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FINAL PROJECT REPORT

Demonstration of High-Efficiency Commercial Cooking Equipment and Kitchen Ventilation Systems

Gavin Newsom, Governor
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PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division manages the Natural Gas Research and Development Program, which supports energy-related research, development, and demonstration not adequately provided by competitive and regulated markets. These natural gas research investments spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

The Energy Research and Development Division conducts this public interest natural gas-related energy research by partnering with research, development, and demonstration entities, including individuals, businesses, utilities and public and private research institutions. This program promotes greater natural gas reliability, lower costs and increases safety for Californians and is focused in these areas:

- Buildings End-Use Energy Efficiency.
- Industrial, Agriculture and Water Efficiency.
- Renewable Energy and Advanced Generation.
- Natural Gas Infrastructure Safety and Integrity.
- Energy-Related Environmental Research.
- Natural Gas-Related Transportation.

Demonstration of High-Efficiency Commercial Cooking Equipment and Kitchen Ventilation Systems is the final report for the Demonstration of High-Efficiency Commercial Cooking Equipment and Kitchen Ventilation System Optimization in Commercial Food Service project (Contract Number: PIR-14-008), conducted by Frontier Energy. The information from this project contributes to Energy Research and Development Division's Natural Gas Research and Development 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.

ABSTRACT

Frontier Energy, Inc., operator of the Food Service Technology Center, conducted a comprehensive commercial kitchen equipment demonstration of the quantitative and qualitative benefits of innovative high-efficiency gas cooking equipment and advanced commercial kitchen ventilation systems in different types of commercial foodservice operations. The project was conducted under a grant from the California Energy Commission's Public Interest Energy Research (PIER) program and supplemented by funding from Pacific Gas and Electric Company, Southern California Gas Company, San Diego Gas & Electric Company, numerous equipment manufacturers, and the respective demonstration sites.

Cookline equipment operation and energy consumption was characterized at six different test sites: a hotel, a hospital cafeteria, an airline caterer, a grocery deli, and two restaurants. The researchers used the findings to identify opportunities to optimize the cooklines at each site. Where possible, the project team consolidated operations and replaced baseline equipment with energy efficient alternatives to minimize energy consumption while maximizing throughput and functionality. In addition, researchers characterized the nitrogen oxide (NO_x) emissions from the baseline and replacement equipment, then estimated the overall NO_x production for each appliance type based on measured energy consumption.

The team implemented demand-controlled kitchen ventilation systems at two of the six test sites. The researchers assessed fan energy and kitchen operating conditions before and after implementing the demand-controlled kitchen ventilation systems. A final portion of the study examined the use of an energy information system to provide real-time feedback on equipment energy intensity. The study demonstrated that staff behavior, particularly equipment training, was critical to achieving persistent energy savings.

Each site saved between 20 percent and 40 percent in energy consumption while offering greater productivity. Demand-controlled kitchen ventilation systems added more than 50 percent ventilation energy savings to two sites. Underfired broilers were the most energy intensive appliance, while combination ovens represented the greatest energy savings opportunity.

Keywords: California Energy Commission, PIER, Frontier Energy, Inc., Food Service Technology Center, commercial foodservice equipment, restaurants, convection oven, fryer, griddle, broiler, commercial kitchen ventilation, steam cooker, baseline, energy-efficiency, energy savings, idle energy use, NOx.

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EXECUTIVE SUMMARY

Introduction

Commercial food service facilities are the largest energy users in the commercial building sector by a significant margin. Food service facilities consume up to five times more energy per square foot than any other type of commercial building and are extremely commonplace. They can be found in several commercial building types, such as large offices, restaurants, retail, schools, healthcare facilities, and lodging.

Commercial food service represents a market sector where strategic improvements in appliance design could result in significant energy savings and emission reductions. In aggregate, restaurants and food stores account for nearly 28 percent of all commercial sector natural gas use, as documented by the California Commercial End-Use Survey in 2006. An estimated 93,300 commercial food service facilities operating in California use roughly 560,000 major commercial natural gas-fired cooking appliances, with a total gas demand of almost 25 percent of the overall commercial gas consumption in the state. This natural gas use accounts for 475 million therms consumed annually. Assuming an average cost of $1 per therm, the natural gas use in foodservice accounts for $475 million annually.

Project Purpose

Frontier Energy aimed to reduce food service related energy consumption by demonstrating the energy savings potential, cost effectiveness, and performance of high-efficiency equipment compared to typical commercial food service equipment. These data increase visibility of high-efficiency technologies and create a business case for food service facilities to proactively optimize their kitchen setups for energy efficiency. Doing so would increase demand and in turn lead manufacturers to create better product options and drive an economic cycle that would expand the energy efficiency movement in the food service sector.

The research project presented in this report builds on previously funded Public Interest Energy Research projects Advanced Foodservice Appliances for California Restaurants (2013) and Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment (2010).

Cooking Equipment

Despite high operating costs and the high volume of facilities operating in the state, the commercial food service industry has been slow to adopt high-efficiency gas-fired cooking equipment. Equipment purchase price primarily drives appliance purchases, often without prior knowledge of potential energy use. With heavy competition among manufacturers for market share within a typically frugal industry, energy-efficient models have struggled for prominence in commercial kitchens. Frontier Energy estimates that only 10 percent of the potential market in California uses high-efficiency ENERGY STAR® commercial gas cooking appliances. This project focused on the financial and operational benefits of wider adoption of high-efficiency equipment.

Ventilation Energy

A key factor the researchers considered in the project was ventilation system energy. The energy required to condition the outdoor air required to replace air exhausted from commercial kitchens (along with the associated fan energy) constitutes at least 50 percent of the total heating, ventilating, and air conditioning load in a commercial food service facility. This often comprises a large portion of the facility's overall energy load. Although it is not necessary to operate exhaust hoods at full speed the entire day, the sector has been slow to install demand-controlled kitchen ventilation technology to reduce energy use. Frontier Energy researchers quantified the significant energy savings potential of this technology using real world replacement results.

Energy Information System

Frontier Energy also explored the potential for minimizing energy waste resulting from staff behavior. Staff are often uninformed on how their behavior affects energy use and operational costs. The lack of knowledge of cookline energy consumption can be addressed implementing an energy information system that displays the current operating status of cooking appliances. While a comprehensive restaurant-ready energy information system is still in the pilot stage, there is potential to use information technology to build awareness of appliance energy use among restaurant staff and impact operating behavior.

NO_x Emissions

Frontier sought to better understand emissions generated by commercial kitchen appliances. Researchers measured emissions directly at the appliance source in laboratory and field contexts. The nitrogen oxide (NO_x) emissions study measured the range of NO_x values in commercial foodservice equipment operation to serve as a foundation for further emissions research in the foodservice industry.

Project Process

The research team engaged a technical advisory committee consisting of end users and utility partners in the site selection process and information dissemination of the baseline and replacement results. Frontier Energy installed metering instruments to measure and characterize cookline equipment operation and energy consumption at six different test sites: a large catering company, university hospital, hotel, restaurant and bar, grocery store, and a full-service restaurant. The researchers used the findings to identify opportunities to optimize the cooklines at each site. Where possible, the team consolidated operations and replaced baseline equipment with energy-efficient alternatives to minimize energy consumption while maximizing throughput and functionality. Frontier Energy researchers monitored the energy use and cooking performance of the replacement equipment and compared them to the baseline results from the original setups, while incorporating feedback from the kitchen staff. In addition, researchers measured the NO_x emissions from the baseline and replacement equipment, then estimated the overall NO_x production for each appliance type based on measured energy consumption.

The project team implemented demand-controlled kitchen ventilation systems at two of the six sites. Researchers assessed fan energy and kitchen operating conditions before and after implementing the demand-controlled kitchen ventilation systems. The team also examined using an energy information system to provide real-time feedback on equipment energy intensity. The study demonstrated that staff behavior, particularly equipment training, was critical to achieving persistent energy savings.

Project Results

Baseline Characterization

The project successfully characterized energy and operating patterns for a variety of standard commercial cooking appliances in six types of commercial kitchens, representing a wide range of use, from light batch cooking at a grocery store to heavy use at a 24-hour catering facility. Each site had different menu, staffing, and production needs from the equipment, and exhibited long operating hours and high energy consumption (Table ES-1).

The most common metered appliances were fryers, broilers, griddles, ovens, and ranges. Underfired broilers were consistently the most energy intensive appliance, whereas oven energy use varied widely by site and model. Fryers and ranges used the least energy but several sites had multiple units, resulting in a high cumulative energy.

Table ES-1: Average Baseline Energy Use for Different Appliances (Therms/Day)

Site/Appliance	Fryer	Broiler	Griddle	Oven	Range
Hotel	3.7	11.9	4.1	5.1	3.2
University Hospital	3.3	N/A	N/A	7.8	N/A
Airline Catering	3.4	18.0	N/A	4.8	5.6
Restaurant / Bar	2.6	5.3	4.9	3.5	3.1
Grocery Store	N/A	N/A	N/A	7.8	N/A
Full-Service Restaurant	3.7	N/A	5.4	3.6	4.2
Average – All Sites	**3.3**	**11.7**	**4.8**	**5.4**	**4.0**

Source: Frontier Energy, Inc.

Cookline Replacement Results

Monitored sites experienced a wide range of cookline natural gas use reduction after the energy efficient appliance replacements, from 19 percent to 68 percent. At the high end of the spectrum was the grocery store, which reduced its gas consumption by 68 percent by adding a combination oven to replace their rotisserie oven, which had dominated the kitchen's natural gas use. On the lower end was the restaurant/bar, which reduced its total gas consumption by 19 percent despite upgrading cooking capacity with a larger broiler and griddle.

Overall, average natural gas savings were about 35 percent for the entire cookline, and no single energy saving replacement type was dominant for all sites (Table ES-2). Sources of energy savings varied significantly per site depending on the make and age of the baseline appliances originally used. Commonly identified significant energy savings options replaced old convection ovens, consolidating convection ovens and steamers into a combination oven, and replacing the energy intensive broilers. Replacing old fryers with energy efficient models was a relatively inexpensive and cost-effective option.

Researchers also monitored electrical energy at three sites. The hotel had three electric two-compartment steamers that were replaced by a natural gas steamer, a natural gas combination oven-steamer (combi), and an electric steamer. The steamer replacement resulted in more than 137 kilowatt-hours (kWh) daily energy reduction and the two gas appliances only added two therms to the daily gas consumption. The restaurant/bar had two kitchen ventilation hoods which were consolidated into one by moving the oven from the prep line to the main cookline. Researchers also installed a demand-controlled ventilation system on the main line hood, which resulted in an additional 30 percent savings and 49 percent electrical savings overall. The team also installed demand-controlled ventilation at the full-service restaurant, which experienced larger electric savings of 49 percent because of more hood space. Ventilation improvements also reduced the amount of conditioned air exhausted out of the restaurant resulting in gas air heating savings.

Table ES-2: Gas and Electric Savings per Site

Site	Gas Savings (therms/day)	Gas Savings	Electric Savings (kWh/day)	Electric Savings (replaced appliances only)
Hotel	11.4	29%	137	71%
University Hospital	8.5	27%	N/A	N/A
Airline Catering	27.1	23%	N/A	N/A
Restaurant / Bar	4.3	19%	32	49%
Grocery Store	5.3	68%	N/A	N/A
Full-Service Restaurant	17.5	43%	49	49%
Total – All Sites	**74.1**	**35%**	**218**	**56%**

Source: Frontier Energy, Inc.

Nitrogen Oxide Emissions Results

Frontier Energy evaluated NO_x emissions from five appliance types: fryers, broilers, griddles, ovens, and ranges. NO_x concentration ranged from 10 to 110 parts per million across these appliance categories, with no noticeable correlation between appliance and burner type (Table ES-3). Some appliance models within the same category, such as fryers, griddles, and with similar burner designs generated different NO_x values. Burner input rate, primary and secondary air flow rates, and number of burners also affected NO_x generation. For this reason, NO_x concentration and mass flow rates are model-specific and no generalizations can be made about relationships between energy efficiency and NO_x or burner type and NO_x. A laboratory NO_x measurement method was developed and tested in the field. Measured NO_x values were combined with measured energy use to estimate annual emissions generated for each appliance type. A regimented study including more appliance types and field sites should be conducted to determine which burner and flue designs produce the least NO_x in each appliance category.

Table ES-3: Average Nitrogen Oxide Generation for Different Appliances (pounds/year)

Site / Appliance	Fryer	Broiler	Griddle	Oven	Range
Average – All Sites	7.7	25.5	9.1	13.7	12.8
Lab	8.4	N/A	10.5	12.6	N/A

Source: Frontier Energy, Inc.

Electronic Information System

The electronic information system installed at the hotel and full-service restaurant sites empowered staff to proactively manage their equipment use and make operational changes. With most appliance energy consumed during idle periods, this tool allowed the operator to check appliance on/off times and find periods when the appliances could be turned off without affecting service. This generated large energy savings from reduced fryer use, which could then be easily quantified by the electronic information system. The feedback from the electronic information system also allowed the kitchen manager to experiment with recipes to optimize their cooking processes for energy efficiency. Owners can also use the EIS planning tools to set energy use goals, encouraging changes in practices necessary to meet these goals.

Technology Transfer

Frontier Energy disseminated technical information and knowledge gained from this demonstration project by leveraging Frontier Energy's long-standing workforce education, training, and information outreach program (www.fishnick.com) for food service as well as the strategic industry partnerships it has forged over the past decades. The objective of the outreach was to communicate the benefits of high efficiency commercial cooking equipment and the various energy efficient options to educate clients on concepts that yield energy savings for their applications with an end goal to accelerate the adoption and implementation of energy efficient commercial cooking equipment in the market place.

Frontier Energy leveraged its partnerships with established industry professional and trade entities, including the media, to relay the data to these memberships and/or trade allies. Information outreach was delivered through various modes and venues including seminars, webinars, industry events, showcases, project webpages (www.fishnick.com/ceccook/), case studies, face sheets, articles, papers, and interviews. Frontier Energy will continue to utilize the results of this study in future educational events and materials.

Benefits to California

As an industry that accounts for an estimated 475 million therms in annual gas consumption, the average demonstrated gas savings of 35 percent for food service establishments is significant. This indicates a potential 166 million therms reduction in annual gas consumption. It may not be possible to achieve such high savings at every single facility due to relatively high initial equipment purchase expense, but this project showed that targeted appliance replacement is possible in any kitchen. Identifying the highest energy-consuming appliance and replacing it with an energy-efficient appliance could cost the operator less than $5,000 and have payback times of less than two years. With most appliances having at least a 10-year lifecycle, the total savings from energy efficient appliances are significant. Despite these evident savings, more education is necessary for the equipment users as well as more energy efficiency incentives to increase market adoption efficient kitchen design and retrofit.

CHAPTER 1: Introduction

Frontier Energy, Inc., operator of the Food Service Technology Center (FSTC) conducted a comprehensive commercial kitchen equipment demonstration of the quantitative and qualitative benefits of innovative high-efficiency gas cooking equipment and advanced commercial kitchen ventilation (CKV) systems. The project was funded by the California Energy Commission's Natural Gas Public Interest Energy Research (PIER) grant program, Pacific Gas and Electric Company (PG&E), Southern California Gas Company (SoCal Gas), San Diego Gas and Electric Company (SDG&E), numerous equipment manufacturers, and the respective demonstration sites.

The project demonstrated the energy savings potential, cost effectiveness, and cooking performance of high-efficiency equipment as compared to typical commercial cooking equipment. Frontier selected six commercial food service (CFS) sites to represent the various facets of the industry: Moffitt Café at the University of California, San Francisco (UCSF) Medical Center, Oliver's Market and Doubletree by Hilton in PG&E service territory; Gate Gourmet and Versailles Restaurant in SoCal Gas service territory; and Werewolf Bar & Grill in San Diego Gas & Electric service territory.

Frontier Energy researchers established baseline energy consumption by submetering the existing cookline and CKV system using commercial-grade gas and electric meters. The baseline standard-efficiency appliances were then replaced with best-in-class, advanced-technology gas cooking equipment, consolidating the cookline where possible. Engineers re-balanced and optimized the commercial kitchen exhaust system utilizing laboratory-proven techniques and, when feasible, installed a demand-controlled kitchen ventilation (DCKV) system after the installation of the replacement cooking equipment. Frontier Energy also investigated the benefits of overlaying a communication network that will report the "operating status" and track energy consumption of each appliance in real-time to an energy information system (EIS) or display dashboard. Researchers evaluated the efficacy of the interactive platform on user behavior to determine if additional energy savings can be achieved from this "intelligent" cookline.

Additionally, Frontier sought to better understand emissions generated by commercial kitchen appliances. Performed in parallel to baseline and replacement energy monitoring, researchers measured emissions directly at the appliance source in both lab and field contexts. The focus of the NO_x emissions portion of this study was to measure the range of NO_x values in commercial foodservice equipment operation to serve as a foundation for further emissions research in the foodservice industry.

The demonstration project presented in this report is a natural extension of two recent Energy Commission-funded PIER projects: Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment in 2010, and Advanced Foodservice Appliances for California Restaurants in 2013.

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. These facilities can be found in several commercial building types: large offices, restaurants, retail, groceries, schools, colleges, healthcare facilities, and lodging.

CFS represents a market sector where strategic improvements in appliance design could result in significant energy savings and emission reductions. In aggregate, restaurants and food stores account for nearly 28 percent of all commercial sector gas use, as documented by the *California Commercial End-Use Survey* (CEUS) in 2006. With an estimated 93,300 CFS facilities operating in California, the total gas load of these establishments approaches 40% of the overall commercial gas consumption in the state (Spoor, 2014). Across all California's foodservice establishments, there are roughly 560,000 major commercial gas-fired cooking appliances, accounting for 475 million therms consumed annually (Spoor, 2014).

Despite high operating costs and the high volume of facilities operating in the state, there has been slow adoption of high-efficiency gas-fired cooking equipment. Appliance purchases are primarily driven by equipment price often without prior knowledge of potential energy use. With heavy competition among manufacturers for market share within a typically frugal industry, energy-efficient models have struggled for prominence in commercial kitchens. Frontier Energy, Inc. estimates that the market penetration of high-efficiency ENERGY STAR® commercial gas cooking appliances is only 10% of the potential market in California. This project focused on the financial and operational benefits of wider adoption of high-efficiency equipment.

The energy required to condition the outdoor air needed to replace air exhausted from commercial kitchens (along with the associated fan energy) constitutes at least 50% of the total heating, ventilating, and air conditioning load in a CFS facility. While it is universally acknowledged that exhaust hoods do not need to operate at full speed the entire day, the adoption rate for DCKV technology in CFS has been slow.

The lack of knowledge of cookline energy consumption can be addressed through the implementation of an EIS that displays the current operating status of cooking appliances. While a comprehensive restaurant-ready EIS is still in the pilot stage, there is potential to use information technology to build awareness of appliance energy usage among restaurant staff and impact operating behavior.

Objective

The objective of the baseline and replacement study was to characterize the energy usage profiles for a variety of commercial cooking appliances in different commercial foodservice applications. The baseline characterization included an assessment of the potential to employ new and energy-efficient technologies to maximize the energy productivity of each operation and optimize staff use of the equipment.

The overall goals of this project were to demonstrate and characterize the energy savings potential, cost effectiveness, and improved cooking performance of high-efficiency equipment when compared with baseline equipment. Frontier Energy, Inc. aims to use the resulting information to build a business case for the kitchen design community to overcome the market barriers of energy-efficiency measures and enable a paradigm shift away from low-efficiency equipment purchases towards higher-efficiency purchases.

The project team bridged the knowledge gap by educating the market sector on total cookline energy consumption and potential energy savings by presenting at various industry forums. Data collected from the demonstration sites was used to support existing utilities' energy-efficiency programs and widen emerging technology programs. These programs ultimately drive greater energy savings and emission reduction in California.

Method

Energy monitoring was conducted on individual baseline appliances for a minimum of two weeks. The instrumentation package that was used for field testing included a diaphragm-type positive displacement gas meter with a range of one-pulse/ft^3 to 20-pulse/ft^3 output (Figures 1 and 2). The meters were installed between the appliance and the gas supply shown in Figures 3 and 4. A data logger was used to log at 30-second intervals and store cumulative gas consumption from the meter's pulse outputs. Appliance operation hours were determined by calculating an hourly input rate using a five-minute moving average. Any recorded data higher than the pilot moving average was considered hours that the appliance was on. Cubic feet were converted into British thermal units (Btu) using a representative heating value of 1,025 Btu per standard cubic foot (Btu/scf), a temperature correction factor of 0.98, and a pressure correction factor of 0.98.

Figure 1: 1 Large 8 Pulse per Square Foot Gas Meter

Source: Frontier Energy, Inc.

Figure 2: Compact 1 Pulse per Square Foot Gas Meter

Source: Frontier Energy, Inc.

Figure 3: Gas Meters Installed at Werewolf Bar and Grill

Source: Frontier Energy, Inc.

Figure 4: Enclosed Gas Meters Installed at Doubletree Hotel

Source: Frontier Energy, Inc.

Figure 5: Electric Meter Inside Werewolf Panel: Ventilation Fan Monitoring

Source: Frontier Energy, Inc.

Figure 6: Electric Meter Current Transducers (CTs)

Source: Frontier Energy, Inc.

The electrical instrumentation package that was used for field testing of the kitchen ventilation equipment included a true energy meter that measured voltage and current (Figure 5 and 6). A data logger was used to log cumulative electric consumption from the meter's pulse outputs. These electric energy meters had a resolution of 0.5 to 1.25 watt-hours (Wh) depending on the size of current transformers used and the energy was recorded at 30-second intervals. Energy metering equipment was placed inside the breaker panel on the exhaust fan breaker. Exhaust fan motors were either single or three-phase. In all cases, current was measured on all legs of the phases to take in account the power factor.

CHAPTER 2:
DoubleTree Hotel by Hilton

Site Description

DoubleTree Hotel by Hilton is an upscale business-oriented hotel in Pleasanton, California (Alameda County) at the doorstep of the Tri-Valley Area (Figure 7). The hotel has a full-service restaurant providing breakfast, lunch, and dinner. The hotel's 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. The hotel is especially busy during the Good Guys auto show, which is held at the Pleasanton Fairgrounds annually.

Figure 7: DoubleTree Hotel Exterior

Source: Frontier Energy, Inc.

The first-floor dining room provides ample seating overlooking the patio pool (Figure 8). There is a full-service bar next to the dining room and several banquet halls for special events. A breakfast buffet is served daily from 6 am to 11 am and dinner service is from 5 pm to 11 pm. Lunch service starts after breakfast and runs into dinner (Figure 9).

Figure 8: DoubleTree Dining Room with Bar in the Background

Source: Frontier Energy, Inc.

Figure 9: DoubleTree Breakfast Buffet

Source: Frontier Energy, Inc.

The restaurant is served by a large kitchen which primarily consists of two cooklines underneath a 25-ft double canopy hood. The front line accommodates cook-to-order items and consists of a two-compartment steamer, two ranges, a griddle, a broiler, and a fryer (Figure 10). The back line consists of a cook-and-hold, four convection ovens, a range, two tilt skillets, and four steamer compartments (Figure 11). Most appliances are gas powered except three steamers and two tilt skillets, which are 480 volt electric. The cook-and-hold is also electric.

Figure 10: DoubleTree Main Cook-to-Order Line

Source: Frontier Energy, Inc.

Figure 11: DoubleTree Back Line

Source: Frontier Energy, Inc.

DoubleTree Results

Fryer Replacement

The restaurant had an older double vat fryer (Figure 12). Each vat was 14″ wide and featured low-efficiency, high-power burners and standing pilots. Fryer use was fairly light and the staff tended to use one vat at a time, reserving the second vat for days with high production. The primary vat consumed an average of 3.7 therms per day. The average on-time for the fryer was 15 hours per day. The fryer is mostly used to cook fries and chicken and occasionally fish and shrimp. Due to flavor transfer in the oil, fish and shrimp were fried in a different vat than the chicken, but were not fried daily.

The double vat fryer was replaced by two ENERGY STAR® fryers: a super-efficient, high volume model (left fryer in Figure 13), and an entry-level ENERGY STAR® fryer designed for moderate throughput (right fryer in Figure 13). The staff was instructed to use the super-efficient fryer as the primary fryer for the higher volume items: chicken and French fries and use the second fryer for less popular food items. The entry-level ENERGY STAR® fryer consumed 1.3 therms per day and spent the majority of its operating time in an idle state. The super-efficient fryer consumed only 0.9 therms per day despite being used more heavily. The combined energy usage of both replacement fryers was 2.3 therms per day, which is 1.4 therms less than the baseline double vat fryer. Neither replacement fryer had a standing pilot, instead using electronic ignition. The super-efficient fryer used a power burner with a submerged heat exchanger design. The staff commented that they were pleased with the performance of both fryers.

Figure 12: Baseline Double Vat Fryer

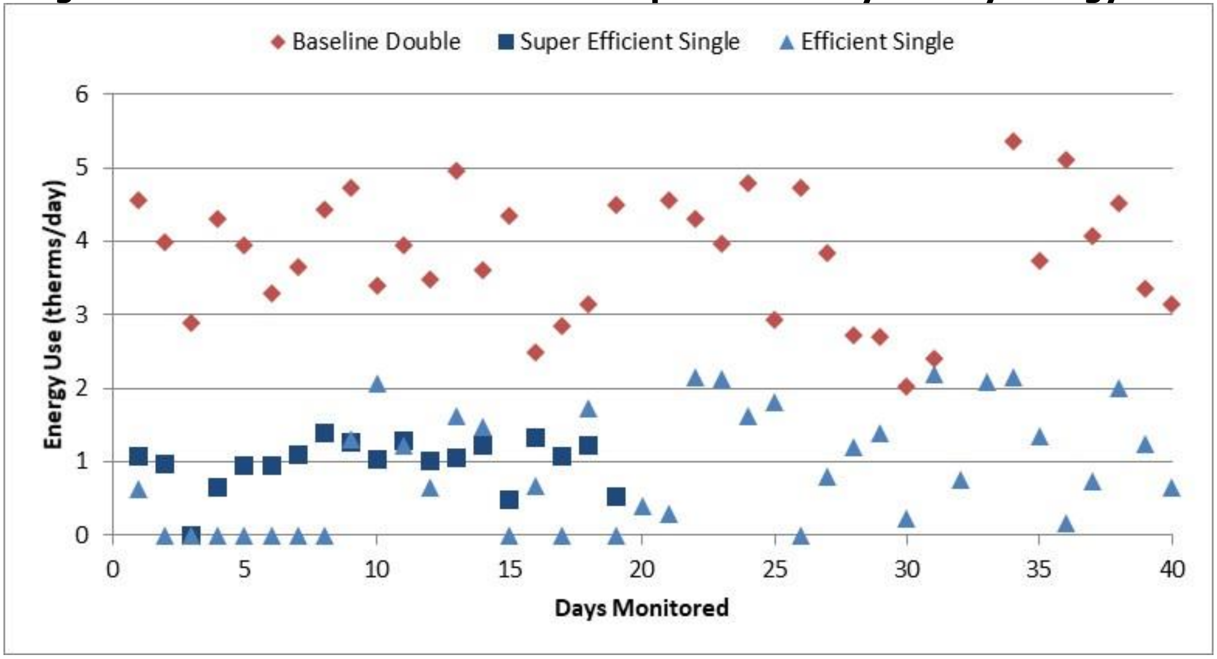
Source: Frontier Energy, Inc.

Figure 13: Replacement Two Separate ENERGY STAR® Fryers

Source: Frontier Energy, Inc.

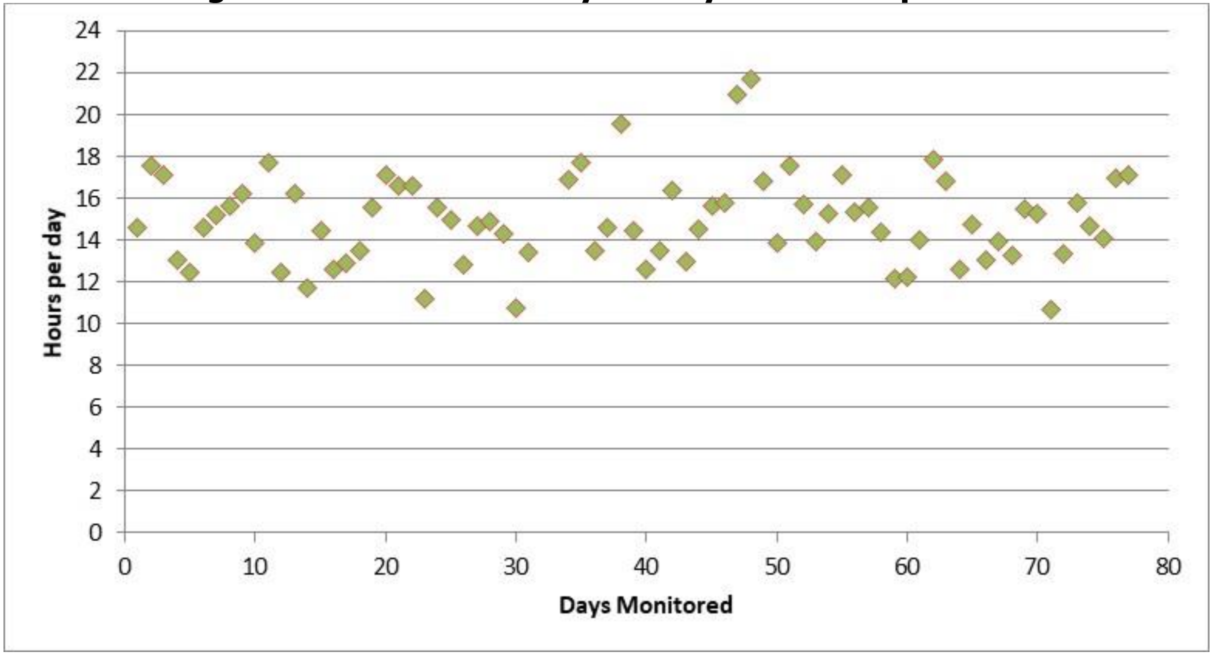
The entry-level ENERGY STAR fryer was later replaced with a similarly efficient fryer because of a gas supply issue. After further investigation, it was determined that the fryer did not have any problems, however it was replaced during the troubleshooting process for expediency in resuming operation. This third replacement fryer consumed an average of 0.5 therms per day, while maintaining the high cooking performance as noted by the staff. Hourly operation and energy usage is shown in Figures 14 and 15. Before and after replacement energy graphs are shown in Figures 16, 17 and 18.

Figure 14: DoubleTree Baseline and Replacement Fryer Daily Energy Use



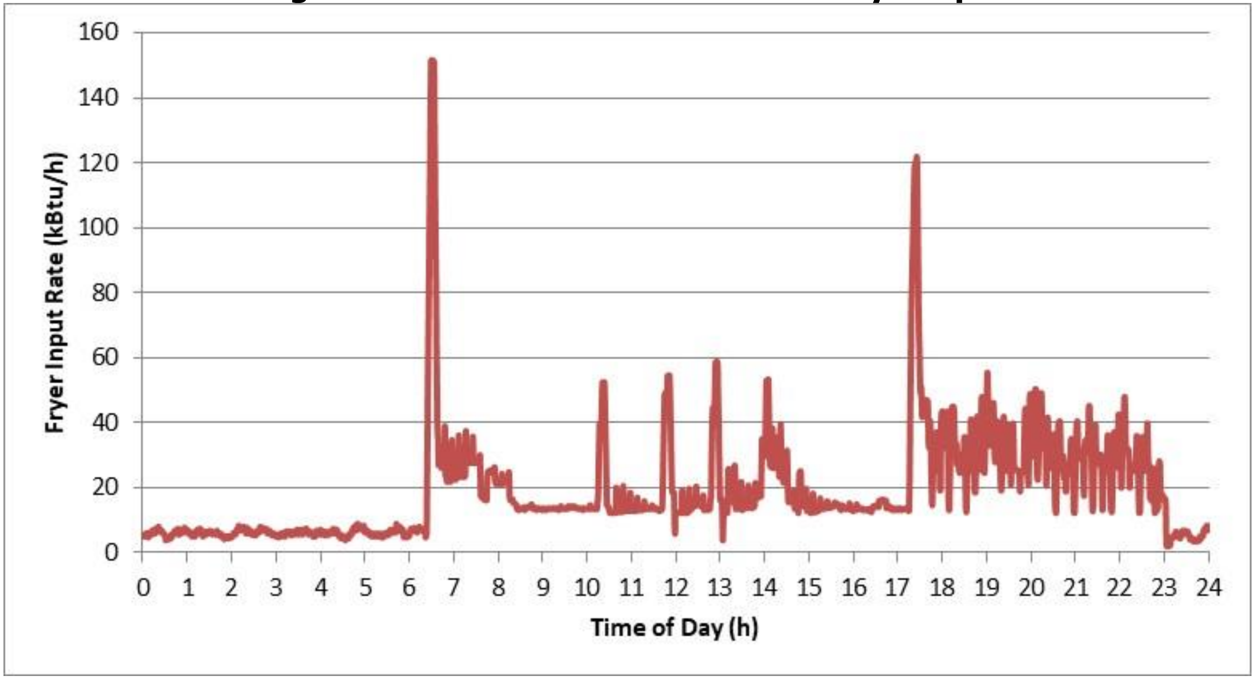
Source: Frontier Energy, Inc.

Figure 15: DoubleTree Fryer Daily Hours of Operation



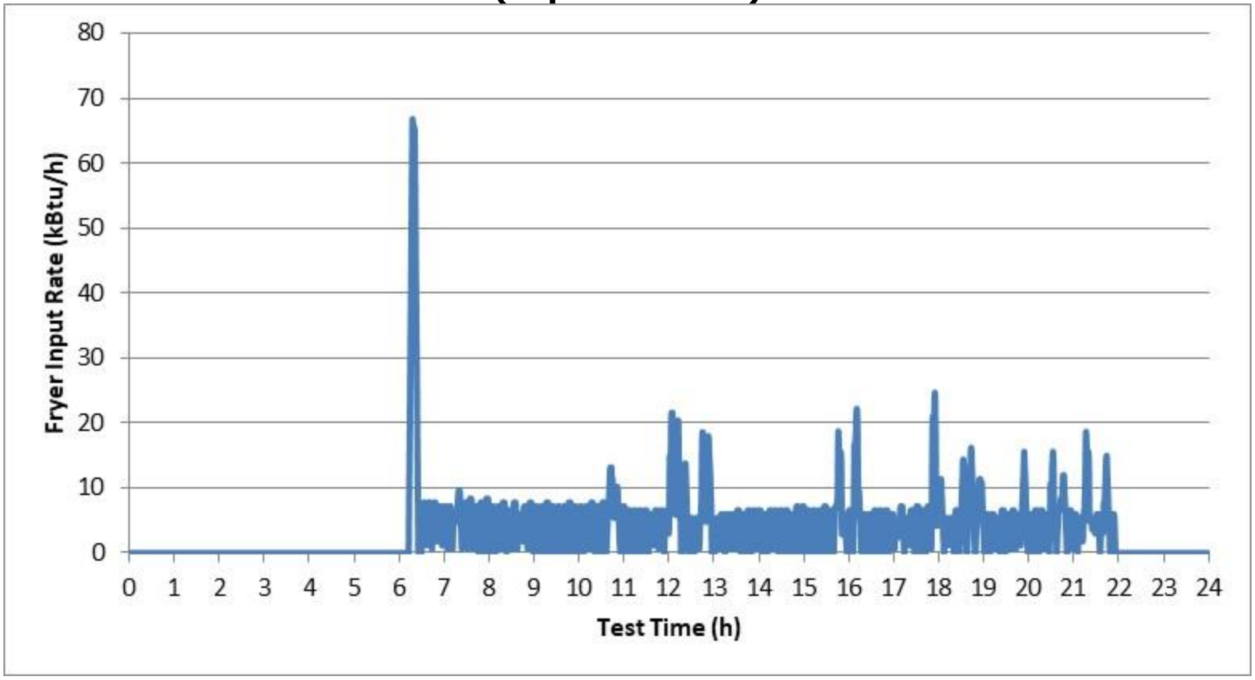
Source: Frontier Energy, Inc.

Figure 16: DoubleTree Baseline Vat Fryer Operation



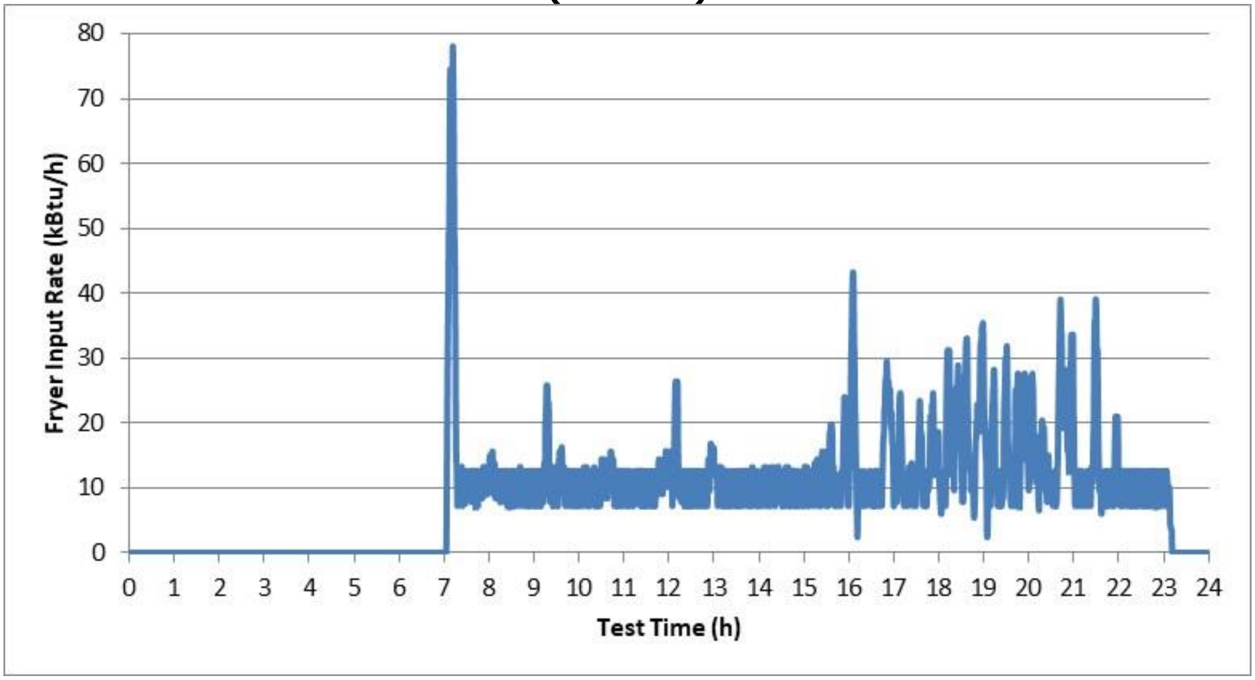
Source: Frontier Energy, Inc.

Figure 17: DoubleTree Replacement Left Fryer w/ Power Burners Operation (Super-Efficient)



Source: Frontier Energy, Inc.

Figure 18: DoubleTree Replacement Right Fryer w/ Atmospheric Burners Operation (Efficient)



Source: Frontier Energy, Inc.

Broiler Replacement

The cook-to-order line originally had a large, 4-foot underfired char-broiler (Figure 19). The broiler operated at a consistent input rate without much adjustment, consuming 11.6 therms per day while operating an average of 17 hours per day. The staff typically turned the broiler on at 6 am and turned it off at 11 pm. The right side of the broiler was the most used for cooking. The most common idle burner position was half power for the right-half burners and low/off for the left-half burners. The broiler was used to cook steak, tri-tip, fish, and hamburgers. Hamburger patties were the most frequently cooked food item and were cooked on the right side of the broiler. The left side was primarily used for finishing thicker cut of meat or for holding/staging food products. The broiler provided enough space to separate food by type (such as beef, chicken, and fish) as described in the operator feedback.

The baseline broiler was replaced with a smaller 3-foot underfired broiler with infrared radiants (Figure 20). The staff did not have a problem reducing the cooking area from 4 feet to 3 feet of linear space, as the relatively low pace and volume of orders never created a space constraint on the broiler. However, the staff experienced slightly longer cook times with the new infrared (IR) plate broiler with products such as burgers taking 1-2 minutes longer to cook even when on the maximum temperature settings. They also noted that the replacement burner created more smoke, which the ventilation hood could not always properly contain. No differences in cooked food product quality were noted. The replacement broiler used only 6.9 therms per day, resulting in a 42 percent reduction in energy use.

Figure 19: DoubleTree Baseline 4-ft. Broiler

Source: Frontier Energy, Inc.

Figure 20: DoubleTree Replacement IR Plate Broiler

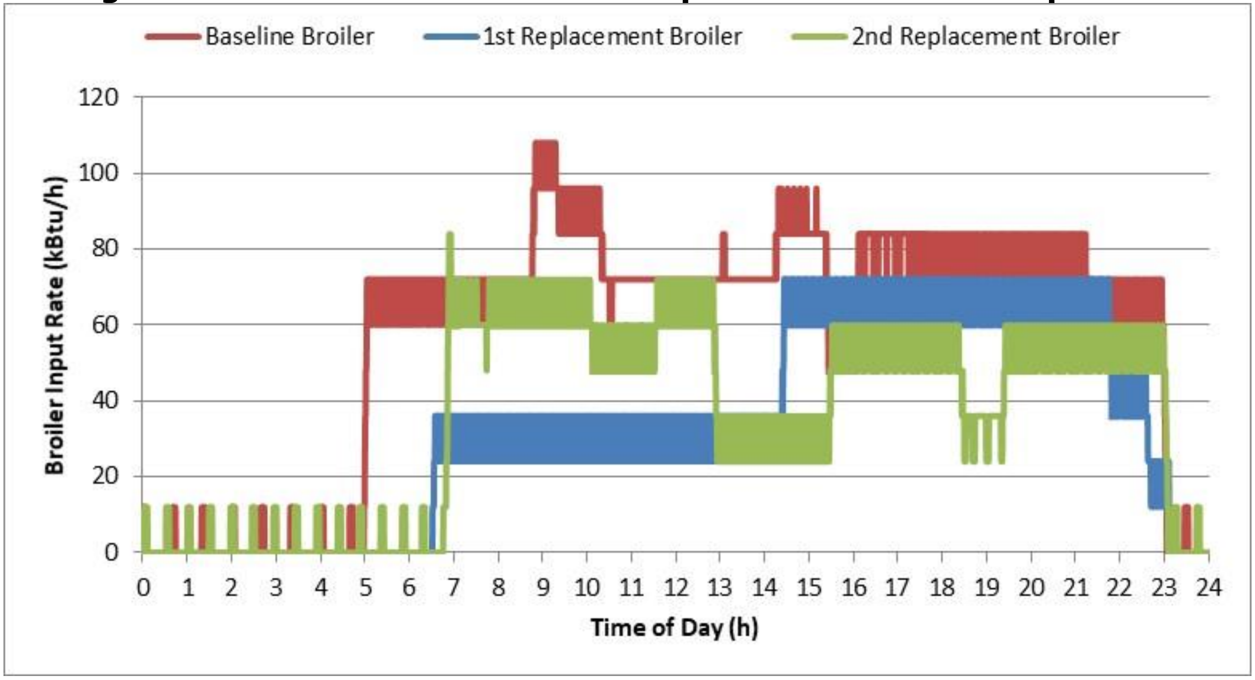
Source: Frontier Energy, Inc.

After several months of use, however, the IR plates on the replacement broiler started warping, which caused uneven cooking temperatures and compromising production. As a result, the 3-ft. IR plate broiler was replaced by a different 3-ft. IR burner broiler, which used slightly more energy, but provided better cooking performance for this operation (Figure 21). The staff was pleased by the quick cook times of the second IR burner broiler and particularly noted the distinct char marks that the broiler imprinted upon the cooked product. The second replacement broiler used an average 7.9 therms per day, a bit higher than the IR plate burner, but still resulting in a 32% energy savings compared to the baseline broiler.

Figure 21: DoubleTree 2nd Replacement IR Burner Broiler

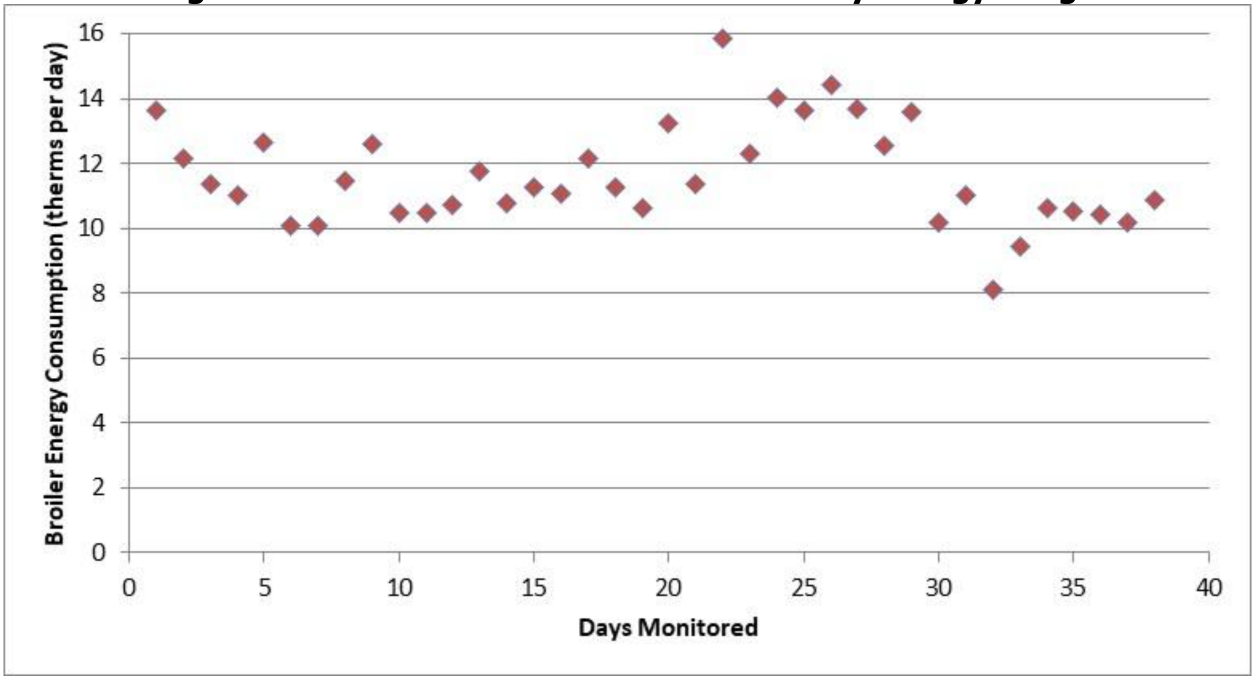
Source: Frontier Energy, Inc.

Figure 22: DoubleTree Baseline vs. Replacement Broiler Comparisons



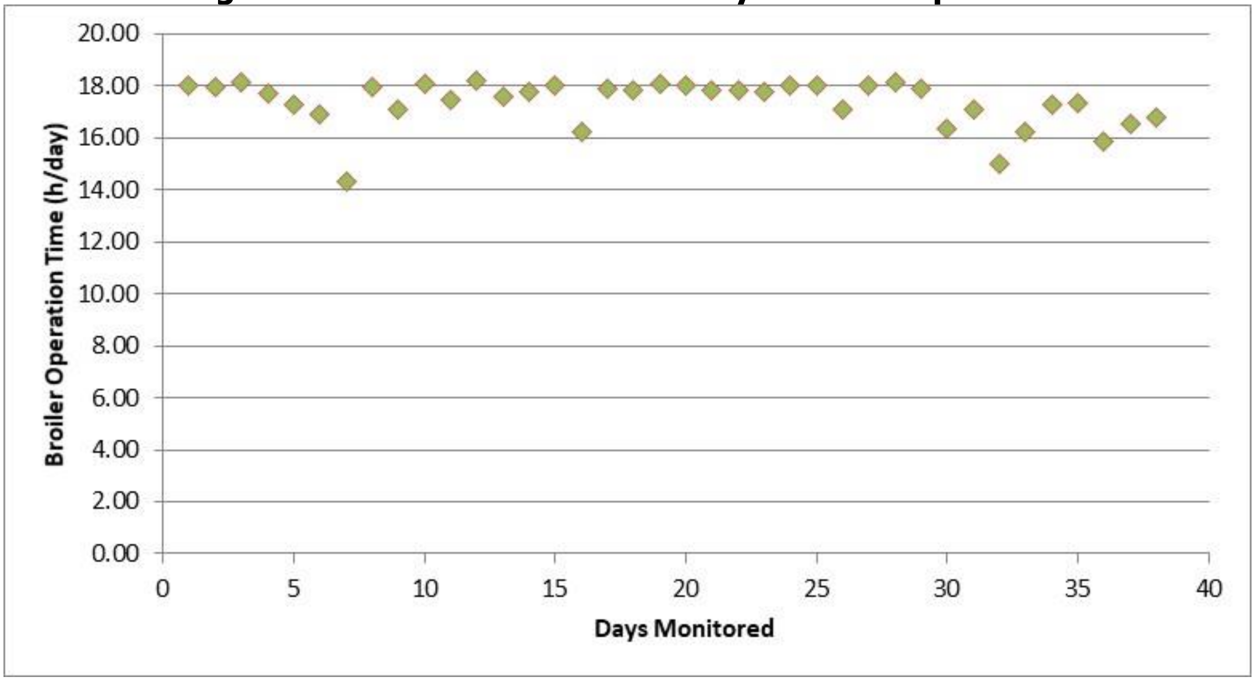
Source: Frontier Energy, Inc.

Figure 23: DoubleTree Baseline Broiler Daily Energy Usage



Source: Frontier Energy, Inc.

Figure 24: DoubleTree Broiler Daily Hours of Operation



Source: Frontier Energy, Inc.

Griddle Replacement

The kitchen initially had a 3-ft. non-thermostatic griddle with a range oven base (Figure 25). The griddle burners were usually set for 60-70% power and not adjusted often. The griddle consumed 4.1 therms per day on average and was on for 12 hours per day. The left side of the griddle was kept hotter than the right side of the griddle, with the left side being used for cooking and the right side primarily for finishing/holding. The griddle was mostly used to cook breakfast items such as bacon, eggs, hash browns, and occasionally grilled cheese sandwiches. The oven underneath the griddle was not used for cooking, only storage.

The non-thermostatic griddle was replaced by a thermostatic energy-efficient griddle of the same cooking surface area (Figure 26). The replacement griddle has three burners with three thermostatic zones. Rather than having a pilot light like the baseline griddle, the replacement griddle featured electronic ignition, eliminating pilot gas consumption. Set for a 375°F cooking temperature, the replacement griddle consumed 3.1 therms per day and operated longer hours at an average 17.3 hours per day. The staff was very happy with the new griddle because now they do not have to adjust the burners manually to maintain the same cooking temperature. Despite longer operating hours and higher production capacity, the replacement griddle reduced gas consumption by 25% over the baseline non-thermostatic griddle.

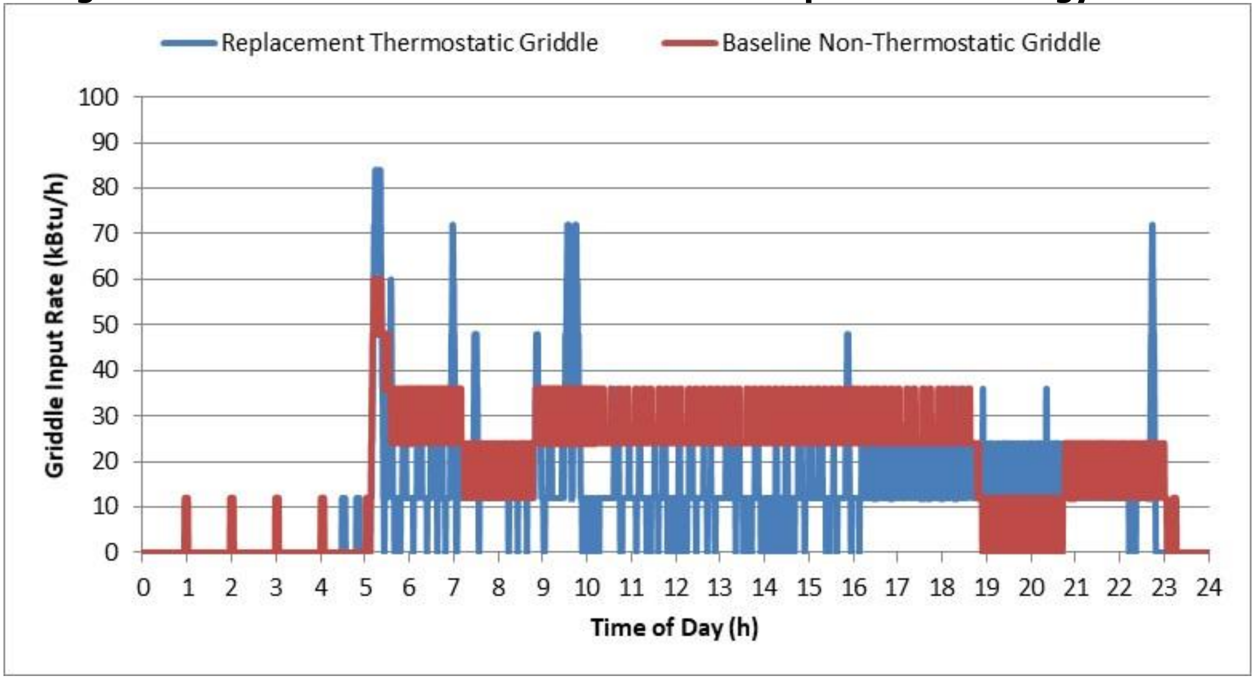
Figure 25: DoubleTree Non-Thermostatic Griddle

Source: Frontier Energy, Inc.

Figure 26: DoubleTree Replacement Thermostatic Griddle

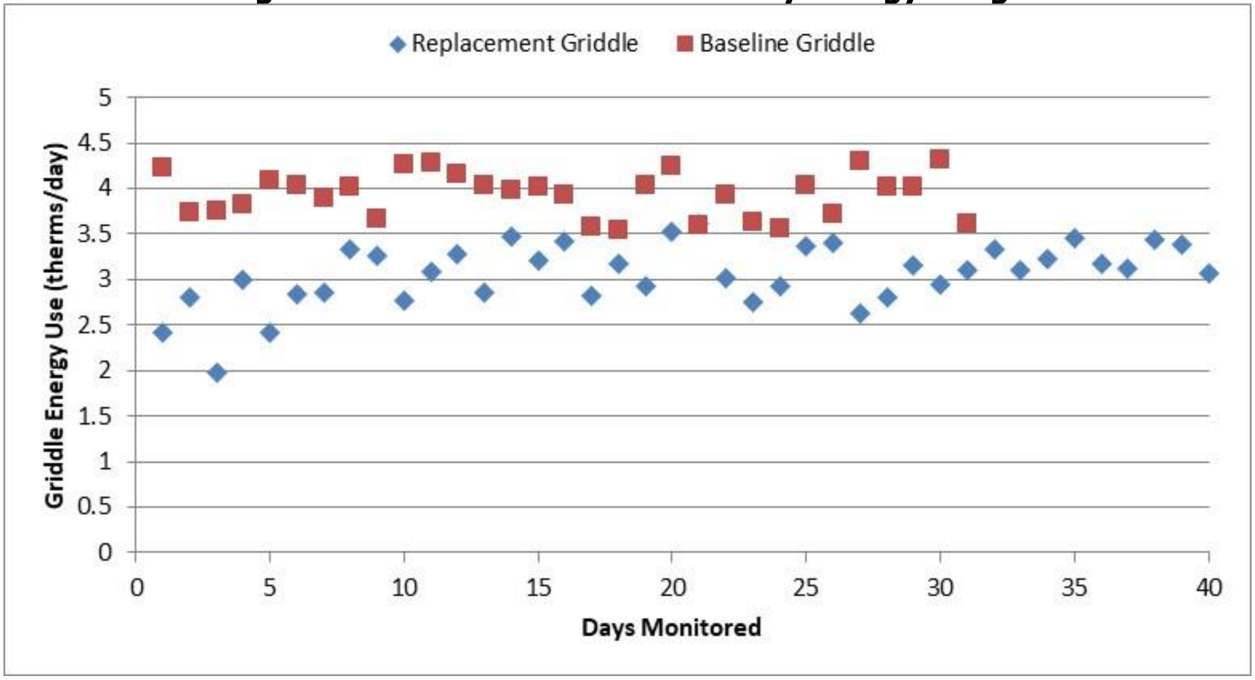
Source: Frontier Energy, Inc.

Figure 27: DoubleTree Thermostatic Griddle Replacement Energy Profile



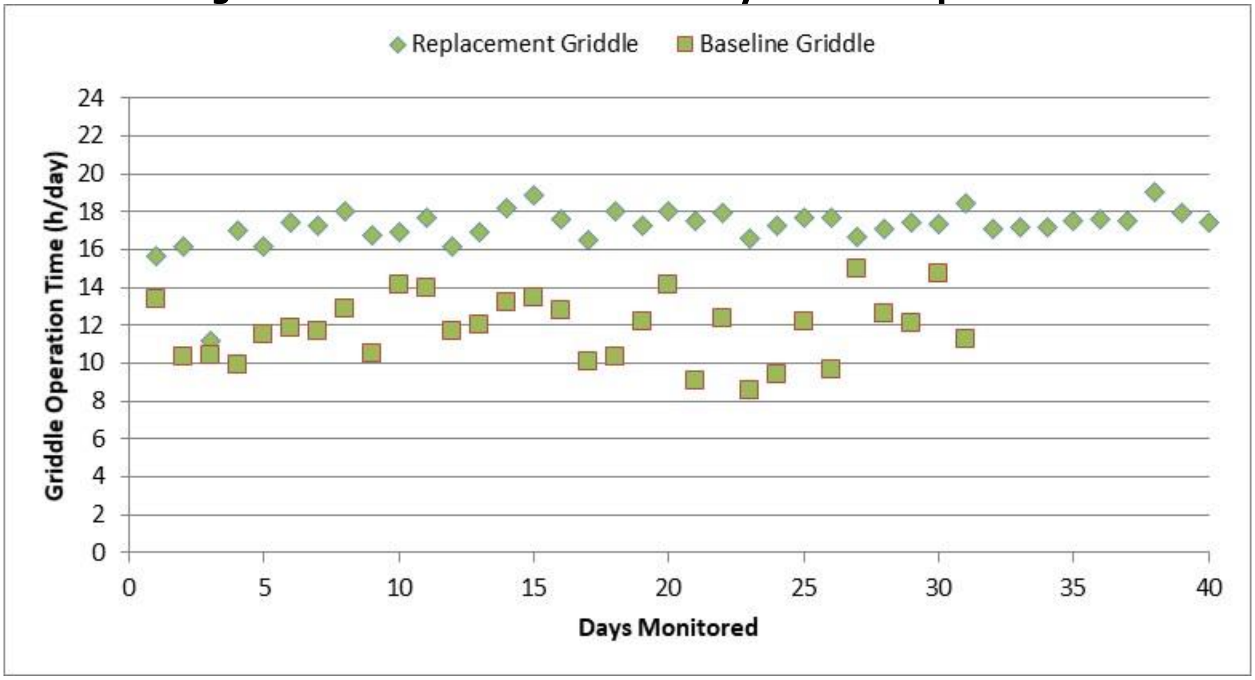
Source: Frontier Energy, Inc.

Figure 28: DoubleTree Griddle Daily Energy Usage



Source: Frontier Energy, Inc.

Figure 29: DoubleTree Griddle Daily Hours of Operation



Source: Frontier Energy, Inc.

Range Energy Monitoring

The kitchen had three six-burner ranges: two heavy duty ranges on the cook-to-order front line and one rage on the back line for soups and stocks (Figure 30). Each range was metered separately. All three ranges were equipped with ovens underneath, which the staff did not use, instead using the dedicated convection ovens on the back line. The left front range also had an overhanging salamander broiler, which was directly connected to the range gas supply. Thus, the recorded energy for that range also includes salamander energy use. The salamander operated at an input rate between 20 and 30 kBtu/h and was used primarily to toast bread and melt cheese.

- The front left salamander range used 5.0 therms per day operating 19 hours per day including the salamander.
- The front right range used 2.8 therms per day operating 16 hours per day.
- The back range used 1.9 therms per day operating 11 hours per day.

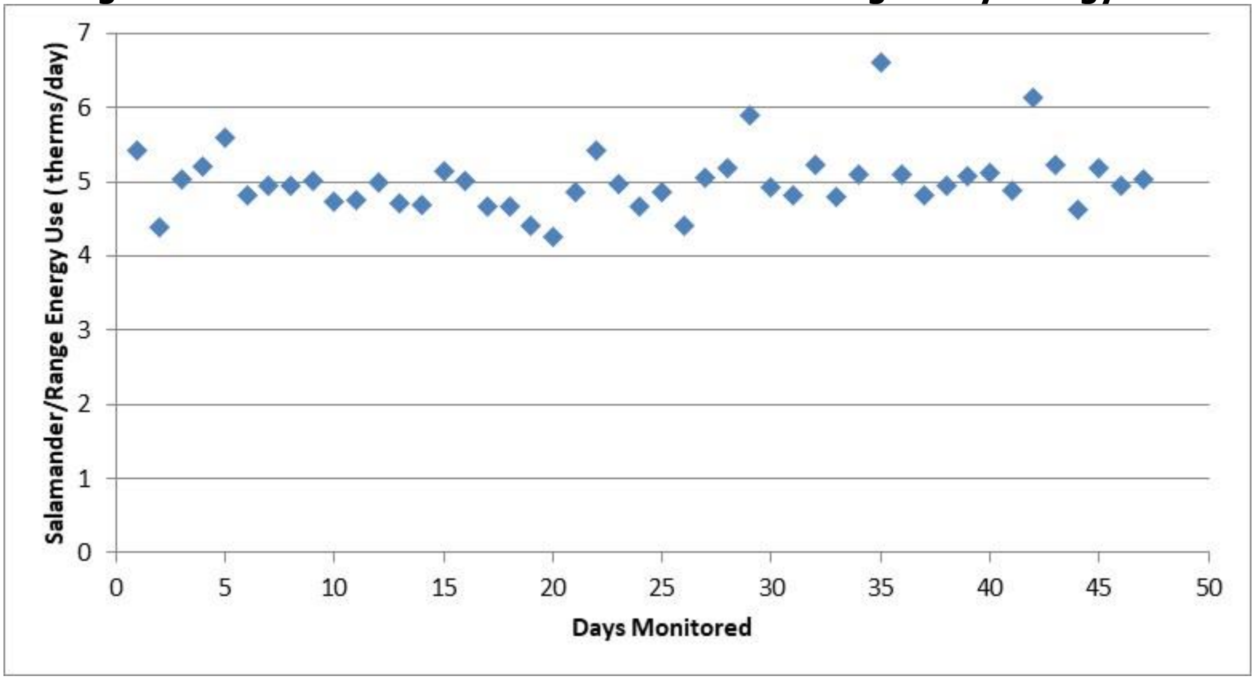
Figure 30: DoubleTree Ranges

Clockwise: front right range, front left range with salamander, back range.

Source: Frontier Energy, Inc.

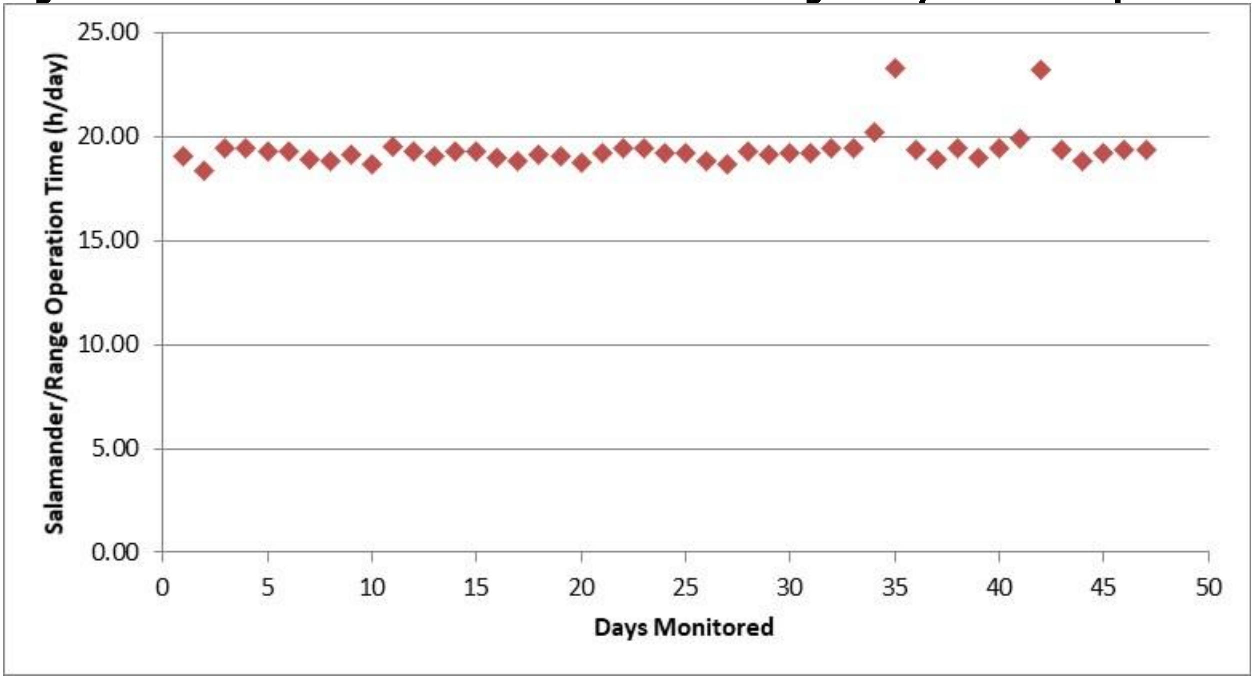
The back prep line range was mostly used for cooking soups, sauces, and heating up refrigerated foods. The front cook-to-order line range was mostly used to cook eggs in pans, different sauces, and more delicate fish.

Figure 31: DoubleTree Front Left Salamander Range Daily Energy Use



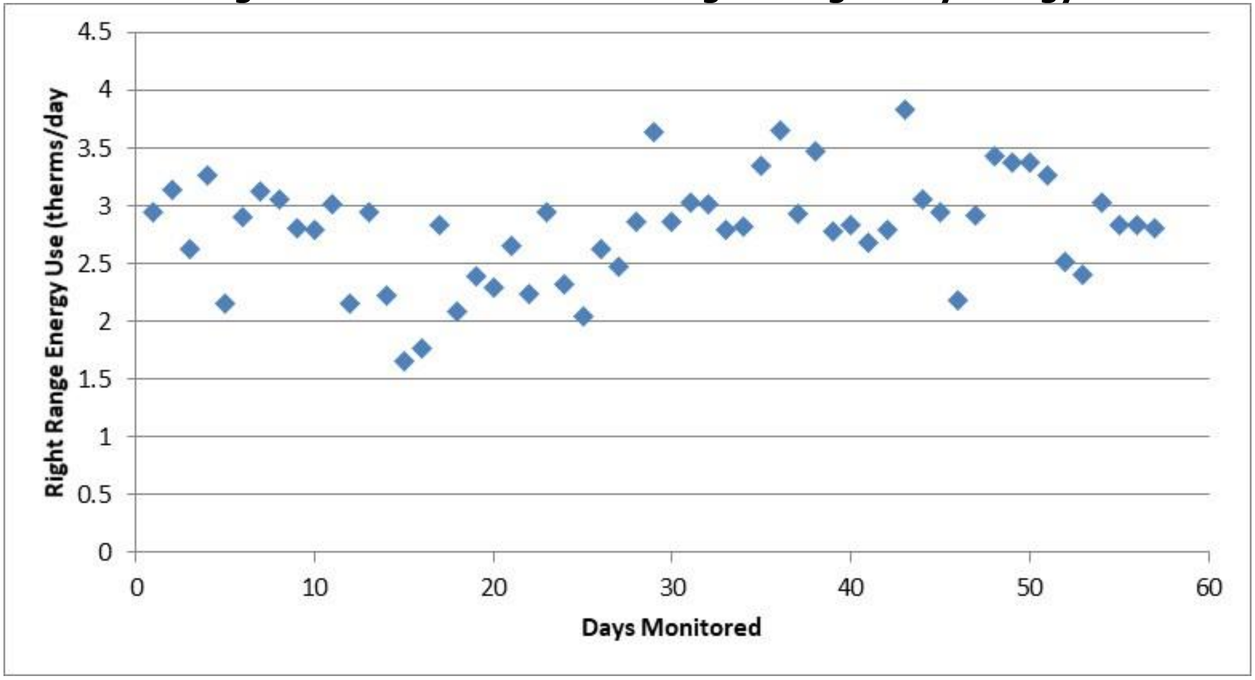
Source: Frontier Energy, Inc.

Figure 32: DoubleTree Front Left Salamander Range Daily Hours of Operation



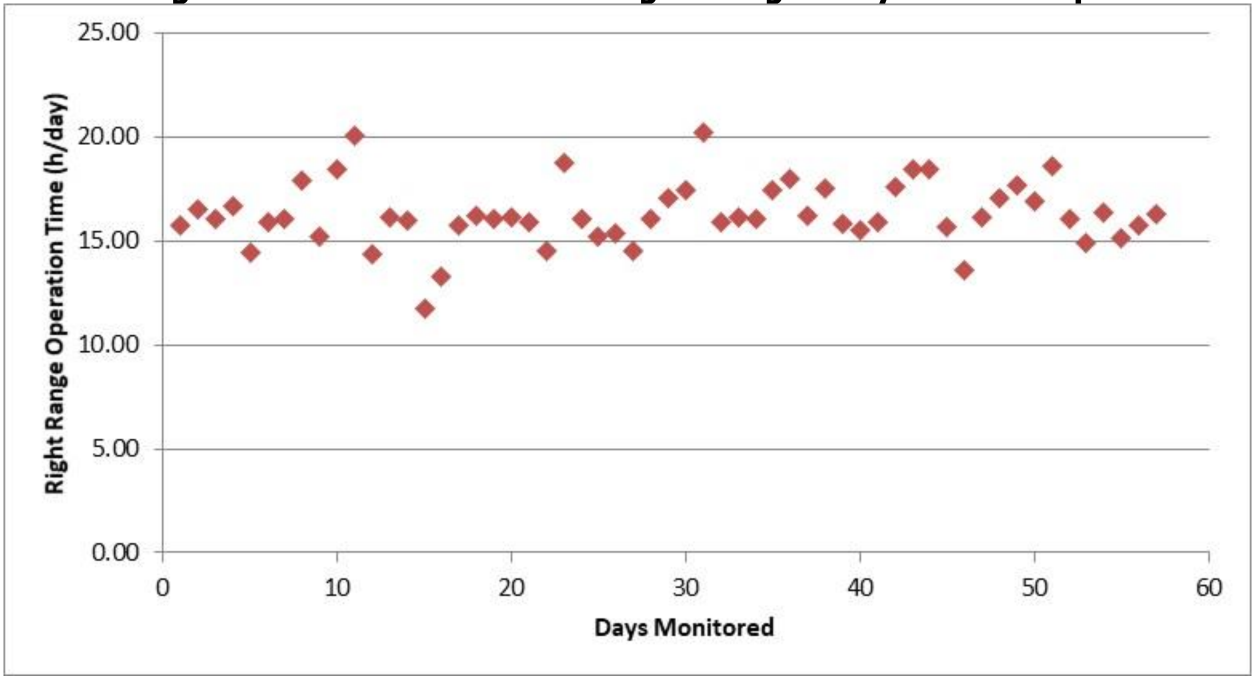
Source: Frontier Energy, Inc.

Figure 33: DoubleTree Front Right Range Daily Energy Use



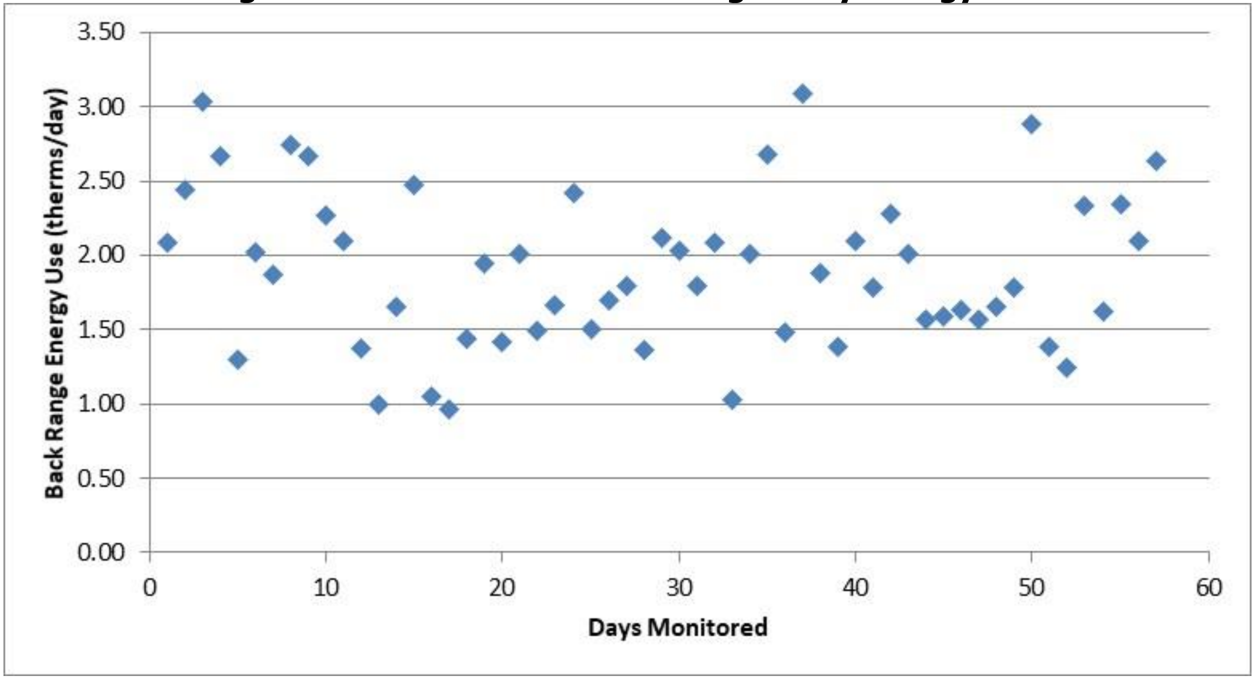
Source: Frontier Energy, Inc.

Figure 34: DoubleTree Front Right Range Daily Hours of Operation



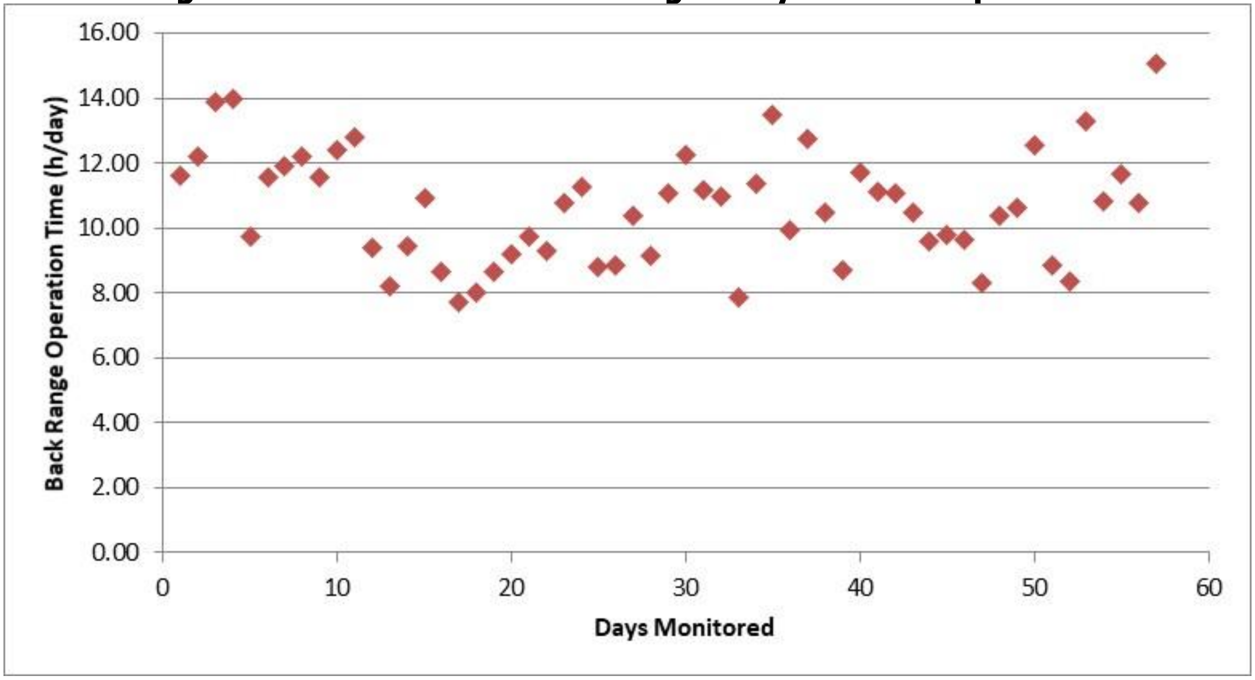
Source: Frontier Energy, Inc.

Figure 35: DoubleTree Back Range Daily Energy Use



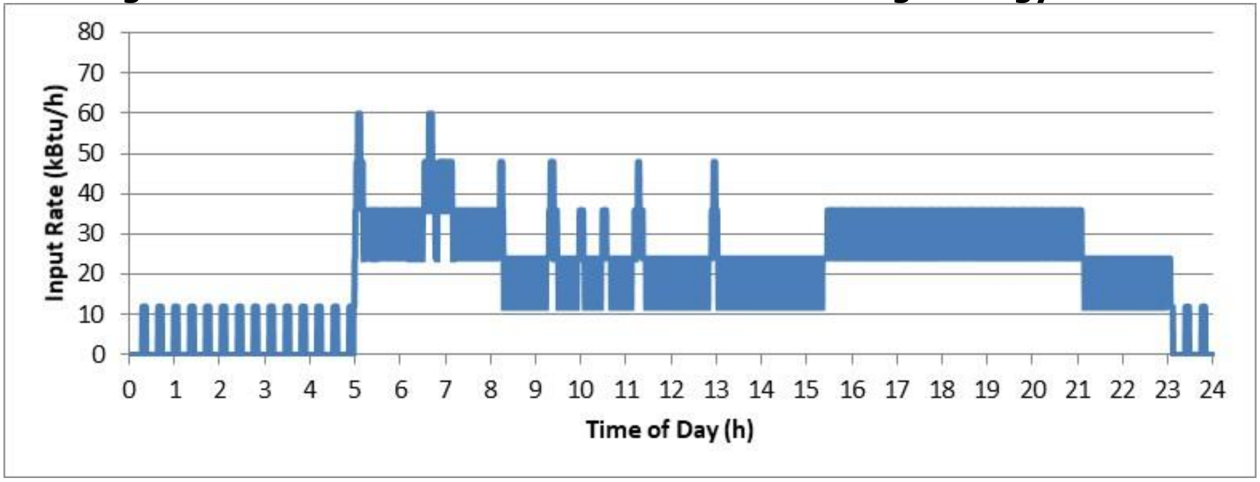
Source: Frontier Energy, Inc.

Figure 36: DoubleTree Back Range Daily Hours of Operation



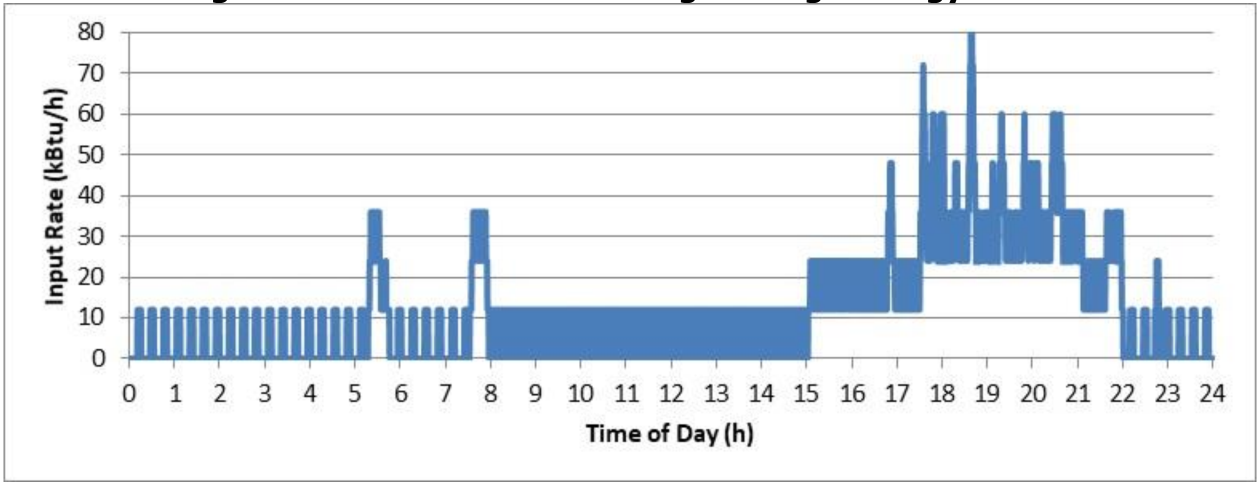
Source: Frontier Energy, Inc.

Figure 37: DoubleTree Front Left Salamander Range Energy Profile



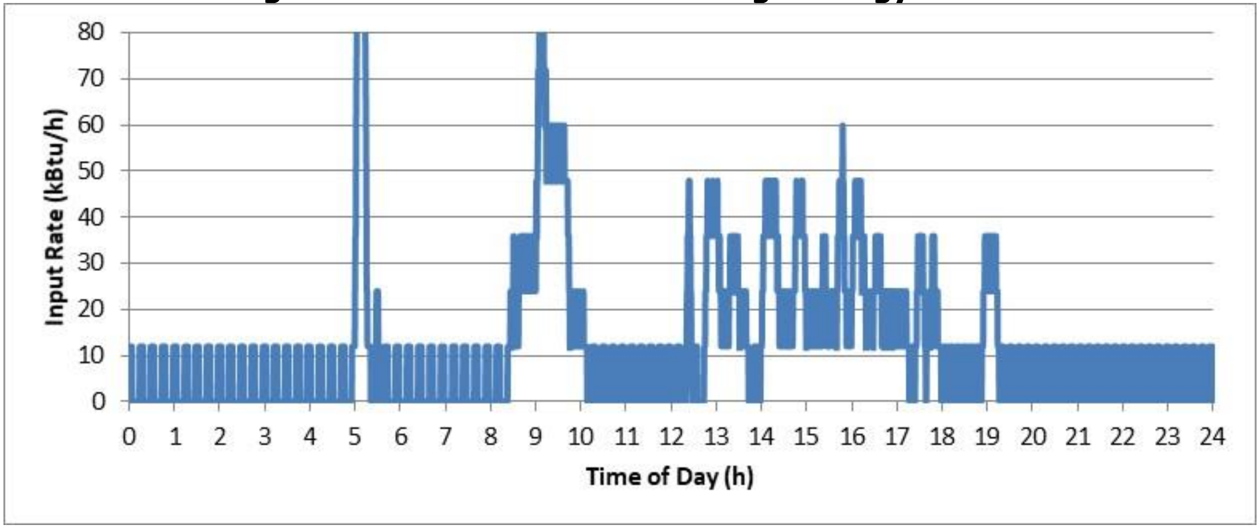
Source: Frontier Energy, Inc.

