T	Workforce Education & Training
Wh	watt-hour, a unit of energy

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APPENDIX A: Participating Sites

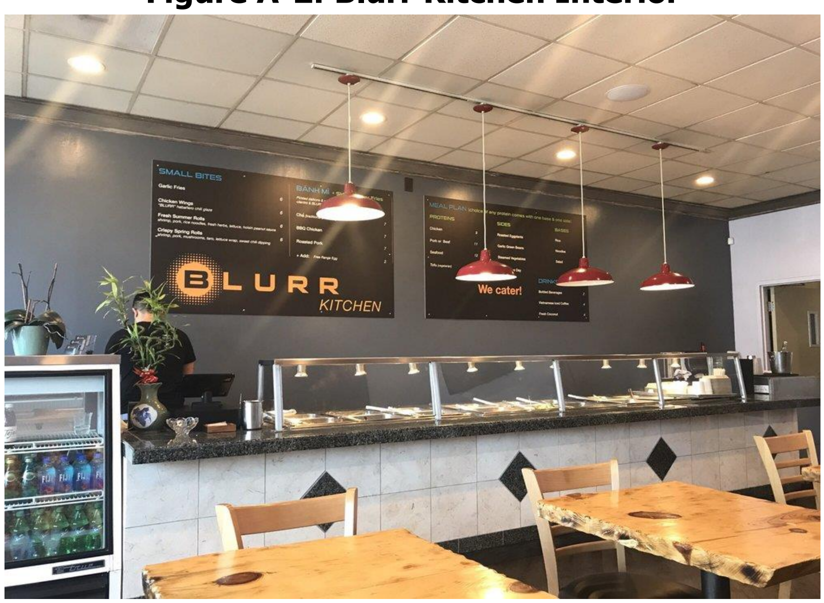
Blurr Kitchen

Blurr Kitchen is quick service restaurant specializing in Vietnamese bahn mi sandwiches and southeast Asian small plates. They are open from 11 AM to 9 PM daily and are located in Santa Clara, in the territory of Silicon Valley Power. Three appliances were monitored at the site, a holding/proofing cabinet and two rice cookers. The holding/proofing cabinet was replaced with a solid door holding cabinet and the energy savings quantified.

Figure A-1: Blurr Kitchen Exterior

Source: Frontier Energy, Inc.

Figure A-2: Blurr Kitchen Interior



Source: Frontier Energy, Inc.

Bridges Restaurant & Bar

Bridges Restaurant & Bar is a 5,000-square-foot, fine-dining restaurant with a 107-seat dining room, 26-seat bar, and 48-seat patio. It is located in Danville, a city in the East Bay of the San Francisco Bay Area with an approximate population of 42,000. The restaurant has been in operation for approximately 25 years and occupies a building that is several years older and has had prior restaurants as tenants. Bridges is open seven days a week, touting an Asian and European-inspired Californian lunch and dinner service that operates for six to eight hours daily, depending on the day. Two appliances were monitored at the site, an espresso machine and a set of heat lamps built into the workstation. No replacements were made at this site.

Figure A-3: Bridges Restaurant & Bar Exterior

Source: Frontier Energy, Inc.

Figure A-4: Dining Room with Bar in the Background

Source: Frontier Energy, Inc.

Café Gabriela

Café Gabriela is a small independent coffee shop that focuses on locally sourced and food and coffee, first established in 2010. It is located in the middle of Oakland's busy downtown district, near several corporate buildings and key public transportation stations. Open on the weekday from 7AM to 5PM, Café Gabriela fuels the local workforce, giving them the energy they need to get through the day. Researchers monitored three appliances at the store: an espresso machine, a rectangular heated well and a conveyor toaster. The baseline espresso machine was replaced with an insulated model featuring a programmable timer system, which researchers monitored to quantify the impact on energy usage.

Figure A-5: Café Gabriela Exterior

Source: Frontier Energy, Inc.

Caffe 817

Caffé 817 is a small neighborhood café and restaurant located in the downtown business district of Oakland, California. Designed to capture a homey and comfortable European vibe, the café features a breakfast and lunch service with a rotating seasonal menu, including daily specials that feature local farmers and ingredients. Caffé 817 is open seven days a week, operating for 10 hours on weekdays and 6.5 hours on weekends. Three appliances were monitored at the site – a cooktop, a conveyor toaster, and a seven-quart soup warmer. All three of these appliances were replaced, with the impact on energy usage monitored and quantified.

Figure A-6: Exterior of Caffé 817

Source: Frontier Energy, Inc.

Chipotle

Chipotle is a large fast-casual chain restaurant specializing in build-your-own Mexican food. The Chipotle location monitored for this study is located in Diablo Plaza, in San Ramon, California. The location is open seven days a week, operating from 10:45 AM to 10:00 PM daily. Four appliances were monitored at the site – a holding cabinet, a heated well, and two tortilla warmers. None of the appliances monitored were replaced or modified.

Figure A-7: Chipotle Front Entrance

Source: Frontier Energy, Inc.

Chromatic Coffee

Chromatic Coffee is a specialty coffee café with a large seating area filled with tables, bar counters, and local art. They are open from 7 AM to 9 PM on the weekdays and 8AM to 9PM on the weekends. Located in south Santa Clara, in the territory of Silicon Valley Power. Three appliances were monitored at the site: a rapid cook oven, an espresso machine and a coffee brewer. None of the appliances monitored were replaced or modified.

Figure A-8: Chromatic Coffee Exterior

Source: Frontier Energy, Inc.

Figure A-9: Chromatic Coffee Interior

Source: Frontier Energy, Inc.

Crossroads Dining Hall at UC Berkeley

Crossroads Dining Hall is the largest and most frequented of UC Berkeley's four dining halls, located just southeast of the UC Berkeley's college campus. It is the first green-certified building at UC Berkeley and features many distinct dining options which rotate as the dining hall operates continuously throughout the day. Crossroads is open seven days a week, from 7 AM to 11 PM from Monday to Thursday, 7 AM to 9 PM on Friday, 10 AM to 9 PM on Saturday, and 10 AM to 11 PM on Sunday. Five appliances were monitored at the site – a panini grill, a conveyor toaster, and three holding cabinets. No replacements were made at this site.

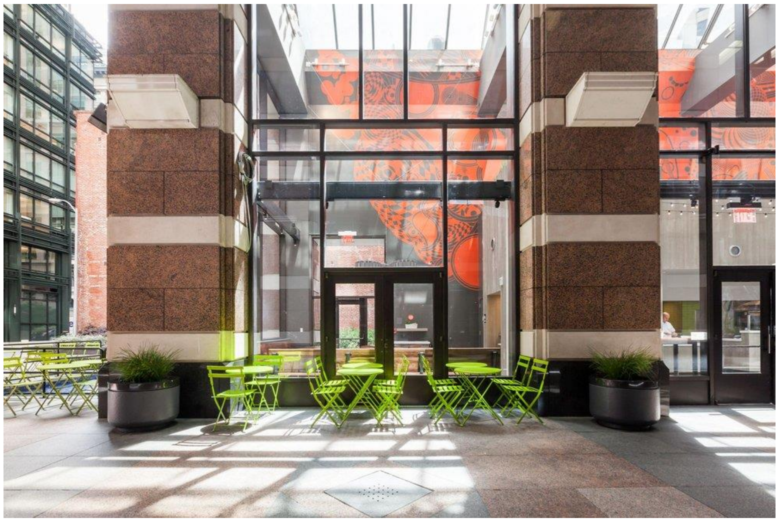
Figure A-10: Exterior of Crossroads Dining Hall

Source: Frontier Energy, Inc.

Dabba

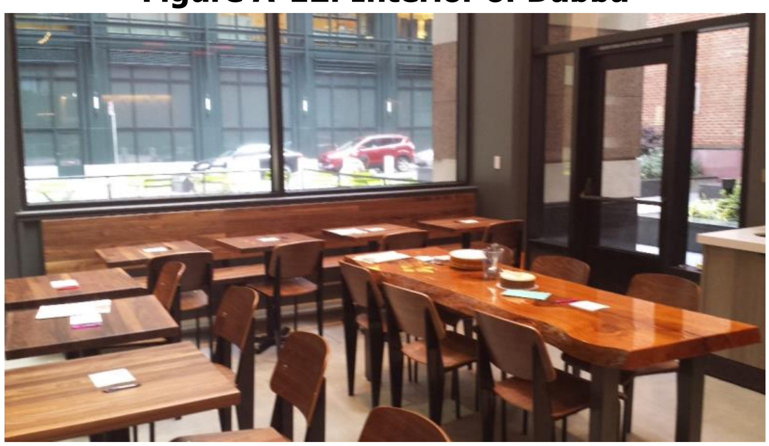
Dabba is the brainchild of acclaimed chef Walter Abrams, a fast-casual restaurant specializing in a unique brand of healthy ethnic fusion food. With humble origins as a food truck, Dabba recently opened this brick and mortar location in downtown San Francisco, near the Montgomery BART station. There, they aim to feed the lunchtime work crowd, serving unique and nourishing combinations every weekday from 7 AM to 3 PM. Two appliances were monitored at the site – the rice cookers and the set of induction warmers. No replacements were made at this site.

Figure A-11: Exterior of Dabba



Source: Frontier Energy, Inc.

Figure A-12: Interior of Dabba



Source: Frontier Energy, Inc.

DoubleTree by Hilton Hotel Pleasanton

DoubleTree Hotel by Hilton is an upscale business-oriented hotel in Pleasanton, California at the doorstep of the Tri-Valley Area. The hotel has a full-service restaurant providing breakfast, lunch, and dinner. Players Restaurant & Lounge is open every day from 6 AM to 11 PM with downstairs dining service as well as room service. With California and Italian specialties, the restaurant serves breakfast items, soups, sandwiches, salads, pizzas, burgers, steaks, seafood, and other dinner entrées. The hotel also caters several events throughout the year including business parties and weddings. A single appliance was monitored at the site, the heat lamps that kept food fresh off the cookline warm while it waited to be served. No replacements were made at this site.

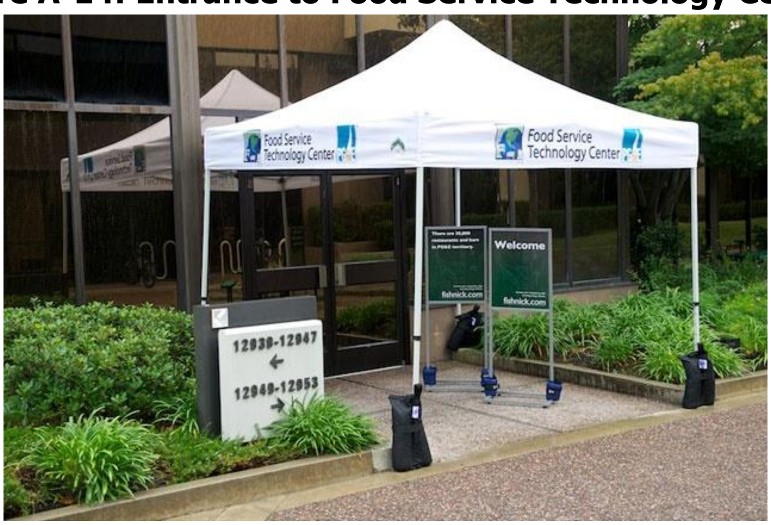
Figure A-13: Exterior of Doubletree Hotel by Hilton

Source: Frontier Energy, Inc.

Food Service Technology Center

The Food Service Technology Center is a testing facility located in San Ramon, California specializing in energy efficiency research in the foodservice industry. The facility is run by approximately 25 members of Frontier Energy and is filled with a myriad of foodservice equipment for testing and demonstration purposes. Typical work hours range anywhere from 7 AM to 6 PM with staff arriving and leaving at slightly different times. Two appliances were monitored at this site – a coffee brewer and an espresso machine. The coffee brewer was outfitted with an external timer and the impact on energy use was characterized.

Figure A-14: Entrance to Food Service Technology Center



Source: Frontier Energy, Inc.

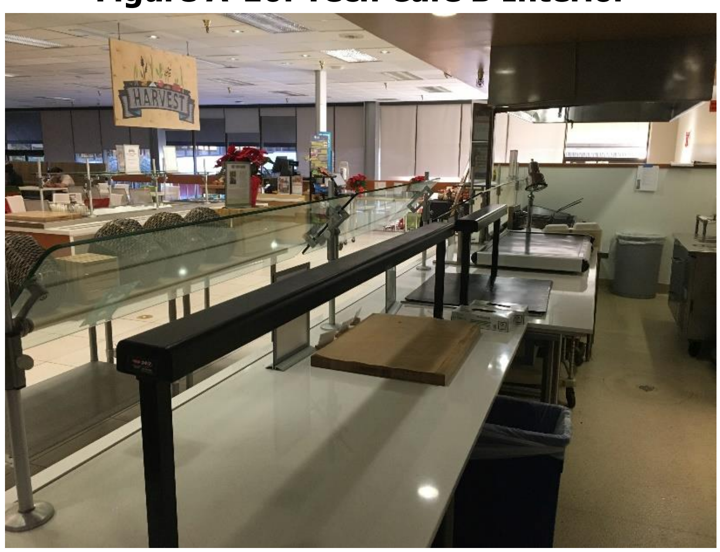
Tech Company

Frontier monitored two cafeterias at the Tech Company: Café A and Café B. These cafeterias serve a full campus of office buildings serving an average of 5,500 meals per day. Both cafés operate only for breakfast and lunch five days a week, with a wide array of cuisines and a menu varying in styles throughout the week. Frontier monitored a total of more than ten appliances at these two sites, including holding cabinets, conveyor toasters, heated shelves, panini grills and rapid cook ovens. Three appliances were replaced at this site: a conveyor toaster, a holding cabinet, and a cook and hold.

Figure A-15: Tech Café A Interior

Source: Frontier Energy, Inc.

Figure A-16: Tech Café B Interior



Source: Frontier Energy, Inc.

Kettle'e

Kettle'e 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. Three appliances were monitored at the site, a countertop oven, a panini press and a rectangular heated well. However, no replacements were made due to lack of suitable technologies.

Figure A-17: Kettle'e Interior

Source: Frontier Energy, Inc.

Lin Jia Asian Kitchen

Located in a residential neighborhood of Oakland, California near Lake Merritt, Lin Jia is an Asian fusion restaurant that focuses primarily on Chinese food. With a semi-open kitchen that displays the wok work of the chefs, Lin Jia positions itself as a mid-priced sit-down restaurant serving a mixture of fusion and traditional dishes. Lin Jia is open seven days a week, operating from 11:30 AM to 9:30 PM daily. Researchers monitored two rice cookers at the Lin Jia site. No replacements were made at this site.

Figure A-18: Exterior of Lin Jia Asian Kitchen

Source: Frontier Energy, Inc.

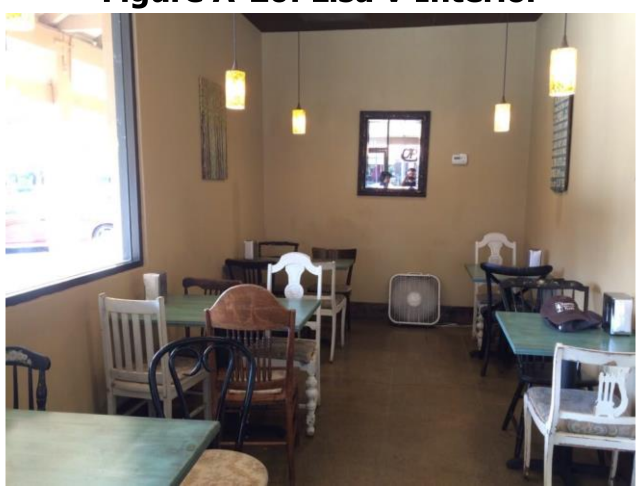
Lisa V

Lisa V is a local restaurant specializing in hot dogs and Mexican food, located in Concord, CA. Lisa V is open seven days a week, varying between five and nine hours of operation, depending on the day. Two tortilla warmers were monitored at the site, but no appropriate technologies were available to make an energy saving replacement.

Figure A-19: Lisa V Exterior

Source: Frontier Energy, Inc.

Figure A-20: Lisa V Interior



Source: Frontier Energy, Inc.

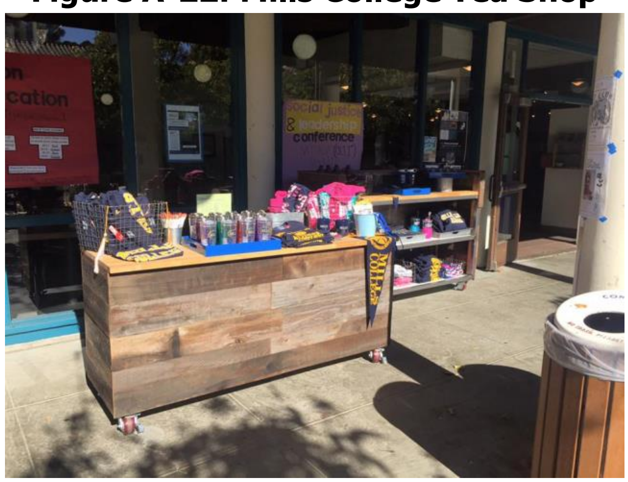
Mills College

Two locations were monitored at Mills College – the Founders Commons dining hall and the Tea Shop café. Mills College focuses on delicious and environmentally sustainable food, featuring seasonal ingredients from local farms including its very own Mills Community Farm. Both locations offer healthy and hearty options for a variety of diets, but Founders Commons serves buffet-style meals whereas Tea Shop offers café-style dining. Founders Commons is open seven days a week for breakfast, lunch, and dinner service on weekdays and brunch and dinner service on weekends. Researchers monitored three appliances at this site – a conveyor toaster and two soup wells. Tea Shop is open from 7 AM to 10 PM from Monday to Thursday, 7 AM to 5 PM on Friday, and 12 PM to 7 PM on Sunday. Five appliances were monitored at this site – a coffee brewer, a tea brewer, a 3-ft. heat lamp, an espresso machine, and a soup well. Frontier replaced the conveyor toaster and 11-qt soup warmer and characterized the impact on energy use.

Figure A-21: Mills College Founders Commons Dining Hall

Source: Frontier Energy, Inc.

Figure A-22: Mills College Tea Shop



Source: Frontier Energy, Inc.

Mission City Grill

Mission City Grill is a medium-sized full-service restaurant and bar specializing in American diner fare. They are located in Santa Clara, in the territory of Silicon Valley Power and are typically open from 7 AM to 9 PM daily, serving breakfast, lunch, and dinner. Three appliances were monitored at the site, conveyor toaster, a waffle iron and a rectangular heated well. Unfortunately, no replacements could be made at the site.

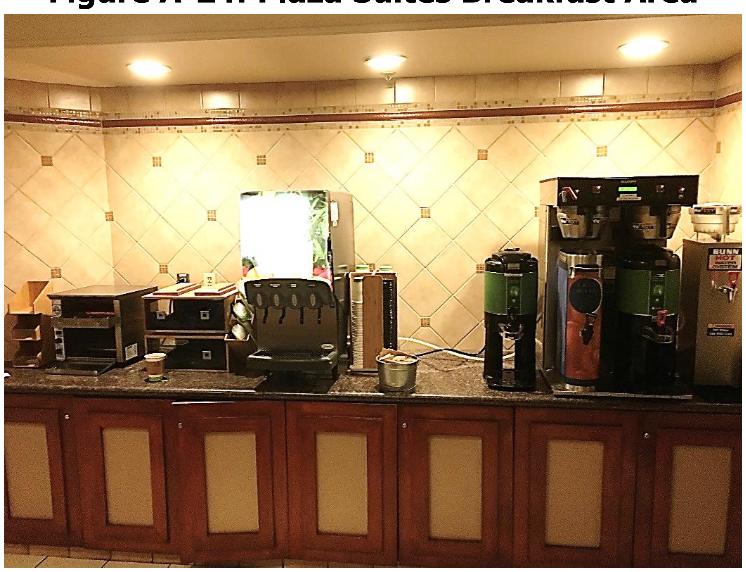
Figure A-23: Mission City Grill Exterior

Source: Frontier Energy, Inc.

Plaza Suites

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, including the holding cabinet, the conveyer toaster and the waffle iron. Frontier replaced the baseline holding cabinet with a new insulated double compartment unit and monitored the energy savings from the replacement.

Figure A-24: Plaza Suites Breakfast Area



Source: Frontier Energy, Inc.

Rebecca Delight Café

Rebecca Delight Café is a small family owned café located in the Sunset Business Park, serving the breakfast and lunch crowd from the nearby businesses. The café offers a variety of drinks, bagels, soups, salads, and sandwiches, focusing on simple and healthy menu options. The café often also offers a daily special, which is usually a Chinese dish unlike anything else on the menu. Rebecca’s is open only during the weekdays, from 8 AM to 3 PM every day except Friday, where it closes an hour earlier at 2 PM. Three appliances were monitored at this site – a coffee brewer, a conveyor toaster, and a rectangular 12″x20″ wet well warmer. Frontier activated the coffee brewer’s built-in energy saving mode programming and characterized the impact it had on energy use.

Figure A-25: Sign into Rebecca Delight Café

Source: Frontier Energy, Inc.

San Ramon Valley Conference Center (SRVCC)

Operated by the Pacific Gas and Electric Company (PG&E), the San Ramon Conference Center is a sprawling facility that hosts business meetings, seminars, retreats, and social events. Offering dining, housing, and a wide variety of meeting/speaking room options, the SRVCC has large influxes of guests, depending on the events being held at the center. Additionally, there is a steady stream of nearby PG&E workers who consistently use the dining facilities. Dining options include the main dining café, along with a taqueria, which only operates at lunch. The dining café, however, offers breakfast, lunch, and dinner services every weekday except Friday, when dinner is not available. Two appliances were monitored at this site – a hot food holding cabinet at the dining café and a tortilla warmer at the taqueria. No replacements were made at this site.

Figure A-26: Exterior of SRVCC

Source: Frontier Energy, Inc.

SaltCraft

Saltcraft is a full-service restaurant that focused on well-crafted farm to table cuisine and a mantra of conscious sustainability, open every day for an average of about ten hours per day. A fairly new restaurant located in Pleasanton, their cookline features the newest and most efficient equipment, delivering a large impact with a small kitchen footprint. Frontier monitored two induction cooktops at the site, to quantify the energy use of these efficient appliances. No appliance replacements could be made at the restaurant, since they were already using the most efficient equipment currently available.

Figure A-27: SaltCraft Exterior

Source: Frontier Energy, Inc.

Figure A-28: SaltCraft Open Kitchen Interior

Source: Frontier Energy, Inc.

Sideboard Danville

Sideboard is a neighborhood kitchen and coffee bar, located in the downtown Danville area. Specializing in innovative, but rustic comfort food, Sideboard positions itself as a cross between hip and homey, creating a comfortable social atmosphere while featuring a wide spread of drink and dining options. Sideboard Danville is open seven days a week, from 8 AM to 9 PM from Tuesday to Saturday and from 8 AM to 8 PM on Sunday and Monday. A single appliance was monitored at this site – a 12″x20″ rectangular wet well warmer. No replacements were made at this site.

Figure A-29: Exterior of Sideboard Danville

Source: Frontier Energy, Inc.

Spreadz

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. Researchers monitored four baseline appliances at this site: two 7-qt soup warmers, one 11-qt soup warmer and one conveyor toaster. Frontier installed one replacement for each appliance type and quantified the resulting energy savings.

Figure A-30: Spreadz Exterior

Source: Frontier Energy, Inc.

Figure A-31: Spreadz Service Counter

Source: Frontier Energy, Inc.

Togo's Sandwiches

Togo's is a large quick service sandwich franchise with many stores across the nation. Frontier researchers monitored equipment at several store locations, which were typically open for about ten hours on weekdays and about 5 hours on weekends. Since they do both delivery and to-order items, they typically serve a high number of meals per day. A number of appliances were monitored at the different sites, including panini grills, soup warmers, microwaves and heated wells. Researchers also monitored a rapid cook oven that was used to replace a panini grill and quantified the energy impact of the replacement.

Figure A-32: Togo's Exterior

Source: Frontier Energy, Inc.

Figure A-33: Togo's Interior

Source: Frontier Energy, Inc.

Voyager Craft Coffee

Voyager Craft Coffee is a popular café 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. Two appliances were monitored at the site, an espresso machine and a conveyor toaster. The baseline toaster was replaced with a toaster with a smart sensor-activated energy saving mode, and the resulting energy savings were quantified.

Figure A-34: Voyager Craft Coffee Exterior

Source: Frontier Energy, Inc.

APPENDIX B: Appliance Direct Replacement Data

Listed in the table below is the data for each of the appliance replacements completed during the project. The data is characterized by energy savings, dollar savings and payback period. The savings metrics for each replacement can differ significantly within each appliance type, depending on the application of the appliance and the energy efficient technology.