Figure 38: DoubleTree Front Right Range Energy Profile



Source: Frontier Energy, Inc.

Figure 39: DoubleTree Back Range Energy Profile



Source: Frontier Energy, Inc.

Convection Oven Replacement

The DoubleTree prep line had two double stack convection ovens next to a two-compartment holding cabinet (Figure 40). There was a total of four standard ovens underneath the ranges and the griddle; however, staff preferred to use the four convection ovens for production. Each convection oven compartment was equipped with standing pilots and rated for 110 kBtu/h maximum input. Each double stack was metered together, since they shared the same gas line. The left oven stack consumed 4.2 therms per day while operating for 19 hours per day. The right oven stack consumed 5.6 therms per day while also operating for 19 hours per day. The ovens were typically turned on at 5 am and turned off at 11 pm. Use of each compartment varied per day, however it was estimated that both compartments were used 20% of the time in the left oven stack and 63% of the time in the right oven stack.

Figure 40: Baseline Double Stack Convection Ovens

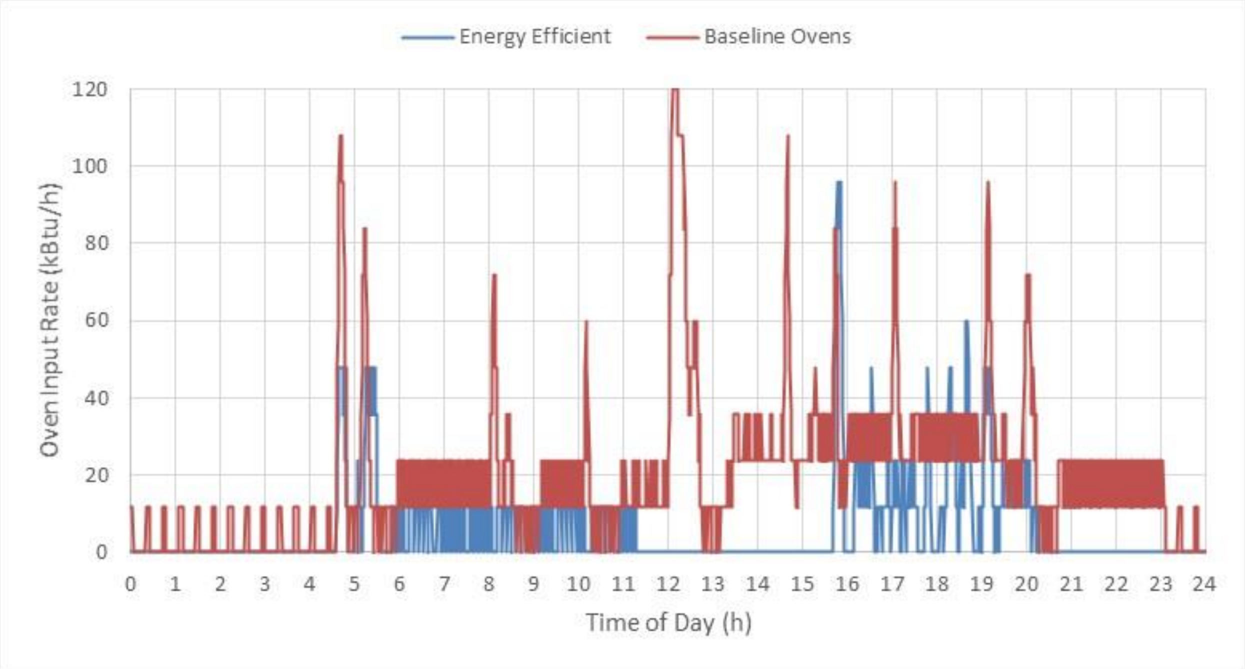
Source: Frontier Energy, Inc.

The left double stack oven was replaced by a more energy efficient model, which was observed to use only 1.6 therms per day, a 62% reduction compared to the baseline oven (Figure 41). The staff initially had some concerns with the new oven's cooking uniformity, but within a few weeks they adjusted and were happy with the new equipment. The kitchen manager mentioned that the staff required time to became more familiar with the replacement ovens and that the ovens functioned well when staff knew how to use them properly. This is a common example of negative staff sentiment to energy efficient equipment replacement because of familiarity issues, which can usually be overcome without any detriment with simple process adjustments and staff training.

Figure 41: Replacement Left Double Stack Convection Oven

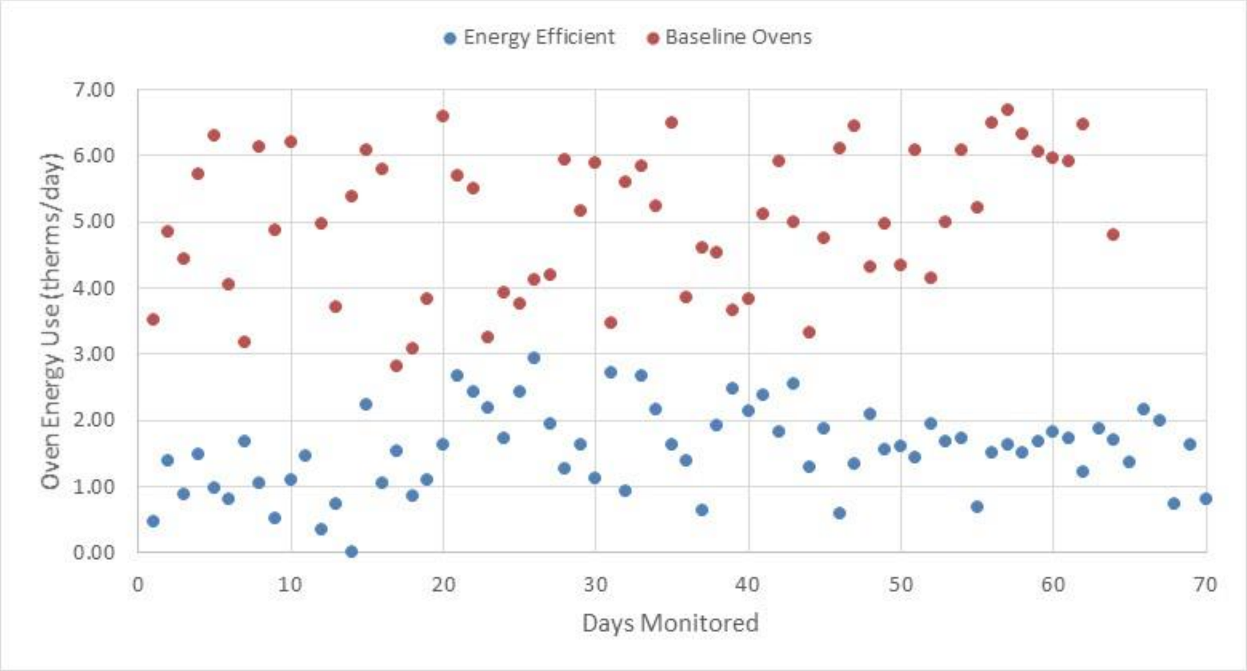
Source: Frontier Energy, Inc.

Figure 42: DoubleTree Left Double Stack Convection Oven Replacement Profile Comparison



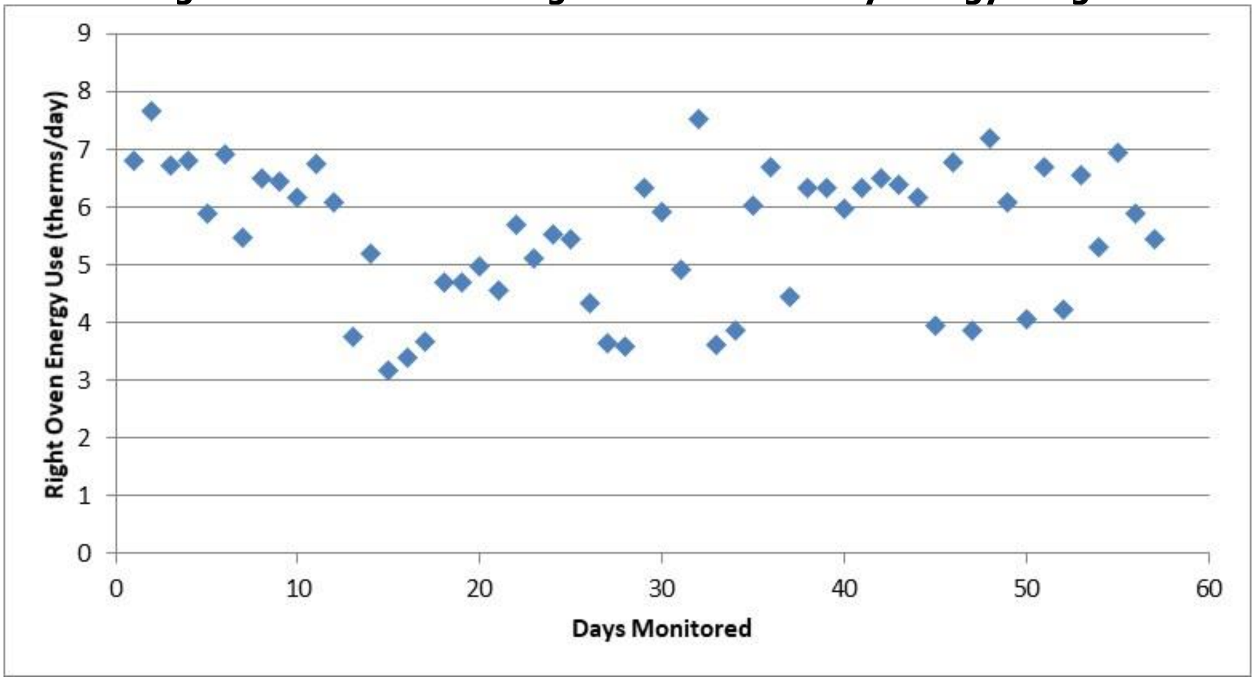
Source: Frontier Energy, Inc.

Figure 43: DoubleTree Left Double Stack Convection Oven Replacement Energy Usage Comparison



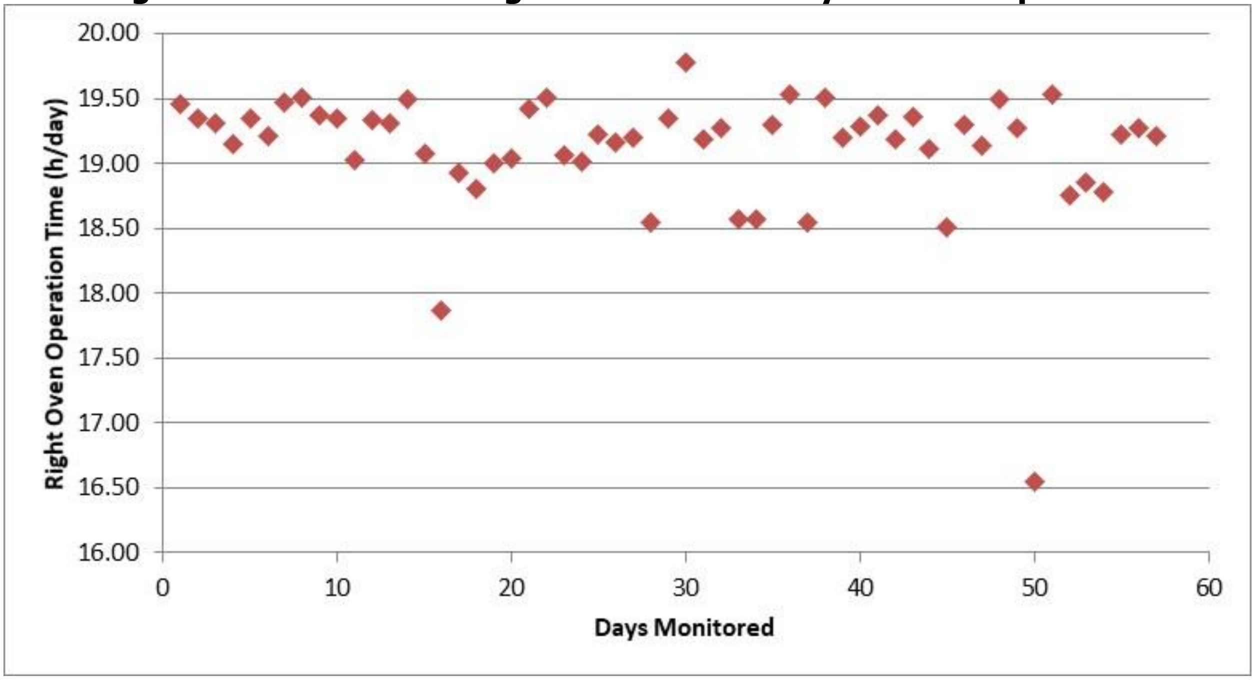
Source: Frontier Energy, Inc.

Figure 44: DoubleTree Right Oven Stack Daily Energy Usage



Source: Frontier Energy, Inc.

Figure 45: DoubleTree Right Oven Stack Daily Hours of Operation



Source: Frontier Energy, Inc.

Baseline Steamers

DoubleTree had three steam-generator type, double-compartment steamers operating at 480 volts. Two of the steamers were on the back prep line (Figure 46) and the third steamer was on the front cook-to-order line (Figure 47). The three steamers were not used simultaneously except in rare heavy catering situations.

Figure 46: Back Prep Line Steamers

Source: Frontier Energy, Inc.

Figure 47: Front Cook-to-Order Line Steamer

Source: Frontier Energy, Inc.

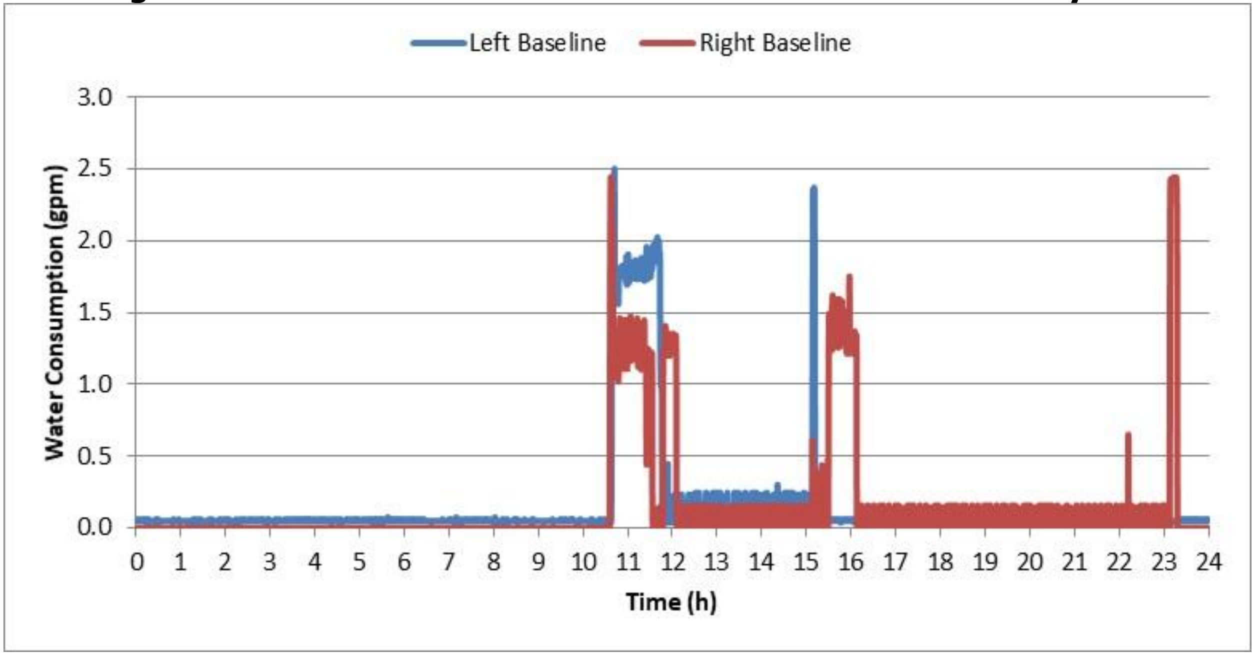
The baseline steamers were at least eight years old and in poor condition. The hotel has a building engineer on staff who occasionally serviced the steamers. All three baseline steamers were the same model. One of the steamers was often inoperable and frequently repaired with spare parts. Staff used the front line steamer mostly for storage (Figure 48). The front line steamer was not operational during a portion of the monitoring process. The staff claimed to have used the back right steamer the most. The back left and front steamers were used intermittently with one of them usually waiting for repair.

Figure 48: Front Line Steamer Used for Storage

Source: Frontier Energy, Inc.

When both back line steamers were used heavily, the water consumption was 209 and 187 gallons per day for the day (Figure 49).

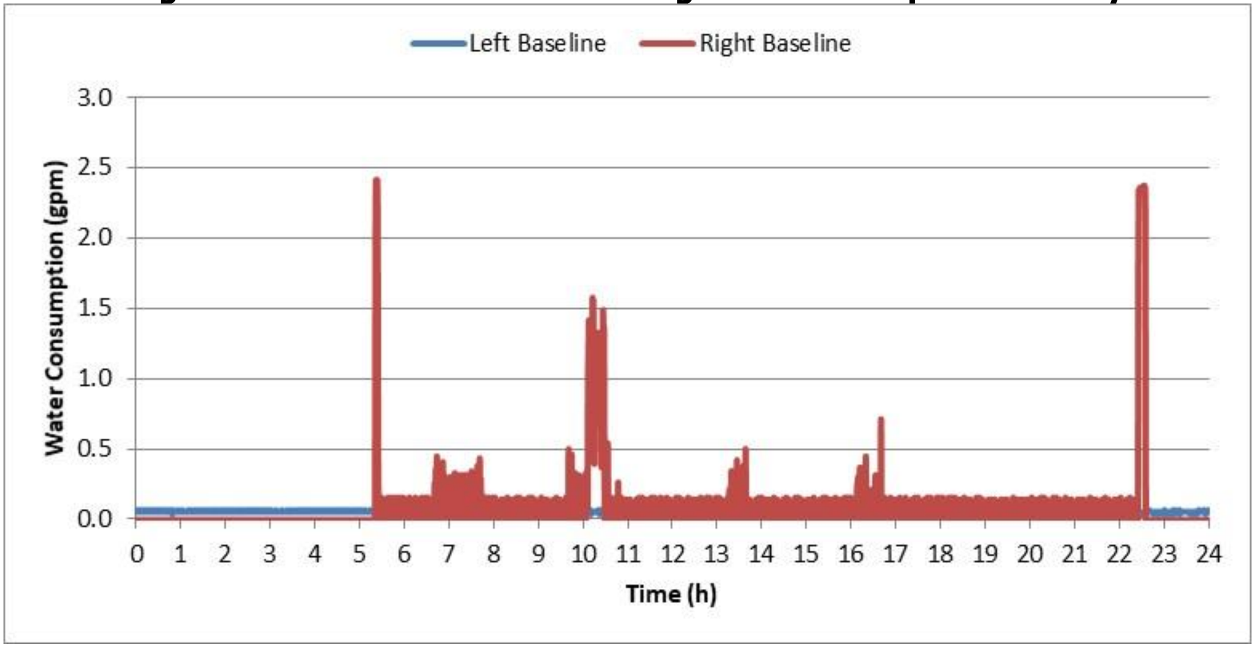
Figure 49: DoubleTree Baseline Steamer Simultaneous Heavy Use



Source: Frontier Energy, Inc.

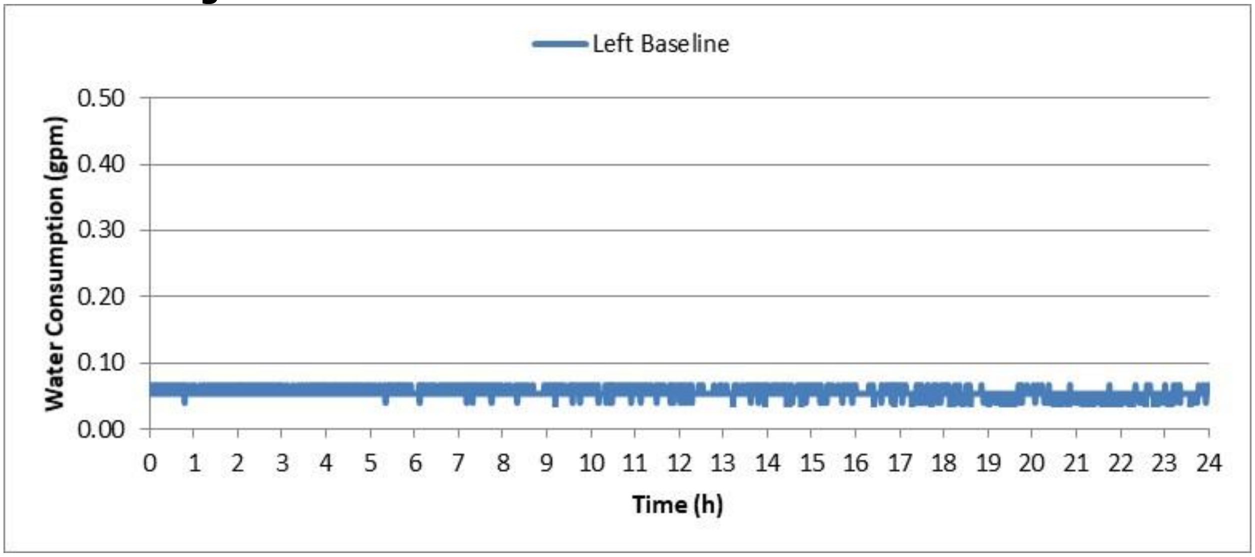
When the steamers were used lightly, using 78 and 93 gallons of water per day, the water consumption profile is illustrated in Figure 50.

Figure 50: DoubleTree Baseline Right Steamer Operation Only



During light days, despite not being used at all, the left steamer consumed 79 gallons of water (Figure 51). This was likely caused by a condensate cooling valve that did not properly close, which resulted in a 0.06 gallons per minute (gpm) leak.

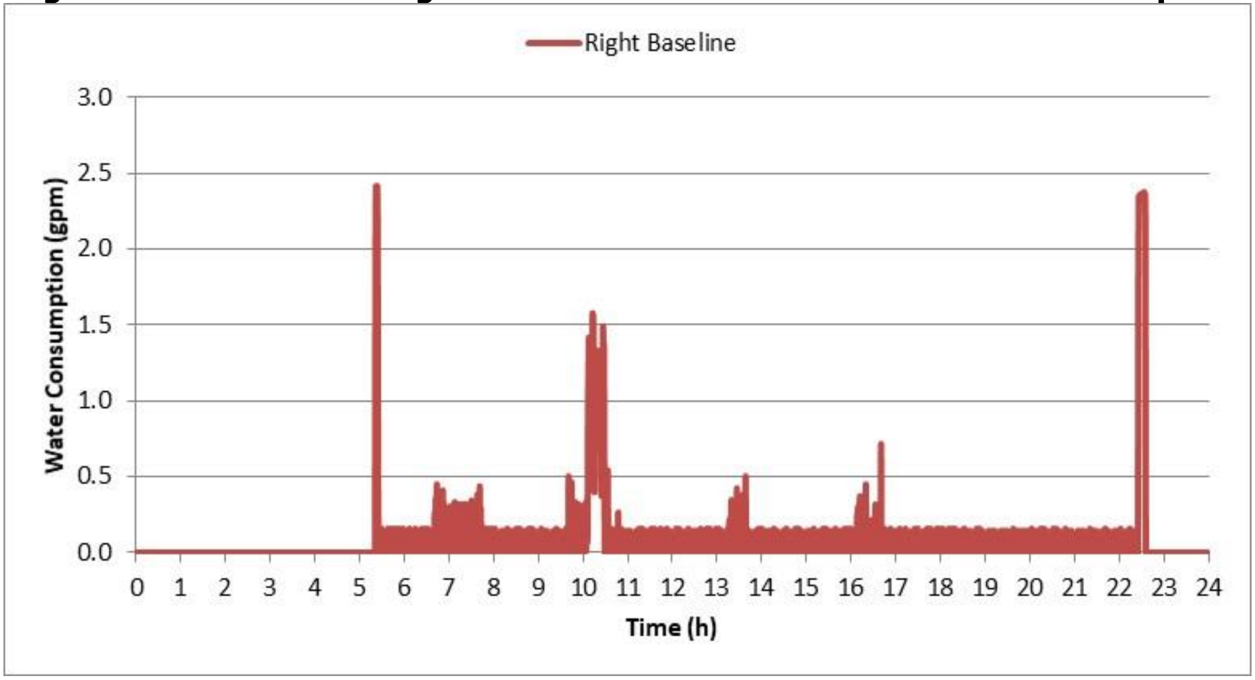
Figure 51: DoubleTree Left Baseline Steamer Water Leak



Source: Frontier Energy, Inc.

The right steamer used water only when it was on. However, during a light day with only four cycles, the steamer still consumed water during standby operation. This steamer filled up in the morning around 5 am and operated with a constant water consumption throughout the day except for a couple of cook cycle spikes at 7 am, 10 am, 1 pm, and 4 pm (Figure 52). When the steamer was turned off at 11 pm, the steam generator was flushed out, resulting in a water consumption spike. When the steamer was on, it operated at a constant water consumption rate of 0.15 gpm to maintain pressure in both steam generators.

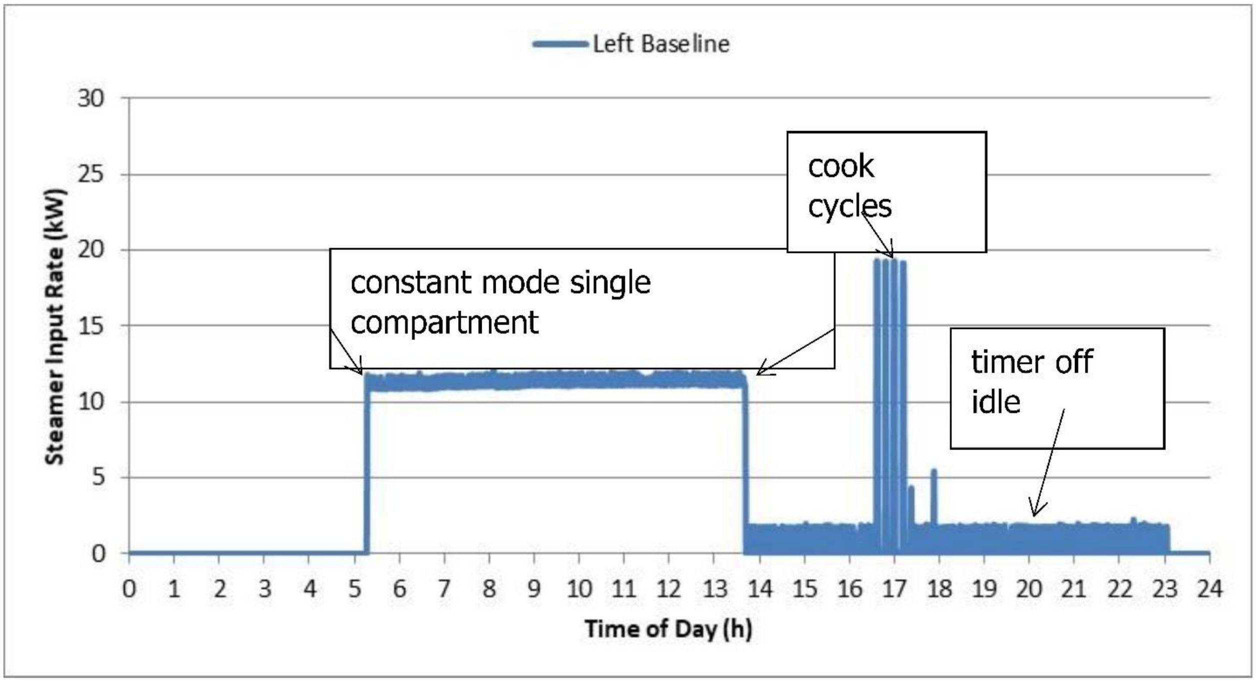
Figure 52: DoubleTree Right Baseline Steamer Constant Water Consumption



Source: Frontier Energy, Inc.

When the steamer controls were set for constant mode, the steamer operated with the heating elements constantly engaged between 5 am and 2 pm. When the steamer was set in timed mode and the timer ran out, it maintained steam generator pressure, but not cavity pressure. It operated at a lower input rate after 2 pm with only a short cook cycle engaged around 5 pm (Figure 53).

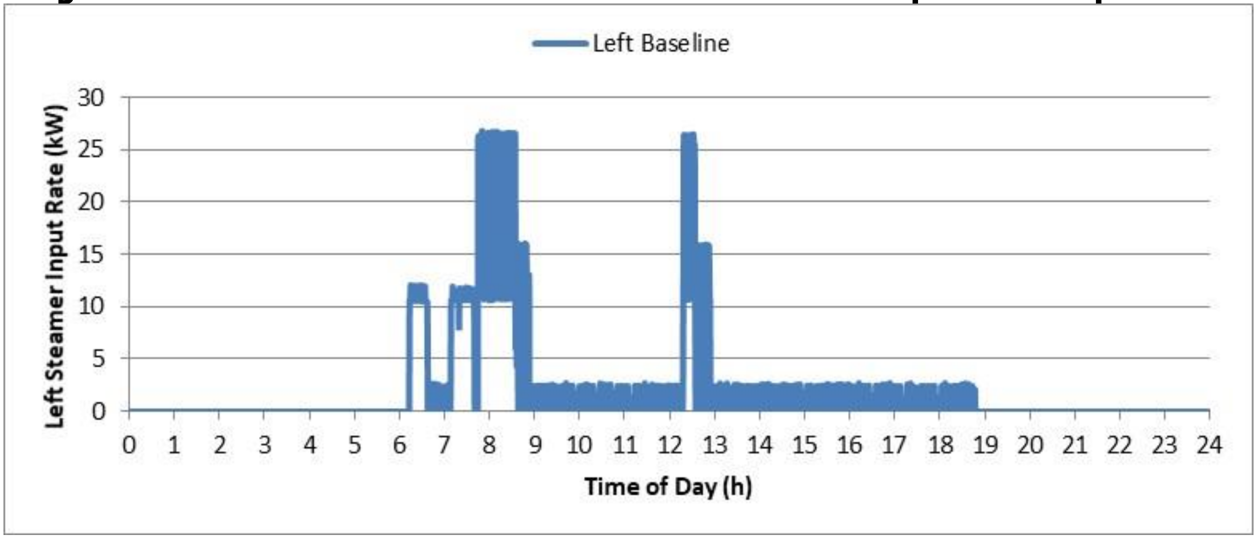
Figure 53: DoubleTree Left Baseline Steamer Morning Constant Mode Energy Consumption



Source: Frontier Energy, Inc.

Each steamer compartment was rated for 15 kW. Figure 54 shows two compartment cooking operation at 8 am and noon. The idle energy rate outside cooking is higher than in the graph above since both compartments were being kept warm. The staff mostly used the top compartment and only used the bottom compartment when necessary.

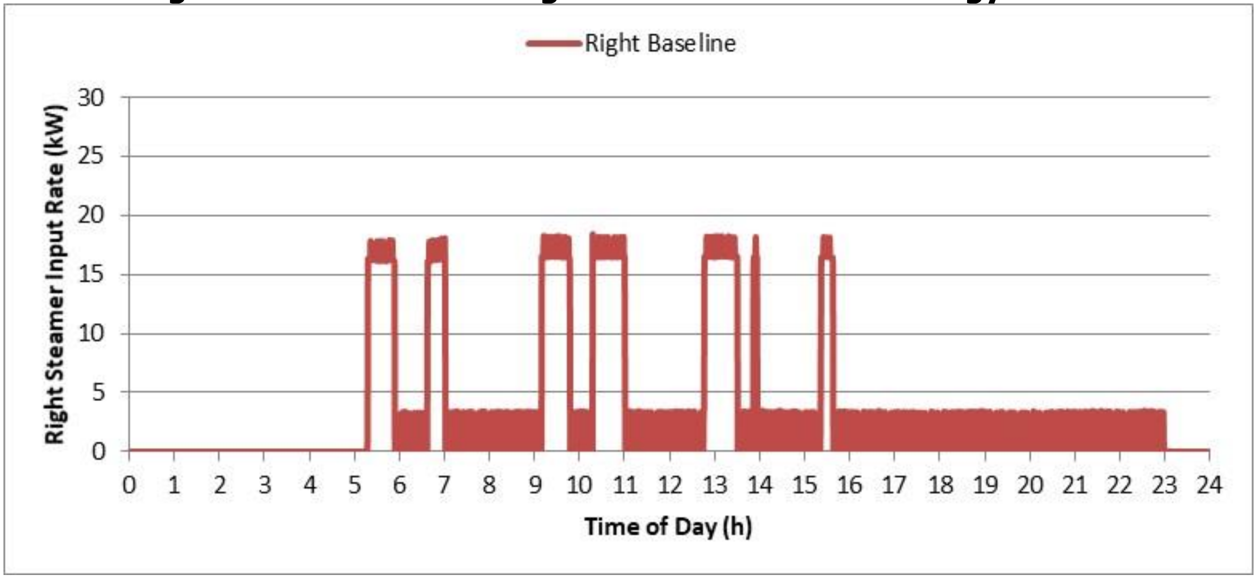
Figure 54: DoubleTree Left Baseline Steamer Dual Compartment Operation



Source: Frontier Energy, Inc.

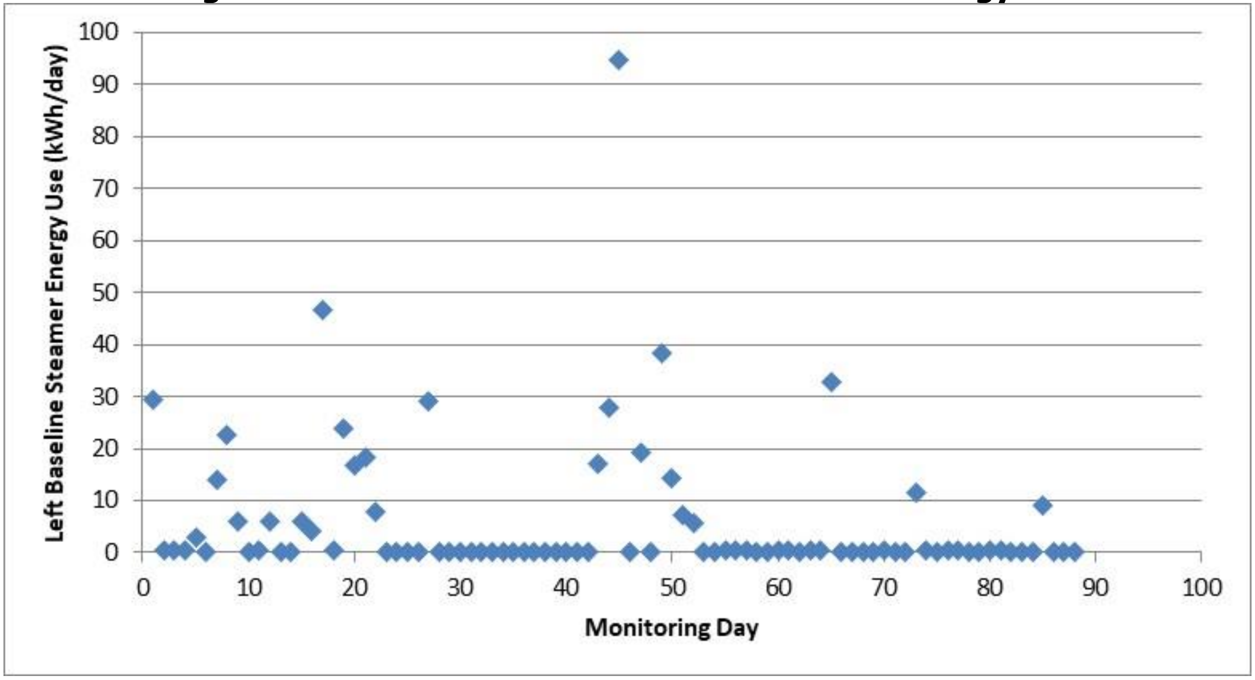
During the three month monitoring period, it was found that the left steamer was turned on only about a quarter of hotel operating days, whereas the right steamer was used on a daily basis. In total, this meant that the left steamer averaged 0.6 hours of cooking operation per day, while the right steamer averaged 5.9 hours per day. Even on days when turned on, the left steamer only averaged 2.2 hours of use, meaning that the right steamer was still used more than twice as often. During this monitoring period, the left steamer averaged **6** kWh/day and the right steamer averaged 91 kWh/day. The average consumption of the front baseline steamer was 50 kWh per day. When the steamers were used they were turned on at 5 am and turned off at 11 pm, for a total of 18 hours of use.

Figure 55: DoubleTree Right Baseline Steamer Energy Profile



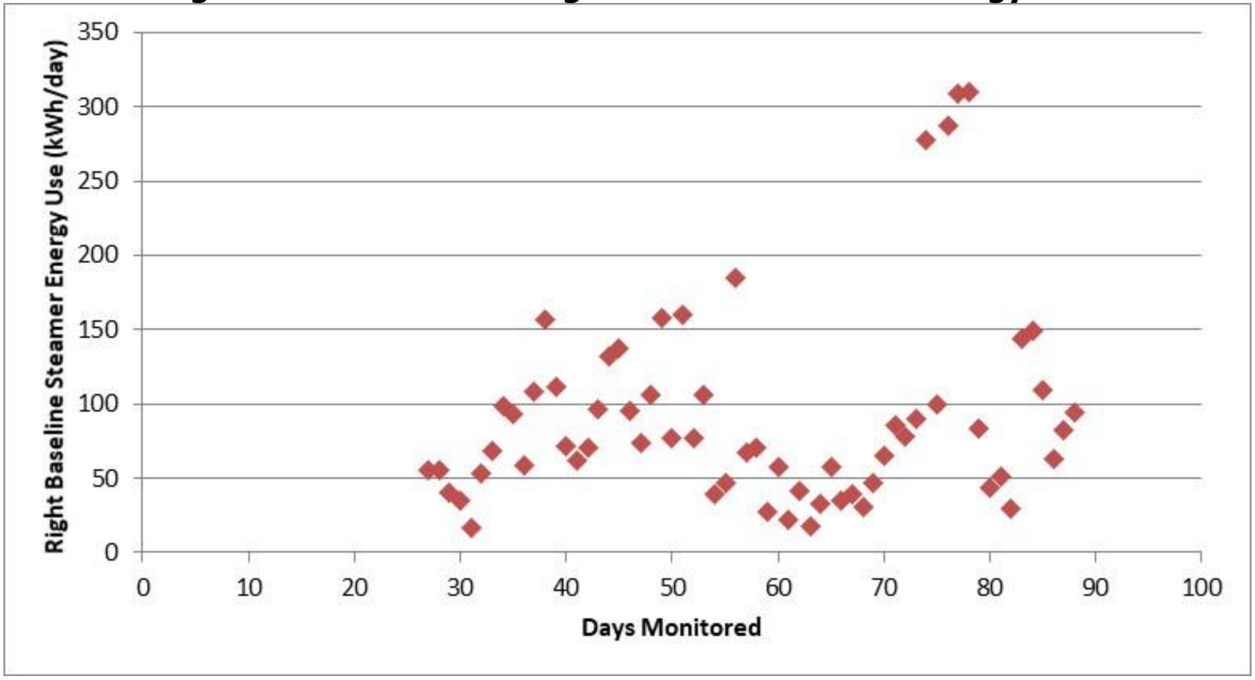
Source: Frontier Energy, Inc.

Figure 56: DoubleTree Left Baseline Steamer Energy Use



Source: Frontier Energy, Inc.

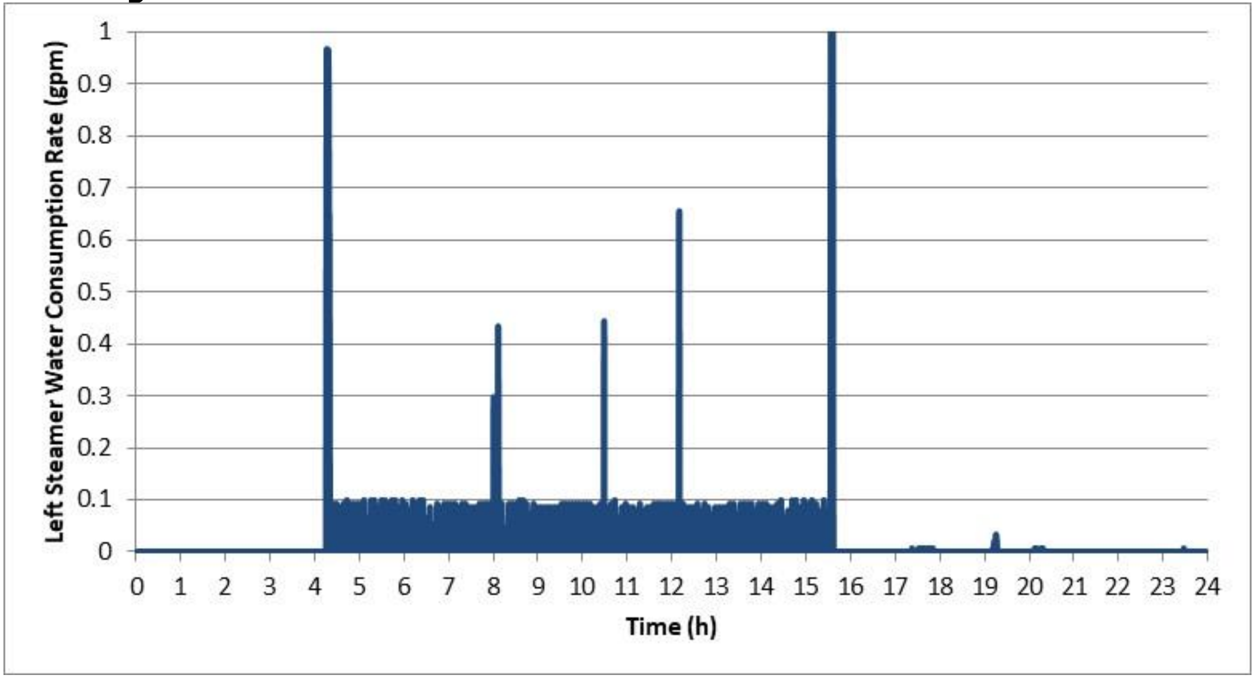
Figure 57: DoubleTree Right Baseline Steamer Energy Use



Source: Frontier Energy, Inc.

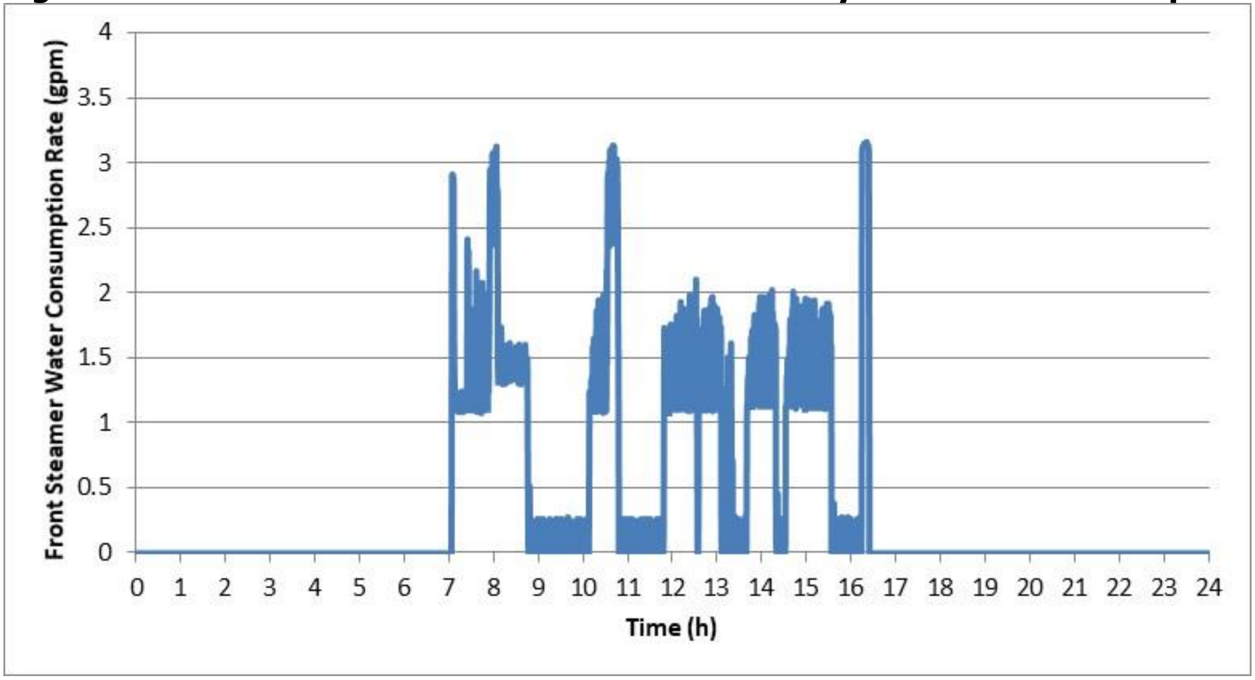
Steamer water and energy consumption are interdependent. It takes energy to create steam and steam is evaporated through the steamer vent. The exception is the condensate leak water consumption in the left baseline steamer (Figure 58). In this case, the steamer used water without using energy during non-operation time (Figure 59).

Figure 58: DoubleTree Left Back Line Baseline Steamer Water Use



Source: Frontier Energy, Inc.

Figure 59: DoubleTree Front Baseline Steamer Heavy Use Water Consumption



Source: Frontier Energy, Inc.

Steamer Replacement

The right steamer was replaced by an energy-efficient steam-generator gas steamer (Figure 60). For the three weeks of initial monitoring, the replacement steamer water consumption averaged to 35.5 gallons per day. The average gas consumption was 1.37 therms per day. Compared to their previous inefficient steamer, however, the staff felt the replacement steamer didn't have as much power, so they used it primarily for reheating food.

The left steamer was replaced by a gas 10-pan boiler-based combination oven (Figure 61). The staff was trained to use the combi oven and instructed to use it as they would their previous steamer. However, the combi training encompassed several cooking demo items which would not be normally cooked in a steamer like pizzas and steaks. Convection cooking with steam injection intrigued the kitchen staff so much that they started using the combi oven primarily for items that they would normally cook in the convection oven instead of the steamer. The combi oven was not used daily and had short operating hours, resulting in a low average gas consumption of only 0.25 therms per day. Based on the water consumption of less than a gallon per day, the combi oven was operated in low humidity mode. The staff mentioned these items were cooked in the combi: tri tip, pot roast, cookies, steamed vegetables, rice, chicken, salmon, potatoes for mash, pork, bacon, breakfast sausage, sweet corn, and roasted potatoes. Only steamed vegetables and rice required a high humidity recipe setting on the combi. Most other items were cooked in dry convection mode with the staff eventually experimenting and learning to use the combi mode as well. The staff was very pleased with the combi cooking performance.

Steamer replacement details are shown in Table 1.

Figure 60: Replacement Combi Oven and Gas Steamer

Source: Frontier Energy, Inc.

Figure 61: Replacement Electric Steamer

Source: Frontier Energy, Inc.

Figure 62: Combi Oven Controls

Source: Frontier Energy, Inc.

Figure 63: Replacement Combi Oven

Source: Frontier Energy, Inc.

The combi oven has a filtered and unfiltered water inlet. Researchers metered both inlets separately. The unfiltered water inlet is mostly used for condensate cooling water. Figure 64 the water use profile, the combi rarely used unfiltered water, consuming less than 1 gallon per day.

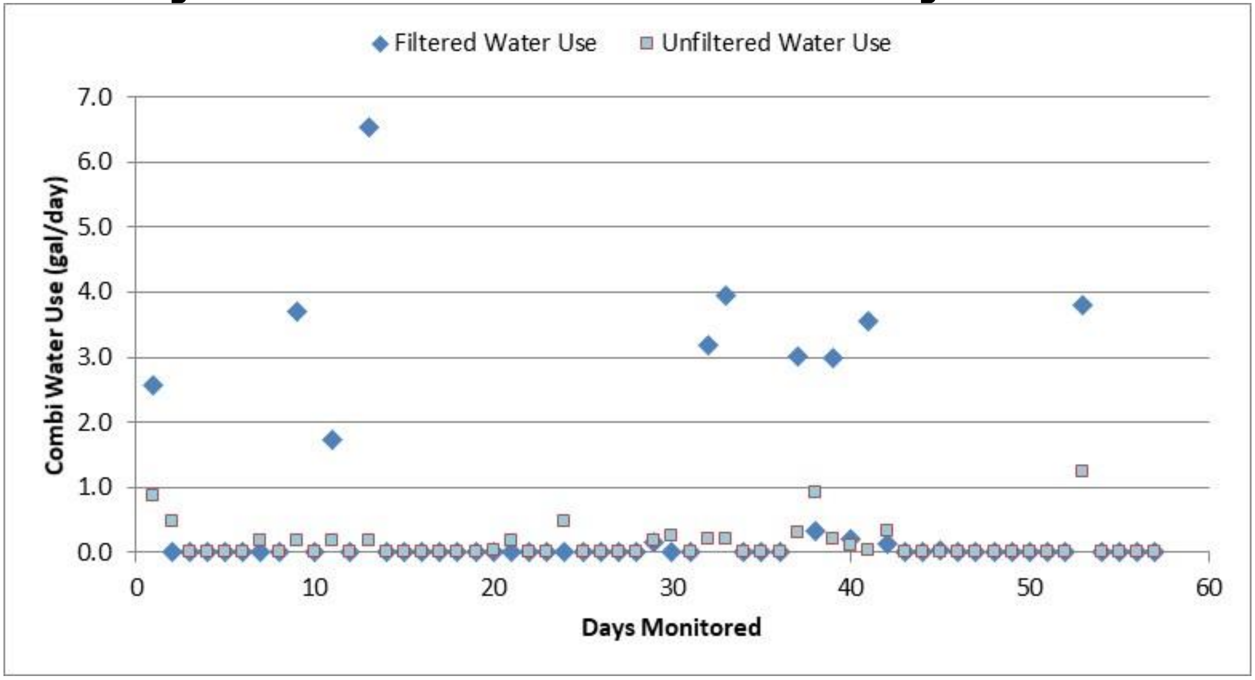
Table 1: DoubleTree Steamer Replacement Energy and Water Savings

Baseline Appliance	Replacement Appliance	Pre Energy Use	Post Energy Use	Baseline Water Use (gal/day)	Replacement Water Use (gal/day)
Front Steamer Electric	Front Steamer Efficient Electric	50 kWh/day	10 kWh/day	317*	20
Left Steamer Electric	Combination Oven Gas	6 kWh/day	0.3 (therms/day)	79	3
Right Steamer Electric	Right Steamer Gas	91 kWh/day	1.4 (therms/day)	167	36
				Electric Energy Savings	**137 kWh/day**
				Added Gas Consumption	**1.4 therms/day**
				Water Savings	**187 gal/day**

***Front line baseline steamer had a leak for a two-week monitoring period when the other two steamers were not being used. The leak is excluded from the total.**

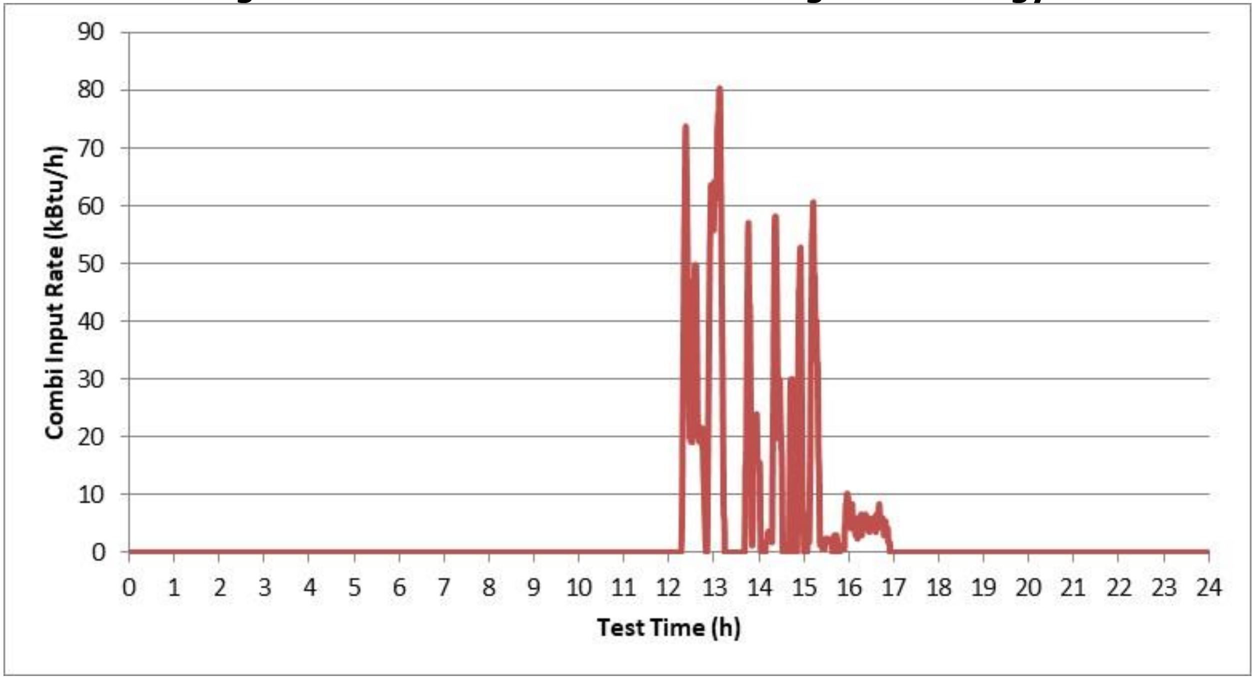
Source: Frontier Energy, Inc.

Figure 64: DoubleTree Combi Condensate Cooling Water Use



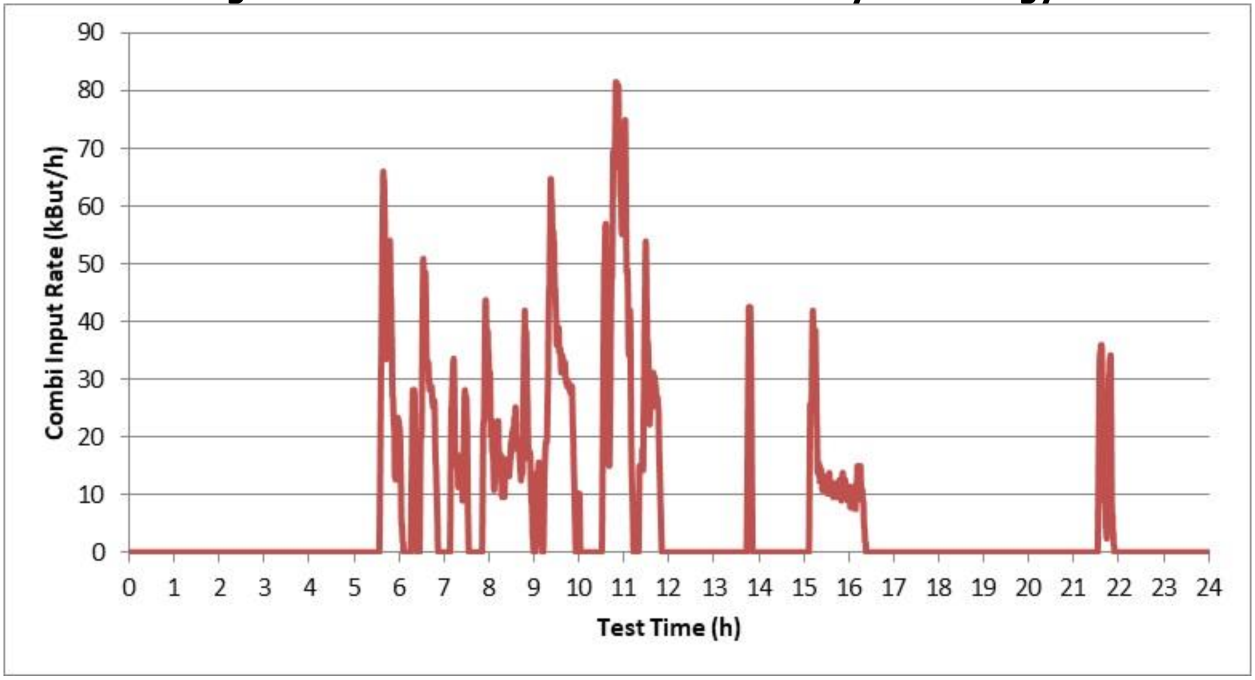
Source: Frontier Energy, Inc.

Figure 65: DoubleTree Combi Oven Light Use Energy



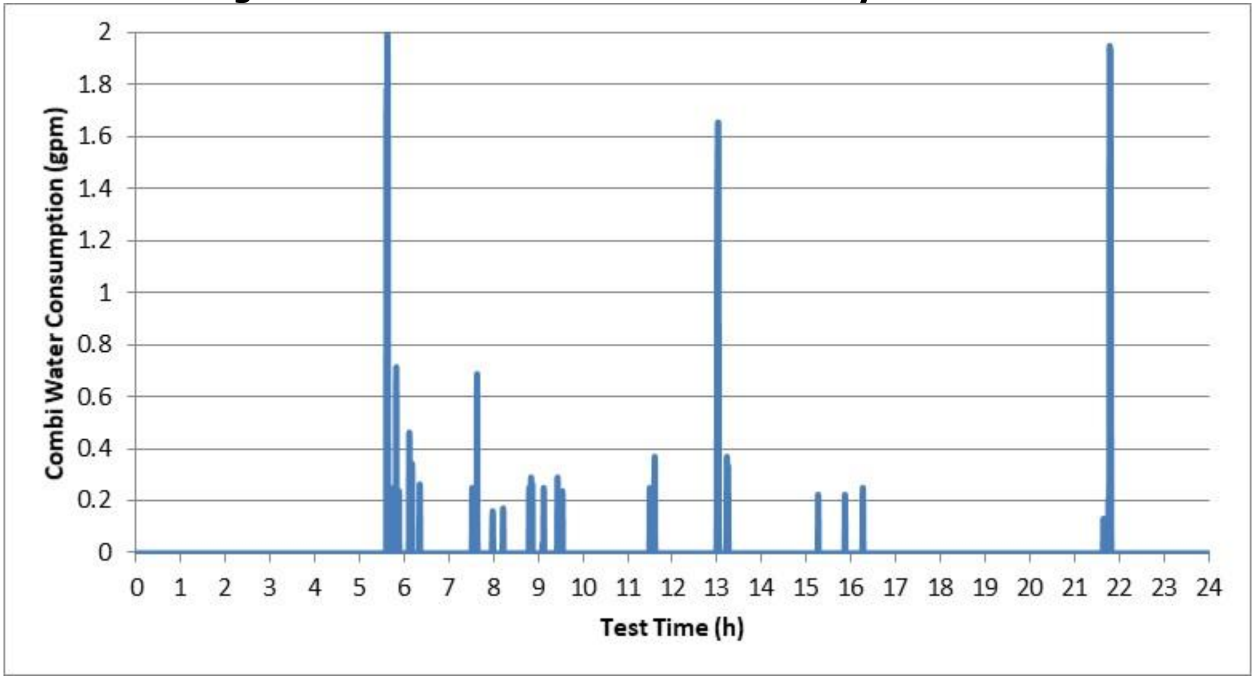
Source: Frontier Energy, Inc.

Figure 66: DoubleTree Combi Oven Heavy Use Energy



Source: Frontier Energy, Inc.

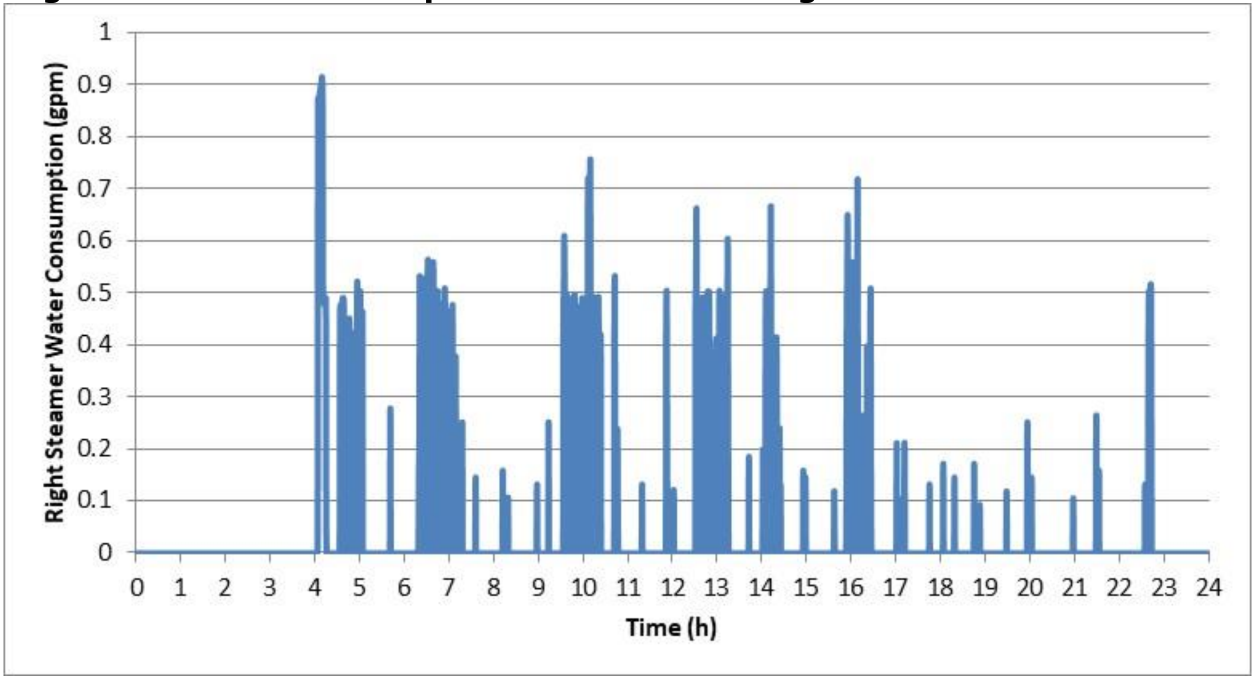
Figure 67: DoubleTree Combi Oven Heavy Use Water



Source: Frontier Energy, Inc.

The combi oven water and energy use had a direct correlation. Combi water use ranged between 2 and 15 gpm with an average of 3 gpm. The combi was turned on around 6 am as seen in the graph with the water consumption spike as the boiler fills. The combi was turned off around 10 pm as seen with the water consumption spike as the boiler gets automatically flushed prior to shut down. There was no energy and water use during hours when there is no cooking. This means that the combi was not operating between cooking cycles and was not in an idle mode, so the oven would have to preheat before each cooking cycle. Light water use showed that most of the cooking was performed with low humidity settings.

Figure 68: DoubleTree Replacement Back Line Right Gas Steamer Water Use

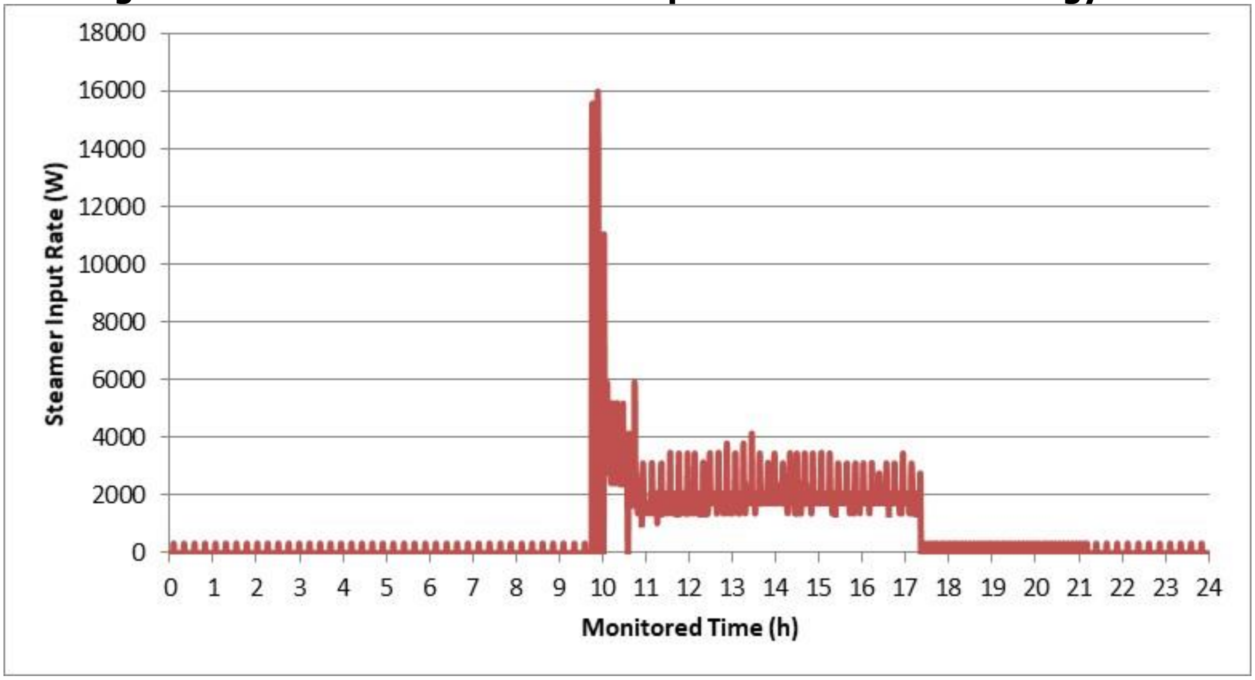


Source: Frontier Energy, Inc.

The operators experienced longer rice cooking times with the replacement energy-efficient gas steamer, so they shifted rice production to the front. The front baseline steamer was used much more in lieu of the left baseline steamer. The average water and energy consumption of the front baseline steamer was 317 gallons of water per day and 50 kWh per day, respectively.

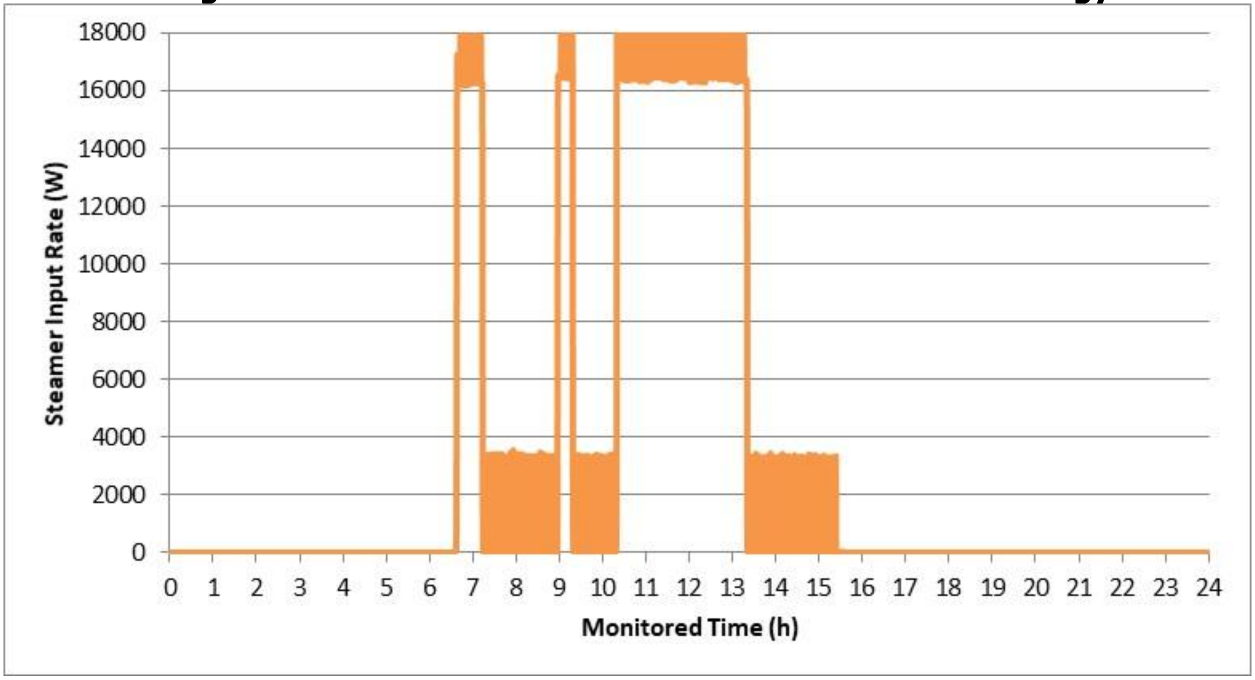
The front line electric steamer was replaced by an energy-efficient steam-generator steamer with a reduced water consumption condensate cooling system. The average water consumption of the replacement front line steamer was under 20 gallons per day, compared to over 300 gallons per day for the baseline steamer. Condensate cooling water consisted of 2/3 of the steamer water consumption. The electrical energy use was also greatly reduced from 50 kWh to 10 kWh per day. The baseline steamer continuously injected steam to keep the cooking cavity in a ready-to-cook state even when the steamer was not actively being used. As a result, the replacement steamer could significantly reduce electrical idle energy by only keeping the steam generator hot when not in use. This meant that the replacement steamer would take slightly longer than the baseline steamer to transition from an idle state to an active cooking state, but the added time was minor enough that the energy savings are well justified. The staff commented that the replacement front line steamer performed well and they had no problems with it.

Figure 69: DoubleTree Front Line Replacement Steamer Energy Use



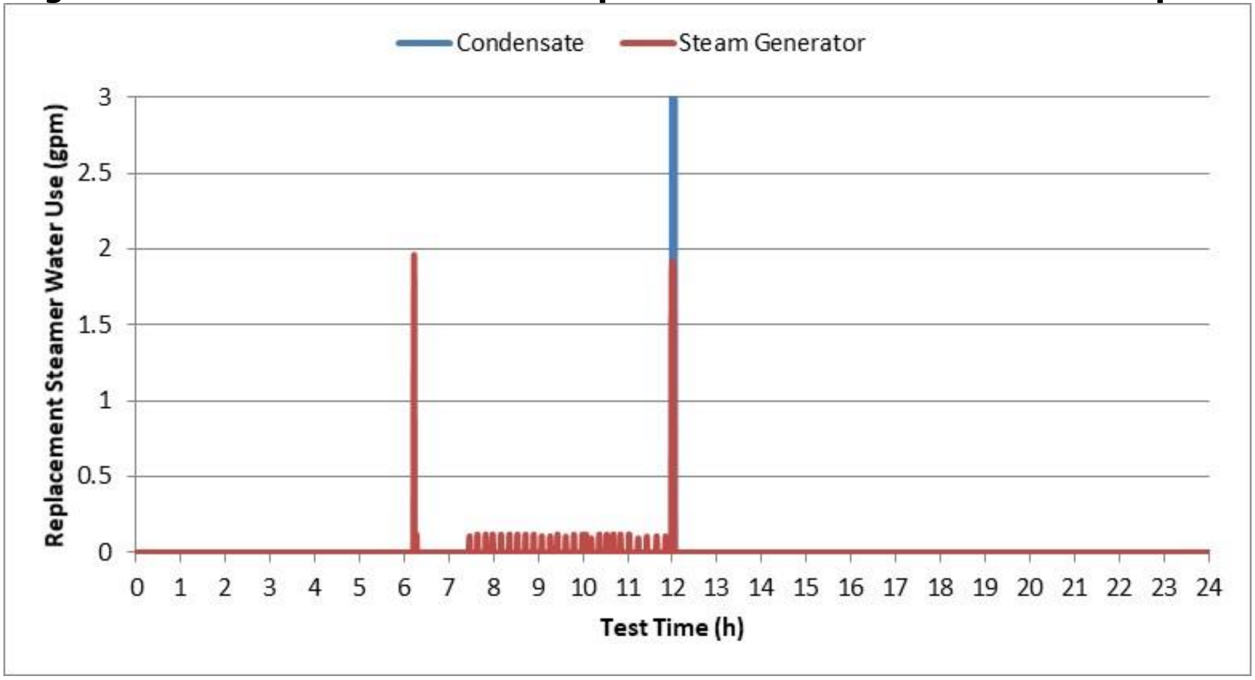
Source: Frontier Energy, Inc.

Figure 70: DoubleTree Front Line Baseline Steamer Energy Use



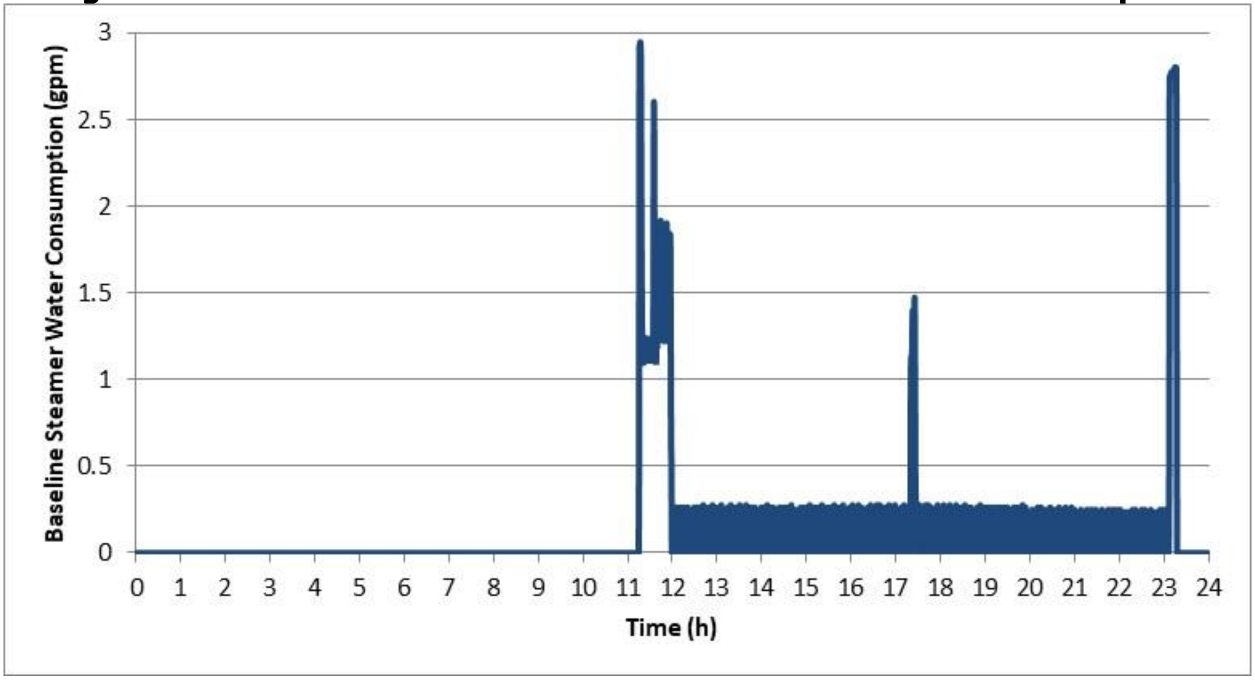
Source: Frontier Energy, Inc.

Figure 71: DoubleTree Front Line Replacement Steamer Water Consumption



Source: Frontier Energy, Inc.

Figure 72: DoubleTree Front Line Baseline Steamer Water Consumption



Source: Frontier Energy, Inc.

New Equipment Behavioral and Operational Changes

The DoubleTree kitchen represents what is commonly seen in mixed-use high-production kitchens in hotels of its size. These kitchens often rely on manual practices while slowly integrating automated solutions as they replace equipment over time. The equipment replacement project demonstrated how newer technologies can offer a worthwhile return on investment (in this case fryers, griddles, and convection ovens) over their predecessor's technologies that are often still available and affordable.

Mixed-production operations like DoubleTree depend on an ability to perform multiple duties while minimizing associated labor costs. These roles include large scale batch cooking and holding for catering, while simultaneously fulfilling cook-and-serve orders to satisfy restaurant and in-room dining guests. For this reason, incorporating equipment pieces that can fulfill multiple roles with an ability to scale production as needed become critical to a successful hotel kitchen operation.

The DoubleTree steamer replacement was a prime example of a shift toward newer technologies that are perceived by staff as identical to or even worse than the old. While the replacement steamers saw significant water and therm savings, the new steamers should not be expected to operate as "one-for-one" to their forerunners. One example would be that rice took longer to cook. To overcome these new equipment challenges requires some minor recipe modification and adjustments to prep schedules to achieve the same result.

On the cook-and-serve line, the fryers highlighted comparable results. Due to the long hours of operation, the fryer idle therm savings were significant. With faster recovery times and shorter cook times, the more efficient fryers offer a shorter return on investment. The higher production capacity may also eliminate the need for other inefficient equipment that was once required to meet production demand.

Mixing and matching fryer types by cooking duty has also been shown to improve energy savings and minimize oil costs. Utilizing smaller fryers, which hold less oil (around 35 pounds), for light-duty frying like French fries or onion rings while reserving the more powerful fryer for higher demand cooking and blanching is a streamlined, cost-saving frying strategy.

The combination oven is another important consideration when specifying equipment for multipurpose kitchen operations like DoubleTree. With the capabilities of high-temperature convective and steam cooking coupled with an ability to perform low-temperature proofing and holding, the versatility of such equipment lends itself to every area of the kitchen production cycle. Batch cooking for the catering operations can be eased through the combi's recipe function, ensuring a more consistent product. Another advantage of batch cooking in combis is the potential to shift variable labor costs to fixed costs by transferring much of those duties to a virtually automated cooking system. If the combi oven is not needed by the catering arm of the kitchen, it can be easily transitioned to the cook-and-serve side whether it be for bulk preparation or service.

Staff adaptability and production scaling are paramount to running successful foodservice operations. With the rising costs of food, fuel, and labor, operators are forced to reexamine the practices of old. Adopting smarter technologies that can streamline existing operations and save on energy costs is becoming more necessary to run profitable foodservice programs in a very competitive industry. Operators should take the time to research key equipment differences and develop a suitable implementation plan before embarking on any new or replacement equipment project.

Ventilation

The DoubleTree kitchen consisted of a large double-island canopy hood with the cook-to-order line in the front and the prep line in the back (Figures 73-75). Each hood line was 25-ft. in length and 5-ft. in depth. The prep line had lighter-duty, less effluent emitting appliances, such as steamers and convection ovens, and the cook-to-order line had heavier-duty appliances such as the broiler, ranges, and fryers. The hood was split up in several sections and was exhausted through a rooftop fan (Figure 76) driven by a single 7.5 HP fan motor (Figure 77). The hood used slot filters with manual dampers to adjust the flowrate of each section. The existing motor was not controlled by a variable frequency drive and ran 24/7 despite the hotel kitchen operating hours of 6 am to 11 pm. The average hood fan motor's power consumption was 3.1 kW, which is 75 kWh per day when operating 24/7. With filter velocities ranging between 500 and 900 feet per minute per section, the total exhaust airflow rate was estimated to be 9,000 cfm. These settings were not adequate for complete capture and containment and researchers observed that the hood was spilling over the cook-to-order line above the broiler and the range.

Figure 73: DoubleTree Cook-to-Order Hood Line

Source: Frontier Energy, Inc.

Figure 74: DoubleTree Prep Line Hood

Source: Frontier Energy, Inc.

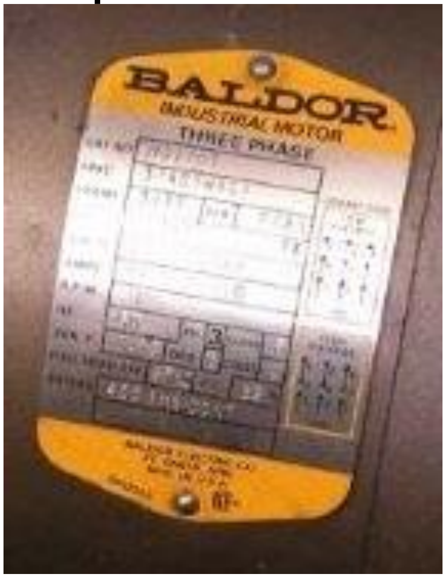
Figure 75: Hood Section Separation Above the Broiler

Source: Frontier Energy, Inc.

Figure 76: Rooftop Exhaust Fan

Source: Frontier Energy, Inc.

Figure 77: 3-phase 480V 7.5 HP fan motor



Source: Frontier Energy, Inc.

Figure 78: Rooftop Makeup Air Evaporative Cooler

Source: Frontier Energy, Inc.

Figure 79: 2 Makeup Air and 1 Hood Breaker

Source: Frontier Energy, Inc.

DoubleTree Summary

The DoubleTree kitchen baseline appliance line used almost 40 therms per day on average. Half that energy was consumed by the broiler and two double stack convection ovens. The broiler alone accounted for more than a quarter of the total energy use. The three ranges, including the salamander, accounted for another quarter of the total energy use (Table 2).

Most of the primary appliances were replaced at DoubleTree, except for the ranges and the right double stack convection oven. The two tilt skillets were electric and were not replaced. The biggest gas savings was achieved by replacing the existing broiler with an infrared broiler, which resulted in a four therms per day savings. The replacement fryers increased the kitchen’s production capacity while also saving about a therm and a half of energy. The baseline electric load was dominated by the three steamers, which were replaced by an energy-efficient gas steamer, a gas combi oven, and an electric steamer resulting in 134 kWh/day and 187 gal/day savings.

Table 2: DoubleTree Energy Summary Before and After Replacement

	Fuel	Operating Hours (h)	Pre Replacement Energy Use	Post Replacement Energy Use	Energy Savings
Range with Salamander	Gas	19.4	5.0	N/A	N/A
Griddle	Gas	11.9	4.1	3.1	1.0 (therms/day)
Front Range	Gas	16.3	2.8	N/A	N/A
Fryer	Gas	14.9	3.7	2.3	1.4 (therms/day)
Broiler	Gas	17.4	11.9	7.9	4 (therms/day)
Left Convection Oven	Gas	19.2	4.2	1.6	2.6 (therms/day)
Right Convection Oven	Gas	19.1	5.6	Not replaced	N/A
Back Range	Gas	10.6	1.9	Not replaced	N/A
Front Steamer	Electric	18	50 kWh/day	10 kWh/day	40 kWh/day
Left Steamer	Electric	Used intermittently	6 kWh/day	0.3 (therms/day)	6 kWh/day
Right Steamer	Electric	18	91 kWh/day	1.4 (therms/day)	91 kWh/day
Exhaust Fan	Electric	24	75 kWh/day	N/A	N/A

Source: Frontier Energy, Inc.