Table B-1: Replacement Appliance Summary

Appliance Type	Site	Energy Percent Savings (%)	Energy Cost Savings ($)	Payback Period (years)
Coffee Brewer	FSTC	41.3	$56.16	1.0
Coffee Brewer	Rebecca's	69.4	$55.10	0 (instant)
Conveyor Toaster	Café/Bakery	45.6	$1,290.60	0.2
Conveyor Toaster	Caffé 817	13.2	$123.18	3.7
Conveyor Toaster	Voyager Craft Coffee	9.7	$98.43	6.1
Conveyor Toaster	Spreadz	10.8	$50.58	0 (instant)
Conveyor Toaster	Tech Company	18.8	$79.91	0 (instant)
Conveyor Toaster	Mills College	14.7	$83.23	5.4
Cook and Hold	Tech Company	-6.4	-$18.58	0 (loss)
Cooktop	Caffé 817	29.0	$163.62	10.4
Espresso Machine	Café Gabriela	68.7	$539.28	0 (instant)
Holding Cabinet	Plaza Suites	70.0	$144.70	0 (instant)
Holding Cabinet	Blurr Kitchen	61.6	$418.88	10.0
Holding Cabinet	Tech Company	43.9	$114.75	12.6
Soup Well	Caffé 817	22.1	$ 6.82	65.7
Soup Well	Mills College	63.2	$ 50.46	7.8
Soup Well	Spreadz	69.4	$49.95	11.9
Soup Well	Spreads	41.6	$15.49	37.5

Source: Frontier Energy, Inc.

APPENDIX C: Detailed Plug Load Equipment Data

Listed in the table below are the comprehensive data characterizing the equipment usage of the 128 plug load foodservice appliances monitored throughout the study, spread across twenty-nine different commercial kitchens in Northern California. The data spans twenty-two different appliance type and represents both baseline and advanced technology equipment.

Table C-1: Plug Load Total Data Summary

Appliance Type	Baseline: Units Monitored	Baseline: Total Average Daily Energy Usage (kWh/day)	Baseline: Normalized Input Rate (kW)	Efficient: Units Monitored	Efficient: Total Average Daily Energy Usage (kWh/day)	Efficient: Normalized Input Rate (kW)	Average Percent Difference (%)	Direct Replacement Savings (%)	Average Annual Savings ($/unit)
Coffee Brewer	7	9.1	0.71	2	1.0	0.18	75.0	55.3	272
Conveyor Toaster	10	19.6	2.08	6	14.0	1.59	20.8	21.0	223
Cook and Hold	1	5.0	0.94	1	5.7	1.00	-6.5	-6.4	-17
Cooktop	1	18.2	2.17	4	3.8	0.76	65.2	29.0	286
Counterto p Oven	1	4.8	0.43	N/A	N/A	N/A	N/A	N/A	N/A
Espresso Machine	6	13.1	0.98	2	4.5	0.45	53.9	68.7	467
Heat Lamp	1	1.4	0.24	N/A	N/A	N/A	N/A	N/A	N/A
Heat Strip	2	13.5	0.98	1	0.9	0.16	81.4	N/A	5941
Heated Shelf	5	2.8	0.43	N/A	N/A	N/A	N/A	N/A	N/A
Heated Well	8	5.1	0.72	1	5.2	0.48	33.8	N/A	941

Appliance Type	Baseline: Units Monitored	Baseline: Total Average Daily Energy Usage (kWh/day)	Baseline: Normalized Input Rate (kW)	Efficient: Units Monitored	Efficient: Total Average Daily Energy Usage (kWh/day)	Efficient: Normalized Input Rate (kW)	Average Percent Difference (%)	Direct Replacement Savings (%)	Average Annual Savings ($/unit)
Holding Cabinet	9	8.1	1.15	3	2.9	0.42	63.7	58.5	258
Microwave	2	3.6	0.86	N/A	N/A	N/A	N/A	N/A	N/A
Panini Press	7	7.7	1.07	4	6.2	0.59	44.5	N/A	1851
Popup Toaster	1	0.6	0.5	N/A	N/A	N/A	N/A	N/A	N/A
Rapid Cook Oven	N/A	N/A	N/A	5	20.3	1.44	N/A	N/A	N/A
Rice Cooker	7	1.7	0.61	N/A	N/A	N/A	N/A	N/A	N/A
Soda Dispenser	1	1.0	0.09	N/A	N/A	N/A	N/A	N/A	N/A
Soup Well	7	0.8	0.16	9	0.6	0.11	32.9	49.1	21
Tea Brewer	3	1.9	0.14	N/A	N/A	N/A	N/A	N/A	N/A
Tortilla Warmer	4	6.3	0.67	N/A	N/A	N/A	N/A	N/A	N/A
Waffle Iron	2	8.7	0.90	N/A	N/A	N/A	N/A	N/A	N/A

1: Savings not from direct replacement but extrapolated from the comparison of normalized average energy rates for baseline and replacement equipment monitored.

Source: Frontier Energy, Inc.

Table C-2: Energy Data for All Monitored Appliances

Site	Equipment Type	Baseline or Replacement?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)
FSTC	Coffee Brewer	Energy Save Mode	1.5	10.0	0.15
Mills	Coffee Brewer	Baseline	8.8	12.0	0.73
Panera	Coffee Brewer	Baseline	18.1	18.0	1.01
Rebecca's	Coffee Brewer	Baseline	1.5	6.0	0.25
Rebecca's	Coffee Brewer	Setback	0.5	6.0	0.08
FSTC	Coffee Brewer (Curtis)	Baseline	2.5	10.0	0.25
FSTC	Coffee Brewer (Super Automatic)	Baseline	1.2	10.0	0.12
Panera	Coffee Brewer	Baseline	19.5	18.0	1.08
Chromatic Coffee	Coffee Brewer	Baseline	11.9	15.0	0.79
Caffe 817	Conveyor Toaster	Baseline	15.5	8.8	1.77
Mills	Conveyor Toaster	Baseline	10.7	11.5	0.93
Rebecca's	Conveyor Toaster	Baseline	10.7	6.0	1.83
Panera	Conveyor Toaster	Baseline	52.4	18.0	2.91
Voyager Craft Coffee	Conveyor Toaster	Baseline	18.4	11.2	1.64
Spreadz	Conveyor Toaster	Baseline	8.2	5.2	1.56
Mission City Grill	Conveyor Toaster	Baseline	46.0	14.5	3.17
Intel RNB	Conveyor Toaster	Baseline	8.0	5.0	1.59

Site	Equipment Type	Baseline or Replacement?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)
Plaza Suites	Conveyor Toaster	Baseline	14.4	11.3	1.28
Café Gabriela	Conveyor Toaster	Baseline	11.3	6.5	1.73
Panera	Conveyor Toaster	Replacement	28.5	18.0	1.58
Caffe 817	Conveyor Toaster	Replacement	15.0	9.8	1.53
Voyager Craft Coffee	Conveyor Toaster	Replacement	17.0	11.5	1.48
Spreadz	Conveyor Toaster	Replacement	7.8	5.6	1.39
Spreadz	Conveyor Toaster	Replacement (change)	6.4	5.1	1.27
Intel RNB	Conveyor Toaster	Replacement	9.0	6.6	1.36
Mills	Conveyor Toaster	Replacement	8.1	11.5	0.71
Intel SC2	Cook and Hold	Baseline	5.0	5.3	0.94
Intel SC2	Cook and Hold	Replacement	5.7	5.7	1.00
Caffe 817	Cooktop	Baseline	18.2	8.4	2.17
Caffe 817	Cooktop	Replacement	7.4	4.8	1.54
Intel SC2	Cooktop	Replacement	3.0	6.1	0.50
SaltCraft	Cooktop	Replacement	1.7	3.8	0.46
SaltCraft	Cooktop	Replacement	2.9	4.8	0.60
Kettle’e	Countertop Oven	Baseline	4.8	11.2	0.43
Mills	Espresso Machine	Baseline	7.9	12.0	0.66
Panera	Espresso Machine	Baseline	4.4	18.0	0.24
Bridges	Espresso Machine	Baseline	12.1	11.6	1.05
Voyager Craft Coffee	Espresso Machine	Baseline	19.4	13.0	1.49

Site	Equipment Type	Baseline or Replacement?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)
Chromatic Coffee	Espresso Machine	Baseline	20.6	15.0	1.37
Café Gabriela	Espresso Machine	Baseline	14.3	11.0	1.30
Café Gabriela	Espresso Machine	Replacement	4.7	10.0	0.45
Intel SC2	Heat Lamp	Baseline	1.4	5.6	0.24
Doubletree	Heat Strip	Baseline	20.4	24.0	0.85
Mills	Heat Strip	Baseline	6.5	8.6	0.76
Intel SC2	Heat Strip	Replacement	0.9	5.5	0.16
Panera	Heated Shelf	Baseline	4.2	18.0	0.23
Intel RNB	Heated Shelf	Baseline	1.8	3.7	0.49
Intel RNB	Heated Shelf	Baseline	3.0	5.5	0.55
Intel SC2	Heated Shelf	Baseline	2.9	4.9	0.60
Intel RNB	Heated Shelf	Baseline	2.2	4.5	0.49
Sideboard	Heated Well	Baseline	5.0	8.6	0.59
Togo’s North Livermore	Heated Well	Baseline	6.9	8.1	0.86
Togo’s North Livermore	Heated Well	Baseline	6.2	11.2	0.56
Rebecca's	Heated Well	Baseline	2.4	4.0	0.60
Togo’s	Heated Well	Baseline	7.9	7.7	1.03
Mission City Grill	Heated Well	Baseline	9.6	9.9	0.97
Kettle’e	Heated Well	Baseline	2.9	4.0	0.72
Café Gabriela	Heated Well	Baseline	2.4	5.5	0.44
Claremont Hotel	Heated Well	Replacement	5.2	10.9	0.48
SRVCC	Holding Cabinet	Baseline	9.6	6.5	1.47
UC Berkeley	Holding Cabinet	Baseline	12.6	12.9	0.98
UC Berkeley	Holding Cabinet	Baseline	13.1	10.9	1.21

Site	Equipment Type	Baseline or Replacement?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)
UC Berkeley	Holding Cabinet	Baseline	5.9	5.7	1.04
Intel RNB	Holding Cabinet	Baseline	5.9	4.5	1.32
Intel RNB	Holding Cabinet	Baseline	6.9	5.3	1.30
Intel RNB	Holding Cabinet	Baseline	4.3	4.7	0.92
Plaza Suites	Holding Cabinet	Baseline	3.9	3.8	1.02
Blurr Kitchen	Holding Cabinet	Baseline	11.0	11.0	1.01
Plaza Suites	Holding Cabinet	Replacement	1.2	3.8	0.31
Blurr Kitchen	Holding Cabinet	Replacement	4.8	12.5	0.39
Intel RNB	Holding Cabinet	Replacement	2.7	5.3	0.52
Chipotle	Hotbox	Baseline	9.6	8.4	1.14
Togo’s	Microwave	Replacement	4.3	8.0	0.54
JIB	Microwave	Baseline	5.7	6.6	0.87
JIB	Microwave	Baseline	1.4	1.7	0.82
UC Berkeley	Panini Grill	Baseline	5.3	4.1	1.31
Togo’s North Livermore	Panini Grill	Baseline	13.9	11.6	1.19
Togo’s Livermore	Panini Grill	Baseline	15.1	12.5	1.21
Togo’s Santa Clara	Panini Grill	Baseline	10.4	8.9	1.17
Intel RNB	Panini Grill	Baseline	0.8	2.4	0.34
Intel RNB	Panini Grill	Replacement	0.9	2.5	0.35
Intel RNB	Panini Grill	Replacement	2.0	2.7	0.74
Intel SC2	Panini Grill	Baseline	1.2	1.6	0.80
Kettle’e	Panini Grill	Baseline	6.9	8.2	0.85
Intel RNB	Pop-up Toaster	Baseline	0.6	1.3	0.47

Site	Equipment Type	Baseline or Replacement?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)
JIB	Rapid Cook Oven	Replacement	27.5	23.5	1.17
JIB	Rapid Cook Oven	Replacement	22.6	24.0	0.94
Togo’s	Rapid Cook Oven	Replacement	12.8	6.2	2.07
Intel SC2	Rapid Cook Oven	Replacement	17.2	6.3	2.74
Chromatic Coffee	Rapid Cook Oven	Replacement	21.3	13.1	1.63
Panera	Rethermalizer	Baseline	64.0	18.0	3.56
Panera	Rethermalizer	Added Lid	57.0	18.0	3.17
Lin Jia	Rice Cooker (Tiger)	Baseline	1.5	8.9	0.17
Lin Jia	Rice Cooker (Zojirushi)	Baseline	2.2	6.0	0.36
Dabba	Rice Cooker	Baseline	1.6	2.8	0.60
Dabba	Rice Cooker	Baseline	1.2	1.9	0.63
UC Berkeley	Rice Cooker	Baseline	1.4	7.2	0.19
Blurr Kitchen	Rice Cooker	Baseline	1.8	9.5	0.19
Blurr Kitchen	Rice Cooker	Baseline	1.9	10.3	0.18
Panera	Sandwich Toaster	Baseline	12.1	18.0	0.67
Panera	Sandwich Toaster	Baseline	9.6	18.0	0.53
Togo’s 1st Street	Soda Dispenser	Baseline	1.0	11.0	0.09
Caffe 817	Soup Well	Baseline	0.9	7.7	0.12
Mills	Soup Well	Baseline	0.9	12.0	0.08
Mills	Soup Well	Baseline	0.6	8.0	0.08
Mills	Soup Well	Baseline	1.5	8.0	0.19
Panera	Soup Well	Baseline	40.9	18.0	2.27
Spreadz	Soup Well	Baseline	0.7	1.7	0.41
Spreadz	Soup Well	Baseline	0.5	2.0	0.26
Spreadz	Soup Well	Baseline	0.4	1.9	0.22
Dabba	Soup Well	Replacement	0.3	4.6	0.06

Site	Equipment Type	Baseline or Replacement?	Total Average Daily Energy Usage (kWh/day)	Total Average Daily Hours of Operation (h/day)	Normalized Energy Usage Rate (kW)
Dabba	Soup Well	Replacement	0.3	5.3	0.06
Dabba	Soup Well	Replacement	0.3	4.1	0.07
Dabba	Soup Well	Replacement	0.2	4.1	0.06
Caffe 817	Soup Well	Replacement	0.4	4.9	0.09
Mills	Soup Well	Replacement	0.5	7.9	0.07
Togo's North Livermore	Soup Well	Replacement	2.3	9.0	0.25
Spreadz	Soup Well	Replacement	0.4	3.2	0.13
Spreadz	Soup Well	Replacement	0.4	2.7	0.15
Mills	Tea Brewer	Baseline	1.6	12.0	0.13
Panera	Tea Brewer	Baseline	1.9	18.0	0.11
Togo's 1st Street	Tea Brewer	Baseline	2.2	11.0	0.20
Lisa V	Tortilla Warmer	Baseline	3.0	7.7	0.40
Lisa V	Tortilla Warmer	Baseline	7.5	9.5	0.79
SRVCC	Tortilla Warmer	Baseline	2.0	2.9	0.66
Chipotle	Tortilla Warmer (Right)	Baseline	8.8	13.3	0.66
Chipotle	Tortilla Warmer (Left)	Baseline	7.1	11.7	0.61
Mission City Grill	Waffle Iron	Baseline	13.9	14.9	0.93
Plaza Suites	Waffle Iron	Baseline	3.6	4.5	0.79

Source: Frontier Energy, Inc.

APPENDIX D:
Appliance Laboratory Analysis - Induction

Introduction

Induction, defined as the production of an electromotive force across an electrical conductor in a changing magnetic field, is a highly efficient method of transferring energy to electrical components like motors, generators, and other media like cookware. In the case of the later, a metal pan or pot becomes the actual heat source once placed in an induction appliance's electromagnetic field. The result is a highly energy efficient appliance when compared to those using conventional heating methods like resistive elements or natural gas flames. These traditional methods rely on conduction, convection and radiation which are inherently less effective at transferring energy to the cookware and ultimately the food being cooked.

First introduced to the American public in middle of the 20th century as a home appliance curiosity, and later in the 1970s for wider general consumption, induction cooktops did not gain any significant consumer uptake due to cost, durability and poor performance. Fortunately, European and Asian manufactures continued to develop induction cooking appliances for their respective residential markets as these homeowners faced energy, space and safety considerations that their American counterparts did not. While induction appliances, mainly small, low power countertop hobs kept a toehold in American commercial kitchens and buffet lines, it is in the most recent decade that a wider range of more powerful and versatile induction cooking and warming appliances have proliferated in these kitchens.

Today, commercial foodservice equipment manufacturers offer high power induction cooktops, as well induction griddles, Chinese woks, soup warmers, rethermalizers and buffet line hot food wells. Nowhere has the power increase in induction cooking appliances been more pronounced than in the cooktop category. To successfully compete with the traditional and entrenched natural gas-powered open burners, manufacturers have developed high power 208 volt/30-amp cooktops. These appliances produce 2.5 kW to 5 kW of power, making them comparable to a 20 kBtu/h to 30kBtu/h natural gas open burner. With regards to the physical cooking surface workspace, multiple 2 and 4 hob induction units can be grouped together to provide equivalent production capacity to the typical natural gas 6 burner open burner ranges.

Figure D-1: Commercial Cooktop Appliances (left to right): Electric Resistance, Natural Gas and Electric Induction

Source: Frontier Energy, Inc.

Induction Market Adoption

Induction and Foodservice Perceptions/Barriers

A common opinion in the foodservice industry is that all electric cooktops are inferior to gas cooktops regarding performance and ease of use. This is generally true when comparing a gas cooktop to an electric resistance element cooktop. Electric resistance cooktops are slow to heat up, cool down, and modulate temperatures for precision cooking. Induction does not share these challenges - the cool down time and temperature modulation capabilities are similar to that of traditional gas cooktops and the heat up time can be considerably faster. However, outdated perspectives on electric cooktops caused by the weak performance of electric resistance units still hinder the perception and adoption of induction cooktops.

Boil & Simmer Test in Real Life

Why is it so hard for chefs and cooks to adopt something that would allow them to cook in a faster and sometimes more precise manner? One reason for this is visual feedback. We can separate most cooktop cooking into two categories, production and execution. Production is the preparation of food products and execution is the finishing portion. If a customer were to order soup at a restaurant, it is a reasonable expectation that the soup would be served within minutes. However, soup often takes much longer to make than a few minutes. Cooks prepare and hold key components of the recipe ahead of time, combining and reheating as needed to deliver the soup in a "reasonable" amount of time.

During the production process, cooks use gas flame size to visually gauge a desired temperature setpoint. This requires adjusting and readjusting the flame as the volume in the pot decreases from evaporation. From an execution perspective, this flame allows cooks to adjust quickly; in time this develops into muscle memory. If the flame visualization is removed from the cooktop, the cooks lose their reference point.

Induction employs a set of different reference points, one being the ability to cook by temperature. From a production standpoint, cooks can choose a desired set point temperature - this is particularly useful when the process requires a constant temperature. When performing this same process with a gas cooktop, constant monitoring is required since volume decreases as water evaporates, meaning cooks need to lower energy to maintain the desired temperature. Induction cooktops have sensors to maintain this temperature automatically, requiring much less effort from cooks.

During execution, the knob position replaces the flame feedback. Cooks often need to compensate for the slow pan preheat time associated with gas cooktops by turning the burner to 100% or near 100% ability to achieve timely preheat. Induction has much more stable temperature control and faster preheat times. This equates to less heat energy needed to achieve preheat and consistent preheat temperatures, with a knob position that can be easily memorized.

Most induction cooktop manufacturers offer different control options. The less expensive controls mimic a gas input rate knob where the power to the HOB correlates to the position on the dial. More sophisticated controls are digital with button incremental temperature adjustment or additional analogue knobs or sliders for quick adjustment. Digital controls often have distinct visualization for the chef that indicate the level of power delivered to the HOB.

Figure D-2: Induction Cooktop Controls

Digital Slider Controls | **Digital Knob Controls** | **Digital Touch Controls** | **Manual Controls**

Source: Frontier Energy, Inc.

Induction Cooktop Pros

Often the menu design and offerings require taking the kitchen's output abilities into account; modular design associated with countertop induction units allows the cook line configuration to be changed as needed to meet business demands. Less radiant heat from an induction cooktop compared to gas or resistance heating results in less heat load to space, thereby saving on HVAC costs as well as creating a more comfortable work environment. Cooler surfaces of induction also decrease the potential for personal injury associated with burns. Faster preheat and cook times create potential for higher revenue potential. Increase in efficiency and decreased cook time may result in the need for less equipment to achieve the same capacity. Certain precision processes like melting chocolate or butter can be done more accurately by setting the temperature of the pan with certain induction cooktops. Cleanability is an advantage of induction cooktops, where a flat surface can be easily wiped down, whereas gas cooktops have more crevices where food can get stuck.

Induction Cooktop Cons

Challenges to adopting induction are the cost of the units being considerably higher than their gas and resistance element counterparts. Installation can also prove to be costly as a retrofit into existing kitchens, as electrical panel and wiring upgrades would be required to support the added electrical load. To achieve maximum effectiveness, induction ready pans are required. This would exclude most aluminum pans on the market, though a few induction manufacturers are stating the ability to use aluminum pans. While the purchase cost of heavier duty induction pans can be considerably more than that of aluminum however, the total lifetime cost is lower since the induction pans last much longer than standard aluminum pans before needing replacement.

The foodservice industry has been slow to adopt induction and other technologies designed to increase speed of service, reduce labor loads, and achieve effective energy use. Gas cooktops due to their simple and robust design have the potential to last much longer than induction tops. Induction hobs have an effective life which often requires for budgeted replacement, but the faster cook times can translate to higher throughput and thus higher revenue potential. The idea is that this will result in a profitable return on investment, but the industry is still uncertain of such claims.

Observations

More power is not always better - higher powered units at the 5kW level seem to be ideal for production, where pot boil volume is higher, or in high heat processes such as wok style cooking. For western style sauté cooking, hobs ranging from 2.5-3.5kW seem to be ideal for most operations. One challenge with higher powered units is that, on a power scale from 1-10, the jump from 2-3 can be much more drastic than that of mid-powered units. Simmering and sautéing once the pot or pan is up to temperature is done at the lower power levels that are 10-30% of the maximum output. Lower input units have more precise power modulation at these lower input rates, giving controllability comparable to the infinitely adjustable manual gas valve.

Appliance Performance Characterization

Frontier Energy conducted a series of controlled laboratory tests to better characterize the operation and energy use of different induction cooktops. The American Standard Test Method for Performance of Range Tops (ASTM F1521) determines the appliance energy efficiency and production capacity with a water "boil" test. Through the application of this test method, natural gas or electrical energy consumption can be accurately measured and applied to operating energy use and cost models. Further, this performance data can help equipment specifiers better match an appliance's production capabilities with the output needs of the operation itself. Outside of the standard test method, a partial energy consumption load test, or "simmer" test helps to further characterize the appliance's ability to maintain a desired food product temperature integrated controls are employed to reduce the energy input of the appliance. Lastly, a fry pan, solid food product or "sauté" test is used to determine the energy use and production capacity of an appliance when cooking a solid food product like hamburger patties.

Maximum Energy Load/Efficiency Test - Boiling

The cooking energy efficiency test consists of bringing a pot filled with 20 lbs of room temperature water to a near boil temperature of 200°F (93°C) while the appliance is set to its maximum control input. This "boil" test precisely measures the amount of energy the appliance consumes as it heats the contents of the pot.

Application of the water boil test at the Frontier Energy Food Service Technology Center (FSTC) on natural gas open burners, resistive electric element cooktops, and induction cooktops has resulted in a comprehensive characterization of the three-heating method's respective energy efficiency performance. Natural gas, resistive electric, and electric induction exhibited ranges of efficiencies between 25% and 40%, 65% and 75%, and 80% to 85%, respectively. Table D-1 summarizes the water boil performance of several induction cooktops tested at the FSTC.

Table D-1: Water Boil Test Results for Popular Commercial Induction Cooktops

	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H
Voltage	120V	120V	120V	208V	208V	208V	208V	208V
Power Per HOB	1.8kW	1.4kW	1.8kW	2.5 kW	3.5 kW	3.5 kW	5 kW	5 kW
Boil Efficiency (%)	82.9	82.7	82.0	87.8	87.0	83.5	83.5	90.4
20lb Boil Time* (min)	33.6	42.1	35.4	22.2	17.2	16.7	13.9	10.5

***70°F to 200°F (21 to 93°C) heat up time**

Source: Frontier Energy, Inc.

Figure D-3: Water Boil Test for Induction Cooktops

Source: Frontier Energy, Inc.

Partial Energy Load Test – Simmering

A simmer is a steady state of boiling without temperature increases or decreases. Although simmer is usually visually quantified by the formation of bubbles on the surface of the water, lab testing was conducted by adjusting the appliance controls to maintain 20lb of water at 210±2°F (99±1°C). This test characterizes how the induction cooktop operates at partial power conditions and its ability to maintain temperature. Higher-end induction cooktops feature multiple feedback temperature sensors which regulate simmer temperature based on setpoint.