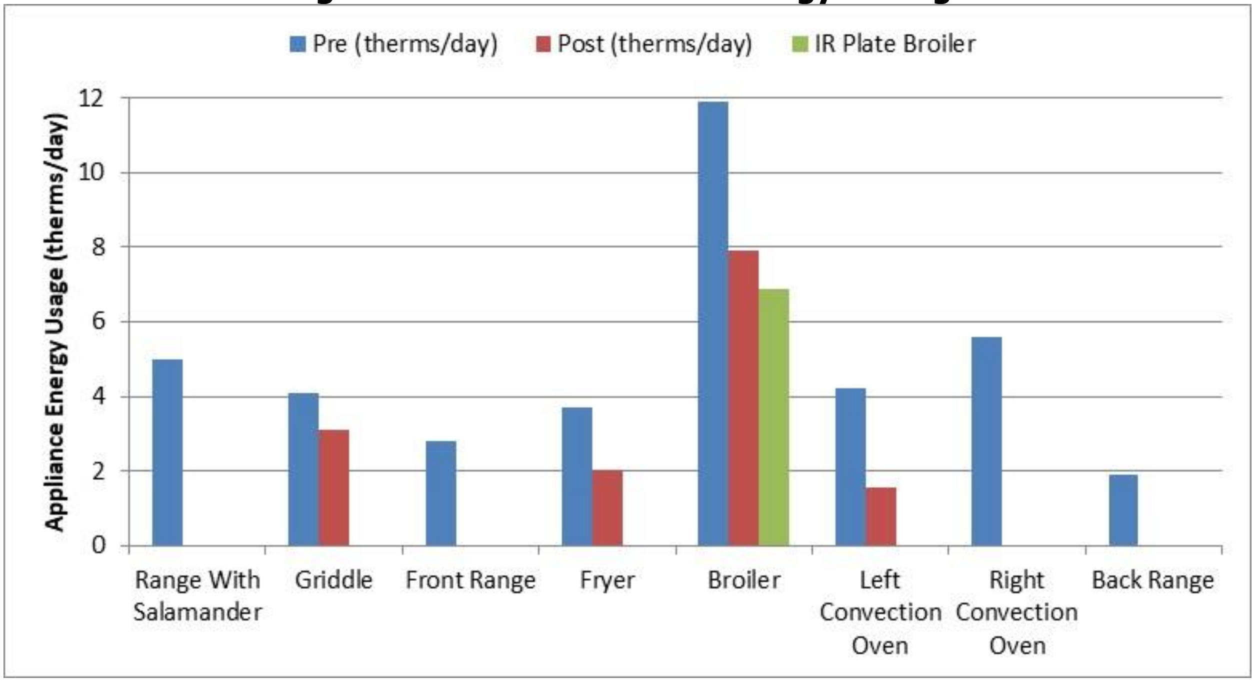
Table 3: DoubleTree Water Use and Projected Savings by Appliance

	Baseline Water Use (gal/day)	Replacement Appliance	Replacement Water Use (gal/day)	Water Savings (gal/day)	Water Savings
Front Steamer	317*	EE Steamer	20		
Back Left Steamer	79	Combi Oven	3		
Back Right Steamer	167	EE Steamer	36		
Total	246		59	187	76%

***Front line baseline steamer had a leak for a two-week monitoring period when the other two steamers were not being used. The leak is excluded from the total.**

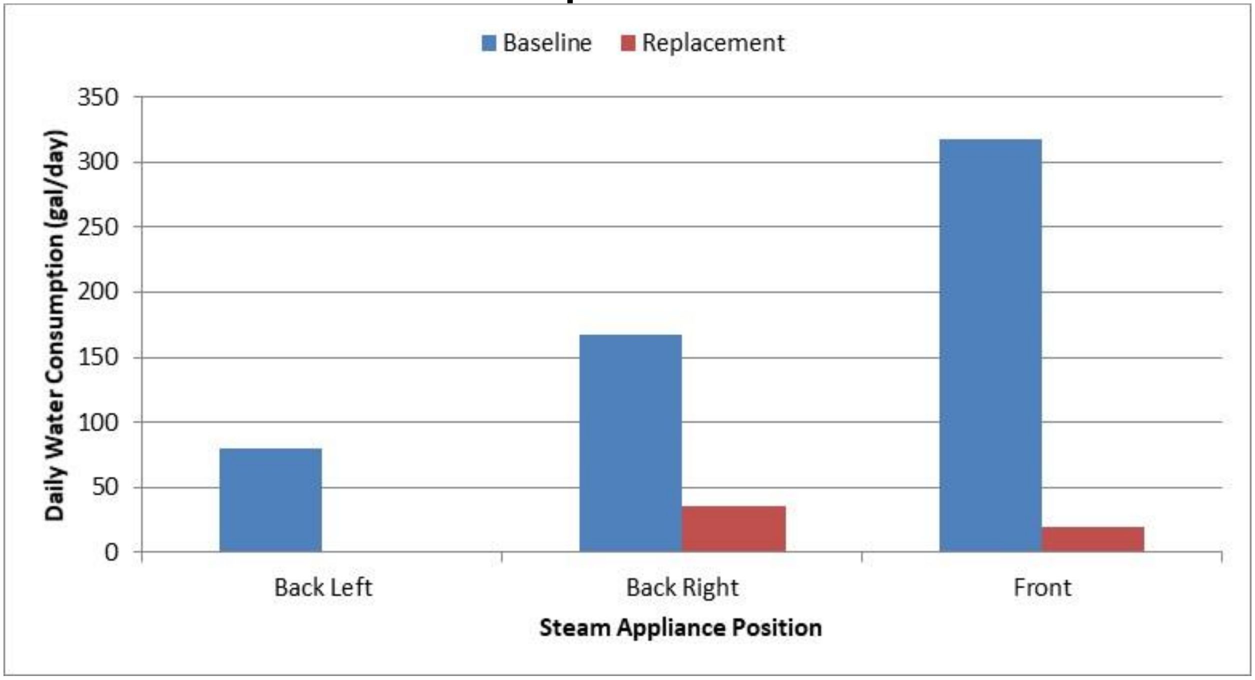
Source: Frontier Energy, Inc.

Figure 80: DoubleTree Gas Energy Savings



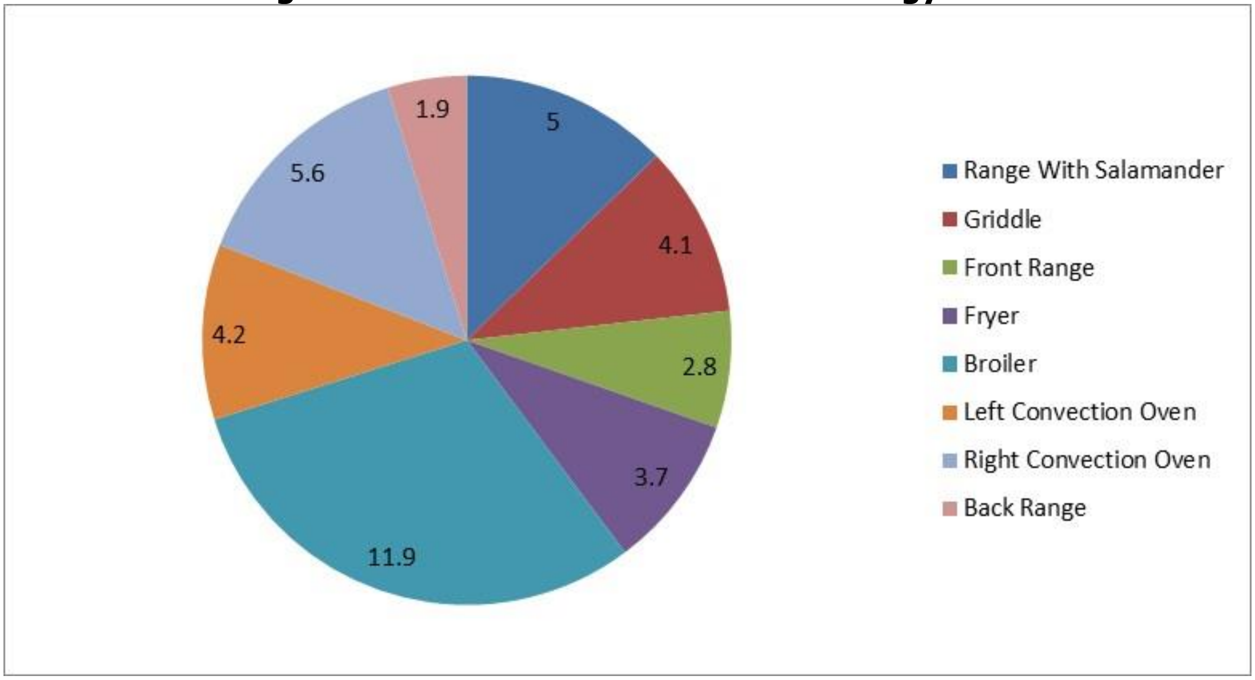
Source: Frontier Energy, Inc.

Figure 81: DoubleTree Water Savings Due to Steamer and Combi Oven Replacement



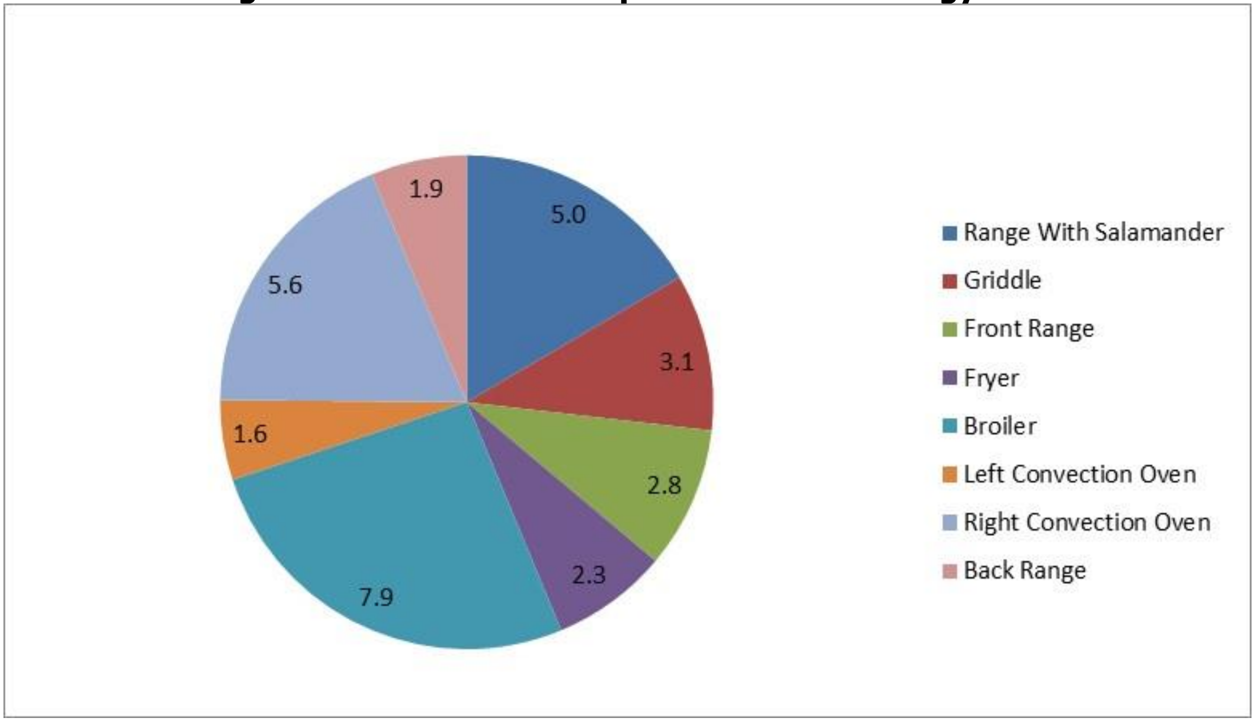
Source: Frontier Energy, Inc.

Figure 82: DoubleTree Baseline Gas Energy Use



Source: Frontier Energy, Inc.

Figure 83: DoubleTree Replacement Gas Energy Use

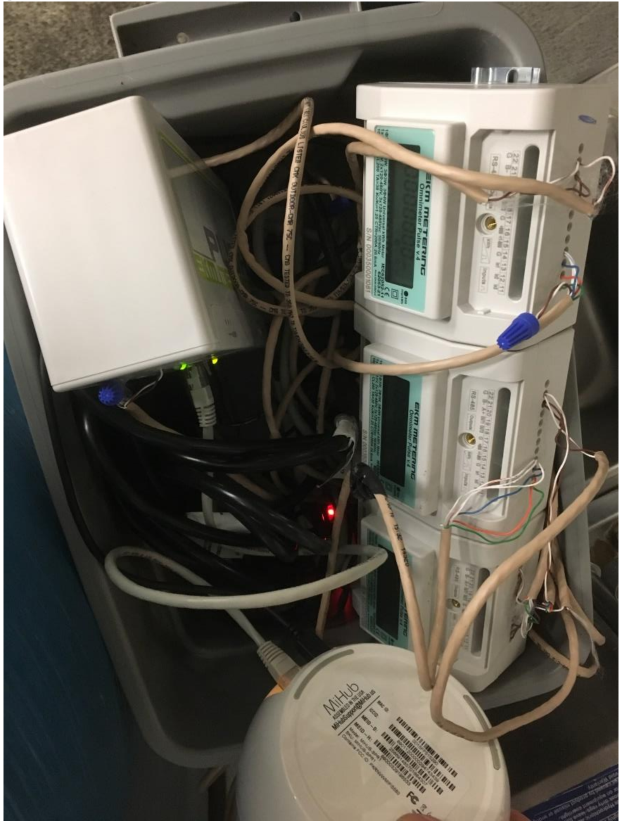


Source: Frontier Energy, Inc.

EIS System in the DoubleTree Hotel

Frontier Energy used an energy information system (EIS) at DoubleTree Hotel to determine comparative energy consumption of their cooking equipment. Researchers installed the EIS on gas meters previously used in the earlier stages of the project. Ovens, steamers, fryers, a griddle and a broiler were submetered at the hotel.

Figure 84: EIS Hardware with Transmitter



Source: Frontier Energy, Inc.

Figure 85: Gas Meters Wired to the EIS Hardware

Source: Frontier Energy, Inc.

Figure 86: EIS System Interface Tutorial with Kitchen Manager

Source: Frontier Energy, Inc.

The hotel kitchen manager was trained on how to use the EIS and how the displayed data relates to each appliance's operation (Figure 86 and 87). With several convection ovens, a combi oven, and a steamer at the kitchen's disposal, the chef had several equipment choices when deciding how to cook a particular dish on the menu. The EIS allowed the kitchen manager to see the most energy-efficient cooking method and determine which piece of equipment to use in the future.

Figure 87: Showing EIS Combi Oven Energy Use

Source: Frontier Energy, Inc.

Figure 88: Energy-Efficient Convection Oven

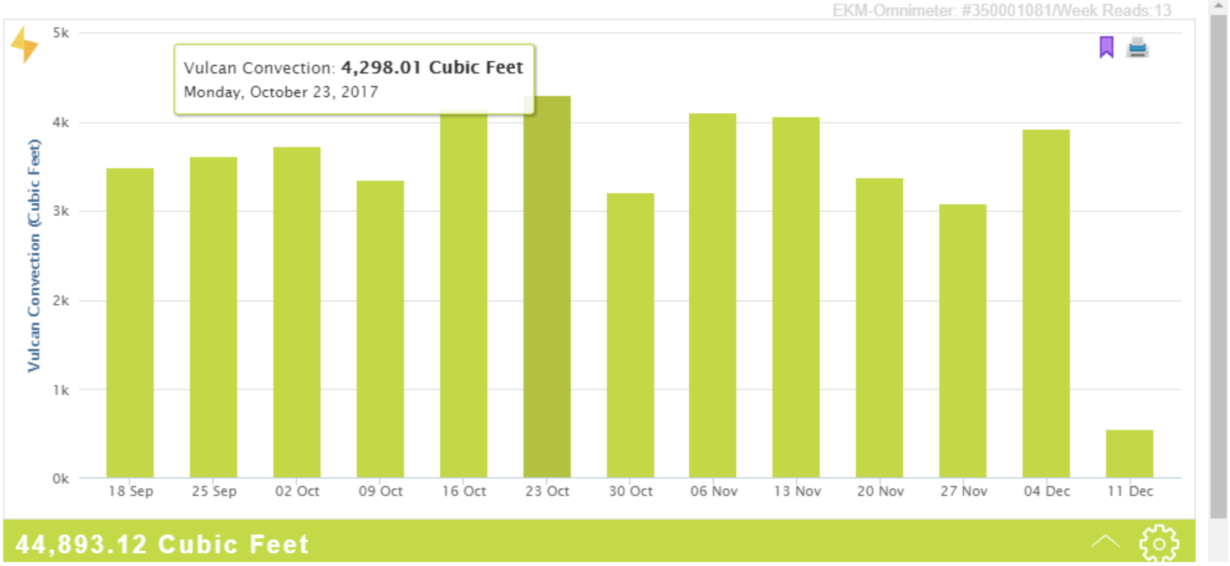
Source: Frontier Energy, Inc.

Figure 89: Baseline Convection Oven

Source: Frontier Energy, Inc.

The following EIS-generated graph shows the restaurant operators weekly energy use by appliance, which allows them to correlate the number of customers served with their energy impact.

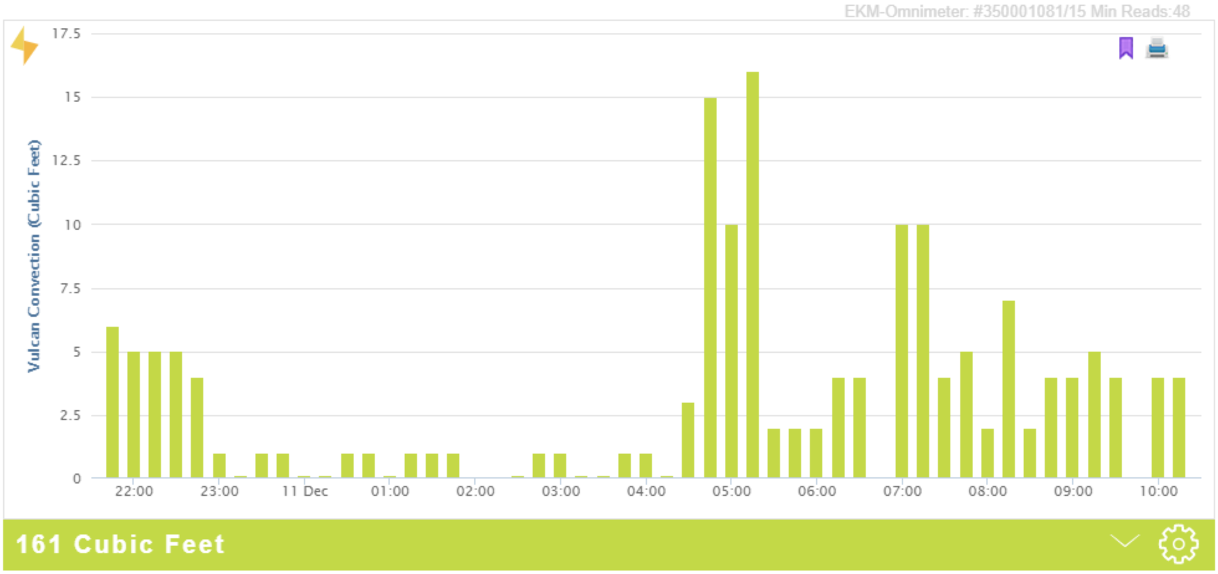
Figure 90: Replacement Energy-Efficient Oven EIS Energy Consumption by Week



Source: Frontier Energy, Inc.

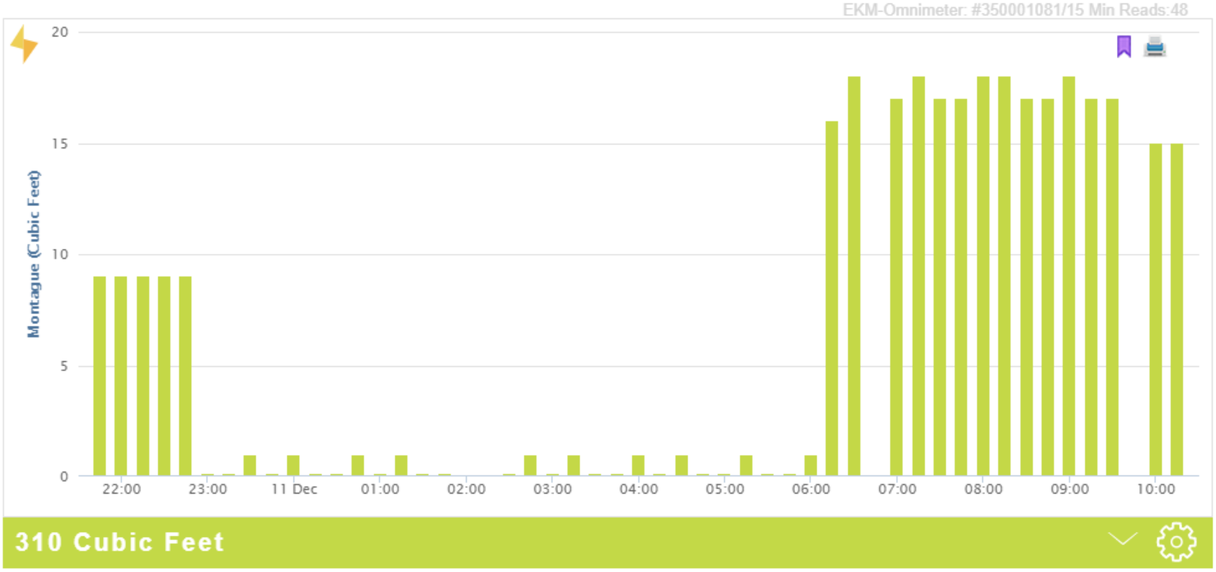
Figure 91 and 92 generated by the EIS dashboard show the appliance startup and shutdown times as well as the amount of energy consumed during each period.

Figure 91: Replacement Energy-Efficient Convection Oven EIS Daily Energy Profile



Source: Frontier Energy, Inc.

Figure 92: Baseline Convection Oven EIS Daily Energy Profile



Source: Frontier Energy, Inc.

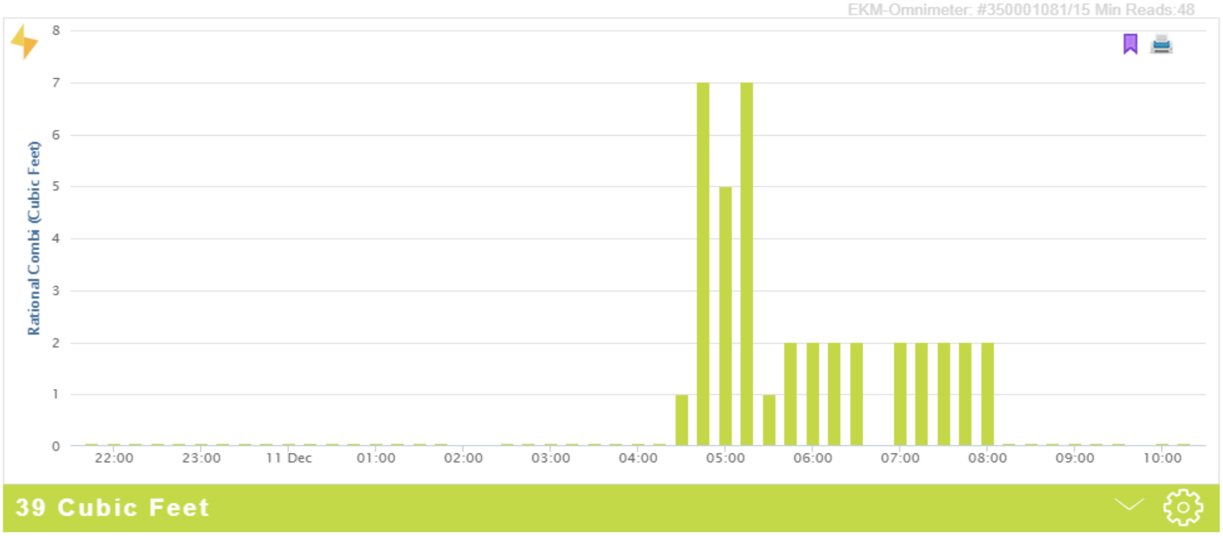
Figure 93: Replacement Combi Oven & Steamer

Source: Frontier Energy, Inc.

When comparing the baseline convection oven with the replacement energy-efficient convection oven, the preheat energy is relatively similar; however, idle energy throughout the day was significantly higher for the baseline ovens, consuming almost double. Based on the EIS data, operators could instruct their staff to use the energy-efficient ovens more often, which was demonstrated by the earlier start up times of the replacement energy-efficient ovens. The restaurant manager was also able to track their employees starting hours based on the oven’s startup energy use.

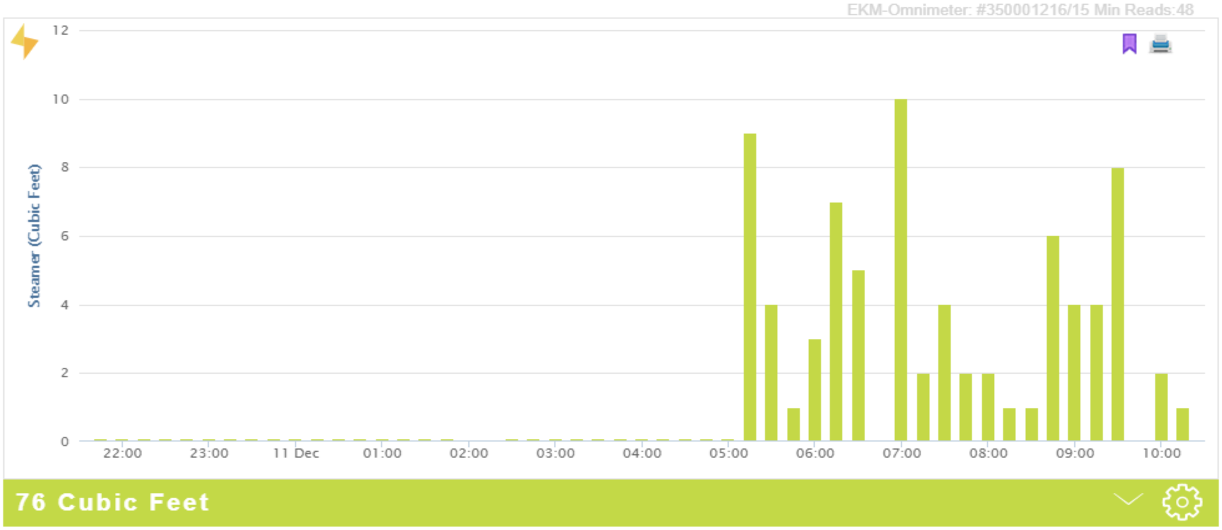
When monitoring the other two energy-efficient replacement appliances, the combi oven and the steamer, the restaurant manager realized that they were underused and consuming significantly less energy than the convection ovens. This led to a decision to move several items that would normally be cooked in the convection ovens to the combi oven. The operators could check the EIS, slowly phase out the baseline ovens from their daily routine, and start cooking most food in the energy-efficient appliances.

Figure 94: Replacement Combi Oven EIS Daily Energy Profile



Source: Frontier Energy, Inc.

Figure 95: Replacement Steamer EIS Daily Energy Profile



Source: Frontier Energy, Inc.

CHAPTER 3: UCSF Medical Center

Site Description

The University of California Campuses are committed to using best energy-efficiency practices to help reach their 2025 Carbon Neutral goals. The University of California, San Francisco (UCSF) has partnered with the California Energy Commission and Frontier Energy previously on many foodservice energy efficiency demonstration projects. UCSF provided match funding in support of this project. The UCSF Medical Center represents an institutional foodservice facility and a market segment willing to adopt successful energy-efficient solutions. The UCSF demonstration will be particularly useful in catalyzing the adoption of energy-efficient technologies in California university and medical foodservice operations.

The UCSF Medical Center on the Parnassus Campus is a 15-story building in San Francisco, California accommodating both inpatient and outpatient services as well as research and educational facilities. The second-floor houses Moffitt Café, which serves as the hospital's main dining facility. Its cafeteria is open 7 am to 7 pm daily serving breakfast, lunch, and dinner for dining room patrons and patient room service.

Figure 96: UCSF Medical Center Hospital Exterior

Source: Frontier Energy, Inc.

The café features a buffet-style serving area with an adjacent kitchen. The main cookline had two double stack convection ovens, a six-burner range, two (3-ft. and 5-ft.) non-thermostatic griddles, and two 18-inch fryers. It was not possible to submeter the range or the griddles for gas consumption at this site because they were hard-piped in series, and the gas lines for the individual appliances were inaccessible. Each convection oven and fryer on the main line was successfully submetered and a daily gas energy consumption profile was determined for each appliance. The broiler in the buffet kitchen was similarly submetered for a brief period, but it was found to be a poor candidate for replacement due to its custom cabinet configuration and low input rate.

Figure 97: UCSF Main Cookline

Source: Frontier Energy, Inc.

Figure 98a: UCSF Main Cookline Appliances Left Double Stack Oven

Source: Frontier Energy, Inc.

Figure 98b: Two-Vat Fryer

Source: Frontier Energy, Inc.

Figure 98c: Broiler

Source: Frontier Energy, Inc.

Figure 98d: Right Double Stack Oven

Source: Frontier Energy, Inc.

Figure 99: UCSF 6-Burner Range and 3-ft. Griddle

Source: Frontier Energy, Inc.

Figure 100: UCSF Large 5-ft. Griddle

Source: Frontier Energy, Inc.

Fryer Monitoring

Each fryer had an 18-in. wide vat, a 65 lb oil capacity, and a maximum input rate of 150 kBtu/h. The left fryer contained no oil and was covered with a sheet pan during instrument installation. The submetering results for the left fryer showed zero energy use during the two-week monitoring period. The right fryer was used for 16.5 hours per day and consumed 3.3 therms per day on average. The fryer is not used often in the hospital and most of the energy consumption was in idle mode.

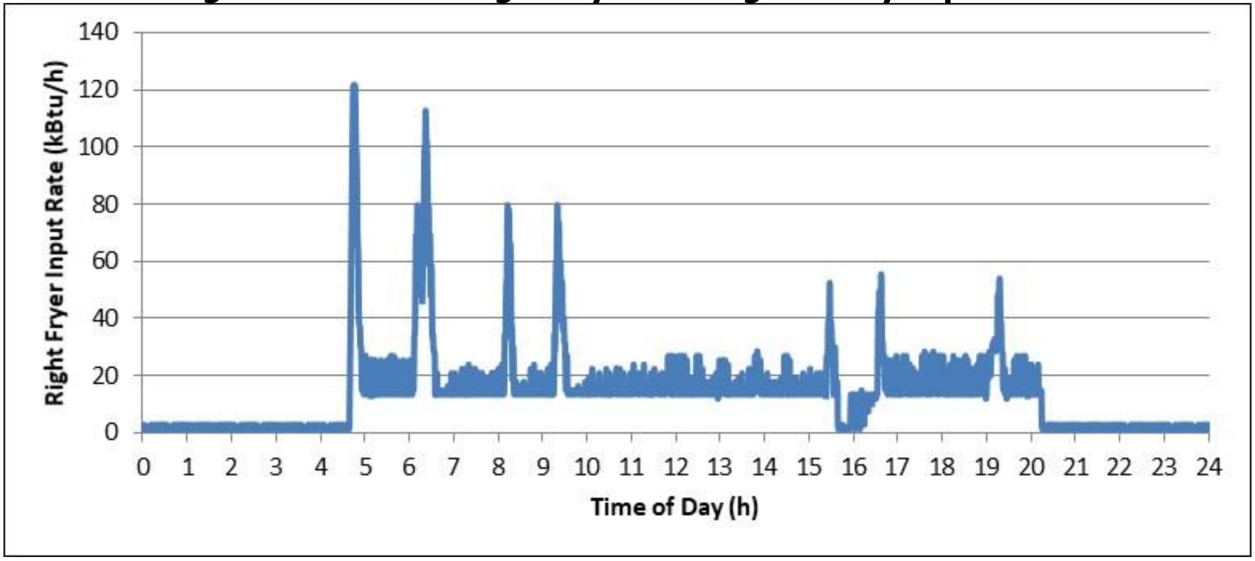
Figure 101: Two Large Vat Fryers

Source: Frontier Energy, Inc.

Figure 102: Fryer Gas Meters

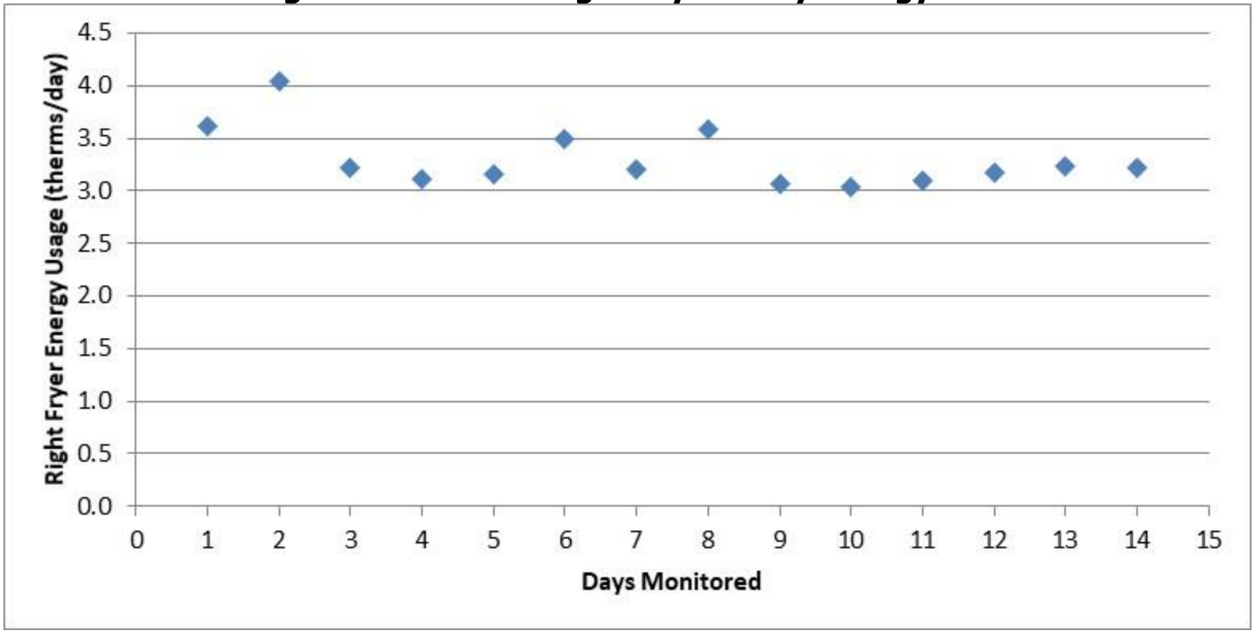
Source: Frontier Energy, Inc.

Figure 103: UCSF Right Fryer Average Hourly Input Rate



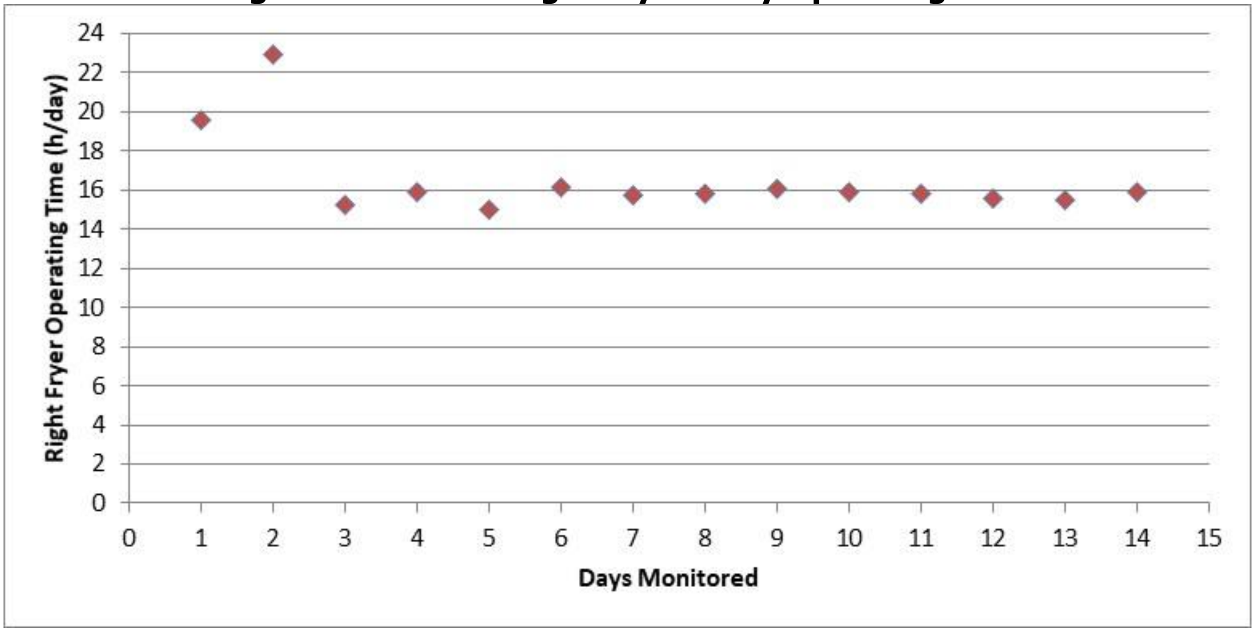
Source: Frontier Energy, Inc.

Figure 104: UCSF Right Fryer Daily Energy Use



Source: Frontier Energy, Inc.

Figure 105: UCSF Right Fryer Daily Operating Time



Source: Frontier Energy, Inc.

Convection Oven Monitoring

The main kitchen line was flanked by two double stack convection ovens. Both oven stacks have been heavily used for many years. As a result, the doors no longer completely seal the oven cavities. This allows ambient air to infiltrate the cooking cavities, causing the ovens to consume more energy to maintain cooking temperatures. Gas meters were placed on the inlet to each double stack oven. The results reported represent total energy consumption per double stack and are not separated for each cavity within a stack. On average, the left oven stack operated for 14 hours per day and consumed 7.0 therms per day, while the right oven operated for 16 hours per day and consumed 8.5 therms per day. Right oven energy usage was more consistent than the left oven, ranging between 7 and 10 therms per day. The left oven consumed between 4 and 10 therms per day depending on hours of operation. Energy consumption for both ovens was highly dependent on hours of operation. Both ovens had a standing pilot and a continuously variable thermostat that would modulate the input to the burners instead of controlling burner operation based on cavity temperature.

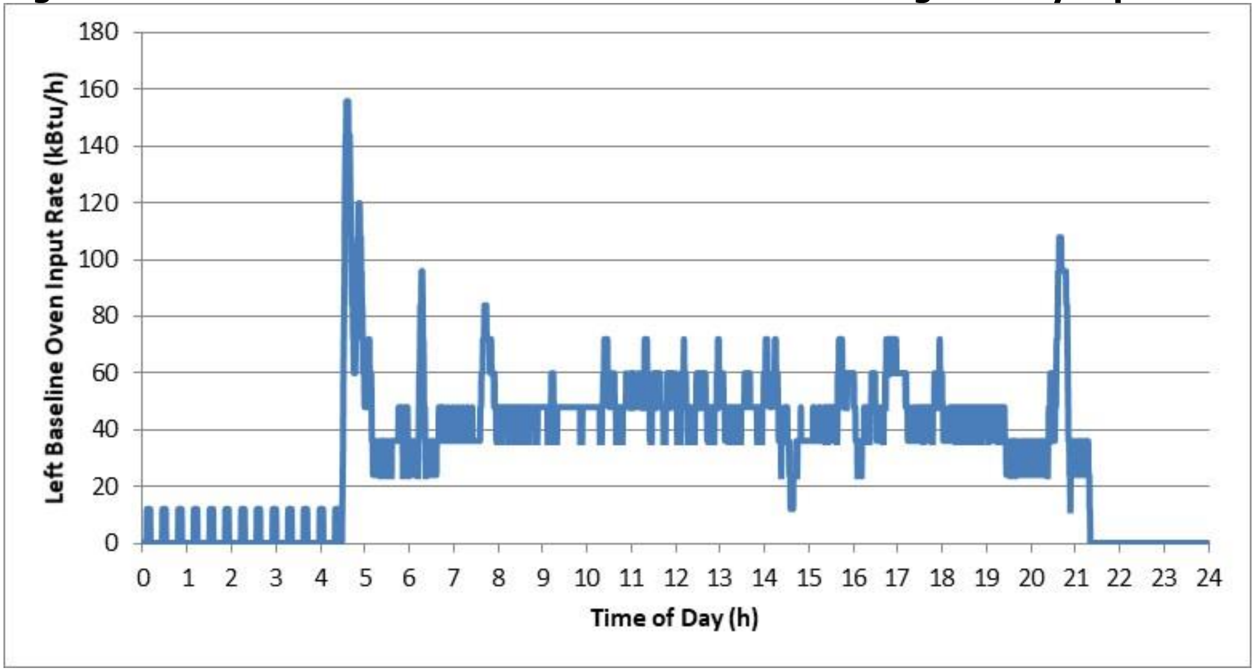
Figure 106: Left Baseline Convection Double Stack Oven

Source: Frontier Energy, Inc.

Figure 107: Right Baseline Convection Double Stack Oven

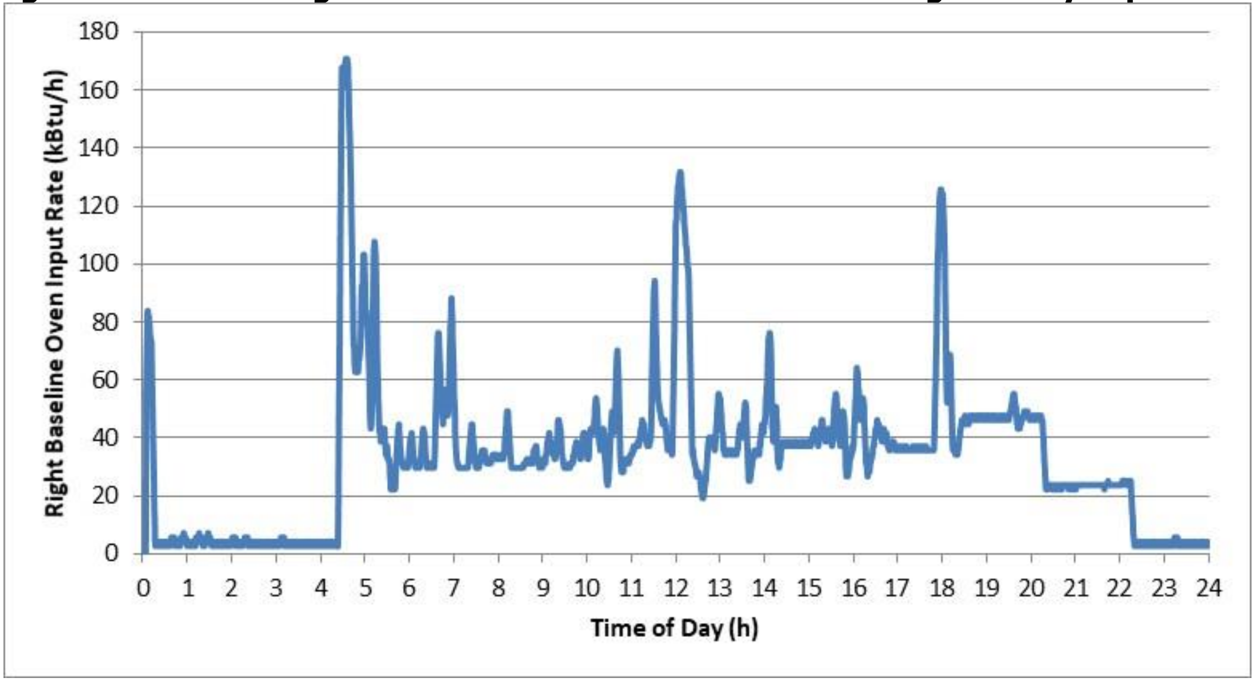
Source: Frontier Energy, Inc.

Figure 108: UCSF Left Baseline Double Stack Oven Average Hourly Input Rate



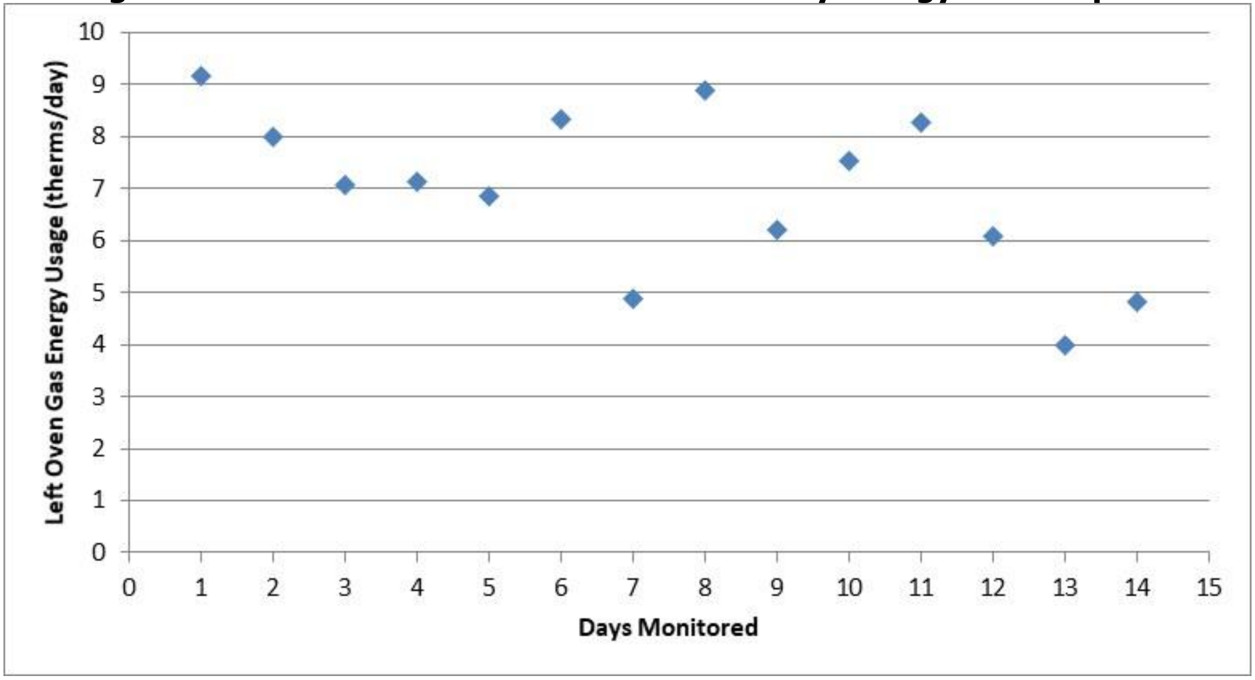
Source: Frontier Energy, Inc.

Figure 109: UCSF Right Baseline Double Stack Oven Average Hourly Input Rate



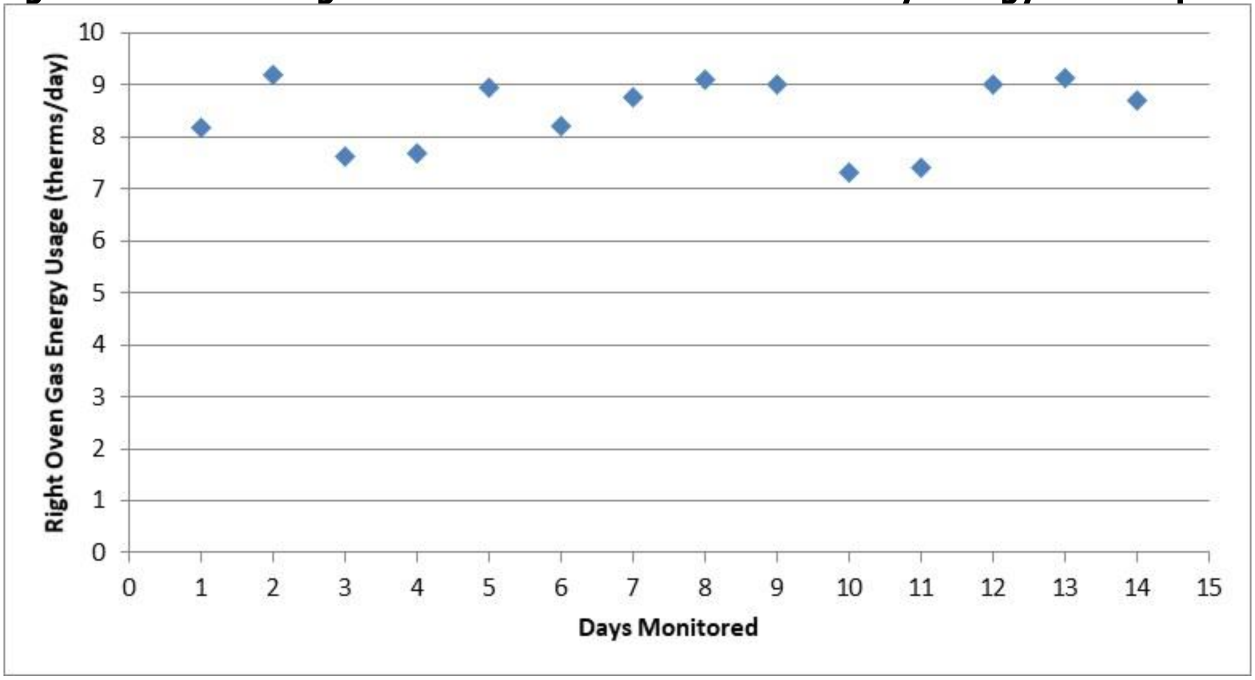
Source: Frontier Energy, Inc.

Figure 110: UCSF Left Double Stack Oven Daily Energy Consumption



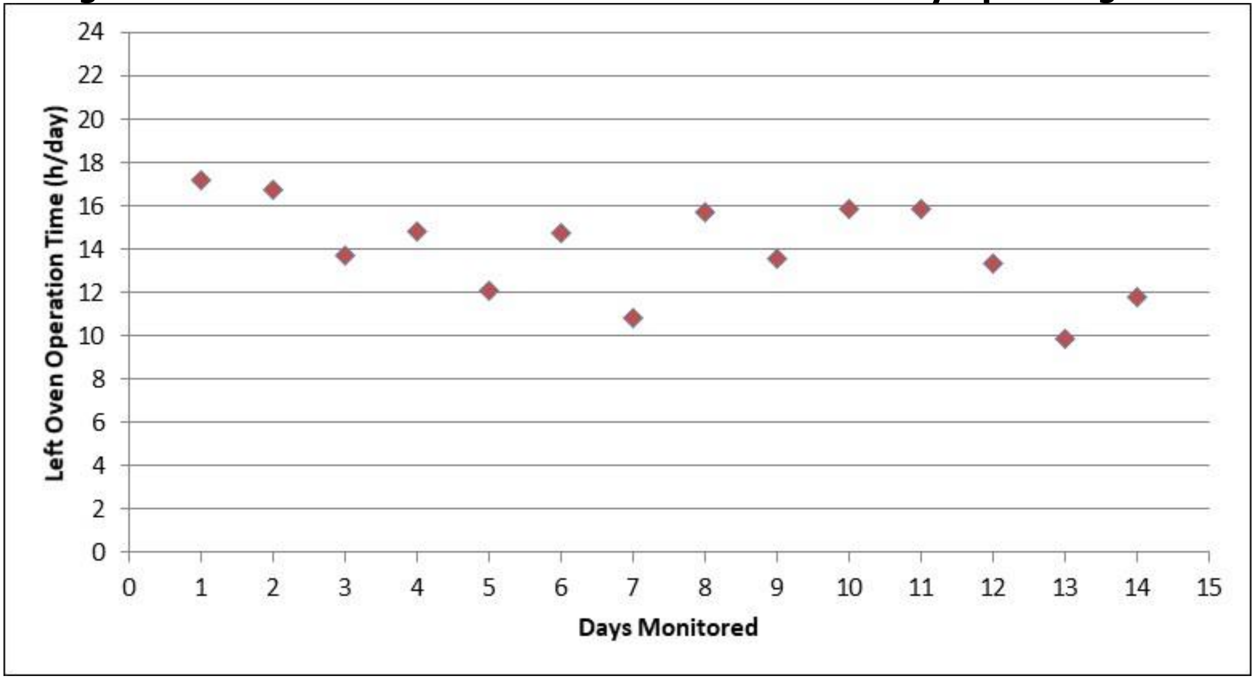
Source: Frontier Energy, Inc.

Figure 111: UCSF Right Baseline Double Stack Oven Daily Energy Consumption



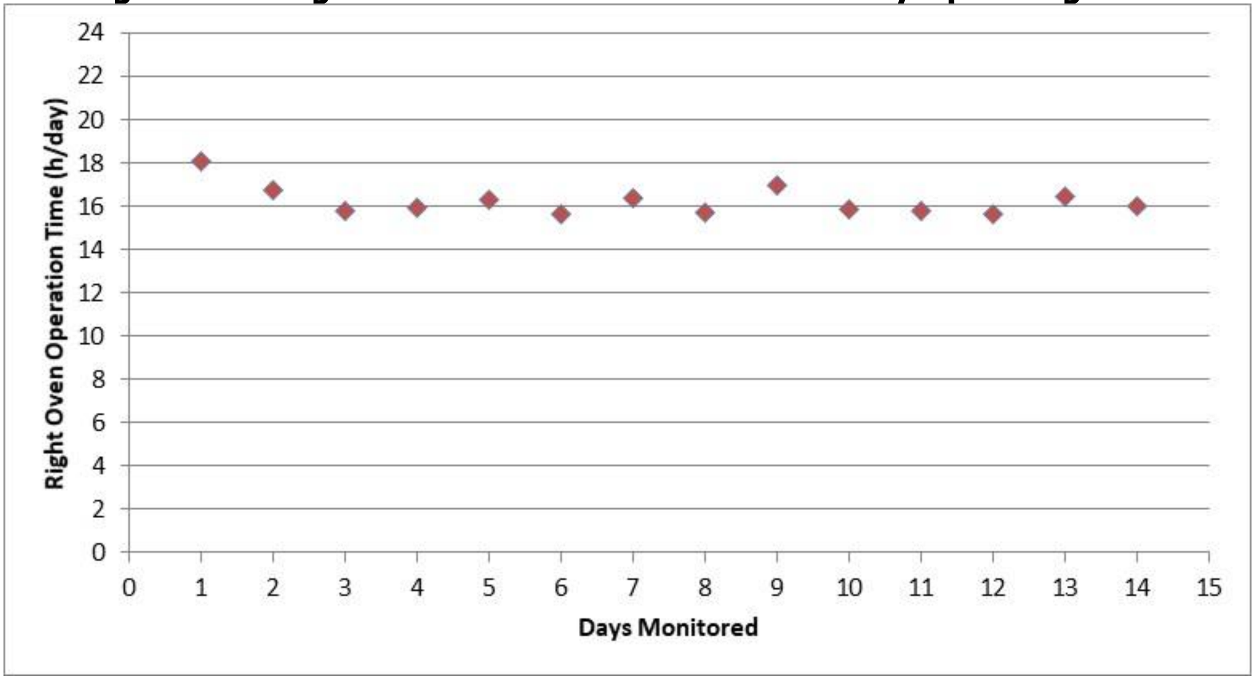
Source: Frontier Energy, Inc.

Figure 112: UCSF Left Baseline Double Stack Oven Daily Operating Time



Source: Frontier Energy, Inc.

Figure 113: Right Baseline Double Stack Oven Daily Operating Time



Source: Frontier Energy, Inc.

Convection Oven Replacement

Both double stack convection ovens were replaced by ENERGY STAR convection ovens. On average, the left oven stack operated for 14.3 hours per day and consumed 3.4 therms per day, while the right oven also operated for 15.0 hours per day and consumed 3.8 therms per day. For both ovens, the operation was consistent with energy consumption ranging between 3 and 4 therms per day. Operating hours and amount of food cooked in the ovens did not change between baseline and replacement periods. The replacement ovens featured automatic ignition, which eliminated the need for standing pilots.

Figure 114: UCSF Left Replacement Oven

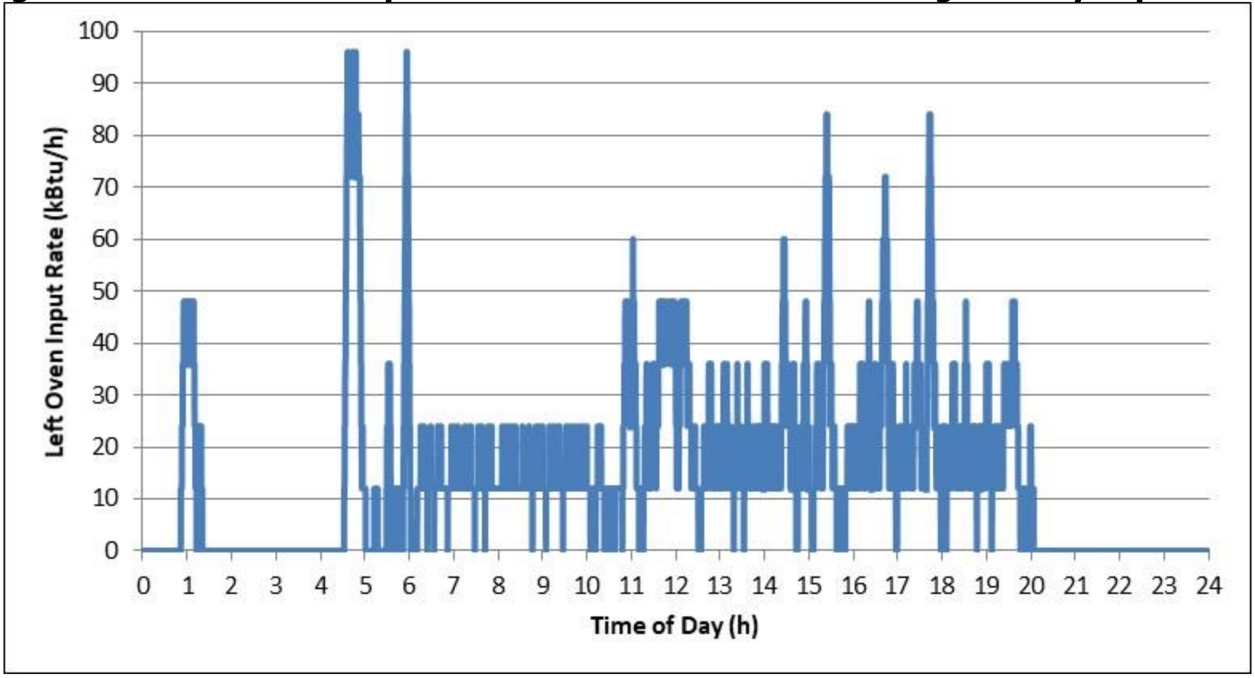
Source: Frontier Energy, Inc.

Figure 115: UCSF Right Replacement Oven

Source: Frontier Energy, Inc.

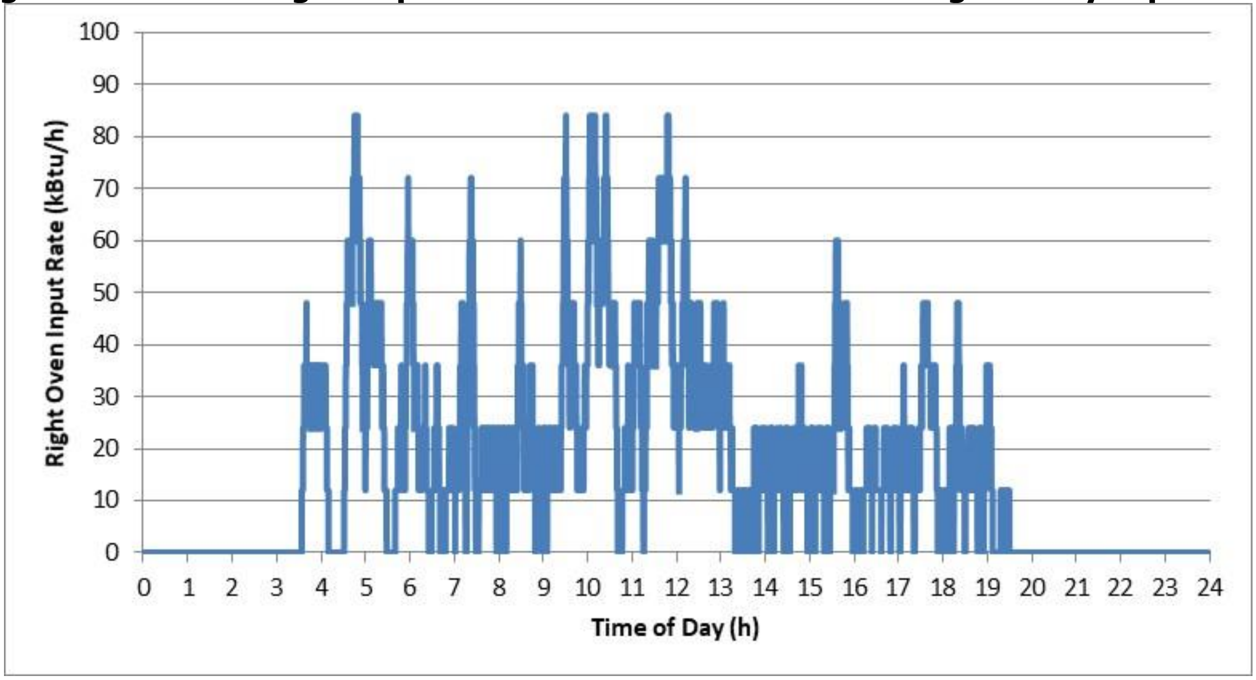
The staff liked the replacement ovens, highlighting improved cooking uniformity, consistent cook times, and ease of operation. The convection ovens were used for cooking chicken, baked pasta, and pizza. The top oven cavities were used more often than the bottom compartments, and the left double stack oven was used more often than the right oven. The temperature set points varied from 350°F to 450°F depending on the type of food cooked. Baked pastas and pizzas were cooked at 450°F and chicken dishes were cooked at 350°F. Usually, researchers observed that the top cavity was set for a higher temperature than the bottom.

Figure 116: UCSF Left Replacement Convection Oven Average Hourly Input Rate



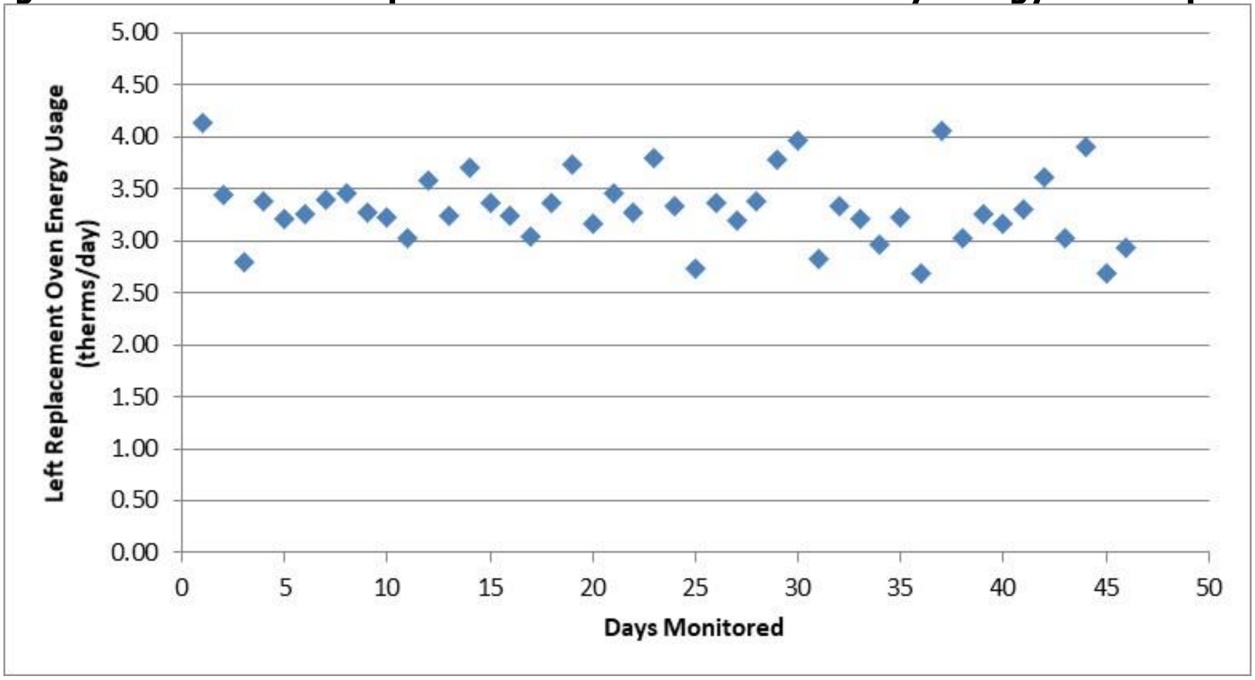
Source: Frontier Energy, Inc.

Figure 117: UCSF Right Replacement Convection Oven Average Hourly Input Rate



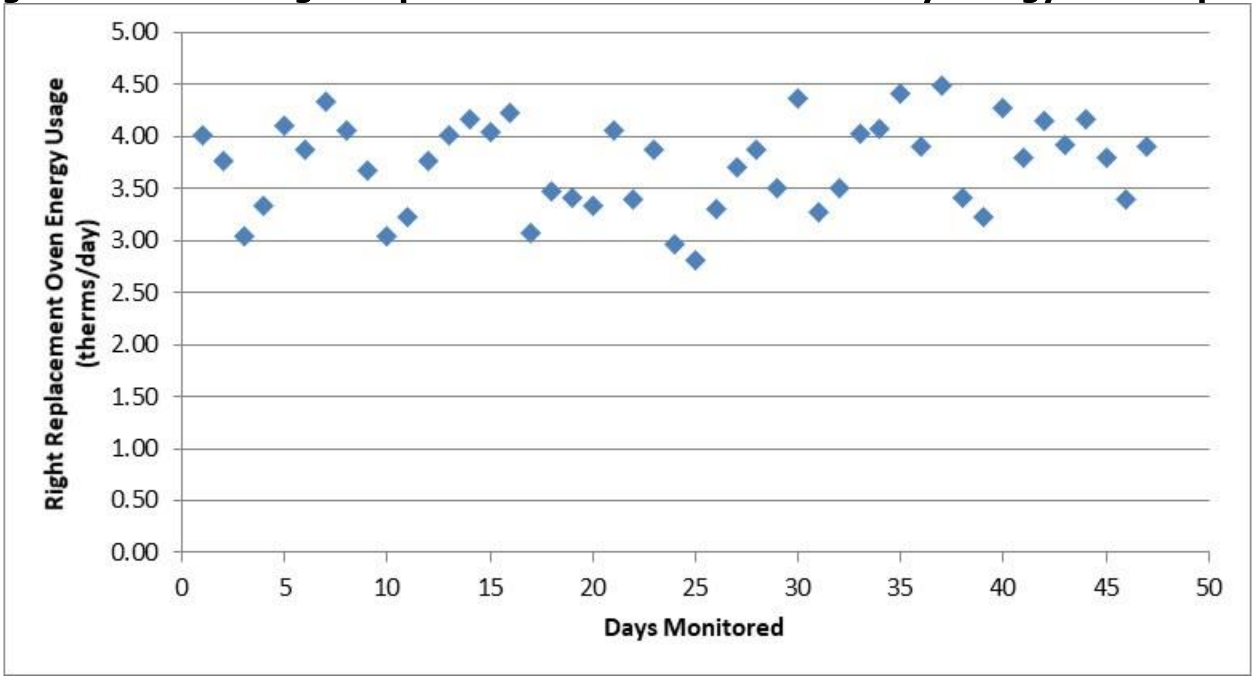
Source: Frontier Energy, Inc.

Figure 118: UCSF Left Replacement Convection Oven Daily Energy Consumption



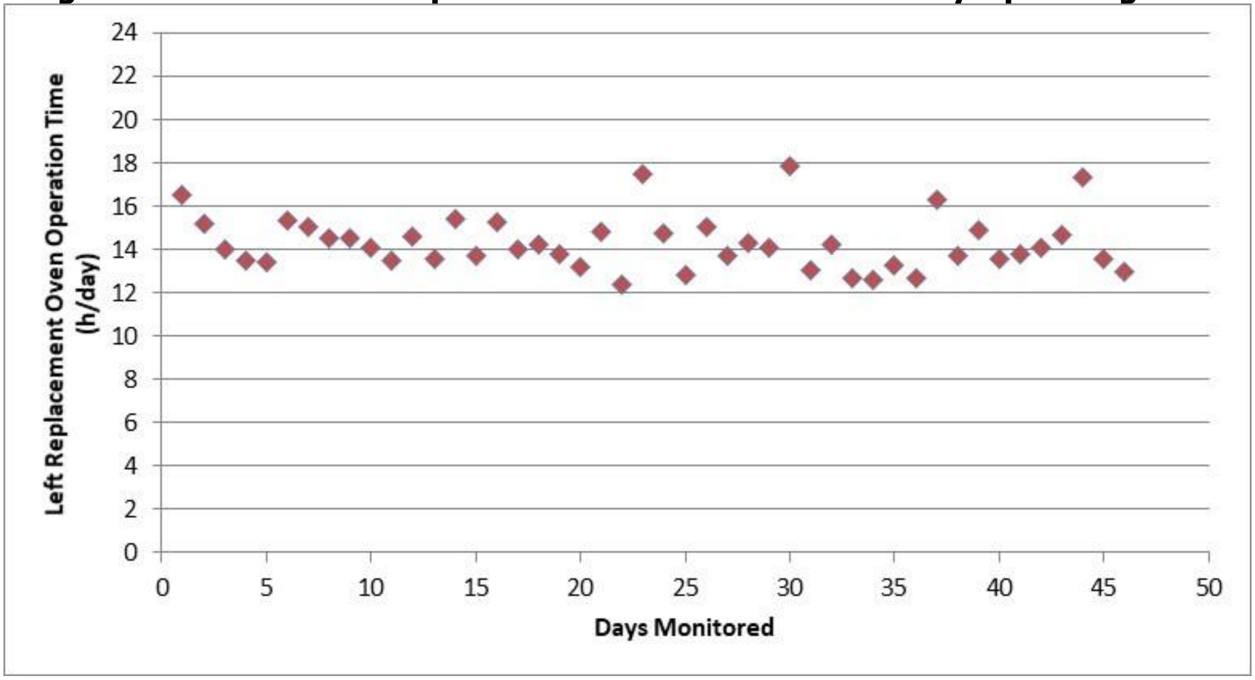
Source: Frontier Energy, Inc.

Figure 119: UCSF Right Replacement Convection Oven Daily Energy Consumption



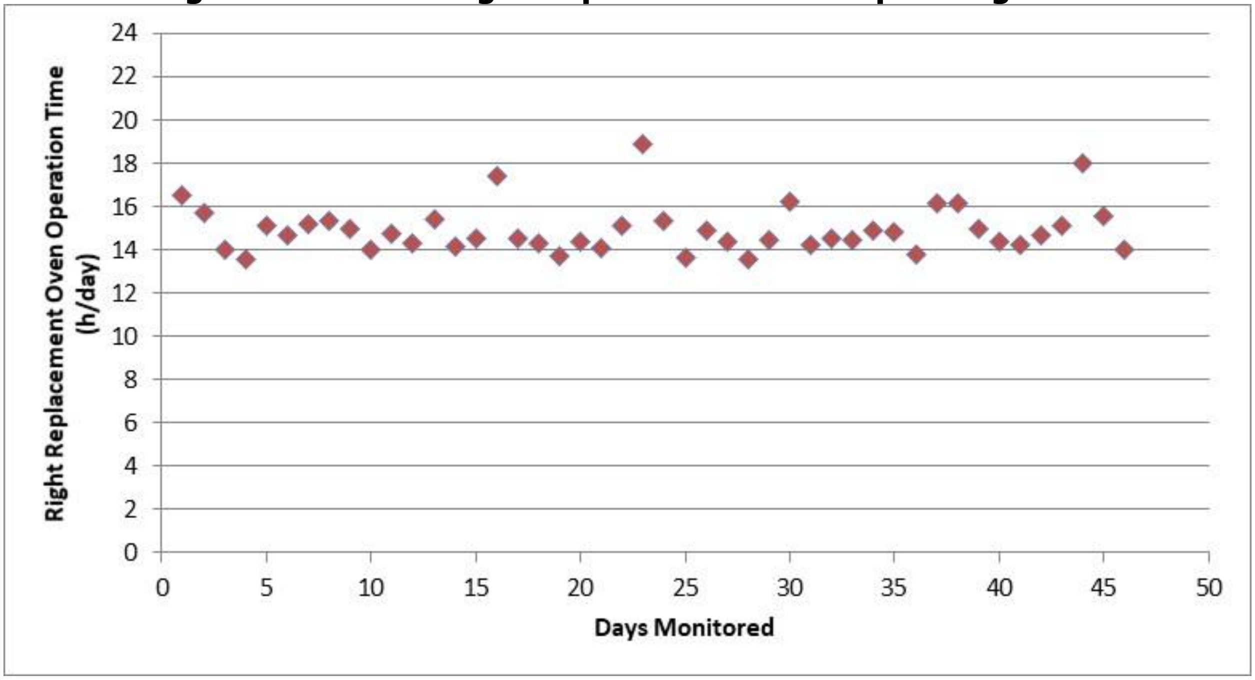
Source: Frontier Energy, Inc.

Figure 120: UCSF Left Replacement Convection Oven Daily Operating Time



Source: Frontier Energy, Inc.

Figure 121: UCSF Right Replacement Oven Operating Time



Source: Frontier Energy, Inc.

UCSF Summary

Researchers were only able to monitor three appliances on the UCSF cookline due to metering restrictions. Researchers did not monitor the range and the two griddles. As such, the results reported for these appliances are estimated from similar research projects. Frontier Energy estimates that the six-burner range consumes 3 therms per day and the 3-ft. non-thermostatic griddle consumes 4 therms per day. Researchers submetered the same model appliances at the DoubleTree Hotel in Pleasanton, California, a site with similar operating hours and cooking demand. Based on the DoubleTree griddle energy use, researchers estimate that the 5-ft. griddle at Moffit Café would have used 6 therms per day, and the 3-ft. griddle would have used 4 therms per day. The double stack ovens used the most energy of any appliance on the line, consuming over 50% of the line's total energy. The total consumption of the front cookline is estimated to be 31 therms per day.

Table 4: UCSF Hospital Replacement Results

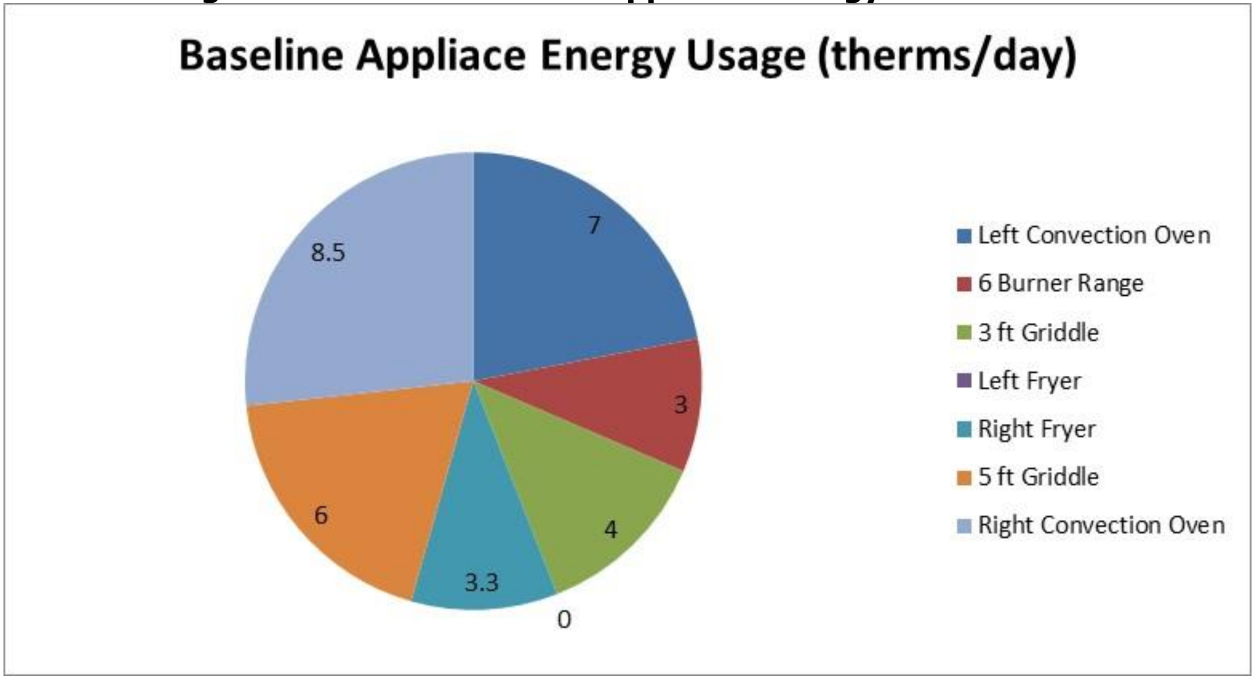
	Method	Operating Hours* pre/post	Pre Energy (therms/day)	Post Energy (therms/day)	Energy Reduction (therms/day)
Left Convection Oven	Measured	14.0/14.3	7.0	3.4	3.6
6-Burner Range	Estimated	N/A	3	3	Not replaced
3-ft. Griddle	Estimated	N/A	4	4	Not replaced
Left Fryer	Measured	0	0	0	Not replaced
Right Fryer	Measured	16.5	3.3	3.3	Not replaced
5-ft. Griddle	Estimated	N/A	6	6	Not replaced
Right Convection Oven	Measured	16.2/15.0	8.5	3.8	4.7

***Operating hours and average input rate not listed for appliances with estimated energy usage.**

Source: Frontier Energy, Inc.

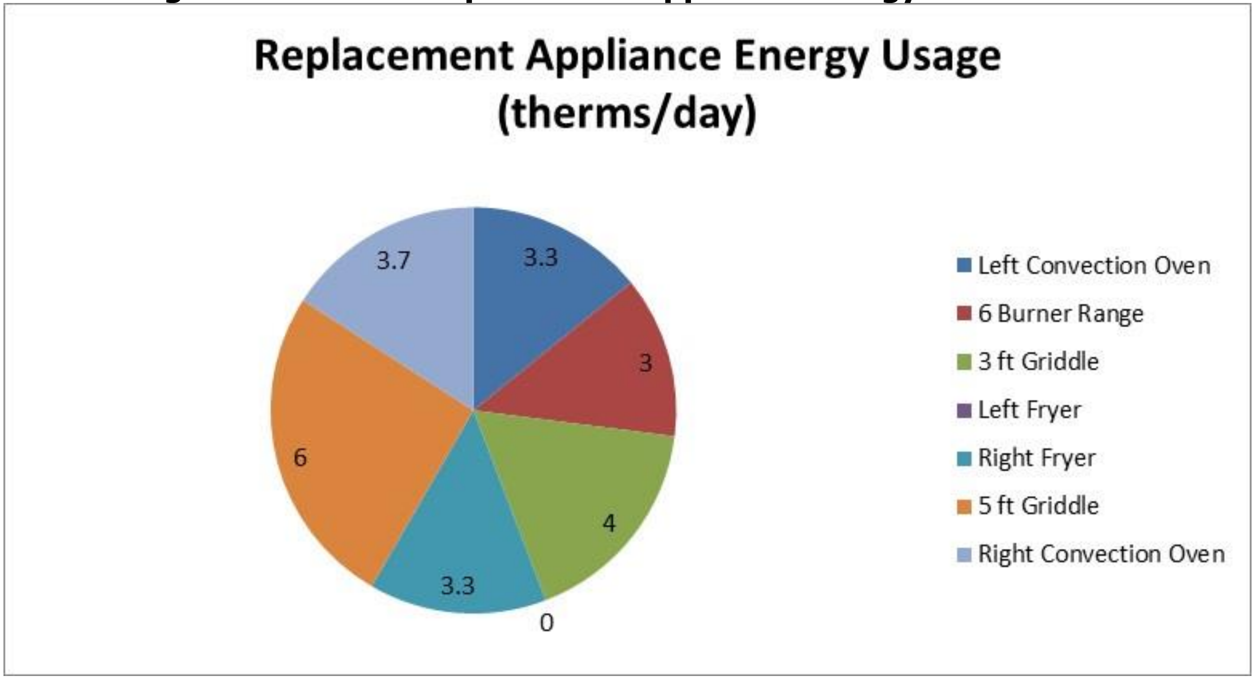
Convection oven replacement resulted in significant energy savings without sacrificing cooking performance. The left double stack convection oven energy was reduced from 7.0 therms to 3.3 therms and the right double stack convection oven energy was reduced from 8.5 therms to 3.7 therms per day. The convection ovens alone accounted for a 55% reduction, from 15.5 therms to 7.0 therms per day, saving 3,100 therms annually. The baseline ovens represented 49% of the total estimated cookline energy use. The new ENERGY STAR ovens now represent 30% of the estimated cookline energy consumption, and with the two standard griddles are now the largest energy-consuming appliances on the line.

Figure 122: UCSF Baseline Appliance Energy Distribution



Source: Frontier Energy, Inc.

Figure 123: UCSF Replacement Appliance Energy Distribution



Source: Frontier Energy, Inc.

CHAPTER 4: Airline Catering

Site Description

Airline catering is an international company providing airline food catering services at almost every major airport. The Los Angeles International airport facility in SoCalGas service territory operates four appliance cooklines and employs dozens of chefs. The catering kitchen operates 24 hours a day, 7 days a week to provide food for domestic and international airlines.

Figure 124: Airline Catering Range and Steam Line – Left Side

Source: Frontier Energy, Inc.

The airline catering company requested design assistance from the SoCalGas Food Service Equipment Center (FSEC) with the goal of specifying energy-efficient equipment that would meet the increasing production demands of their fast-paced kitchen. With a 24/7 operation, multiple shifts, and various cooking techniques, the cooking equipment is in continuous use and consumes substantial amounts of energy. Coincident with the heavy usage, the equipment needs to be maintained at higher than average maintenance intervals. An oven that is only a few years old may look like it has been used for decades in this high-volume kitchen. With such a large staff, the cleaning crew does not communicate with the cooking staff which can lead to equipment damage during cleaning. Personnel from SoCalGas worked directly with the operation managers at the catering company for over a year to ensure staff adapt to the new equipment and ensure properly maintenance practices to get the most out of their equipment.

Figure 125: Airline Catering Range, Braising Pan, and Steam Line – Right Side

Source: Frontier Energy, Inc.

The airline catering kitchen consisted of range, grill, steam, and mixed-duty lines to accommodate the high volume and varied menu items for various airline customers. All airline food is produced in bulk, processed, blast chilled, and portioned. Some foods, such as proteins, are cooked on one piece of equipment (for example, broiler) and finished in another (such as the oven). There are several cooklines where some equipment is duplicated for peak period usage during the summer. In each case, the primary unit was monitored based on direction from the executive chef.

Airline Catering Company Results

Fryer Replacement

The existing baseline fryer was a typical standard-efficiency high-volume gas fryer. The fryer was used periodically for tempura items, chips, and garnishes. Although fried food is not heavily featured on many client menus, the fryer was typically left on all day (except when changing oil) and had an average energy consumption of 3.6 therms per day. Energy usage ranged from 1 to 7 therms per day depending on use and hours of operation, which ranged between 12 and 24 hours. Standard practice involved changing out oil daily.

The older standard fryer was replaced with an energy-efficient fryer with built-in filtration.