Of the 6 induction cooktops for which the simmer test was conducted, 3 of the units had energy use rates of approximately 0.95 kW, while two others had moderately higher energy input rates of approximately 1.10 kW. The final and lowest energy consuming unit had an energy input rate of 0.88 kW. Table D-2 summarizes the simmer performance of the induction cooktops tested at the FSTC.

Table D-2: Simmer Test Results for Popular Commercial Induction Cooktops

	Model B	Model D	Model E	Model F	Model G	Model H
Voltage	120V	208V	208V	208V	208V	208V
Power Per HOB (kW)	1.4	2.5	3.5	3.5	5.0	5.0
Control Setpoint	220°F	220°F	215°F	Level 3	Level 3	Level 4
Average Simmering Power (kW)	0.94	0.88	1.10	1.08	0.98	0.95

Source: Frontier Energy, Inc.

Solid Food Energy Load Test – Sauté Test

ASTM F1275 Standard Test Method for Performance of Griddles quantifies commercial griddle performance and was used to assess the cooking appliances' energy efficiency and production capacity when tasked with cooking solid food product like hamburger patties. Sauté pans and griddle surfaces cook food in the same manner, via conduction between the food product and a flat heated surface. While the griddle test is conducted with multiple frozen burgers, the cooktop and accompanying 10" sauté pan cooked a single ¼ lb 80% protein/20% fat burger. The pan is first preheated to 375°F (191°C), then a frozen burger is placed in the pan, flipped when 60% of the cook time elapses and cooked until it reaches a weight loss of 35% which correlates to a temperature of 175°F (79°C).

The sauté test captured a wide range of varying levels of performance from unit to unit, most notably with regards to fry pan pre heat times. Unsurprisingly, the higher the appliance's power input, the faster the accompanying pan's heat up time. Also notable was the average power consumption of the two 5.0 kW units with one having an average energy rate of 1.36 kW and the other with a power consumption rate 35% lower at 0.87 kW. Table D-3 summarizes the sauté performance of several induction cooktops tested at the FSTC.

Table D-3: Burger Sauté Results for Popular Commercial Induction Cooktops

	Model B	Model D	Model E	Model G	Model H
Voltage	120V	208V	208V	208V	208V
Power Per HOB (kW)	1.4	2.5	3.5	5.0	5.0
Cooking Efficiency (%)	42.5	39.5	38.3	34.8	39.5
Burger Cook Time (min)	5.96	5.28	5.75	5.24	5.48
Pan Preheat Time (min)	1.46	1.66	1.54	0.71	0.63
Cooking Power Level	30-50%	20-30%	20-30%	20-30%	20-30%
Average Cooking Power (kW)	0.67	0.78	0.77	1.36	0.87

Source: Frontier Energy, Inc.

Figure D-4: Frozen Burger Sauté Test

Source: Frontier Energy, Inc.

Conclusions

Application of the regimented ASTM test method, simmer test and sauté test demonstrated notable performance differences across induction models, often correlating with the maximum input rate of the appliance. Boil efficiencies generally increased with the input power of the unit. Higher power leads to quicker boiling times, which minimizes the time for the pot to lose heat to the ambient air. However, simmering and sauté cooking efficiencies were generally higher among the lower powered units. Higher powered units can sometimes have larger gaps between their available power settings, so this difference may be due to the ability of lower powered units to more precisely find the optimum rates for simmering and sautéing. Frontier Energy recommends that the ASTM methodology for testing cooktops be modified to include the simmer and sauté test, which more fully characterize the possible uses and advantages of different cooktop designs. The boil test alone is not sufficient for characterizing energy efficiency, especially for cooktops with advanced energy saving control algorithms.

Despite the differences across units though, the test results indicate that induction cooktops are consistently energy efficient when compared to traditional heating methods, which have a boil efficiency in the 70 – 80% range. Once the hurdles of adequate electrical service, proper cookware and operator perception are overcome, induction cooktops can offer significant benefits. Induction cooktops cook more efficiently and consistently, reduce heat gain to the kitchen, reduce burn risks, simplify cleaning and improve indoor air quality. Together, these qualities help to overcome the initial purchase price premium and potential infrastructure costs of induction appliances.

Frontier Energy recommends further testing to characterize how induction compares to other cooktop technologies during sautéing and simmering, to more fully characterize the energy efficiency differences. Additional research to determine whether different cookware affects the energy test results could also better inform more comprehensive kitchen design optimization. The focus is often placed on the appliance, but the cookware paired with the equipment might also prove to have a significant impact.

Test Methodology

1. Install cooktop according to manufacturer's specifications
2. Use the same cookware set for all ranges tested
    - Stainless steel large 20-quart pot with lid: 20lb of water, covered
    - Stainless steel pan medium 10" top diameter, 2 ± 0.2 lb: ¼lb 80/20 frozen hamburger, uncovered
3. Attach thermocouples to each cooking vessel:
    - Pot:
        - Geometric center 1" from the bottom
        - Geometric center 1" submerged in liquid from the top lid
    - Pan:
        - Welded to cooking surface, 1" from handle joint, not to interfere with hamburger cooking
    - Freezer:
        - Monitor temperature for the last hour of burger holding with a thermocouple logger and a thermocouple inside the burger box
4. Verify the test voltage at full burner input is within 5% of specification
5. Verify the tested input rate is within 5% of specification during water boil test
6. Water boil test conducted with the pot and water volume specified in section 2a.
    - Initial water temperature 70±2F
    - Record pot weight and material
    - Burner input rate set to maximum
    - Final water temperature 200F per DAQ, needs to get higher for simmer
    - Conducted as a single replicate
    - Record temperature, time, energy and voltage
    - Leads to simmer test
7. Simmer test conducted after the boil test with the pot and water volume specified in section 2a.
    - Achieve 212F±2
    - Set burner input level to maintain simmer
    - Record temperature, time, energy and voltage during simmer for 15 mins
    - Verify simmer conditions are steady throughout the 15-minute test
    - Adjust input rate and repeat if 7d not met
8. Sauté test conducted with the pan and product specified in section 2b.
    - Use frozen product stabilized in a 0F±5F environment for at least 12 hours, do not have product out of freezer for more than 1 minute prior to cooking
    - Record pan weight and material
    - Record initial food product weight using a high-resolution scale

- Preheat pan to 375F±5F per welded thermocouple
- Record temperature, time and energy to preheat pan
- Place frozen hamburger patty in the hot pan and adjust controls as needed to maintain pan temperature at 375F±25F throughout sauté test
- After 60% of estimated sauté time elapses, flip the patty with a spatula
- Remove patty after estimated sauté time and stop recording temperature, time and energy to cook burger.
- Record final product weight using a high-resolution scale
- Verify cooked weight loss was 35±2%, adjust cook time or setting if not
- Conduct additional tests until three completed tests meet the 8j conditions

APPENDIX E: Appliance Laboratory Analysis - Conduction

Introduction

The California Energy Commission (CEC) has funded a comprehensive commercial kitchen plug load equipment study designed to assess the energy load and energy reduction potential of unventilated commercial plug load foodservice equipment. The goals of this project are to quantify the energy use of the various types of plug load equipment and characterize the energy savings potential, cost effectiveness, and improved cooking performance of energy efficient plug load equipment compared to baseline equivalents. By demonstrating energy savings potential using innovative energy efficient appliance technologies, the data from this project will be used to accelerate the adoption of advanced energy efficient cooking equipment within the CFS industry.

As a component of the study, Frontier Energy has characterized the performance and energy use of the new Condeco electric conduction cooktop in a controlled laboratory environment. The cooktop's energy saving features include smart controls that adjust input rate based on temperature sensor feedback, insulation that captures and directs heat energy for minimal losses, and durable, precisely flat surfaces for maximum heat transfer efficiency. The conduction cooktop was tested in conjunction with a residential induction range, representative of the most energy efficient option currently available in residential kitchens.

Testing Approach

Under controlled laboratory conditions, Frontier Energy researchers performed the following tests on each cooktop type to assess:

- Heat-Up – The time and energy required to bring 5-lb of 70°F (21°C) water to 200°F (93°C). This test is used to evaluate both the production capability and energy efficiency of the cooktop.
- Simmer – Once the water is boiling, the energy required to maintain a pot of water at a simmer. This test is used to measure energy consumption under regular cooking conditions.
- Sauté – The energy and time required to pan-cook a typical food product. This test also evaluates both the production capability and energy efficiency of the cooktop.

Each of the performance tests used a modified methodology based on the American Society for Testing and Materials (ASTM) F1521 Standard Test Methods for Performance of Range Tops for the heat-up tests and ASTM F1275 Standard Test Method for Performance of Griddles for the sauté tests. These tests mirrored prior testing done as part of the Residential Cooktop Performance and Energy Comparison Study conducted in July 2019. A summary of the test methodology is provided in Appendix A.

Technology Description

Cooktop technology can be described in terms of respective modes of heat transfer. Identifying the distinct physics of each cooktop technology and the method in which they transfer heat to cookware is the best way to characterize the inherent benefits and drawbacks of each mode.

Conduction Cooktop Prototype

The heat source for the conduction cooking system is a thick metallic film layer (silver / palladium) applied to the back of a ceramic silicon nitride cooktop, which serves as an ohmic resistor. An 18 mm thick insulation plate directs the heat through the ceramic cooktop to the paired conduction cookware via conduction. Both the ceramic cooktop and the bottom of the cookware are made of high-quality ceramic material engineered to be precisely flat to maximize contact and heat transfer efficiency.

Beyond the precision engineered flat bottom, the paired cookware also features double walls on both the sides and the lid to minimize heat loss to ambient air. The conduction cooktop also features temperature feedback and programmable features to increase ease of use and maximize energy savings. The featured electronic controls give users the ability to precisely set and maintain a certain temperature. When the sensors read the proper temperature, the unit will cease heating functions until the temperature begins to drop. Maximum temperature is set at 175°C (347°F) for health and safety reasons.

Figure E-1: Condeco Electric Conduction Cooktop

Source: Frontier Energy, Inc.

Figure E-2: Double-Walled Conduction Cookware

Source: Frontier Energy, Inc.

Induction Cooktops

Electric induction ranges are gaining traction in the residential appliance market and have proven to be more efficient than standard electric resistance coil ranges. Induction heating is accomplished by a high-frequency alternating current flowing through a tightly wound coil of wire, generating a rapidly changing magnetic field on the surface of the cooktop. When a pot or pan containing ferrous (magnetic) material is placed on the surface of the cooktop, the magnetic field induces an "eddy current" in the material, causing heat to be generated directly in the bottom and sides of the cookware. Non-magnetic materials are not affected by the presence of the magnetic field, therefore nearly all heat energy is transferred directly into the cookware. The surface material for an induction cooktop is typically glass-ceramic. The specific induction unit used for comparison with the conduction cooktop prototype featured digital rotary controls and a seven-inch diameter cooking surface.

Results

Frontier Energy researchers used the following performance metrics to compare the two cooktop categories under test:

- Heat-Up Time and Efficiency
- Simmer Energy Consumption
- Sauté Energy Efficiency

Heat-Up Test

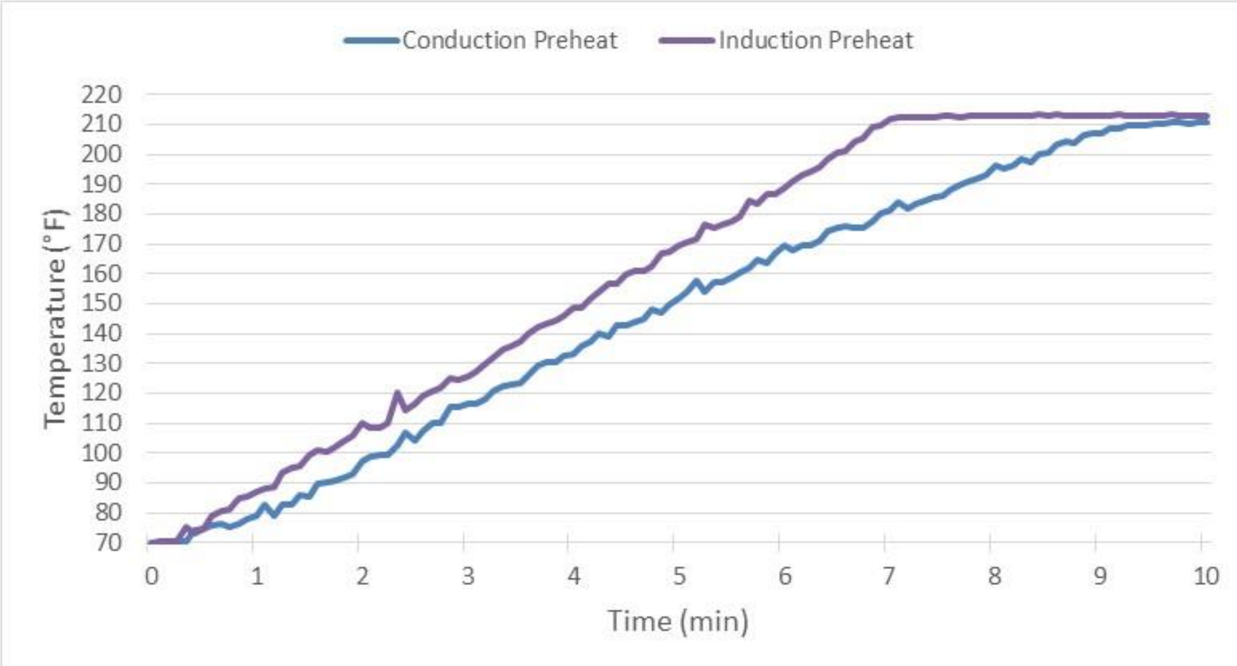
Heat-up time is a function of both cooktop power and efficiency – the more powerful and efficient the cooktop, the faster it will heat up a pot of water. A cooktop may have a high input rate and low efficiency, but heat up water just as fast as a low input and high-efficiency range top. Both the conduction and induction cooktops were heated using their maximum settings, resulting in quicker heat-up times for the induction cooktops. Across two tests, the induction cooktop brought 5 pounds of water from 70°F (21°C) to 200°F (93°C) in 6.54 minutes while operating at a 2.2 kW rate. The induction cookware used for testing weighed 3.32 lb. The conduction cooktop took a minute and a half longer, bringing the water to 200°F (93°C) in just under eight minutes while operating at a 1.8 kW rate. The conduction cookware used for testing weighed 4.87 lb. Though the conduction cooktop boiled water at a slower rate due to its lower power, it did so more efficiently – more of the electrical energy used by the cooktop went into the water as heat energy. The conduction pot was also heavier (4.9 lb) than the induction pot (3.3 lb) and thus had a greater thermal mass, contributing to the slower heat-up time. The results from the heat-up tests are presented in Table E-1.

Table E-1: Cooktop Heat-Up Time Results

	Conduction	Induction
Heat-Up Time (min)	7.96	6.54
Heat-Up Rate (°F/min)	16.5	20.0
Heat-Up Energy (Wh)	236.8	243.8
Input Rate (W)	1,791	2,236
Heat-Up Efficiency (%)	90.5	84.8

Source: Frontier Energy, Inc.

Figure E-3: Induction Cooktop Water Heat-Up Test Results



Source: Frontier Energy, Inc.

Simmer Test

A common cooking practice is to bring a pot to a boil using maximum input then reduce the input to maintain a simmer, or low boil. This test was designed to compare the energy required to maintain five pounds of water in a just boiling state inside a covered pot. This simmer state would be verified using a visual indication of bubbling to mirror residential cooking practices. For the conduction cooking system, this test was performed by setting the temperature to 100°C (212°F), which the system then maintained through its smart controls. The cookware used for testing was the double-walled conduction pot with a simmer surface diameter of 8 inches. For the induction range, the test was conducted using different knob settings to mirror possible residential cook settings and determine the minimum setting that provided the boiling desired. The cookware used for testing was an induction pot with a simmer surface diameter of 7.25 inches. Researchers also measured the temperatures of both the pot exterior and lid during these tests to determine the effect of the conduction cookware's double-walled construction on kitchen safety.

Researchers tested the induction range in four different modes deemed most likely to be used for simmering purposes. The "Simmer" setting was too weak to produce any bubbles. Bubbles were first detected using the 4th setting, which was able to maintain the boiling state. However, the "Medium" setting is the most clearly marked on the unit and thus is most likely to represent the common user's default lower boil setting. The 6th setting was excessively strong and would be unlikely to be used for simmering purposes.

Figure E-4: Conduction Simmering Setpoint

Source: Frontier Energy, Inc.

Figure E-5: : Knob Controls on the Induction Range

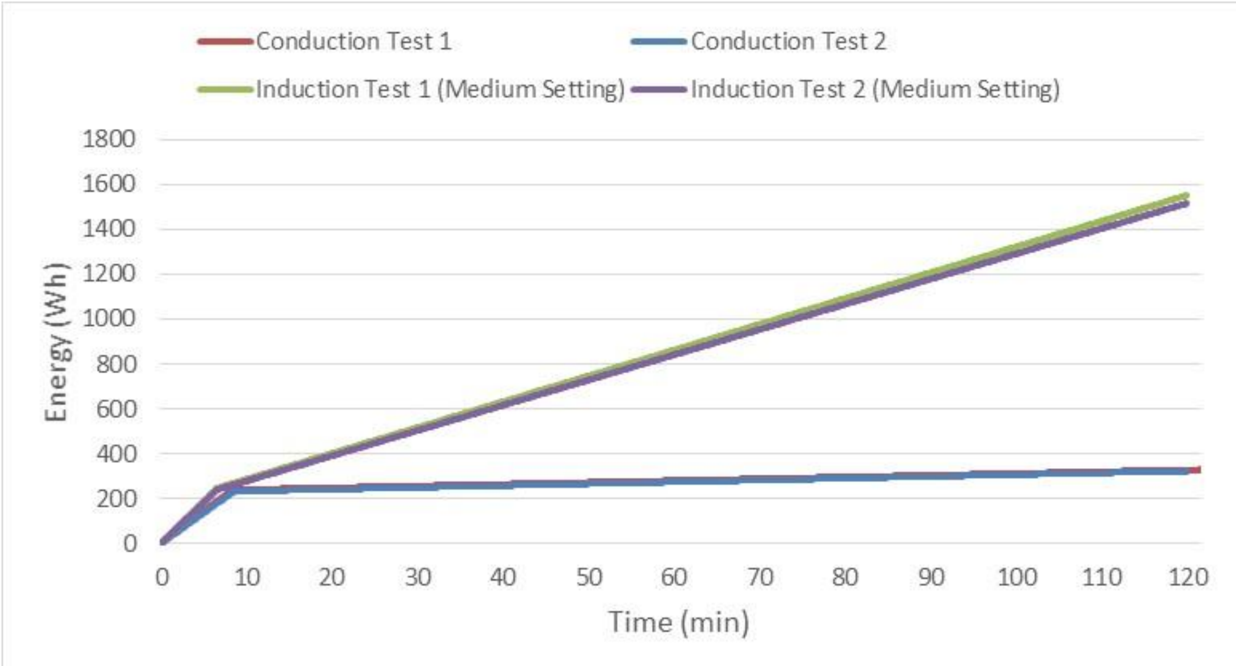
Source: Frontier Energy, Inc.

Table E-2: Induction Range 5-lb Pot Simmer Test Energy Rate Results

Setting	Simmer (2nd Setting)	4th Setting	Medium (5th Setting)	6th Setting
Energy Rate (W)	105	450	683	885
Water Temp (°F)	205.4	212.2	213.1	213.0
External Pot Temp (°F)	201.7	209.0	209.9	209.7
Pot Lid Temp (°F)	193.7	205.5	207.7	207.8

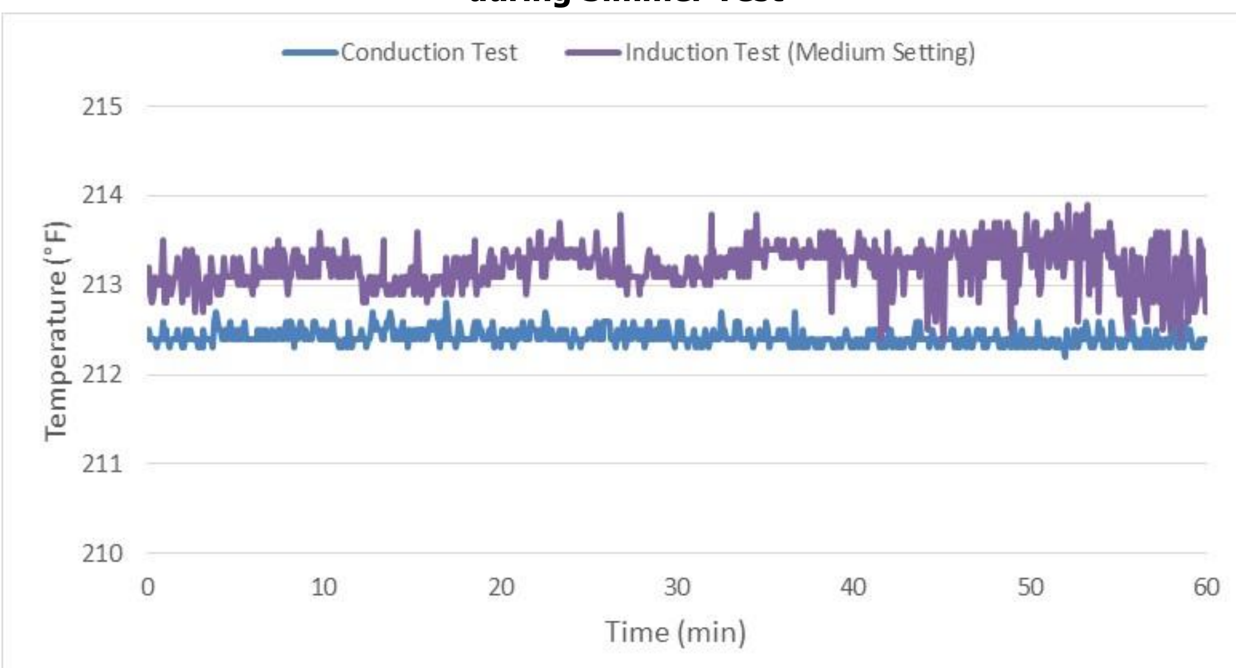
Source: Frontier Energy, Inc.

Figure E-6: Energy Consumption Over Time of Conduction vs Induction (at Medium Setting) during Simmer Test



Source: Frontier Energy, Inc.

Figure E-7: Temperature Profiles of Conduction vs. Induction (at Medium Setting) during Simmer Test



Source: Frontier Energy, Inc.

The conduction unit maintained the simmering state using an idle rate significantly lower than any of the tested induction range settings including the "Simmer" setting that was unable to maintain the desired boiling state. When used in conjunction with the specialized conduction cookware, the conduction unit used 89% less energy than the induction range's 4th setting and 93% less energy than the induction range's "Medium" setting. The simmer duty cycle, defined as the ratio of simmer energy to the total maximum input energy was very low. Given this sizable difference, researchers also tested the conduction cooking unit using the same pot used to perform the induction test, to determine whether the energy savings were due to the conduction cooktop or the specialized insulated cookware. The results indicated that the energy savings was due to both the cooktop and the cookware.

Testing the induction pot on the conduction cooktop required researchers to increase the setpoint on the conduction cooktop from 100°C (212°F) to 120°C (248°F) to maintain the simmer state within the pot. The conduction cooktop prototype controls were calibrated to match with the specific pot provided for testing, and the weaker surface contact with the induction pot meant that the 100°C (212°F) could no longer generate a 100°C (212°F) temperature within the pot. This doubled the simmering energy rate from 48.5W to 98W, which was still significantly below the input rates of the induction range's 4th or "Medium" settings. The input rate was still even below the "Simmer" setting on the induction range, which was unable to maintain the boil state when tested with the same induction pot. Thus, while the conduction cooking system benefits most substantially when paired specifically with the conduction cookware (because of the matching flat surfaces and added insulation), the conduction cooktop itself still offers an energy benefit in comparison to the induction range. However, the time required to boil the water in the induction pot on the conduction cooktop was much longer than with the paired conduction pot. For practical application, it is not recommended that the conduction cooktop be used with anything other than the corresponding cookware.

Table E-3: Condeco Conduction Range 5-lb Pot Simmer Test Energy Rate Results

	Conduction Pot	Induction Pot
Energy Rate (W)	49	98
Simmer Duty Cycle	1.9%	3.8%
Water Temp (°F)	212.2	210.8
External Pot Temp (°F)	178.8	205.6
Pot Lid Temp (°F)	139.3	200.1

Source: Frontier Energy, Inc.

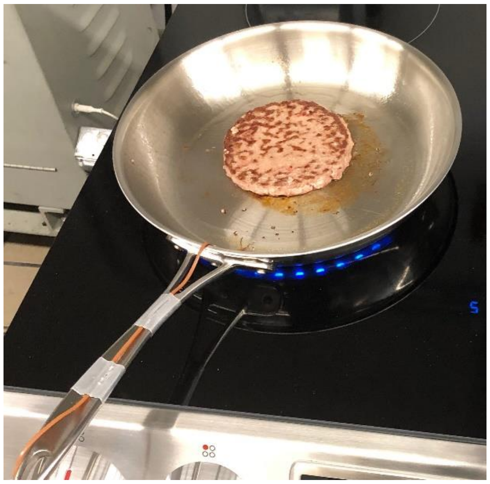
Sauté Cooking Energy Efficiency

Cooking energy efficiency is defined as the ratio of energy into the food product versus the energy into the appliance. The higher the energy efficiency, the lower the thermal losses into the kitchen environment. Efficiency tests were conducted by determining the time and energy required to properly cook a burger, which is representative of pan frying or sautéing. Researchers conducted the burger test with a frozen 80/20 burger patty cooked to 35% moisture loss, which provided a 165°F (74°C) internal temperature (per ASTM F1275). Sauté cooking requires a lower input rate as to not burn the food product before the internal temperature reaches the target. Testers selected a power level to achieve a 350 – 400°F (177 – 204°C) nominal pan temperature before placing the frozen burger in the pan, which was the 4th setting for the induction range and 175°C (348°F) for the conduction cooktop. The conduction test was conducted with the paired test pot that weighed 4.9 lb to deliver heat more quickly and maintain more precise temperature control of the product. The induction test was conducted using a pan that weighed 2.0 lb. Researchers attempted to conduct a cook test on the conduction unit with same pan as the induction unit for comparative purposes, but the heat-up and cooking were too slow for practical usage – the conduction unit can only be properly used with the paired conduction cookware. The table below shows conduction pot and induction pan heat up times and energies prior to and during cooking.

Figure E-8: Conduction Burger Cooking

Source: Frontier Energy, Inc.

Figure E-9: Induction Burger Cooking



Source: Frontier Energy, Inc.

Table E-4: Sauté Cooking Energy Efficiency Test Results

	Condeco Conduction Cooking System	Induction Range
Setpoint	175°C (348°F)	4th Setting
Heat Up Time (min)	1.33	2.44
Heat Up Energy (Wh)	45	30
Sauté Time (min)	9.17	7.05
Sauté Energy (Wh)	38	61
Sauté Input Rate	245 W	515 W
Sauté Duty Cycle	9.6%	22.3%
Sauté Efficiency*	92.7%	54.0%

***Sauté efficiency was calculated according to ASTM F1275 which takes in account initial and final moisture content of the burger patty, specific heat of ground beef and energy for melting phase change of the burger heated from 0 to 165°F (-18 to 74°C). Sauté efficiency does not account for pan heat up energy.**

Source: Frontier Energy, Inc.

The conduction cooking system took about two minutes longer than the induction range to cook the product to the required specifications but did so while operating at less than half the electric input rate and a significantly higher efficiency. Like the heat-up test, the sauté test indicated that the conduction cooking system may perform more slowly than induction due to the functions of the smart control algorithms, which were designed to prevent the burning of food product for health purposes. Like the simmer tests, however, the sauté test also reinforces that the heating done through the conduction cooking system is significantly more efficient. The conduction cookware also requires more energy to heat up before cooking though because of its higher thermal mass – this may be reduced once specific cookware for sautéing is developed. Since the heat is transferred directly from the plate, there is also the possibility for food to be cooked directly on the cooktop surface in future iterations of the conduction cooktop. This would theoretically make the cooktop more efficient, lowering the heat up energy to around 12 Wh. However, the specific energy implications of direct grilling could not be evaluated given the unsealed structure of the prototype.

Energy Cost Model

Frontier Energy aggregated the test data to create an energy cost model, estimating and comparing the expected annual energy cost of residential conduction and induction units for an average household. Below is a table of input assumptions for the energy model derived from the cooking usage findings in The Lawrence Berkeley National Laboratory (LBNL) study Cooking Appliance Use in California Homes and closely mirroring the previous Frontier Energy study Residential Cooktop Performance and Energy Comparison Study. The average household is assumed to use their range five days a week, cooking two sauté dishes and boiling one five-pound pot of water (followed by 15 minutes of simmering) per day of use.

Table E-5: Energy Model Assumptions

Assumption	Value
Days Cooking Per Week	5
Number of 5-lb pots boiled per day	1
5-lb pot simmer duration	15 minutes
Number of sauté dishes cooked per day	2
Days Cooking Per Year	260
Electric Energy Cost	$0.16 / kWh*

***average cost of electricity in California**

Source: Frontier Energy, Inc.

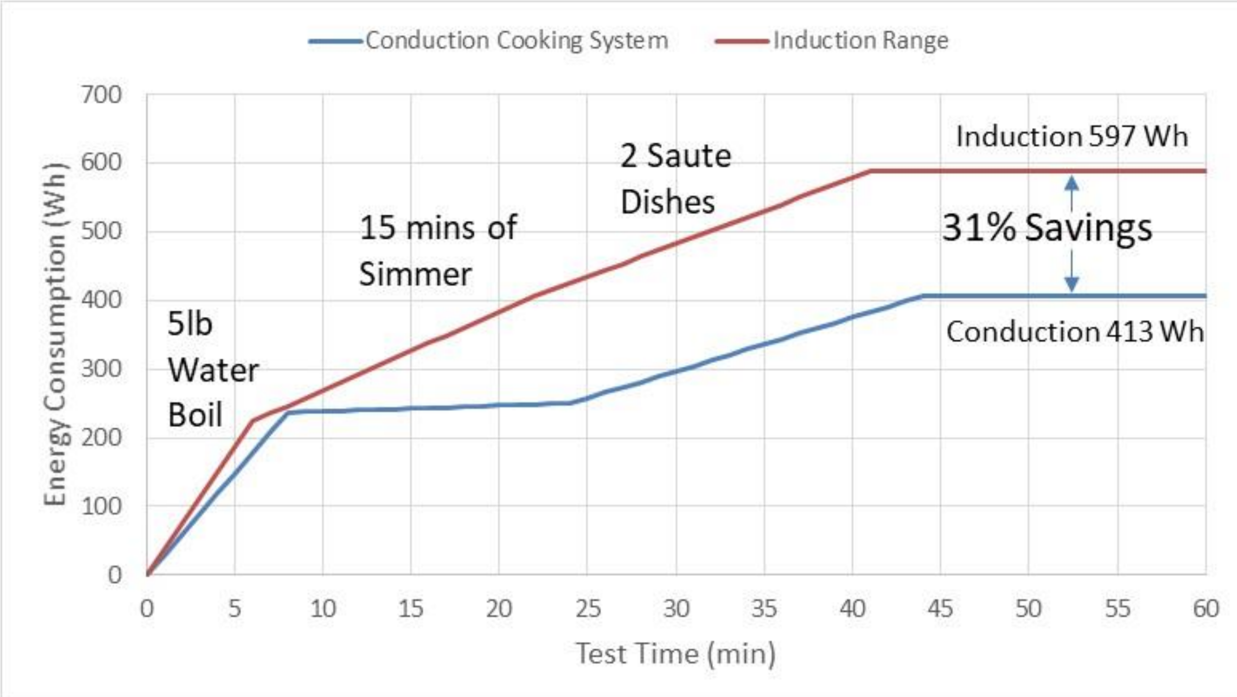
Table E-6: Energy Model Calculations

Cooktop	Conduction Cooking System	Induction Range*
Boil Energy Per Day (Wh)	236	244
Simmer Energy Per Day (Wh)	12	171
Sauté Energy Per Day (Wh)	165	182
Total Energy Per Day (Wh)	413	597
Total Energy Per Year (kWh)	107	155
Energy Cost Per Year ($)*	$17.26	$24.95

***using $0.16/kWh average cost of electricity in California**

Source: Frontier Energy, Inc.

Figure E-10: Daily Cooking Energy for Average Household



Source: Frontier Energy, Inc.

While the conduction cooking system saves energy while sautéing, most of the energy savings are from the conduction cooking system's much lower simmering energy. Based off the findings of the LBNL study, the average household is expected to reduce their cooking energy by about 31% using the conduction system compared to the induction range, saving $7.69 annually on their electricity bill. However, cooking practices vary substantially from household to household and the savings can be substantially larger for households which do a lot of boiled dishes or broth/soup making. Table E-7 lists the savings for households who engage in extensive simmering when cooking.

Table E-7: Energy Savings for Higher Usage Households

	Average Daily Simmering Duration			
	15 min	**30 min**	**1 hour**	**2 hours**
Energy Cost Per Year Conduction ($)*	$17.26	$17.77	$18.77	$20.78
Energy Cost Per Year Induction ($)*	$24.95	$32.08	$46.36	$74.91
Annual Savings ($) *	$7.69	$14.32	$27.59	$54.13
Annual Savings (kWh)	48	89	172	337
Percent Energy Savings (%)	31%	45%	60%	72%

*using $0.16/kWh average cost of electricity in California

Source: Frontier Energy, Inc.

Conclusion

The conduction and induction cooktops demonstrated similar heat-up energy requirements, though the lower input rate resulting from the smart controls resulted in the conduction cooking system taking about a minute and a half longer to reach boiling temperature. The simmer and sauté tests showed that the conduction cooking system operated significantly more efficiently than induction when cooking. This difference in energy efficiency is particularly apparent when requiring precision – the conduction system allows for more exact temperature control with its temperature feedback system than an induction system with a smaller number of discrete power settings. The energy efficiency of the conduction system is maximized when paired with the conduction cookware; energy savings are theoretically still possible when using the conduction cooktop with a normal induction pot, but the effect of the pot on the smart controls makes the heating too slow to be practical. The conduction system also currently operates slightly slower than induction due to its lower input rate and smart control algorithms, though the control algorithms could possibly be modified to increase input rate to make boiling time on par with induction. The current algorithms programmed to promote healthy cooking make the duty cycles of the conduction cooktop significantly lower. The double-walled construction of the conduction cookware also reduces external pot temperature in comparison to induction by about 25°F (11°C) for the sides of the pot and 60°F (33°C) for the lid. This results in safer and more efficient cooking, but the specific savings per household will vary depending on usage. Table E-8 compares the final test results from the conduction and induction cooktops.

Table E-8: Conduction vs. Induction Cooktop Test Results Summary

Cooktop	Conduction Cooking System	Induction Range*
Heat-Up Input Rate (W)	1.8 kW	2.2 kW
5-lb Water Heat-Up Time (min)	8.0	6.5
5-lb Water Heat-Up Energy (Wh)	236	244
5-lb Water Heat-Up Efficiency (%)	90.5	84.8
Production Capacity (lb/h)	37.7	45.9
5-lb Water Simmer Energy Rate (W)	48	683
Simmering Pot Exterior Temperature (°F)	179	210
Simmering Pot Lid Temperature (°F)	139	208
Cooking Heat-Up Time (min)	1.33	2.44
Cooking Heat-Up Energy (Wh)	45	30
Sauté Time (min)	9.17	7.05
Sauté Energy (Wh)	38	61
Sauté Input Rate (W)	245	515
Sauté Duty Cycle	9.6%	22.3%
Sauté Efficiency	92.7%	54.0%

***Heat-Up done with Power Boil setting, Simmer done on Medium setting (5th setting) and Sauté done on 4th setting**

Source: Frontier Energy, Inc.

Test Methodology

1. Install cooktop according to manufacturer's specifications
2. Document cooktop burner input rates per manufacturer's documentation for each burner
3. Attach thermocouples to each cooking vessel:
    a. Conduction Pot:
        i. Geometric center 1" from the bottom
        ii. Geometric center 1" submerged in liquid from the top lid
    b. Induction Pot:
        i. Geometric center 1" from the bottom
        ii. Geometric center 1" submerged in liquid from the top lid
    c. Pan:
        i. Welded to cooking surface, 1" from handle joint, not to interfere with hamburger cooking
4. Verify the test voltage at full burner input is within 5% of specification
5. Verify the tested input rate is within 5% of specification during water heat-up test
6. Water heat-up test:
    a. Record pot weight and material
    b. Fill pot with five pounds of water
    c. Ensure initial water temperature is 70 ± 2°F (21 ± 1°C)
    d. Ensure initial burner/element/hob temperature is 70 ± 2°F (21 ± 1°C)
    e. Start data acquisition program and set burner input rate set to maximum
    f. Record temperature, time, energy, and voltage until the water temperature reaches 200°F (93°C) per data acquisition system
7. Simmer test – conducted immediately following the water heat-up test:
    a. Achieve 212 ± 2°F (100 ± 1°C)
    b. Set burner input level to maintain simmer
    c. Record temperature, time, energy, and voltage while in the simmering state
    d. Verify simmer conditions are steady and appropriate for use
    e. Adjust input rate and repeat if 7d not met
8. Sauté test conducted with a pan and product specified in section 4c
    a. Prepare ¼-lb, 80/20 frozen hamburgers stabilized in a 0 ± 5°F (-18 ± 3°C) environment for at least 12 hours
    b. Estimate a cook time required to produce a 35 ± 2 % moisture loss in the burger
    c. Record pan weight and material
    d. Record initial food product weight using a high-resolution scale (do not have product out of freezer for more than 1 minute prior to cooking)
    e. Preheat pan to 375°F (191°C)

f. Record temperature, time, and energy to preheat pan
g. Place frozen hamburger patty in the hot pan
h. After 60% of estimated cook time, flip the patty with a spatula
i. Remove patty once the total cook time reaches the initial estimate
j. Stop recording temperature, time, and energy to cook burger
k. Record final product weight using a high-resolution scale
l. Verify cooked weight loss was 35 ± 2%; if not, modify the estimated cooking time and repeat steps c-l until the proper conditions are reached.

Detailed Test Results

Table E-9: Cooktop Heat-Up Test Detailed Results

	Conduction		Induction	
	Test #1	Test #2	Test #1	Test #2
Heat-Up Time (min)	7.42	8.50	6.58	6.50
Heat-Up Rate (°F/min)	17.6	15.3	19.9	20.1
Heat-Up Energy (Wh)	240.0	232.5	247.5	240.0
Input Rate (W)	1941	1641	2257	2215
Heat-Up Efficiency (%)	89.2	91.8	83.5	86.0

Source: Frontier Energy, Inc.

Table E-10: Conduction Cooktop Sauté Test Detailed Results

	Test #1	Test #2
Test Time (min)	10.92	10.92
Cook Time (min)	9.17	9.17
Burger Initial Weight (lb)	0.245	0.250
Burger Final Weight (lb)	0.155	0.160
Burger Initial Moisture Content (%)	58.6%	58.6%
Burger Final Moisture Content (%)	46.2%	46.4%
Burger Fat Content (%)	23.9%	23.9%
Test Voltage (V)	219	218
Electric Energy Consumption (Wh)	38	38
Ambient Temperature (°F)	70.1	70.2
Burger Weight Loss (%)	36.7%	36.0%
Specific Heat of Burgers (Btu/ lb °F)	0.72	0.72
Sensible Energy (Btu)	29	30
Latent Fusion Energy (Btu)	21	21
Latent Vaporization Energy (Btu)	70	70
Total Energy to Food (Btu)	120	121
Energy to Food (Btu/lb)	120	121
Electric Cooking Energy Rate (kW)	0.21	0.21
Energy to Equipment (Btu/lb)	531	520
Cooking Energy Efficiency (%)	92.3	93.1
Production Capacity (lb/h)	1.3	1.4

Source: Frontier Energy, Inc.

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APPENDIX F: Appliance Laboratory Analysis - Rapid Cook Ovens

Frontier Energy conducted additional laboratory testing on rapid cook ovens given the recent increased interest in the technology, particularly from larger chain accounts. Today's foodservice customers demand freshly cooked food and short wait times. Food must be cooked-to-order and served hot. This demand has encouraged many foodservice operators to shift their process from batch cooking-and-holding to rapid cooking. Quickly heating food from a refrigerated or frozen state in single batches has increasingly gained traction in the foodservice industry over the traditional method of cooking and holding large quantities of food in a ready-to-serve state. Blast chillers have facilitated this cooking process change by rapidly reducing the temperature of single serving packages of cooked food before being staged for rapid cooking. Vacuum sealing these single meal servings is also becoming common as a method of food prep for rapid cooking. The table below shows the differences between the two cooking processes.

Table F-1: Batch Cooking Vs Rapid Cooking Processes

	Batch Cooking	Rapid Cooking
Food Product Refrigeration	Refrigerated or Defrosted	Refrigerated or Frozen
Cooking Method	Convection Oven, Combi Oven	Rapid Cook Oven, Panini Press
Cooking Temperatures	300 – 400°F (149 – 204°C)	450 – 550°F (232 – 288°C)
Servings Cooked at a Time	5+	1-2
Ventilation Requirements	Type II Hood	Usually Ventless with Catalyst
Holding Method	Hot Food Holding Cabinet, Steam Table, Blast Chiller (multistage cooking)	None, served right after cooking
Applications	Catering and Hotels, Cafeterias, Full-Service Restaurants, Buffets	Quick-Service Restaurants, Quick-Service Convenience, Full-Service Restaurants, Stores / Gas Stations, Cafés and Pastry Shops, Bars
Advantages	High customers served to labor spent ratio	Fast cook times, customer impression of freshness, single stage process
Disadvantages	Requires multiple steps, can lead to product waste if customers served is overestimated, can lead to long wait times	Cannot serve large volumes of customers, high energy density, product needs to be served immediately

Source: Frontier Energy, Inc.

Although the table above categorizes each cooking process by market segment, some operations may use a mix of both processes. For example, food can be prepped and pre-cooked using a batch cooking process, then blast chilled and reheated using rapid cooking techniques. A large cafeteria may have several batch cooked items and a separate cook station dedicated to serving rapidly cooked-to-order items.

Many quick-service restaurants are already making the process switch from batch to rapid cooking, while smaller bakeries, cafés, gas stations, and bars are expanding their food menus with the help of rapid cook ovens.

Current Rapid Cook Oven Technologies

Rapid cooking occurs at high temperatures of about 450 – 550°F (232 – 288°C) typically using a combination of convection, impingement, and/or microwaves. Oven cavities can be enclosed or open, or a hybrid of both. Microwave technology can only be used in models with closed cavities and no windows. Partially open cavity models using contact cooking include conveyor ovens and panini griddles. All rapid cook oven technologies use high-speed hot air to add crispiness to the food product. The random circulation of heated air in convection oven cooking is replaced with precise directional high-velocity hot air directed toward the food product in rapid cook ovens. Rapid cook ovens have high-temperature cooking chambers which run 100+°F (55+°C) higher than conventional convection oven settings. Hot air velocity is also two to three times greater than convection ovens, which results in decreased cook times. Some models can also pulse microwave energy, giving the small cooking chambers even more power to reduce cook times.

Figure F-1: Hot Air Impingement Rapid Cook Ovens

Source: Frontier Energy, Inc.

The elevated temperatures of rapid cook ovens allow for the use of catalysts that may qualify the oven for ventless operation if it passes the EPA 202 grease emissions threshold of 5.0 mg/m3 (UL KNLZ) as well as NFPA96 and 101 fire safety standards. The emissions test is conducted using pepperoni pizza; most ovens are not allowed to be installed without a hood if raw protein product is being cooked.

Figure F-2: Rapid Cook Ovens with Microwave

Source: Frontier Energy, Inc.

The following technologies are NOT considered rapid cook:

- Standard Microwaves without convection fans or resistance elements
- Panini Makers with no magnetrons
- Mini Combination Ovens

As of June 2019, there are four major equipment manufacturers in this field representing some of the largest foodservice conglomerates:

- Amana ACP (Ali Group)
- MerryChef (Wellbilt)
- TurboChef (Middleby)
- Ovention (Hatco)

Rapid cook ovens can be classified into four categories including: high temperature microwave ovens, door type hot air impingement ovens, conveyor hot air impingement ovens and microwave panini makers.

High-Temperature Microwave Ovens

High-temperature microwave ovens are one of the most popular rapid cook technologies, combining a heated cavity (typically in the range of 450-550°F (230 – 299°C)), dual convection fans, and microwave magnetrons. The cavity is enclosed with no windows and is usually smaller in volume compared to the size of the unit. The most popular models on the market are listed below:

- Amana ACP
    - ACE 14 and ACE 19
    - ARX1 and ARX2
    - AXP22T
- MerryChef
    - Eikon e2s
    - Eikon e3

- Eikon e4s
- Eikon e5

- TurboChef
  - Eco
  - Sota (i1) also Panini and Waterless Steamer
  - i3
  - Bullet
  - i5

Figure F-3: High-Temperature Microwave Rapid Cook Oven Models

	Amana	MerryChef	TurboChef
Small			
Medium			
Large			

Source: Frontier Energy, Inc.

Table F-2: High-Temperature Microwave Rapid Cook Oven Dimensions

Cavity Size (W"x H"x D")	Amana	MerryChef	TurboChef
Small	ARX (12.3x7x12.3)	e2 (12x7x12)	Eco / Sota (12.5x7.2x10.5)
Medium	ACE (13x10.5x15)	e3 (13x12.6x12.8)	Bullet (15.5x6x14.5)
Large	AXP (16x10x15)	e4 (14.8x8.6x12.3)	I3 (19.4x6.9x12.8)
Extra Large	N/A	e5 (19.5x10.2x14.1)	I5 (24x10x14)

Source: Frontier Energy, Inc.

High-temperature microwave ovens have four energy consuming components:

- Resistance Electric Heating Element (highest input)
- Microwave Magnetron (some larger ovens have dual magnetrons)
- Air recirculation convection fan (approximately 100W)
- Controls (low energy)

Table F-3: High-Temperature Microwave Rapid Cook Oven Input Rates

Power (micro+conv)*	Amana	MerryChef	TurboChef
Small	ARX1 3.6 kW (1+3) ARX2 6.0 kW (2+3)	e2 4.5 kW (1+2.2) e2s 6.0 kW (2+2.2)	Eco 3.5 kW (2+2) Sota 6.2 kW (3.2+6.0)
Medium	ACE 14 3.2 kW (1.4+2.7) ACE 19 5.3 kW (1.9+2.7)	e3 4.7 kW (1+3) e3s 6.2 kW (1.5+3.2)	Bullet 6 kW (3.5+NA)
Large	AXP 5.7 kW (2.2+2+3IR)	e4 6.2 kW (1.8+3.2)	I3 8.3 kW (N/A)
Extra Large	N/A	e5 6.2 kW (1.4+3.2)	I5 9.5 kW (N/A)

***Microwave power is shown as output instead of input, all specs shown at 208V 1PH.**

Source: Frontier Energy, Inc.

The total input rate for the ovens is listed in the table. Microwave magnetron output power and resistance heating element power in kW are shown in parentheses, respectively. Some ovens do not allow the resistance heating element to operate at full power when the microwave is on as to have a lower amperage rating.

Small and medium size high temperature microwave ovens are the most popular - some restaurants have two units, which can be operated simultaneously to double production capacity and have redundancy in case of an equipment failure. These would be 3-6 kW units which can be run off a single phase 208V 30A or 40A receptacle. The resistance elements are usually 2-3kW and the microwave magnetrons draw an additional 2-3 kW.

Door-Type Hot Air Impingement Ovens

Door-type hot air impingement ovens do not use microwave magnetrons. Instead, these ovens achieve elevated temperatures of 450 – 550°F (232 – 288°C)using resistance heating elements and high velocity air impingement to aid in product crisping. These closed cavity ovens usually have a glass door unlike their microwave counterparts. The models listed below are the most popular on the market:

- TurboChef
  - Fire
  - Single Batch
  - Double Batch
  - High h Batch
- Ovention
  - Milo Single
  - Milo Double
- Alto Shaam
  - Vector H2
  - Vector H3
  - Vector H4
  - Vector F3
  - Vector F4

Figure F-4: Door-Type Hot Air Impingement Ovens Models

	TurboChef	Ovention	Alto Shaam
Small (single cavity)			N/A
Medium (dual cavity)			
Large (3+ cavity)	N/A	N/A	

Source: Frontier Energy, Inc.

Table F-4: Door-Type Hot Air Impingement Oven Dimensions and Input Rates

Dimensions and Input* Rate	TurboChef	Ovention	Alto Shaam
Small (single cavity)	Fire (14.8x14.8) 3.7 kW Single Batch (18.5x16.3x5.5) 5.6 kW High h Batch (18.8x16.8x8) 5 kW	Milo Single (15.5x14.3x4) 7.2 kW	N/A
Medium (dual cavity)	Double Batch (18.1x17.1x3.3x2) 8.3 kW	Milo Double (17.5x18.3x4x2) 11.8 kW	Vector H2 (15x19x14) 5.2 kW
Large (3+ cavity)	N/A	N/A	Vector H3 (15x19x21) 7.9 kW Vector H4 (15x19x28) 10.6 kW

***Shown for 208V**

Source: Frontier Energy, Inc.