Figure 126: Baseline Fryer

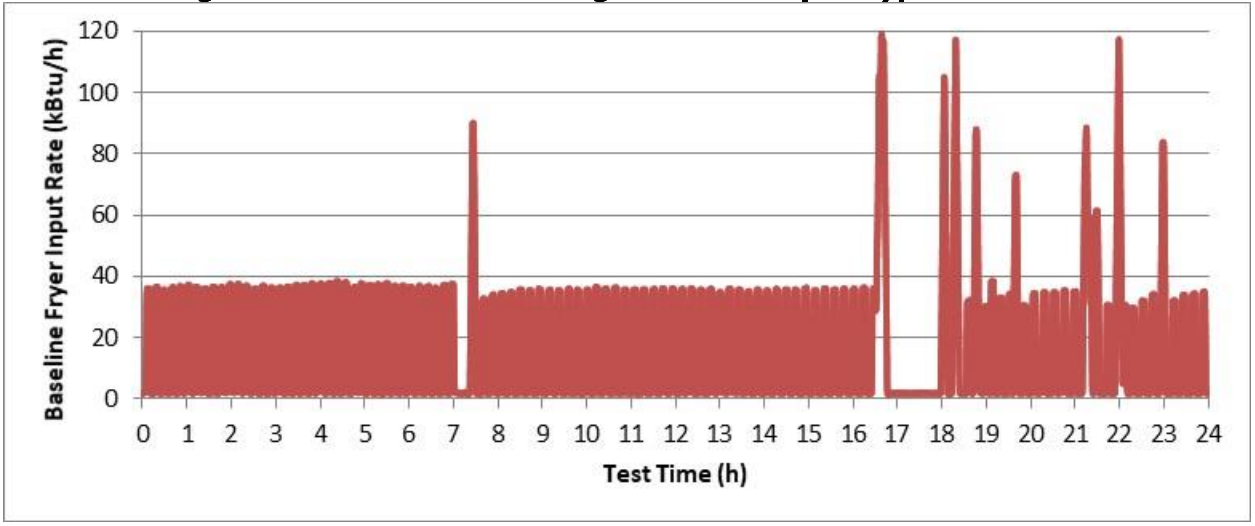
Source: Frontier Energy, Inc.

Figure 127: Replacement Fryer with Filtration

Source: Frontier Energy, Inc.

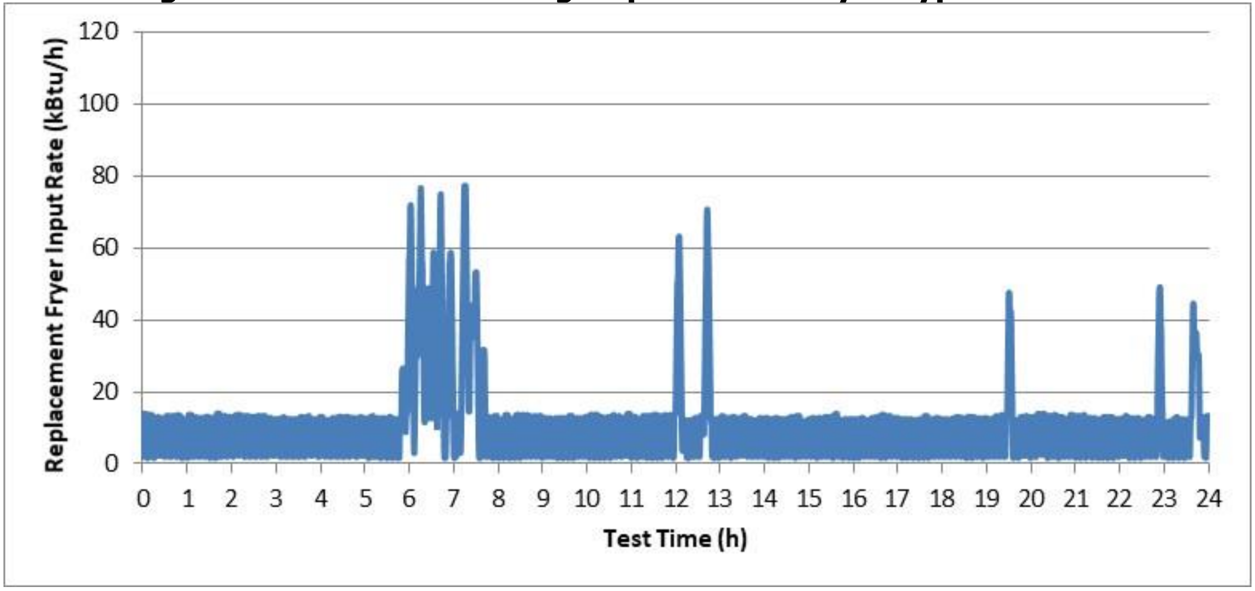
The existing baseline fryer used 3.6 therms per day while the replacement fryer used only 2.6 therms per day. The operator replaced oil every day with the old fryer, so the addition of an oil filtration system was necessary to extend oil life. Now staff change oil once every three days, saving around $5,808 per year on oil costs alone (based on $24/jug). The savings are equivalent to 242 jugs of oil annually. The filtering process necessitated some staff training, but it was eventually adopted into the kitchen's routine. The operators really liked the new filtration system and the replacement fryer performance. The fryer operated 24 hours a day, so most of the energy savings derived from the replacement fryer's lower idle rate.

Figure 128: Airline Catering Baseline Fryer Typical Profile



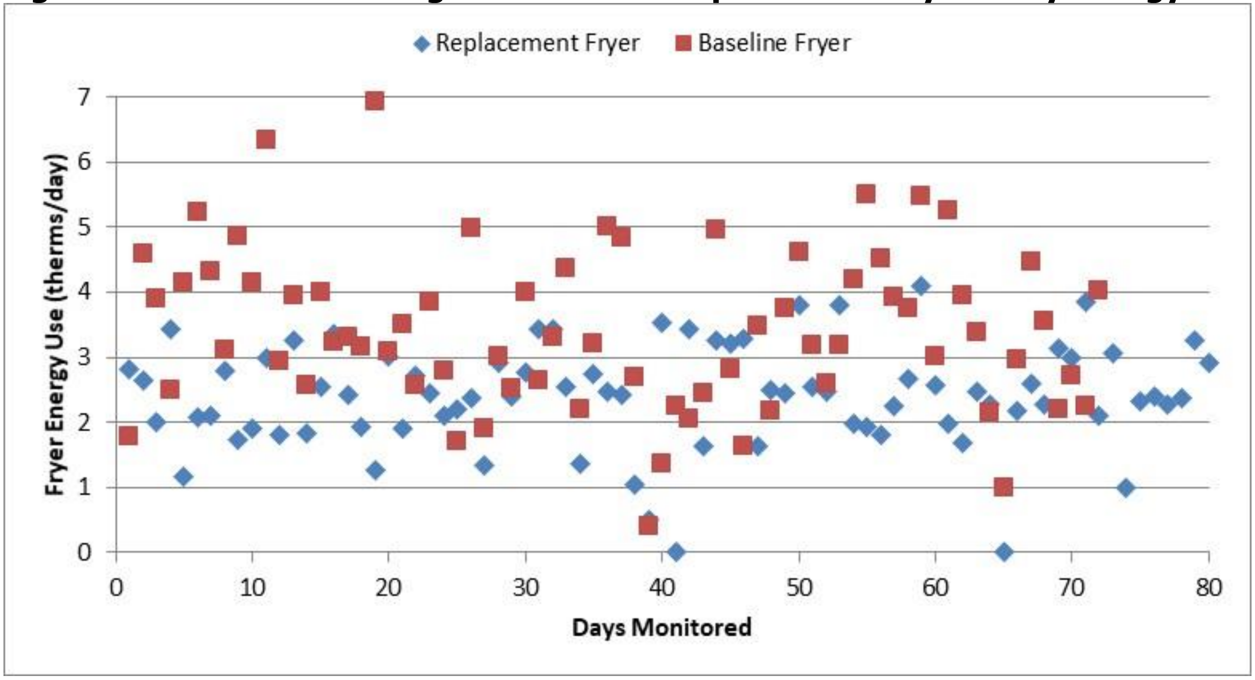
Source: Frontier Energy, Inc.

Figure 129: Airline Catering Replacement Fryer Typical Profile



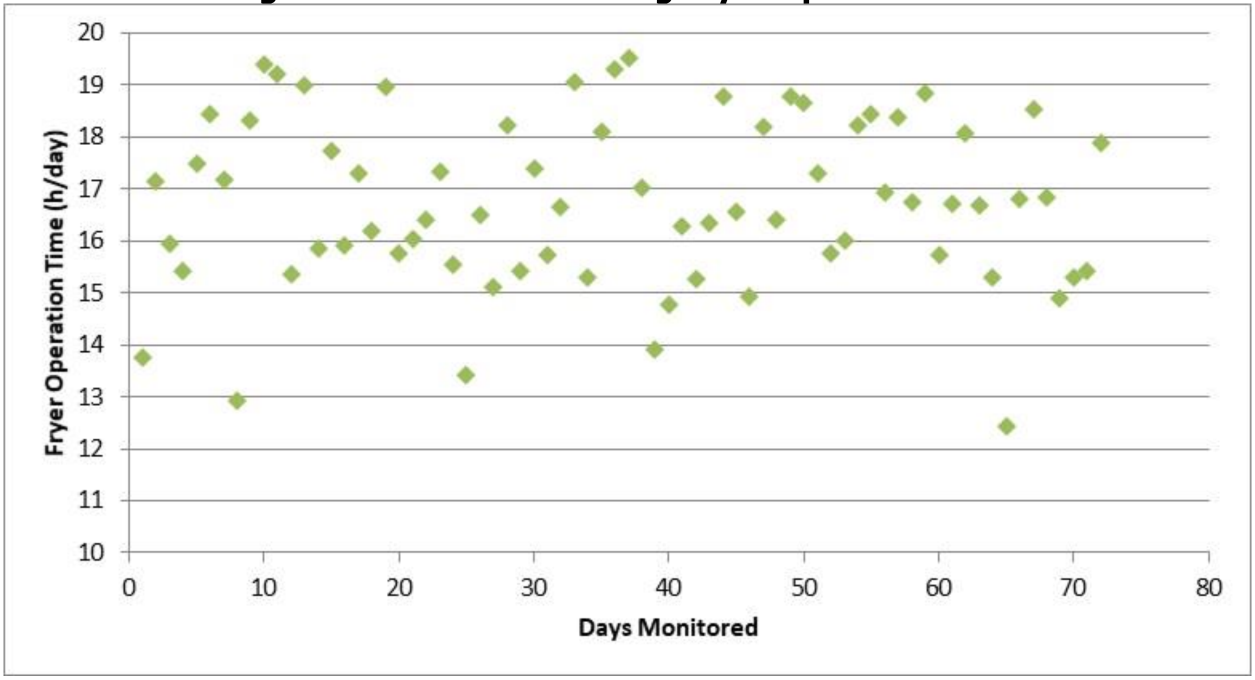
Source: Frontier Energy, Inc.

Figure 130: Airline Catering Baseline and Replacement Fryer Daily Energy Use



Source: Frontier Energy, Inc.

Figure 131: Airline Catering Fryer Operation Time



Source: Frontier Energy, Inc.

Steam Kettle Replacement

The kitchen had two 60-gallon steam kettles primarily used for quick blanching vegetables. The kettles were operated constantly with the lid up and a full rolling boil during both idle and production periods. Researchers monitored only one of the steam kettles assuming both kettles operated in a similar manner based on operator interviews. The left steam kettle used 13.8 therms per day with daily energy consumption ranging from 11 to 17 therms per day and daily operating hours ranging from 12 to 20 hours per day.

The steam kettle was replaced with a two-compartment ENERGY STAR steamer that reduced energy usage to 2.6 therms per day. Staff operated the steamer for 20 hours per day. Although water consumption was not directly measured, Frontier Energy estimated that the steamer consumed 30 to 50 gallons of water per day based on monitoring of the same model steamer at the DoubleTree Hotel site. The baseline steam kettle had a 60-gallon capacity, meaning it would use about the same amount of water as the two-compartment steamer per day. The staff liked the ease of use of the new steamer. The steamer was also able to replace several countertop rice cookers, saving more energy and time on labor. The staff plans on replacing the second steam kettle with a similar steamer in the near future, which would double the total savings.

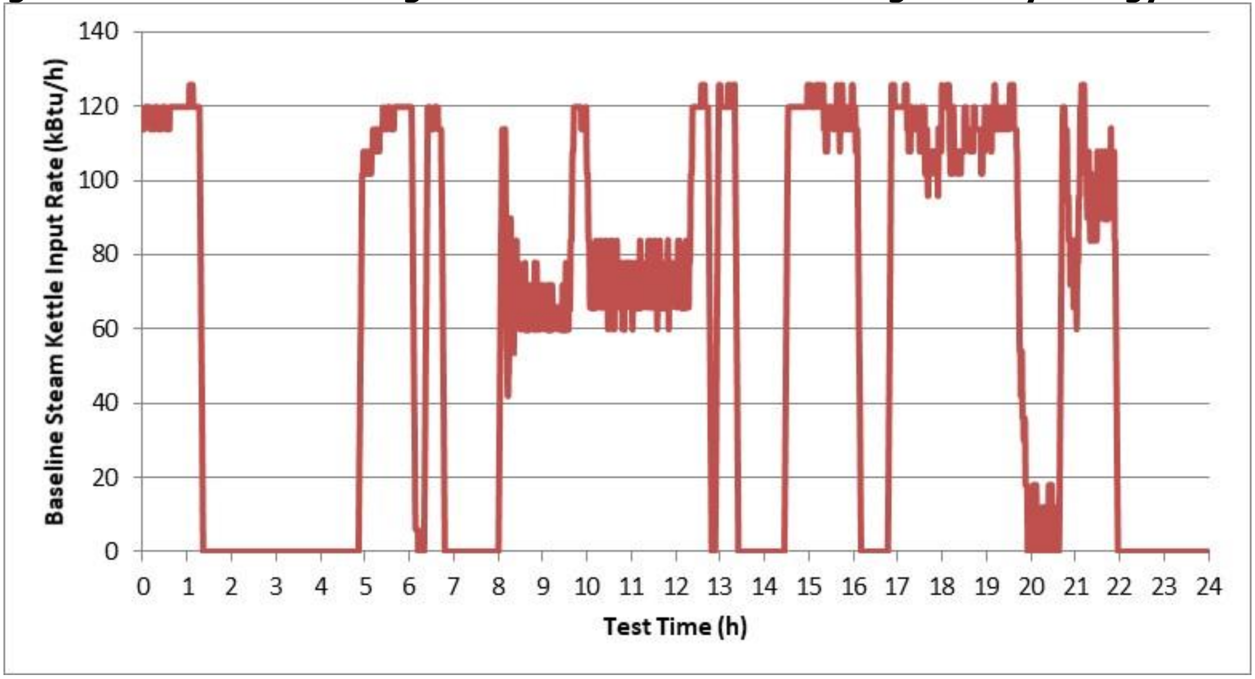
Figure 132: Existing Steam Kettle

Source: Frontier Energy, Inc.

Figure 133: Replacement Two-Compartment Steamer

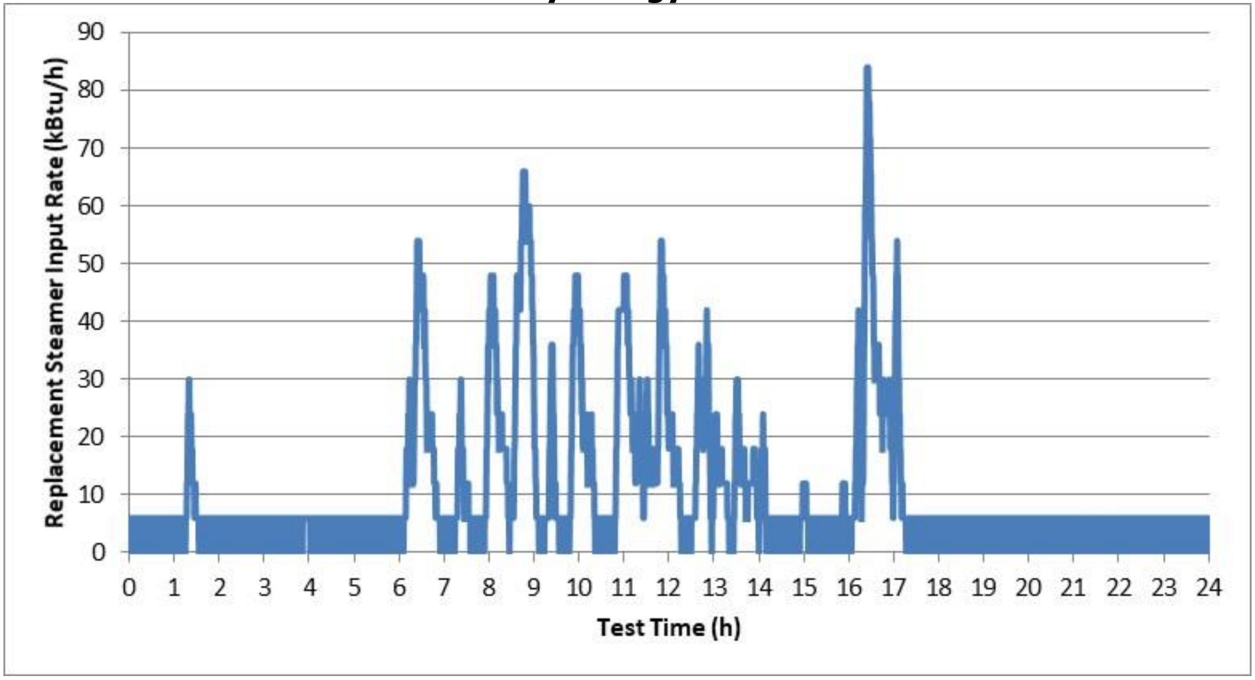
Source: Frontier Energy, Inc.

Figure 134: Airline Catering Baseline Steam Kettle Average Hourly Energy Profile



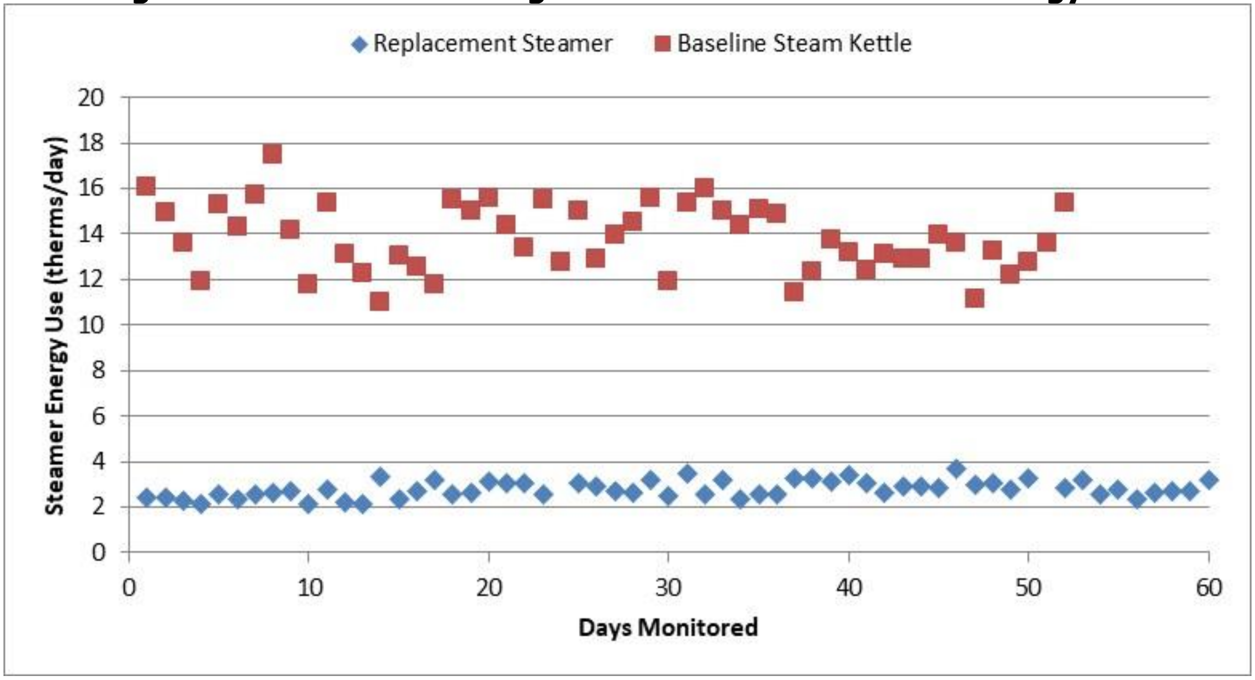
Source: Frontier Energy, Inc.

Figure 135: Airline Catering Replacement Two-Compartment Steamer Average Hourly Energy Profile



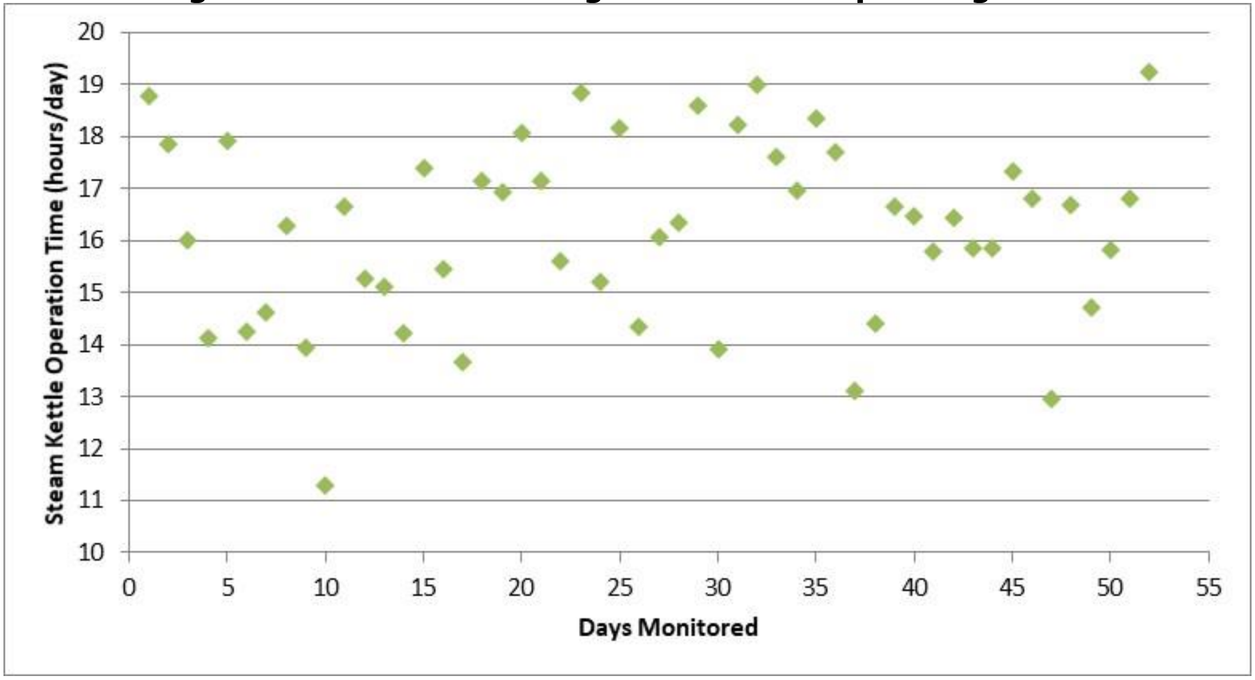
Source: Frontier Energy, Inc.

Figure 136: Airline Catering Steamer vs. Steam Kettle Energy Use



Source: Frontier Energy, Inc.

Figure 137: Airline Catering Steam Kettle Operating Hours



Source: Frontier Energy, Inc.

Broiler Replacement

The production kitchen had two 4-foot underfired char-broilers for grilling food product. Staff prepared typical food items in batches, grilling them on the broilers imparting cross-hatch grill marks, then setting aside the items for finishing in one of the production ovens. Typical items included red meat, poultry, and vegetables. Researchers monitored only one of the broilers for gas consumption; however, all the broilers are expected to use the same amount of energy. The existing 4-ft. underfired broiler used 18.0 therms per day, ranging from 13 to 21 therms per day based on hours of operation. The broiler was turned on at 5 am and off at 1 am. The hours of operation ranged from 18 to 21 hours per day. With consistent operation time and energy consumption, the broiler used 0.8 to 1.0 therms per hour. The broiler was occasionally turned down between lunch and dinner.

Figure 138: Existing Underfired 4-ft. Broiler

Source: Frontier Energy, Inc.

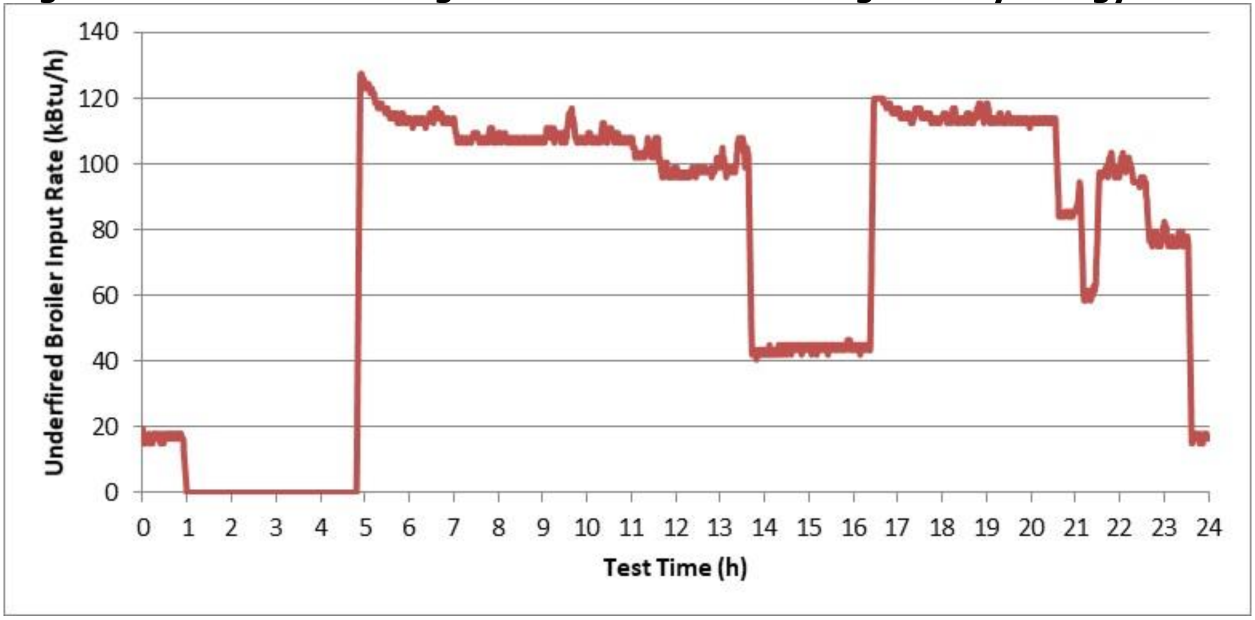
Figure 139: Replacement Conveyor Broiler

Source: Frontier Energy, Inc.

Researchers replaced the underfired broiler with a conveyor broiler equipped with two speed-controlled conveyors and a cooking chamber operating close to 600°F. With a more enclosed cooking chamber than the underfired broiler, conveyor broilers can consume less energy. While conveyor broilers have found wide market adoption in quick-service restaurants, they have not yet gained popularity in other restaurant sectors.

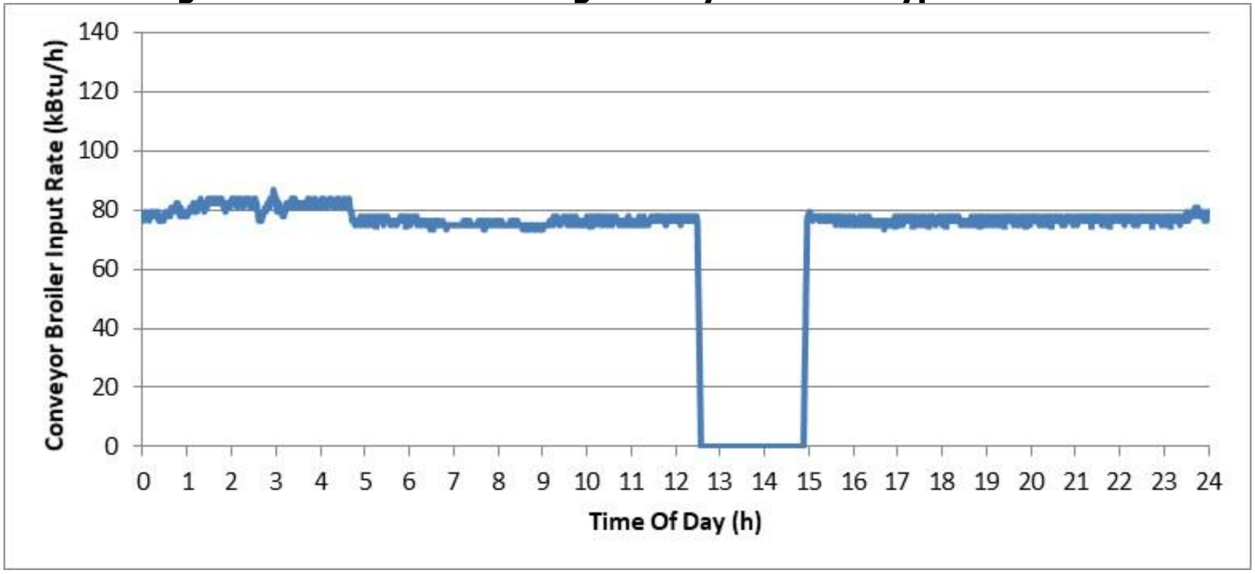
Staff did not immediately acclimate to the new conveyor broiler. Several training sessions were necessary to teach staff how to clean and operate the broiler properly. Additional training sessions occurred to teach staff how to optimize the broiler's production capacity and cook a variety of foods. Staff operated the broiler 24/7, turning it off for several hours per day for cleaning. The broiler can be turned off at night as well as between lunch and dinner hours to reduce its energy usage. Researchers found that the broiler was left on all day and overnight occasionally. Sometimes the broiler was turned off for longer periods of time.

Figure 140: Airline Catering Underfired Broiler Average Hourly Energy Profile



Source: Frontier Energy, Inc.

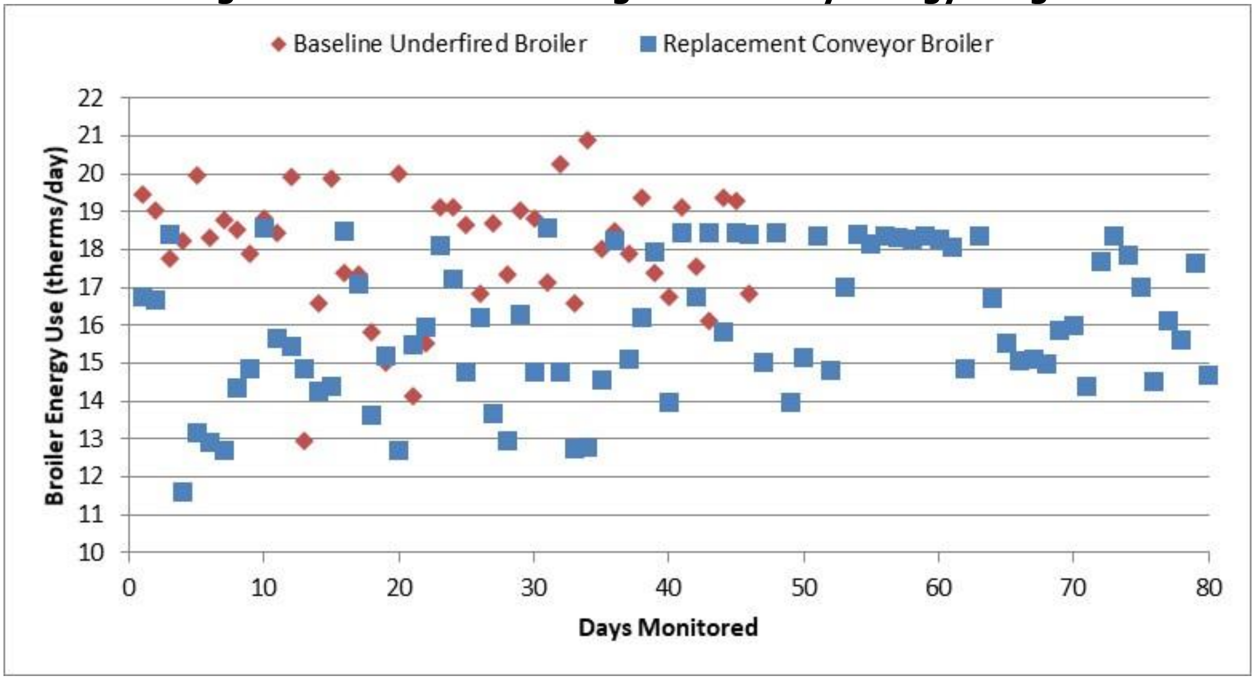
Figure 141: Airline Catering Conveyor Broiler Typical Profile



Source: Frontier Energy, Inc.

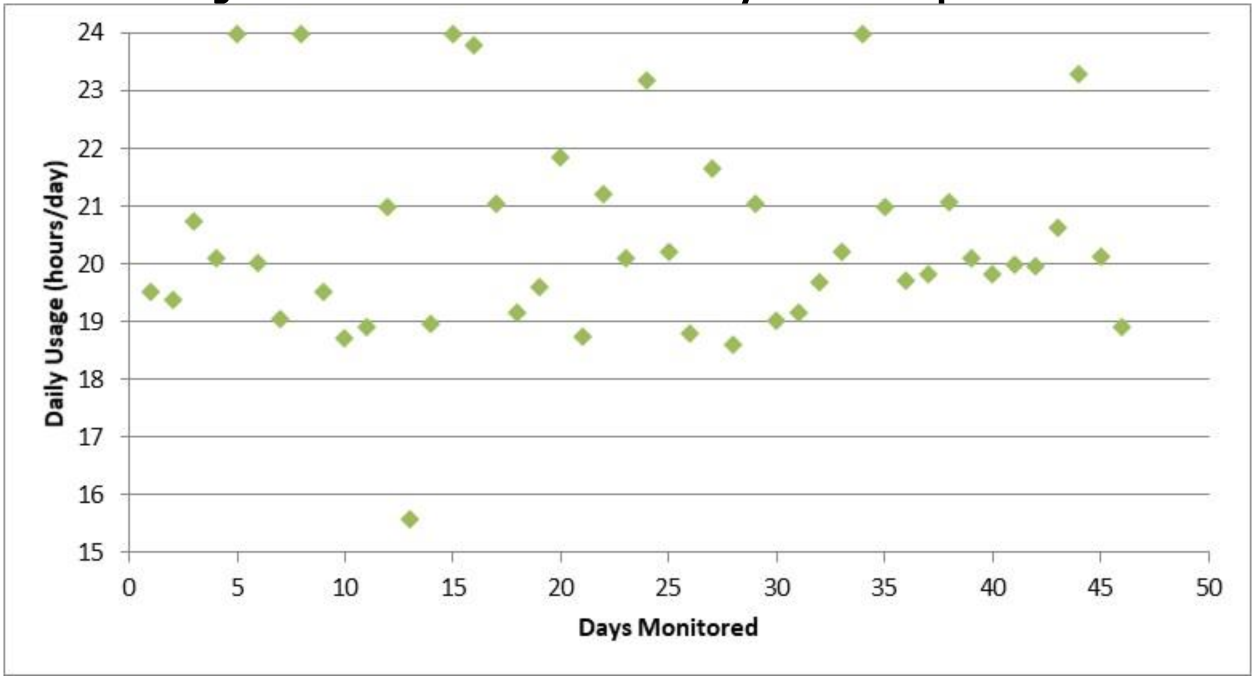
Based on operator feedback after the replacement, staff can cook diverse food products on the new conveyor broiler consistently and reduce the heat load generated from the old underfired broiler. The conveyor broiler greatly improved kitchen comfort through ambient temperature reduction. The replacement conveyor broiler used 15.7 therms per day resulting in a 2.3 therm savings.

Figure 142: Airline Catering Broiler Daily Energy Usage



Source: Frontier Energy, Inc.

Figure 143: Underfired Broiler Daily Hours of Operation



Source: Frontier Energy, Inc.

Combi Oven Replacement

The kitchen had a legacy roll-in electric combination oven that had been converted into a convection oven. The electric consumption of the old combi oven was not measured. The old roll-in combi was replaced with a double stack convection oven equipped with steam injection capability. The replacement double stack convection oven consumed 5.5 therms per day for both compartments. The top compartment was utilized more often than the bottom compartment. Both ovens were turned on at 5 am and turned off at different times after midnight.

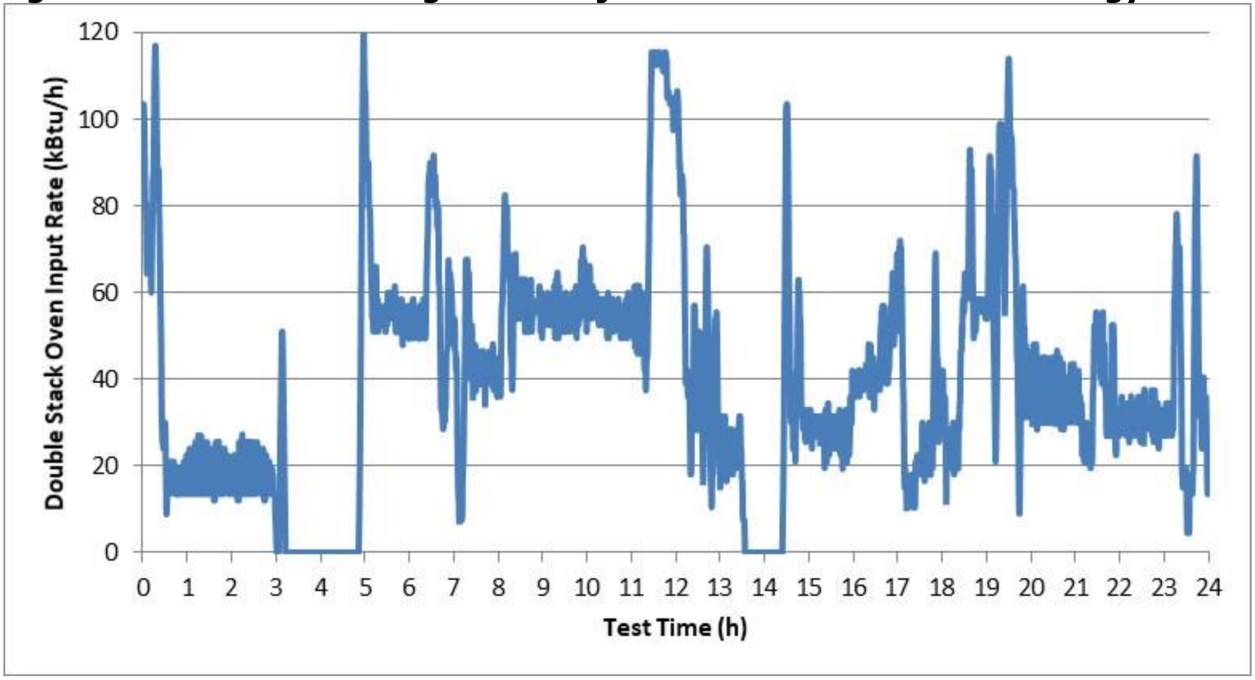
Figure 144: Old Electric Combi Oven

Source: Frontier Energy, Inc.

Figure 145: Replacement Double Stack Convection Oven with Steam Injection

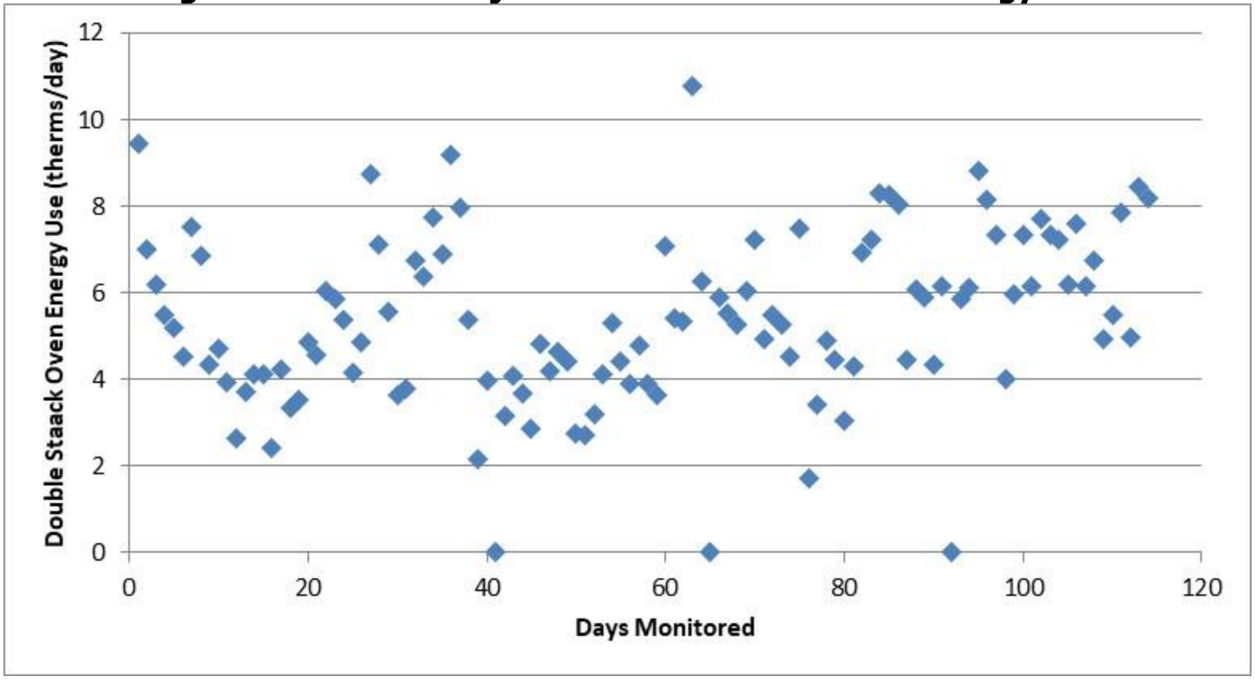
Source: Frontier Energy, Inc.

Figure 146: Airline Catering Steam Injection Double Stack Oven Energy Profile



Source: Frontier Energy, Inc.

Figure 147: Steam Injection Double Stack Oven Energy Use



Source: Frontier Energy, Inc.

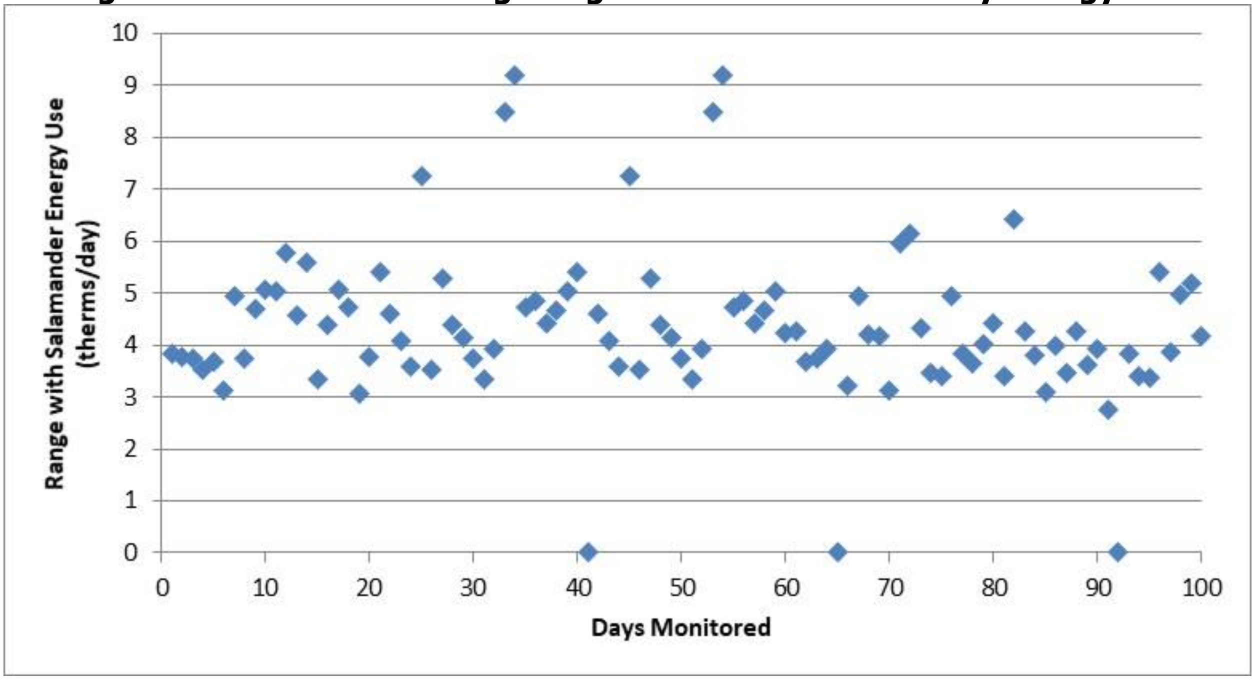
Range Energy Monitoring

Researchers replaced and monitored the new range for energy consumption. Since there are no energy-efficient range alternatives, there were no energy savings. The four-burner range contained an above-hanging salamander. Staff mostly used the range to cook stocks and soups. The range consumed 4.7 therms per day with the salamander energy accounting for a majority of the usage. The average on-time for the range with salamander was 12.8 hours per day. Researchers provided the operator several sets of energy-efficient cookware to use on the range. The operator liked the cookware citing decreased cook time and improved consistency.

Figure 148: 4-Burner Range w/ Salamander Above

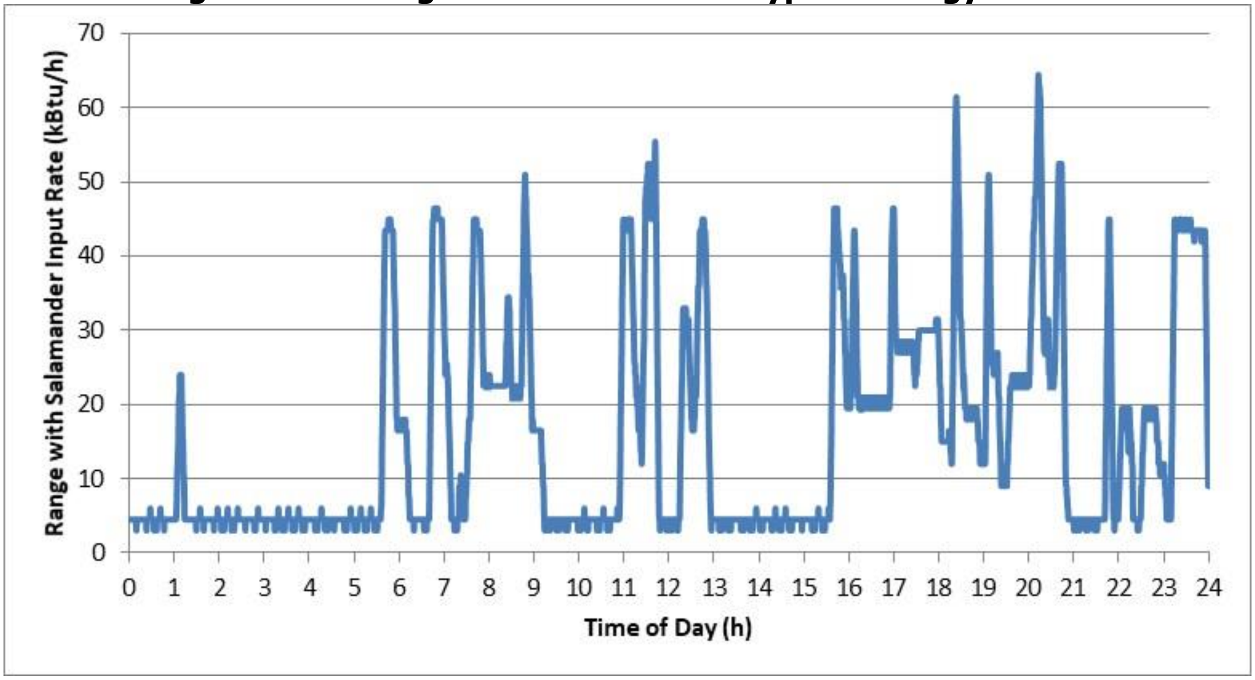
Source: Frontier Energy, Inc.

Figure 149: Airline Catering Range with Salamander Daily Energy Use



Source: Frontier Energy, Inc.

Figure 150: Range with Salamander Typical Energy Profile



Source: Frontier Energy, Inc.

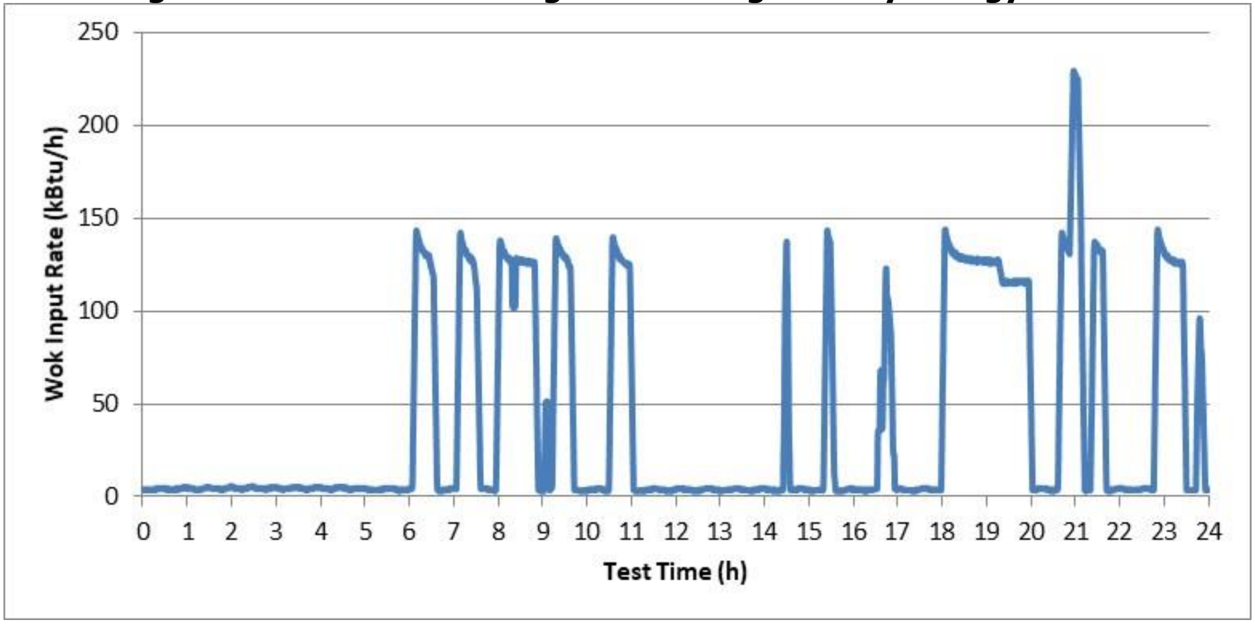
Wok Energy Monitoring

Staff used woks to prepare specialty ethnic items. Large amounts of food were prepared in concentrated batches. Staff regularly turned off wok burners when not cooking. Researchers replaced and monitored the wok for energy consumption. Since there is no energy-efficient wok alternative, there were no calculable energy savings. The left wok had a single ring burner and the right wok had a double ring burner. The entire wok consumed an average 10.2 therms per day with a wide range of 5 to 19 therms per day depending on the hours of operation. The wok operated for an average 10.5 hours per day with a range of 7 to 19 hours per day.

Figure 151: Dual Wok Range

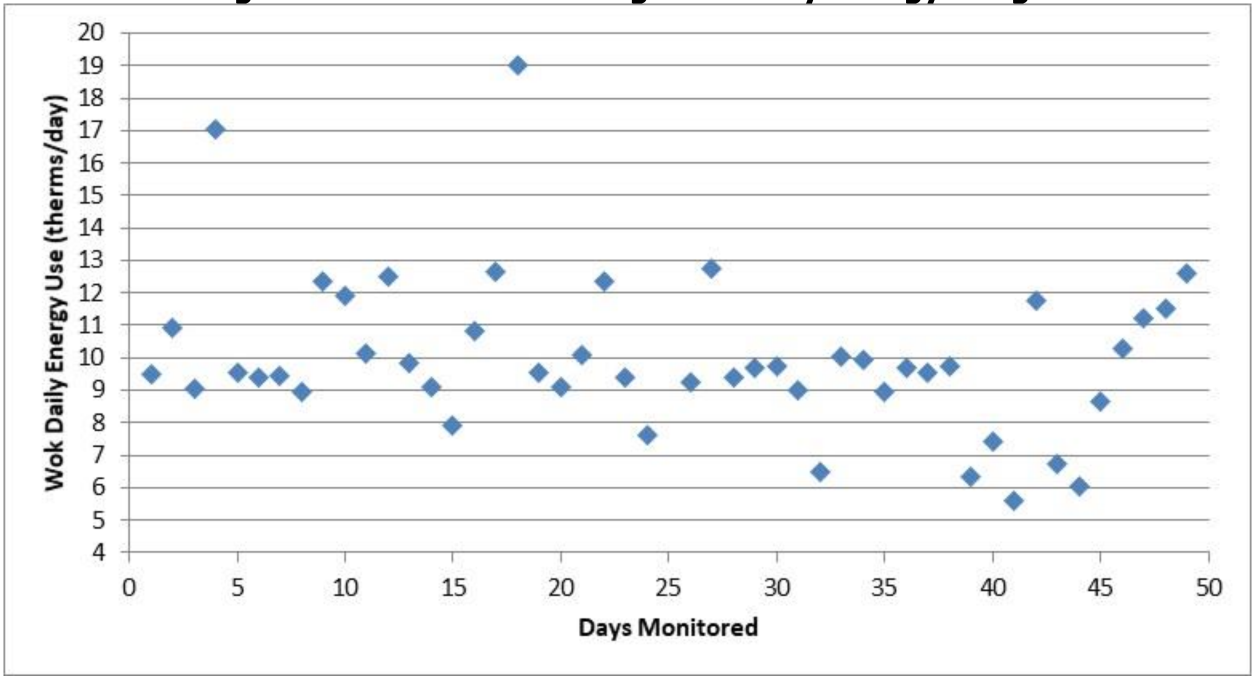
Source: Frontier Energy, Inc.

Figure 152: Airline Catering Wok Average Hourly Energy Profile



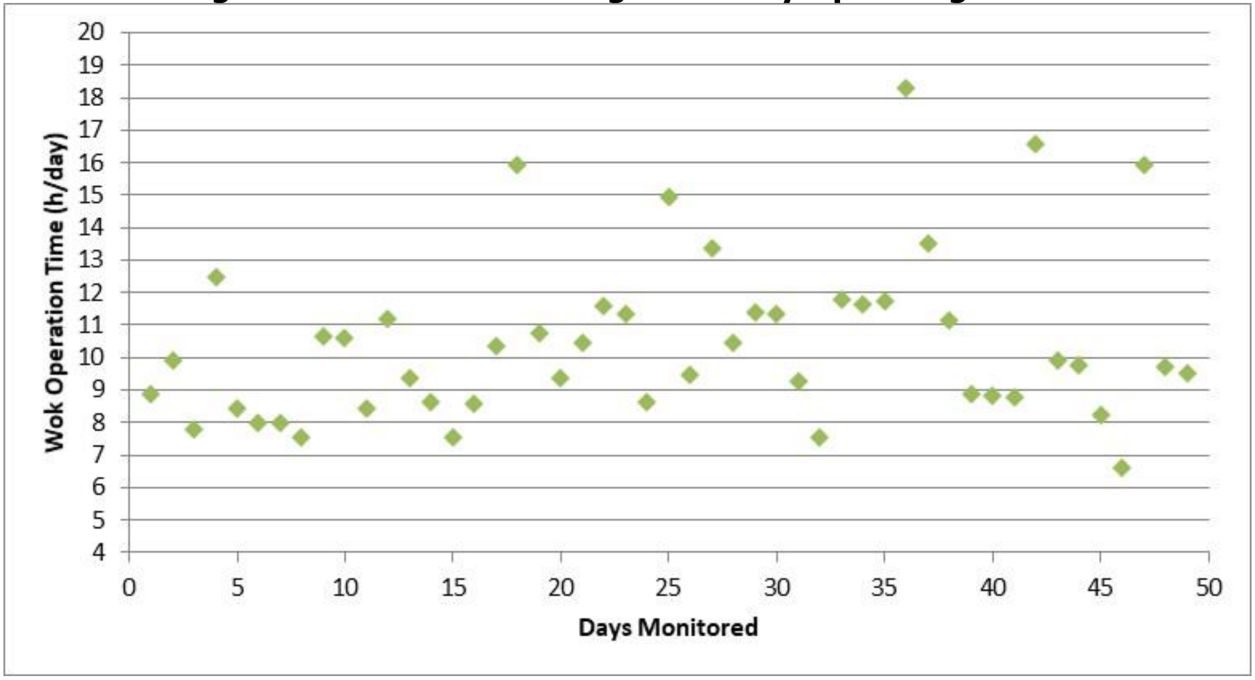
Source: Frontier Energy, Inc.

Figure 153: Airline Catering Wok Daily Energy Usage



Source: Frontier Energy, Inc.

Figure 154: Airline Catering Wok Daily Operating Hours



Source: Frontier Energy, Inc.

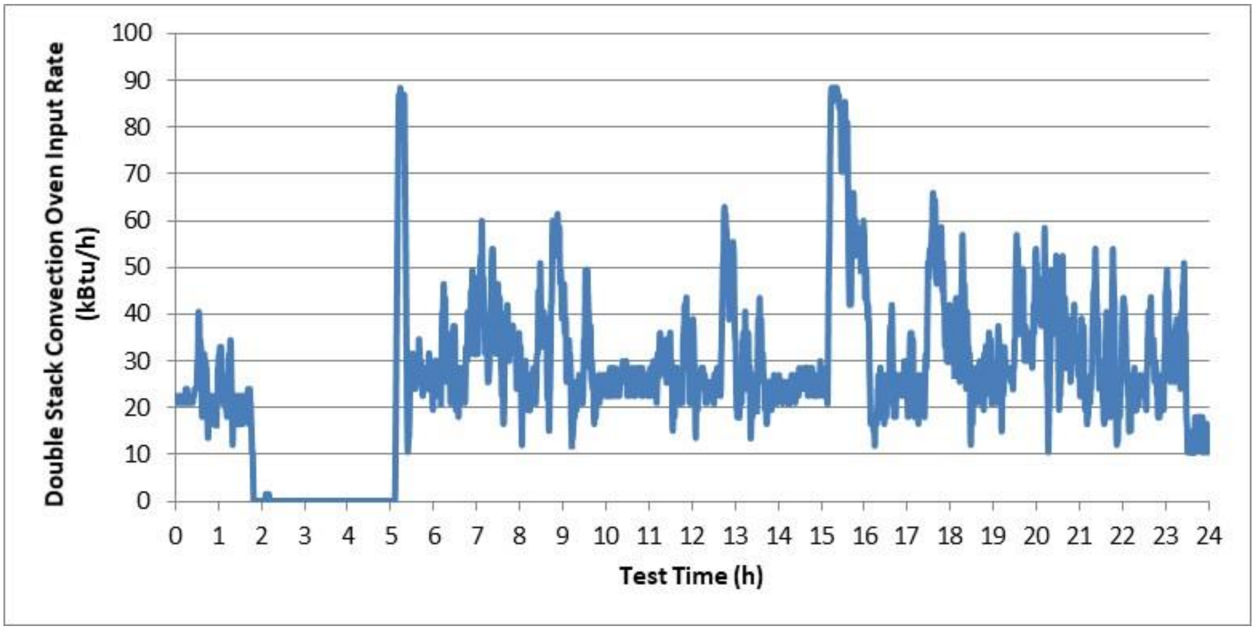
Double Stack Convection Oven Energy Monitoring

The kitchen had a double stack ENERGY STAR convection oven that had been replaced within the past two years. The ovens were used to finish meat and poultry items and prepare large quantities of baked entrees. Although the ovens operated for 17.6 hours per day and used heavily, the average energy consumption was 5.9 therms per day for both cavities. Daily energy usage ranged from 4 to 8 therms per day depending on whether the bottom cavity was used.

Figure 155: Double Stack Convection Oven

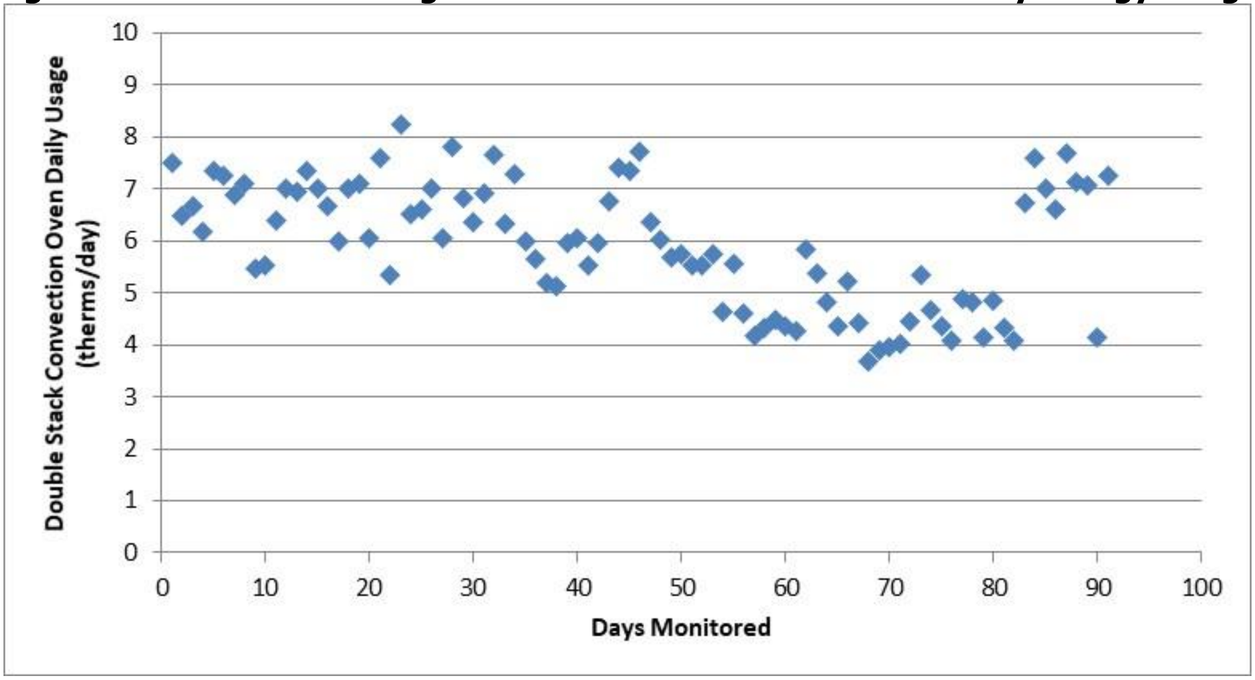
Source: Frontier Energy, Inc.

Figure 156: Airline Catering Double Stack Convection Oven Average Hourly Energy Profile



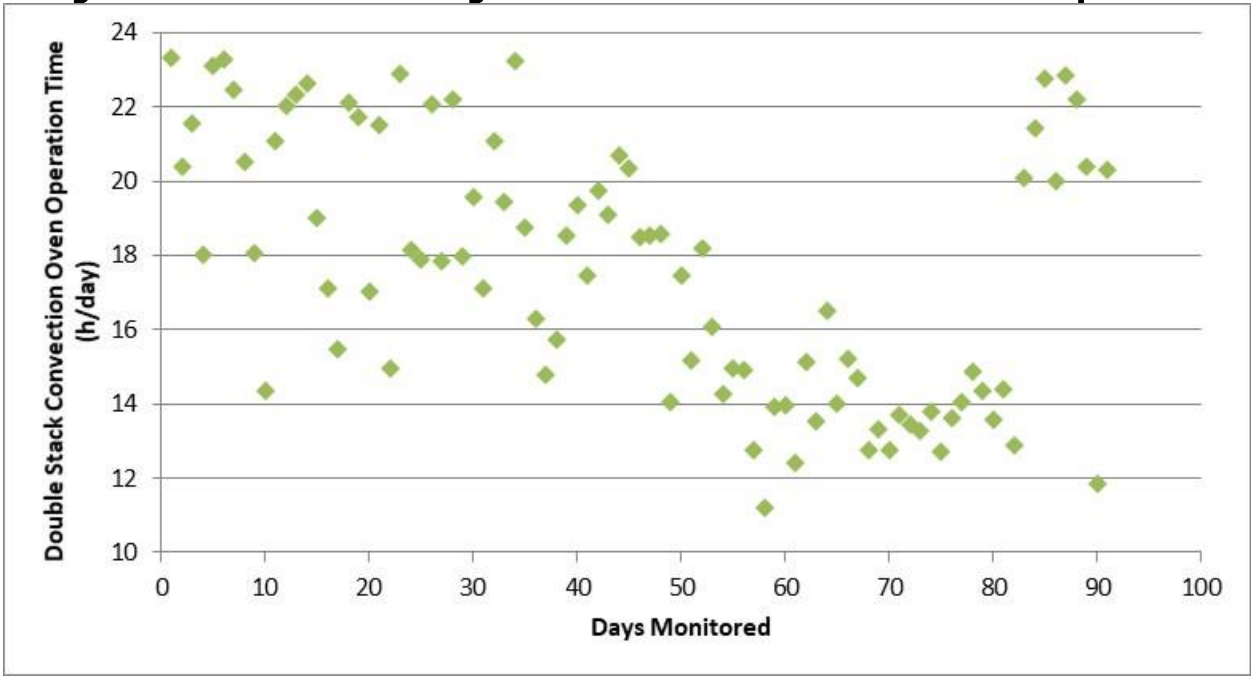
Source: Frontier Energy, Inc.

Figure 157: Airline Catering Double Stack Convection Oven Daily Energy Usage



Source: Frontier Energy, Inc.

Figure 158: Airline Catering Double Stack Convection Hours of Operation



Source: Frontier Energy, Inc.

Single Convection Oven Energy Monitoring

The kitchen had an older convection oven on the range line that was used in concert with the range operation, finishing food started on the sauté station. Staff operated the single oven 24/7. The oven consumed an average of 4.21 therms per day. Oven energy use was directly related to hours of operation and was consistent throughout the monitoring period with operating hours ranging from 16 to 24 hours per day.

Researchers replaced the convection oven with a double stack combination oven. The bottom combi compartment was electric while the top was gas. Combi energy consumption was not measured, but researchers estimated the combi used 2 to 3 therms per day based on monitoring a similar combi oven at the Werewolf American Pub.

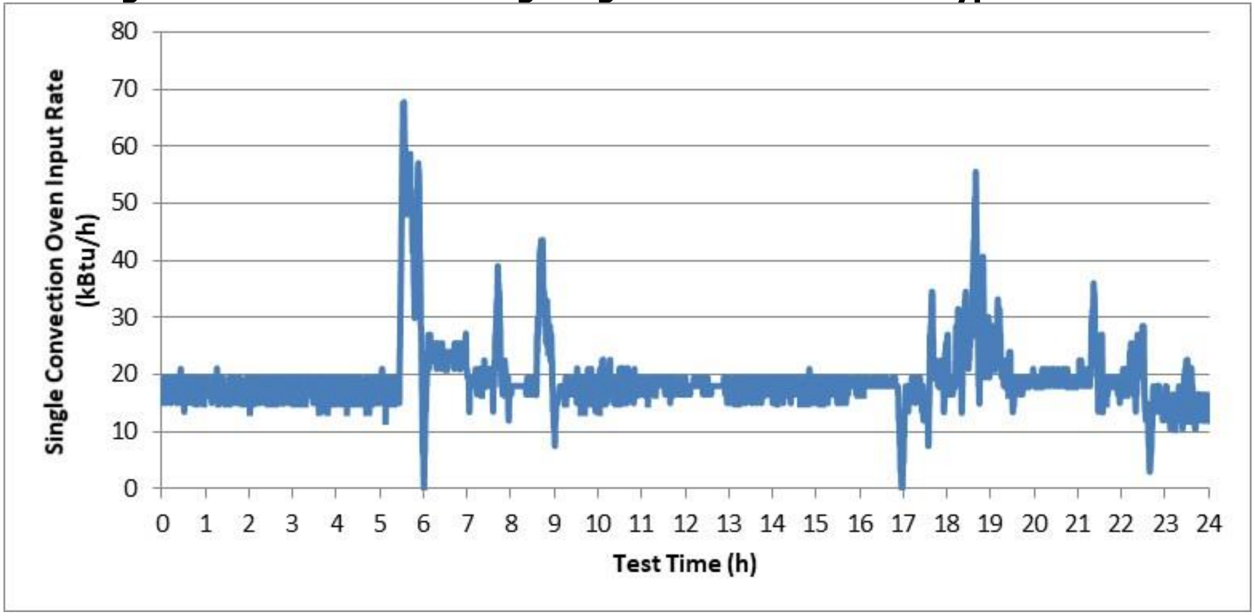
Figure 159: Baseline Convection Oven

Source: Frontier Energy, Inc.

Figure 160: Replacement Combi Oven

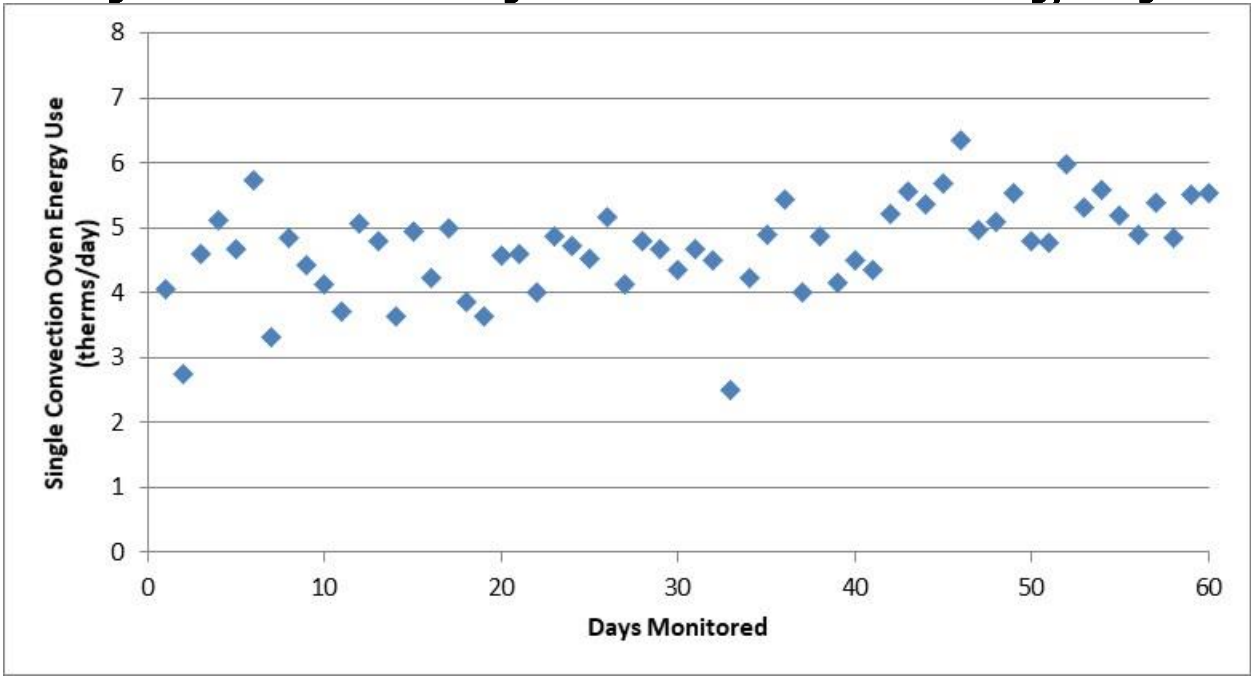
Source: Frontier Energy, Inc.

Figure 161: Airline Catering Single Convection Oven Typical Profile



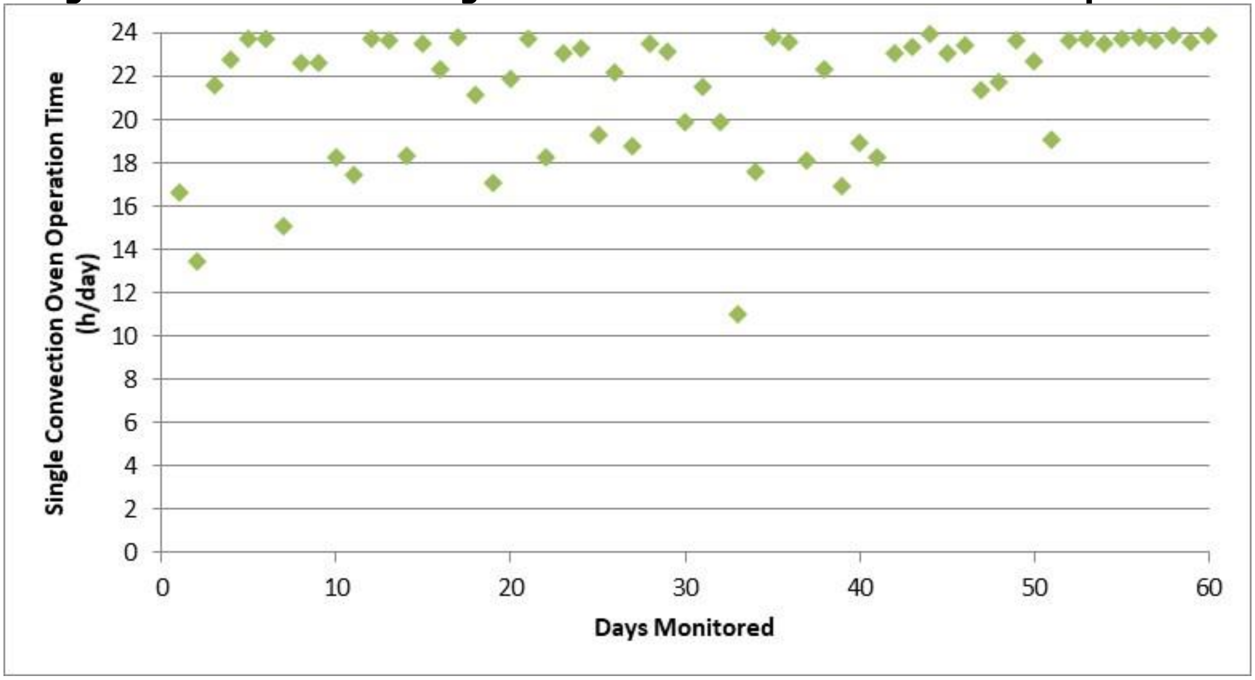
Source: Frontier Energy, Inc.

Figure 162: Airline Catering Baseline Convection Oven Energy Usage



Source: Frontier Energy, Inc.

Figure 163: Airline Catering Baseline Convection Oven Hours of Operation



Source: Frontier Energy, Inc.

Airline Catering Company Summary

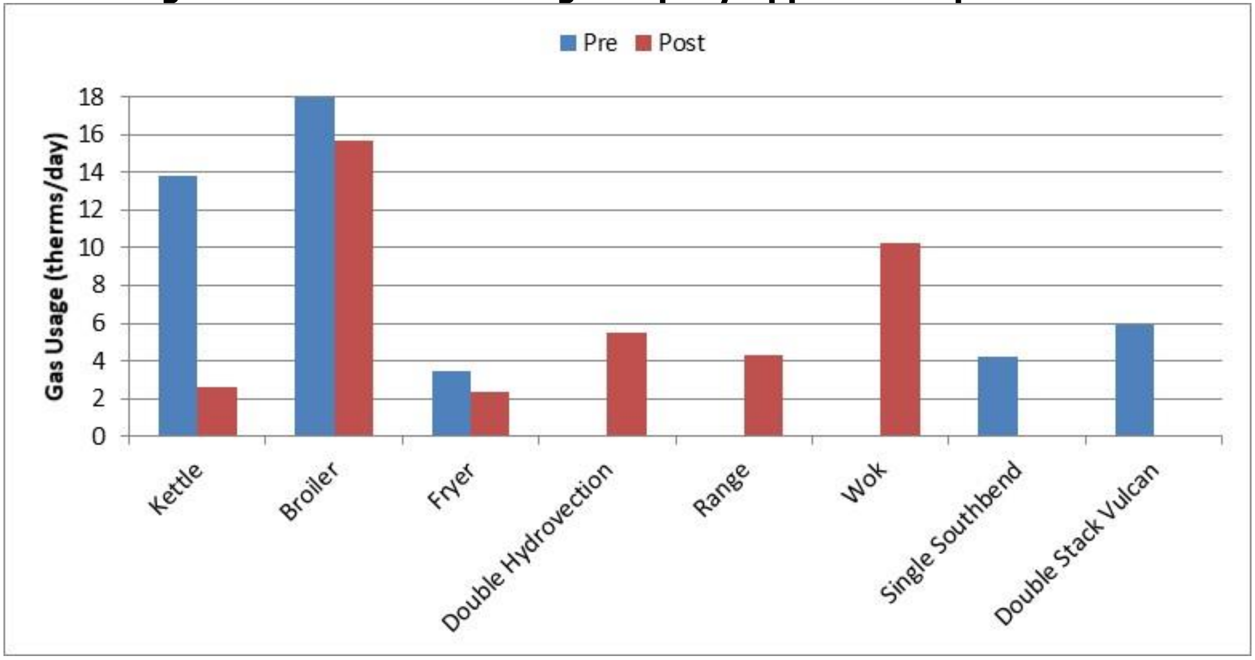
The table below summarizes the monitoring results of appliances at the airline catering company. Researchers only monitored appliances that were candidates for replacement. If the appliance had a duplicate, only one appliance was monitored. Researchers assumed the second appliance used the same amount of energy as the first.

Table 5: Airline Catering Company Energy Summary

	Operating Hours	Pre (therms/ day)	Post (therms/ day)	Therm Savings	% Savings
Steam Kettle / Steamer Replacement	16.2 pre / 19.9 post	13.83	2.62	11.21	81%
Broiler	20.3	18.01	15.70	2.31	13%
Fryer	16.7	3.42	2.36	1.06	31%
Double Stack Convection Oven with Spritzer	22.0	Electric Combi	5.48	N/A	N/A
Range	12.8	Not Metered	4.30	N/A	N/A
Single Convection Oven	18.7	4.21	Not Replaced	N/A	N/A
Wok	10.5	Not Metered	10.22	N/A	N/A
Double Stack Convection Oven	17.6	5.92	Not Replaced	N/A	N/A

Source: Frontier Energy, Inc.

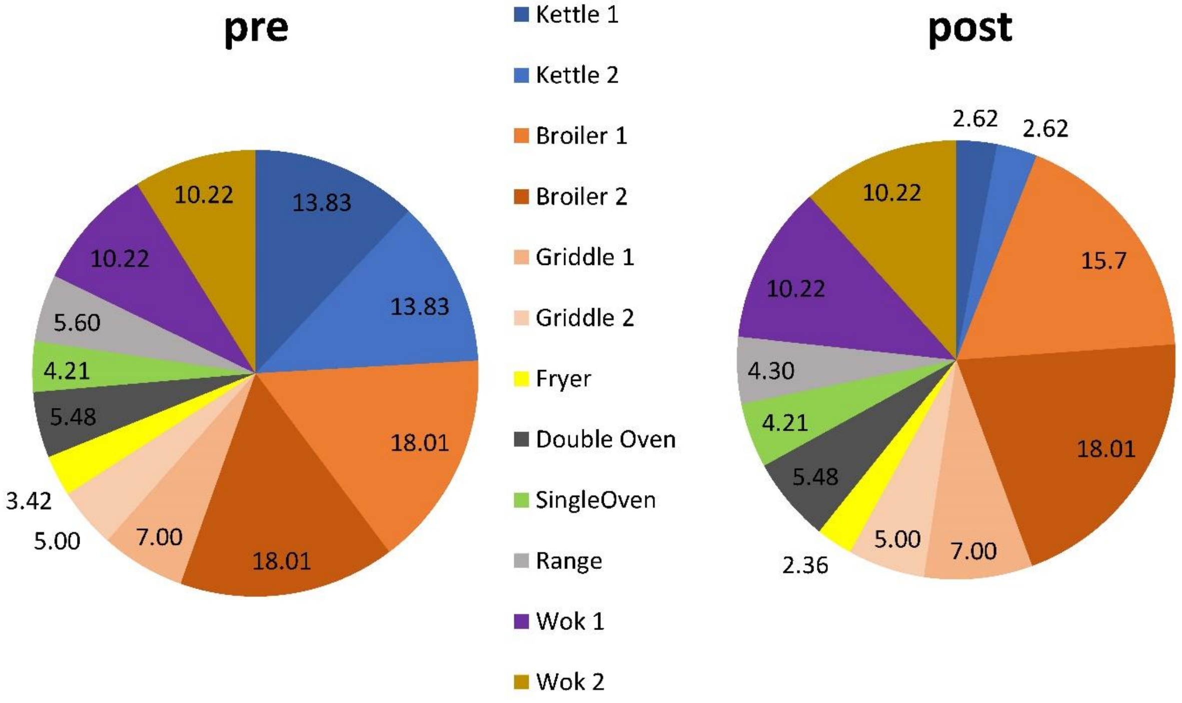
Figure 164: Airline Catering Company Appliance Replacement



Source: Frontier Energy, Inc.

The Airline Catering company had redundant appliances on the main production lines to accommodate peak production periods and provide redundancy in case of equipment failure. In each case, the primary appliance was monitored. Researchers did not monitor the baseline range; baseline range energy usage was estimated based on the replacement range energy use. The Frontier Energy[1] documented the energy reduction when employing energy-efficient cookware in a laboratory. The two griddles were not monitored, nor replaced, however, it is estimated that the 5-ft. griddle consumed 7 therms per day and the 4-ft. griddle consumed 5 therms per day. Researchers estimated griddle energy usage based on prior monitoring results from a FSTC field study,[2] normalizing for 24-hour operation and linear foot of griddle cooking area.

Figure 165: Airline Catering Company Appliance Energy Share



Source: Frontier Energy, Inc.

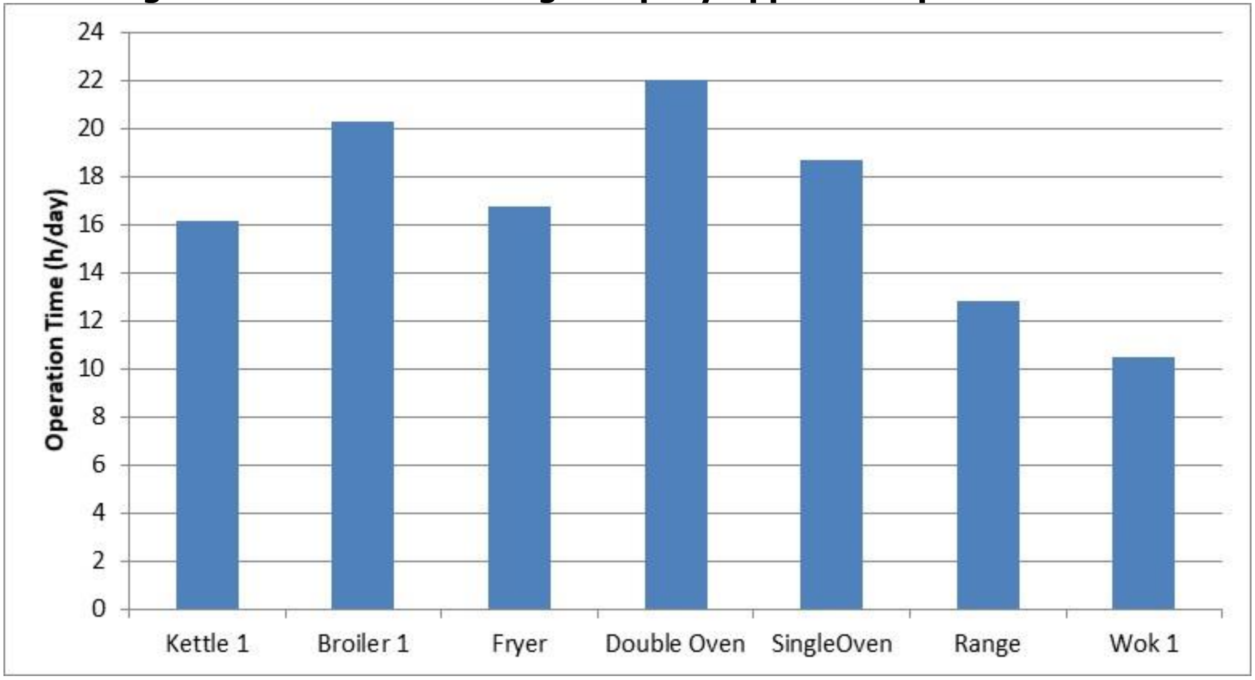
Prior to replacement, the two steam kettles accounted for almost a quarter of the Airline Catering company's total cooking energy use. Once the steam kettle was replaced by the ENERGY STAR steamer, the steamer accounted for less than 10% of the total energy. Researchers did not initially monitor the rice cookers, which were eliminated from the production line after rice production was shifted to the steamer, resulting in even greater energy savings.

Prior to replacement, the two broilers and two steam kettles accounted for more than half of the total energy consumed by the entire kitchen line. This energy was reduced to 40% through replacement. After replacement, the two woks now account for almost a quarter of the energy with the rest of the energy consumed by other appliances such as ranges, ovens, griddles, and the fryer.

Prior to replacement, Frontier Energy estimated that the two cooklines consumed 115 therms per day. After replacement, daily energy consumption was reduced to 88 therms per day, a 24% reduction in cooking energy consumption.

In the standard operation with the baseline equipment, the broilers and steam kettles accounted for over half of the total cookline energy consumption. The woks and griddles were the next largest energy users.

Figure 166: Airline Catering Company Appliance Operation Time



Source: Frontier Energy, Inc.

CHAPTER 5:
Werewolf American Pub

Site Description

Werewolf American Pub is a bar and restaurant located in downtown San Diego in the historic Gaslamp District. Serving breakfast, lunch, and dinner, it is a popular spot for locals and tourists alike. With weekly specials such as "all you can eat tacos" on Tuesday and brunch on weekends, the kitchen operates long hours and the restaurant is open every day.

Figure 167: Werewolf American Pub Restaurant Exterior

Source: Frontier Energy, Inc.

San Diego Gas & Electric (SDG&E) had been working with the owners of the Werewolf restaurant for several years to reduce their energy consumption. This business location has had a high turnover rate with several short-lived establishments, like diners and sushi restaurants, occupying the space prior to the Werewolf opening. The kitchen had a history of being remodeled several times during changes in ownership; however, many appliances that have served several previous owners remained in use in the Werewolf kitchen. Old appliances and high operating hours made this site a great candidate for a casual dining appliance cookline retrofit.

Figure 168: Werewolf Restaurant Interior

Source: Frontier Energy, Inc.

The restaurant's dining room can seat around 50 people. There is a large bar with a serving window leading into a long kitchen. The kitchen consists of a main line, prep line, and a dishwashing area. The main hood line includes a six-burner range, 4-ft. prep table, two 14-inch fryers, a 2-ft. broiler, and a 3-ft. griddle with an overhanging salamander. The main line consists of two adjacent 8-ft. ventilation hoods and the prep line has a 6-ft. hood with a convection oven underneath. The broiler and griddle reside on top of a 6-ft. refrigerated chef base. Both main line hoods are run off one ventilation fan. The prep line has a 6-pan convection oven and a batch coffee brewer. All large cooking appliances are natural gas-fueled.

Figure 169: Werewolf Main Cookline

Source: Frontier Energy, Inc.

Figure 170: Werewolf Prep Line

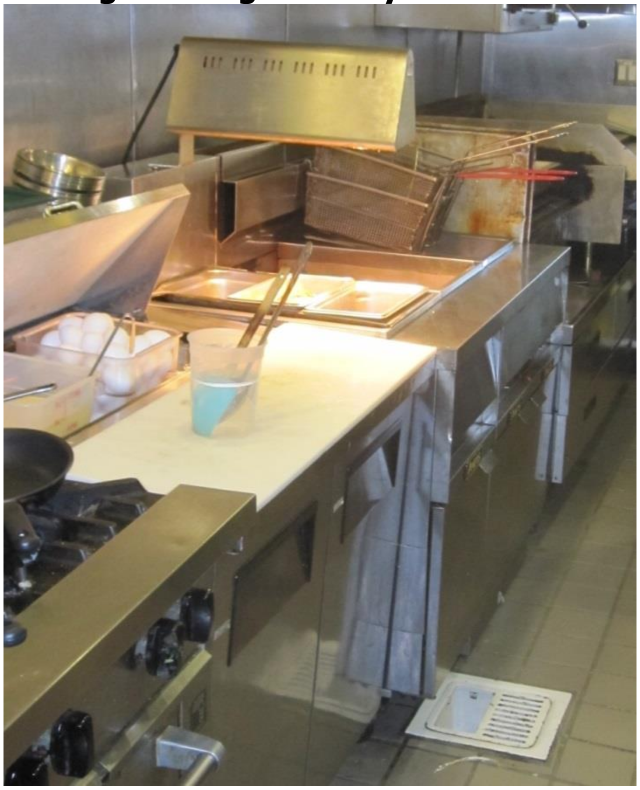
Source: Frontier Energy, Inc.

Werewolf Results

Fryer Replacement

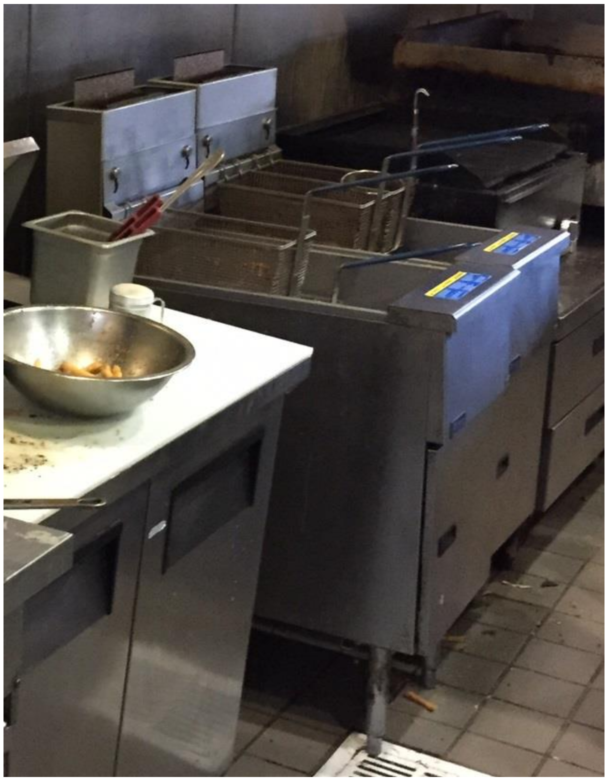
The restaurant inherited an older inefficient fryer from the previous owner. The original fryer had a large vat and a holding station. The fryer was replaced with two entry-level rebate-qualifying ENERGY STAR fryers two years before this project commenced. The replacement had been as brought about through a SDG&E energy audit. The restaurant serves a large amount of French fries and tater tots, so the fryers were in frequent use. One of Werewolf’s signature dishes is chicken wings, which are deep fried then baked. Researchers monitored the two ENERGY STAR replacement vat fryers for several months.

Figure 171: Original Large Vat Fryer and Warming Station



Source: Frontier Energy, Inc.

Figure 172: Newer "Baseline" Small Vat Fryers



Source: Frontier Energy, Inc.

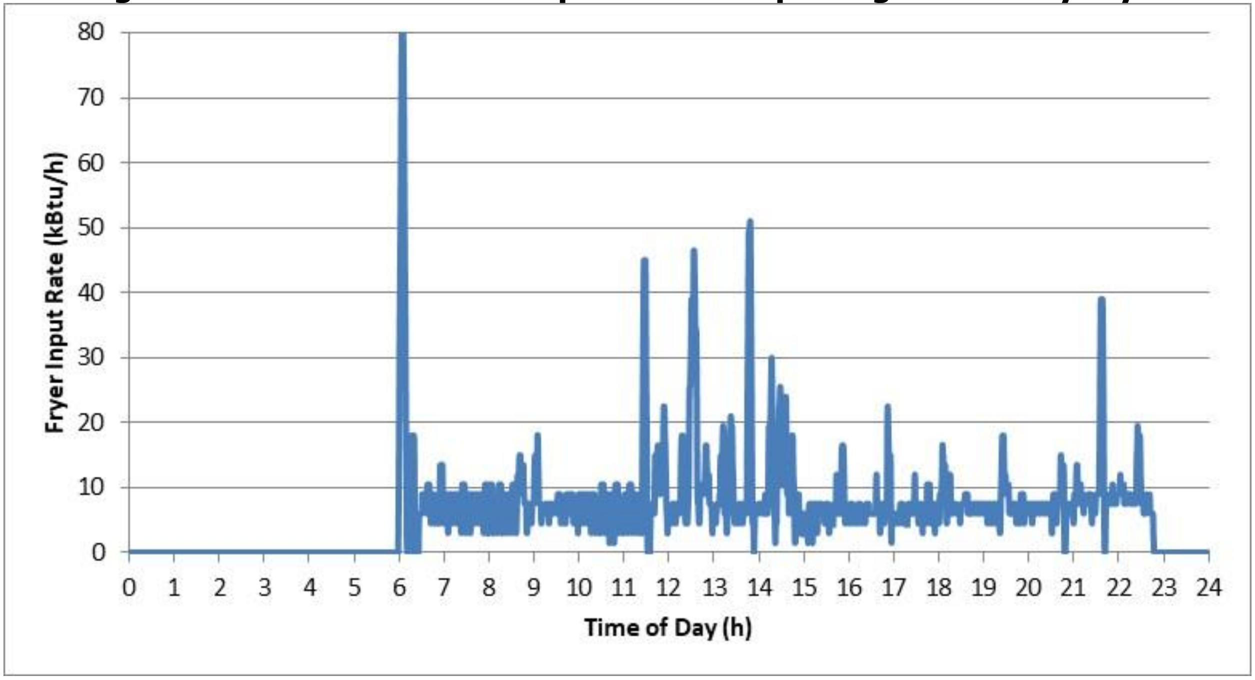
The existing left baseline fryer used 2.7 therms per day and the right fryer used 2.5 therms per day. Both fryers are the same make and model. The fryers were turned on at 6 am every day and turned off around midnight on weekdays and about 1-2 am on weekends. The staff had complained that the fryers were taking longer to cook when the restaurant was cooking several loads in succession. This is probably due to the long recovery times and lower capacity of the fryers not keeping up with the higher demand at the Werewolf kitchen. The right fryer operated for a longer period, 18.6 hours per day, than the left fryer, which operated for only 11.0 hours per day. Both fryers had similar energy usage, which implies that although the right fryer operated for a longer time, the left fryer was used for heavier cooking loads.

Since the left fryer used more energy, it was replaced by a super-efficient, high production ENERGY STAR fryer. The replacement fryer also had a higher tested production capacity of 78 pounds per hour (lb/h) of French fries compared to the 58 lb/h tested production capacity for the baseline fryer. The replacement fryer used only 1.8 therms per day, while producing more food.

Figure 173: Replacement Super High-Efficient Fryer (left) and the Existing Budget High-Efficient Fryer (right)

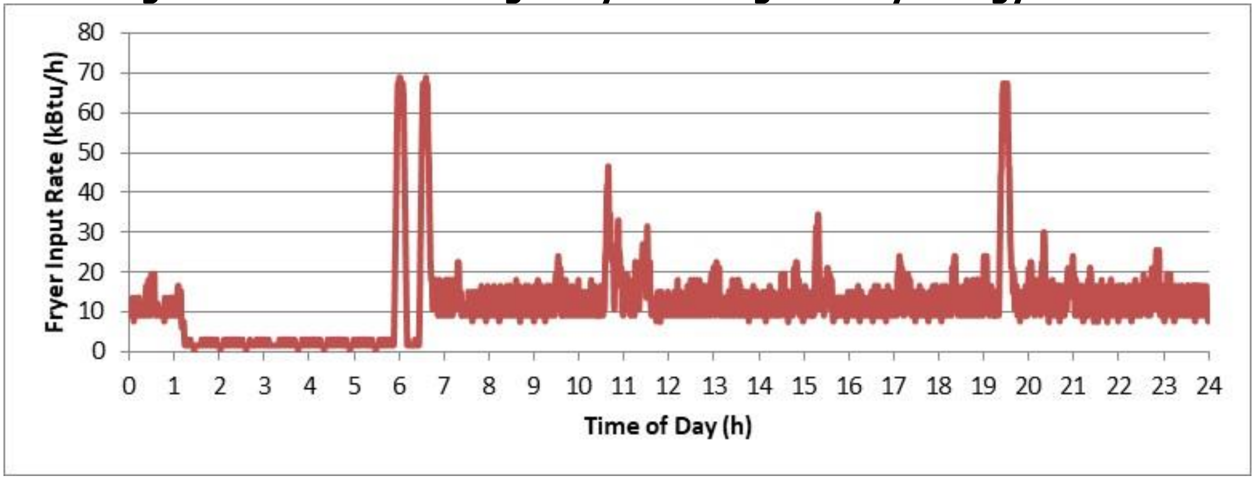
Source: Frontier Energy, Inc.

Figure 174: Werewolf Left Replacement Super High Efficiency Fryer



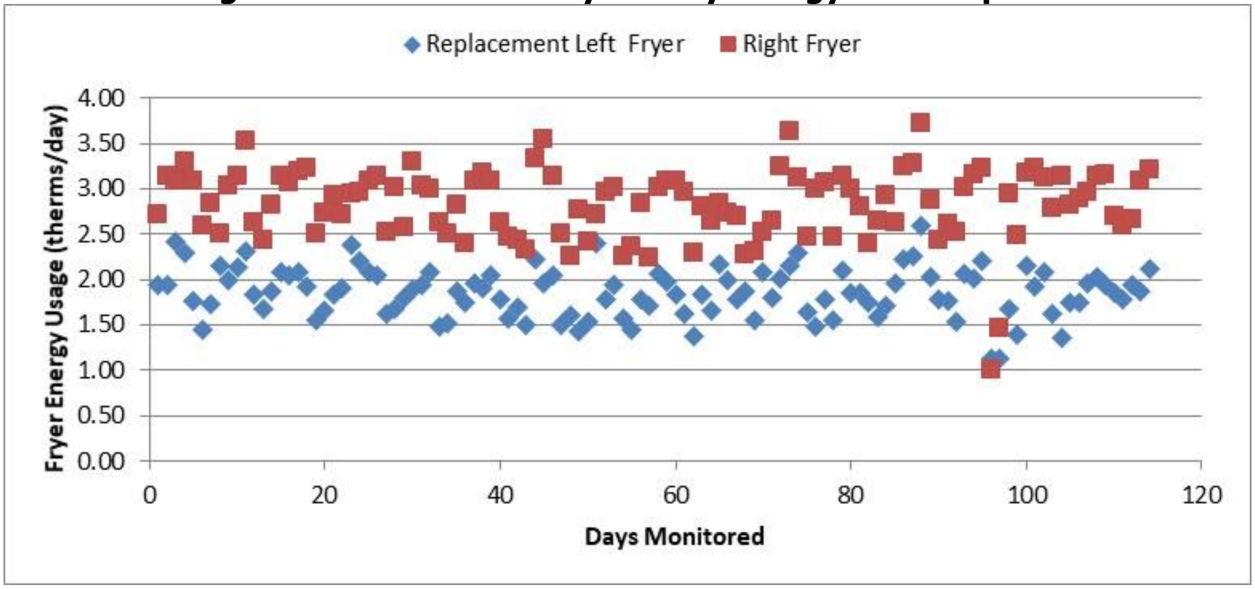
Source: Frontier Energy, Inc.

Figure 175: Werewolf Right Fryer Average Hourly Energy Profile



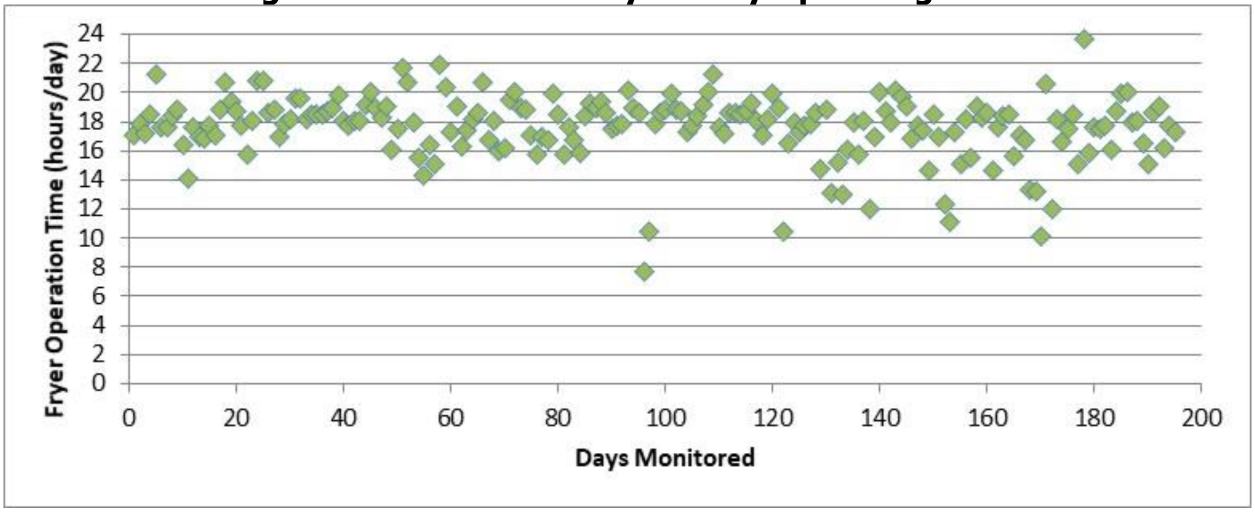
Source: Frontier Energy, Inc.

Figure 176: Werewolf Fryer Daily Energy Consumption



Source: Frontier Energy, Inc.

Figure 177: Werewolf Fryer Daily Operating Time



Source: Frontier Energy, Inc.

Broiler Replacement

The main kitchen line had a 2-ft. countertop broiler with two burners. The broiler was used to cook corn as well as finish chicken wings after they have been fried. The broiler had a standing pilot, which was very difficult to light, and was installed without feet, which would have been necessary to provide proper airflow to the burners. The baseline broiler used 5.3 therms per day and was turned on first thing in the morning and turned off past midnight with an average on-time of 19 hours per day. The broiler operation time was very consistent.

The broiler was replaced with an infrared energy-efficient broiler. The replacement broiler had the same 2-ft. width, however, it was a half-foot deeper than the baseline broiler, increasing the overall cooking surface area from 3 square feet to 4 square feet. The replacement broiler had no standing pilot and utilized a manual piezoelectric ignitor to start the burners. The burners were covered with radiant emitter plates that transfer heat to food more efficiently and operate at a lower input rate, while also reducing heatgain to the space. The replacement broiler reduced the energy consumption to 4.9 therms per day with a similar operation time.

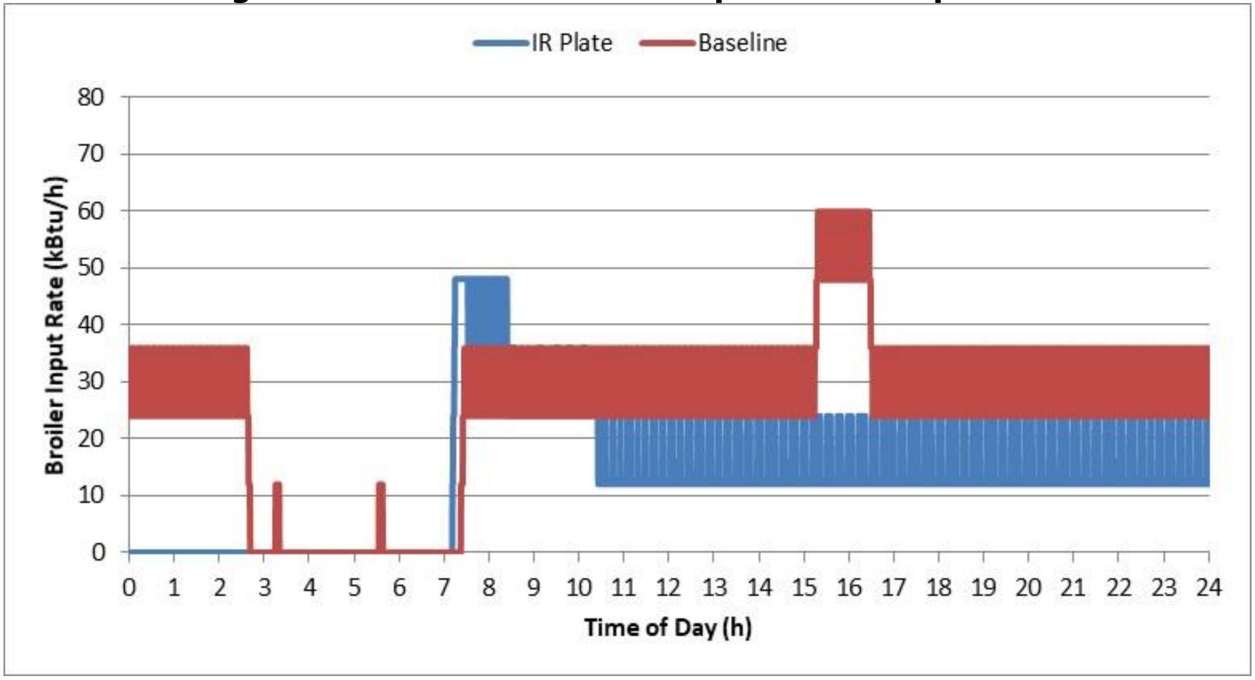
Figure 178: Existing Underfired 2-ft. Broiler

Source: Frontier Energy, Inc.

Figure 179: Replacement IR Broiler

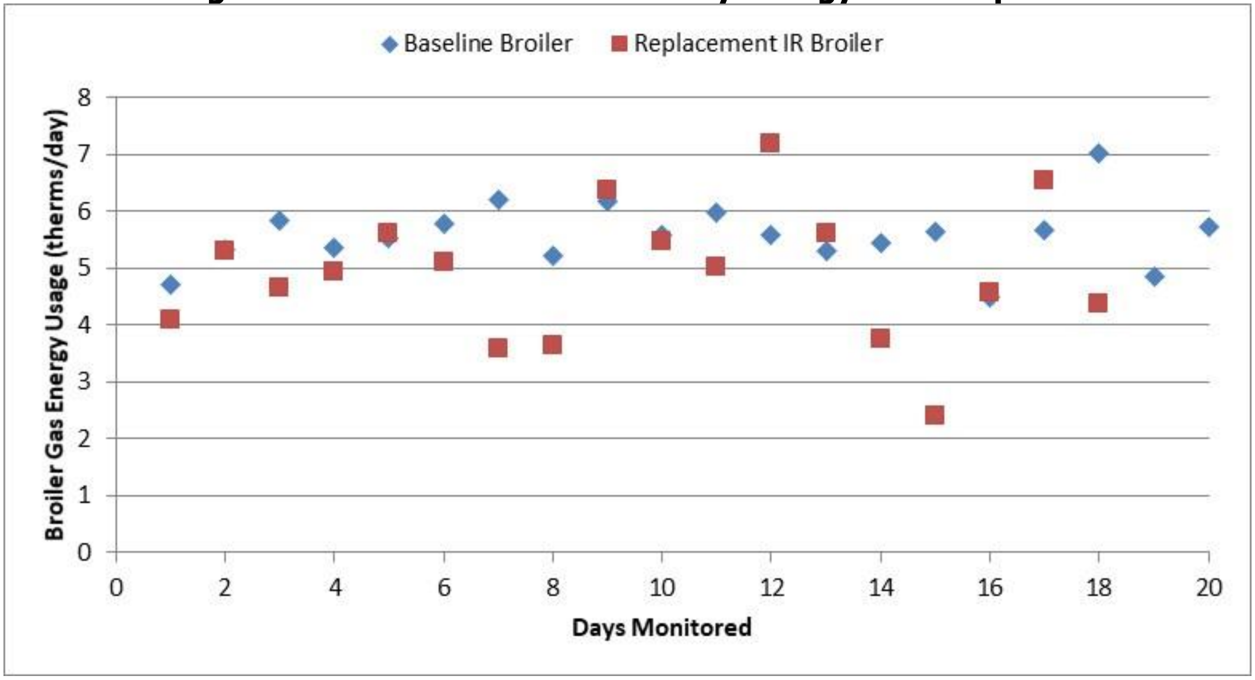
Source: Frontier Energy, Inc.

Figure 180: Werewolf Broiler Input Rate Comparison



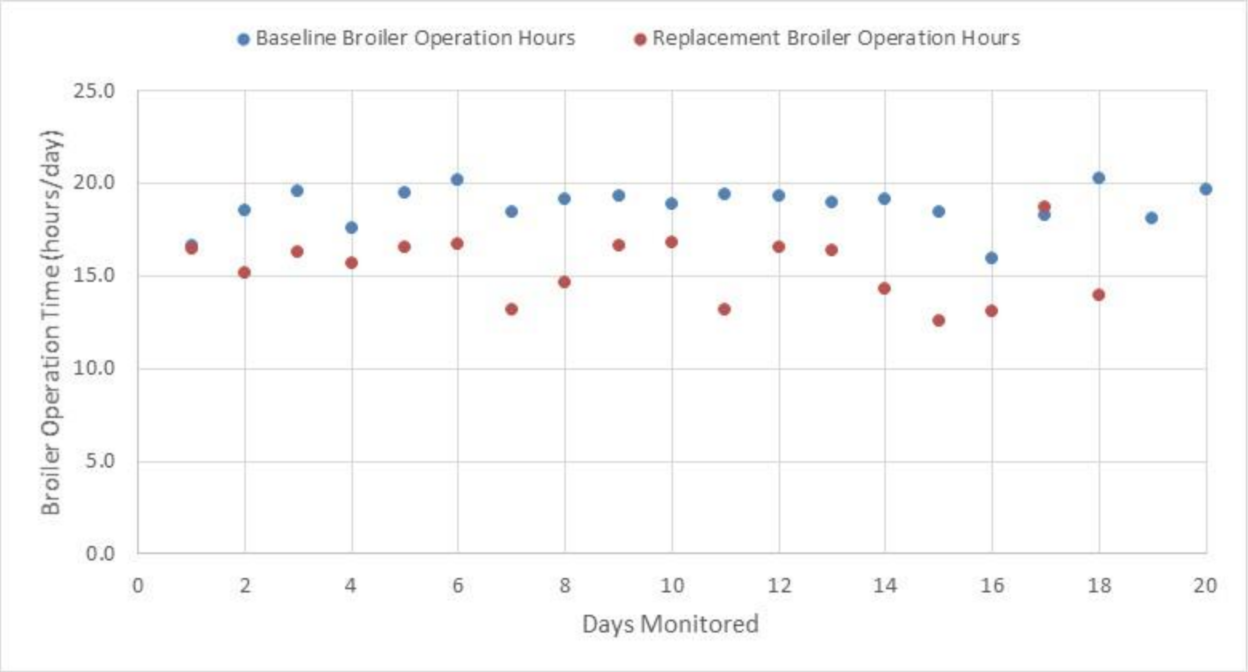
Source: Frontier Energy, Inc.

Figure 181: Werewolf Broiler Daily Energy Consumption



Source: Frontier Energy, Inc.

Figure 182: Werewolf Broiler Daily Operating Time



Source: Frontier Energy, Inc.

Griddle Replacement

The kitchen had a 3-ft. thermostatically-controlled griddle, which was used to cook eggs, bacon, hash browns, and burgers at Werewolf. The existing griddle had a missing front panel and a standing pilot for each of the three burners. The existing griddle consumed 4.86 therms per day while operating at an average of 17.5 hours per day consistently day-to-day.

The 3-ft. griddle was replaced with two, 2-ft. thermostatic griddles. The new high-efficiency griddles featured electronic ignition and infrared burners. The cooking surface area increased from 6 ft² to 8 ft² and allowed the operator to separate vegetarian and non-vegetarian items. The two replacement griddles were metered with a single gas meter and consumed a combined 4.92 therms per day. The griddle replacement resulted in a 33% increase in overall cooking area, and offered greater operational flexibility with a minimal impact on energy consumption.

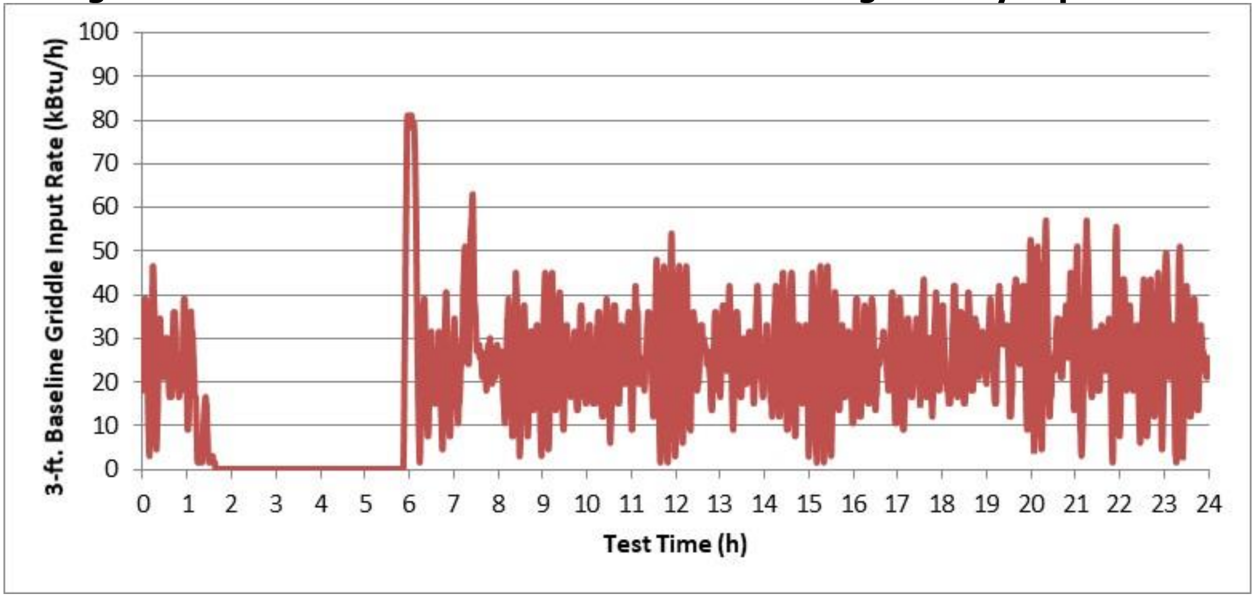
Figure 183: Baseline 3-ft. Griddle

Source: Frontier Energy, Inc.

Figure 184: Two Replacement 2-ft. Griddles

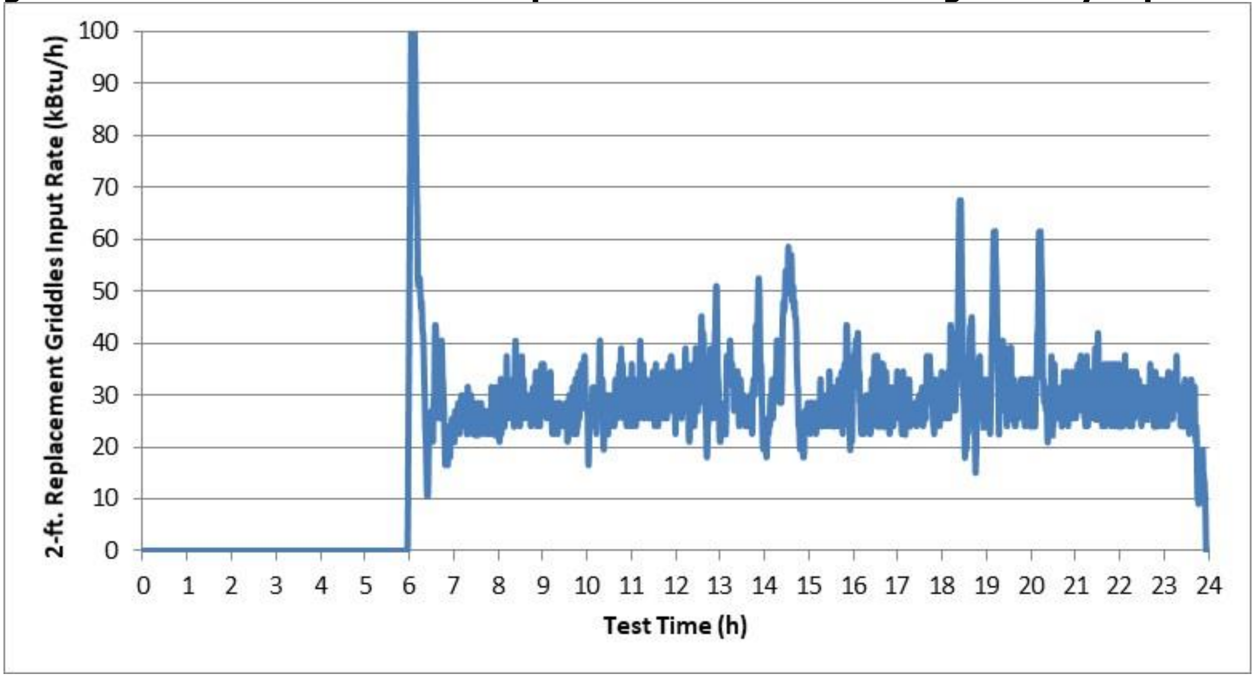
Source: Frontier Energy, Inc.

Figure 185: Werewolf 3-ft. Baseline Griddle Average Hourly Input Rate



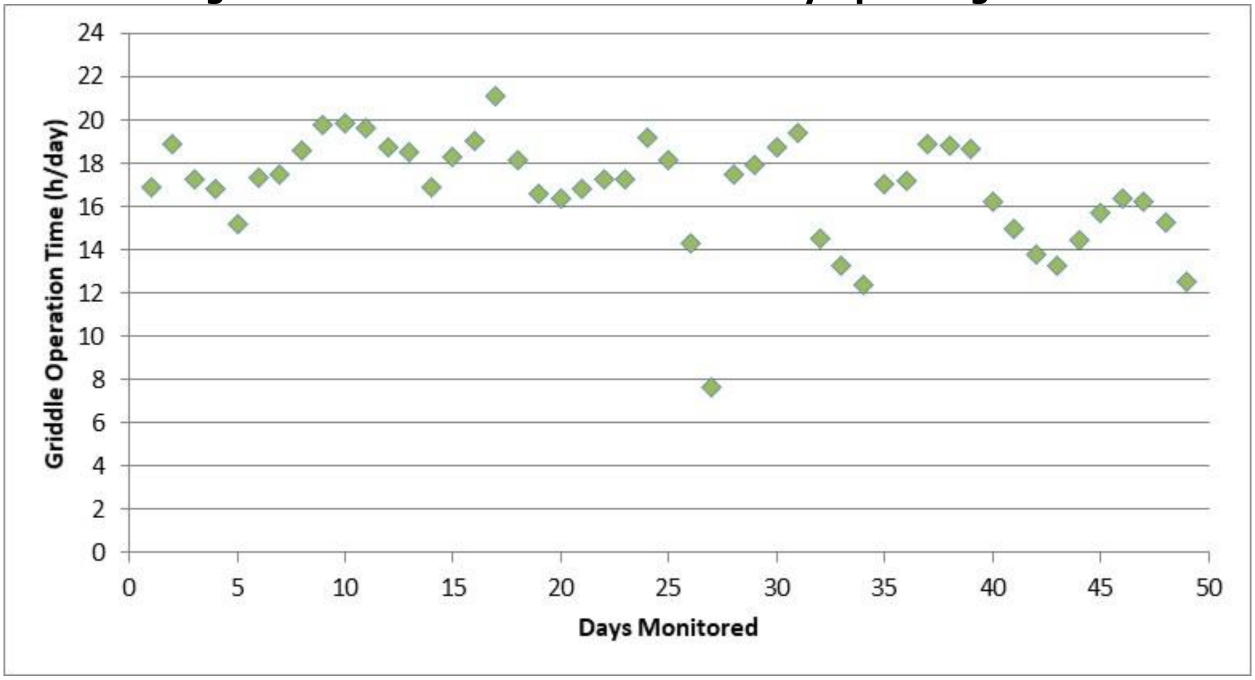
Source: Frontier Energy, Inc.

Figure 186: Werewolf Two 2-ft. Replacement Griddles Average Hourly Input Rate



Source: Frontier Energy, Inc.

Figure 187: Werewolf 3-ft. Griddle Daily Operating Time



Source: Frontier Energy, Inc.

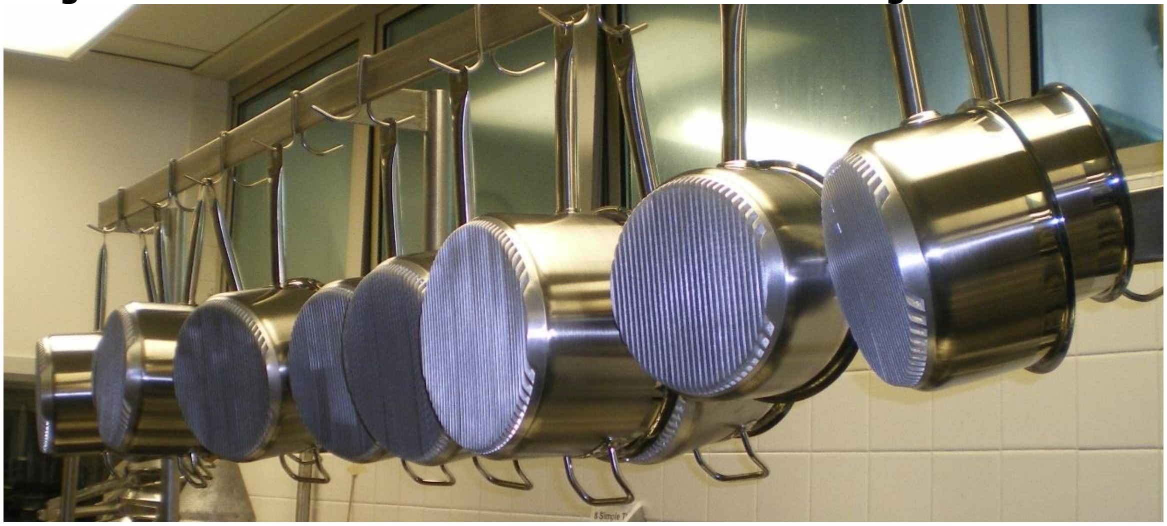
Range Energy Reduction

Researchers monitored the six-burner range for energy consumption. The range was mostly utilized for cooking breakfast products in the morning and afternoon hours. The range had an oven underneath it, which was not used very often. The range had six standing pilots accounting for a large portion of the energy consumption. The range consumed 3.0 therms per day. Researchers conducted range monitoring over two time periods. During the first period, all six pilot lights were on, which resulted in a constant pilot input rate of 4 kBtu/h. During the second monitored period, only two pilots were operational, reducing the pilot rate to 1.5 kBtu/h. At least one range burner was on for an average time of 7.2 hours per day.

Figure 188: Werewolf Six-Burner Range with Non-Convection Oven Underneath

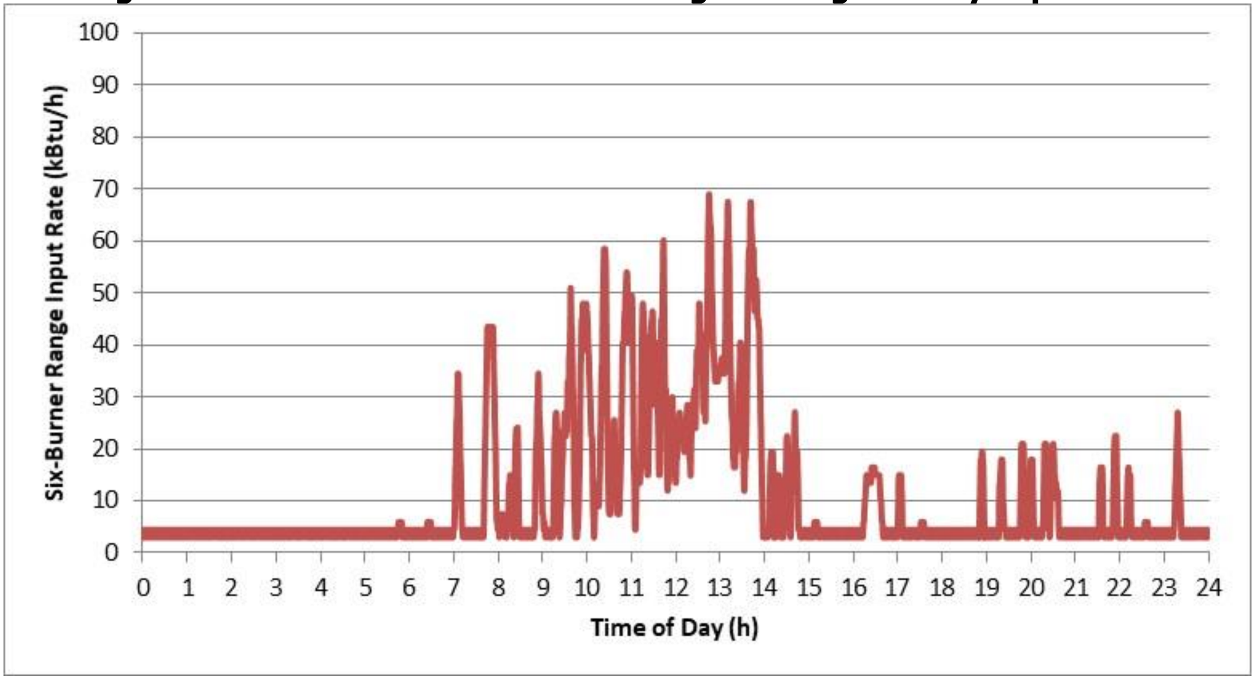
Source: Frontier Energy, Inc.

Figure 189: Finned Bottom Pots for Increased Cooking Heat Transfer



Source: Frontier Energy, Inc.

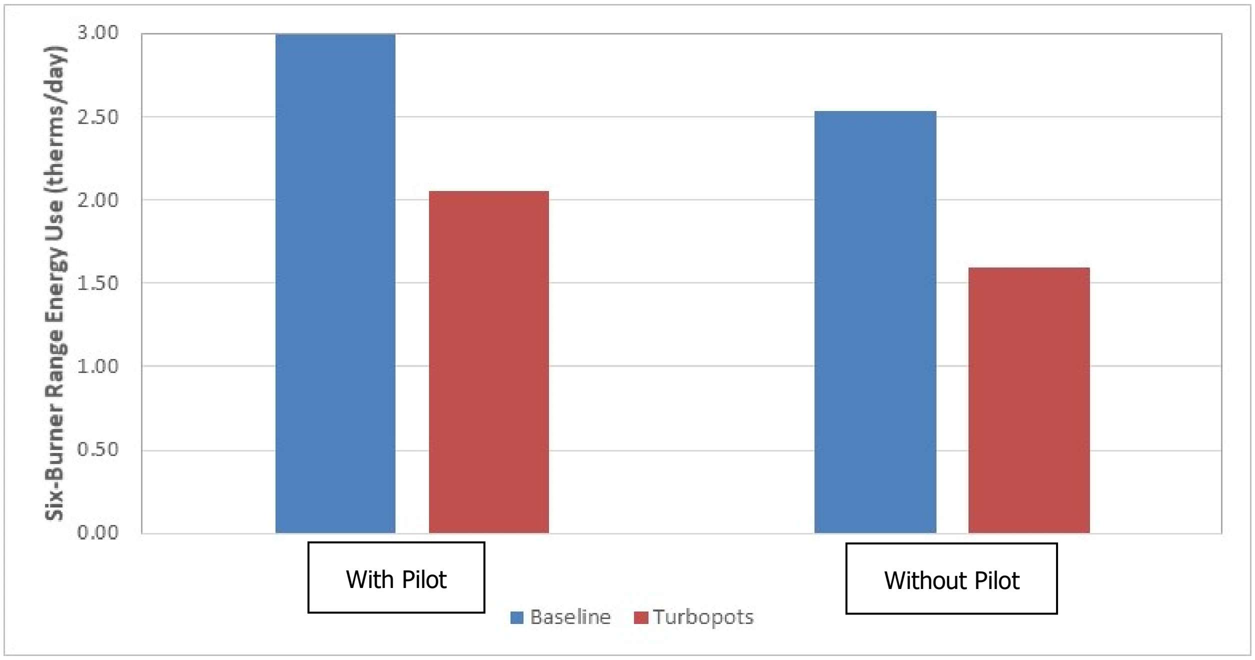
Figure 190: Werewolf Six-Burner Range Average Hourly Input Rate



Source: Frontier Energy, Inc.

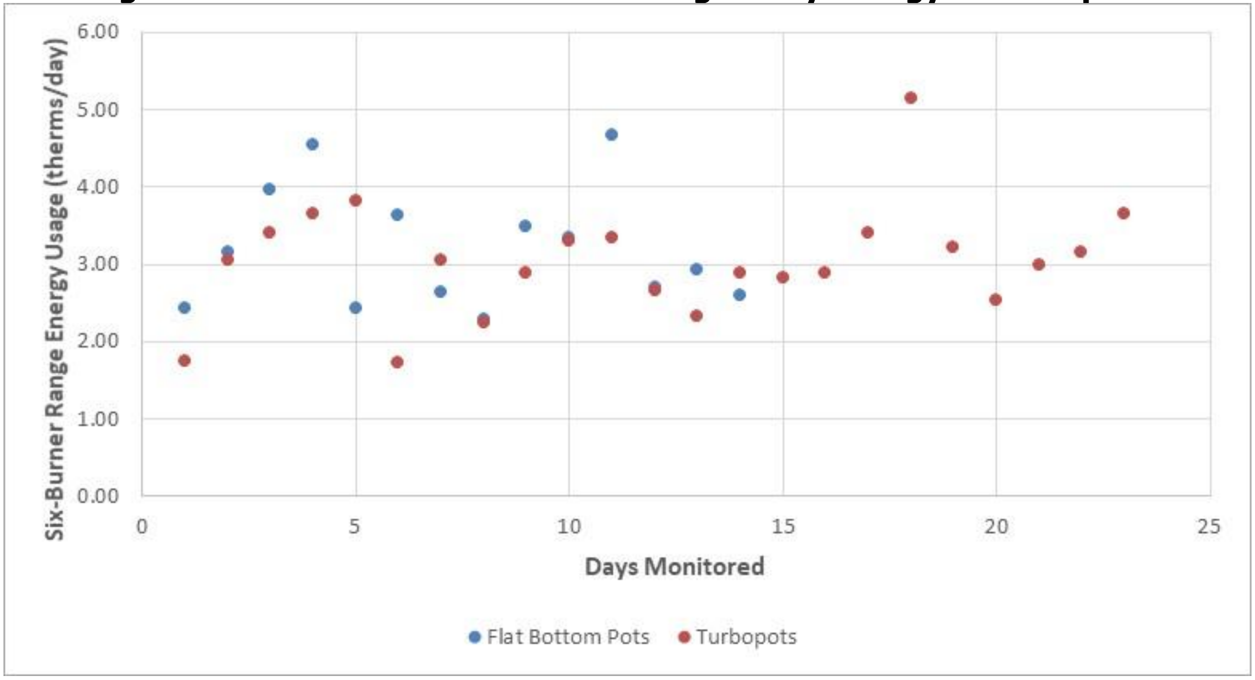
The energy-efficient cookware featured integrated heat sinks or “fins” at the bottom of each pot and pan. The heat sinks absorb more of the burner energy into the pot or pan resulting in faster cook times and less energy to achieve similar results. Researchers implemented energy-efficient cookware (pots and pans) at the Werewolf site, which resulted in 15% range energy savings, including pilot energy use. The cooking energy savings were 22% excluding pilot energy which accounted for 0.94 therms per day for six pilots.

Figure 191: Werewolf Range Energy Reduction – Energy Efficient Cookware



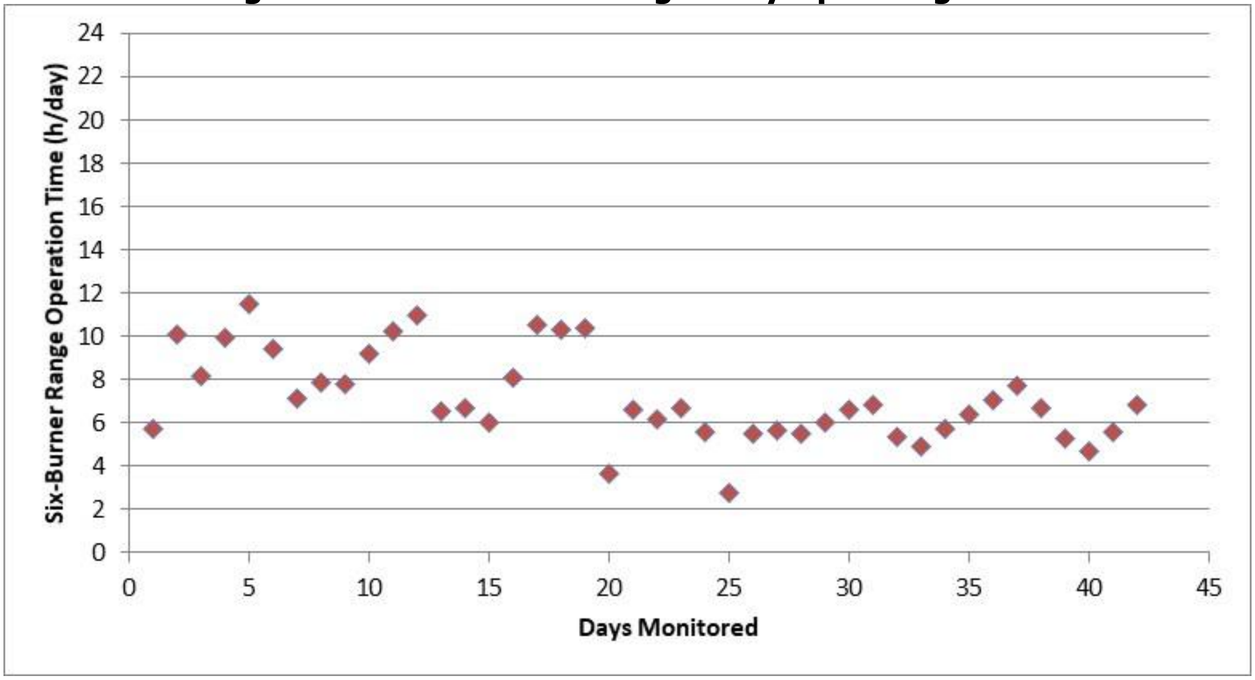
Source: Frontier Energy, Inc.

Figure 192: Werewolf Six-Burner Range Daily Energy Consumption



Source: Frontier Energy, Inc.

Figure 193: Six-Burner Range Daily Operating Time



Source: Frontier Energy, Inc.

Convection Oven Replacement with Combi Oven

The Werewolf back prep line had a 6-pan convection oven that was installed under a separate ventilation hood. The convection oven used 3.5 therms per day. Staff turned the oven on first thing in the morning around 6 am and turned it off at the end of service around midnight. With an 18- to 20-hour operation time, the oven burner operated for 5.8 hours on average, resulting in a 30% burner duty cycle. The oven was utilized to cook various meats including Werewolf's signature pork belly.

The existing convection oven was the only appliance that required ventilation under the prep line hood. Researchers replaced the convection oven with a combination oven, which was then moved to the main cook line in place of the prep table. By consolidating ovens, the prep line ventilation hood could be turned off. The replacement combi oven holds 10 steam pans and performs the same convection oven duties more efficiently. The combi oven reduced the energy to 1.7 therms per day while operating 18 hours per day. Additionally, the combi can perform moisture cooking, which allowed the restaurant to consolidate other cooking tasks and add menu items. The chicken wings could now be baked instead of being fried without losing their moisture as they would in the convection oven. The combi oven also has a built-in automatic cleaning cycle, which was engaged at the end of each day.

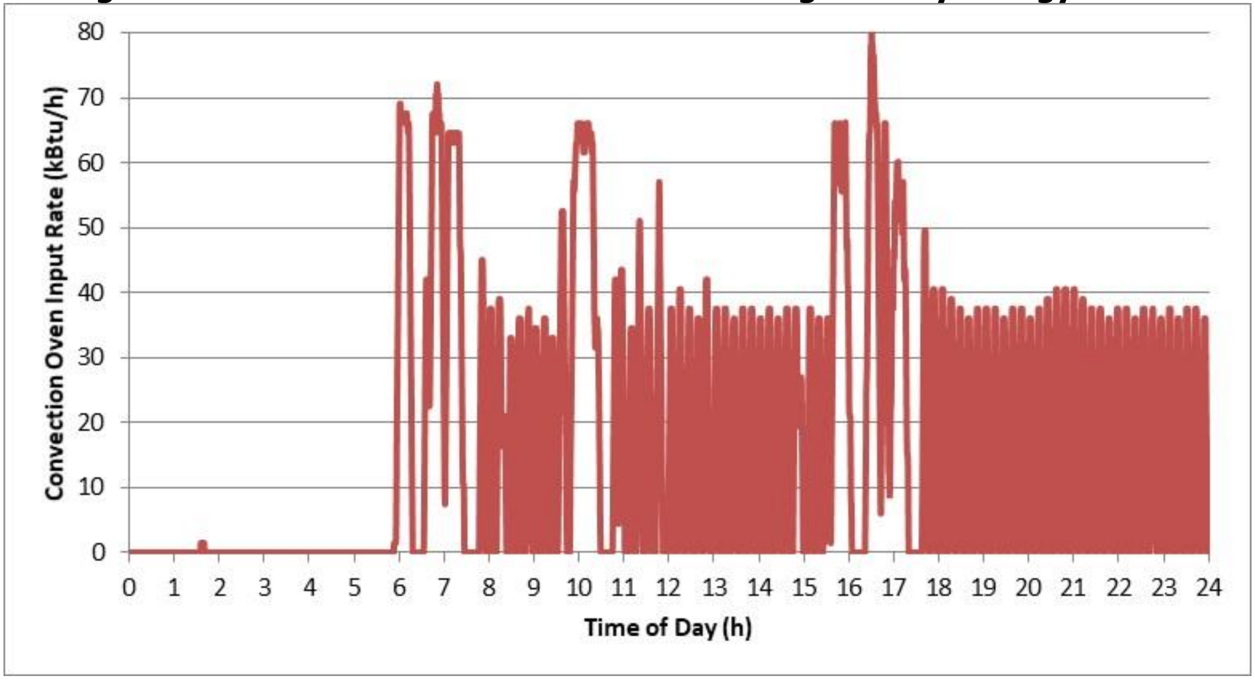
Figure 194: Baseline Convection Oven

Source: Frontier Energy, Inc.

Figure 195: Replacement Combi Oven

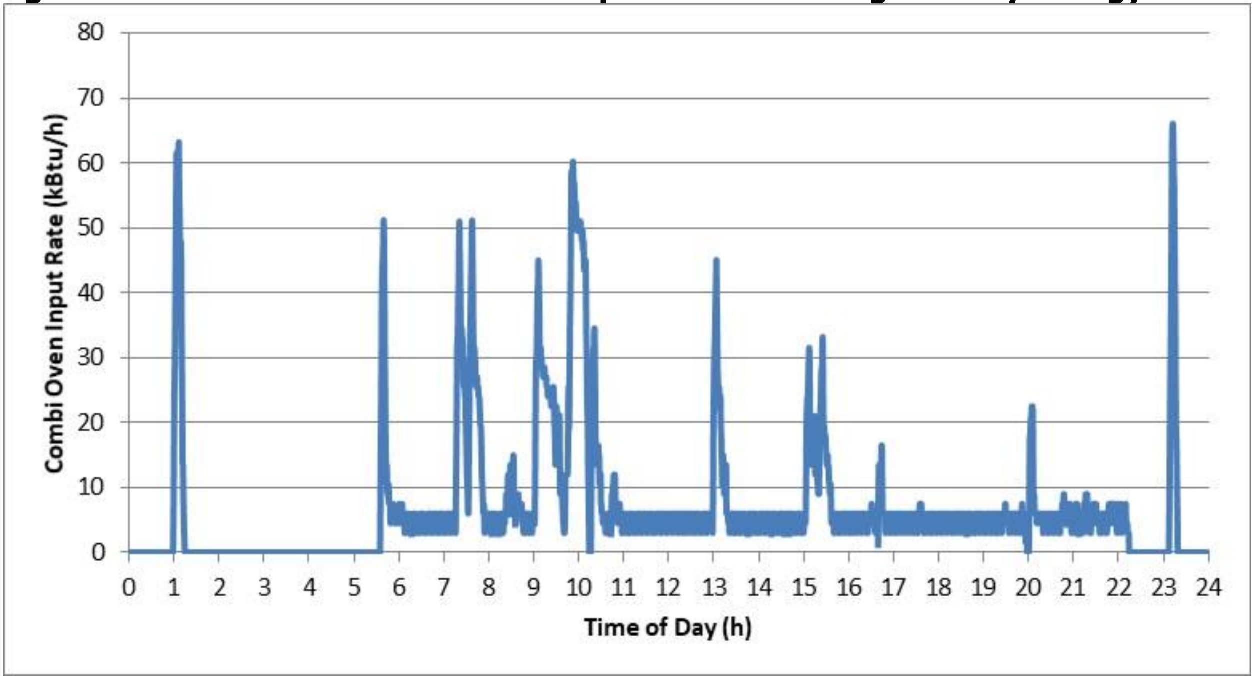
Source: Frontier Energy, Inc.

Figure 196: Werewolf Convection Oven Average Hourly Energy Profile



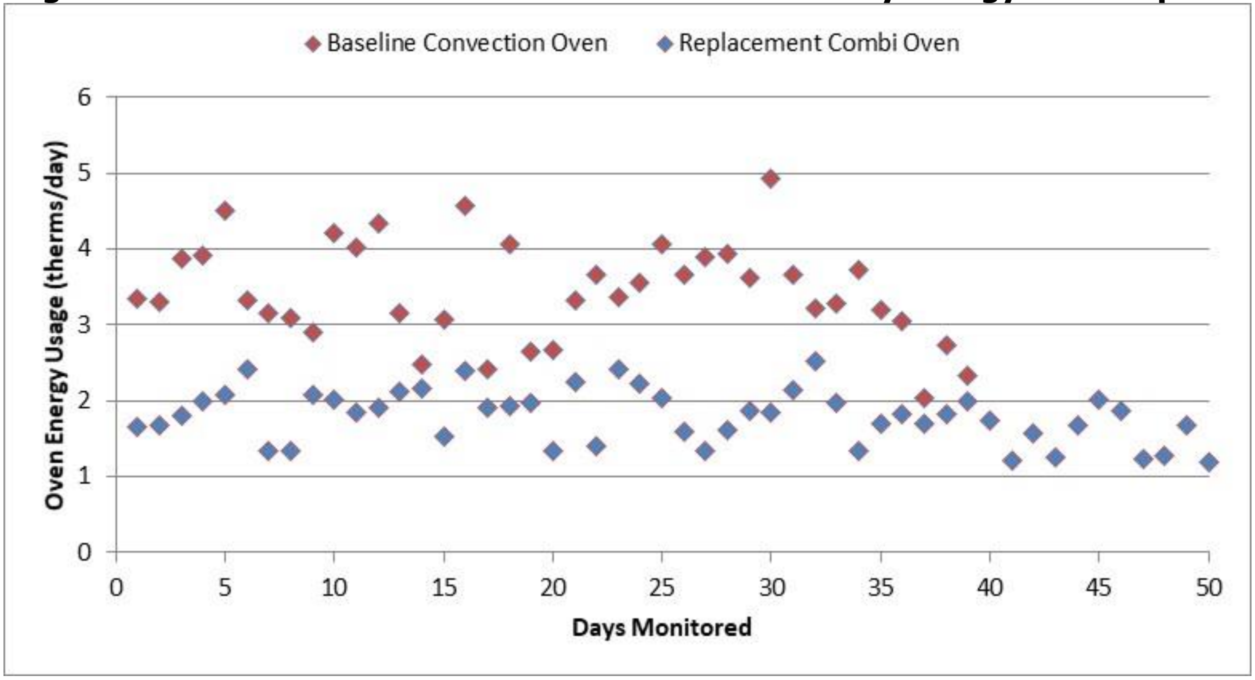
Source: Frontier Energy, Inc.

Figure 197: Werewolf Combi Oven Replacement Average Hourly Energy Profile



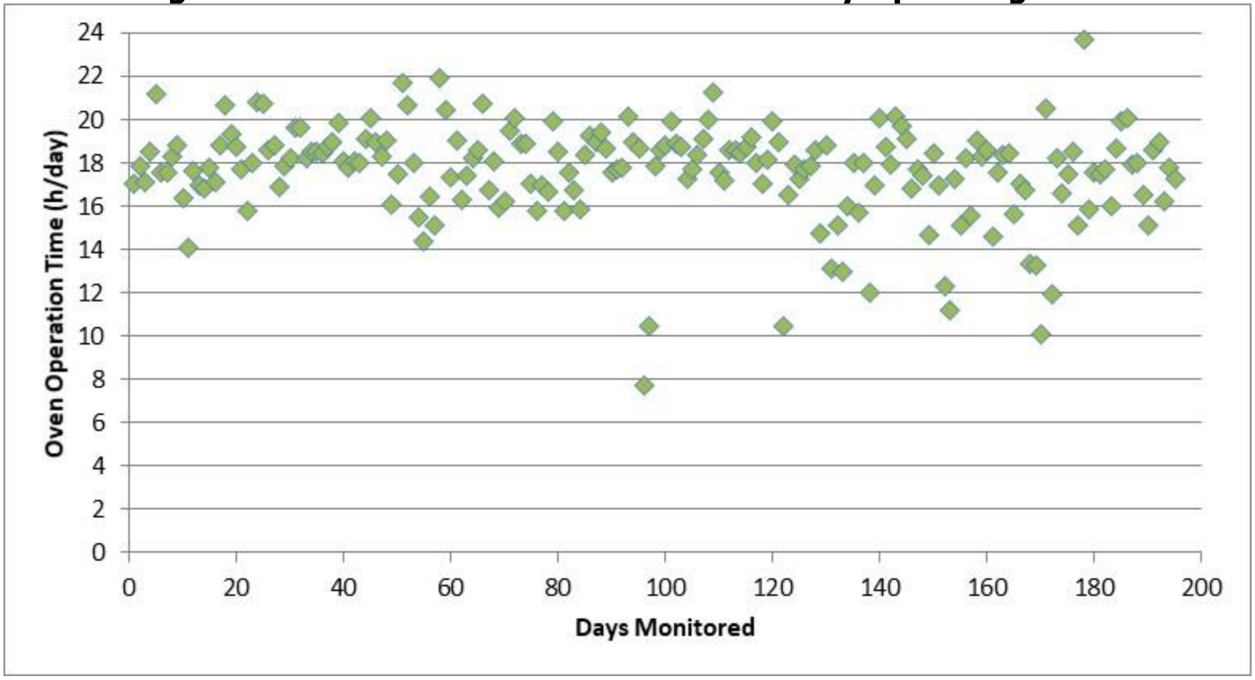
Source: Frontier Energy, Inc.

Figure 198: Werewolf Convection vs. Combi Oven Daily Energy Consumption



Source: Frontier Energy, Inc.

Figure 199: Werewolf Convection Oven Daily Operating Time



Source: Frontier Energy, Inc.

Ventilation

The main cookline consisted of two adjacent 8-ft. hoods and the prep line consisted of a 6-ft. hood with a convection oven underneath. All hoods were Type-II rated for grease cooking. The two 8-ft hoods on the main line were exhausted using a single 2 horsepower (HP) fan motor. There were four supply air vents in front of the hood. Two evaporative coolers on the roof conditioned the supply air to the entire kitchen. The manual switches on the wall turned on the main line and prep line hoods separately. The main line hood operated at a constant

2.3 kW load. The main line hood is typically turned on when the kitchen opens and turned off when the restaurant closes with an average operating time of 20.6 hours per day. The main cookline hood energy usage was consistent, averaging 46.9 kWh per day.

Figure 200: Main Cookline Dual Hood

Source: Frontier Energy, Inc.

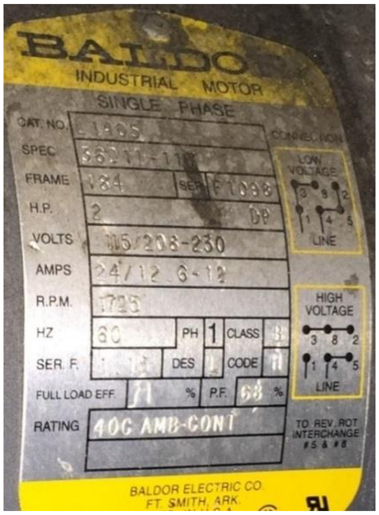
Figure 201: Main Cookline Dual Hood

Source: Frontier Energy, Inc.

Figure 202: Main Cookline Rooftop Fan

Source: Frontier Energy, Inc.

Figure 203: Fan Motor Nameplate



Source: Frontier Energy, Inc.

The existing convection oven was the only appliance that required ventilation under the prep line hood. The other 3-ft. of hood space was occupied by a coffee maker, which did not require ventilation. As detailed previously in this study, researchers replaced the convection oven with a combi oven, which was moved under the main cook line in place of the prep table. By consolidating ovens, the prep line ventilation hood could be decommissioned. The prep line was exhausted by a separate smaller 1 HP fan, which had an average input rate of 0.8 kW and was turned on and off at the same time as the main cookline exhaust fan with an average operating time of 20 hours per day. The prep line exhaust fan consumed 15.5 kWh per day on average.

The replacement of the convection oven with a combi oven and moving the combi oven to the main line to replace the prep table eliminated the need for a prep line exhaust, which saved 15.5 kWh per day.

Figure 204: Prep Line Exhaust Hood with Convection Oven and Coffeemaker Underneath

Source: Frontier Energy, Inc.

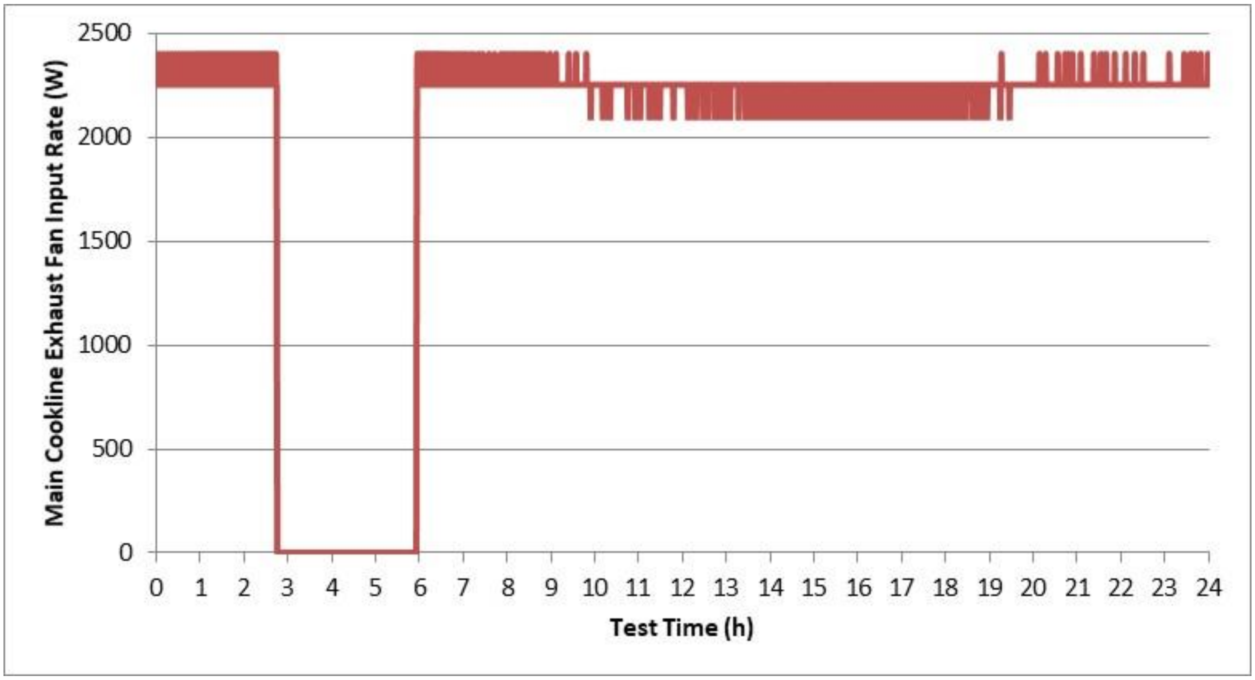
Figure 205: Prep Line Exhaust Fan on the Roof of the Restaurant

Source: Frontier Energy, Inc.

Figure 206: Rooftop Evaporative Coolers Conditioning Kitchen Makeup Air

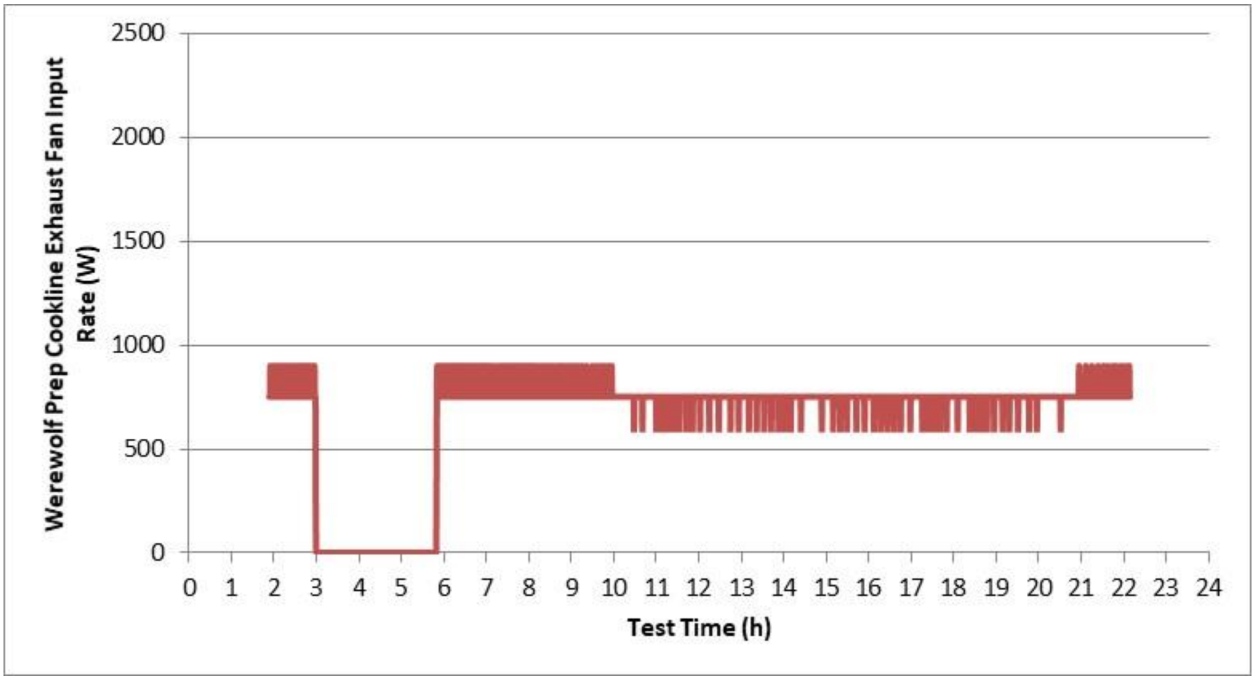
Source: Frontier Energy, Inc.

Figure 207: Werewolf Main Cookline Hood Exhaust Fan Average Hourly Energy Profile



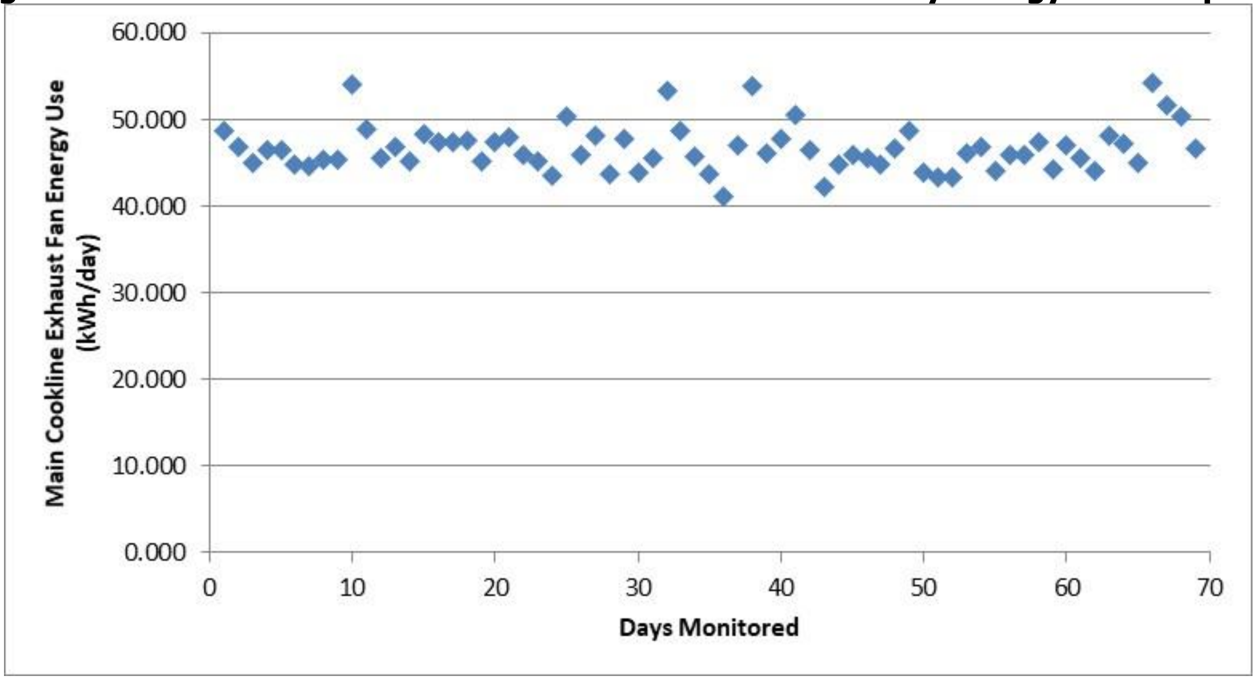
Source: Frontier Energy, Inc.

Figure 208: Werewolf Prep Cookline Hood Exhaust Fan Average Hourly Energy Profile



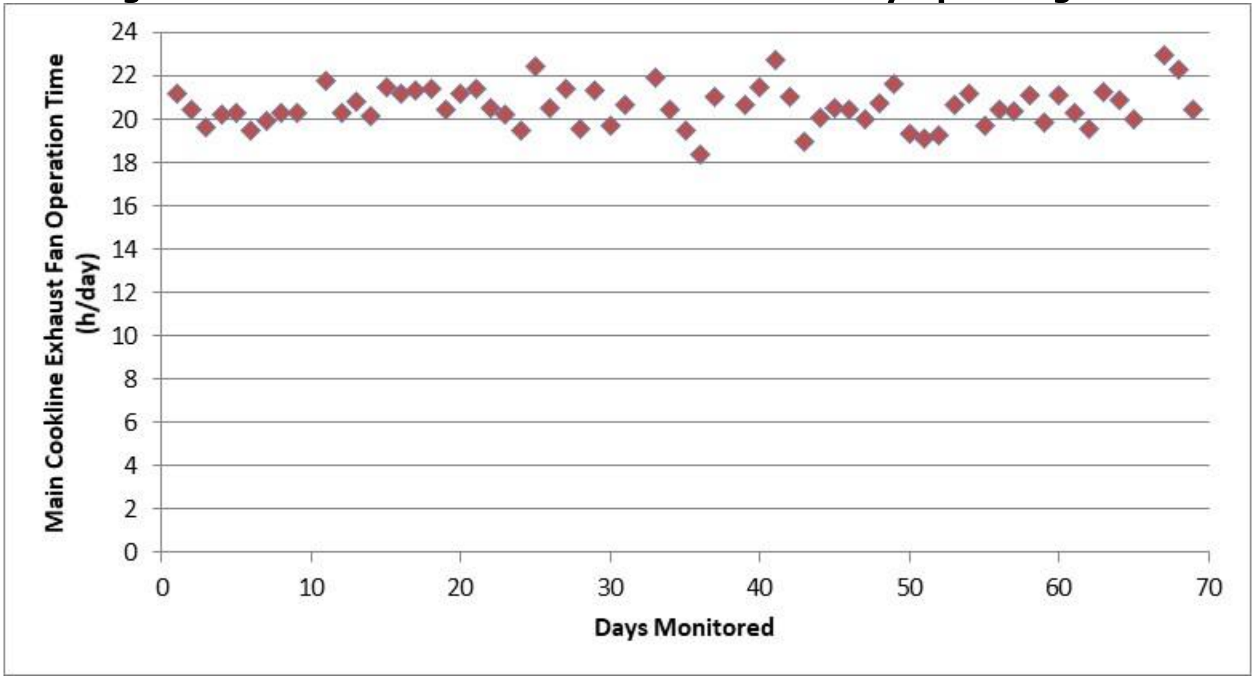
Source: Frontier Energy, Inc.

Figure 209: Werewolf Main Cookline Hood Exhaust Fan Daily Energy Consumption



Source: Frontier Energy, Inc.

Figure 210: Main Cookline Hood Exhaust Fan Daily Operating Time



Source: Frontier Energy, Inc.

DCKV System Retrofit

After consolidating all the appliances under one cookline exhaust hood, researchers installed a demand-controlled kitchen ventilation (DCKV) system on the main cookline ventilation system. The exhaust fan motor was upgraded from single-phase to three-phase to work better with the variable frequency drive (VFD). VFDs were installed on both the exhaust fan motor and the supply fan motor for the evaporative cooler. Both VFDs were connected to the DCKV system to modulate both motors in unison to maintain an airflow balance and neutral pressures within the restaurant.

Figure 211: Exhaust Hood Optical Sensor

Source: Frontier Energy, Inc.

The DCKV system used temperature sensors in the hood collar to detect heat and an optical sensor in the kitchen hood to detect cooking effluent. A hole was cut into the hood partition for both optical sensors to correspond with each other. The temperature and optical sensors were linked to the control panel opposite of the hood, which showed exhaust and supply fan speed. The system was set to operate between 30% (idle) and 100% (cooking) fan speed by responding to an exhaust duct temperature range of 70 to 110°F. Smoke or vapor from heavy cooking that triggered the optical sensor caused the system to operate at 100% fan speed for short periods of time.

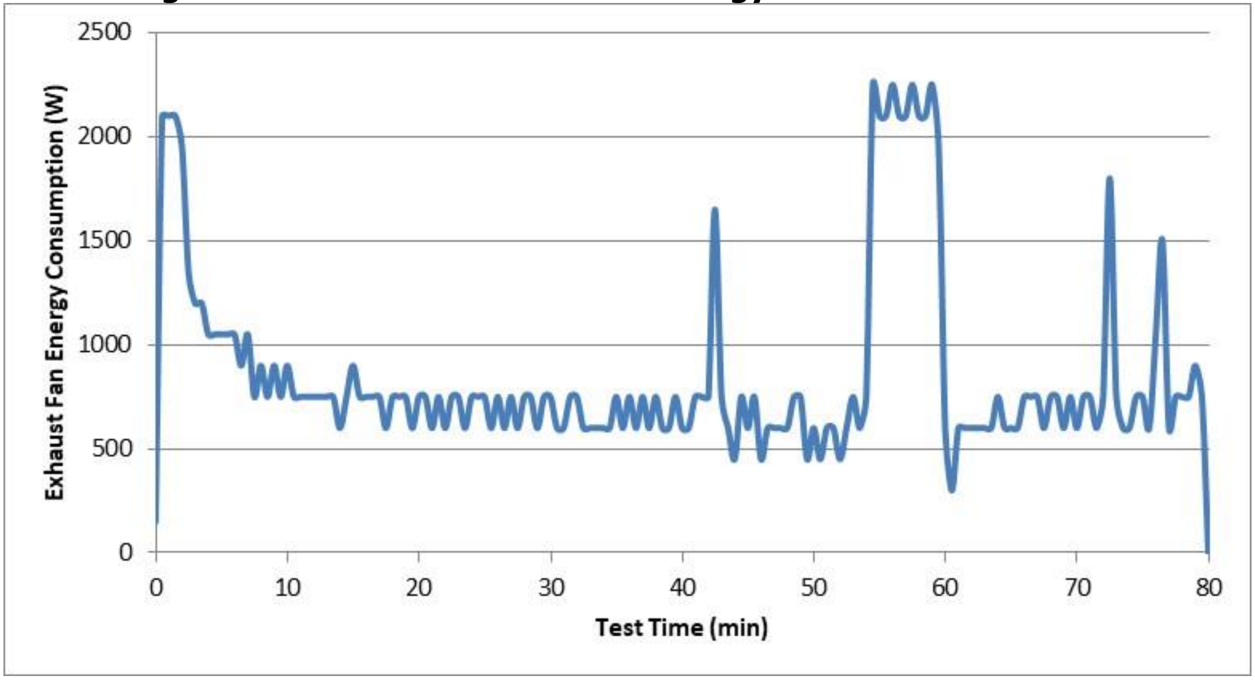
Figure 212: Exhaust and Supply Fan VFDs

Source: Frontier Energy, Inc.

Figure 213: DCKV control panel

Source: Frontier Energy, Inc.