Conveyor Hot Air Impingement Ovens

Conveyor hot air impingement ovens do not use microwave magnetrons. Instead, these ovens achieve elevated temperatures of 450 – 550°F (232 – 288°C) using resistance heating elements and high velocity air impingement to aid in product crisping. The food is placed on the conveyor belt which carries the food product through a heated cavity. Cooktime can be changed by adjusting the conveyor belt speed. Fans force air from the top of the cavity onto the food product. Constant moving of the product past the heating elements ensures uniform cooking. Heat settings can be adjusted separately for the bottom and the top. The models listed below are the most popular on the market:

- TurboChef
  - High h Conveyor 1618
  - High h Conveyor 2020
  - High h Conveyor 2620
- Ovention
  - Conveyor 2000
  - Shuttle 1718
  - Matchbox M1313
  - M360
- Lincoln
  - CTI V2500
  - 1180-1V

The conveyor belt is usually open on both ends of the cooking cavity, however Ovention makes batch conveyor models with closing doors that allows the product to enter the cavity, cook with the door closed, and then exit. Ovention also makes a model that uses a rotating turn table, where half of the turntable is inside the cooking cavity while the other half can be loaded with the next batch. These two designs limit the escape of hot air, which could reduce energy use.

Figure F-5: Conveyor Hot Air Impingement Oven Models

	TurboChef	Ovention	Lincoln
Small			N/A
Medium			
Large		N/A	

Source: Frontier Energy, Inc.

Table F-5: Conveyor Hot Air Impingement Oven Dimensions and Inputs Rates

Cavity Dimensions and Input Rate*	TurboChef	Ovention	Lincoln
Small	High h Conveyor 1618 (16x18) 7.4 kW	M360-12 (12x24) 6.4 kW Shuttle 1200 (17x15) 6.7 kW Matchbox 1313 (13x13) 7.0 kW	N/A
Medium	High h Conveyor 2020 (20x20) 40A	M360-14 (14x27) 8.3 kW Conveyor 2000 (20x21) 12.6 kW Shuttle 2000 (20x21) 12.6 kW Matchbox 1718 (17x18) 11.8 kW	DCTI V2501 (20x20) 6 kW
Large	High h Conveyor 2620 (26x20) 40A	Conveyor 2600 (26.5x21) 14.1 kW	1130-1V (x28) 10 kW

***Input rate shown for 3 phase 208V**

Source: Frontier Energy, Inc.

Electric conveyor hot impingement ovens fill the void between electric conveyor toasters and large gas conveyor pizza ovens. Operating at similar temperatures, they can provide much faster production capacity than conveyor toasters without having the ventilation requirements of large gas conveyor pizza ovens.

Contact Cooking with Microwave (Panini Presses)

Traditional panini presses are a contact cooking device which produces a crispy outer shell while the inside may stay at a colder temperature. The inner temperature depends on the product thickness, so traditional panini presses may overcook the outside while undercooking the inside. Microwave panini presses solve this issue by using the traditional contact cooking methodology for the outer shell but using microwave cooking to heat the inside of the product. This results in much faster cook time and improved uniformity. The top and bottom contact plates have resistance heating elements, and the magnetron is usually located above or below the cooking surface. These types of microwave panini presses are much more expensive than conventional models due to the addition of the magnetron and its controls, with similar pricing to high temperature microwave ovens. Several microwave panini makers include:

- Electrolux 603874 Speedelight
- Nemco 6900 Panini Pro
- TurboChef Panini (i1)

- Amana AXP with Panini Attachment
- Merrychef e2s with Panini Attachment

Two high temperature microwave oven manufacturers have integrated the panini attachment into their cooking cavity as an option. The panini metal contact surfaces are heated by convection in a high temperature cavity, which compresses as the door is closed to contact the food product. The magnetron in the back of the oven cooks the inside of the food product.

Figure F-6: Microwave Panini Maker Models and Specifications

Electrolux	Nemco	TurboChef
		
Electrolux 603874 Speedelight (8.1" x 8.5") 5 kW (0.8 kW top 2x1 kW magnetrons)	Nemco 6900 Panini Pro (10.5" x 10.5") 4 kW (2 kW resistance, 2 kW magnetron)	TurboChef Panini (i1) (9.8" x 15.2") 6.2 kW (6 kW resistance, 3.2 kW magnetron)

Source: Frontier Energy, Inc.

Rapid Cook Oven Technology Consumption

Rapid Cook Oven Energy Comparison

The various rapid cooking appliance that have emerged over the past decade have their various pros and cons, along with their own specialized uses. Frontier Energy tested these technologies under controlled conditions to characterize and compare their energy consumption and production capacity. Using this summarized information, foodservice operators can better understand the equipment that might best suit the demands of their operation. An appliance like a high-temp convection conveyor toaster could be perfect fit for a high throughput kitchen, but unnecessarily raise energy cost for a smaller operation.

Table F-6: Rapid Cook Oven Energy Comparison

	Conv with Micro	HT Conv Door	HT Conv Conveyor	Contact Micro
Production Capacity	Medium	Medium	Very High	Medium
Energy Intensity	High	High	Very High	Medium

Source: Frontier Energy, Inc.

Frontier Energy tested the ovens at 500°F (260°C) in both idle standby mode (using the setback mode where applicable) and cooking mode. The cooking method for each oven was based on a modification of the standard test methods ASTM F2238-16 (Rapid Cook Ovens) and ASTM F1817-17 (Conveyor Ovens). The testing for the various convection type ovens used the standard ASTM test product of thick crust pizza, cooking the pizzas from 38°F (3°C) to 195°F (91°C). Various models of each category were tested where available, representing different sizes and demand requirements. The results from this testing are summarized in the tables below, exhibiting a minimum and maximum range for sizes where multiple units were available for testing.

Table F-7: High Temperature Microwave Oven Energy Consumption Range

Size	Idle Rate (kW)	Cooking Input Rate (kW) and Production Capacity (lb/h)*
Small	0.68 kW (setback mode) – 0.82 kW	2.63 kW @ 16.7 lb/h – 4.95 kW @ 52.1 lb/h
Medium	1.20 kW – 1.33 kW	4.84 kW @ 49.7 lb/h
Large	0.72 kW (setback mode) – 1.78 kW	4.77 kW @ 54.5 lb/h – 5.76 kW @ 56.0 lb/h
Extra Large	0.99 kW	5.03 kW @ 48.6 lb/h

Source: Frontier Energy, Inc.

Table F-8: Door-type Hot Air Impingement Oven Energy Consumption Range

Size	Idle Rate (kW)	Cooking Input Rate (kW) and Production Capacity (lb/h)*
Small (single cavity)	1.15 kW – 1.24 kW	1.99 kW @ 17.8 lb/h – 2.63 kW @ 28.4 lb/h
Medium (dual cavity)	2.08 kW – 2.88 kW	N/A
Large (3+ cavity)	1.58 kW	N/A

Source: Frontier Energy, Inc.

Table F-9: Conveyor Hot Air Impingement Oven Energy Consumption Range

Size	Idle Rate (kW)	Cooking Input Rate (kW) and Production Capacity (lb/h)*
Small	2.34 kW	5.87 kW @ 55.7 lb/h
Medium	2.10 kW – 2.7 kW	3.43 kW @ 19.4 lb/h - 7.14 kW @ 56.7 lb/h

Source: Frontier Energy, Inc.

Panini Press Energy Comparison

The panini press with magnetrons were tested with a chicken quesadilla as the test product, since pizzas would not be appropriate for this application. Testing consisted of a back to back batch load of pre-prepared (using refrigerated cheese, warm chicken and room temperature tortilla) chicken quesadillas in order to test each unit under heavy-load cooking conditions. Cook times were determined based on metrics such as tortilla browning, internal temperature and quality of cheese melt inside the quesadilla and ranged between 20 and 30 seconds. The two units that performed the best were those who were specifically designed for panini/sandwich pressing. The third unit was a rapid cook oven modified with top and bottom plates for sandwich pressing capabilities. Standby idle energy, which is known to be one of the largest contributors to energy usage, was also measured for each unit. The unit with the lowest idle energy consumption had an eco-setback mode, which allowed it to idle at nearly half the rate of the other two units. The contact plates usually operate at 500-600F, but the setback mode lowered the temperature down to 400-500F during periods of inactivity.

Table F-10: Microwave Panini Press Energy Consumption Range

Idle and Cooking	A	B	C
	A: 0.5 kW Idle, 2.13 kW cook @ 62.6 items/h	B: 1.1 kW Idle, 1.88 kW cook @ 47.0 items/h	C: 0.9 kW Idle, 4.30 kW cook @ 62.6 items/h

Source: Frontier Energy, Inc.

Figure F-7: Example of 7 Run Batch Load

Source: Frontier Energy, Inc.

Food Product Variation Testing

A series of food products were chosen to test the performance of two units in three cooking scenarios. The first unit was a rapid cook hot air impingement deck oven, while the second unit was a hot air impingement conveyor oven with batch cooking capabilities. For the conveyor oven, when operating as a continuous conveyor, the cooking chamber is open at the entrance and exit of the oven with the conveyor belt set to a programmable constant speed. When operating as a batch cooking oven, the cooking chamber has doors that open to allow for loading/unloading food product and close during idle or cooking periods. Both the deck oven and the conveyor oven had programmable recipe features.

The cooking method for each oven was based on a modification of the standard test methods ASTM F2238-16 (Rapid Cook Ovens) and ASTM F1817-17 (Conveyor Ovens). The objective was to test and compare each cooking scenario with popular food products and the standard ASTM thick crust pizza test product. The final product was examined qualitatively (color, cheese melt, and so forth) and quantitatively (internal temperature) to determine an appropriate cook time for each item. A corporate chef was evaluating the qualitative aspects of the cooking process. Sub sandwiches, refrigerated chicken wings, thin crust pizzas and refrigerated thick crust pizzas were cooked on wire mesh screens. Fresh chopped veggies were cooked on ½ size sheet pans.

Figure F-8: Sub Sandwich Test

Source: Frontier Energy, Inc.

Figure F-9: ASTM Specification Thick Crust Pizza Test

Source: Frontier Energy, Inc.

Figure F-10: Chicken Wings Test

Source: Frontier Energy, Inc.

Figure F-11: Roasted Vegetables Test

Source: Frontier Energy, Inc.

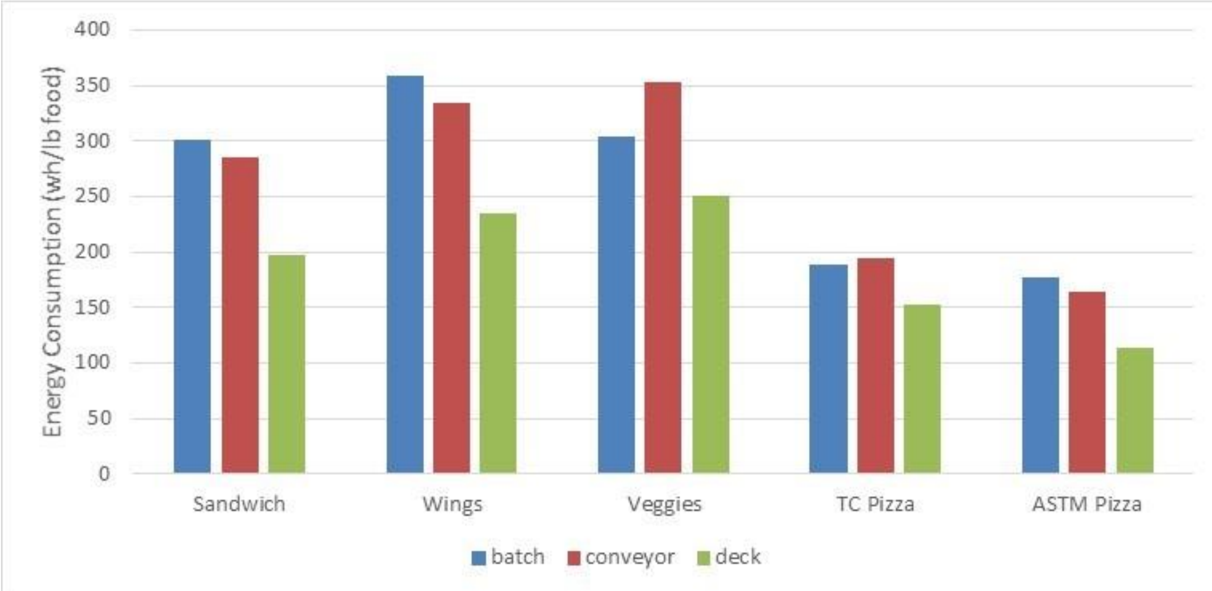
In summary, there was a strong correlation between products with a higher moisture content and energy consumed during cooking period per pound of food. Both ASTM and Thin Crust Pizzas consumed the least amount of energy per pound of cook product due to the lower moisture content and shorter cook duration. The chicken wings and vegetables were the two items that consumed the most energy per pound of cooked product. For the vegetables, this was a direct result of the high moisture content and the additional power required for the heating elements due to the cooling caused by vaporization. The chicken wings resulted in a higher energy consumption due to the longer cook time required to achieve an appropriate average internal temperature. On average, the deck oven consumed less energy per pound of cook product but yielded a lower production capacity for each cook item when compared to the conveyor oven. The rapid cook conveyor oven consumed on average nearly the same amount of energy per pound of cook product for both batch and conveyor mode. However, batch mode cooking resulted in a considerably lower production capacity.

Table F-11: Food Product Cooking Comparison for Various Rapid Cook Oven Setups

	Appliance	Sandwich	Wings	Vegetables	TC Pizza	ASTM Pizza
Normalized Energy Consumption (Wh/lb)	Batch	301	358	304	188	177
	Conveyor	285	335	353	194	163
	Deck	197	234	251	152	114
Moisture Content After Cooking (%)	Batch	6.4	17.7	38.2	16.2	5.9
	Conveyor	10.8	16.2	45.3	9.4	7.5
	Deck	3.4	18.5	38.0	12.1	17.8

Source: Frontier Energy, Inc.

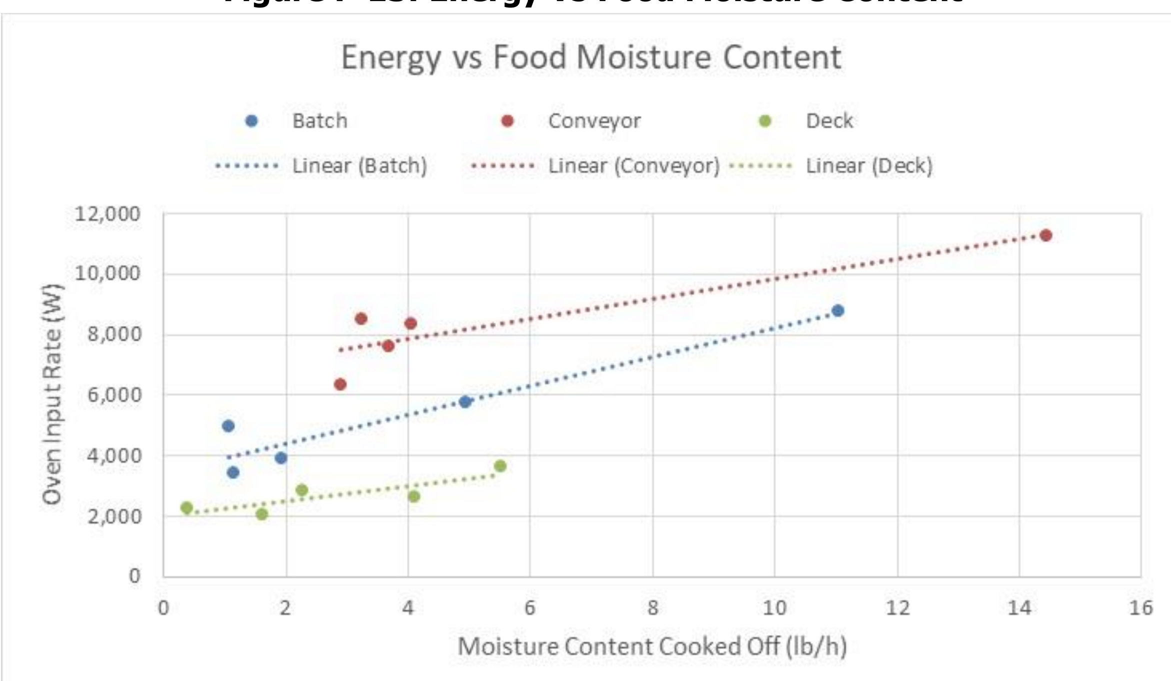
Figure F-12: Comparison of Energy Intensity Required for Cooking Various Food Products



Source: Frontier Energy, Inc.

Frontier Energy observed that the moisture content of the cooked food product directly correlated to the oven input rate required to cook the food product on the appliance input rate for each cooking scenario. This data can be useful to a restaurant operator who wants to estimate energy usage and operating costs for menu items. Additionally, an operator may consider the demands of their operation. While a conveyor oven can achieve higher production capacities, it immediately sacrifices efficiency when not loaded in a continuous setting.

Figure F-13: Energy Vs Food Moisture Content



Source: Frontier Energy, Inc.

Rapid Cook Oven Energy and Cost Analysis

Frontier Energy monitored rapid cook ovens installed in market segments ranging from small cafés to large cafeterias. With 343 days and 14.4 hours per day operation, the average energy consumption per rapid cook oven was 6964 kWh per year. Assuming a cost of $0.15 per kWh, the annual operating cost of each rapid cook oven is about $1,000 per year. The average cooking and idle energy rate based on the field data was 1.4 kW for rapid cook ovens.

Table F-12: Rapid Cook Oven Site Energy Data

Site	Rapid Cook Oven Size	Hours of Operation	Days Per Year	kWh/day
Sandwich Shop	Medium	9.7	364	12.8
Cafeteria	Large	9.1	261	24.9
QSR	Small (2x)	24	364	22.6 + 27.7
Large Café	Small (2x)	16	364	16.2 + 18.3
Small Café	Medium	13.1	364	21.3
Average per Oven		14.4	343	20.3

Source: Frontier Energy, Inc.

Advanced panini presses used less energy than rapid cook convection ovens based on the data from two sites. With 313 days and 11 hours per day operation, the average energy consumption per panini press is 2066 kWh per year. Assuming a cost of $0.15 per kWh, the annual operating cost of each panini press is $300 per year. The average cooking and idle energy rate based on the field data was 0.6 kW for advanced panini press.

Table F-13: Microwave Panini Press Site Energy Data

Site	Number of Advanced Panini Grills	Hours of Operation	Days Per Year	kWh/day
Large Café	2	18	364	12.1 + 9.6
Cafeteria	2	4.1	261	3.1 + 1.4
Average per Grill		11	313	6.6

Source: Frontier Energy, Inc.

APPENDIX G: Technology Transfer Plan

Technology Transfer Plan Execution

The Frontier Energy Food Service Technology Center (FSTC) Outreach Team successfully implemented the technology/knowledge transfer activities outlined in the Technology/Knowledge Transfer Plan that was submitted to the CEC as a requirement of the project workplan in June 2018.

Frontier Energy disseminated technical information and knowledge gained from this demonstration project by leveraging the FSTC's long-standing workforce education and training and information-outreach program (www.fishnick.com) for foodservice as well as the strategic industry partnerships it has forged over the past three decades. The objective of the education and outreach was to communicate the benefits of high efficiency, electric, commercial grade, cooking and holding equipment from both an energy/carbon reduction and a performance standpoint. The technology transfer program used a variety of teaching and demonstration formats to highlight the various energy efficient equipment options available with an end goal to overcome traditional market barriers and accelerate the adoption and implementation of energy efficient electric cooking and holding equipment in the CFS market place. In addition to sharing information specific to the appliances studied in the project, the education and training included best design practices that are necessary to create the right economic and performance environment for the successful integration of high-efficiency electric appliances into current commercial kitchen operations.

Workforce Education and Training (WE&T) is an ongoing program offered to the foodservice sector by California's four Investor Owned Utilities (IOUs) through the statewide California Energy Wise (CAEnergyWise.com) seminar program. Energy efficiency seminars, workshops, and webinars provide a forum in which a group of market actors is delivered extensive information on energy efficient technology and/or the application of energy efficient technology. The Frontier Energy Outreach Team leveraged data and information gleaned from the CEC demonstration project to enhance existing seminar sessions and develop fresh seminars and webinars built around the new-found knowledge/information and tools. Frontier Energy coordinated development, promotion, and delivery of these seminars. Many of the education and outreach events were facilitated using the Frontier Energy Food Service Technology Center in collaboration with the PG&E's Workforce Education and Training (WE&T) program. Other seminars and workshops were offered in southern California in collaboration with the SDG&E, SCE, and SoCalGas foodservice energy efficiency training centers.

Frontier Energy also leveraged its partnerships with established industry professional and trade entities, regional and national conferences, and media organizations, to share the lessons learned from the CEC research to the wider foodservice and design industry including kitchen designers, equipment specifiers, architects, engineers, energy efficiency consultations, utility professionals, policy makers, and other high-level market actors. Information outreach was delivered through various modes and venues including seminars, demonstrations, poster sessions, webinars, articles, papers and interviews.

Additionally, the data filtered through to CFS industry actors via design consultations; energy efficiency site audits for local restauranteurs; routine interface with manufacturers and their representatives; and the Frontier Energy Food Service Technology Center website at www.fishnick.com. Three (3) representative case studies were developed to highlight key findings and promote market acceleration for the most promising technologies. The case studies were distributed through existing FSTC and CEC outreach channels.

Targeted Audience

In order to break down long-standing market barriers and actualize behavior change within an industry as large and diverse as CFS, it is necessary to address the widest possible audience of market actors and focus the message on the needs, values, and incentives of each target audience. The CEC Plug Load Project technology transfer and education program included the following influential groups:

- Engineers and Architects
- Facility Designers/Consultants
- Equipment Specifiers and Foodservice Directors
- Equipment Manufacturers
- Equipment Dealers & Representatives
- Equipment Service Agents
- Contractors and Installers
- Utility professionals, Energy-Efficiency Consultants, and Policy Makers
- Commercial foodservice Operators – larger and smaller chains, franchisees, and independent owner/operators
- Non-commercial (institutional) foodservice Operators such as hotel, hospital, business, commissary kitchens, K12 Unified School Districts, and campus kitchen/dining facilities
- Culinary Students, Hospitality and Foodservice Management Students, and Foodservice Instructors
- Professional / Trade Organizations, Associations and Societies
    - California Restaurant Association (CRA), the Golden Gate Restaurant Association (GGRA) and the National Restaurant Association (NRA)
    - American Culinary Federation (ACF)
    - North American Association of Food Equipment Manufacturers (NAFEM)
    - Manufacturers Agents for the Food Service Industry (MAFSI)
    - Restaurant Facility Management Association (RFMA)
    - Commercial Foods Equipment Service Association (CFESA)
    - Foodservice Consultants Society International (FCSI)
    - The Edison Electric Institute (EEI)
    - The New Buildings Institute (NBI)
    - The American Institute of Architects (AIA) SF Chapter
    - The League of Women Voters (LOWV)

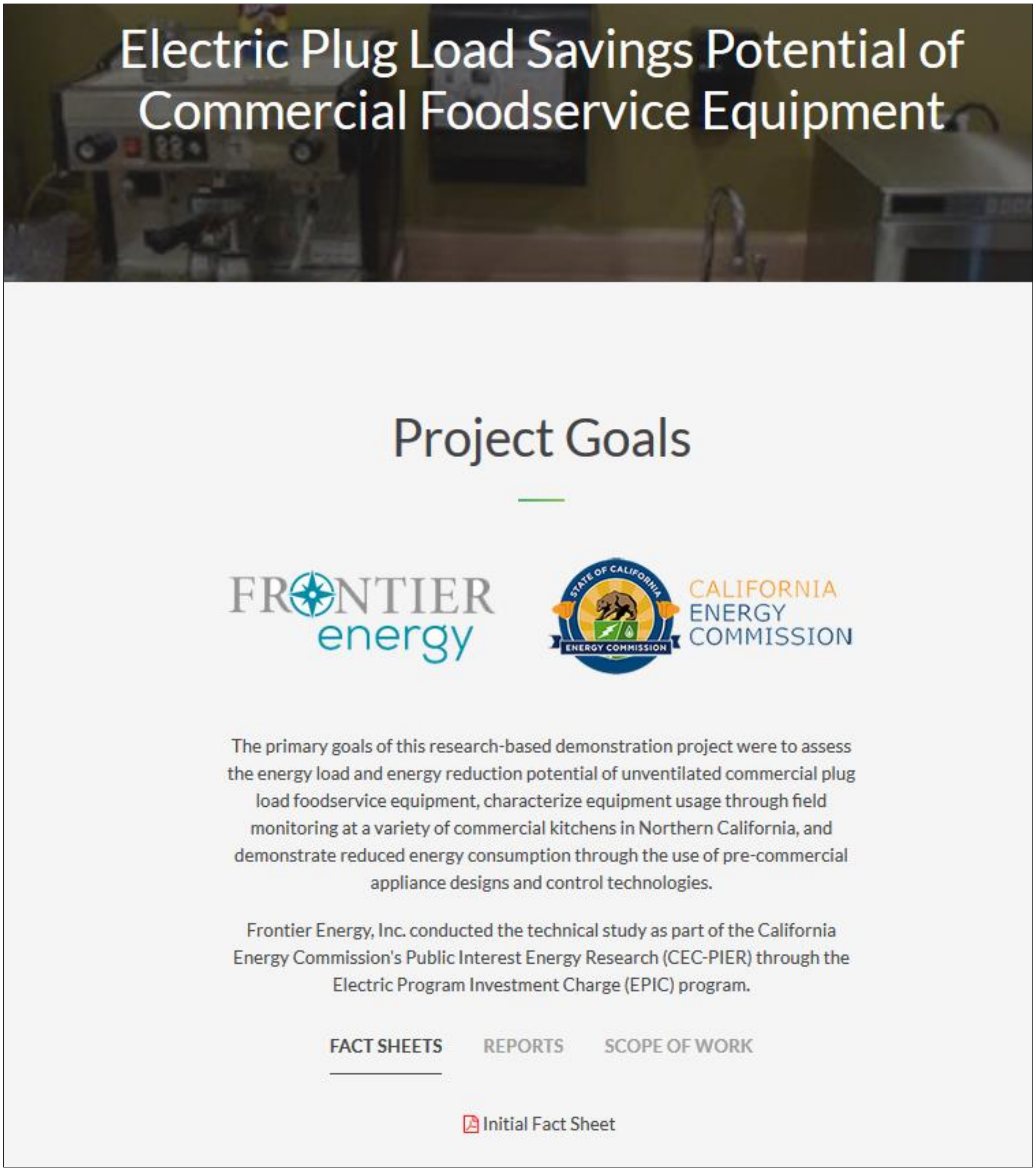
    - The American Society of Plumbing Engineers (ASPE) Northern CA Chapter
- Media – articles, technical features and/or interviews including Foodservice equipment Reports magazine, Nation’s Restaurant News (NRN), and Foodservice Equipment Reports magazine
- Government entities such as correctional, military kitchen/dining facilities
- Codes and Standards bodies/advocates
    - ASTM
    - Consortium for Energy Efficiency (CEE)
    - California Energy Commission (CEC)
    - Department of Energy – Environmental Protection Agency (DOE EPA)
    - The City of Berkeley City Council
    - The San Francisco Department of the Environment
- Utilities – Energy Centers, CA Statewide IOU Advisory Council Meetings, Codes & Standards, Incentives and Emerging Technologies groups
- Other Research Organizations