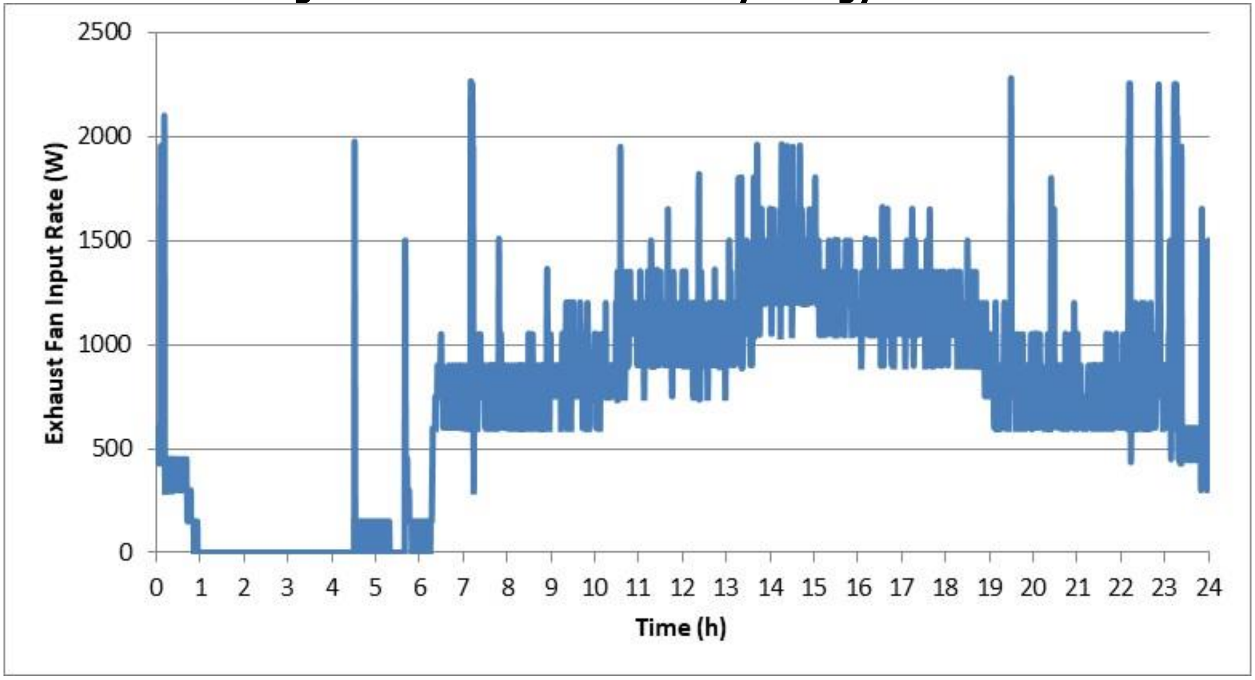
Figure 214: Werewolf DCKV Fan Energy 30-100% Modulation



Source: Frontier Energy, Inc.

Prior to DCKV system installation, the exhaust fan operated at a constant speed, consuming 2,300 watts (W) on average. The new three-phase motor consumed 2,100 W at full fan speed and only 700 W at 30% speed. During low cooking and idle conditions, the fan modulated down to 30%, operating between 700W and 2,100W. Temperature modulation occurred between 400W and 1,500W. The optical sensor triggered the 2,100W spikes at 100% fan speed.

Figure 215: DCKV Fan Full Day Energy Profile



Source: Frontier Energy, Inc.

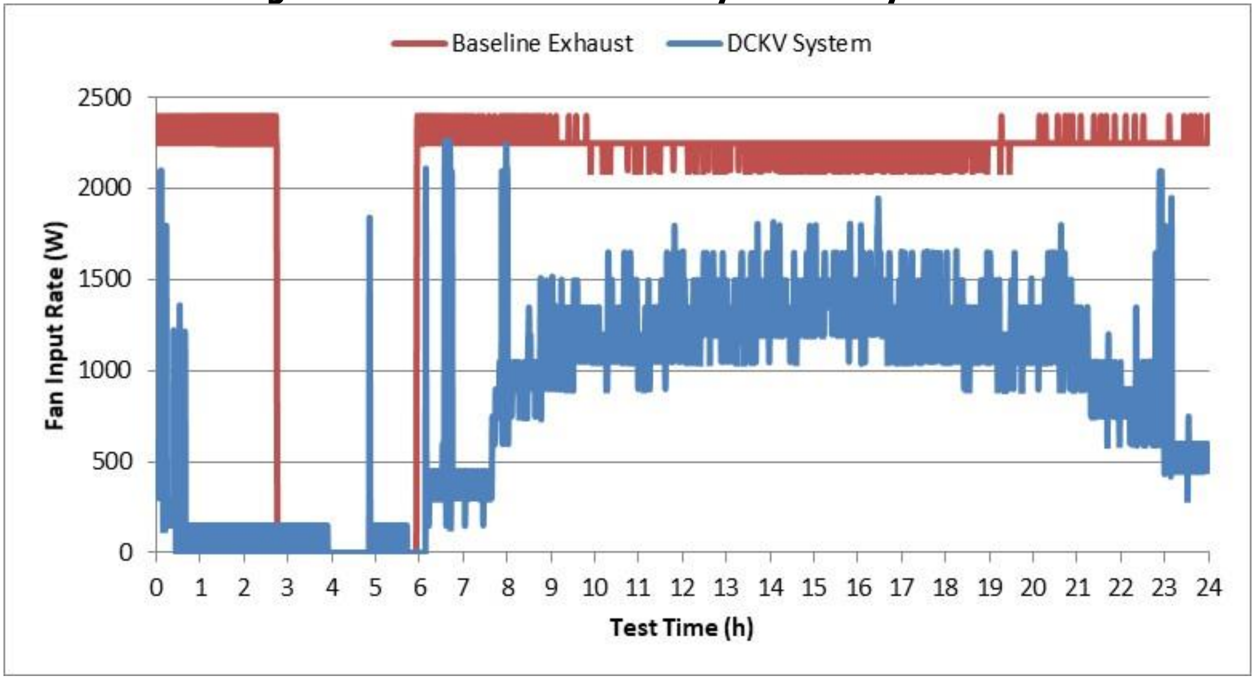
Researchers analyzed exhaust fan modulation through energy measurement over a period of 40 days. Most of the time the DCKV system modulated between 50% and 75% fan power and exceeded 75% less than 10% of the time. Seventy five percent of the time was spent between 25% and 75% of full power.

Table 6: Werewolf DCKV Power Operation

Fan Power Level	25%	50%	75%	100%
Measured Fan Power	< 500W	> 500W < 1000W	> 1000W < 1500W	> 1500W
Time Spent in Power Mode	11%	30%	51%	8%

Source: Frontier Energy, Inc.

Figure 216: Werewolf DCKV System Daily Profile



Source: Frontier Energy, Inc.

The exhaust fan with the DCKV retrofit used only 26 kWh on average per day. The reduction resulted in 45% exhaust fan energy savings. Researchers assumed that the exhaust fan operated at 1-inch of static pressure and the evaporative cooler's supply fan operated at 0.5-inch of static pressure. Researchers did not measure supply fan energy; however, it can be estimated to be proportional to the pressure drops assuming similar airflow rates. The supply fan energy dropped from 24 kWh to 13 kWh per day. Additional savings can be calculated from transfer air heating in the San Diego climate. Frontier Energy estimates that the reduced exhaust airflow would save 1,200 therms annually on heating of the dining room, which supplies transfer air for the kitchen.

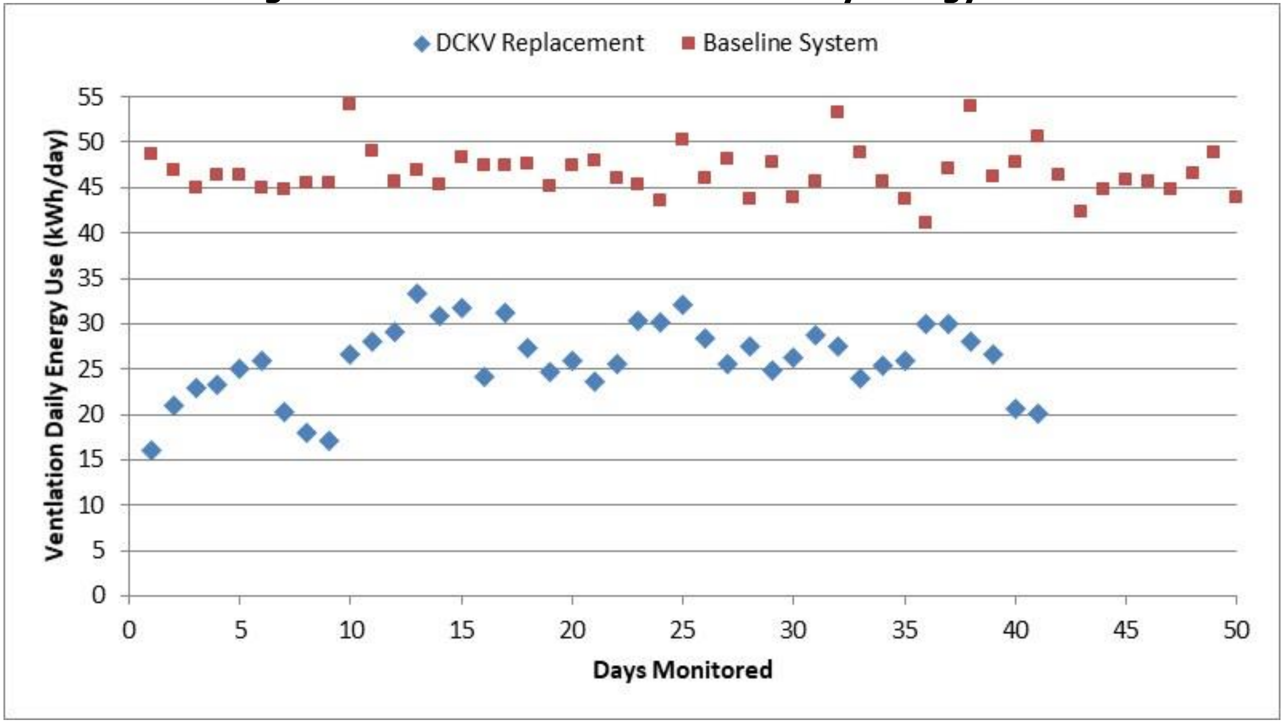
Table 7: Werewolf DCKV Retrofit Savings

	Pre DCKV	Post DCKV Retrofit	Savings
Exhaust Fan	46.9 kWh/day	26.0 kWh/day	20.9 kWh/day
Supply Fan*	23.5 kWh/day	13.0 kWh/day	10.5 kWh/day
Heating	N/A	N/A	1,200 therms/yr
Cooling	No Cooling	No Cooling	0
Total Savings			11,467 kWh/yr 1,200 therms/yr

***Estimated based on 1" static pressure for exhaust and 0.5" static pressure for supply fan.**

Source: Frontier Energy, Inc.

Figure 217: Werewolf Ventilation Daily Energy Use



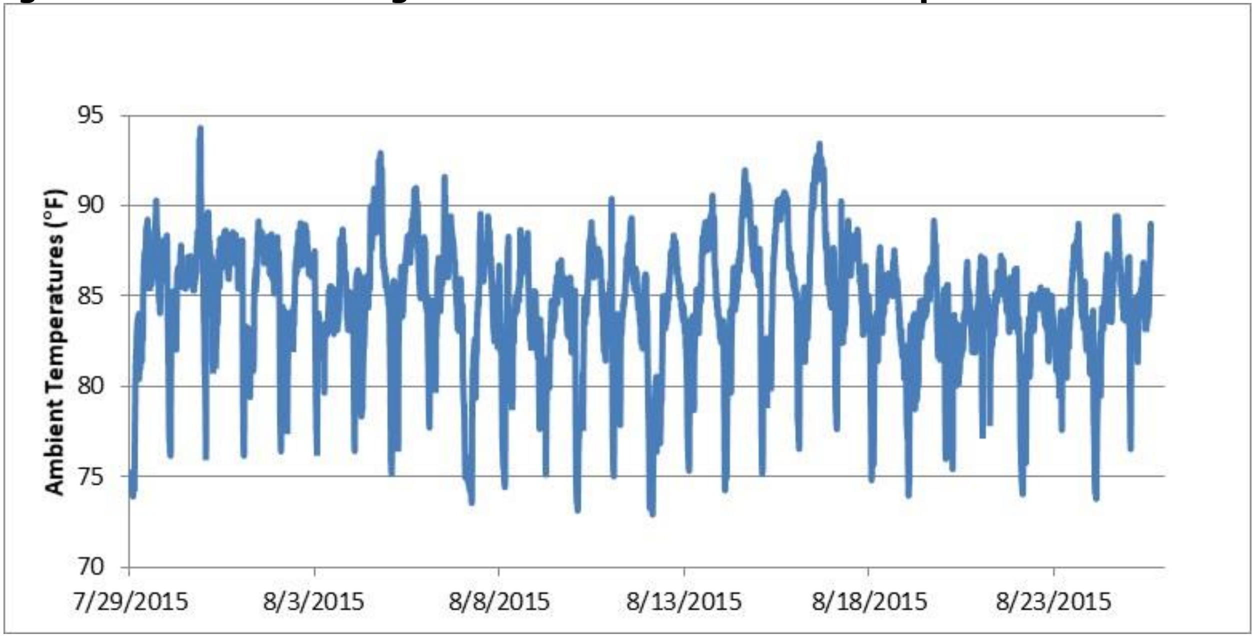
Source: Frontier Energy, Inc.

Thermal Comfort

San Diego has one of the mildest climates in the United States with average temperatures hovering in the 70 to 80°F range. Researchers placed two temperature and humidity sensors in two locations in the Werewolf kitchen to record ambient conditions. Summertime temperatures in the kitchen rose to 90°F during the day and dropped down to 70°F at night.

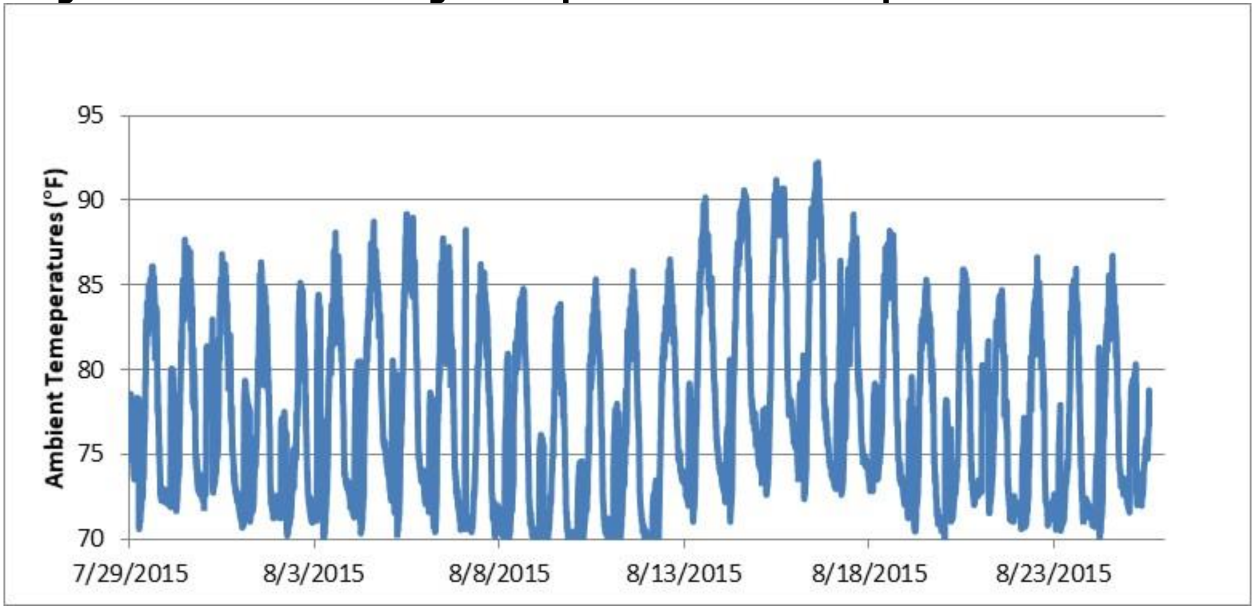
Five evenly spaced diffusers supplied air to the kitchen, which was conditioned by two rooftop evaporative coolers.

Figure 218: Werewolf August Main Cookline Ambient Temperature Fluctuations



Source: Frontier Energy, Inc.

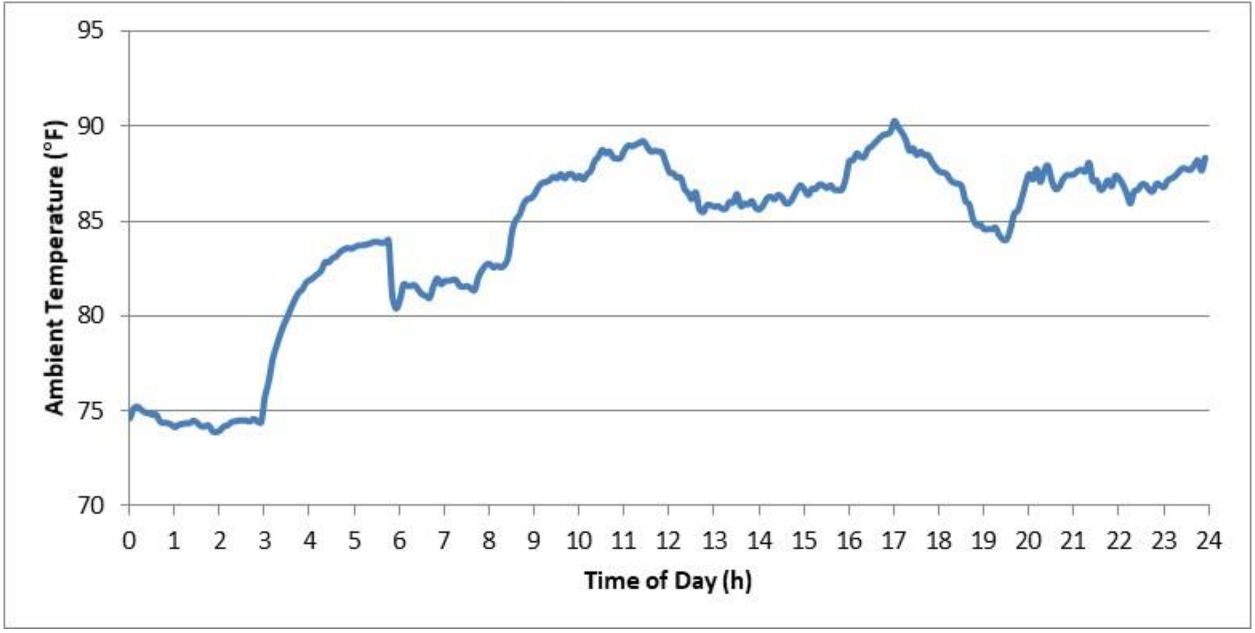
Figure 219: Werewolf August Prep Line Ambient Temperature Fluctuations



Source: Frontier Energy, Inc.

As seen in Figure 226, the temperature in the kitchen rises above 85°F after 9 am and does not dip below 85°F until the restaurant is closed.

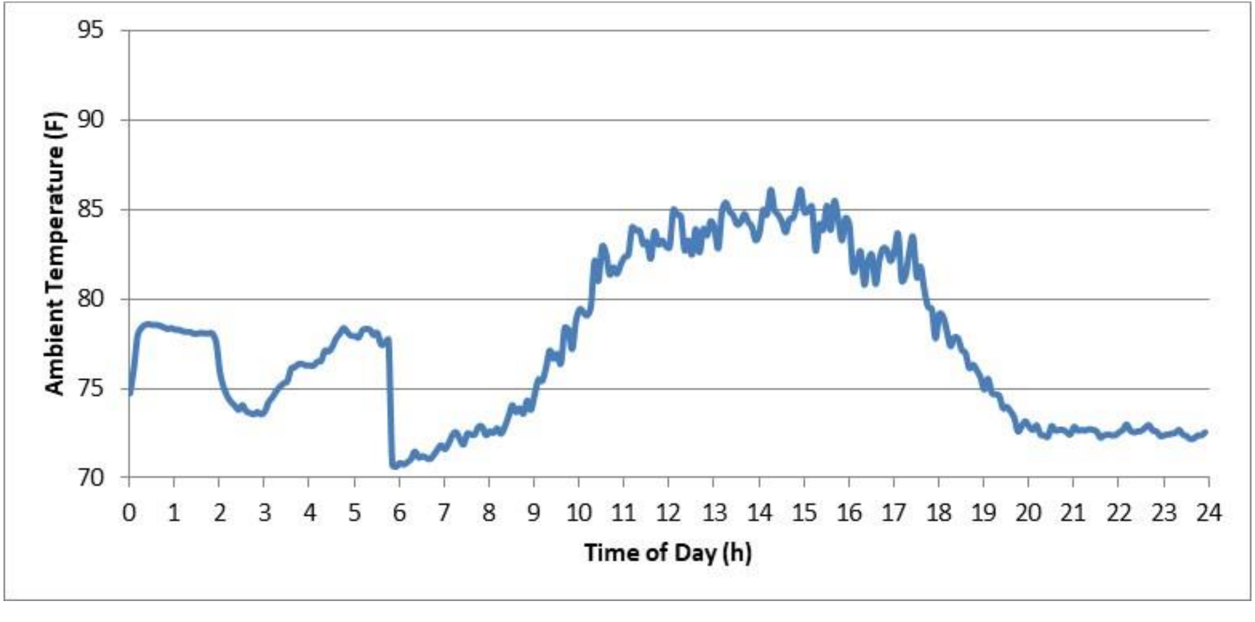
Figure 220: Werewolf Main Cookline Average Hourly Ambient Temperature on 7/29/2015



Source: Frontier Energy, Inc.

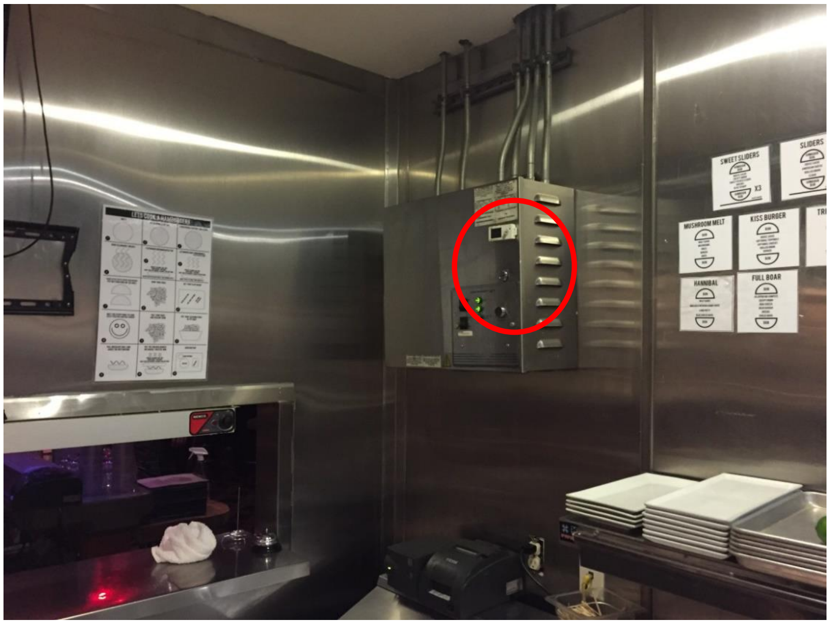
The prep line was slightly cooler because there was less heat load generated by appliances. The prep line does not receive as much conditioned air as the cookline, which was evident by the increased temperature curve during the day. When the restaurant closed, the exhaust fan was turned off, causing the ambient temperature to rise due to the hot, unventilated convection oven on the prep line.

Figure 221: Werewolf Prep Cookline Average Hourly Ambient Temperature on 7/29/2015



Source: Frontier Energy, Inc.

Figure 222: Front of the Kitchen Ambient Temperature Measurement Location Next to Order Window



Source: Frontier Energy, Inc.

Figure 223: Prep Line Ambient Temperature Measurement Near Convection Oven

Source: Frontier Energy, Inc.

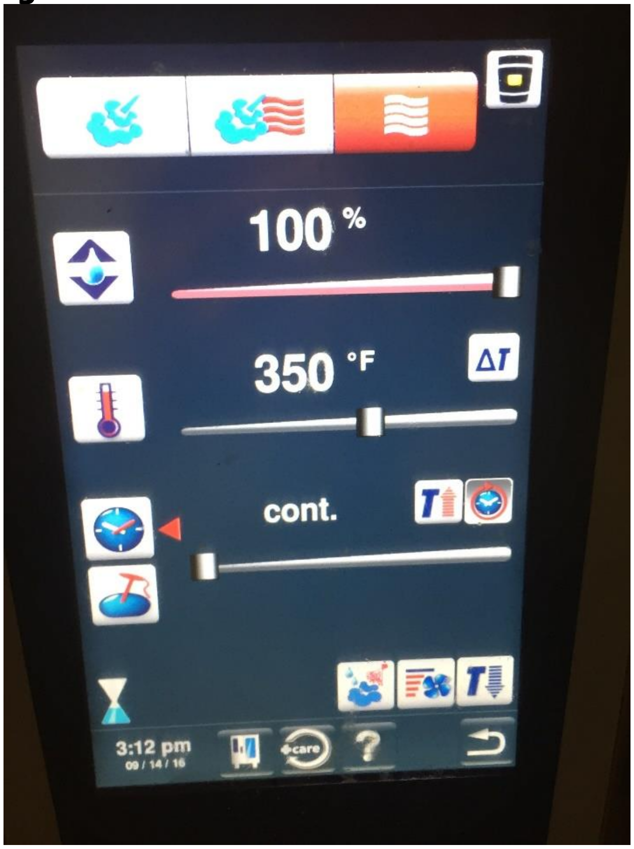
New Equipment Behavioral Changes

Werewolf was an ideal location to represent a casual scratch cooking food concept and how the potential to be realized can take time and work. Many of the techniques used are classic, tried and true methods. Observed food production processes were traditional and yielded a result which satisfied guest expectations. Changing these processes in a thoughtful manner can take time not only for the management but for the staff as well.

Replacement of the convection oven with the combination oven provided a significant opportunity not only for therm savings but also increased production potential along with the addition of steam cooking expanded cooking possibilities were added as well. This was all done in an equal footprint of the previous convection oven.

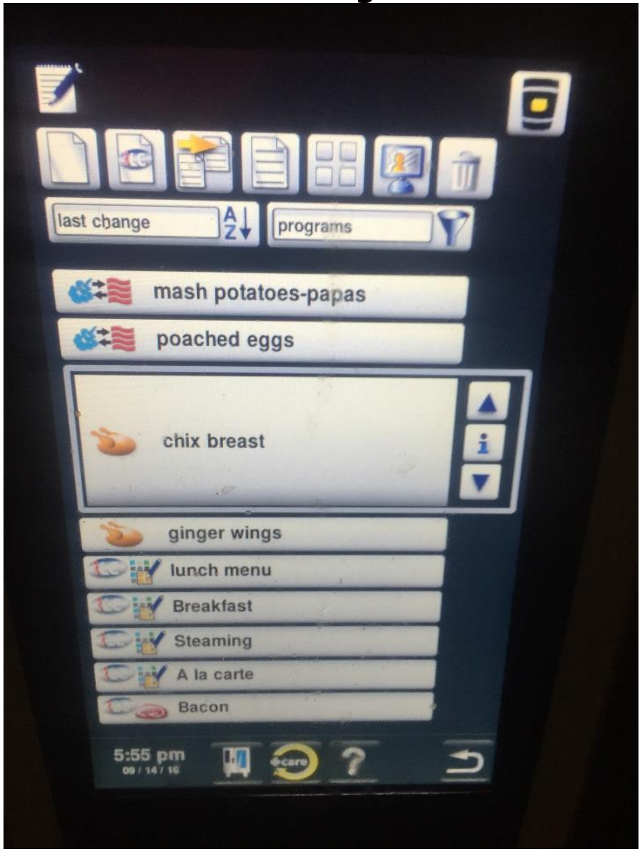
One challenge to combination ovens is the learning curve. Integrating this technology into an existing food system that already up and running can present its own challenges one being how do you "fix" something that isn't broken. Understanding the hows and whys these new controls and variability give you is essential before proper integration takes place. Once these concepts are understood you must then review what you have done and using this modern technology to ease stress on production while maintaining or increasing final product quality.

Figure 224: Combi Oven Manual Controls



Source: Frontier Energy, Inc.

Figure 225: Combi Oven Programmable Menu Items



Source: Frontier Energy, Inc.

Werewolf had to revisit some of these processes and harness these modern technologies to streamline their processes while meeting their customers' expectations. The combination oven not only proved to be an asset with preparation but was able to speed up service times as well.

One example is their version of chilaquiles a traditional Mexican dish in which they build the entire dish of layered tortillas, eggs, sauce and cheese and then finished in the oven. Staff discovered as they added a bit of moisture to the cavity they could raise the cavity temperature, this resulted in roughly a minute and half being taken off the previous 4-minute cook time in the convection oven. This was achieved with no burning, desired internal temperature and a nice melt to the cheese. Food product consistency easier to manage with the usage of individual shelf timers built into the ovens interface; these timers alerted the cooks when the dishes on a specified oven shelf were finished.

This plays a key role to operations especially cook and serve style concepts where communication is very important. The less unnecessary communication and the more definite information you can relay is imperative when managing multiple items at once. These simple steps help speed up service times, increases revenue potential, reduces workplace stress and increases service staff confidence.

Another area of opportunity was the implementation of the Turbopots, which represent a prime example of low tech therm savings. In speaking with the management at Werewolf one thing they really liked about the Turbopot was not how hot it could get but rather the opposite. When making their cheese sauce they are using low heat to melt the cheese, the Turbopots were proven to be quite effective as the cooks could exercise more control over the burner heat to the pot. They also reported that due to the uniformity they could melt the cheese a bit quicker, they reported a 30-minute reduction in cook time which cut the melt time to about 45 minutes.

While overall therm savings were not significant what is promising is that for roughly the same amount of energy usage the capabilities of the kitchen’s production potential have increased significantly. By decreasing service times tables can be turned quicker, expanded griddle space and faster fryer recovery times creates a potential for higher throughput. Only time, trial and training will tell us how far they can go.

Werewolf Summary

Researchers measured almost all gas-consuming appliances at Werewolf excluding the water heater. Energy use was evenly spread across all appliances with the small broiler using the most energy. The total cookline gas consumption was 22 therms per day. Most appliances were turned on at 5amM and turned off just after midnight. The kitchen electric energy load was dominated by the main fan, which consumed 48 kWh per day with both hoods using 64 kWh per day.

Table 8: Werewolf Energy Use

	Operation Time (h/day)	Pre Energy (therms/ day)	Post Energy (therms/ day)	Therm Savings	Percentage Savings
6-Burner Range	7.2	2.99	2.53	0.46	15%
Oven	19 (5.8* burner on)	3.48	1.72	1.76	51%
Fryer Left	11.0 (2.7* burner on)	2.65	1.82	0.83	31%
Fryer Right	18.6 (2.5* burner on)	2.47	2.95	Not Replaced	Not Replaced
Broiler	18.9	5.28	4.90	33% Cooking Area Increase	7%
Griddle	17.5	4.86	4.94	33% Cooking Area Increase	N/A
Main Hood	21.2	46.9 kWh/day	26.0 kWh/day	20.9 kWh/day	45%
Prep Hood	21.2	15.5 kWh/day	Disabled	15.5 kWh/day	100%

***This is a thermostatically controlled appliance; time that the burner is on divided by time that the appliance is on is the burner duty cycle.**

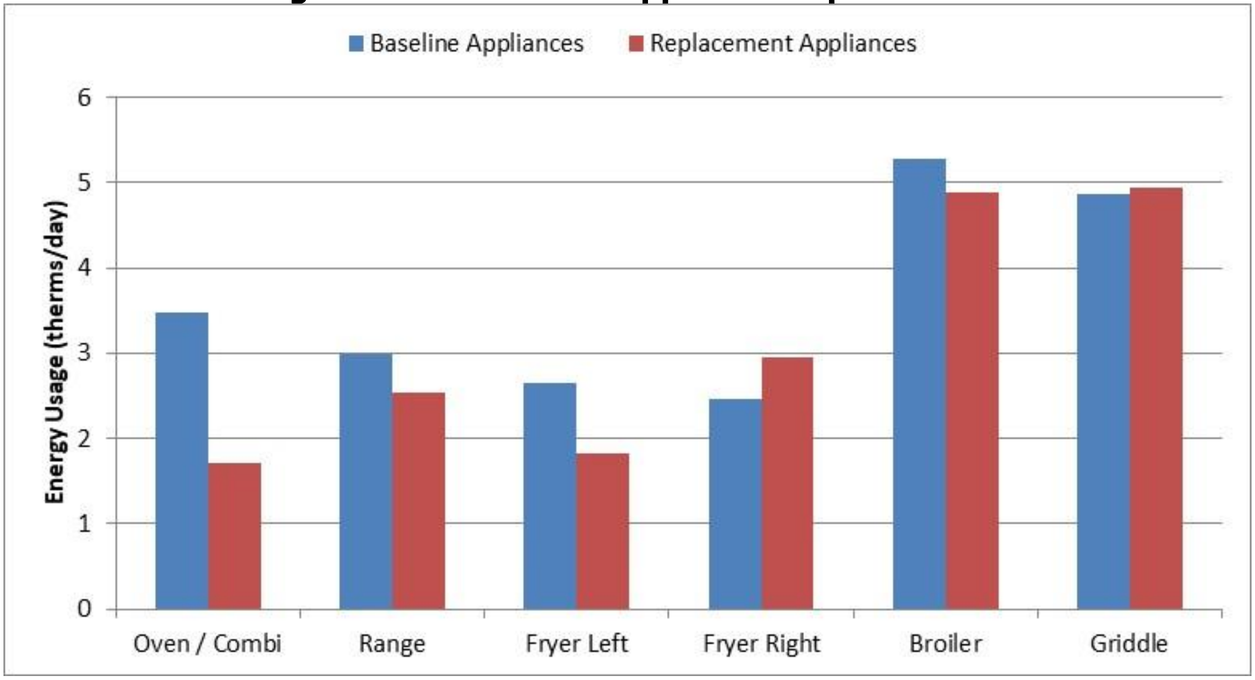
Source: Frontier Energy, Inc.

Convection oven replacement with a combi oven resulted in the highest energy savings, 51%. In addition, the restaurant could expand their menu with the combi steam cooking technology.

The super energy-efficient fryer reduced energy by 30%; however, the staff used the right fryer more often. The broiler replacement resulted in only 7% energy savings; however, the replacement broiler increased the cooking area by 25% by increasing broiler depth over the older, inefficient broiler. There were no griddle energy savings because a single 3-ft. griddle was replaced with two 2-ft. griddles. However, the replacement griddles increased the cooking area by 25% and allowed vegetarian food items to be prepared separately from the meat cooked on the second griddle.

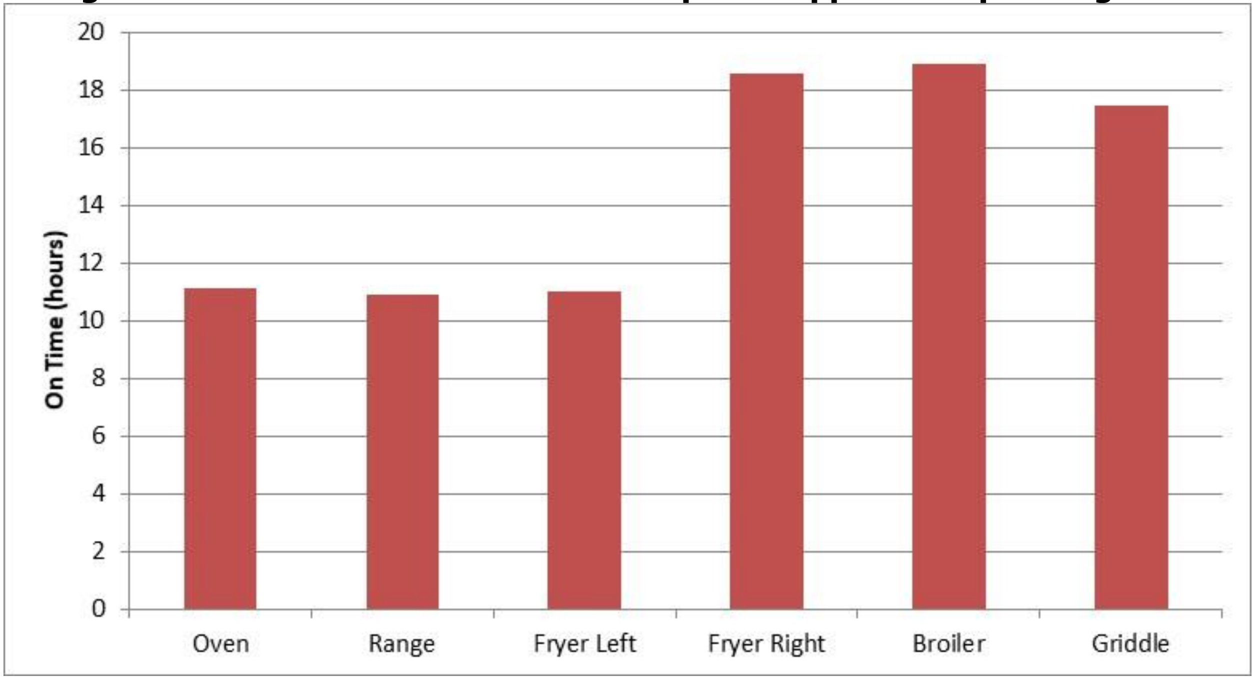
Werewolf did not experience significant gas energy savings, but the increase in production capacity with a more efficient fryer and larger cooking surfaces for the broiler and the griddles eliminated the need for the restaurant to purchase additional energy intensive equipment. Werewolf benefited from significant electrical savings due to ventilation system optimization. Consolidating the cookline with more efficient gas cooking appliances allowed the ventilation rate to be reduced using a Demand Control Ventilation system, resulting in 45% savings on both the exhaust and supply side.

Figure 226: Werewolf Appliance Replacement



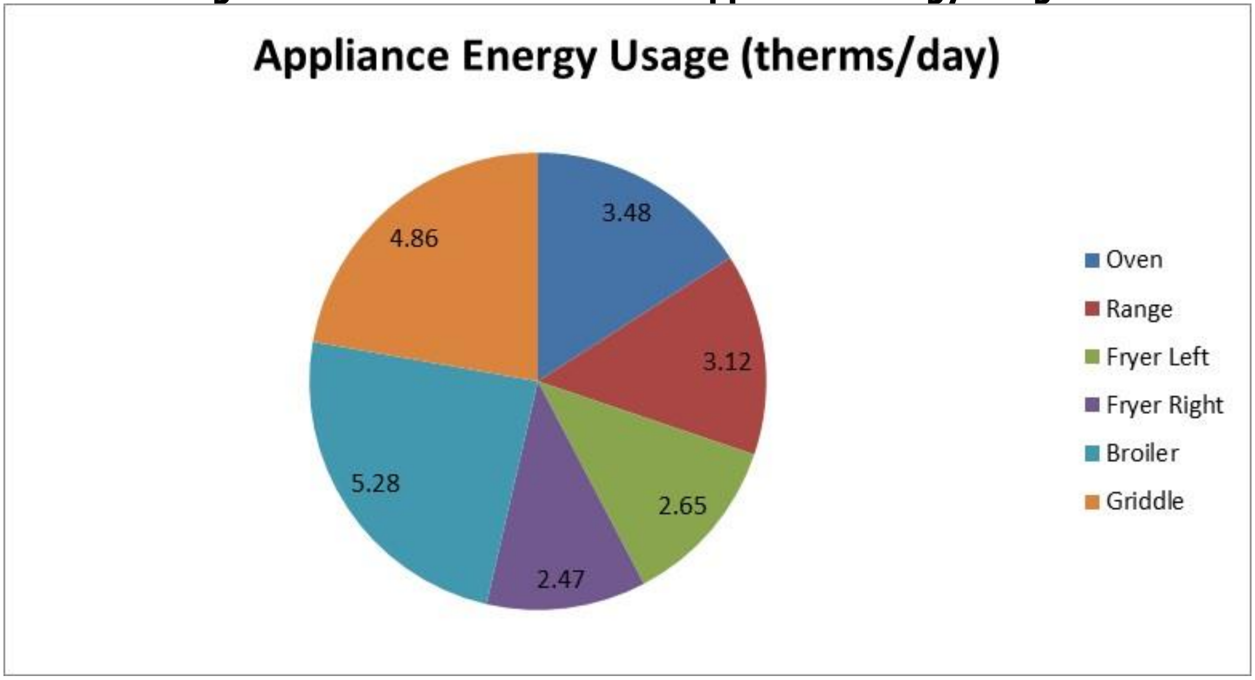
Source: Frontier Energy, Inc.

Figure 227: Werewolf Cookline and Prep Line Appliance Operating Time



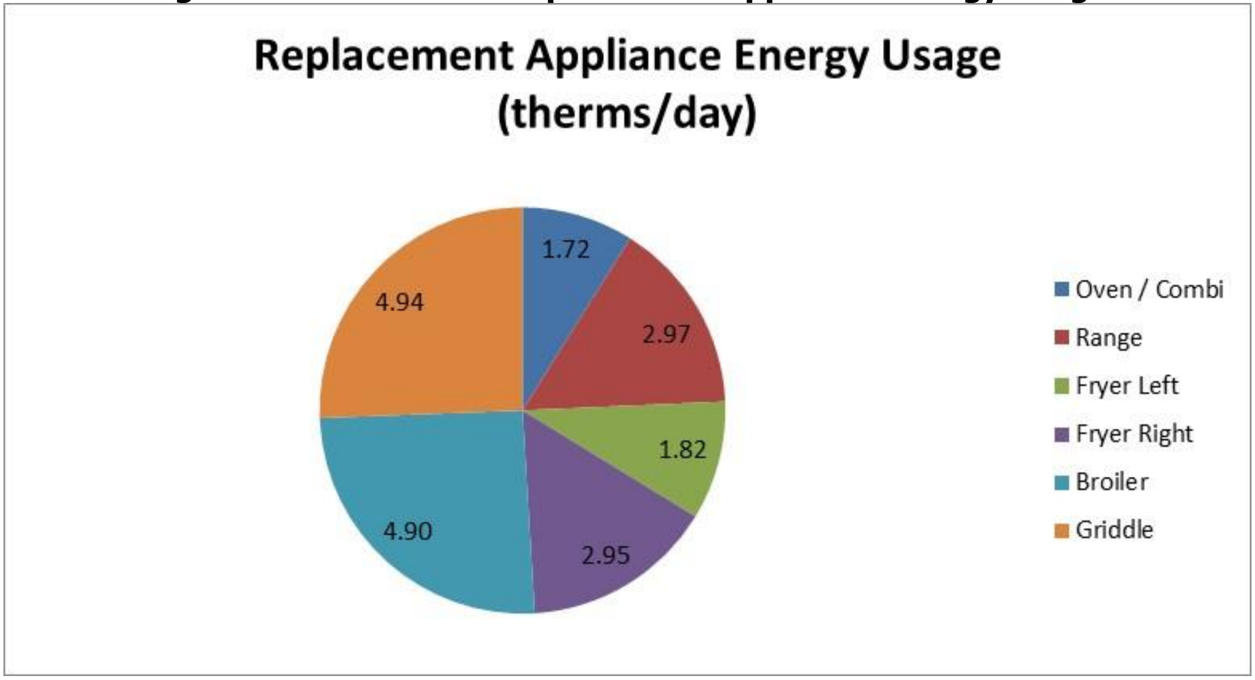
Source: Frontier Energy, Inc.

Figure 228: Werewolf Baseline Appliance Energy Usage



Source: Frontier Energy, Inc.

Figure 229: Werewolf Replacement Appliance Energy Usage



Source: Frontier Energy, Inc.

After replacement, the energy was reduced to 18.9 therms per day resulting in a 1,047 therm annual energy savings. The kitchen electric energy load was dominated by the main fan, which consumed 48 kWh per day. Both hoods used a total of 64 kWh per day. The consolidation of the cookline to only one exhaust fan resulted in 15.5 kWh/day savings. The installation of the DCKV system resulted in 20.9 kWh/day savings on the exhaust side and 10.5 kWh/day savings on the supply side. Frontier Energy estimates a total electrical savings of 46.9 kWh/day or 17,119 kWh per year. Should the restaurant be heated during the winter, gas space heating would see an additional 1,200 therms per year in gas space heating savings.

CHAPTER 6: Versailles Cuban

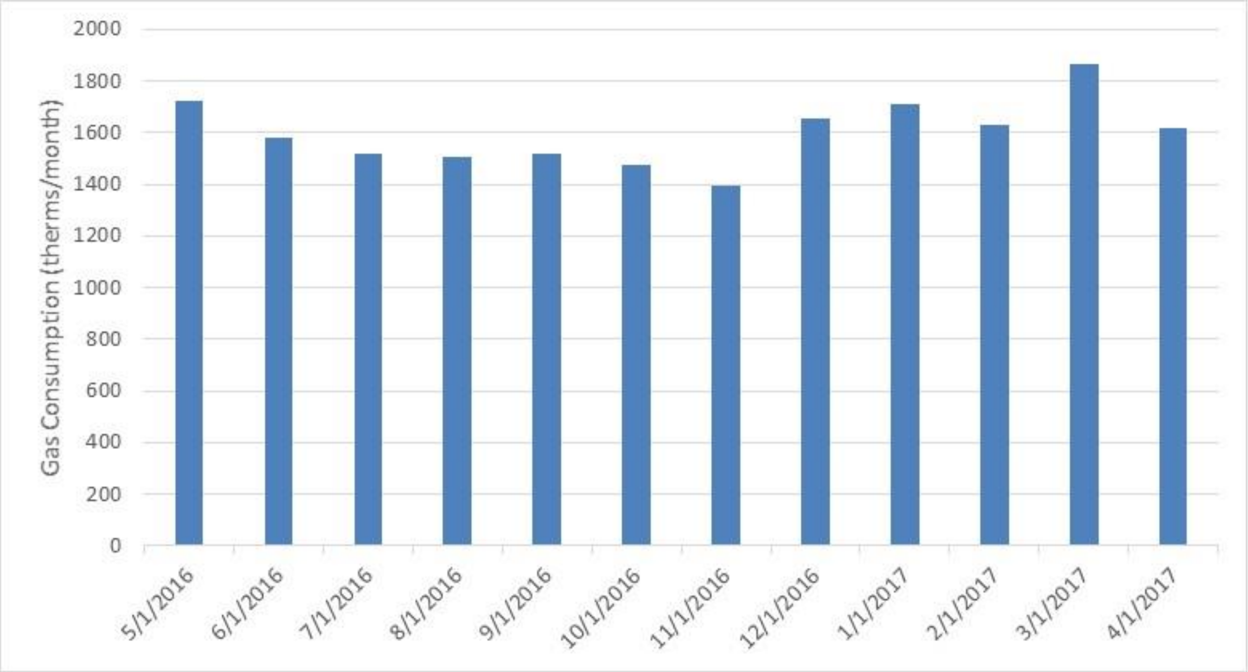
Site Description

Located in the Palms neighborhood of Los Angeles, Versailles Cuban restaurant is one of four establishments owned and operated by the Garcia family. Famous for their roast chicken marinated in "mojo" sauce, this original location has served up classic Cuban dishes since 1981. Versailles is a casual dining restaurant of approximately 1,500 square feet and has been in operation for nearly 40 years. Typical dishes cooked include lechon asado, yuca frita, mojo chicken, and oxtail stew. While its dining room serves lunch and dinner between the hours of 11 am and 11 pm seven days per week, the back-of-house is in operation from 9 am to 11 pm daily. On average, Versailles serves 600 meals per day. The average annual natural gas usage was 19,200 therms prior to equipment replacement.

Figure 230: Versailles Cuban Restaurant

Source: Frontier Energy, Inc.

Figure 231: Versailles Cuban Total Gas Usage (2016 – 2017)



Source: Frontier Energy, Inc.

Kitchen Cookline Description

Like all restaurants, Versailles' profits are continually pinched by food, labor, insurance, maintenance, and utility costs. Hoping to better control natural gas and electricity costs, owner John Smith was interested in opportunities to rethink his production line. The Versailles cooklines, referred to as "front line" and "back line", are situated back-to-back under a double-sided island canopy hood having a length of 16 feet. Both cooklines are similar in composition with fryers, convection ovens, ranges with ovens, as well as griddle/range suites. While the dimensions of the ranges differ somewhat, their functionality is the same. Only the back line has the distinction of a salamander. Table 9 documents the original cooklines and the new appliances installed as part of the replacement project.

Figure 232: Back Cookline

Source: Frontier Energy, Inc.

Figure 233: Front Cookline

Source: Frontier Energy, Inc.

Figure 234: Back Cookline 4-Burner Range/Griddle Combination

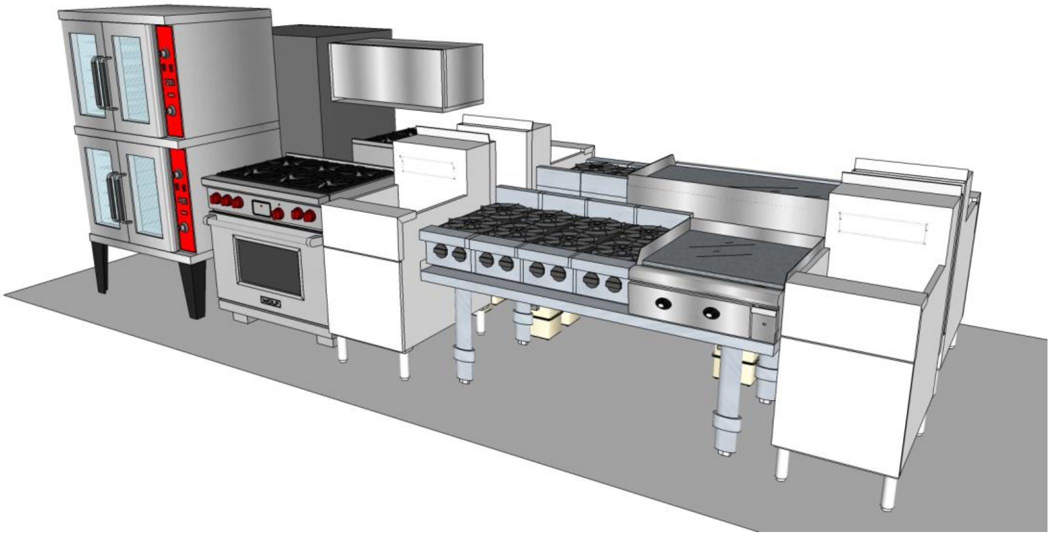
Source: Frontier Energy, Inc.

Table 9: Versailles Cuban Hooded Gas Appliances

Prior To Replacement	After Replacement
4 – 18″ Fryers 2 – 6-burner Ranges 1 – 8-burner Range with 2′ griddle 1 – 4-burner Range with 4′ griddle 2 – Double stack convection ovens	2 – 18″ Fryers 1 – Dual 14″ Fryer 3 – 6-burner Ranges 2 – 2-burner Stockpot Ranges 1 – Double stack Convection Oven 1 – Combination Oven 1 – 3′ Griddle

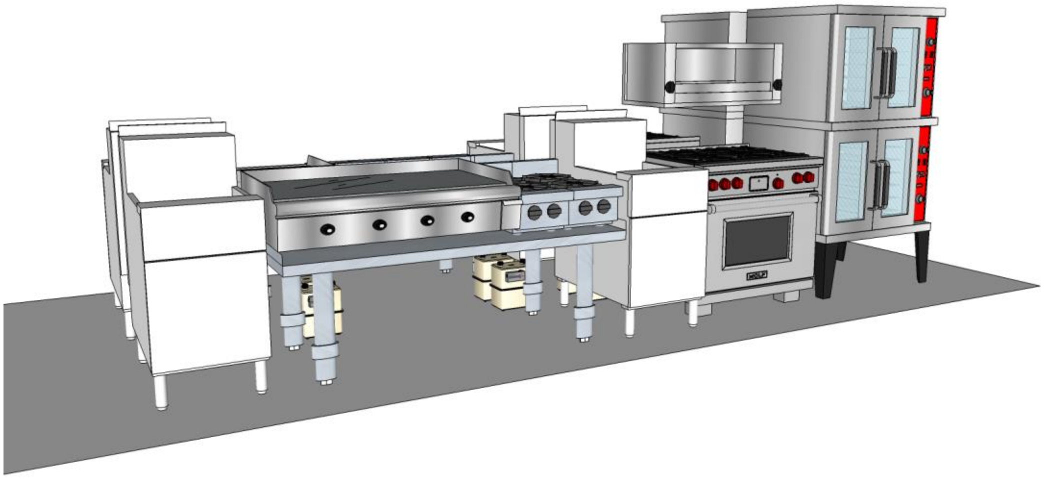
Source: Frontier Energy, Inc.

Figure 235: Front Cookline Diagram



Source: Frontier Energy, Inc.

Figure 236: Back Cookline Diagram



Source: Frontier Energy, Inc.

Versailles Cuban Results

Griddle/Range Suite Replacement and Energy Efficient Cookware

Each side of the cookline had a griddle/range combination unit. The back line had a 4-ft. griddle with a 4-burner range and the front line had a 2-ft. griddle with an 8-burner range. Both suites had dual ovens underneath, which were not utilized for cooking. Both griddles were non-thermostatic. The energy use of the front suite was 5.93 therms while the back suite used 4.87 therms per day. The constant-input griddle suite on the back and front cooklines operated for 13.3 and 14.5 hours per day, respectively.

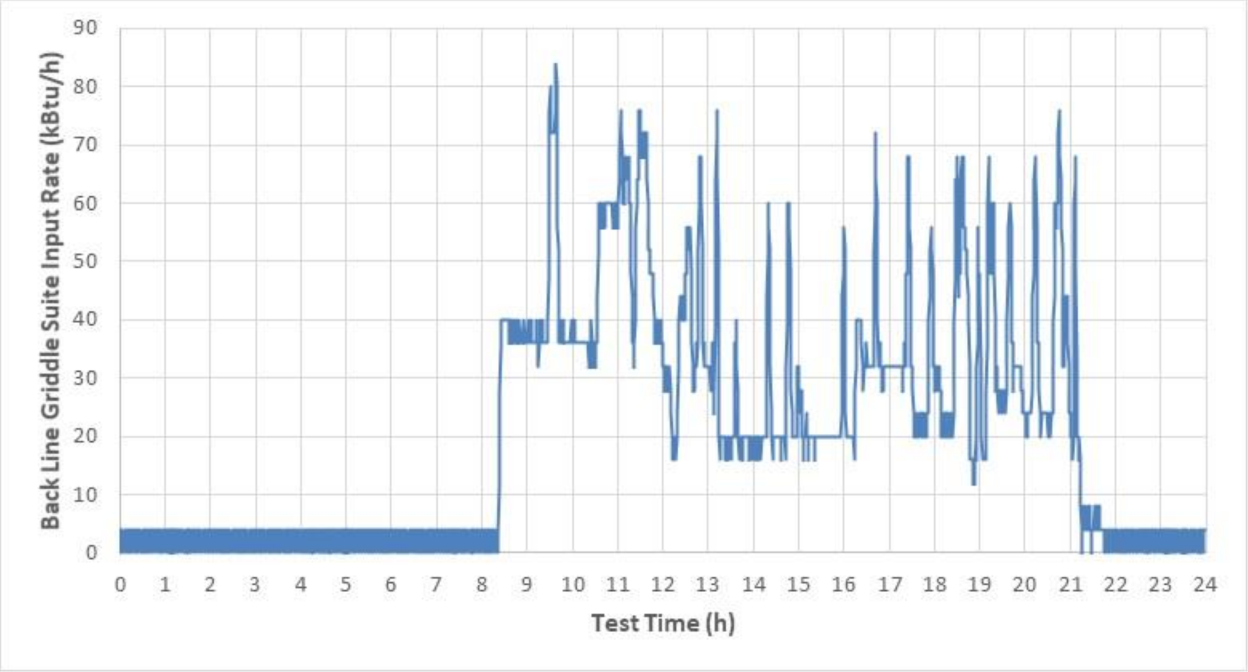
Figure 237: Back line 4-ft. Griddle/4-Burner Range Combo

Source: Frontier Energy, Inc.

Figure 238: Front Line 2-ft. Griddle/8-Burner Range Combo

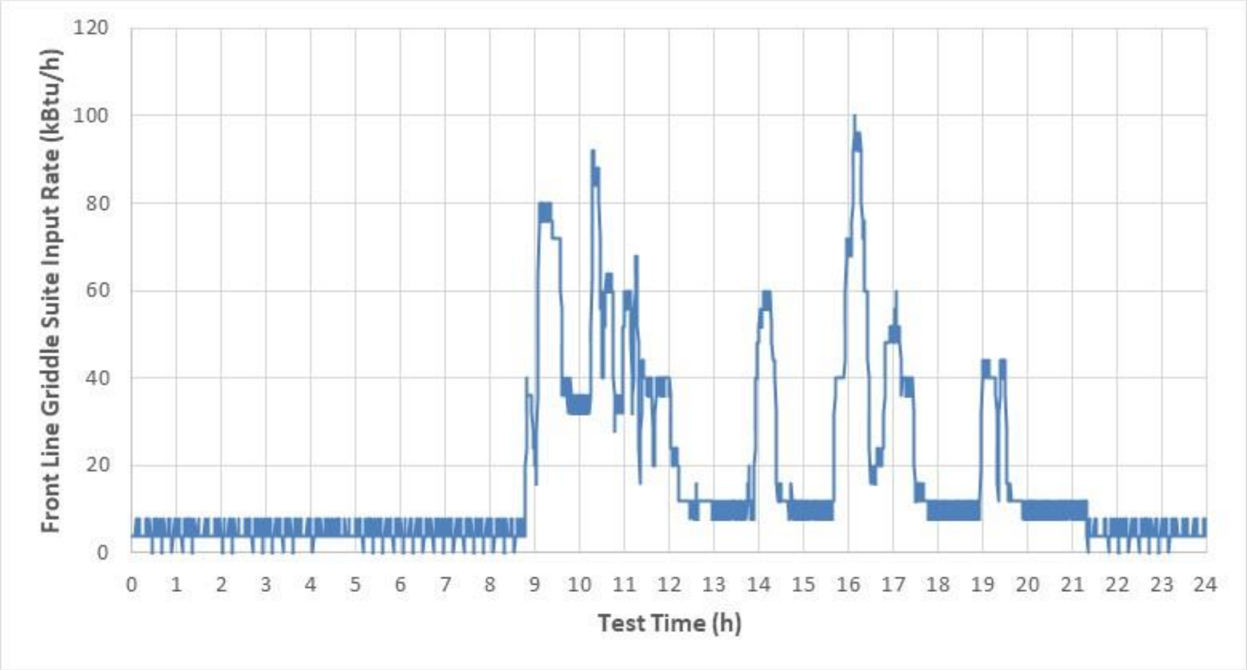
Source: Frontier Energy, Inc.

Figure 239: Versailles Back line 4-ft. Griddle/4-Burner Range Energy Profile



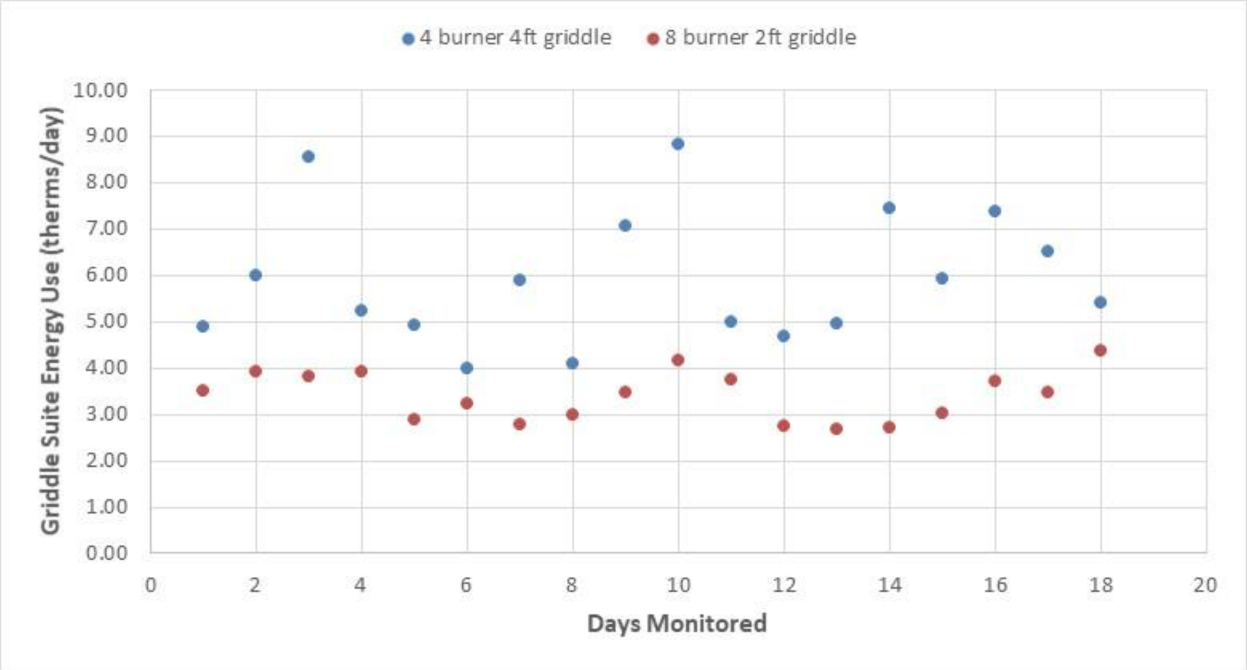
Source: Frontier Energy, Inc.

Figure 240: Versailles Front Line 2-ft. Griddle/8-Burner Range Energy Profile



Source: Frontier Energy, Inc.

Figure 241: Versailles Griddle/Range Comparison



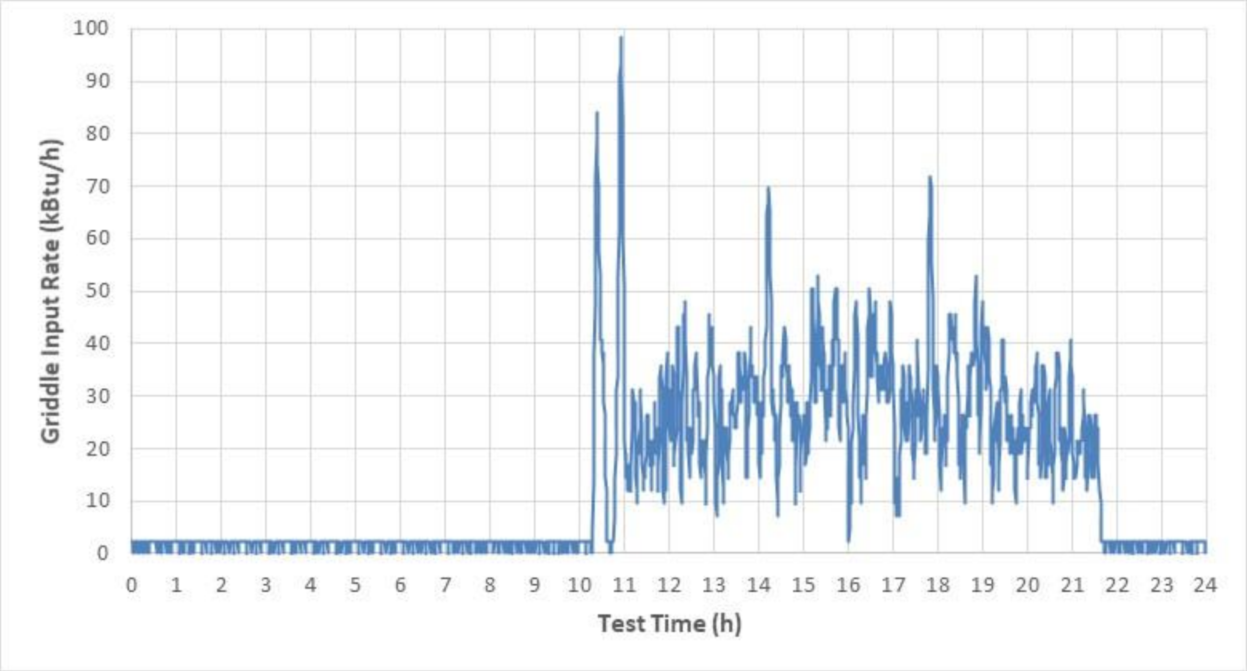
Source: Frontier Energy, Inc.

Both griddle suites were replaced with the following: a 3-ft. thermostatic griddle, a 6-burner range, and two 2-burner stockpot ranges. The replacement thermostatic griddle consumed 3.4 therms while operating 11.8 hours per day. In addition to the appliance suite upgrades, researchers inventoried and replaced all pots and pans with energy-efficient finned-bottom cookware that greatly improve range flame heat transfer to the cooking surface of the pots and pans. The countertop 6-burner range consumed 1.58 therms per day while operating 5.7 hours per day.

Figure 242: Replacement Griddle and 6-Burner Range

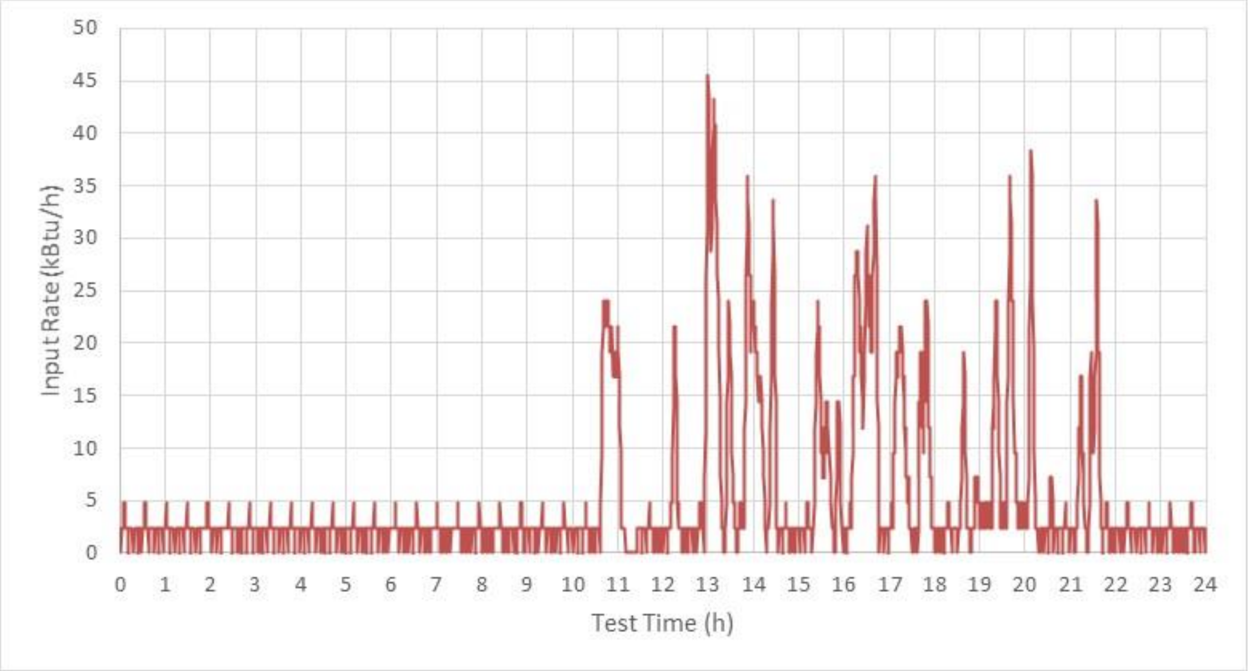
Source: Frontier Energy, Inc.

Figure 243: Versailles Replacement Griddle Energy Profile



Source: Frontier Energy, Inc.

Figure 244: Versailles Replacement Countertop Range Energy Profile



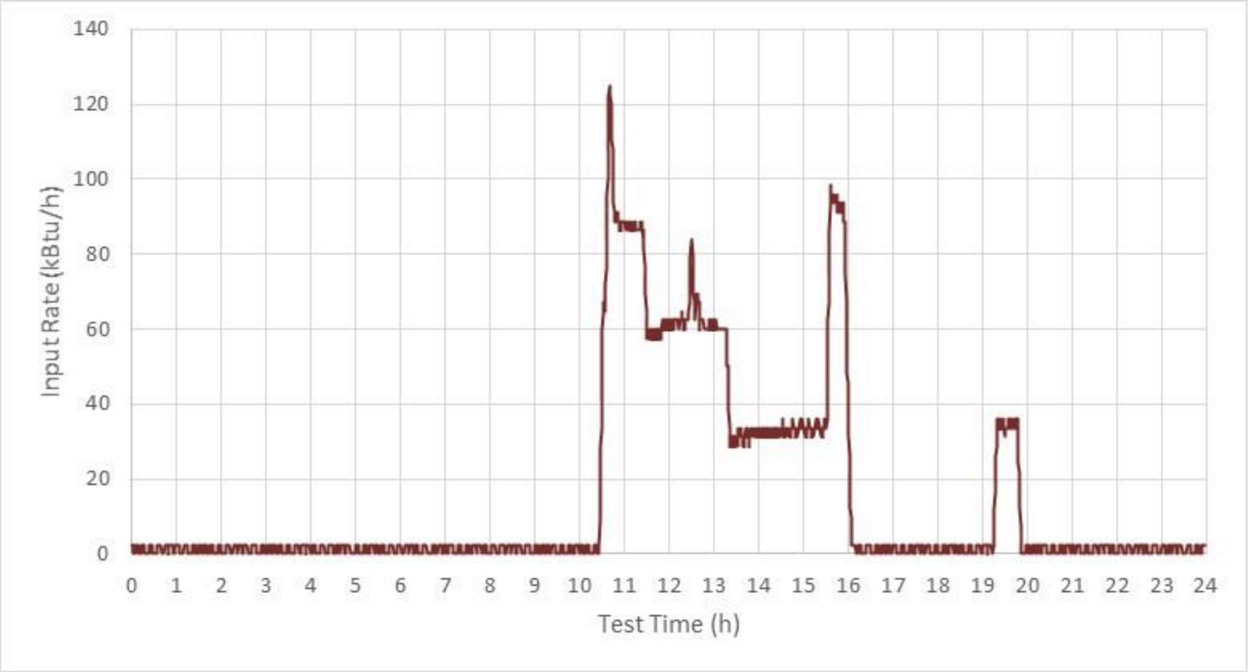
Source: Frontier Energy, Inc.

The stock pot ranges consisted of two dual-concentric ring burners with high input rates topped with 60-qt. finned-bottom stock pots. The left stockpot range consumed 1.91 therms per day and the right stockpot range consumed 1.58 therms per day while both operated for an average of 6.8 hours per day. The new range burner diameter matched the large stock pot diameters and the finned-bottom pots transferred heat from the flame to the pot contents more efficiently resulting in faster heat up times and reduced energy consumption.

Figure 245: Replacement Stockpot Ranges

Source: Frontier Energy, Inc.

Figure 246: Versailles Stockpot Range Energy Profile



Source: Frontier Energy, Inc.

Figure 247: Back line Range with Salamander

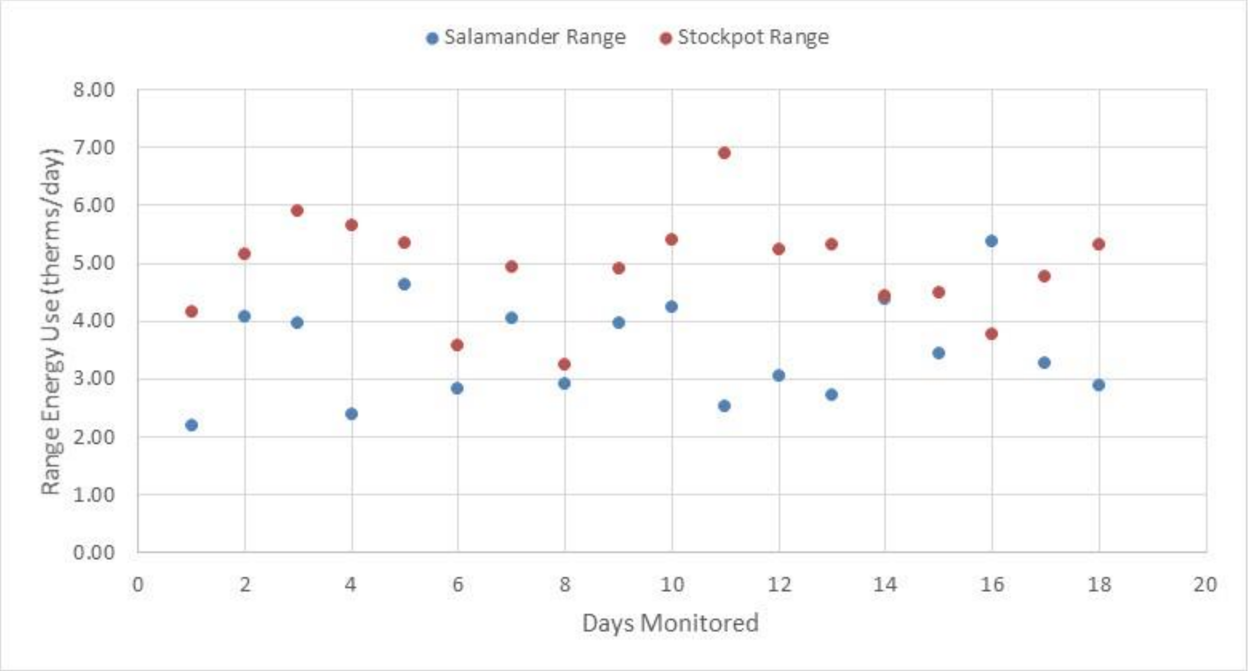
Source: Frontier Energy, Inc.

Figure 248: Front Line Stock Pot Range

Source: Frontier Energy, Inc.

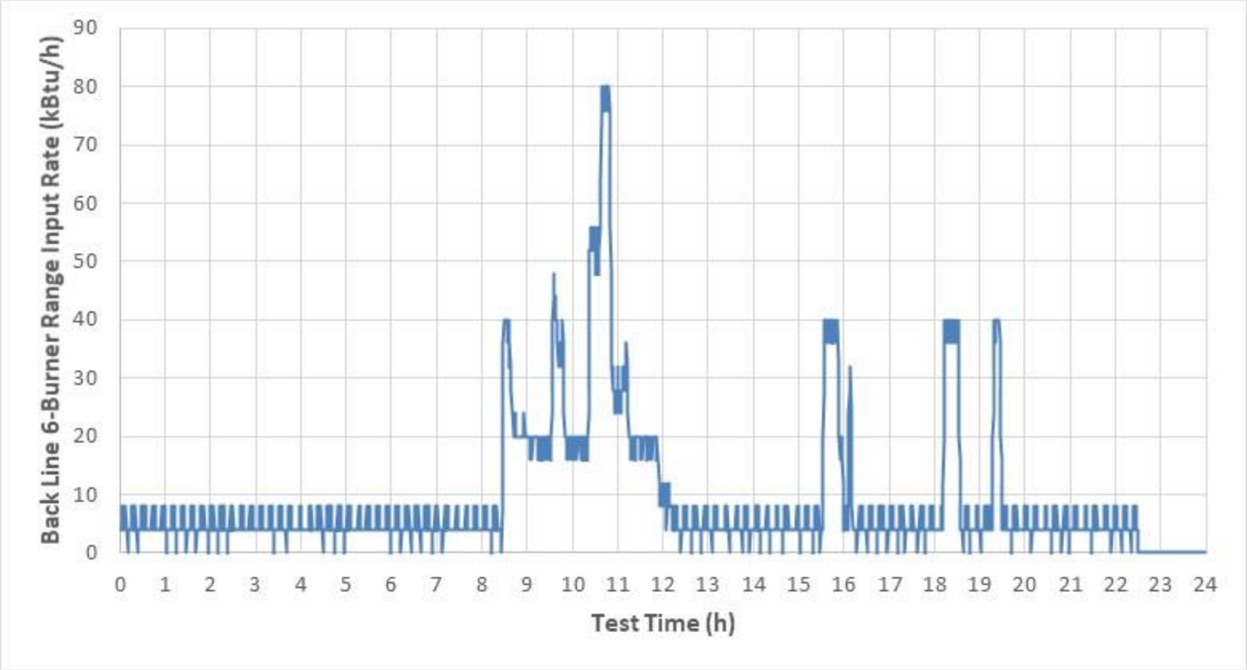
Versailles had two 6-burner ranges on the cookline. The backline range, equipped with an overhanging salamander, was used for cook-to-order dishes, while the frontline range was mostly used for preparing stocks. The backline cook-to-order range used 3.50 therms per day and the frontline stockpot range used 4.92 therms per day while operating longer hours.

Figure 249: Versailles 6-Burner Range Energy Use



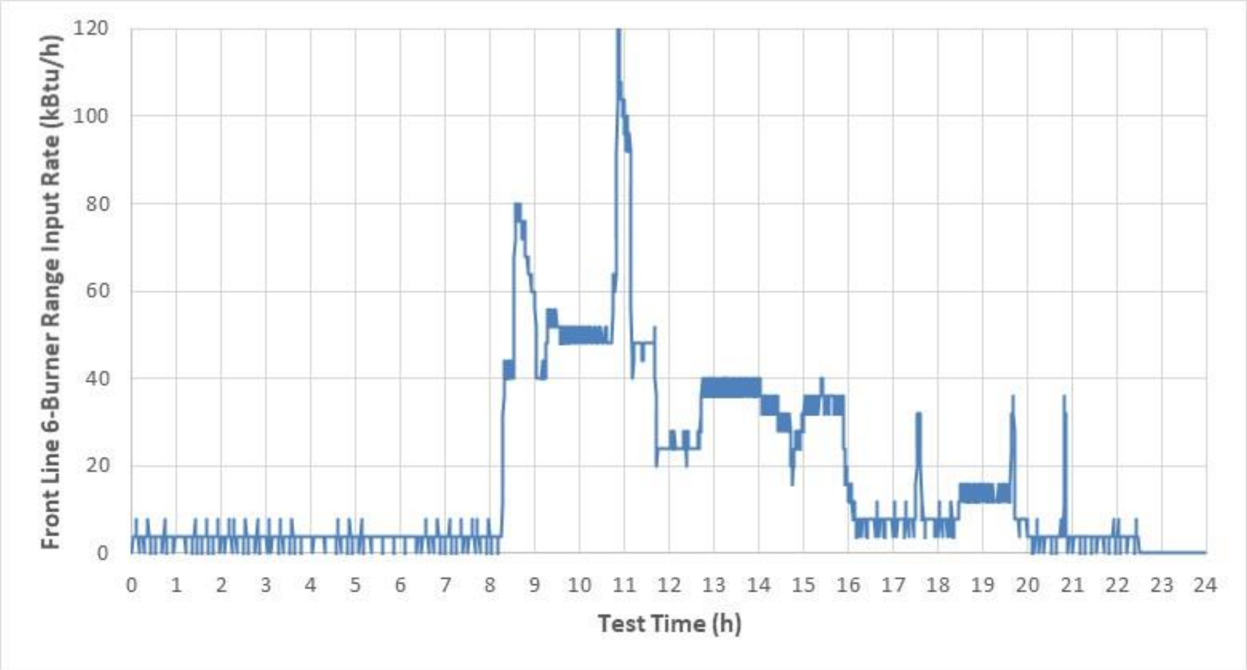
Source: Frontier Energy, Inc.

Figure 250: Versailles Back line 6-Burner Range w/ Salamander Energy Profile



Source: Frontier Energy, Inc.

Figure 251: Versailles Front Line 6-Burner Range Energy Profile



Source: Frontier Energy, Inc.

The baseline range setup consisted of two six-burner ranges and two ranges with griddles. One of the rages had a salamander, however the salamander was rarely used. The replacement setup consisted of the same two six-burner ranges, two new stock pot ranges, and a new countertop six-burner range, with new pots and pans. Energy usage should be analyzed in toto instead of by individual appliances because the new ranges were not one-for-one replacements. With a total of 24 burners and 6-ft. of griddle space for the baseline setup and 22 burners and 3-ft. of griddle space for the replacement setup, the restaurant reduced their energy usage from 19 to 13 therms per day through consolidation of the two griddles and finned-bottom pots and pans.

Table 10: Gas Range and Griddle Details

Baseline Appliance	Pre Energy (therms/day)	Replacement Appliance	Post Energy (therms/day)
6-burner range with salamander	3.50	Not replaced	1.75
6-burner range	4.92	Not replaced	2.44
8-burner range with griddle	4.87	2-burner stockpot range left	1.91
4-burner range with griddle	5.93	2-burner stockpot range right	1.58
		6-burner countertop range	1.78
		3-ft griddle	3.54
Total	19.22		13.00

Source: Frontier Energy, Inc.

Fryer Replacement

The Versailles Cuban cookline had a total of four 18″ fryers. The two fryers on the end of the front and back cook lines closest to the serving window consumed 4.57 and 3.02 therms per day, respectively. The middle fryers on the back and front lines consumed 3.78 and 3.40 therms per day, respectively. All fryers were turned on at 10 am and turned off at 10 pm on weekdays and operated for longer periods on weekends.

Figure 252: Back Line – Middle Fryer

Source: Frontier Energy, Inc.

Figure 253: Back Line – End Fryer

Source: Frontier Energy, Inc.

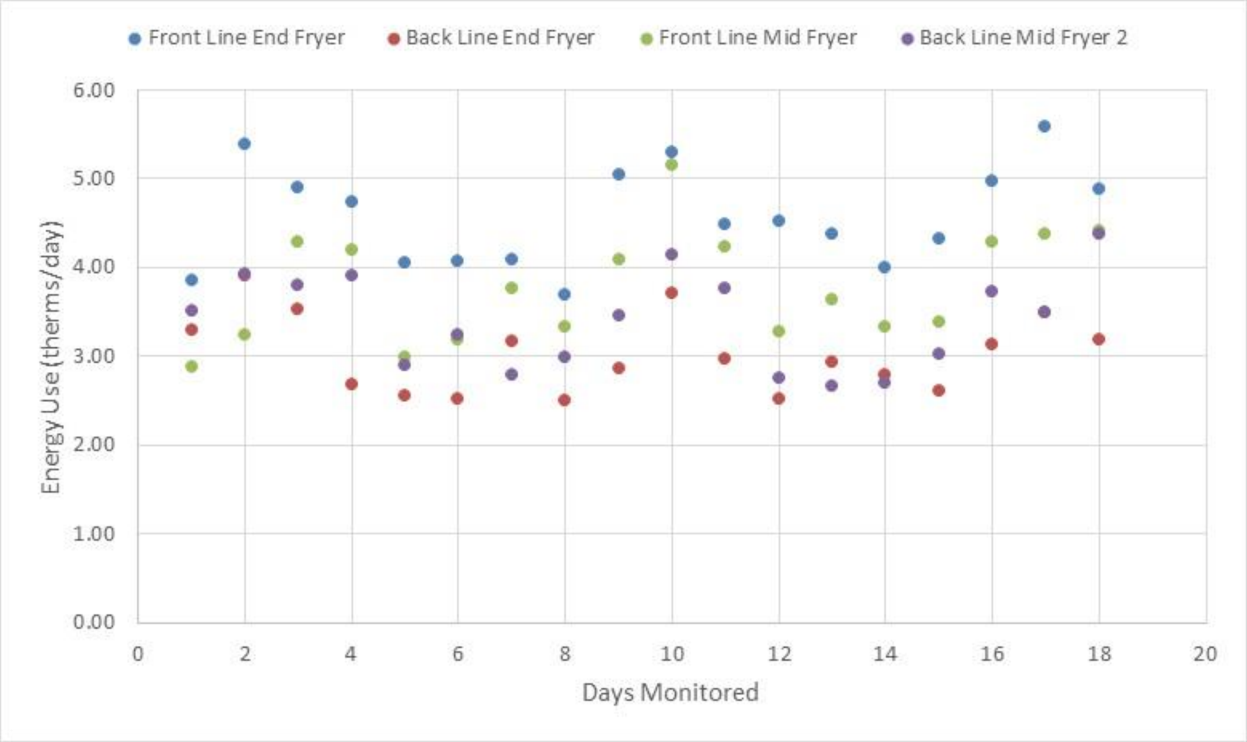
Figure 254: Front Line – Middle Fryer

Source: Frontier Energy, Inc.

Figure 255: Front Line – End Fryer

Source: Frontier Energy, Inc.

Figure 256: Versailles Fryer Energy Use



Source: Frontier Energy, Inc.

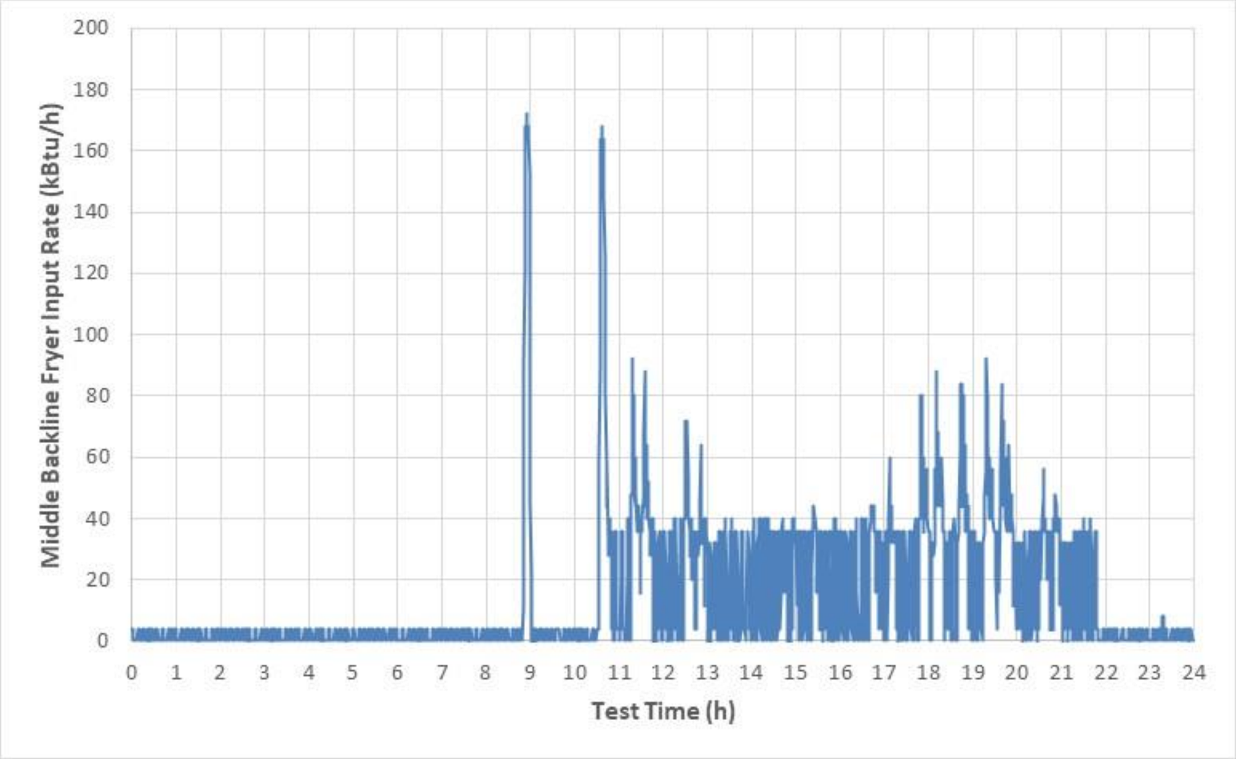
Versailles used 74 cases of non-hydrogenated oil for the month of August. Each case of oil weighed 35 pounds. For other months, oil usage remained within a range of 70 to 80 cases. Below is a list of foods cooked in the fryers relative to energy use. The French fry and plantain fryer had the highest energy usage. The large vat fryers used slightly less energy.

Table 11: Versailles Cuban Fryer Details

Fryer Location	Food Cooked	Average Energy Use (therms/day)	Hours of Operation (h)
Front Line Middle	fried plantains	3.78	15.5
Front Line End	fries, and all other appetizers	4.57	15.0
Back Line Middle	chicken	3.40	14.8
Back Line End	chicken, fish, pork	3.02	15.5

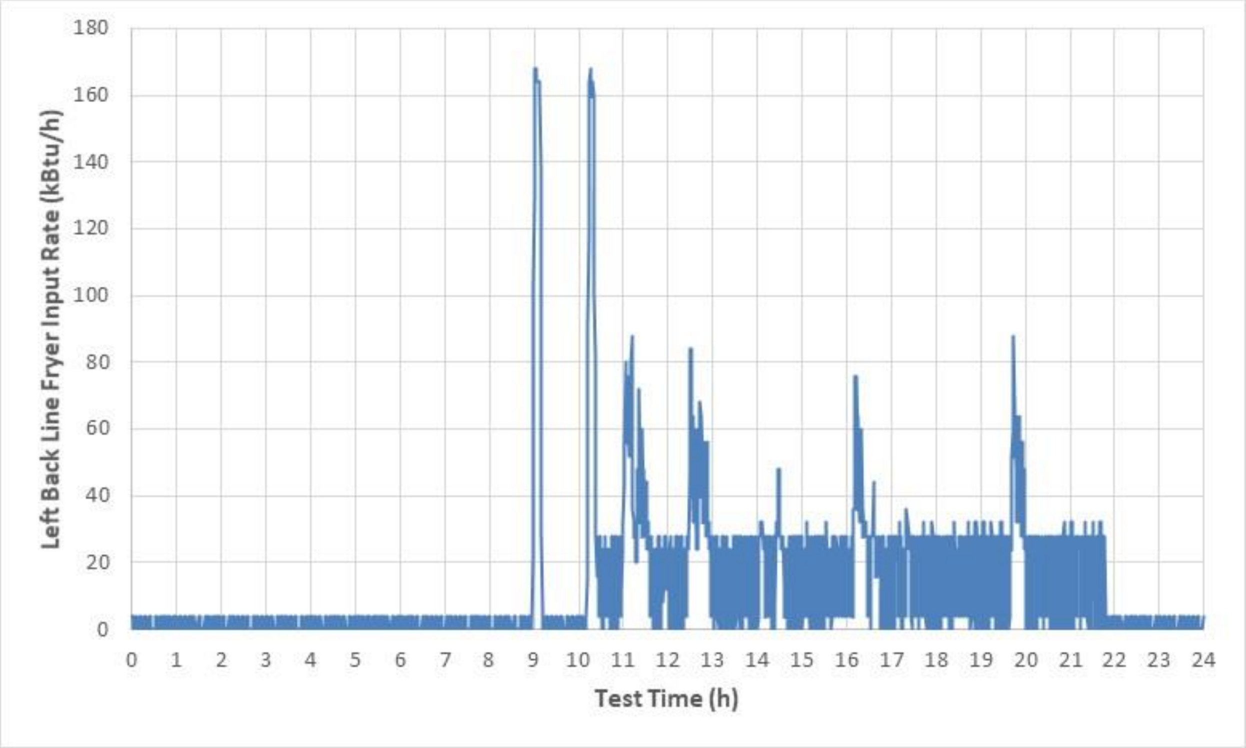
Source: Frontier Energy, Inc.

Figure 257: Versailles Middle Back Line Fryer Energy Profile



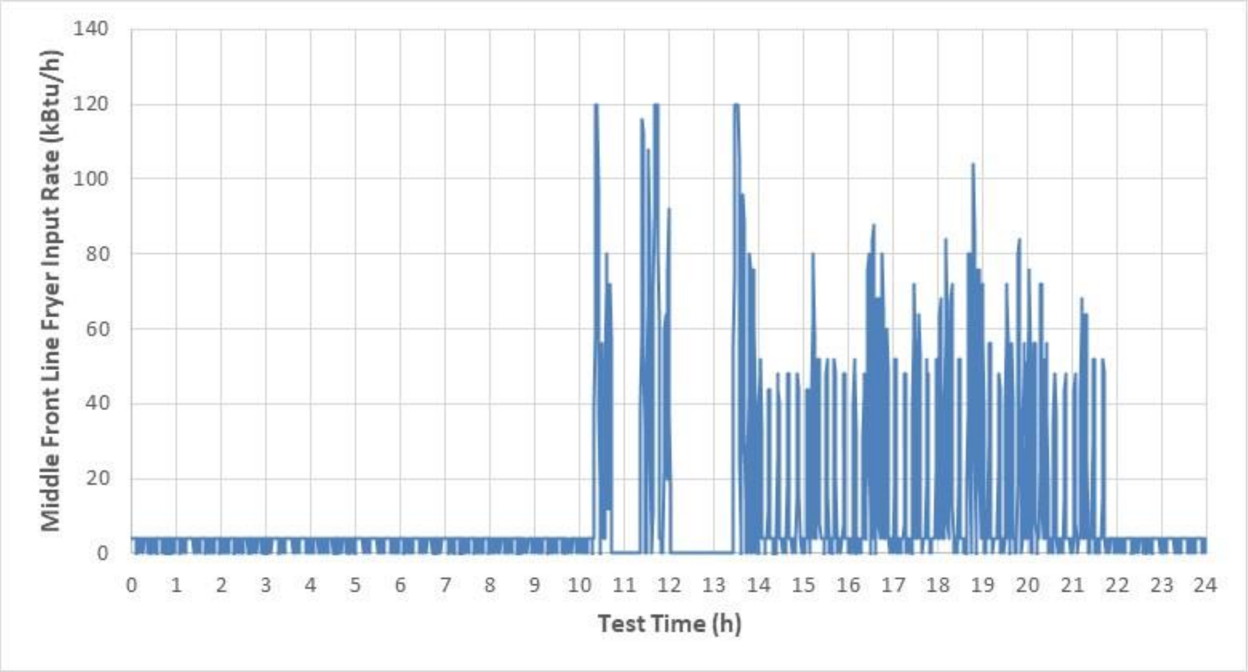
Source: Frontier Energy, Inc.

Figure 258: Versailles Left Back Line Fryer Energy Profile



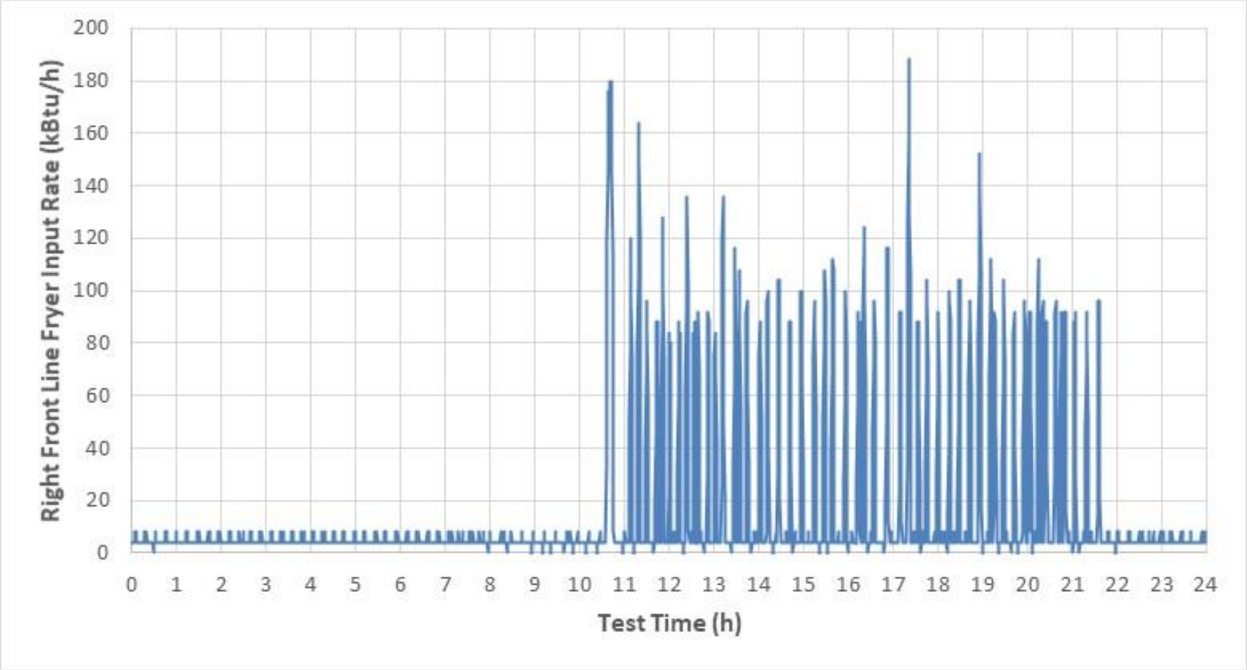
Source: Frontier Energy, Inc.

Figure 259: Versailles Middle Front Line Fryer Energy Profile



Source: Frontier Energy, Inc.

Figure 260: Versailles Right Front Line Fryer Energy Profile



Source: Frontier Energy, Inc.

Researchers replaced four baseline fryers with three energy-efficient fryers. Two of the fryers were direct 18″-wide replacements and the third fryer was a dual-vat 14″ fryer with built-in filtration. The two 18″ replacement fryers consumed 2.2 and 0.2 therms per day while the dual 14″ fryer consumed 1.7 therms per day. Replacement fryer operating hours ranged from 8 to 13 hours per day. Total frying energy was reduced from 14.8 to 4.0 therms per day. Besides the improvement in fryer energy efficiency, the energy reduction could also be attributed to Versailles shifting the chicken production from the fryers to the combi oven.

Previously, the restaurant pre-cooked their chicken in an oven (which took about 50 min), stored the chicken in the fridge, and reheated it in the fryer to order. The process was changed after installation of the replacement equipment with the combi oven cooking the chicken much more quickly (25-30 min). Once cooked, the chicken was then kept warm in a holding cabinet and served immediately to order. This process significantly cut down on fryer energy usage, specifically the dual-vat fryer. The dual-vat fryer now only cooks pork chunks, breaded chicken, steak, empanadas, croquettes, and special orders for customers who want extra well-done chicken. Fryer production volumes decreased significantly due to the process change. Now 18″ fryers are used to cook plantains in one vat and French fries and appetizers in the other. After several months of operation, the mixed fryer production was relegated to a single 18-inch fryer, further lowering energy use of this equipment.

The fryer oil usage was reduced by 42 oil jugs per month due to fryer filtration and combi cooking which amounted to $1,200 savings per month additional to the energy savings.

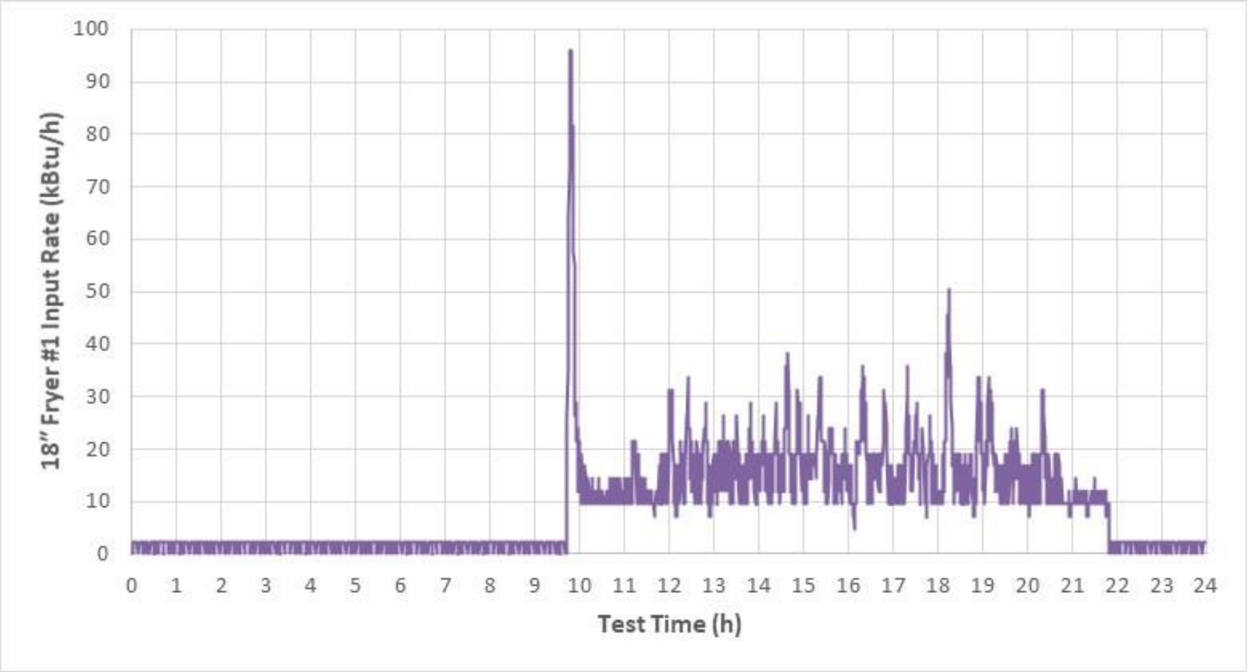
Figure 261: Replacement Dual-Vat Fryer

Source: Frontier Energy, Inc.

Figure 262: Replacement 18” Fryers

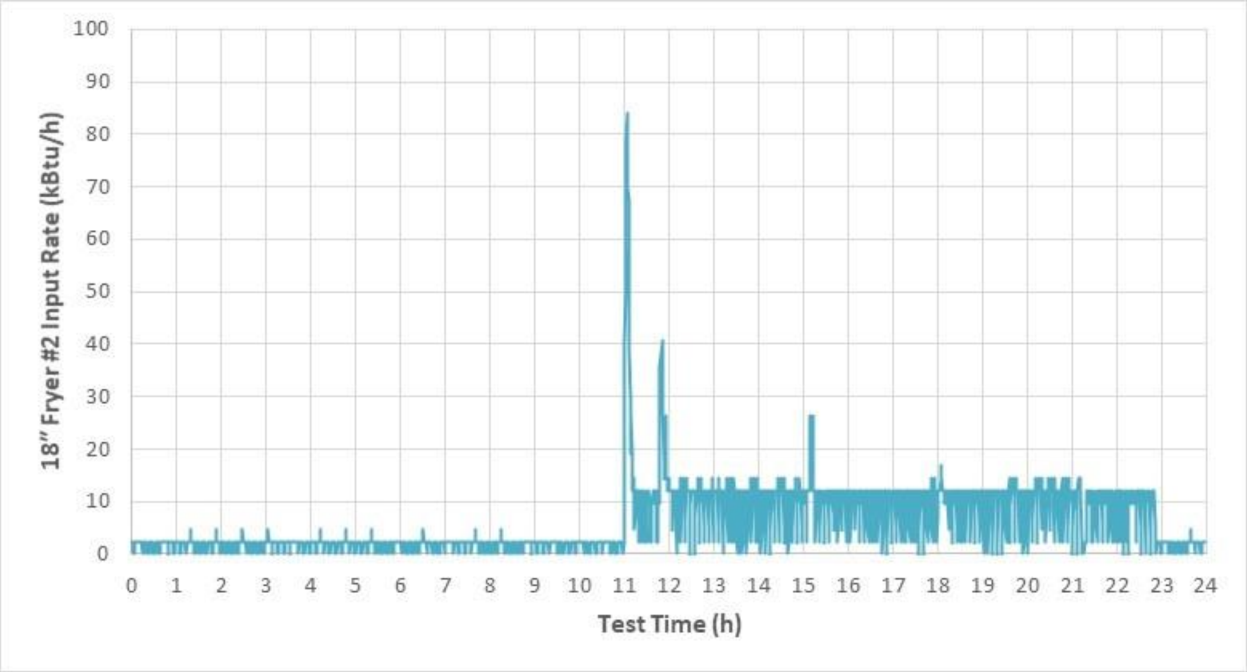
Source: Frontier Energy, Inc.

Figure 263: Versailles Replacement 18″ Fryer #1 Profile



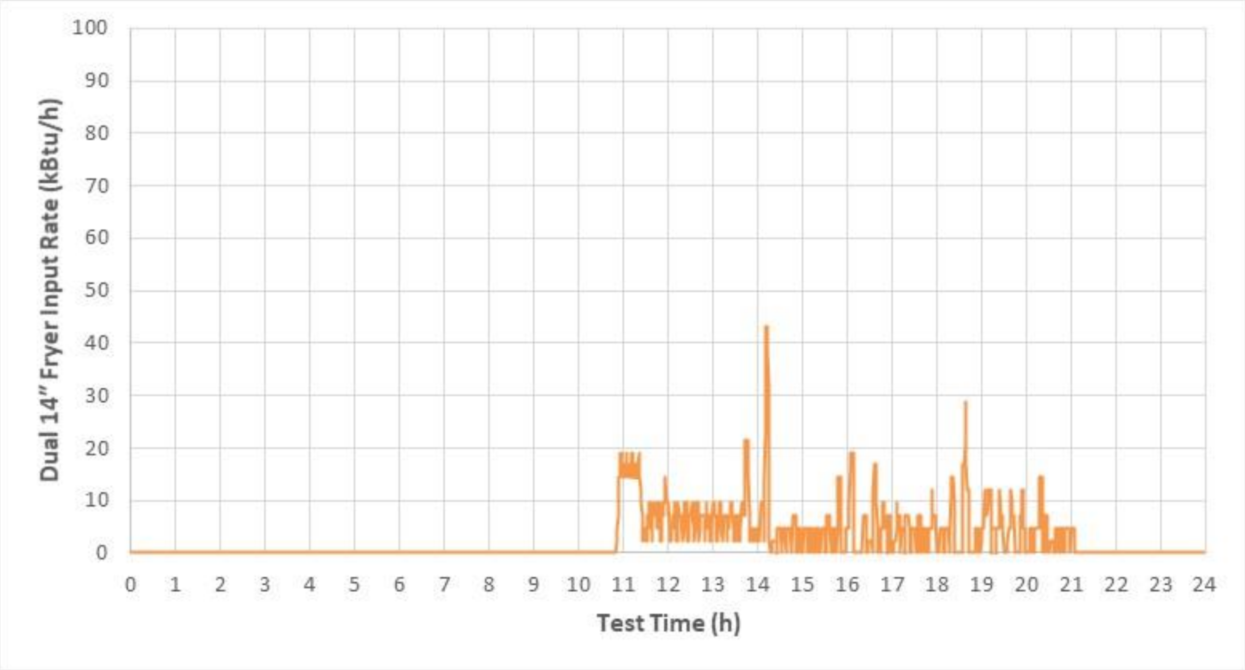
Source: Frontier Energy, Inc.

Figure 264: Versailles Replacement 18″ Fryer #2 Profile



Source: Frontier Energy, Inc.

Figure 265: Versailles Replacement Dual 14” Fryer Profile



Source: Frontier Energy, Inc.

Table 12: Versailles Cuban Fryer Replacement Energy Savings

Fryer Location	Food Cooked	Hours of Operation (h)	Pre Energy (therms/day)	Post Energy (therms/day)
Front Line Middle	fried plantains	15.5	3.78	0.13
Front Line End	fries, and all other appetizers	15	4.57	2.23
Back Line Middle	chicken	14.8	3.40	1.67
Back Line End	chicken, fish, pork	15.5	3.02	
Combined Fryer Energy Use			14.77	4.03

Source: Frontier Energy, Inc.

Steam Table Monitoring

The steam tables were located at the end of the cookline next to the serving window. Both custom steam tables were gas heated by open burners below. The right steam table consumed 3.52 therms per day while operating for 13.3 hours per day. Researchers assumed that the left steam table had similar operating hours since neither table has a pilot. Each table required manual ignition.

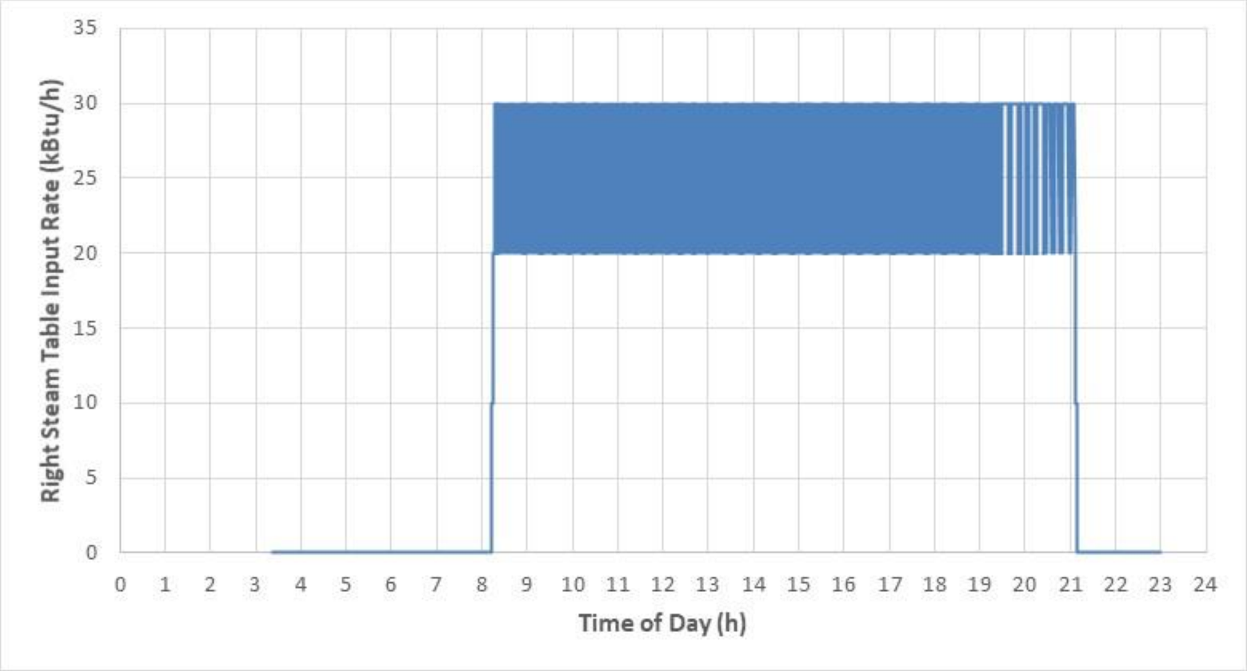
Figure 266: Left Steam Table with Tube Burner

Source: Frontier Energy, Inc.

Figure 267: Right Steam Table with Dual Bulb Burners

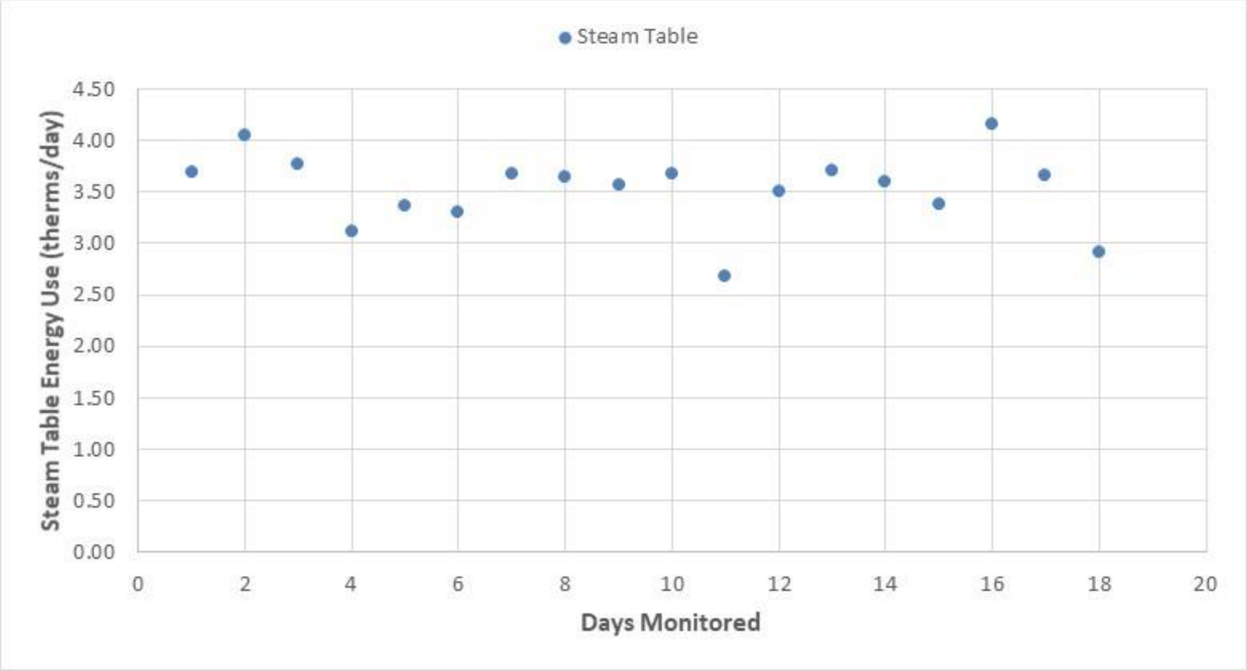
Source: Frontier Energy, Inc.

Figure 268: Versailles Right Steam Table Average Daily Energy Profile



Source: Frontier Energy, Inc.

Figure 269: Versailles Steam Table Daily Energy Use



Source: Frontier Energy, Inc.

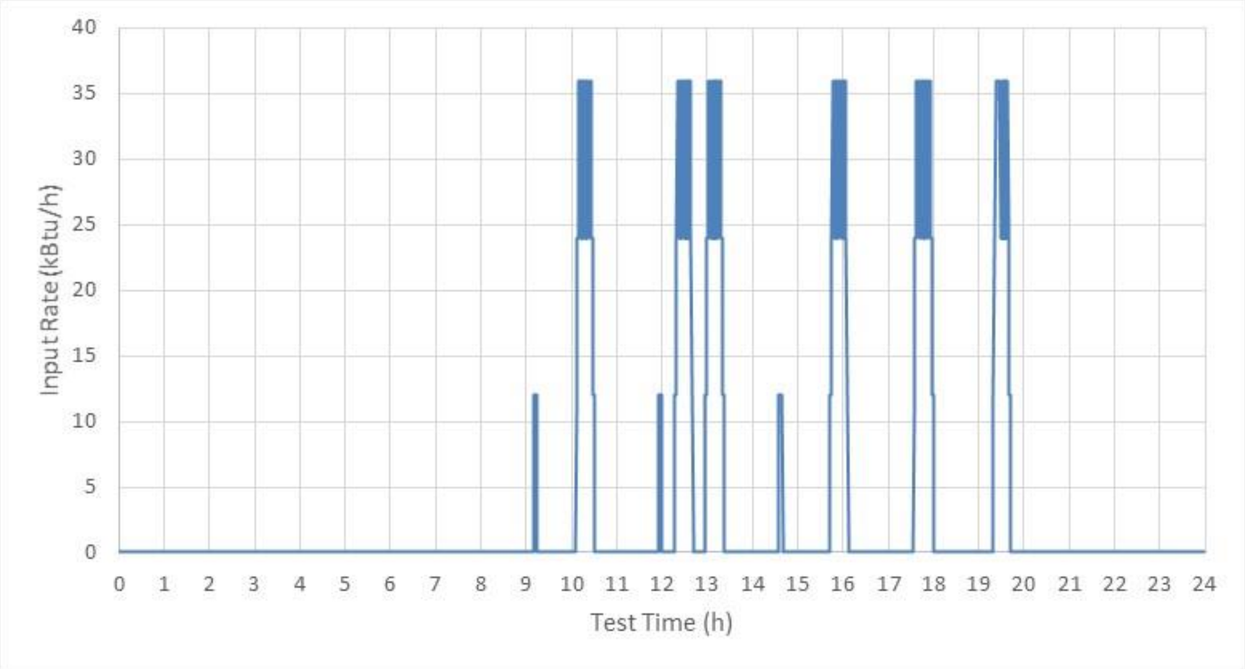
Rice Cooker Monitoring

The rice cooker was located at the end of the cookline closest to the serving window. Researchers submetered the rice cooker for three weeks. The rice cooking cycle was 25 minutes long with a constant input rate of 35 kBtu/h and no idle energy usage between cycles. With an average daily energy of 0.96 therms per day and 3.5 hours of operation, researchers estimated that there were 6 to 8 cook cycles conducted per day. Rice cooker energy could be eliminated if the rice was cooked in the combi oven in steam mode.

Figure 270: Versailles Rice Cookers

Source: Frontier Energy, Inc.

Figure 271: Versailles Rice Cooker Energy Profile



Source: Frontier Energy, Inc.

Demand Control Ventilation System

The main kitchen line consisted of a 16′ double-island canopy exhaust hood. The hood had three ducts leading to rooftop mushroom fans. There were two 2 HP exhaust fans, one 5 HP exhaust fan, and the supply air was cooled with a 5 HP evaporative cooler. A ventilation balance report was performed on the system with the three exhaust fans operating between 800 RPM and 1,050 RPM, pulling a combined 11,200 cubic feet per minute (cfm) of exhaust. The static pressures for the exhaust and supply ducts were 0.8 inch water column (inWC) and 1.3 inWC, respectively.

Staff turned the exhaust hoods on at 10 am and turned off at 11 pm. The three exhaust fans and swamp cooler had a maximum draw of 7 kW. The 2 kW swamp cooler sometimes had shorter operating hours, being turned on 2 hours after the exhaust fans. With an average operating time of 15.8 hours per day, the kitchen ventilation system consumed 101 kWh per day.

Figure 272: Three Rooftop Exhaust Fans

Source: Frontier Energy, Inc.

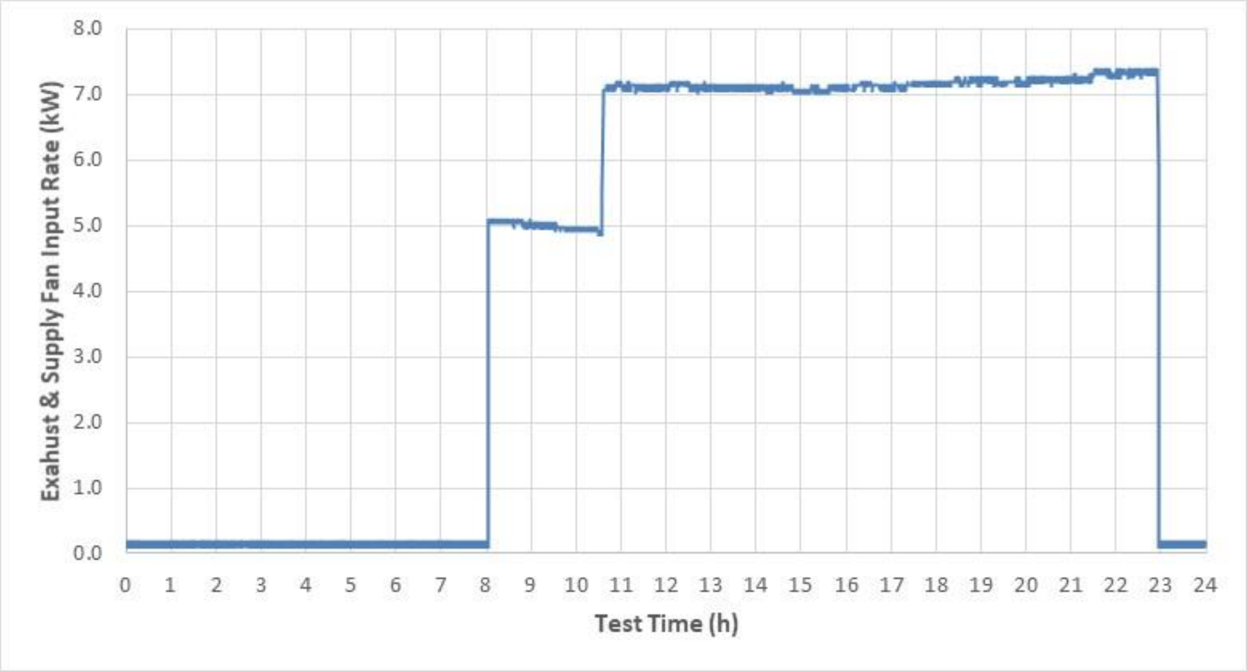
Figure 273: Supply Air Swamp Cooler

Source: Frontier Energy, Inc.

Figure 274: Kitchen Ventilation Hood

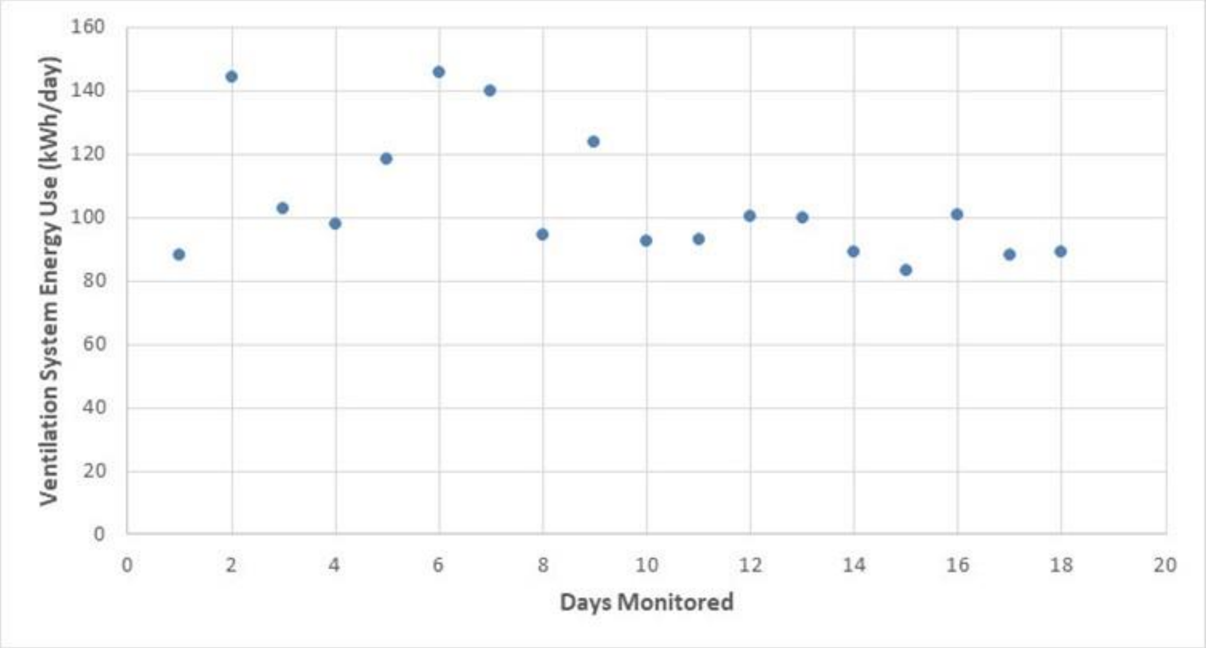
Source: Frontier Energy, Inc.

Figure 275: Versailles Exhaust and Supply Fan Energy Profile



Source: Frontier Energy, Inc.

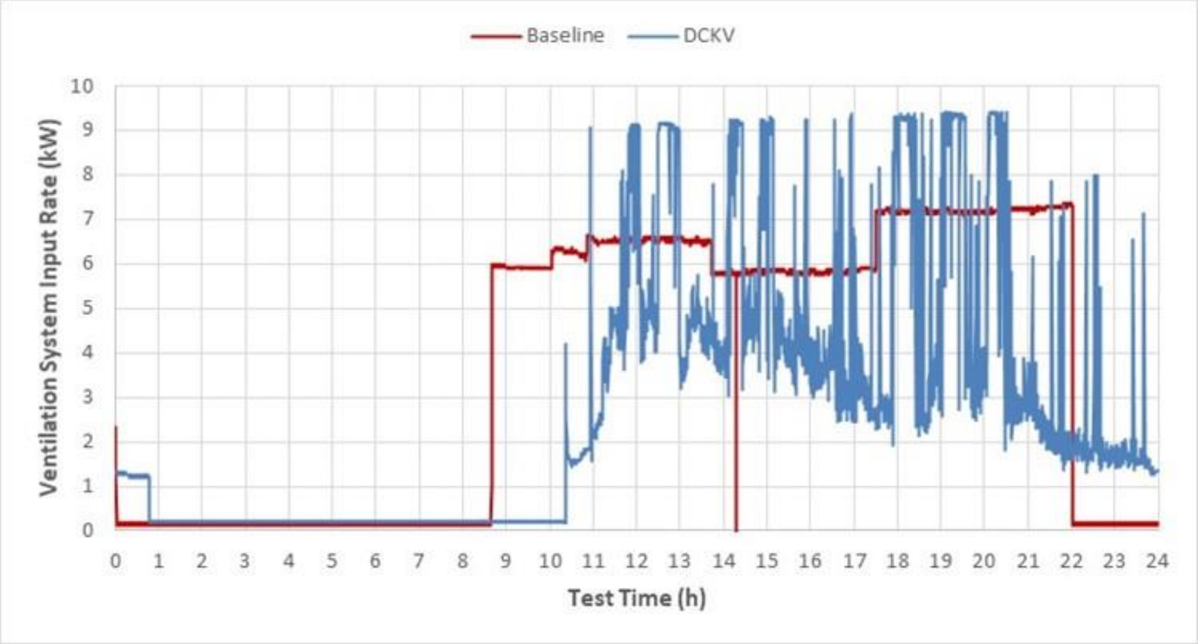
Figure 276: Versailles Ventilation System Daily Energy Use



Source: Frontier Energy, Inc.

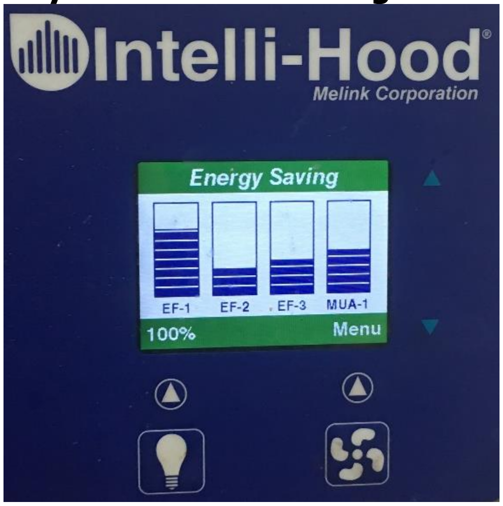
Researchers retrofitted the ventilation system with a demand controlled system. All three exhaust fans were replaced to support three-phase power including two 2 HP and one 3 HP motor. The retrofit system included three duct temperature sensors and two sets of optical sensors to control the ventilation rate. Researchers set up the fans to operate at 1700 RPM and the system could modulate between 30% and 100% fan speed. Researchers also put the system on a timer to automatically shut down between 11:30 pm and 8 am. The DCKV system reduced the energy use from 101 to 52 kWh per day for all three exhaust fans and the swamp cooler supplying air to the kitchen. The hoods were on for an average of 16.8 hours per day with an estimated airflow reduction from 11,200 to 8,700 CFM.

Figure 277: DCKV System Energy Reduction



Source: Frontier Energy, Inc.

Figure 278 DCKV System Panel Showing Individual Fan Speeds



Source: Frontier Energy, Inc.

Figure 279: DCKV System Optical Opacity Sensor in the Hood

Source: Frontier Energy, Inc.

Versailles Summary

Versailles Cuban restaurant had an average total baseline gas consumption of 53 therms per day. The cookline accounted for 43 therms per day with the remaining energy consumption attributed to water and space heating. The ovens were replaced with energy-efficient convection ovens and a combi oven. All four fryers were replaced with energy-efficient fryers resulting in 10 therms per day saved. The griddle range suites were replaced with a thermostatic griddle and stock pot ranges with finned-bottom pots and pans which resulted in additional 5 therms per day savings. Total appliance replacement resulted in 18 therms and 50 kWh per day saved, translating to 6,500 therms and 17,800 kWh saved per year at Versailles Cuban.

Table 13: Versailles Cuban Results

	Operation Time (h/day)	Pre Energy (therms/day)	Post Energy (therms/day)	Therm Savings	Percentage Savings
Double Stack Oven – Back Line	4.3	3.55	3.25	0.30	8%
Range w/ Salamander	9.8	3.50	1.75	1.75	50%
Middle Fryer – Back Line	15.5	3.78	0.13	3.65	96%
4-Burner Range/Griddle	13.3	5.93	5.12	0.81	14%
End Fryer – Back Line	15.5	3.02	Removed		0%
Double Stack Oven – Front Line	5.4	1.04*	1.62		
6-Burner Range	12.7	4.92	2.44	2.48	50%
Middle Fryer Front Line	14.8	3.40	0.13	3.27	96%
8-Burner Range/Griddle	14.5	4.87	4.35	0.52	11%
End Fryer – Front Line	15.0	4.57	2.23	2.34	51%
Steam Table	13.3	3.52	3.52	not replaced	0%
Rice Cooker	3.5	0.96	0.96	not replaced	0%
Total Energy Use		**43.1**	**25.6**	**17.5**	**41%**
Ventilation System	15.8	101 kWh/day	52 kWh/day	49 kWh/day	49%

***Baseline convection oven was not functioning properly.**

Source: Frontier Energy, Inc.

Versailles Cuban did not use an energy-intesive broiler like many other sites in this study and employed multiple range-top burners in their operation. As such, Versailles presented an opportunity to replace the existing equipment with smaller, more efficient equipment. All four existing fryers were 18″ large vat models with high-input rates and low-efficiency burners, which presented an excellent opportunity for replacement with economy ENERGY STAR fryers costing only $2,400 each. With over 10 therms per day saved, the new fryers presented only a 2.5-year payback. Fryer savings were taken further by upgrading two of the fryers to a best-in-class fryer array with built-in oil filtration. Energy-efficient fryers have better temperature uniformity with less hot spots that scorch and carbonize cooking debris that can significantly reduce oil longevity. Frequent oil filtration removes these particles and increases oil life. Versailles Cuban reduced their oil usage by over 42 jugs per month through fryer replacement and routine oil filtration, which resulted in over $10,000 annual oil savings.

The versatility of the new combi oven allowed the restaurant to cook the same menu items using different appliances. The multistep process of cooking Versailles’ signature chicken dish was time consuming and required the use of several appliances: a convection oven and a fryer. The combi oven could be programmed to perform the multistep process within the same cavity. The transition to the combi greatly reduced overall cooking time and appliance energy use. The process change furthermore provided better management of production, allowing the restaurant to prepare smaller batches and avoid food waste. Other menu items traditionally cooked on the rangetop could also be cooked in the combi oven using steam injection to reduce rangetop energy use and maximize productivity.

Range burners are inherently inefficient appliances with no direct energy reduction alternatives. Utilizing energy-efficient cookware improves heat transfer between the burner and the cooking vessel. This results in faster cook times to heat up a traditional container. The project replaced Versailles' 80 pots and pans with finned-bottom TurboPots resulting in $2,200 annual energy savings while saving time on cook-to-order items. Pot and pan replacement with finned-bottom cookware is a simple and cost-effective way to reduce energy without having to replace an entire appliance.

While most appliances replaced qualify for existing California rebates, the cookware findings from this project demonstrate energy savings that could support finalization of an in-progress energy-efficient cookware workpaper for a potential rebate category. Other unique appliances examined in this study, like the rice cooker and the steam table, require further research to discover potential energy-efficient alternatives.

Versailles Cuban serves as an energy efficiency success story with $6,370 annual gas savings and $2,675 annual electric savings achieved with appliance replacement. The replaced equipment with an estimated cost of $65,000 including DCKV install qualified for $8,550 in rebates. With annual fryer oil savings of $14,400 added to the energy savings, the ROI for the entire cookline replacement is only 2.8 years.

EIS System Implementation

Frontier Energy deployed an energy information system (EIS) at Versailles Cuban Restaurant to increase owner/operator visibility of energy usage information and determine whether the system could result in additional energy savings. Researchers removed manual retrieval data loggers previously affixed on the gas meters and connected the gas meters to the EIS directly. Twelve appliances were connected to the EIS in total: three fryers, three ovens, five ranges, and a griddle.

Figure 280: EIS Data Collection Hardware with 3 Transmitters in a Central Location

Source: Frontier Energy, Inc.

Figure 281: EIS Component Wiring to Gas Meters

Source: Frontier Energy, Inc.

The EIS system consisted of receiving nodes that could accommodate up to 3 inputs. The system had a total of 4 nodes with 12 inputs. Three gas meters were connected to each node. The nodes were then connected to a receiver, which accumulated the gas data (similar to a hub). The receiver was connected to a portable wireless router with internet access. The gas usage data was uploaded to the cloud and hosted on the EIS vendor's server. The system uploaded data to the server at 15-minute intervals.

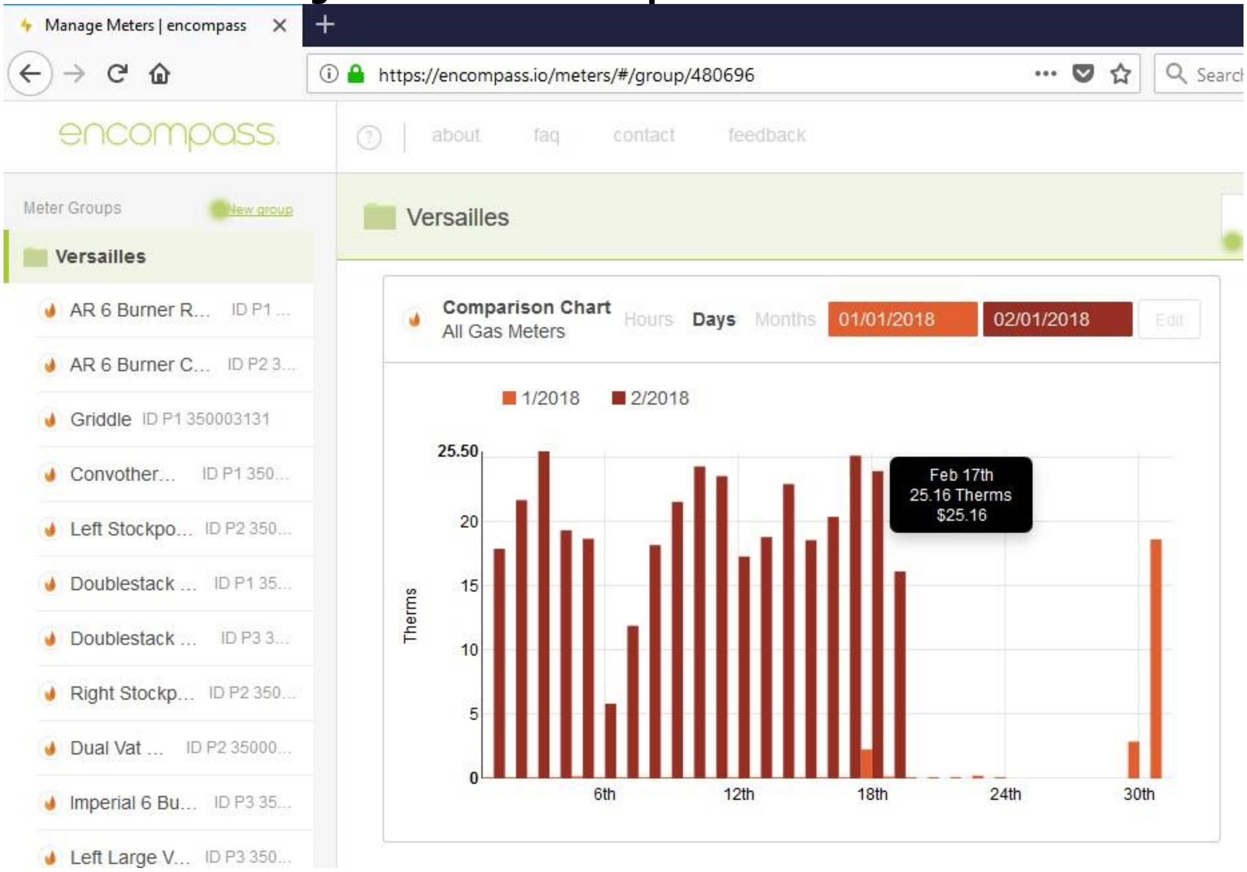
The entire setup was consolidated in an enclosure and run off a 120 volt <15 amp. Wires from the nodes to the gas meters were routed along the gas lines to reduce the probability of the staff damaging the setup during cleaning.

Figure 282: EIS System Connections at Gas Meters

Source: Frontier Energy, Inc.

Frontier Energy presented the owners of Versailles Cuban with two different interfaces to view their energy data from the cloud. The first was an *encompass.io* account which was pre-formatted by the Frontier Energy team to display overall energy usage data in an effective and user-friendly manner. The main account page visually displays cumulative energy usage from all twelve gas meters using a bar graph with daily energy use expressed in both gas usage and monetary cost. Similar bar graphs were also generated for each individual appliance for the operator to compare costs and optimize their cooking operation for best practices. Credentials (username/password) were required to access the information and the interface could be viewed from any computer or tablet, inside or outside of the restaurant.

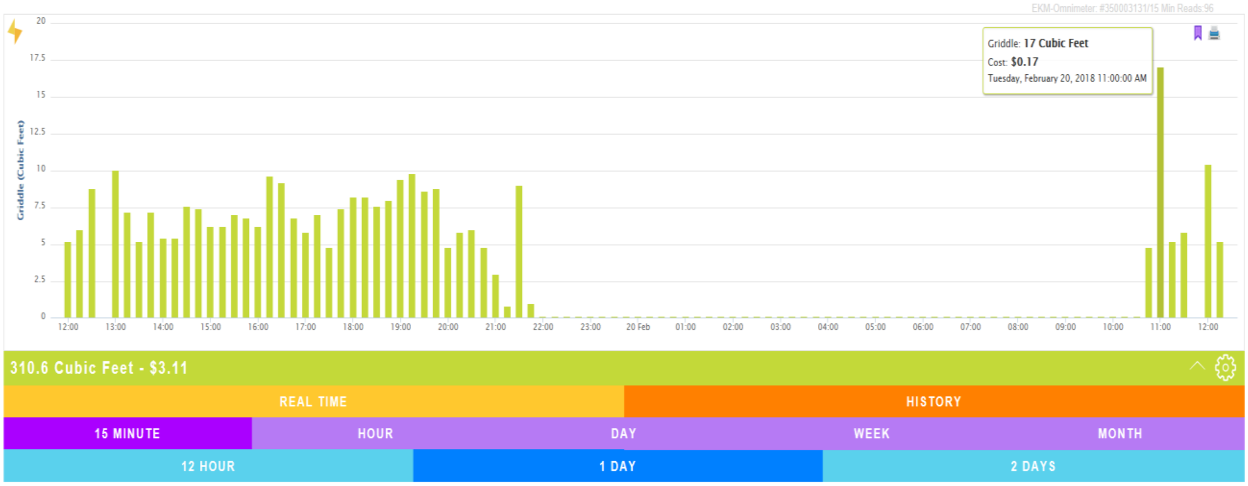
Figure 283: EIS Encompass Interface View



Source: Frontier Energy, Inc.

The second interface incorporates online widgets, which provide more detailed and customizable data visualizations for each individual appliance. Unlike the Encompass interface, which is better for longer viewing windows, the widgets can portray the data with higher granularity. The widget graphs allow up to 15-minute intervals, giving operators a complete picture of how each appliance is being operated. This includes critical data like fire-up and shutoff times, along with energy usage during slow business periods, all of which are key energy-saving opportunities. The widget view helps pinpoint inefficiencies with how each individual appliance is being used. By combining big-picture insights from the Encompass interface with detailed analysis from the Widget interface, owners can experiment with their current operational setups to determine the best way to run their kitchens. Operators can identify issues with Encompass and figure out how to best solve them using the Widgets.

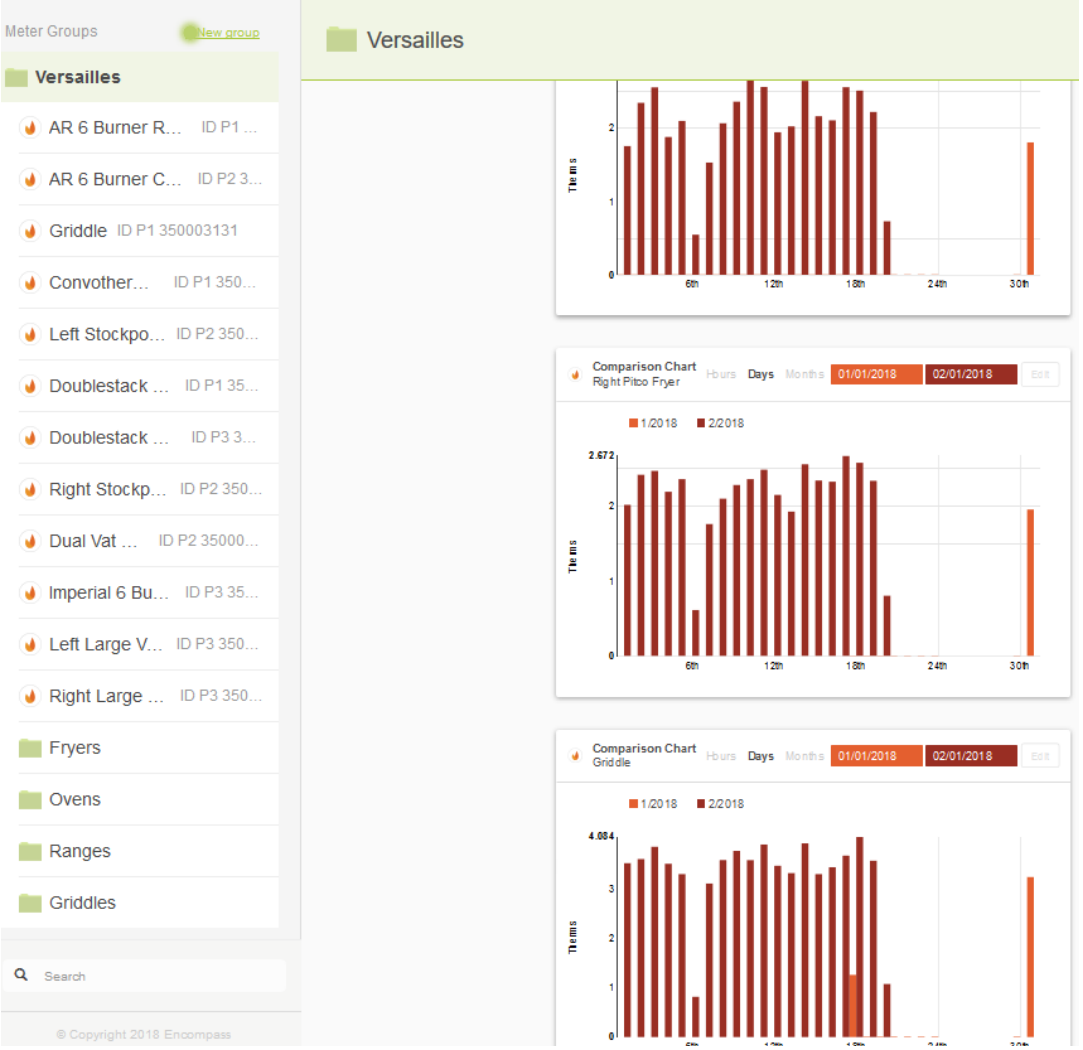
Figure 284: EIS Widget Interface View for Griddle Daily Usage



Source: Frontier Energy, Inc.

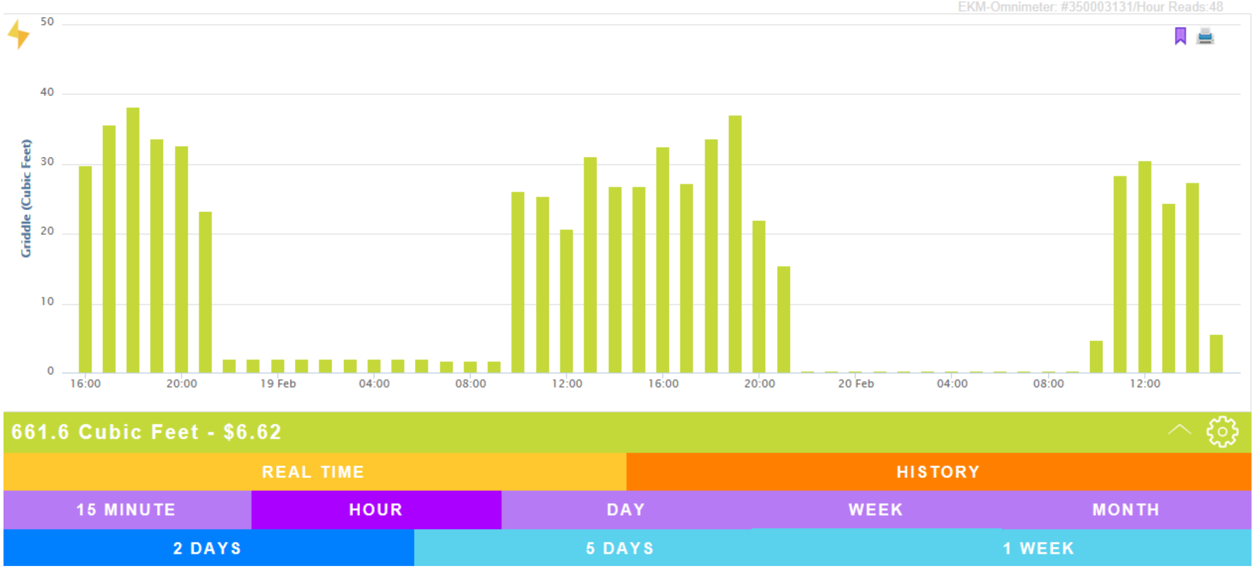
For example, the Encompass site shows that the griddle is currently the highest energy-consuming appliance with a daily average of around 3.5 therms. A closer look at the data via the Widget shows a large spike around 11 am, which would correspond to the initial fire-up, followed by a steep drop in energy usage until another spike at about 12 pm. This indicates that the griddle was turned on earlier than necessitated by demand, since it was idling for almost an hour after startup before finally being used for a cook load. Similarly, the griddle dropped to idling levels after 8 pm, but was not turned lower and cleaned until 9:30 pm. These inefficiencies are somewhat necessary to keep the kitchen ready for service throughout all of its operating hours, but indicate possible savings opportunities by idling at lower rates or making small timing adjustments. The EIS also makes it very clear when an appliance has not been properly shut off, saving energy that would be wasted throughout the night.

Figure 285: EIS Encompass Interface Appliance Daily Energy Use Comparison



Source: Frontier Energy, Inc.

Figure 286: EIS Widget Graph Indicating Failure to Shut Griddle

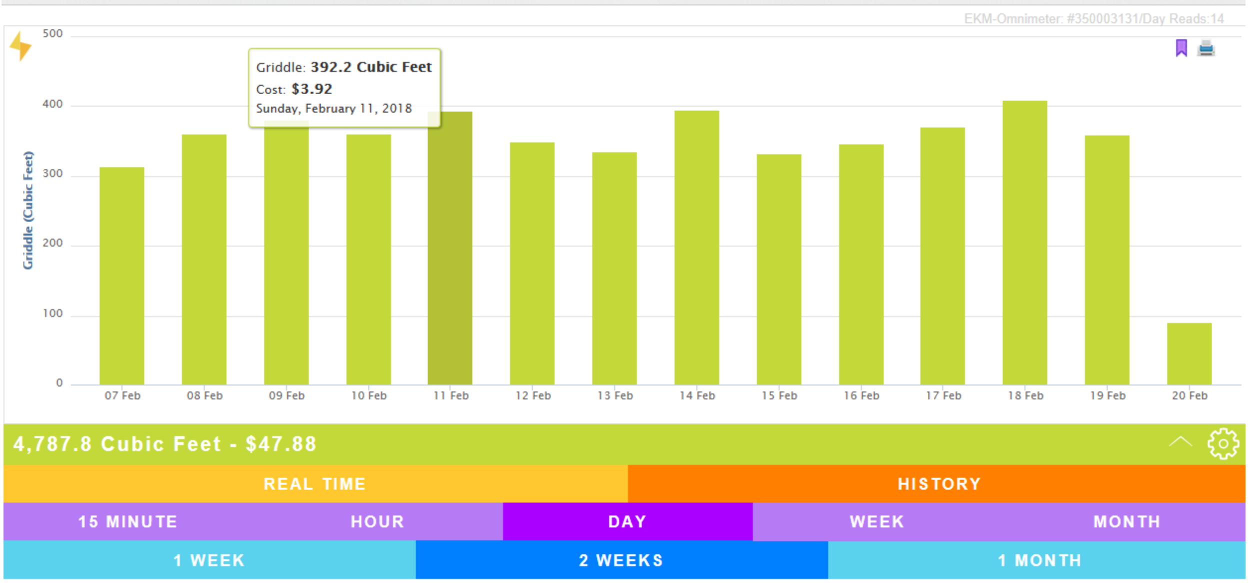


Source: Frontier Energy, Inc.

The owners of Versailles Cuban Restaurant are already taking advantage of the newly revamped cookline to make significant operational changes. With the new combi oven, which reduced the initial cook time of their most popular chicken dish by about 50%, the restaurant has switched from large batch cook and rethermalizing methodology to a small batch and holding method. This has generated large energy savings from reduced fryer usage; these savings can now be seen and quantified by the easily accessible EIS system. With three ovens, three fryers, five ranges, and a griddle now at the kitchen’s disposal, the chef has many equipment choices when deciding how to cook a particular dish on the menu. The EIS allows the kitchen manager to see the most energy-efficient cooking method and determine which piece of equipment to use in the future.

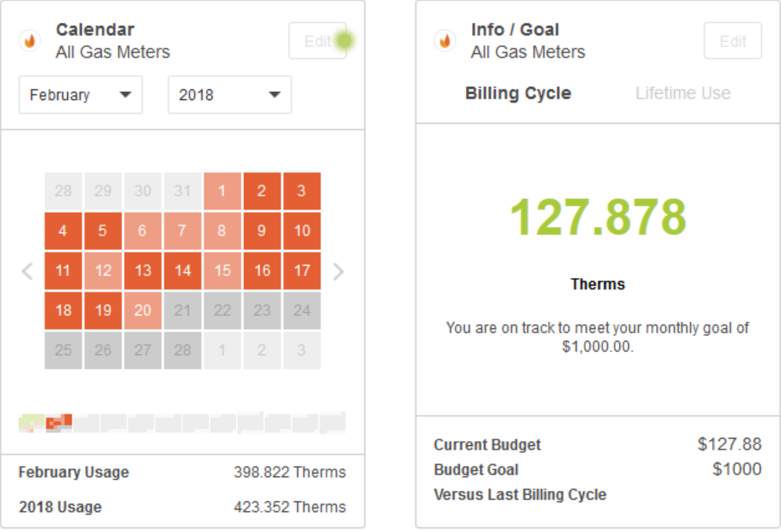
The following EIS-generated graph shows the restaurant’s daily energy usage by appliance, which allows operators to correlate the number of customers served with their energy impact.

Figure 287 Replacement Energy-Efficient Griddle EIS Energy Consumption by Day



Source: Frontier Energy, Inc.

Figure 288: Encompass Energy Planning Tools



February Usage 398.822 Therms
2018 Usage 423.352 Therms

127.878
Therms

You are on track to meet your monthly goal of $1,000.00.

Current Budget $127.88
Budget Goal $1000
Versus Last Billing Cycle

Source: Frontier Energy, Inc.

Owners can also use the Encompass planning tools to set energy usage goals, encouraging changes in practices needed to meet these goals. These can be set cumulatively while initially experimenting with different energy saving measures and then on an individual appliance basis, to serve as an alert for ensuring that the reduced energy consumption level is maintained.

CHAPTER 7: Oliver's Market

Oliver's Market is a North-Bay grocery store chain which serves, among other prepared items, rotisserie chickens. Frontier Energy researchers measured the energy impact of cooking chickens at two Oliver's Market locations in Cotati and Windsor, CA. The store in Cotati is the first location in the chain and uses a conventional rotisserie, whereas the store in Windsor is newer and cooks its chickens in a combination oven. Both stores sell similar numbers of rotisserie-style chickens, but the conventional rotisserie used 7.8 therms per day while the combi used 2.5 therms per day.

Figure 289: Oliver's Market Cotati

Source: Frontier Energy, Inc.

Figure 290: Oliver's Market Windsor

Source: Frontier Energy, Inc.

Figure 291: Oliver's Market Rotisserie

Source: Frontier Energy, Inc.

Figure 292: Oliver's Market Combi Oven

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RIGHT SIDE 2 IN.

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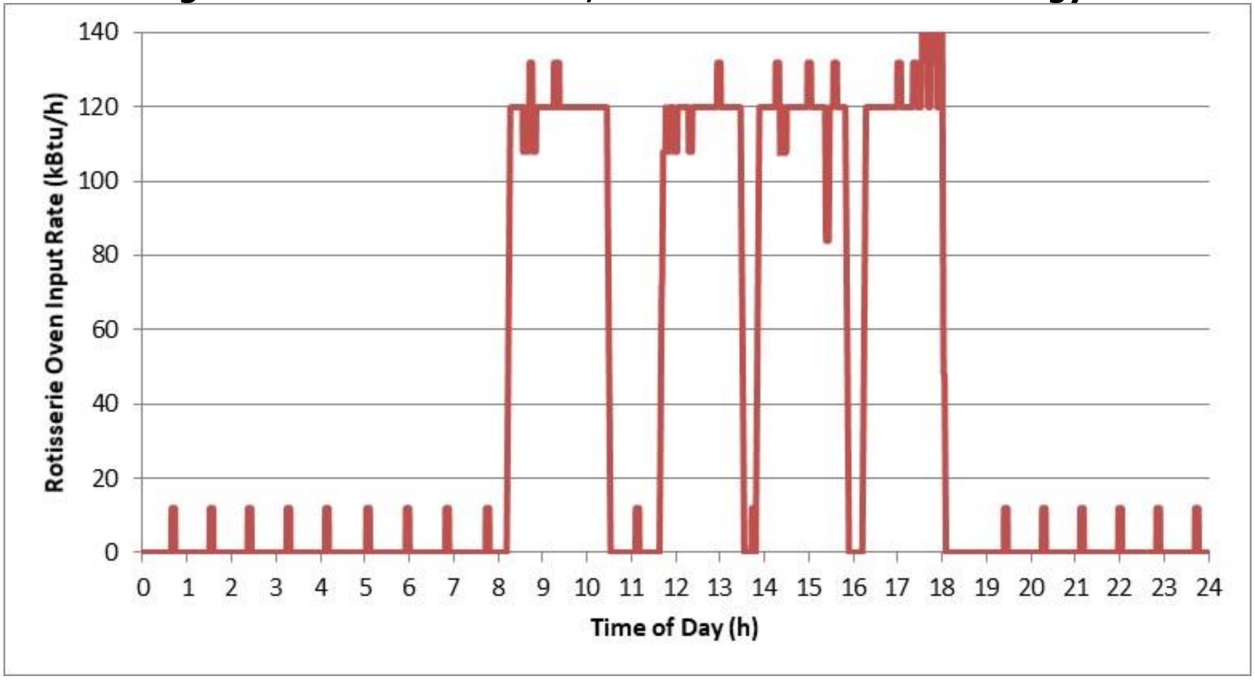
NSF

INTENDED FOR OTHER THAN HOUSEHOLD USE

PRUDUCT NO. SCC 102G
proudly assembled by
Adolf Runge

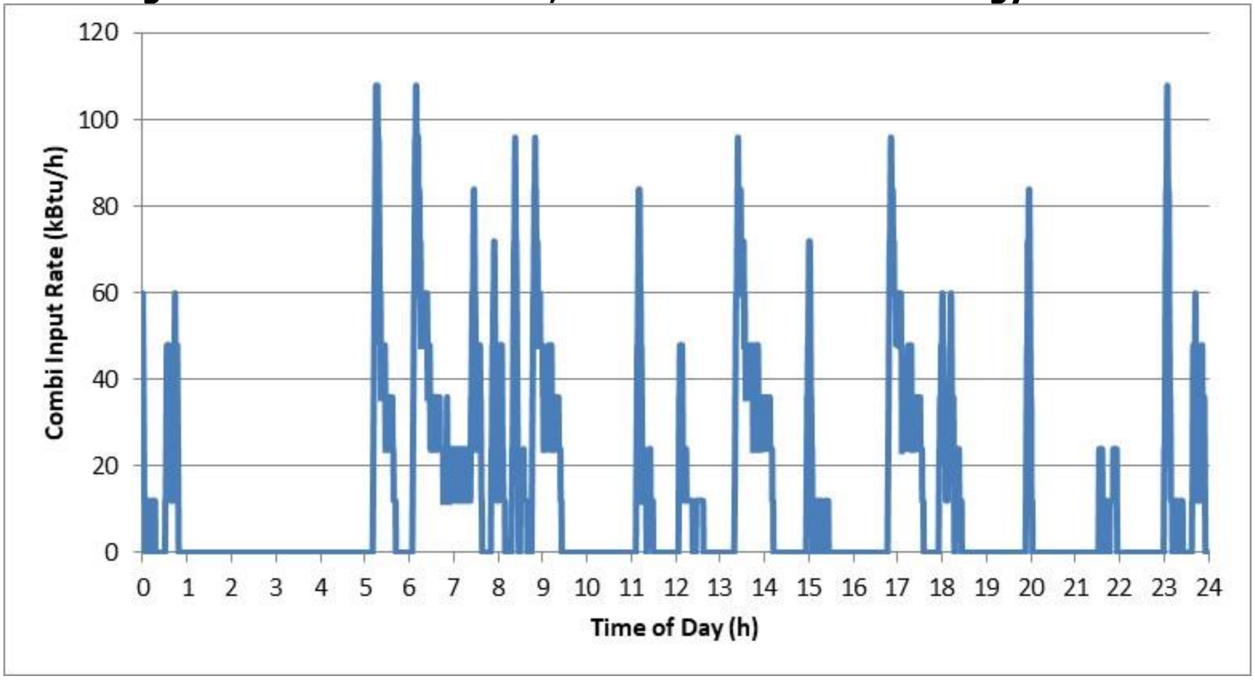
Source: Frontier Energy, Inc.

Figure 293: Oliver’s Market, Cotati Rotisserie Oven Energy Profile



Source: Frontier Energy, Inc.

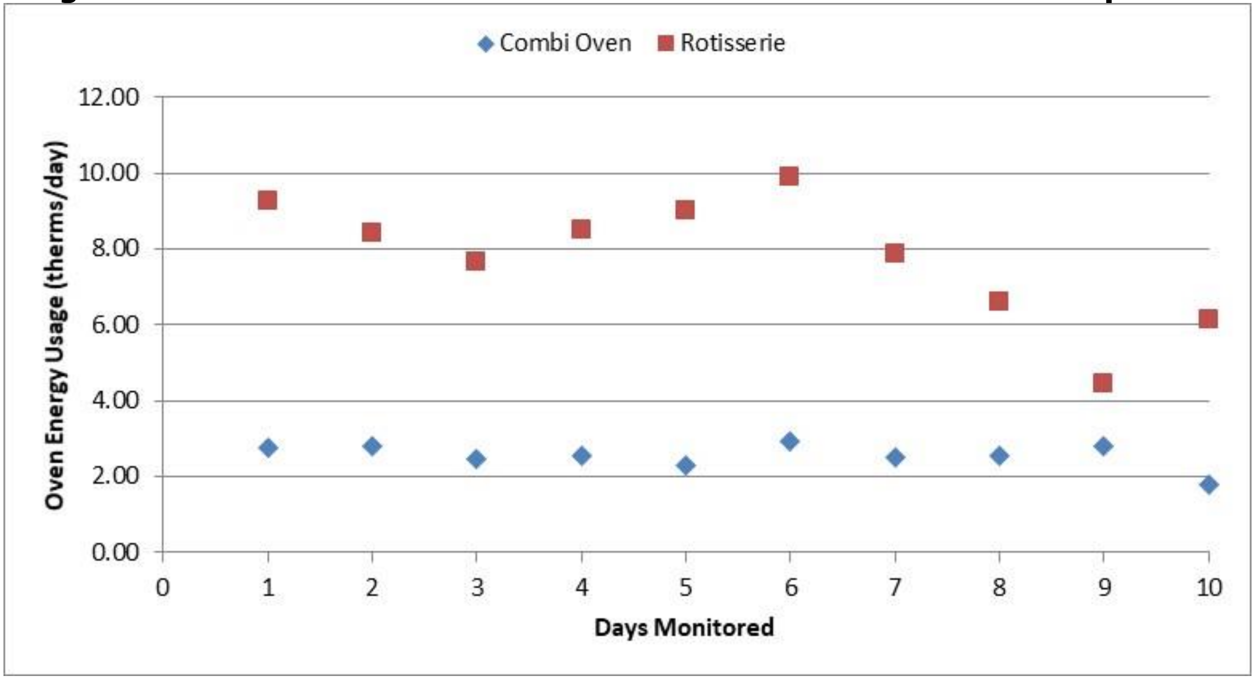
Figure 294: Oliver’s Market, Windsor Combi Oven Energy Profile



Source: Frontier Energy, Inc.

The combi demonstrated a more variable energy use profile than the rotisserie. During each cook cycle, the combi uses a burst of gas to recover to its setpoint cavity temperature, then uses gas at a lower rate to maintain cooking conditions. This use pattern led to a much more efficient operation. Operators also turned the combi completely off when it wasn’t cooking, which avoided idle energy losses typically observed in other foodservice establishments. The combi oven was used more often per day than the rotisserie partially because the combi can cook a smaller number of chickens at one time than the rotisserie. However, the combi has a shorter overall chicken cook time. Based on late operating hours and more frequent cook cycles, staff also used the combi to cook items other than chicken, since some observed cook times were much shorter than the minimum cook time for whole chickens. The amount of energy used for cooking just chicken is likely significantly less than what researchers measured in this study.

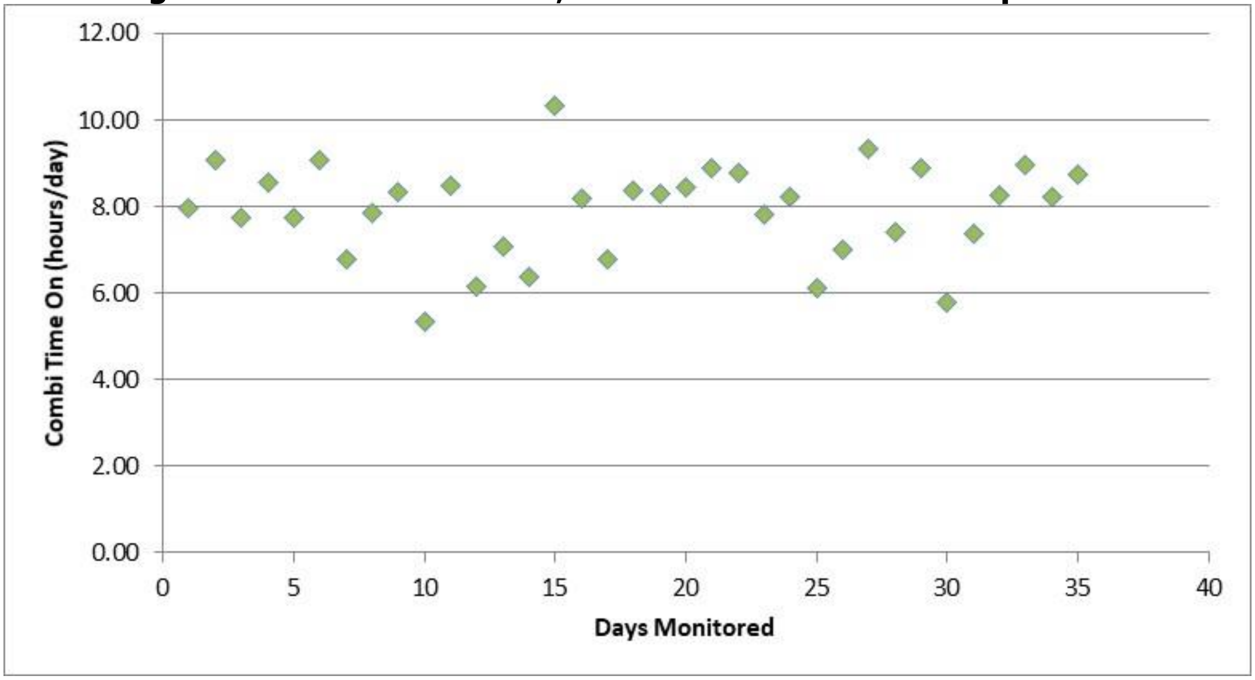
Figure 295: Olivers' Market Combi and Rotisserie Oven Profile Comparison



Source: Frontier Energy, Inc.

The total energy use for the rotisserie depended almost entirely on how many loads of chicken were cooked on a given day, and therefore varied greatly on a day-to-day basis. It should be noted that on days 9 and 10, the rotisserie only had two cook cycles as opposed to its normal 3 or 4. By contrast, the combi's daily energy use was more consistent throughout the monitored period.

Figure 296: Oliver's Market, Windsor Combi Hours of Operation



Source: Frontier Energy, Inc.

Apart from several outlier days, the combi was in use for about 8 hours per day, which is consistent with the small degree of variation in its daily energy use.

CHAPTER 8:
Appliance NO_x Measurement

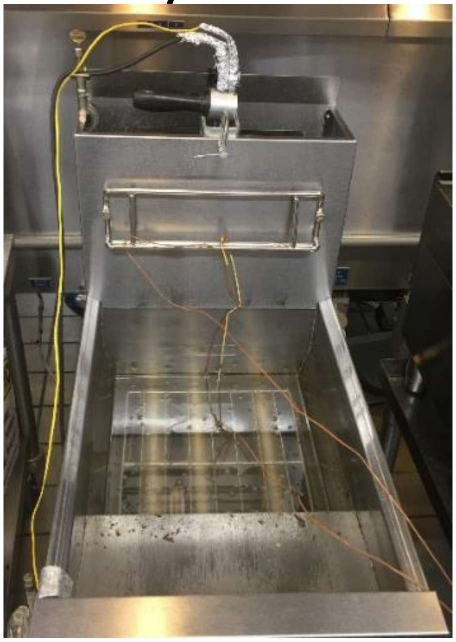
Introduction

The foodservice industry is arguably the highest energy consumer per square foot in the commercial sector. Energy consumption and emissions generation are interrelated. To better understand emissions generated by commercial kitchen appliances, researchers measured emissions directly at the appliance source. The focus of this NO_x emissions study was to measure the range of NO_x values in commercial foodservice equipment operation to serve as a foundation for further emissions research in the foodservice industry.

Frontier Energy, Inc. partnered with researchers at SoCalGas and GTI to perform combustion analysis and measure O_2, CO, and NO_x emission concentrations from several types of gas-fired appliances including ovens, griddles, fryers, steamers, and broilers. The object of this research project was to develop and demonstrate a test procedure for measuring emissions on gas-fired commercial cooking equipment. For each appliance type, emissions were characterized based on burner type and the associated NO_x and CO readings. The burner systems developed and installed for each commercial appliance were tested for NOx emissions, using the best available sampling and analysis methodology. SoCalGas researchers collaborated with Frontier on NOx measurement test method development and provided graphs on modulating and snap action thermostats as well as griddle sampling methodology diagrams.

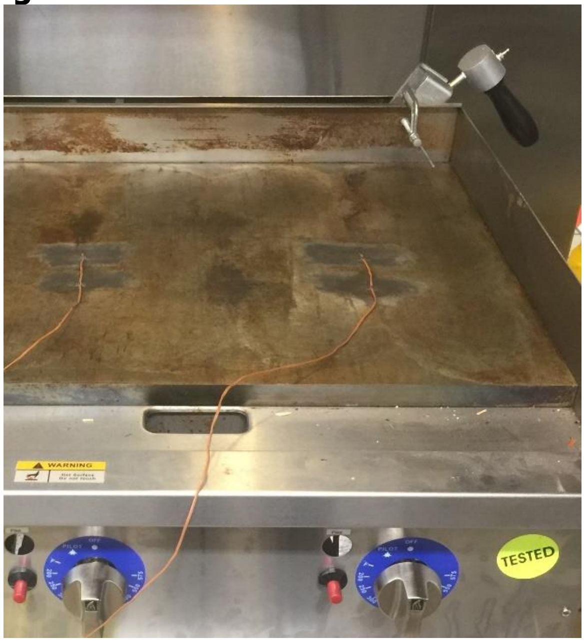
The testing was comprised of three primary activities: Evaluation of draft protocols for measuring NO_x emissions form commercial cooking equipment, Laboratory based testing of a sample of baseline and energy efficient appliances, and field measurement of the NO_x emissions from the existing baseline and energy-efficient replacement appliances at four demonstration sites. The Laboratory emissions testing was conducted following the individual ASTM test methods for input rate, preheat and idle energy consumption. Flue sampling methods in both lab and the field environments followed draft protocols under development by the ASTM F26 committee on Food Service Equipment for the individual appliance types and flue configurations (see Figures 297 and 298).