Technology Transfer Platform

Project Webpage

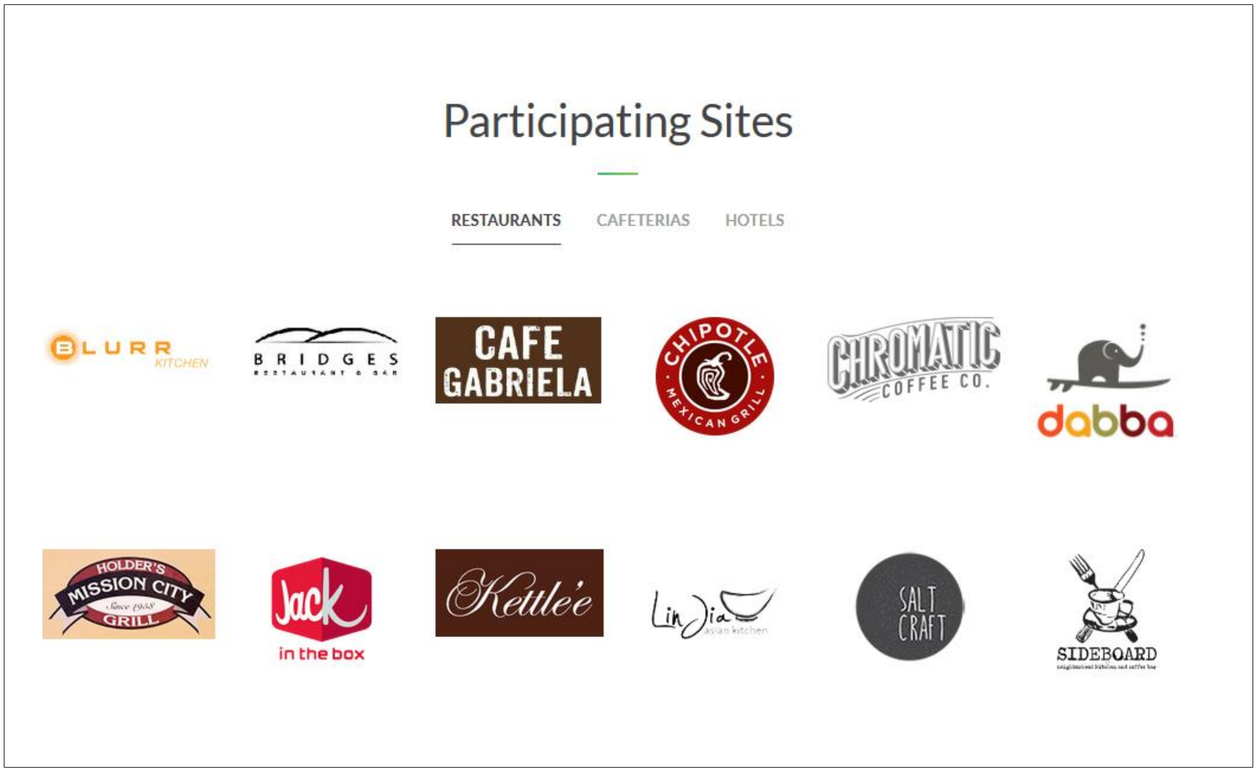
In order to organize and showcase the extensive results of the Plug Load project, Frontier Energy developed a comprehensive project webpage unique to the research project: https://fishnick.com/cecplug/ The following figures show sample pages from the site.

Figure G-1: Sample Page with Project Goals



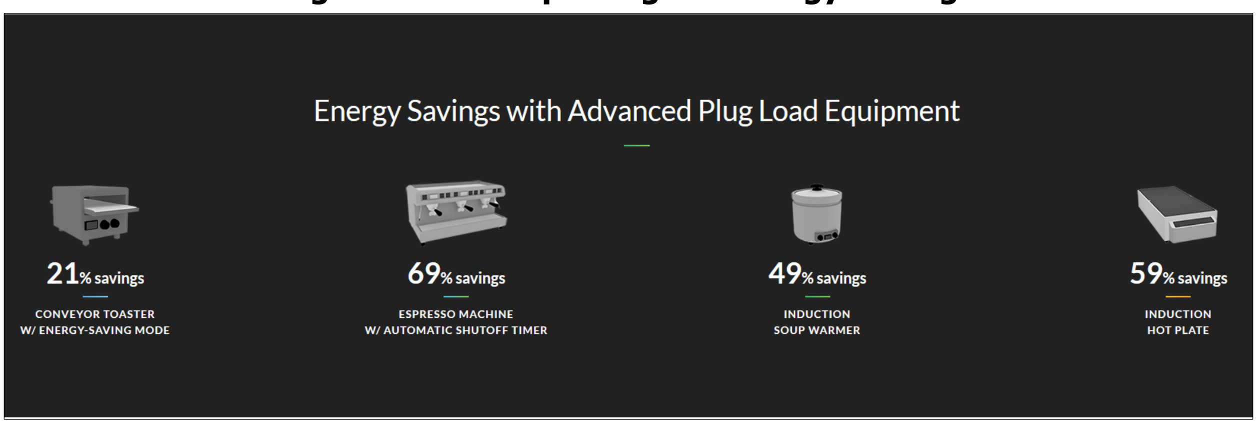
Source: Frontier Energy, Inc.

Figure G-2: Sample Page of Participating Sites



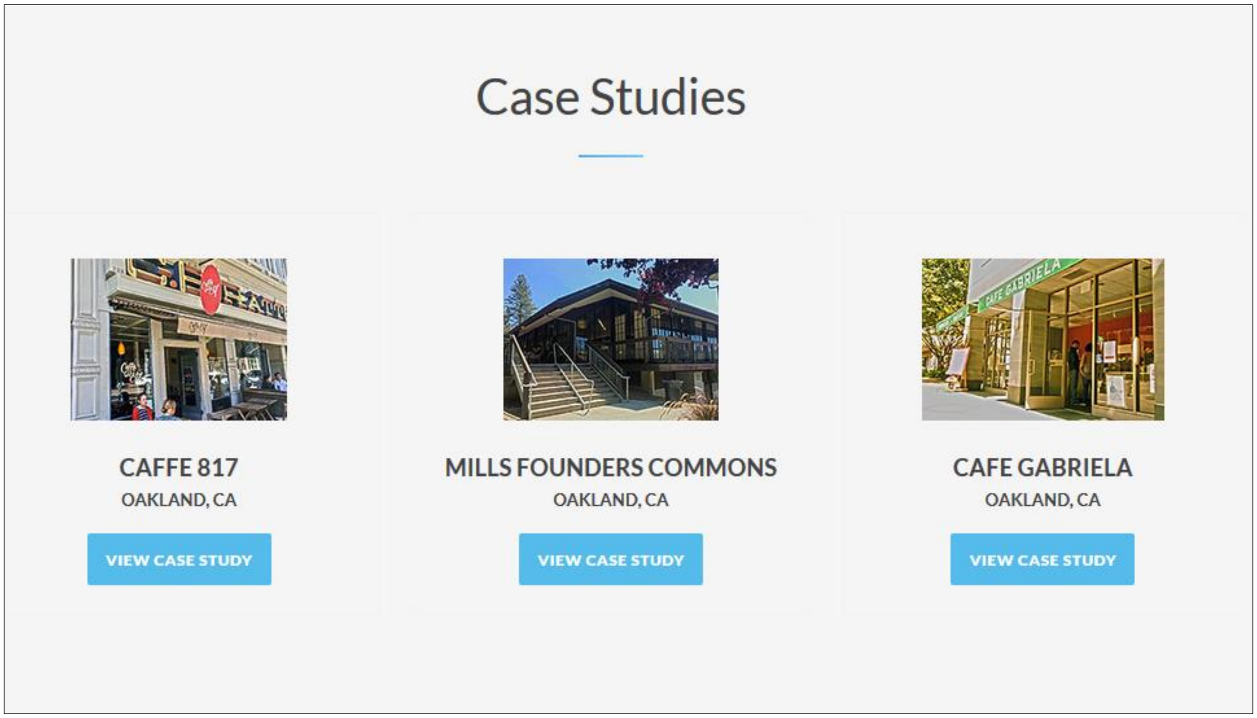
Source: Frontier Energy, Inc.

Figure G-3: Sample Page of Energy Savings



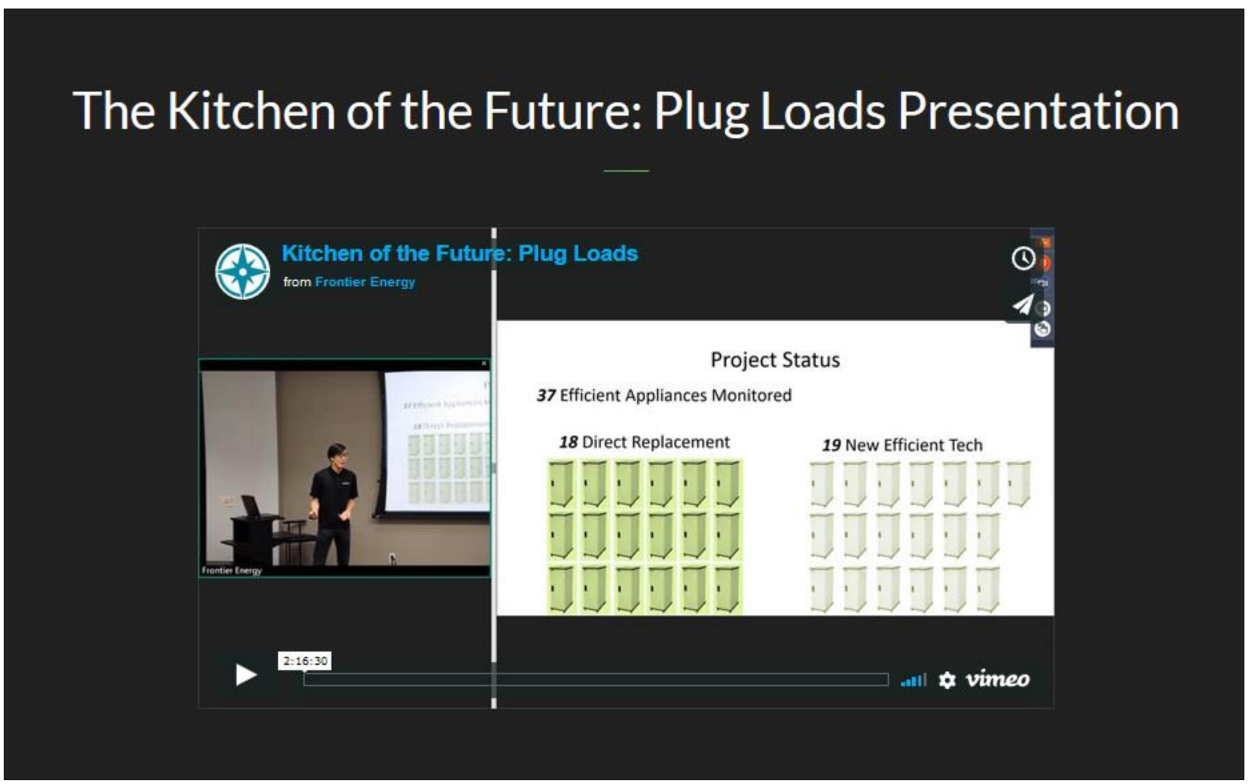
Source: Frontier Energy, Inc.

Figure G-4: Sample Page of Case Studies



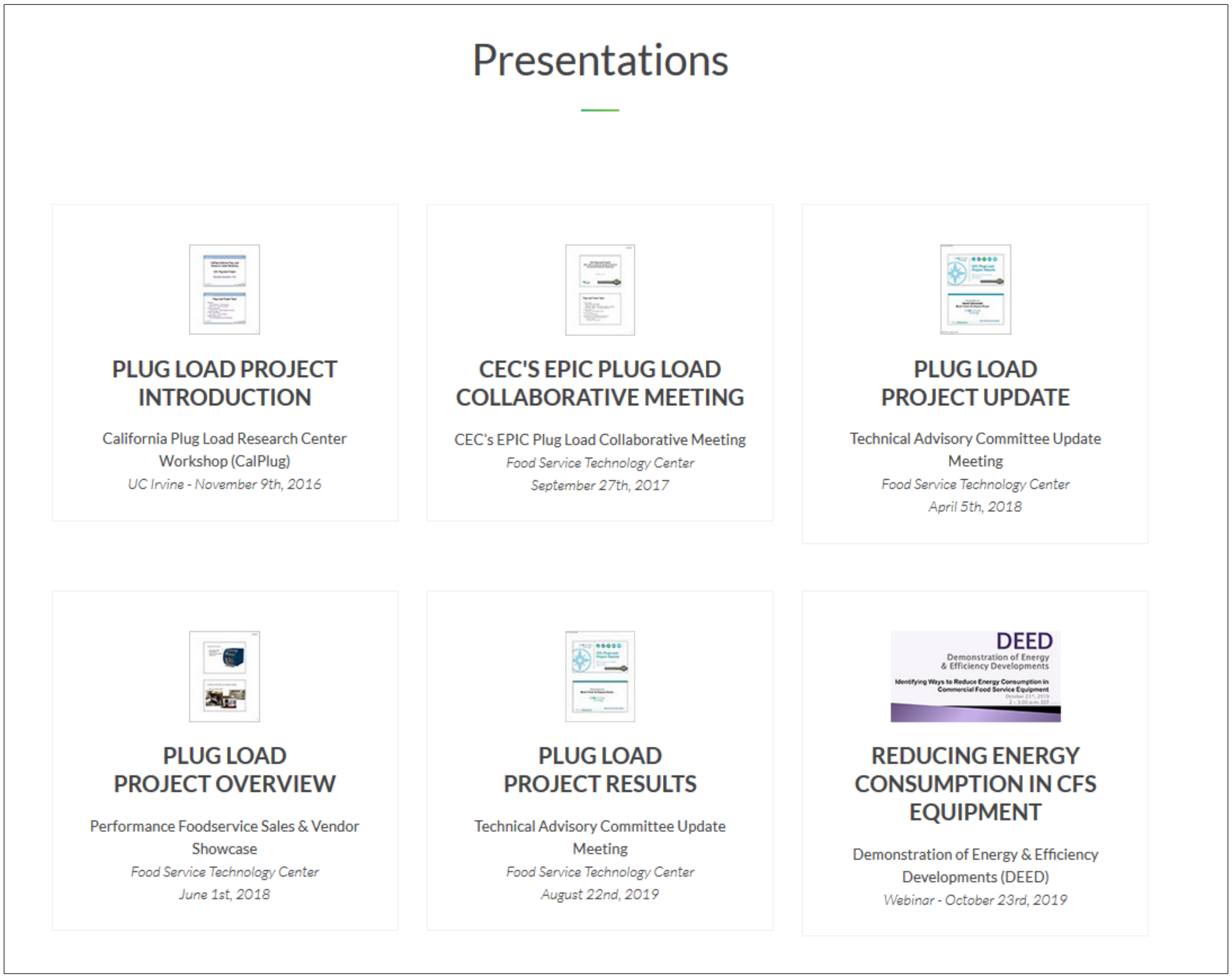
Source: Frontier Energy, Inc.

Figure G-5: Sample Page of Kitchen of the Future



Source: Frontier Energy, Inc.

Figure G-6: Sample Page of Presentations Sites



Source: Frontier Energy, Inc.

- 06/01/2016 – Launched Project Webpage: Project webpage was originally created for the Technical Advisory Committee (TAC) to access necessary documents and information regarding the project (meeting agendas, meeting minutes, presentations and project updates). It required a login and password to access information.
- 05/02/2018 – Launched Public Facing Version: Project webpage was updated to a public facing page and accessible without a password or login. The page provides an overview of the project, case studies, media coverage and more. The documents associated to the TAC are still accessible via login and password.

Project Case Studies

Developed three case studies showcasing the successes and lessons learned for three of the represented technologies at three different sites.

- Induction Soup Well Study – Caffe 817 – Oakland, CA
- High Efficiency Espresso Machine Study – Café Gabriela – Oakland, CA
- High Efficiency "Smart" Toaster Study – Mills College - Oakland, CA

The case studies are available at https://fishnick.com/cecplug/

Figure G-7: Project Case Studies

Source: Frontier Energy, Inc.

Project Fact Sheets

Developed two fact sheets summarizing the project.

- Initial Project Fact Sheet – developed prior to the start of the project to highlight and outline the goal of the project.
- Final Project Fact Sheet – developed at the completion of the project to highlight the project outcomes.

The project fact sheets are available at: https://fishnick.com/cecplug/

California Energy Wise (CEW) Seminars

Frontier Energy created and delivered a series of two-hour (2 h) seminars in partnership with the California Energy Wise program highlighting results from the CEC demonstration project. Presentation materials were developed for new plug load specific seminars such as Putting the Kitchen of the Future to the Test and CEC project results were also incorporated into existing seminar materials such as Fast, Small, Flexible Kitchens. CEW seminars are directed at a wide variety of market actors including, but not limited to, commercial and non-commercial foodservice operators/owners, the engineering and design community, manufacturers and their representatives, contractors and installers, government entities, codes and standard bodies and advocate groups, utilities and other researchers.

Delivered Seminars

Topic: High Speed Ovens: High Tech Solutions for Production Challenges

Outcome: Participants learned about the different types of countertop high speed ovens, how they can be used effectively, and how they fit into the modern commercial kitchen. Shared results from the plug load project.

- Date: August 27, 2019
  - Location: Foodservice Technology Center, SoCal Edison – Irwindale, CA
  - Audience: Manufacturer Reps, End Users, Consultants, Manufacturer, Government
  - Number of Attendees: 35
  - Speaker: David Zabrowski, Frontier Energy Project Manager

- Date: April 30, 2019
    - Location: Frontier Energy, Foodservice Technology Center (FSTC), San Ramon, CA
    - Audience: Manufacturer Reps, End Users, Consultants, Manufacturer, Government
    - Number of Attendees: 53 (includes live broadcast attendees)
    - Speaker: Richard Young, Frontier Energy Director of Education

Figure G-8: High Speed Ovens Demonstrated during the Seminar

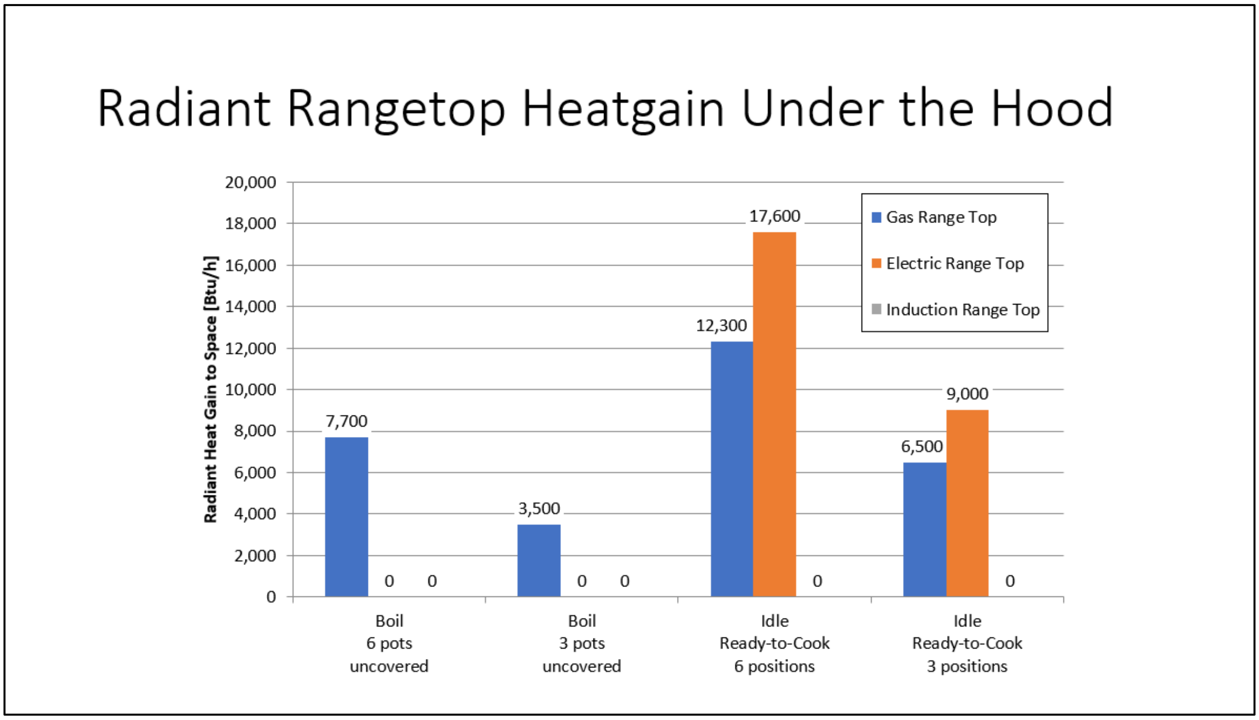
Source: Frontier Energy, Inc.

Topic – Cool It: How to Create More Comfortable Kitchens

Outcome: Participants learned about the findings and results from the plug load project and that relates to creating more comfortable kitchens for workers.

- Date: July 25, 2019
    - Location: Frontier Energy, Foodservice Technology Center (FSTC), San Ramon, CA
    - Audience: Manufacturer Reps, End Users, Consultants, Manufacturer, Government
    - Number of Attendees: 35
    - Speaker: Richard Young, Frontier Energy Director of Education

Figure G-9: Slide Comparing Radiant Heatgain for Gas, Electric Resistance and Induction Rangetops



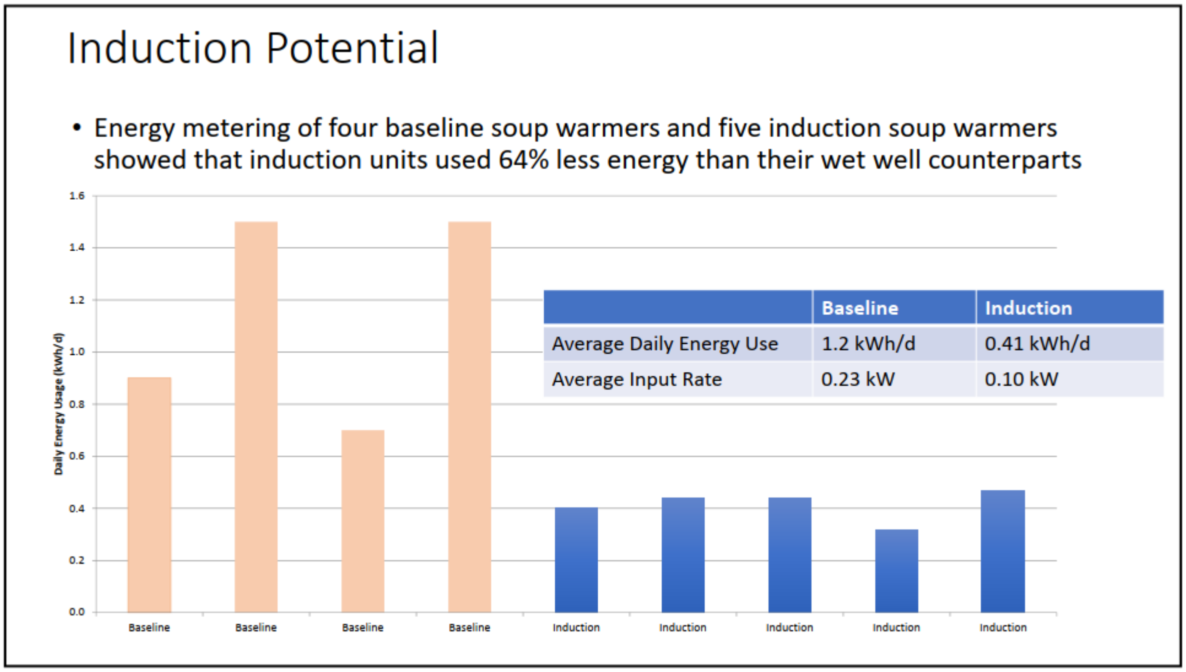
Source: Frontier Energy, Inc.

Topic – Putting the Kitchen of the Future to the Test: Real Stories from the Frontline of Equipment Efficiency

Outcome: Participants learned about an overview of the plug load projects, the results and findings from field studies and discussed specific case studies from the project.

- Date: March 19, 2019
  - Location: Foodservice Technology Center, SoCal Edison – Irwindale, CA
  - Audience: Manufactures, end-users, manufacture reps, suppliers and schools
  - Number of Attendees: 27
  - Speakers: David Zabrowski, Frontier Energy Project Manager
- Date: November 20, 2018
  - Location: Frontier Energy, Foodservice Technology Center (FSTC), San Ramon, CA
  - Audience: Manufacturers, Operators, Consultants, Manufacturer Reps, Government
  - Number of Attendees: 15
  - Speakers: Richard Young, Frontier Energy Director, Mark Finck, Frontier Energy Lab Manager and Edward Ruan, Frontier Energy Engineer

Figure G-10: Presentation slide showing field-measured energy savings of induction soup wells



Source: Frontier Energy, Inc.

Topic – Build a Better Burger

Outcome: Provided an overview of energy efficiency in commercial foodservice, descriptions of different types of efficient equipment for specific operations. Shared findings from field studies from the plug load project.

- Date: October 17, 2019
  - Location: Foodservice Technology Center, SoCal Edison – Irwindale, CA
  - Audience: Restaurant operators/owners, manufacturer reps and consultants
  - Number of Attendees: 25
  - Speaker: Richard Young, Frontier Energy Director of Education
- Date: September 14, 2017
  - Location: Foodservice Technology Center, SoCal Edison – Irwindale, CA
  - Audience: Restaurant operators/owners, manufacturer reps and consultants
  - Number of Attendees: 20
  - Speaker: Mark Finck, Frontier Energy Project Manager
- Date: September 12, 2017
  - Location: Frontier Energy, Foodservice Technology Center (FSTC), San Ramon, CA
  - Audience: Restaurant operators/owners, manufacturer reps and consultants
  - Number of Attendees: 15
  - Speaker: Mark Finck, Frontier Energy Project Manager

Topic – Where are all the Cooks? Solving Labor and Production Challenges with the Kitchen of the Future

Outcome: Participants learned about different technologies such as programmable and self-cleaning ovens, easy to maintain induction cooking and holding. Provided an overview of energy efficiency in commercial foodservice, descriptions of different heating technologies, benefits of induction for cooking applications and case studies in energy efficiency using induction technology. Shared findings from field studies from the plug load project.

- Date: May 30, 2019
  - Location: Frontier Energy, Foodservice Technology Center (FSTC), San Ramon, CA
  - Audience: Manufacturer Reps, End Users, Consultants, Manufacturer, Government
  - Number of Attendees: 23
  - Speaker: Richard Young, Frontier Energy Director of Education & Mark Duesler, Frontier Energy Chef Consultant

Topic – Hot Induction Technology for Cooler Kitchens

Outcome: Provided an overview of energy efficiency in commercial foodservice, descriptions of different heating technologies, benefits of induction for cooking applications and case studies in energy efficiency using induction technology.

- Date: November 15, 2018
  - Location: Foodservice Technology Center, SoCal Edison – Irwindale, CA
  - Audience: Manufacturers, Operators, Consultants, Manufacturer Reps, Government
  - Number of Attendees: 60
  - Speaker: Richard Young, Frontier Energy Director of Education

Figure G-11: Induction Equipment used in classes and demonstrations

Source: Frontier Energy, Inc.

Topic – Fast, Small & Flexible

Outcome: Provided the findings from different types of plug load equipment that have been monitored and replaced in different commercial kitchens. Shared which unhooded electrical appliances had the greatest energy savings potential and results.

- Date: September 2018
  - Location: Foodservice Technology Center, SoCal Edison – Irwindale, CA
  - Audience: Utilities, Government, Operators and Energy Consultants
  - Number of Attendees: 24
  - Speaker: Mark Finck, Frontier Energy Lab Manager

Topic – Take Your BBQ to the Next Level

Outcome: Provided the findings from different types of plug load equipment that have been monitored and replaced in different commercial kitchens. Shared which unhooded electrical appliances had the greatest energy savings potential and results.

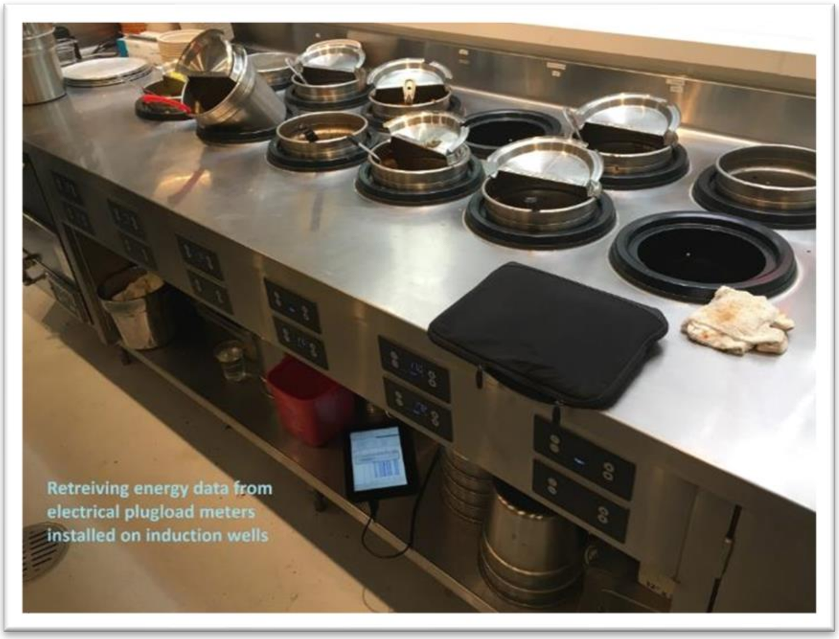
- Date: September 2018
  - Location: Frontier Energy, Foodservice Technology Center (FSTC), San Ramon, CA
  - Audience: Utilities, Government, Operators and Energy Consultants
  - Number of Attendees: 25
  - Speaker: Mark Finck, Frontier Energy Lab Manager

Topic – Fast Track for Transitioning to Food Trucks

Outcome: Shared Plug Load energy results from the monitoring of the induction tables at Dabba in San Francisco compared to standard steam tables.

- Date: July 2017
  - Location: SoCal Gas, Food Service Equipment Center, Downey, CA
  - Audience: Utilities, Government, Operators and Energy Consultants
  - Number of Attendees: 58
  - Speaker: Mark Finck, Frontier Energy Lab Manager

Figure G-12: Monitoring Induction Hot Wells at Dabba Restaurant



Source: Frontier Energy, Inc.

Topic – Foodservice in Motion: From the Food Truck to Brick & Mortar
Outcome: Shared Plug Load energy results from the monitoring of the induction tables at Dabba in San Francisco compared to standard steam tables.

- Date: July 2017
    - Location: Frontier Energy, Food Service Technology Center, San Ramon, CA
    - Audience: Utilities, Government, Operators and Energy Consultants
    - Number of Attendees: 18
    - Speaker: Mark Finck, Frontier Energy Lab Manager

Topic – Setting Up a New Restaurant
Outcome: Shared summary of the Plug Load Project.

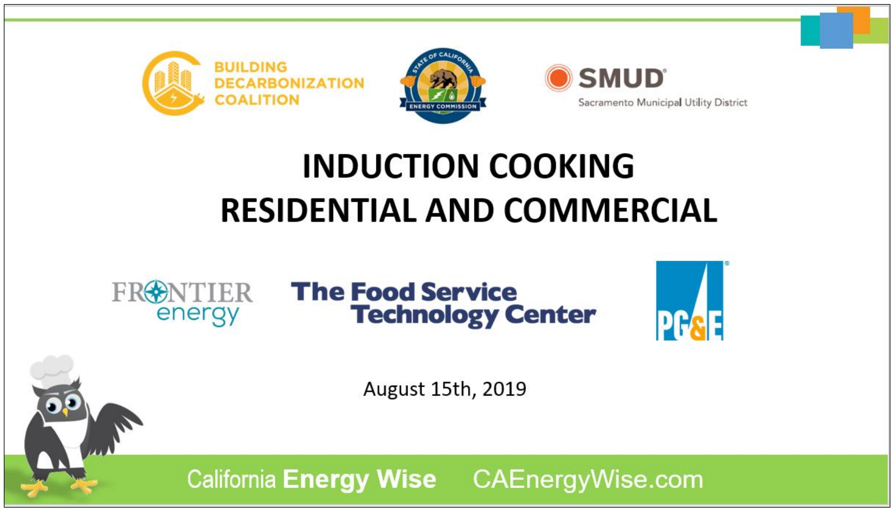
- Date: April 2017
    - Location: San Diego Gas & Electric, Energy Innovation Center, San Diego, CA
    - Audience: Utilities, Government, Operators and Energy Consultants
    - Number of Attendees: 11
    - Speaker: Mark Finck, Frontier Energy Lab Manager

Delivered Webinars:
Topic – Building Decarbonization Coalition
Outcome: Participated in a webinar and discussed the results and findings from the Plug Load Project.

- Date: August 15, 2019

    - Audience: Cross-section of Commercial Foodservice industry professionals: architects, utilities, designers, consultants, end users
    - Number of Attendees: 119
    - Speakers: Richard Young, Frontier Energy Director of Education

Figure G-13: Partnering with the Building Decarbonization Coalition



Source: Frontier Energy, Inc.

Topic: What You Need to Know Before NRA Webinar

Outcome: Participants learned about small appliance category of new equipment being introduced at the NRA Show and called out to manufacturers that would like to support the project with some of these new appliances.

- Date: May 2018
    - Audience: Facility managers, equipment manufacturers and industry professionals
    - Number of Attendees: 37
    - Speakers: Richard Young, Frontier Energy Director of Education, David Zabrowski, Frontier Energy General Manager, and Mark Finck, Frontier Energy Lab Manager

Industry Outreach

Project data, results, and lessons learned with shared with high-level industry professionals in a variety of ways including seminars, demonstrations, poster sessions, webinars, articles, papers, and media interviews. Social media was also used to promote the project results including Facebook, LinkedIn, Twitter, Instagram and the fishnick.com website. Outreach events were primarily delivered to targeted audiences at invitation of industry hosts. Events were chronicled in the Monthly Progress Reports. Successful industry outreach events delivered to date along with scheduled events are listed below.

Delivered Industry Seminars

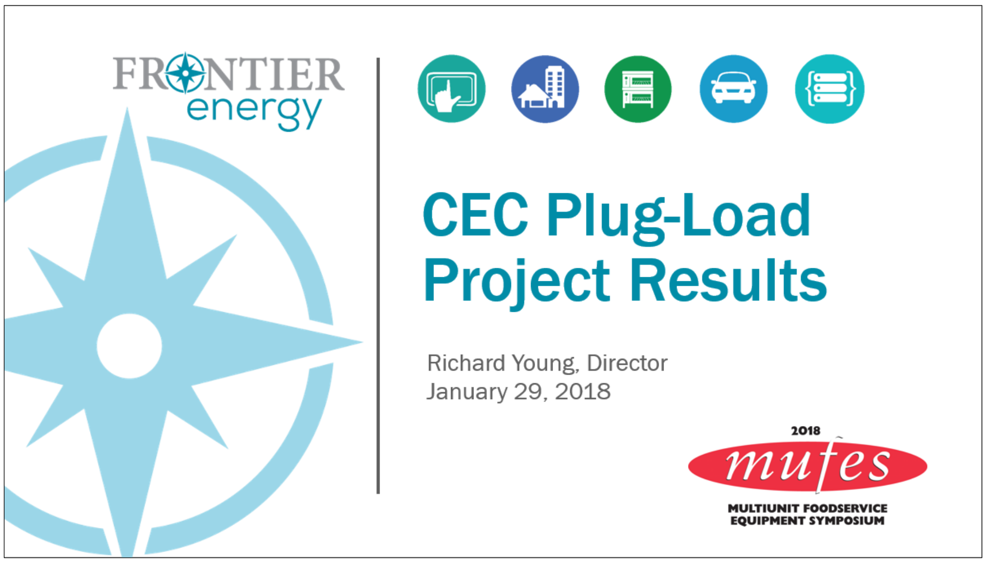
Multi-Unit Foodservice Equipment Symposium (MUFES) Conference

Topic – CEC Plug Load Project Results

Outcome: Provided an overview on the project and findings from the Plug-Load research project to-date. Put out a call to manufacturers for equipment.

- Date: January 16, 2018
    - Location: Austin, TX
    - Audience: Foodservice consultants/designers, manufacturers, industry media, engineers, and architects, directors of industry associations – mostly related to large restaurant chains
    - Number of Attendees: 100
    - Speaker: Richard Young, Frontier Energy Director of Education

Figure G-14: Behavior, Energy, and Climate Change (BECC) Conference



Source: Frontier Energy, Inc.

Topic: Using Energy Efficiency to Decarbonization Commercial Kitchens

Outcome: Richard Young presented on Using Energy Efficiency to Decarbonize Commercial Kitchens in a class that included a poster presentation as well as a Poster Session and hands-on induction cook-top training at the BECC Conference in Sacramento. The presentation focused on high efficiency electric cooking and holding equipment, including induction cooktops and soup wells. Shared results from the Plug Load project.

- Date: November 19, 2019
    - Location: Sacramento, CA
    - Audience: Consultants, Designers, Architects
    - Number of Attendees: 24
    - Speaker: Richard Young, Frontier Energy Director of Education

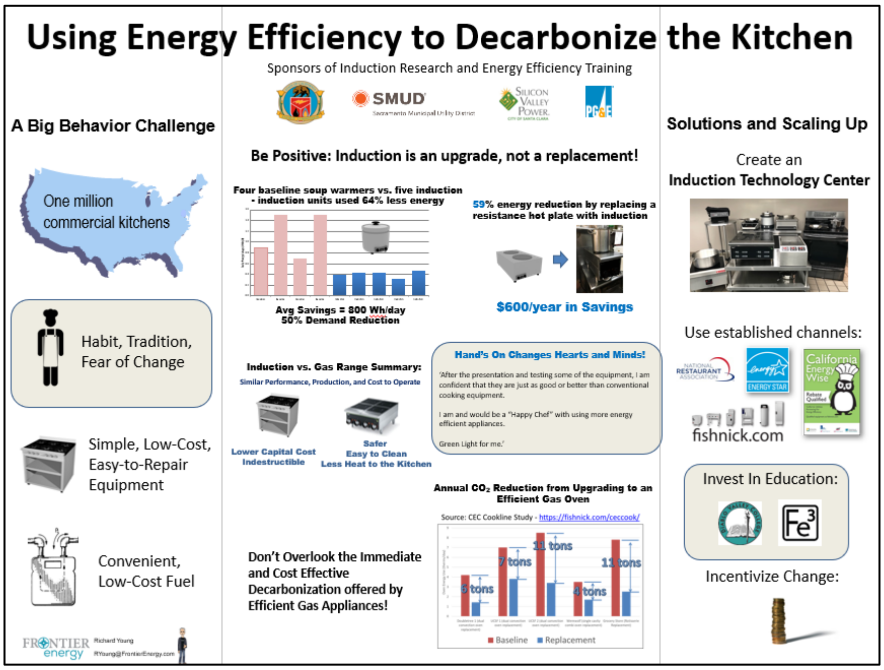
Topic: Using Energy Efficiency to Decarbonization Commercial Kitchens

Outcome: Richard Young presented on "Using Energy Efficiency to Decarbonize Commercial Kitchens" at the Behavior Energy and Climate Change conference in Sacramento. The presentation also promoted high-efficiency gas appliances as a direct means to quickly and effectively reduce carbon emissions in commercial kitchens and presented findings from the case study performed by the FSTC for the CEC. Co-presenters included the UC Office of the

President Department of Sustainability and the session was moderated by Laurie ten Hope of the CEC.

- Date: November 20, 2019
  - Location: Sacramento, CA
  - Audience: Consultants, Designers, Architects
  - Number of Attendees: 47
  - Speaker: Richard Young, Frontier Energy Director of Education

Figure G-15: Poster for BECC Poster Session and Induction Range Demonstration



Source: Frontier Energy, Inc.

New Building Institute (NBI) Conference

Topic: Using Energy Efficiency to Decarbonization Commercial Kitchens

Outcome: Frontier Energy's Richard Young and Chef Mark Duesler presented on Using Energy Efficiency to Decarbonize Commercial Kitchens in a class that included a poster presentation as well as a hands-on induction cook-top training at the New Buildings Institute conference in Oakland. The presentation focused on high efficiency electric cooking and holding equipment, including induction cooktops and soup wells. They also shared results from the Plug Load project.

- Date: October 11, 2019
- Location: Oakland, CA
- Audience: Foodservice Industry
- Number of Attendees: 18
- Speaker: Richard Young, Frontier Energy Director of Education & Mark Duesler, Frontier Energy Chef Consultant

Topic: Using Energy Efficiency to Decarbonization the Commercial Kitchens

Outcome: Frontier Energy's Richard Young presented on Using Energy Efficiency to Decarbonize Commercial Kitchens at the New Buildings Institute conference in Oakland. The presentation focused on high efficiency electric cooking and holding equipment, including induction cooktops, combination ovens and induction woks. Richard also discussed the latest results from the Plug Load project.

- Date: October 12, 2019
  - Location: Oakland, CA
  - Audience: Foodservice Industry
  - Number of Attendees: 82
  - Speaker: Richard Young, Frontier Energy Director of Education & Mark Duesler, Frontier Energy Chef Consultant

National Restaurant Association (NRA) Show

Topic – CEC Plug Load Project

Outcome: Frontier Energy, David & Richard followed up with manufacturers on new technology candidates for the Plug Load project. Promoted the case studies to stakeholders. Reviewed new technologies on display at the Kitchen Innovations pavilion and met with trade allies, including Foodservice Equipment Reports and Foodservice Equipment & Supplies magazines to promote the findings from the project and highlight energy efficiency outcomes.

- Date: May 18-21, 2019
  - Location: Chicago, IL
  - Audience: Met with over 80 manufacturers, manufacturers reps, foodservice design consultants, foodservice media, and chain restaurant specifiers
  - Number of Attendees: 43,000+
  - Speaker: David Zabrowski, Frontier Energy Project Manager & Richard Young, Frontier Energy Director of Education

Topic – CEC Plug Load Project

Outcome: Frontier Energy, David & Richard met with different manufacturers to discuss the project with and see if they would like to participate in the project.

- Date: May 2018
  - Location: Chicago, IL
  - Audience: Facility managers, equipment manufacturers and industry professionals
  - Number of Attendees: 50
  - Speaker: David Zabrowski, Frontier Energy Project Manager & Richard Young, Frontier Energy Director of Education

Topic – CEC Plug Load Project

Outcome: Frontier Energy, David & Richard met with Laura Thomas (CEE) at the NRA Show. Provided an overview of the project to Laura. Laura presented this project to her utility members to determine if Plug Load may be a category, they want to focus future efforts on.

Identified manufacturers of Plug Load equipment exhibiting at the show and spent time learning more about their product line, technology and whether they could provide energy saving plug load solutions for the project. Met with Bunn and discussed their participation in the project. Spoke with Hatco at the show and got a first-hand look at their new line of smart toasters.

- Date: May 2017
  - Location: Chicago, IL
  - Audience: Facility managers, equipment manufacturers and industry professionals
  - Number of Attendees: 6
  - Speaker: David Zabrowski, Frontier Energy Project Manager & Richard Young, Frontier Energy Director of Education

Utility Energy Forum

Topic – CEC Plug Load Results

Outcome: Poster presentation of the CEC Plug Load results, co-presented with SMUD on induction cooktops

- Date: April 24-26, 2019
  - Location: Cambria, CA
  - Audience: RFMA members, Facility Managers from national restaurant chains, equipment manufacturers and industry media.
  - Number of Attendees: 60
  - Speaker: Richard Young, Frontier Energy Director of Education

Edison Electric Institute (EEI)

Topic: Electrification and Decarbonization in the Commercial Kitchen

Outcome: Presented Electrification and Decarbonization in the Commercial Kitchen which focused on energy efficiency results from the plug load project.

- Date: April 7-10, 2019
  - Location: Seattle, WA
  - Audience: Chain restaurant, big box grocery and retail commercial foodservice operators and utilities experts and other energy experts
  - Number of Attendees: 40
  - Speaker: Richard Young, Frontier Energy Director of Education

Restaurant Facility Management Association (RFMA)

Topic: CEC Plug Load Project

Outcome: Met with restaurant operators and discussed the latest draft results from the CEC project, shared the Plug Load project website and solicited operators for additional sites for the project field testing.

- Date: February 11-12, 2019
  - Location: Austin, TX

    - Audience: Foodservice customers and market actors, such as chain restaurant operators, service agents, and manufacturers
    - Number of Attendees: 10,000
    - Speaker: Richard Young, Frontier Energy Director of Education

Topic: CEC Plug Load Project

Outcome: Hosted a booth and met with restaurant operators and discussed the latest draft results from the CEC project, shared the Plug Load project website and solicited operators for additional sites for the project field testing.

- Date: March 4-6, 2018
    - Location: Phoenix, AZ
    - Audience: Foodservice customers and market actors, such as chain restaurant operators, service agents, and manufacturers
    - Number of Attendees: 25
    - Speaker: Richard Young, Frontier Energy Director of Education

North American Association of Food Equipment Manufacturers (NAFEM) Trade Show

Topic: CEC Plug Load Project

Outcome: Met with over 50 different industry contacts for extensive networking opportunities to get more manufactures involved with the project. CEC project learnings were offered and mentioned the project web site for follow-up of appliance data learnings.

- Date: February 7-9, 2019
  Location: Orlando, FL
    - Audience: Manufactures, End Users
    - Number of Attendees: 22,000
    - Speaker: Mark Finck, Frontier Energy Lab Manager & David Zabrowski, Frontier Energy Project Manager

Foodservice Consultants Society International (FCSI)

Topic: Tackling the Big Challenges of Commercial Kitchen Energy Efficiency and the Role of Ventilation Hoods

Outcome: Included project results in FCSI presentation. Coordinated with manufactures during the meetings.

- Date: February 5-6, 2019
    - Location: Orlando, FL
    - Audience: Designers, Manufactures
    - Number of Attendees: 100
    - Speakers: David Zabrowski, Frontier Energy Director of Education

Emerging Technologies (ET) Summit: Fall 2018

Topic: Commercial Kitchens: Keeping Technologies Fresh

Outcome: Presented an overview of the energy consumption and energy savings potential within the commercial foodservice sectors, illustrating with specific case study examples derived from the two studies. The audience was educated on the overall state of available technology for the commercial foodservice sector, as well as both the unique challenges faced by restaurant operators and the potential opportunities generated by new energy efficient appliance technologies.

- Date: October 10, 2018
    - Location: Downey, CA
    - Audience: 3rd party program implementers, cities, utility program managers, technology companies and government agencies
    - Number of Attendees: 75
    - Speaker: David Zabrowski, Frontier Energy Vice President

Pacific Energy Center – Open House

Topic: Induction Cooking Demonstration

Outcome: Provided a short demonstration on how induction cooking works. Discussed the findings from different types of plug load equipment that have been monitored and replaced in different commercial kitchens. Shared which unhooded electrical appliances had the greatest energy savings potential and results.

- Date: September 2018
    - Location: San Francisco, CA
    - Audience: Utilities, Government, Operators and Energy Consultants
    - Number of Attendees: 100
    - Speaker: Richard Young, Frontier Energy Outreach Manager, & Mark Duesler, Frontier Energy Chef Consultant, Foodservice

Topic: Commercial Kitchen Plug Load

Outcome: Provided the findings from different types of plug load equipment that have been monitored and replaced in different commercial kitchens. Shared which unhooded electrical appliances had the greatest energy savings potential and results.

- Date: May 2017
    - Location: San Francisco, CA
    - Audience: Architects and Engineers
    - Number of Attendees: 25
    - Speaker: Richard Young, Frontier Energy Outreach Manager

Electric Power Research Institute (EPRI) Electrification Conference

Topic: Electrification in the Foodservice Industry

Outcome: Provided the findings from different types of plug load equipment that have been monitored and replaced in different commercial kitchens. Shared which unhooded electrical appliances had the greatest energy savings potential and results.

- Date: August 2018
    - Location: Long Beach, CA
    - Audience: Utilities, Government, Operators and Energy Consultants
    - Number of Attendees: 25
    - Speaker: David Zabrowski, Frontier Energy Vice President

Topic: Advancing Foodservice with Electricity

Outcome: Provided the findings from different types of plug load equipment that have been monitored and replaced in different commercial kitchens. Shared which unhooded electrical appliances had the greatest energy savings potential and results.

- Date: August 2018
    - Location: Long Beach, CA
    - Audience: Utilities, Government, Operators and Energy Consultants
    - Number of Attendees: 60
    - Speaker: David Zabrowski, Frontier Energy Vice President

MISE Conference

Topic: Designing for Tomorrow: What Technology Can Do for Sustainable Kitchens Presentation

Outcome: Provided an overview of the CEC Plug Load Project.

- Date: August 2017
    - Location: Atlanta, GA
    - Audience: Hotel Chefs and National Hotel Chains
    - Number of Attendees: 70
    - Speaker: Mark Finck, Frontier Energy Project Manager

Other Industry Outreach Events:

- Northwest Energy Efficiency Exchange Conference – Portland, OR – May 2019
    - Frontier Energy spoke with TrickleStar and Embertec - both manufacturers of advanced power strips to learn more about the power strips and determine if they could be a good fit for the Plug Load project.
- F26 ASTM Committee Meeting – Chicago, IL - May 2017
    - Frontier Energy staff participated in the meeting and provided updates on the Plug Load project.
- Foodservice Equipment Reports Magazine Meeting – Chicago, IL – May 2017
    - Frontier Energy - met with Beth Lorenzini (Foodservice Equipment Reports) magazine during the NRA Show to discuss coverage for the Plug Load project in FER Magazine. Beth agreed to send an E-blast out to their readers regarding the project which will include a call out to manufacturers interested in participating in the project.
- California Energy Wise Quarterly Planning Meeting – San Ramon, CA – September 2017

    - Frontier Energy held the California Energy Wise Quarterly Planning Meeting at the center and provided an update on the Plug Load project during the quarterly meeting.
- EPIC Plug Load Collaborative Meeting – Sacramento, CA – September 2017
    - Frontier Energy discussed results and promoted synergies between the CEC's EPIC funded plug load projects. CEC staff and the grant recipient's principal investigator led discussions about plug load research, project results and remaining barriers to overcome.
- North West Utilities Meeting – September 2017
    - Frontier Energy met with NW utilities: shared results from the project with Tianna Byrtus - Puget Sound Energy and John Petosa - Snohomish PUD.
- National Culinary Review (Journal of the American Culinary Federations) – September 2017
    - Frontier Energy - Mark Finck participated in an interview with Karen Wiesberg for an upcoming article in the National Culinary Review (the journal for the American Culinary Federation). The article will make mention of the Plug Load project.
- Foodservice Equipment Reports (FER) Magazine – October 2017
    - Frontier Energy discussed the opportunity for Foodservice Equipment Reports (FER) to write an article on the project following the Plug-Load presentation at MUFES in January 2018.
- Vollrath Truck Demonstration – San Ramon, CA – October 2017
    - Frontier Energy invited guests to view the Vollrath Truck demonstration and provided the opportunity to discuss the Plug Load project with attendees and to show examples of Plug Load equipment to 10 attendees which included: Manufacturer Reps, Manufacturers, Operators, Consultants and Schools/Universities.
- Commercial Food Equipment Service Agent (CFESA) – Austin, TX – October 2017
    - Frontier Energy shared information on the Plug Load project with 15 attendees at the Commercial Food Equipment Service Agent (CFESA) conference.
- SoCal Gas 7th Annual Foodservice Equipment Expo – Downey, CA – October 2017
    - Frontier Energy discussed project with attendees and vendors at the 7th Annual SoCalGas Foodservice Equipment Expo 15 attendees.
- Silicon Valley Power Meeting – Santa Clara, CA – November 2017
    - Frontier Energy shared the Plug Load project with Mary Medeiros of Silicon Valley Power (SVP). SVP would like to know how they can get involved with the project by providing co-funding or site recommendations for monitoring. Mary recommended a smart power strip manufacturer (Embertec) that may be worth connecting with in addition to looking into Wemo - smart outlets as opportunities for the Plug Load Project.
- NAFEM TLC, ASTM F26 Meeting – Washington D.C. – November 2017

    - Frontier Energy – Denis Livchak, shared information about the plug load project results and needs for toasters, holding cabinets and induction equipment during the meeting.
- Wendy’s Corporate Meeting – Washington D.C. – November 17
    - Frontier Energy discussed project with Wendy's Corporate during the ASTM F26 meeting to see if they had an interest in participating in the project.
- Hatco Meeting – Washington D.C – November 2017
    - Frontier Energy connected with representatives from Hatco during the ASTM F26 meeting and shared the research that has been collected to date on the baseline Hatco toasters. Helped Hatco to understand energy use of existing models and the need and opportunity for energy efficient smart technology.
- McDonald’s Corporate Training – San Ramon, CA – November 2017
    - Frontier Energy – Richard Young, Kiana Caban, Edward Ruan & Mark Duesler, discussed plug load project with representatives from McDonald's corporate during McDonald's training held at the Food Service Technology Center in November. Shared the need for locations to monitor existing toasters for baseline data and the new replacement toasters that McDonald's is using in several of their location. The results from the monitoring will be used for the plug load project in addition to supporting PG&E efforts to develop rebates for toasters to 50 attendees which included: McDonald’s corporate, franchisees and employees.
- EPIC Conference – Napa, CA – April 2018
    - Frontier Energy – Richard Young, spoke to Hatco about induction and their strip warmers. Discussed the findings from different types of plug load equipment that have been monitored and replaced in different commercial kitchens to 30 attendees which included: manufactures and industry professionals.
- Herspring Gibbs Staff Training – San Ramon, CA – June 2018
    - Frontier Energy – Edward Ruan, discussed the findings from different types of plug load equipment that have been monitored and replaced in different commercial kitchens. Shared which unhooded electrical appliances had the greatest energy savings potential and results to 12 attendees which included: food distributors and industry professionals
- Performance Foodservice Group Sales Meeting – San Ramon, CA – June 2018
    - Frontier Energy – Edward Ruan, discussed the findings from different types of plug load equipment that have been monitored and replaced in different commercial kitchens. Shared which unhooded electrical appliances had the greatest energy savings potential and results to 45 attendees which included: Facility managers, equipment manufacturers, food distributors and industry professionals.
- Acterra Event – San Francisco, CA – September 2018
    - Frontier Energy – Mark Duesler, discussed the findings from different types of plug load equipment that have been monitored and replaced in different commercial kitchens. Shared which unhooded electrical appliances had the

greatest energy savings potential and results to 30 attendees which included: Utilities, Government, Operators and Energy Consultants.

- SoCal Gas 8th Annual Foodservice Equipment Expo – Downey, CA – October 2018
    - Frontier Energy – David Zabrowski and Richard Young, staffed the California Energy Wise joint-utility booth at the event. They leveraged the opportunity to speak with other exhibitors and attendees about the CEC Plug Load research project. Identified new potential technologies that could be demonstrated under the scope of the project and solicited support from local manufacturer's representatives in facilitating case studies to assess the behavior associated with using energy save modes on new equipment. Spoke to 944 attendees over two day which included: restaurant operators, kitchen managers, equipment representatives, foodservice design consultants, equipment dealers, culinary college students, utility employees.
    - Event video available at: https://youtu.be/TucMFd9xDrg
- San Francisco Unified School District Training – San Ramon, CA – November 2018
    - Frontier Energy – Mark Duesler, provided a hands-on training to learn more about different energy efficient qualified equipment types as well as the processes and best practices to make these processes as ergonomic as possible. Shared what a plug load appliance is and the latest findings from the project to 5 attendees which included: Directors of Sustainability, Head of Operations, Director of Foodservice, Director of Student.
- Togo's Training – San Ramon, CA – March 2019
    - Frontier Energy – Richard Young, shared the latest draft results from the CEC Plug Load Project, shared the Plug Load project website and mentioned about looking for additional sites for the field testing to 25 attendees which included: Franchisee's and CEO.
- FCSI Chapter Meeting – San Ramon, CA – March 2019
    - Frontier Energy – David Zabrowski, shared the latest draft results from the CEC Plug Load Project, shared the Plug Load project website and mentioned about looking for additional sites for the field testing to 27 attendees which included: manufacture reps and consultants.
- Building Decarbonization Coalition Tour/Meeting – San Ramon, CA – April 2019
    - Frontier Energy – Richard Young, presented electrification and decarbonization in the commercial kitchen which focused on energy efficiency results from the plug load project to 8 attendees which included: Panama Bartholomy from the Building Decarb coalition and other coalition members including PG&E, Acterra, City of San Jose, the CEC, and the Marin CCA.
- Togo's Training – San Ramon, CA – April 2019
    - Frontier Energy – Richard Young, shared the latest draft results from the CEC Plug Load Project, shared the Plug Load project website and mentioned about looking for additional sites for the field testing to 25 attendees which included: Franchisee's and CEO.
- Equipment Demonstration – San Ramon, CA – July 2019

    - Frontier Energy – Mark Duesler, shared the latest draft results from the CEC Plug Load Project, shared the Plug Load project website and mentioned about looking for additional sites for the field testing to 9 attendees which included: Manufacturer Reps, End Users.
- Northern California Power Agency (NCPA) – San Ramon, CA – July 2019
    - Frontier Energy – Richard Young, presented what is a plug load appliance and results from the Plug Load project to 16 attendees which included: municipalities, electric utilities and rural electric cooperatives
- Diablo Valley College (DVC) Summer Camp – San Ramon, CA – July 2019
    - Frontier Energy – Mark Duesler, presented what is a plug load appliance and results from the Plug Load project to 40 attendees which included: culinary students and culinary instructors.
- National Student Leadership Conference – San Ramon, CA – August 2019
    - Frontier Energy – Richard Young, presented "Engineering, Energy Efficiency and Commercial Food Service" and discussed efficiency in the kitchen, sustainability and did an exercise on the CA Energy Wise page and calculated ROI and carbon savings. He also discussed what is a plug load appliance and the results from our plug load project. Following the presentation, they toured 4 stations in the lab to learn more about what we do at the center to 81 attendees which included: engineering students from across the United States.
- UC Davis Exchange Students – San Ramon, CA – August 2019
    - Frontier Energy – Michael Slater, presented what is a plug load appliances and results from the Plug Load project to 25 attendees which included: professors and students from UC Davis.
- Center of Ecoliteracy Training – San Ramon, CA – August 2019
    - Frontier Energy – Mark Duesler, presented what is a plug load appliances and results from the Plug Load project to 15 attendees which included: Oakland Unified School District – Foodservice Managers.
- Equipment Demonstration – San Ramon, CA – August 2019
    - Frontier Energy – Mark Duesler, shared the latest draft results from the CEC Plug Load Project, shared the Plug Load project website and mentioned about looking for additional sites for the field testing to 3 attendees which included: Manufacturer Reps, End Users – Great Full Gardens Restaurant.
- Equipment Demonstration – San Ramon, CA – August 2019
    - Frontier Energy – Mark Duesler, shared the latest draft results from the CEC Plug Load Project, shared the Plug Load project website and mentioned about looking for additional sites for the field testing to 3 attendees which included: Manufacturer Reps, End Users – Cocina Molinga.
- Equipment Demonstration – San Ramon, CA – August 2019
    - Frontier Energy – Mark Duesler, shared the latest draft results from the CEC Plug Load Project, shared the Plug Load project website and mentioned about looking for additional sites for the field testing to 3 attendees which included: Manufacturer Reps, End Users – Virtual Kitchen Design.

- Equipment Demonstration – San Ramon, CA – August 2019
    - Frontier Energy – Mark Duesler, shared the latest draft results from the CEC Plug Load Project, shared the Plug Load project website and mentioned about looking for additional sites for the field testing to 2 attendees which included: Manufacturer Reps, End Users – Three Pillars Group.
- Equipment Demonstration – San Ramon, CA – August 2019
    - Frontier Energy – Mark Duesler, shared the latest draft results from the CEC Plug Load Project, shared the Plug Load project website and mentioned about looking for additional sites for the field testing to 3 attendees which included: Manufacturer Reps, End Users – Great Full Gardens Restaurant.
- SF Chapter of the AIA – Burlingame, CA – October 2019
    - Frontier Energy – Mark Duesler, participated in the meeting and shared updates on the Plug Load project, provided a demonstration of induction & other plug load equipment to 25 attendees which included: architects, utilities, designers, consultants and end users.
- League of Women Voters – San Ramon, CA – November 2019
    - Frontier Energy - Richard Young presented "Using Energy Efficiency to Decarbonization Commercial Kitchens" to the League of Women Voters. Young discussed the big challenges facing utilities, regulators, municipalities, and foodservice operators as we move towards: decarbonization and electrification and shared results from the Plug Load project to 25 attendees which included: government, architects, designers and consultants.
- California Energy Efficiency and Demand Control Committee Meeting – Oakland, CA – October 2019
    - Frontier Energy - Richard Young, participated in the meeting and provided updates on the Plug Load project and shared a link to the project website to Energy Solutions, Steve Shiller, and the CA Energy Storage Association.
- Pyatok Architects – Oakland, CA – November 2019
    - Frontier Energy - Richard Young, participated in the meeting and gave an hour-long presentation on electric kitchens including the Plug Load project results. The audience included 22 attendees from the firm who work in design of low-income residential and commercial foodservice kitchens.
- PG&E Engineering Staff Training – San Ramon, CA – November 2019
    - Frontier Energy – Todd Bell, discussed what is a plug load appliance, shared recent results from the Plug Load project and link to the project website to 11 attendees which included: engineers.
- NAFEM National Technical Liaison Committee Meeting – Atlanta, GA – November 2019
    - Frontier Energy assisted Hatco with presentation of Plug Load findings which included: Manufacturer Reps, End Users, Consultants & Manufacture.
- Visit to Inspire Brands (Arby’s) – Oakland, CA – November 2019

- Frontier Energy - Richard Young, met with the director of equipment and discussed what is a plug load appliance and shared the latest results from the Plug Load project.

- Berkeley City Council Meeting – Berkeley, CA – December 2019
    - Frontier Energy - Richard Young, participated in the meeting and provided updates on the Plug Load project and shared a link to the project website to approximately 20 attendees which included: government, architects, designers and consultants.

Figure G-16: Induction Demonstration at a Berkeley - Stop Waste Electrification Event

Source: Frontier Energy, Inc.

- Bay Area Food Technical Advisory Committee – Alameda, CA – December 2019
- Frontier Energy – Richard Young gave a two-hour presentation on kitchen electrification and induction cooking including results from the Plug Load project. The audience had 11 attendees which included representatives from all the Bay Area environmental health departments.

Media / Media Events

Press releases available at: https://fishnick.com/cecplug/

- Press Release – 07/10/2017
- Foodservice Equipment Reports
- Fisher-Nickel Changes Name to Frontier Energy
- Press Release – 09/01/2017
- Foodservice Equipment Reports
- Energy Smart
- Press Release – 04/01/2018
- Global Coffee Report

- Coffee’s Hidden Carbon Footprint
- Press Release – 04/01/2018
- Foodservice Equipment Reports
- MUFES 2018
- Press Release – 06/01/2018
- Foodservice Equipment Reports
- Under the Radar: Plug Loads
- Press Release – 06/01/2018
- Foodservice Equipment Reports
- Crash Course: Conveyor Toasters
- Press Release – 09/10/2018
- Greentech Media
- Restaurants Can Slash Energy Use with Electric Induction Technology
- Press Release – 08/2019
- Foodservice Consultant – insert Heat Wave
- Cooking Innovations Heats Up

Project Showcases

Hosted one Project Showcase event to highlight the key successes and lessons learned from the work at each of the sites. The information was shared with a wide cross-section of the industry via presentations and hands-on demonstrations of equipment featured in the research project.

Showcase 1: Putting the Kitchen of the Future to the Test Showcase Event

Partnership with PG&E and the California Energy Wise program at the Frontier Energy Food Service Technology Center

Focused on the work performed at all sites

- Date: November 19, 2019
    - Location: Food Service Technology Center in San Ramon, CA
    - Audience: Cross section of foodservice industry professionals incl. Manufacturers, Equipment Reps, Dealers, Utility Representatives, Operators, Media, Designers, Industry Association Representatives, and TAC Members.
    - Number of Attendees: 15 (Additional attendees watched the online lecture after the showcase event concluded.)
    - Speakers: Denis Livchak, Frontier Energy Engineer, Edward Ruan, Frontier Energy Engineer, and Mark Duesler, Frontier Energy Chef Consultant
    - Presentations: provided an overview of the project followed by key successes, highlights and lessons learned.
    - Hands-On Equipment Demonstrations: guests were invited to participate in the hands-on demonstration featuring the equipment showcased in the project.

- Future Technology Transfer: Technology transfer is ongoing into 2020. The Frontier Energy Food Service Technology Center will continue to leverage the results from the plug load study for energy efficiency technical transfer moving forward. This includes classes and industry presentations, trade publications, equipment demonstrations, and design consultations.

Figure G-17: Hands-On Equipment Demonstrations

Source: Frontier Energy, Inc.

Scheduled Seminars – 2020:

Topic – 2020 Food Service Forecast

Outcome(s) to be achieved: Participants learned an overview of the plug load projects, the results and findings from field studies and the plug load website where you can find the latest on the project.

- Date: March 4, 2020
  - Location: Foodservice Technology Center, SoCal Edison, Irwindale, CA
  - Audience: Foodservice equipment representatives, equipment manufacturers and industry professionals
  - Number of Attendees: 25
  - Speaker: Richard Young, Frontier Energy Director of Education
- Date: March 5, 2020
  - Location: Food Service Technology Center, Frontier Energy – San Ramon, CA
  - Audience: Foodservice equipment representatives, equipment manufacturers and industry professionals
  - Number of Attendees: 40
  - Speaker: Richard Young, Frontier Energy Director of Education

Topic – The Ventless Kitchen

- Location / Date: Foodservice Technology Center, SoCal Edison – Irwindale, CA – April 14, 2020

Topic – Build It: Better Burgers and Fries

- Location / Date: Food Service Equipment Center, SoCal Gas – Downey, CA – April 7, 2020

Topic – Decarbonizing the Commercial Kitchen with Energy Efficient Equipment

- Location / Date: Food Service Technology Center, Frontier Energy – San Ramon, CA – April 30, 2020

Topic – Specifying Efficient Equipment for Production Kitchens

- Location / Date:
  - Food Service Technology Center, Frontier Energy – San Ramon, CA – May 21, 2020
  - Foodservice Technology Center, SoCal Edison – Irwindale, CA – November 17, 2020

Topic – Cool It: How to Create More Comfortable Kitchens

- Location / Date:
  - Food Service Technology Center, Frontier Energy – San Ramon, CA – July 9, 2020
  - Foodservice Technology Center, SoCal Edison – Irwindale, CA – August 18, 2020

Topic – Cook, Hold & Chill: Equipment and Techniques that Save Energy, Reduce Waste and Cut Labor Costs

- Location / Date: Food Service Technology Center, Frontier Energy – San Ramon, CA – September 17, 2020

Topic – Exploring Ventless Technologies: High Tech Equipment for the Modular Kitchen

- Location / Date: Food Service Technology Center, Frontier Energy – San Ramon, CA – November 5, 2020

Confirmed Industry Events - 2020

Multi-Unit Foodservice Equipment Symposium (MUFES) Conference

Topic – Big Gains in Small Appliances: CEC Plug Load Project

Outcome: Provided an update of the findings from the multiyear California Energy Commission study of electric countertop plug-load equipment, including savings from switching to efficient replacements for heating, holding and beverage appliances. Key take-aways basic technologies can have big benefits; controls are a powerful tool but work better when they are easy to use; staff training is critical to maximizing operation.

- Date: January 27, 2020
- Location: Nashville, TN
- Audience: Multi-unit commercial and non-commercial foodservice facility operators, equipment specifiers and manufacturers.
- Number of Attendees: 50
- Speaker: David Zabrowski , Frontier Energy, Project Manager

Figure G-18: David Zabrowski presenting at MUFES 2020

Source: Frontier Energy, Inc.

Topic – Heat, Trash & Carbon – The Changing Legal Landscape

Outcome: Provided basic information about the plug load project and let people know to attend David's presentation to learn more about the results and findings from the project.

- Date: January 27, 2020
- Location: Nashville, TN
- Audience: Multi-unit commercial and non-commercial foodservice facility operators, equipment specifiers and manufacturers.
- Number of Attendees: 100
- Speaker: Richard Young, Frontier Energy, Director

Figure G-19: Richard Young presenting on electrification and the need for high efficiency appliances

Source: Frontier Energy, Inc.

San Francisco Energy Fair

Topic: Induction Demonstration

Outcome(s) to be achieved: Participants will learn about design challenges of commercial kitchen ventilation systems and how they affect operator comfort, exhaust air heat recovery and demand control commercial kitchen ventilation (DCKV). DCKV systems will be presented from the perspective of available technologies, codes and standards, performance issues and commissioning.

- Date: February 25, 2020
- Location: San Francisco, CA
- Audience: Homeowners
- Number of Attendees: 50
- Speaker: Todd Bell, Energy

RestaurantSpaces

Topic: Heat, Trash and Carbon: The Changing Legal Landscape

Outcome(s) to be achieved: Participants will learn latest laws that have already passed, what is in the legal pipeline, and what the implications will be. In addition, Richard will share some of the technologies and techniques that restaurant operators need to embrace in order to remain ahead of the game. Share some findings and results from the plug load project.

- Date: March 3, 2020
- Location: Pasadena, CA
- Audience: Foodservice equipment representatives, equipment manufacturers and industry professionals
- Number of Attendees: 40
- Speaker: Richard Young, Frontier Energy Director of Education

Figure G-20: Richard Young presenting at Restaurant Spaces

Source: Frontier Energy, Inc.

Other Activities:

- Sacramento State University – Sacramento, CA – February 2020
- Frontier Energy – Richard Young, shared the induction information to the students and shared findings and results from the project to approximately 40 attendees which included students.
- Mission College – Santa Clara, CA – February 2020
- Frontier Energy – Richard Young, shared the induction information to the students and shared findings and results from the project to approximately 18 attendees which included students.
- UC Berkeley – Berkeley, CA – February 2020
- Frontier Energy – Richard Young, shared the induction information to the students and shared findings and results from the project to approximately 26 attendees which included students.
- NAFEM Meeting – San Ramon, CA – February 2020
- Frontier Energy – Richard Young & David Zabrowski, shared CEC Plug Load results and findings from the project with Charlie Sourhada, NAFEM.
- PG&E Induction Program – February 2020
- Frontier Energy – Richard Young, shared induction information with PG&E as part of the effort to set up an induction demo/training program.
- McKinstry Visit – San Ramon, CA – February 2020
- Frontier Energy – Richard Young & Mark Duesler, shared information and did a demonstration for the design/construction/operation firm McKinstry.
- Culinary Institute of America (CIA) Flavor Summit – Napa, CA – March 2020
- Frontier Energy – Richard Young, shared information on the CEC induction information with Four Seasons operators as well as the Rational representatives.
- RFMA – March 2020
- Frontier Energy – Richard Young, shared information on the CEC Plug Load project and shared the website link to 50 people which included: Coffee and Bagel Brands (which used to be Noah's/Einsteins), Sweetgreens, and Inspire Brands (Arby's, Buffalo Wild Wings, and so forth).

National and State Conferences – 2020

- ACFSA – American Correctional Foodservice Association
- ACF – American Culinary Federation
- ASTM F26 Committee Meetings – Spring and Fall 2020
- CEHA – California Environmental Health Association – Sacramento, CA – March 2018
- CEW EPC – California Energy Wise Executive Planning Council - Quarterly
- CSNA – California School Nutrition Association
- Energy Efficiency Exchange NW
- FCSI – Foodservice Consultant Society International

- GGRA – Golden Gate Restaurant Association
- Menus of Change
- NACUFS – National Association of College and University Foodservice
- NAFEM/FEDA/CFESA Joint Conference – North American Association of Food Equipment Manufacturers/ Foodservice Equipment Dealers Association / Commercial Foodservice Equipment Service Association
- NRA Show– National Restaurant Association – Chicago, IL – May 2020
- RFMA – Restaurant Facility Management Association
- SoCalGas Foodservice Equipment Expo – Downey, CA – October 2020
- MUFES - Multi-Unit Foodservice Equipment Symposium – Austin, TX – January 2020