Figure 297: Fryer Flue Measurement



Source: Frontier Energy, Inc.

Figure 298: Griddle Flue Measurement



Source: Frontier Energy, Inc.

Figure 299: NO_x Analyzer Calibration Gases

Source: Frontier Energy, Inc.

Figure 300: NO_x Analyzer Thermoelectric Cooler

Source: Frontier Energy, Inc.

Frontier Energy measured combustion emissions with a calibrated portable handheld Enerac 500 v3 dry gas emissions analyzer. Each appliance was tested to determine the amount of nitrous oxide and carbon monoxide emissions generated. NO_x is generated only at high temperatures when a flame causes nitrogen in the fuel or air to combine with oxygen via the combustion process. With burner temperatures being the primary driver of NO_x generation, the highest NO_x concentrations occur at the end of an appliance preheat and at the end of each consecutive burner cycle. The total mass of NO_x generated by an appliance is dependent on the duration and frequency of the burner duty cycle. Energy consumption data from the field sites was used to estimate the amount of emissions generated per year for different appliance types.

Appliance Burner Types

Foodservice appliances use a variety of burners for heating air or contact surfaces to transfer heat for cooking processes. Each burner type is designed for the specific application and each manufacturer may use different burner designs for the same appliance category. Burner types often determine appliance cost and appliance cooking and combustion efficiencies.

Atmospheric burner is the most common burner used in gas appliance designs. Atmospheric burners are gas burners that use the appliance gas inlet pressure to entrain primary-air to the burner where it is mixed with gas. The atmosphere provides the air needed for combustion without the need for a mechanical blower. These burners rely on a fuel/air mixture to be controlled by the gas volume and pressure; the primary air mixture is controlled by air shutter openings. As gas and air enter the Venturi (mixing chamber), this mixture is released out of the burner tube through burner ports (holes/openings). When ignited, these ports will burn as a blue flame with the correct volume of secondary air to support combustion. The design shape of these burners can be straight, U-shaped, T-shaped, or custom shaped to the appliance.

Figure 301: Straight Steel Tube Burner

Source: Partstown

Figure 302: Steel Tube U-Burner

Source: Partstown

Atmospheric burners are suitable up to approximately 100,000 Btu/h. Many of the lower cost and lower efficiency appliances are designed with this type of burner requiring less components to operate. Burners are typically cast iron or steel tube with round ports that are drilled or punched. Some of the stamped steel burner designs use lanced or slotted holes as ports resulting in different flame patterns.

Figure 303: Cast Iron H-burner

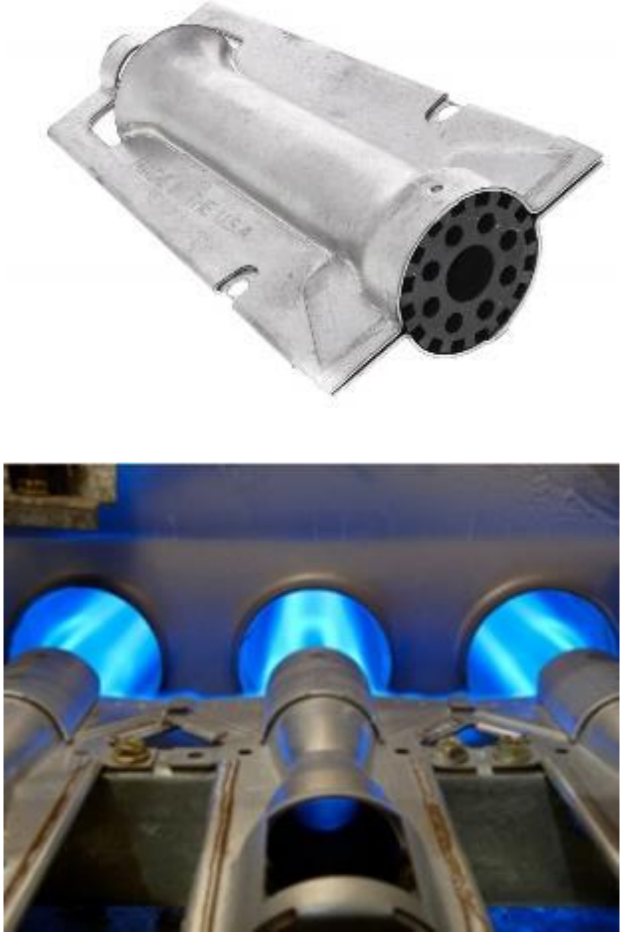
Source: Partstown

Figure 304: Cast Iron Range Burner

Source: Partstown

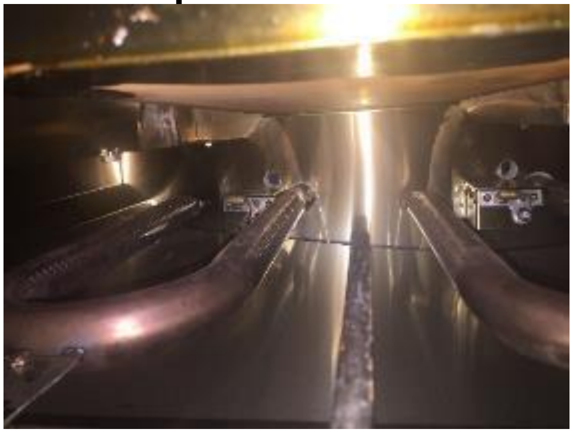
Another atmospheric burner style is referred to as an "in-shot" burner. Gas fuel under pressure passes through a central port located at the inlet of a burner Venturi. These burners develop a torch-like flame typically used in air heating. These burners are commonly 20,000 Btu/h or lower each and designed to operate in multiples for higher total input appliances.

Figure 305: In-Shot Burner



Source: Upper image, Partstown; lower image, Alpine Temperature Control

Figure 306: Atmospheric U-Tube Burners Griddle D



Source: Frontier Energy, Inc.

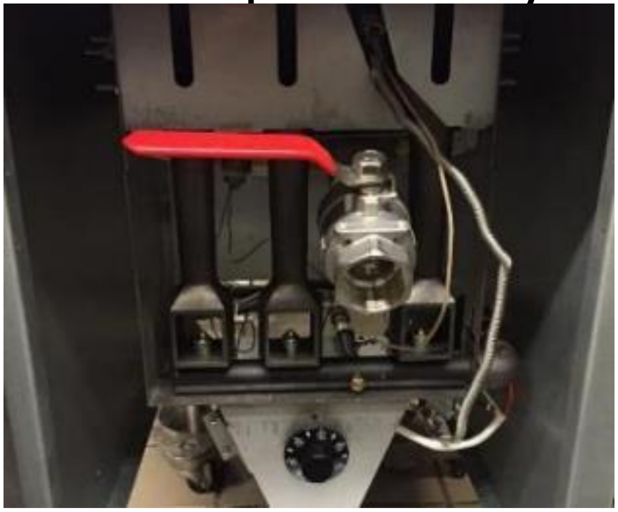
Figure 307: Atmospheric U-Tube Burners Griddle C

Source: Frontier Energy, Inc.

Figure 308: Atmospheric Burners Fryer G

Source: Frontier Energy, Inc.

Figure 309: Atmospheric Burners Fryer B & F



Source: Frontier Energy, Inc.

Infrared Burner (IR) is a heating surface that uses light in the infrared spectrum to produce heat energy. This technology creates even heating over the entire surface of the burner, making it a popular choice to heat cooking surfaces that require uniform temperature distribution such as a fryer vat or a griddle. Short-wave IR energy generated by these burners can also be used for cooking food directly as with salamanders and over-fired broilers. These box burners have a wire mesh or ceramic surface with air passageways. The air-fuel mixture is supplied into the enclosed box typically with a mechanical fan controlling the primary air-fuel mixture (power burner). The short flame heats the burner surface to 1,100-1,500°F or greater resulting in infrared heat. Due to their high initial cost, IR burners represent only 5% to 10% of gas fryers or griddles in the marketplace.

Figure 310: Ceramic Tile IR Burner

Source: Partstown

Figure 311: Cylindrical IR Burner

Source: Partstown

Figure 312: Infrared Burners Griddle C

Source: Frontier Energy, Inc.

Power Burners force a controlled volume of air into the air-to-fuel mixture by a mechanical blower. Power burners can mix with greater amounts of gas than atmospheric burners while sustaining the constant air-to-gas mix ratio. Greater efficiencies and performance are achieved by regulating the excess air which drives down burner efficiency in atmospheric burners. These types of burners are typically used on large rack ovens as well as combination ovens and high-end fryers with input rates exceeding 100,000 Btu/h. Burner air-to-fuel ratio can sometimes be controlled by a variable frequency drive fan motor for the blower that can increase or decrease the airflow to the mixing valve.

Like infrared burners, power burners operate with little or no excess air, allowing a greater percentage of the energy generated by combustion of gas to be transferred to the appliance. Power burners can be used with either standard or IR burners.

Figure 313: Power Burner – Combination Oven (Blower on the left, Gas Regulator on the Right)

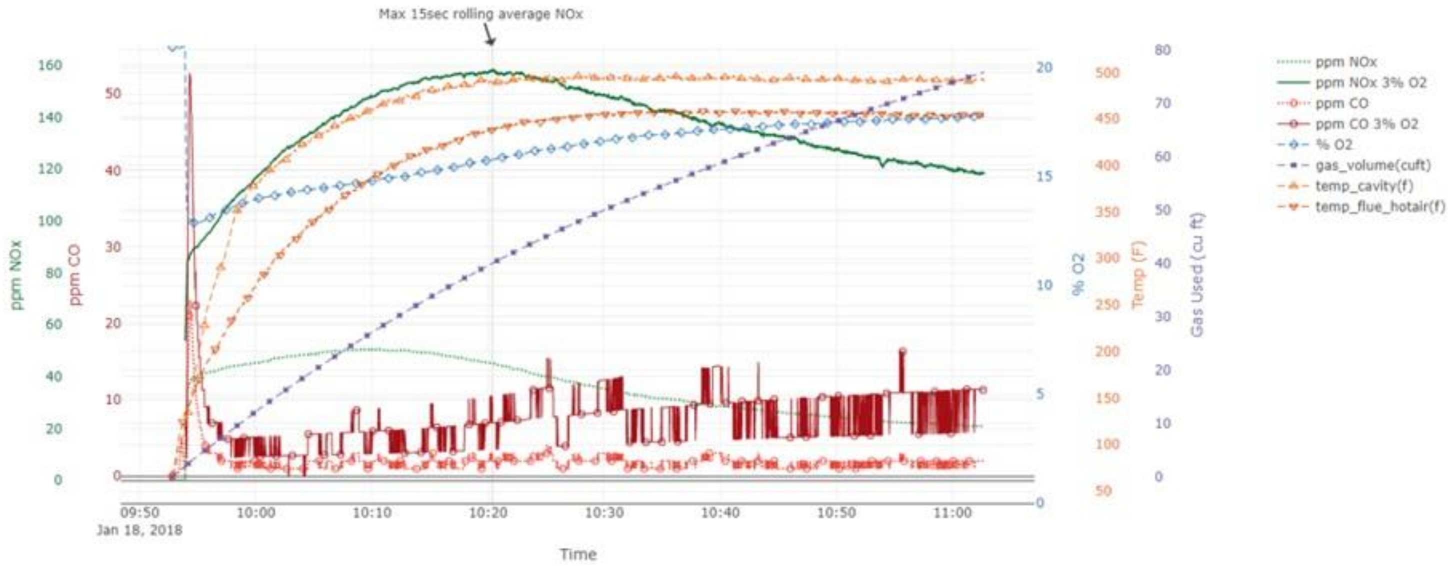
Source: Frontier Energy, Inc.

Burner Control Strategies

Modulating and snap action are the two primary types of thermostat controls. The difference between the two thermostat strategies determined when researchers took final NO_x and CO readings.

Modulating (or throttle) thermostats adjust the gas flow incrementally to achieve a "soft landing" at the set point temperature without overshoot. These types of thermostats typically include a flame bypass, which maintains a minimum flame level in the burner as long as the appliance is on. Modulating thermostats use bulb-type sensors. They are typically used in low-cost appliance models and have slower responses than snap action sensors. Although modulating is less popular than the snap action thermostat, they are sometimes used in convection ovens and pizza ovens. NO_x and CO readings from modulating thermostats were taken at peak NO_x readings before the burner started throttling down. Modulating thermostat appliances may operate at a fraction of the input rate most of the time and the peak NO_x value may overstate the average emissions value. It is recommended that two measurements are made: one at peak during preheat and another during stabilized idle operation.

Figure 314: Emissions profile of a convection oven with a modulating thermostat

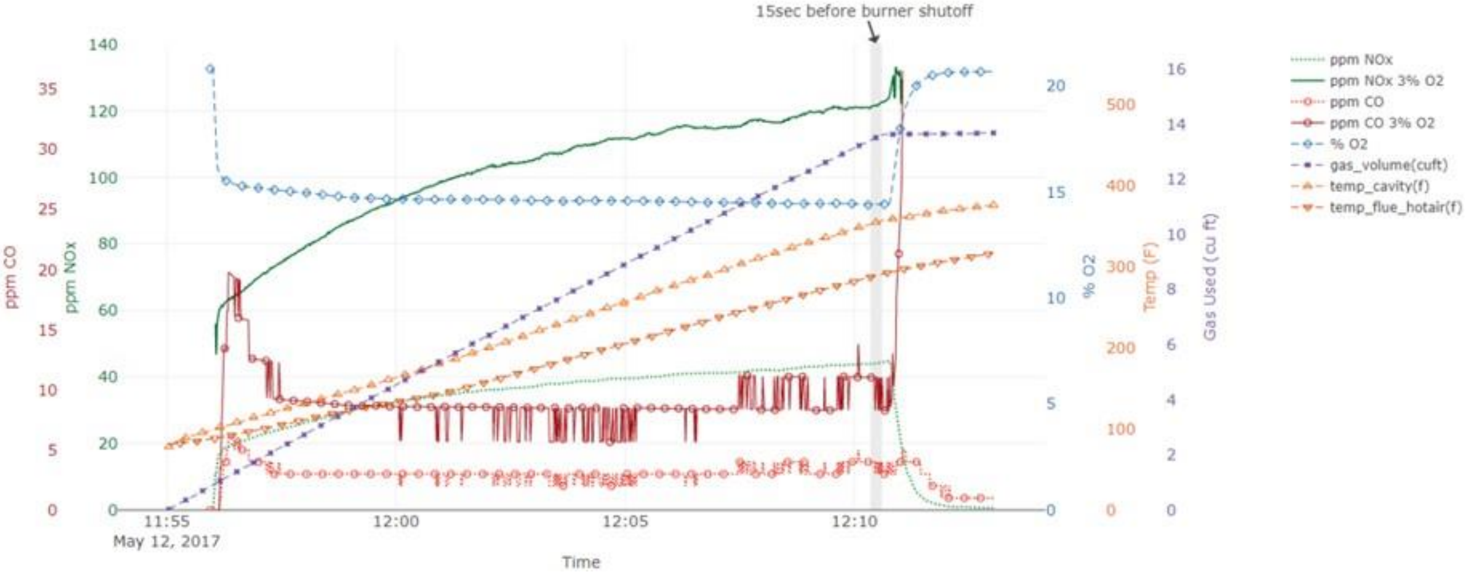


The concentration of NO_x and CO along the primary vertical axis, O_2%, Oven Cavity Temperature (˚F), and total volume of gas consumed (ft^3) along the secondary vertical.

Source: Jason Wang, Southern California Gas

Snap action thermostats turn the burner on or off based on sensing temperature. These thermostat valves can either be mechanically controlled (spring clip) by the working fluid from the sensing bulb or electrically controlled by a solenoid (solid-state sensor). The function of the two types of snap action thermostats is essentially the same with the electrically-powered thermostats exhibiting a tighter bandwidth around the setpoint than the mechanical variety. Final NO_x and CO readings from snap action thermostats were taken right before the burners cycled off.

Figure 315: Emissions profile of a convection oven with a snap action thermostat



The concentration of NO_x and CO along the primary vertical axis, O_2%, Oven Cavity Temperature (˚F), and total volume of gas consumed (ft^3) along the secondary vertical.

Source: Jason Wang, Southern California Gas

Appliance Types Tested

Researchers tested the following commercial appliances for NO_x emissions: fryers, griddles, ovens, steamers, combination ovens, broilers, and ranges. Fryers, ovens, combination ovens, and steamers typically have small-to-medium diameter concentrated flues located near the top or back of the appliance. Griddles have a wide flue located at the back of the appliance. Broilers and ranges have no flue with open flames directly contacting the cooking vessel or cooking grates. The flue geometries of each appliance type determined the sampling methodology:

Fryer (medium width rectangular flues) is an appliance where food is cooked by being placed in hot oil between 325-375°F. The oil is contained in a vat and heated by burners underneath or by a submerged heat exchanger.

Griddle (wide, rectangular flues) is a device for cooking food in its own juices by direct contact with a hot surface at 350-405°F that is heated underneath. The flue usually spans the entire width of the griddle. Atmospheric burner griddles represent the low-end of the heavy-load cooking efficiency range for griddles. However, the best atmospheric gas griddles can approach the performance of an infrared griddle in heavy-load cooking efficiency and idle energy consumption rate. Atmospheric griddles commonly use a U-shaped burner for every linear foot of cooking surface with the curved end facing the back of the griddle. Griddles usually have one or two burners per linear foot.

Convection Oven (medium width rectangular flues) is a device that uses forced convection and radiant heat to cook food products. Heat is produced in a compartment underneath the cooking cavity.

Combination Oven (small, concentrated flues) is a device that combines the function of hot-air convection (oven mode), steam injection (steam mode), and a combination of both to perform steaming (low- or high-temperature steaming), baking, roasting, rethermalizing, and proofing of various food products. In general, the term combination oven is used to describe this type of equipment, which is self-contained. Boiler-based combination ovens often have two flues, one for the boiler burner and another for the hot-air burner.

Rack Oven (small to medium flues) is a stainless-steel box capable of high-production baking and roasting in a relatively compact space. These large capacity, roll-in rack ovens fill the requirements of high-volume institutional operations. The ovens are often shipped to the site in separate pieces and assembled on site. Cooking cavity heating is done using a large power burner that heats up a heat exchanger connected to the cavity.

Steamer or steam cooker (small, concentrated flues) is a cooking appliance where heat is imparted to food in a closed compartment by direct contact with steam. The compartment can be at or above atmospheric pressure. Steam can either be generated within the cooking cavity or in a separate compartment (boiler).

Underfired Broiler (no dedicated flue, large surface area) is an appliance where the food is cooked by radiant heat generated by burners that are covered with radiant plates of various shapes. Food is placed on a grate that is heated by the radiant plates. Operating temperatures vary between 500°F and 700°F.

Range (no flue, concentrated open burner) is a device for cooking food by heating a cooking vessel, usually a pot or pan. Most commercial ranges have a pilot light for each burner.

Fryers, convection ovens, combination ovens, and steamers typically have dedicated small-to-medium diameter flues. Combustion gases concentrate in smaller flues before exiting, allowing for a more uniform measurement sample. As such, researchers should use a direct, single point probe for measurement on these appliances.

Griddles have dedicated flues that are wide and may have different concentrations of gases depending on the measurement location in the flue. To obtain the most accurate measurements, a manifold probe that spans the width of the griddle should be used. The manifold probe spanning the width of the flue has multiple gas intake openings that provide a more uniform flue gas sample. The manifold probe should have at least 4 openings and span at least the width of the burner or 12″. If using a single point probe, at least 3 measurements must be conducted in different locations of the griddle flue.

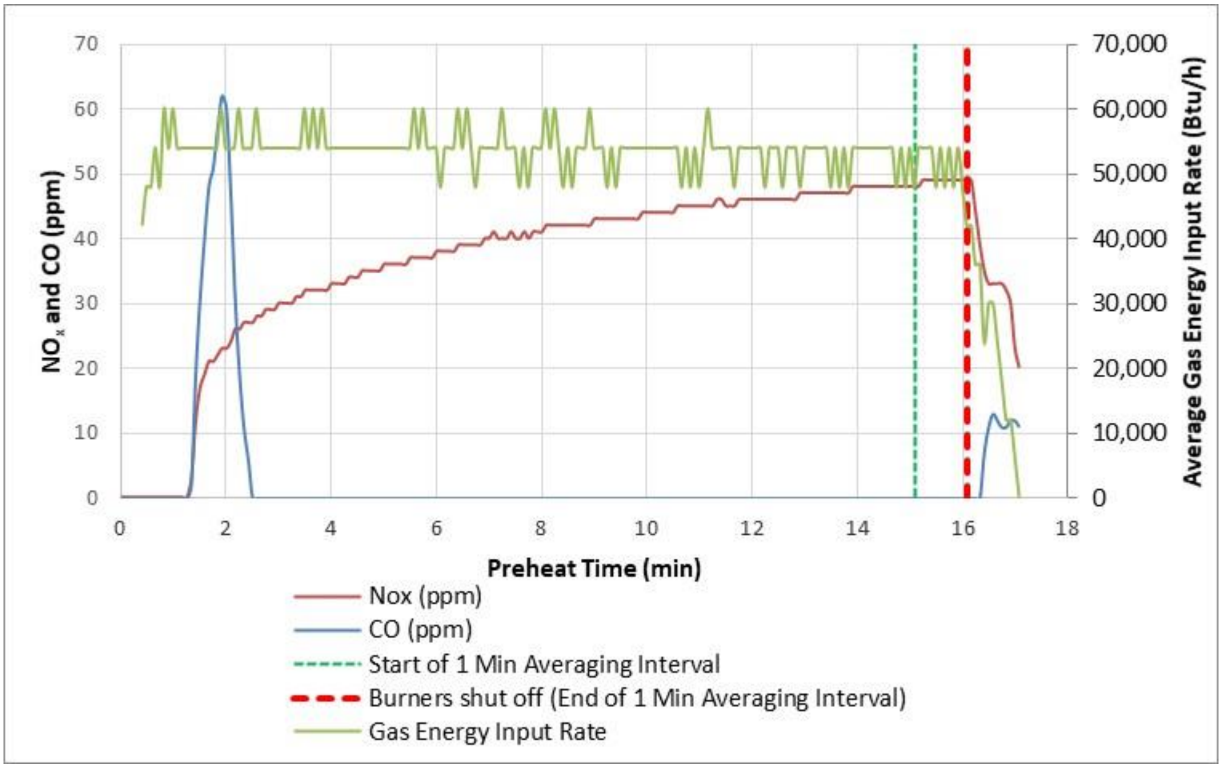
Ranges and broilers have no dedicated flue and operate open to the atmosphere. For these appliances, researchers used two methodologies. The first method uses an open 20″ length by 12″ diameter cylindrical duct with a hole drilled 6-inches from the bottom where a probe is inserted in the side of the duct to measure emissions. If emission readings were too dilute (<18% oxygen), researchers used an alternative method of an upside-down metal bowl (12″ diameter) with holes drilled into it. The bowl gave a more stabilized gas emissions sample (with less oxygen %) and the drilled holes minimized the effects of air blockage to the burner.

Lab Methodology and Instrumentation

Frontier developed lab testing protocol as a series of test procedures to address requirements of various cooking appliances and establish a standard procedure for quantifying emissions from commercial fryers, convection ovens, rack ovens, and griddles. Researchers referenced the testing requirements specified in South Coast Air Quality Management District Draft Test Protocol for Determining NO_x Emissions, ASTM D6522-00 (2005), ANSI Z83.11, and appliance-specific ASTM energy performance test methods including F1361-07 (2013), F1496, F2083, and F1275.

Researchers characterized emissions after the burner was on for the longest amount of time so that the combustion flame had time to reach a steady state. Most commercial kitchen appliances (except for broilers) were non-continuous burner operations and only cycled the burners on when there was a demand for heat. The longest burner on-time for snap action thermostat appliances was preheat; therefore, NO_x and CO parts per million by volume (ppm) concentrations were measured at the end of the burner cycle. Raw CO and NO_x emissions were measured in ppm, averaged, and corrected to 0% O_2.

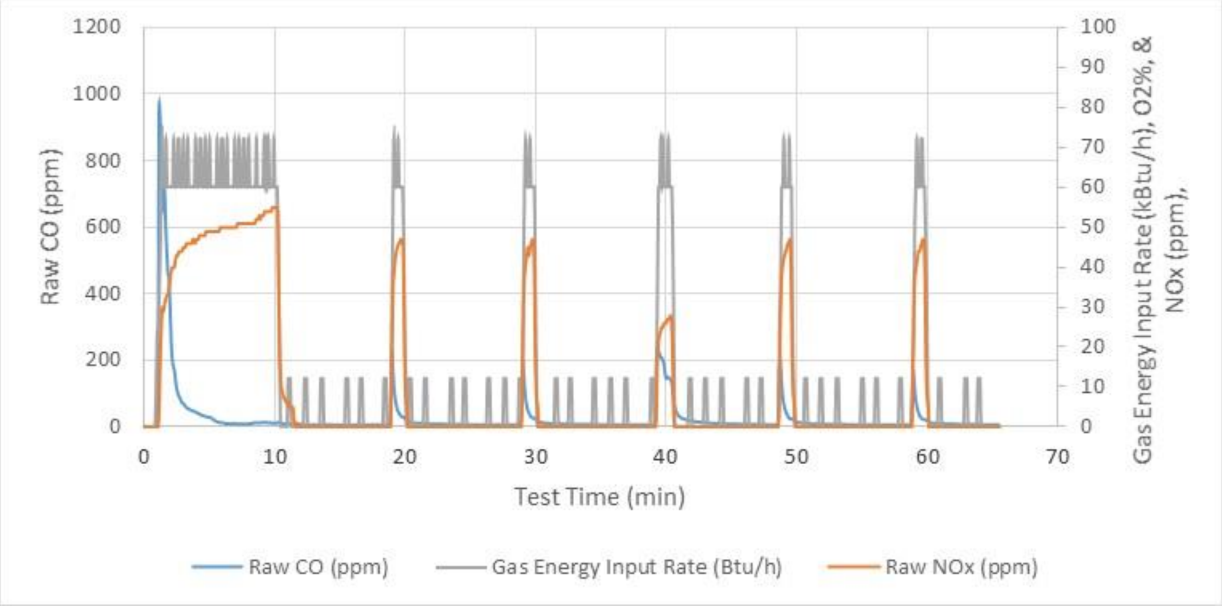
Figure 316: Preheat profile of an efficient commercial gas fryer with a snap action thermostat



Emissions were recorded for the entire preheat duration and the results were taken for the last 1-minute before the burners shut off.

Source: Frontier Energy, Inc.

Figure 317: 10-minute preheat from an efficient fryer with snap action thermostat



10-minute preheat from an efficient fryer with snap action thermostat and the first 50-minutes of its idle. NO_x reaches its maximum concentration during preheat. When the appliance idles, NO_x generation is only 15-20% of its maximum.

Source: Frontier Energy, Inc.

ASTM D6522 Applicability to Foodservice Appliances

D6522 is the Standard Test Method for Determination of Nitrogen Oxides, Carbon Monoxide, and Oxygen Concentrations in Emissions from Natural Gas Fired Reciprocating Engines, Combustion Turbines, Boilers, and Process Heaters Using Portable Analyzers. ASTM D6522 criteria is referenced in the draft protocol test methods used to sample and measure NO_x and CO emissions from the stack of commercial kitchen appliances developed by SCAQMD.

ASTM D6522 focuses on calibration rather than sampling location, methodology, and appliance setup. The test method requires selection of an analyzer with negligible drift. The analyzers with acceptable zero and span drift parameters are typically listed at upwards of $10,000. These analyzers can run ASTM D6522 protocol and have the capability to pass the required tolerances. All portable analyzers will naturally drift with age and need routine maintenance and frequent sampling cell replacement to keep up with test method criteria.

The test method involves multiple steps: a pre-calibration, test run, post-calibration, stability test, and a linearity test. All tests must successfully pass their respective criteria or else the data is to be invalidated. In addition, the test method does not specify how long to purge gas from the analyzer after sampling gas to analyze cross sensitivities. Adjustments are often needed before pre-test calibration to ensure criteria is met. The test method requires selection of proper concentration of calibration gases to obtain the best accuracy. The selection process is dependent on the expected gas concentrations measured in the source exhaust and the accuracy range of the portable analyzer.

Calibration gas concentrations that are 50 ppm or lower will be extremely difficult to pass criteria without a stable analyzer designed for accurate low NO_x concentration measurement. The stability criteria for a 30-minute test is 2% of the span gas reading, so at 80 ppm span gas, the reading is not allowed to drift more than 2 ppm. This would translate to only ±1 ppm at 40 ppm span gas, which is dwarfed by the sampling measurement error. A 15-minute test may be performed only if the reading is within 1% of the span gas concentration. The total stability check duration should be relative to an appliance preheat duration and not be fixed to a 15- or 30-minute stability time. For foodservice appliance tests, NO_x is measured for the duration of the entire preheat, but averaged for only the last minute before the burner cycles off.

The test method provides criteria for careful selection of calibration gas concentrations based on expected stack concentrations and some sensors inside portable analyzers have a linear correlation of concentration to voltage. A 2-point linearity check using span gas and zero gas should be sufficient to ensure the analyzer accuracy based on selection of calibration gases; however, a 3-point linearity procedure is still required by test method protocol. Adding a midspan gas to the calibration process proved that the analyzer’s electrochemical cells were linear and did not deviate from the 2-point test.

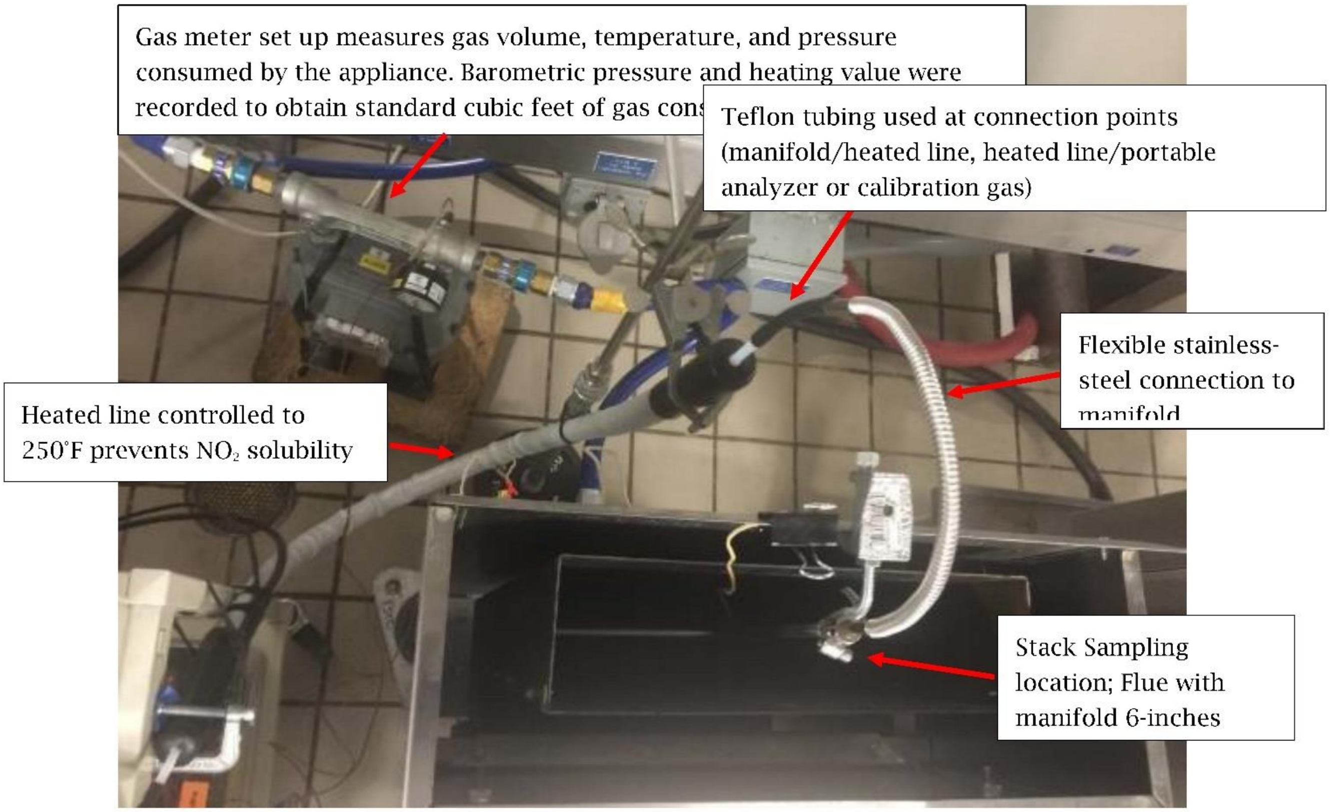
It is recommended that ASTM develop its own NO_x measurement standard applicable to foodservice appliances. The standard should outline the flue measurement location methodology and durations in more detail than D6522 while reducing the stability test durations and tolerances that are more applicable to the duration of the appliance preheat duration. The linearity test should not be applicable to electrochemical cell emissions analyzers.

Schematics of Stack Sampling Locations

The lab set up for calculating NO_x requires a dry gas emissions analyzer for measuring stack emissions. A sampling probe (preferably stainless steel or Inconel material) is placed in the stack upstream of the emissions analyzer to handle high flue temperatures ranging from 500°F - 1000°F. A heated line is preferred (but not necessary) in conjunction with a thermoelectric cooler to separate water (naturally occurring at high temperatures in the flue stream) from dry effluent was installed between the probe and the analyzer. The emissions analyzer has a water filter on the inlet to act as a final barrier to prevent moisture accumulation on emissions cells.

Gas consumption data was collected to verify that the appliance was operating at its rated input. A volumetric gas meter was used to measure gas consumed by the appliance. Gas temperature, gas pressure, and barometric pressure were recorded to correct measured volume to standard conditions. A gas calorimeter was used to measure the gas calorific higher heating value. An exhaust flow rate of 300 cfm per linear foot of hood space was set for all testing to mimic real world conditions.

Figure 318: Fryer flue manifold, heated line, and thermoelectric cooler set up per test protocol



Gas meter set up measures gas volume, temperature, and pressure consumed by the appliance. Barometric pressure and heating value were recorded to obtain standard cubic feet of gas cons

Teflon tubing used at connection points (manifold/heated line, heated line/portable analyzer or calibration gas)

Flexible stainless-steel connection to manifold

Heated line controlled to 250°F prevents NO_2 solubility

Stack Sampling location; Flue with manifold 6-inches

Source: Frontier Energy, Inc.

Single Point Probe Measurement Methodology (SPPM)

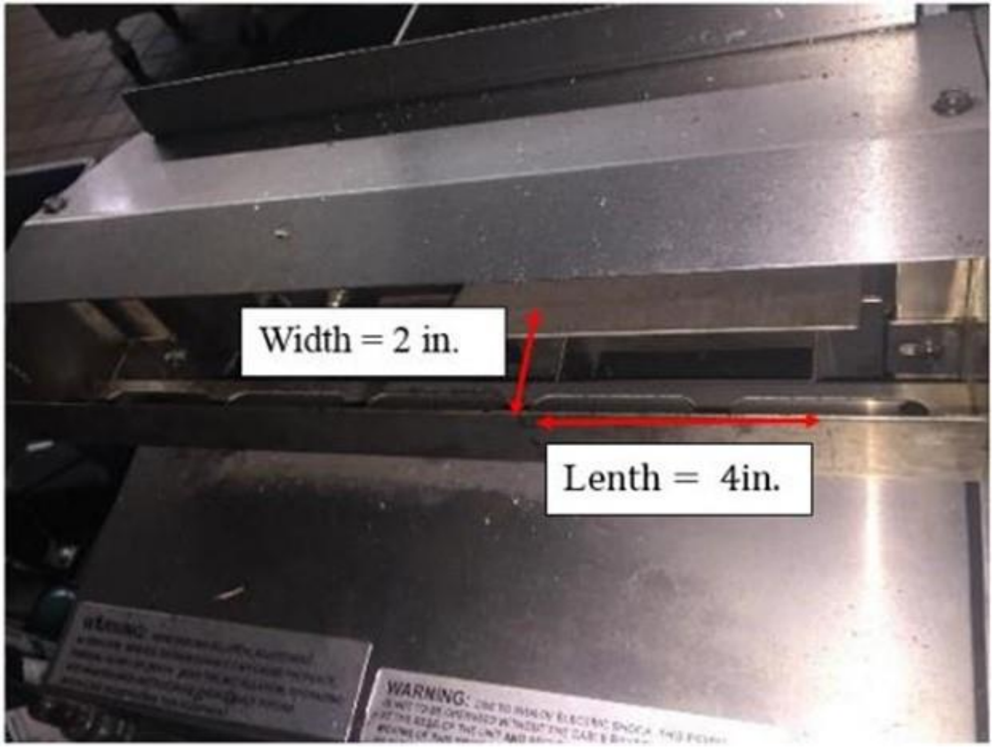
If the flue is 4-inches in diameter or less, a single point probe measurement is appropriate. According to EPA Method 7E, which is referenced in ASTMD6522, Section 8.1.2, Determination of Stratification, a stratification test is not required for small stacks that are less than 4 inches in diameter.

For rectangular stacks, the method would require the equivalent hydraulic diameter defined by Eq. 2-1 in EPA Method 2 as follows:

$$D_e = 4\,x\,\frac{Area}{Wetted\ Perimeter} = \frac{2LW}{(L+W)}$$

Where, D_e = Equivalent hydraulic diameter in inches
L = Length of stack in inches
W = Width of stack in inches

Figure 319: Dimensions of a fryer stack

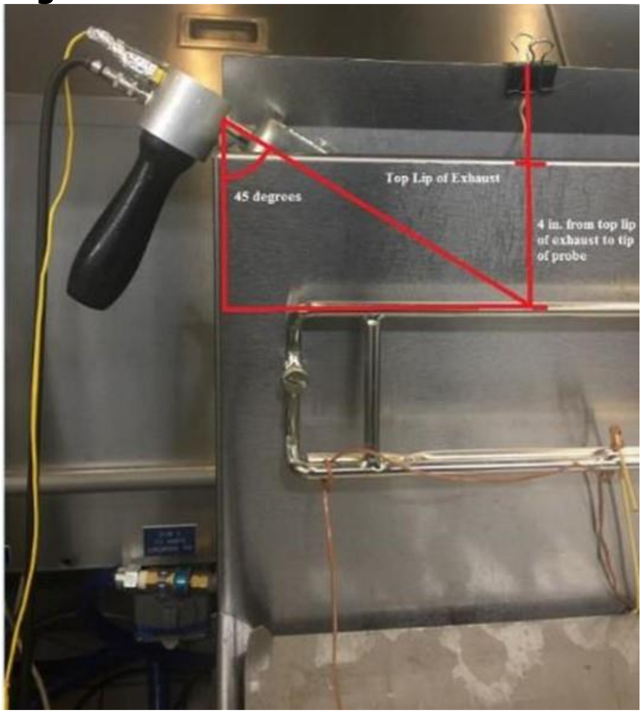


Dimensions of a fryer stack where the width was 2-inches and the length was 4-inches. The equivalent calculated diameter was 2.7 inches, less than 4-inches.

Source: Frontier Energy, Inc.

The measurement probe was angled 45-degrees and positioned at the centroidal area of the fryer flue so as not to melt the thermocouple probe or sampling line by the heat of flue gases. The probe was 4-inches below the lip, centered in the flue. Sampling traverse points were not included in this test. The analyzer recorded the start of preheat until the end of testing to give thermal NO_x optimal time of exposure at peak temperatures. The final 1-minute of NO_x readings were averaged right before the burners cycled off. Single point probe measurement performed on a 10-inch-wide fryer flue showed similar CO and NO_x results to a T-manifold setup.

Figure 320: Single Point Probe Measurement Geometry on a Fryer



Source: Frontier Energy, Inc.

Manifold Probe Measurement Methodology

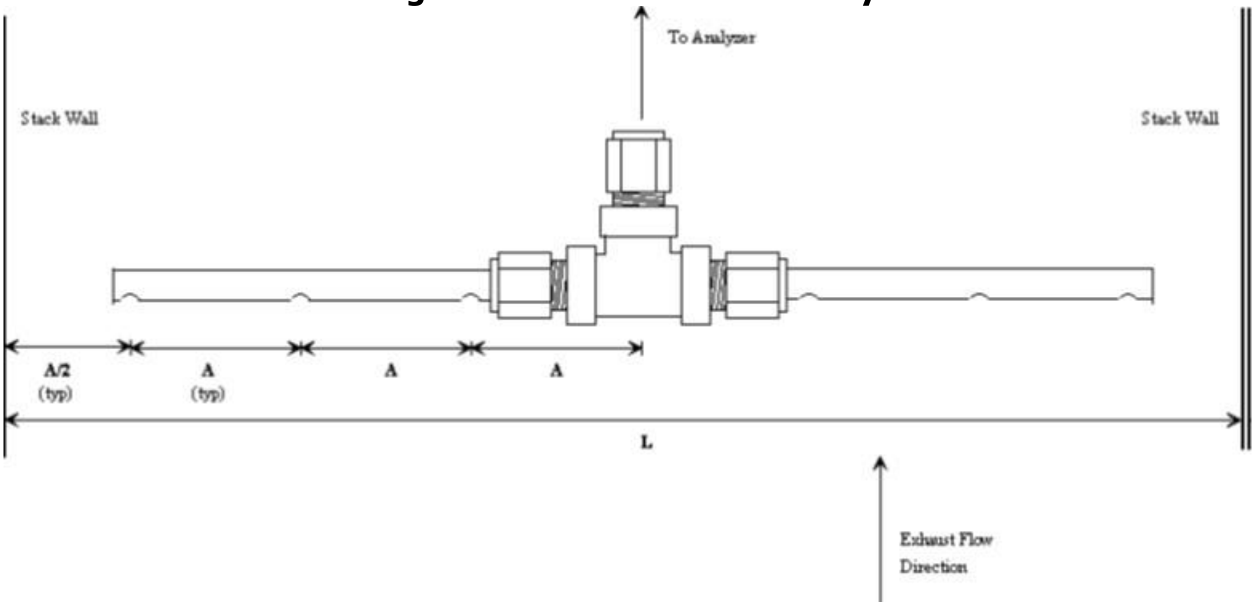
Researchers used a quarter-inch diameter integrated probe, constructed from materials inert to combustion products, to collect emissions from the fryer exhaust. The probe was positioned perpendicular to the exhaust flow along the length (longest axis) of the exhaust vent and placed at least 2-inches below the top lip of the outlet. The probe may be placed lower than 2 inches to reduce oxygen intake, as long as sampling probe is located far from the combustion zone and flue gas emissions are fully mixed. For rectangular exhausts, the integrated sampling probe was installed equidistant to the vent's width (smallest axis). For circular exhausts, an integrated probe shall be installed along the diameter with the highest expected stratification gradient. Nominal diameter of the sample holes shall be 0.076 inches and located according to the schematics.

The goal of using a T-manifold to measure contaminant gases was to mitigate stratification effects inside the flue. For exhaust ducts on appliances that had hydraulic diameters greater than 4-inches, the manifold setup was used.

Figure 321: Manifold Measurement on a Fryer

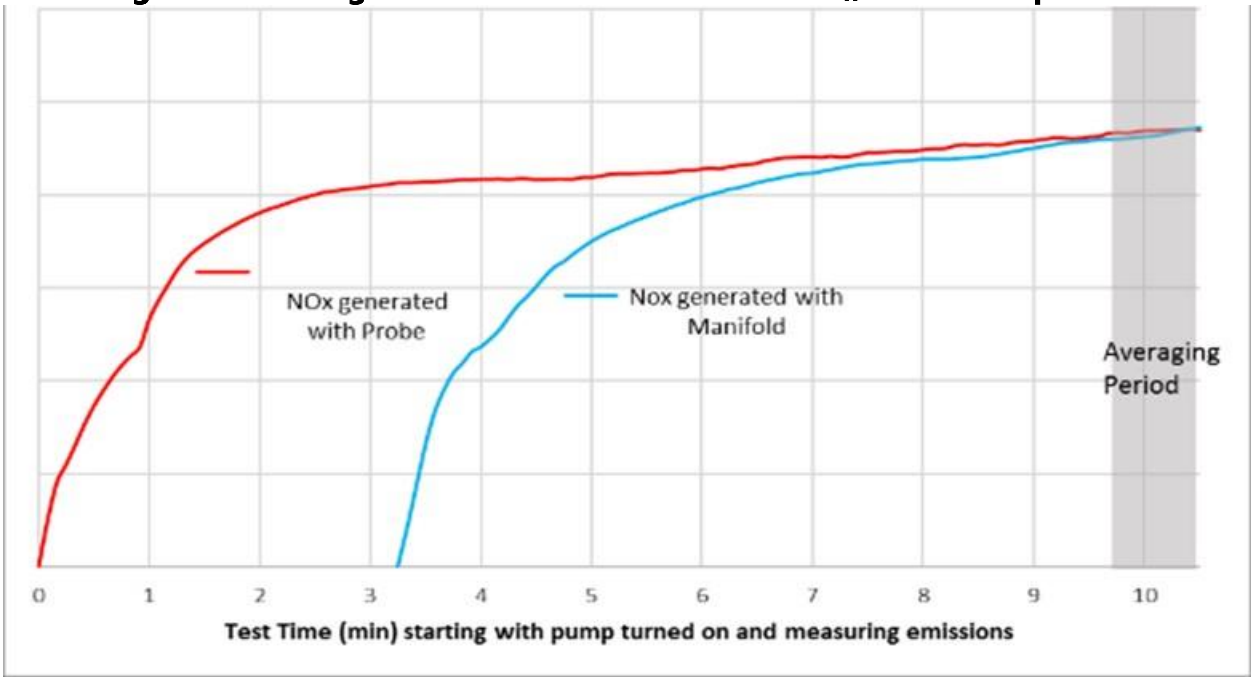
Source: Frontier Energy, Inc.

Figure 322: Manifold Geometry



Source: South Coast Air Quality Management District Draft Test method

Figure 323: Single Point Probe vs Manifold NO_x Level Comparison



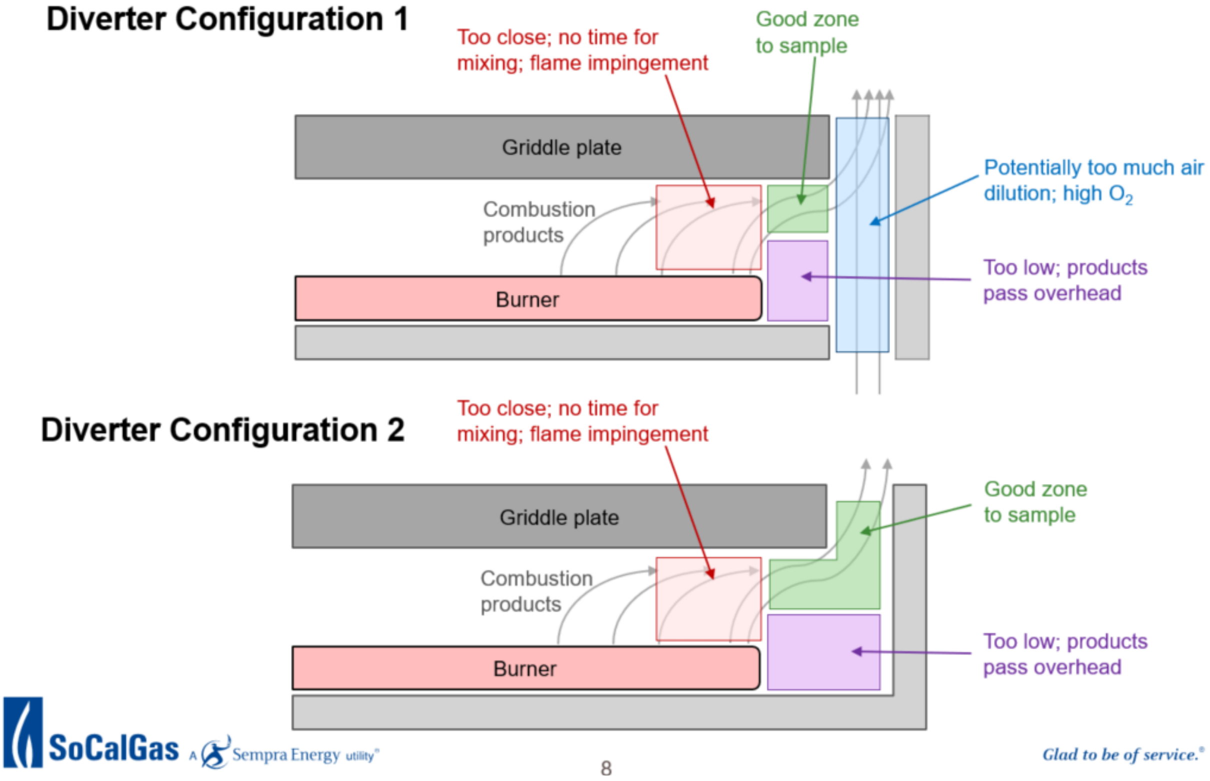
Source: Frontier Energy, Inc.

Probe versus T-manifold NO_x comparison shows the time the pump on the portable analyzer was sampling flue gases until the burners cycled off. The test time for the manifold started around 3-minutes because the pump was turned on later, but still resulted in the same NO_x values as the test performed with the single point probe. The emissions during the last 1-minute of preheat were averaged.

Griddle Sampling Zones

Sampling location is crucial to recording an undiluted emissions reading. Southern California Gas Company did extensive research on the effects probe placement has on NO_x and CO concentrations. The following figure shows two configurations. Configuration 1 shows a griddle with an open bottom flue diverter. Secondary or tertiary air supplies the griddle burner cavity and directs exhaust gases upward via the sampling zone. In configuration 1 there is a potential for too much air dilution and high oxygen readings if the sample is not taken deeper into the burner cavity. Configuration 2 shows a closed bottom flue diverter where there is no secondary air supply. In configuration 2 there is a larger undiluted sampling zone closer to the outlet of the flue. Sampling too close to the burner directly above the combustion zone or behind the burner may result in an improperly mixed sample.

Figure 324: Flue Sample Locations for Griddles



Diverter Configuration 1

Too close; no time for mixing; flame impingement

Good zone to sample

Griddle plate

Combustion products

Burner

Potentially too much air dilution; high O_2

Too low; products pass overhead

Diverter Configuration 2

Too close; no time for mixing; flame impingement

Griddle plate

Combustion products

Burner

Good zone to sample

Too low; products pass overhead

SoCalGas A Sempra Energy utility

8

Glad to be of service.

Source: Jason Wang, Southern California Gas

Figure 325: Lab set up with a top view of the griddle and the manifold probe positioned in the sampling zone

Source: Frontier Energy, Inc.

Figure 326: Another View of the manifold probe inside the sampling zone and burner cavity

Source: Frontier Energy, Inc.

Broiler Sampling Methodology

Ranges and broilers are open to the atmosphere with no dedicated flue. Researchers used two methodologies for these appliances. The first method used an open 20"-length by 12"-diameter cylindrical duct with a hole drilled 6-inches from the bottom where the probe is inserted in the side of the duct to measure emissions. If emissions were too dilute (<18% oxygen), an alternative method was used with an upside-down metal bowl (12"-diameter) with holes drilled into it. The bowl concentrated emissions to reduce the effects of external dilution air so that a more accurate measurement could be made. Additional holes were drilled to counteract the effects of air blockage to the burner.

Figure 327: Cylindrical Duct Methodology

Source: Frontier Energy, Inc.

Figure 328: Bowl Methodology

Source: Frontier Energy, Inc.

Rack Oven Sampling Methodology

Rack ovens are one of the biggest appliances in commercial kitchens and are often assembled/installed on site instead of out of the box. Certified technicians perform the on-site assembly and often tune the power burners as well. The burner tuning includes air-to-fuel ratio adjustment either by changing the speed of the intake air fan blower or by adjusting gas pressure or both. Technicians that tune the burners usually use a field emissions analyzer to measure combustion efficiency and carbon monoxide levels. This is one of the only appliance types where installers measure emissions on site. Rack ovens have varying flue configurations. The rack ovens tested in the lab had flues with a blower exhaust fan on top, a closed duct with flue damper on top, and a direct-fired exhaust opening on top oriented to the front. Diagrams below show three different rack oven flue configurations tested in the lab.

Figure 329: Emissions sample was taken at the outlet of the blower exhaust fan on top of the oven

Source: Frontier Energy, Inc.

Figure 330: Hole was drilled to fit the probe into a closed duct below the flue damper

Source: Frontier Energy, Inc.

Figure 331: Direct-fired rack oven combustion products are exhausted from an opening on top oriented to the front

Source: Frontier Energy, Inc.

Lab Test Results

Table 14: Lab Fryers

	Burner and Heat Exchanger (HX)	NO_x ppmv ([1]corr)	CO ppmv (corr)	CO_2%	O_2%
Fryer A (ENERGY STAR)	Power burner, IR Cylindrical Mesh, 5-pass HX in oil	105	39	10.4	2.4
Fryer B	U-Tube Orifice Burner with Metal Targets, HX beneath vat	35	254	5.1	11.7
Fryer C	Three 90-degree cast burner, HX in oil	69	641	8.1	6.7
Fryer D	Front Face, Stamped Tube Burner, HX in oil	106	<15	8.1	6.5
Fryer E	U-Tube Orifice Burner with Metal Targets, HX beneath vat	77	125	7.1	8.1
Fryer F (ENERGY STAR)	Power burner, IR Ceramic Box Burner, HX outside vat	22	17	10.1	2.8
Fryer G (ENERGY STAR)	Power Draft, Venturi Short Side Cast Burner, HX in oil	45	181	8.5	5.7
Fryer H (ENERGY STAR)	Cast burner, Right Angle, HX in oil	96	<20	5.1	11.1

Source: Frontier Energy, Inc.

Table 15: Lab Griddles

	Burner and Heat Exchanger (HX)	NO_x ppmv ([1]corr)	CO ppmv (corr)	CO_2%	O_2%
Griddle A (ENERGY STAR)	Infrared box burner	13	over	10.5	2.1
Griddle B (ENERGY STAR)	Ceramic infrared; steam sandwich plate griddle	<16	24	7.4	7.7
Griddle C	U-Shape Tube Burners	102	<18	6.3	9.6
Griddle D (ENERGY STAR)	U-Shape Tube Burners	58	257	8.0	6.6
Griddle E	U-Shape Tube Burners	107	<20	5.9	10.3

Source: Frontier Energy, Inc.

Table 16: Lab Convection Ovens

	Burner and Heat Exchanger (HX)	NO_x ppmv ([1]corr)	CO ppmv (corr)	CO_2%	O_2%
Oven A	Straight Tube with lanced ports	85	<10	4.8	12.2
Oven B (ENERGY STAR)	Drill port “H” style	98	<10	6.7	8.8
Oven C (ENERGY STAR)	U-Tube with center venture lanced port	91	<10	4.3	14.5
Oven D (ENERGY STAR)	In-shot	38	29	6.3	9.5

Source: Frontier Energy, Inc.

Table 17: Lab Rack Ovens

	Burner and Heat Exchanger (HX)	NO_x ppmv ([1]corr)	CO ppmv (corr)	CO_2%	O_2%
Oven A (ENERGY STAR)	Modulating Burner with variable speed blower	47	<13	9.3	5.2
Oven B (ENERGY STAR)	In-shot burner with linear counter-flow heat exchanger	33	30	9.5	7.0
Oven C (ENERGY STAR)	Power Burner with variable speed blower	41	<13	8.8	5.2

[1]corr (corrected to 0% Oxygen)

Source: Frontier Energy, Inc.

Portable NO_x Analyzer Comparison

Standalone gas analyzers are not practical for the measurement of combustion emissions from appliances inside commercial foodservice facilities. As such, researchers and installers use handheld or portable analyzers. Currently available portable analyzers include the Testo 350, the Enerac M500, and Bacharach PCA3. To validate the accuracy of these analyzers, the Gas Technology Institute (GTI) conducted comparative tests at its combustion test facility by comparing these analyzers with GTI's set of standalone analyzers.

GTI's state-of-the-art standalone analyzers work by drawing combustion gases through a conditioning train for drying before being pumped to a set of continuous emission monitors (CEMs). From the sampling probes, the sample enters two dry filters followed by a membrane dryer to remove water vapor from the sample. After drying, the sample is sent to a sample flow control and distribution panel for channeling to the gas analyzers. All the components from the sampling probes to the gas analyzers are connected by quarter-inch Teflon tubing. Samples are analyzed for nitrogen oxide (NO), nitrogen dioxides (NO_2), oxygen (O_2), carbon monoxide (CO), carbon dioxide (CO_2), and total unburned hydrocarbons (THC). Instrument grade nitrogen was used to zero the instruments and to purge the sampling lines between sampling. Signals from the analyzers were connected to a data acquisition system to monitor their mole fractions during the tests. All the gas analyzers were zeroed and calibrated at the beginning of any data set.

Table 18: Continuous Emission Monitors (CEMs) Gas Analyzers, Standalone

Make and Model #	Detection Technique	Gases Analyzed
Thermo Environmental Instruments 42C	Chemiluminescence	NO and NO_2
Beckman Industrial 755	Paramagnetic	O_2
Rosemount Analytical 880A	Infrared	CO
Rosemount Analytical 880A	Infrared	CO_2
Rosemount 400A	Flame ionization	THC

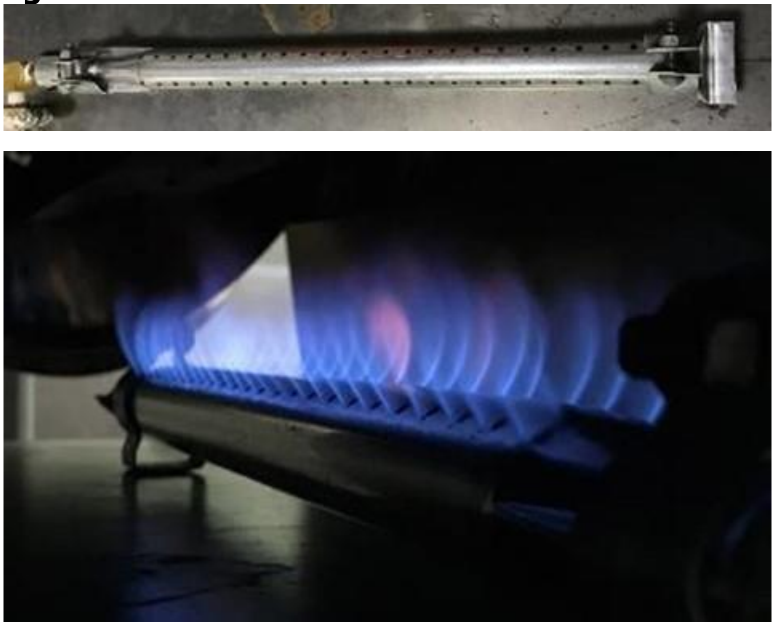
Source: Frontier Energy, Inc.

Figure 332: Continuous Emission Monitors (CEMs) Gas Analyzers, Standalone

Source: Frank Johnson, Gas Technology Institute

Combustion emissions were drawn at the same point for a standard tube burner installed in a burner test stand developed by GTI.   These samples were simultaneously measured and compared by CEMs and handheld analyzers.

Figure 333: Tube Burner for Emission Generation



Source: Frank Johnson, Gas Technology Institute

Figure 334: Tube Burner Test Setup and Different Emissions Probes inside of Test Stand

Source: Frank Johnson, Gas Technology Institute

Different NO_x and CO emission were generated by adjusting the burner firing rate, air-to-fuel ratio, and changing the amount of secondary air available to the burner.

The burner firing rate was adjusted by changing the supply gas pressure to the burner or changing the orifice size supplying gas to the burner. The air-to-fuel ratio was adjusted by changing the opening size of the air shutter on the burner. The amount of secondary air available to the burner was adjusted by changing the size of the openings around the burner that let in outside air used for secondary combustion and by changing the opening on the flue using a damper.

Figure 335: Tube Burner Test at Different Test Conditions: appearance of the flame changed for different burner operational settings

Source: Frank Johnson, Gas Technology Institute

For the first set of tests, the Bacharach and Testo were compared with the CEMs. The portable units were set up for sampling and zeroed before the burner was turned on. The CEMS were also calibrated based on standard operation procedures for burner testing and in compliance with the unit’s operational manuals. The same procedures were repeated for comparing the Enerac and Testo with the CEMs.

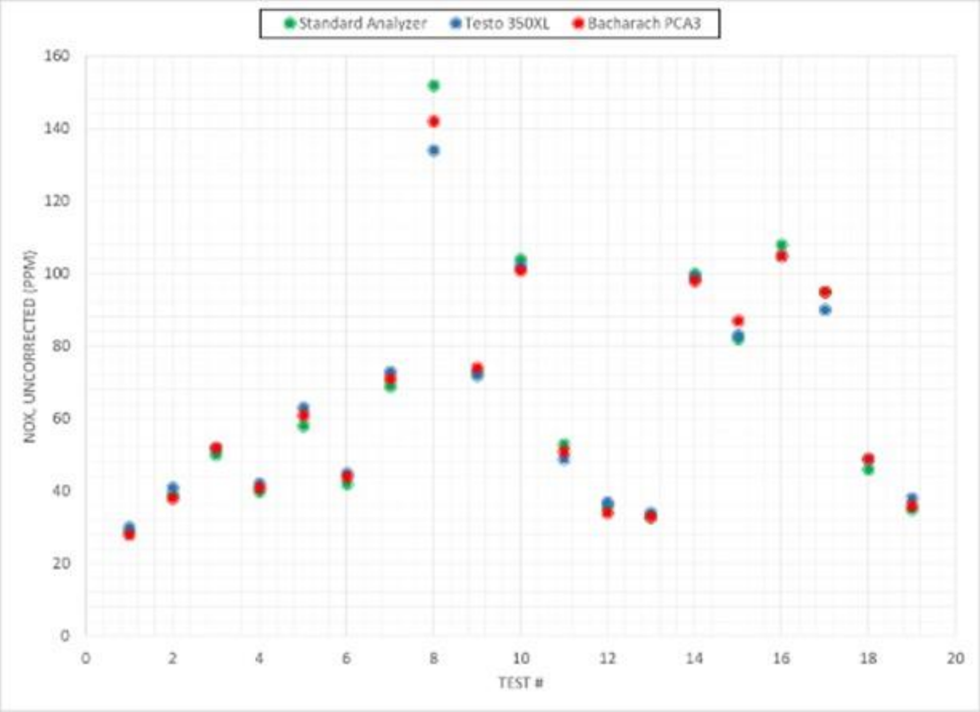
Before each burner test at different emissions values, the burner is ignited and allowed to equilibrate for between 40 to 60 minutes based on the stability of the emission values and the temperature in the flue of the burner test setup.

A complete set of data is given in Appendix A for all emissions values. Because of the emphasis on NO_x emissions and the concerns of accurate measurement using handhold analyzers.

Only three analyzers could be compared during a single test, therefore testing was divided into two groups. Group 1 compared the CEMs (labeled Standard Analyzer in the figures) with the Testo 350XL and the Bacharach PCA3. Group 2 compared the CEMs (labeled Standard Analyzer in the figures) with the Testo 350XL and the Enerac M500.

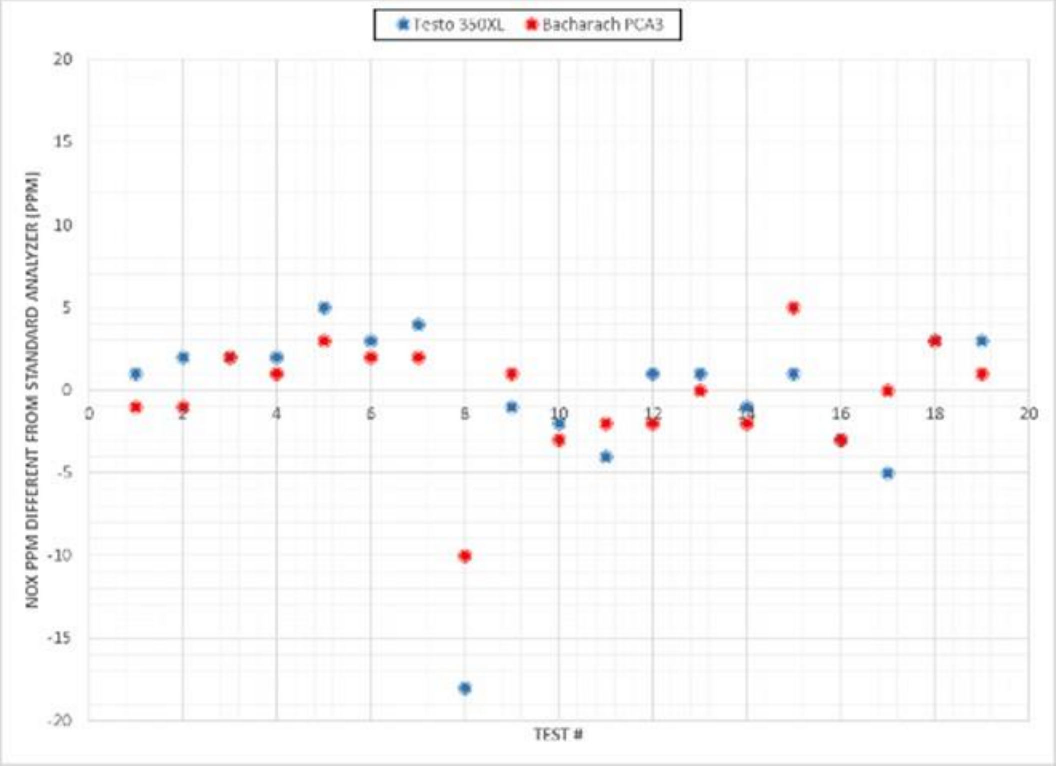
The figure below compares the CEMs (Standard Analyzer) with the Testo 350XL and the Bacharach PCA3 for 19 tests with varying NO_x emissions. The firing rates and other emission values for each test (1-19) is given in Appendix A. The emphasis of these tests was not to test a range of typical firing rates for commercial foodservice appliances, but to test a range of known NO_x emissions for CFS units. The figure shows that uncorrected or raw emissions values varied from about 25 to 150 ppm. For all tests but one, NO_x emissions values were within 5 ppm for the value recorded by the Standard Analyzers (CEMs) represented as the zero value on the x-axis. The emissions values for Test 8 behaved differently from the other values and was most likely due to issues with burner operation and achieving a stable flame. The flame and emissions values were observed to vary more than the other tests.

Figure 336: Uncorrected NO_x Emissions for Group 1



Source: Frank Johnson, Gas Technology Institute

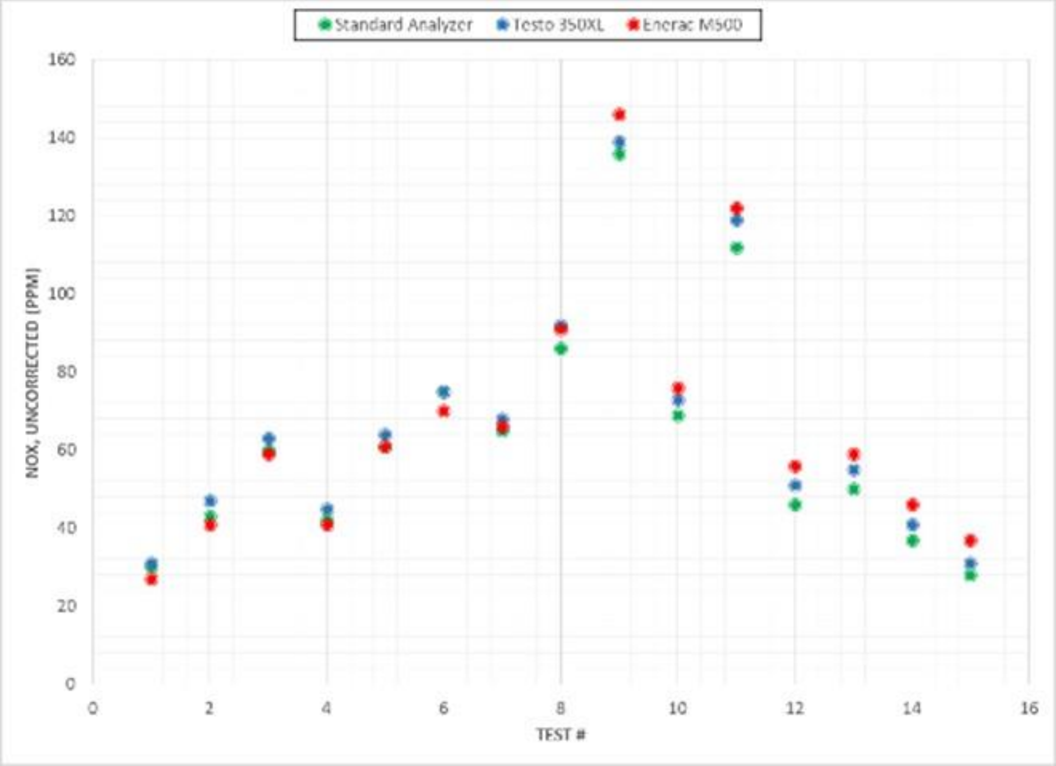
Figure 337: NO$_x$ Emissions Differences for Group 1



Source: Frank Johnson, Gas Technology Institute

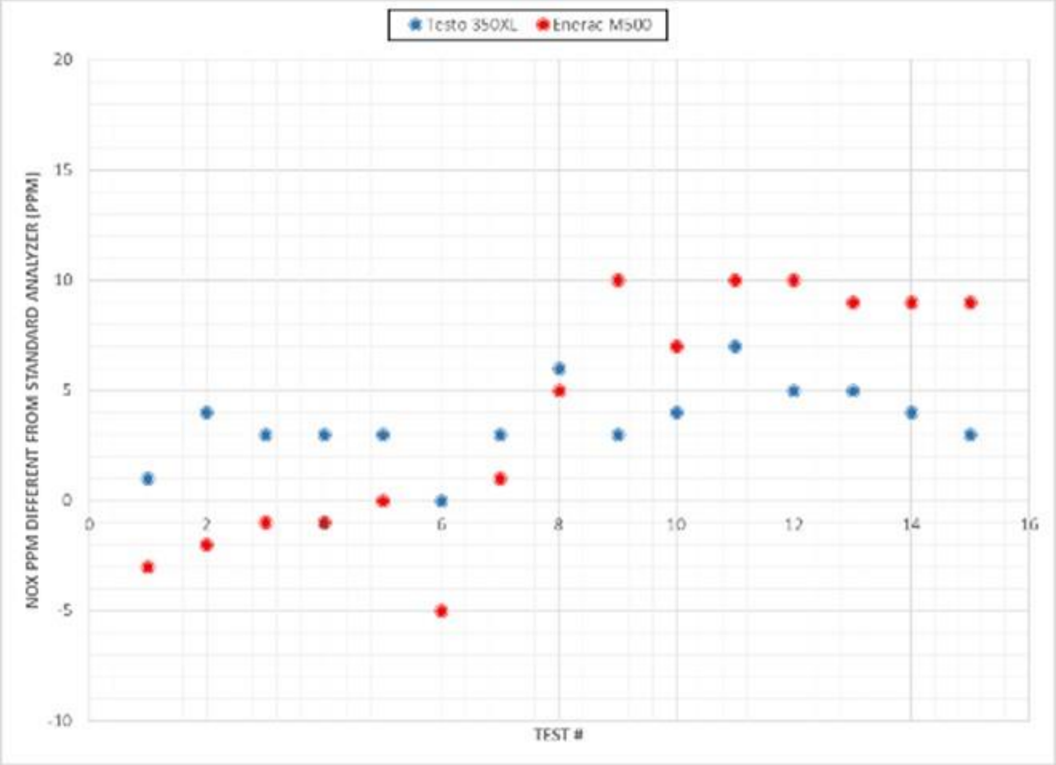
The same type of data was repeated for Group 2 using the Enerac M500 in place of the Bacharach PCA3. The figure below compares the CEMs (Standard Analyzer) with the Testo 350XL and the Enerac M500 for 15 tests with varying NO$_x$ emissions. The firing rates and other emission values for each test (1-15) are presented in Appendix A for Group 2 testing. The figure shows that uncorrected emissions varied from about 25 to 150 ppm. For the initial tests, as Figure 43 shows, the NO$_x$ emissions values were within 5 ppm for the value recorded by the Standard Analyzers (CEMs) represented as the zero value on the x-axis. However, as tests continued, the emission values for Enerac M500 appeared to drift farther away from the Standard Analyzers values. Unlike the tests for Group 1, Group 2 tests were run continuously over a 2-hour period for all 15 tests. The Group 1 tests were run in two sets over a single day. After about an hour of continuous monitoring, the Enerac M500 drifted off by a range of 5 to 10 ppm compared to the Standard Analyzers with a range of 0 to 5 ppm from the earlier testing. Some drift was also observed for the Testo 350. The results emphasized that portable analyzers are designed for spot testing of emissions values for periods lasting minutes instead of hours.

Figure 338: Uncorrected NO_x Emissions for Group 2



Source: Frank Johnson, Gas Technology Institute

Figure 339: NO_x Emissions Differences for Group 2



Source: Frank Johnson, Gas Technology Institute

Data collected for NO_x emissions from a typical commercial foodservice burner have shown that portable analyzers such as the Testo 350XL, Bacharach PCA3, and Enerac M500 can give readings within 5 ppm or about 6% compared to state-of-the-art analyzers. The limitations of portable analyzers compared to the CEMs is that the portable units are not designed for continuous monitoring lasting more than one hour. If used for measuring NO_x emissions, portable units should be used for emissions readings lasting less than one hour and should be checked and recalibrated based on manufacturer recommendations. However, as demonstrated in these tests, portable analyzers are capable of measuring NO_x emissions for commercial foodservice appliances with acceptable accuracy when compared with state-of-the-art analyzers.

Field Measurements

Researchers measured NO_x levels with a portable handheld emissions analyzer that was calibrated on an annual basis. Moisture from the flue gas was separated using a condensate trap prior to entering the analyzer cell.

Researchers measured CO and O_2 levels in conjunction with NO_x levels because these values are dependent on air-to-fuel combustion ratios. Oxygen levels were an indicator of measurement reliability with flue oxygen concentrations over 18% resulting in higher measurement uncertainty.

Field Measurement Methodology

Researchers took measurements by placing the NO_x analyzer probe in the flue of gas appliances and averaging measurements when the appliance burner stabilized. Readings were averaged either at the end of the appliance preheat or at the end of the burner cycle. All NO_x values reported in ppm were corrected to 0% oxygen. Researchers measured appliances without a defined flue using a metal chimney or a bowl to concentrate the flue gases for measurement. Range emissions readings were taken at a single burner. Researchers performed most measurements in the field with a single point probe for ease of use. Based on laboratory testing, there were no significant deviations when sampling exhaust gases with a manifold or single point probe from fryer and oven flues. Griddle measurements were either taken with a manifold or a single point probe traversing the width of the flue.

Figure 340: Field setup at local catering hotel with manifold sampling probe, heated line, thermoelectric cooler, and computer (data acquisition system)

Source: Frontier Energy, Inc.

Figure 341: Manifold sampling probe was placed in the high O_2 sampling zone region to mitigate potential flame impingement as observed in the lab

Source: Frontier Energy, Inc.

The biggest challenge in field emissions measurement was working in a uncontrollable environment. Emissions needed to be measured at the end of a long burner cycle for each appliance without disturbing kitchen operations. Researchers contacted the restaurant operator to coordinate the site visit with the downtime of the cooking staff. Most cooking staff had short windows of downtime before they needed to prep for the next lunch or dinner rush. Staff preheated the appliances early in the morning, so any site visit in the afternoon would require the appliances be cooled down rapidly prior to start of emissions measurement. This would ensure a long burner on-time until the thermostat setpoint was met and the burner shutoff. Griddle surfaces were cooled with pitchers of water and oven doors were opened with the fans set to high to expel hot air. Oil in fryers took the longest duration to cool down due to the high thermal mass of the oil. The cooling time was extended to allow flue temperatures to stabilize for sufficient burner on-time. Despite the scheduling challenge, the fundamentals of the field procedure were consistent with the emissions tests performed in the lab. Researchers sampled NO_x and CO emissions over the duration of an appliance preheat after cooldown.

Figure 342: Single point probe placed in the flue of a double vat fryer

Source: Frontier Energy, Inc.

Figure 343: Flue of a double stack convection oven, 6-7 feet high

Source: Frontier Energy, Inc.

Field Results

Researchers measured NO_x for baseline and replacement appliances at five different monitored sites: Pleasanton DoubleTree hotel, UCSF Medical Center, Werewolf restaurant in San Diego, and Versailles Cuban restaurant in Los Angeles. Researchers collected energy consumption data at each site with calibrated gas meters to ensure the appliances were operating at their designed input rate and had no malfunctions. It is customary for equipment installers to adjust the gas manifold pressure to ensure proper gas supply; therefore, it was assumed that the appliances were operating within 5% of its rated manufacturer gas input rate when emissions were measured. Most replacement appliances were measured for emissions under laboratory conditions prior to field placement.

Table 19: DoubleTree Baseline NO_x

	NO_x (corr)	CO (corr)	CO_2%	O_2%
Griddle (non-thermostatic)	65	13	N/A	19.3
Front Range	72	176	N/A	18.3
Fryer (Dual-vat)	87	N/A	10.5	2.4
Broiler (4-ft.)	88	482	8.1	6.5
Left Convection Oven	67	160	5.0	12.1
Right Convection Oven	60	212	4.5	12.9
Back Range	81	199	N/A	17.6

Source: Frontier Energy, Inc.

Table 20: DoubleTree Replacement NO_x

	NO_x (corr)	CO (corr)	CO_2%	O_2%
Thermostatic Griddle	78	209	0.8	19.3
Fryer #1	45	10	9.0	4.7
Fryer #2	51	N/A	7.5	7.9
IR Broiler	83	184	6.8	8.9
Gas Steamer	47	N/A	7.3	7.9
Combi Oven	44	23	9.0	4.6
Convection Oven	108	24	3.7	14.1

Source: Frontier Energy, Inc.

Table 21: UCSF Baseline NO_x

	NO_x (corr)	CO (corr)	CO_2%	O_2%
Left Bottom Convection Oven	85	16	4.2	13.4
Left Top Convection Oven	91	0	3.4	14.8
Fryer Right	66	N/A	8	6.7
Right Bottom Convection Oven	82	26	4.5	14.7
Right Top Convection Oven	88	4	3.0	15.4
Broiler (Inverse Bowl)	72	200	2.3	18.6

Source: Frontier Energy, Inc.

Table 22: UCSF Replacement NO_x

	NO_x (corr)	CO (corr)	CO_2%	O_2%
Left Bottom Convection Oven	N/A	N/A	N/A	N/A
Left Top Convection Oven	83	11.9	5.8	10.4
Right Bottom Convection Oven	54	0	1.8	17.5
Right Top Convection Oven	38	29.2	6.3	9.5

Source: Frontier Energy, Inc.

Table 23: Gate Gourmet Replacement NO_x (measured in the FSTC lab)

	NO_x (corr)	CO (corr)	CO_2%	O_2%
Fryer with Filtration	78	18	8.5	5.8
Convection Oven with Steam	84	5	5.3	11.5
Dual Compartment Steamer	35	174	7.1	8.3

Source: Frontier Energy, Inc.

Table 24: Werewolf Baseline NO_x

	NO_x (corr)	CO (corr)	CO_2%	O_2%
6-Burner Range	94	22	6.2	10.0
Convection Oven	59	87	7.1	8.4
Fryer Left	51	N/A	11.6	0.2
Fryer Right	42	N/A	10.4	2.5
Broiler (bowl)	24	N/A	2.8	15.9
Griddle	48	153	7.1	8.3

Source: Frontier Energy, Inc.

Table 25: Werewolf Replacement NO_x

	NO_x (corr)	CO (corr)	CO_2%	O_2%
6-Burner Range	91	30	1.3	18.4
Combi Oven	44	0	9.9	3.1
Fryer Left	56	0	11.2	1.3
Fryer Right	68	208	9.1	4.8
Broiler (bowl)	21	N/A	4.4	12.9
Griddle	<10	24	2.9	15.6

Source: Frontier Energy, Inc.

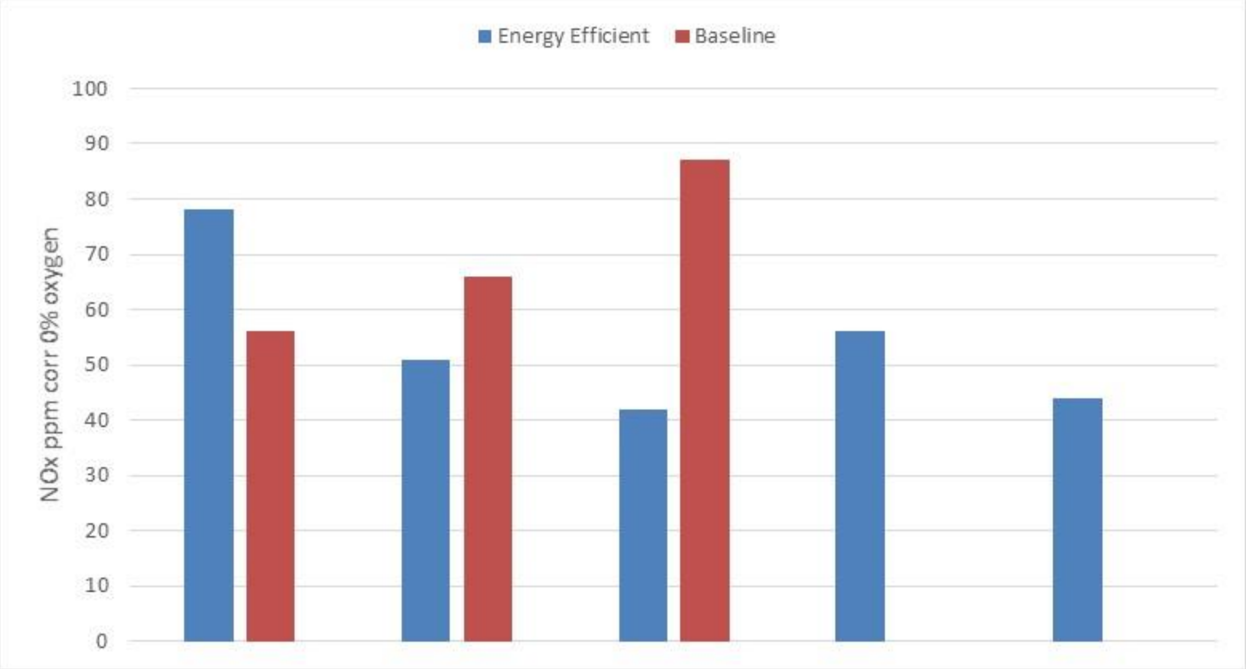
Table 26: Versailles Baseline NO_x

	NO_x (corr)	CO (corr)	CO_2%	O_2%
Southwest Fryer	54	157	8.7	5.2
Southeast Fryer	63	128	8.9	4.8
Northwest Fryer	27	205	7.6	7.0
Northeast Fryer	25	186	7.7	6.4

Source: Frontier Energy, Inc.

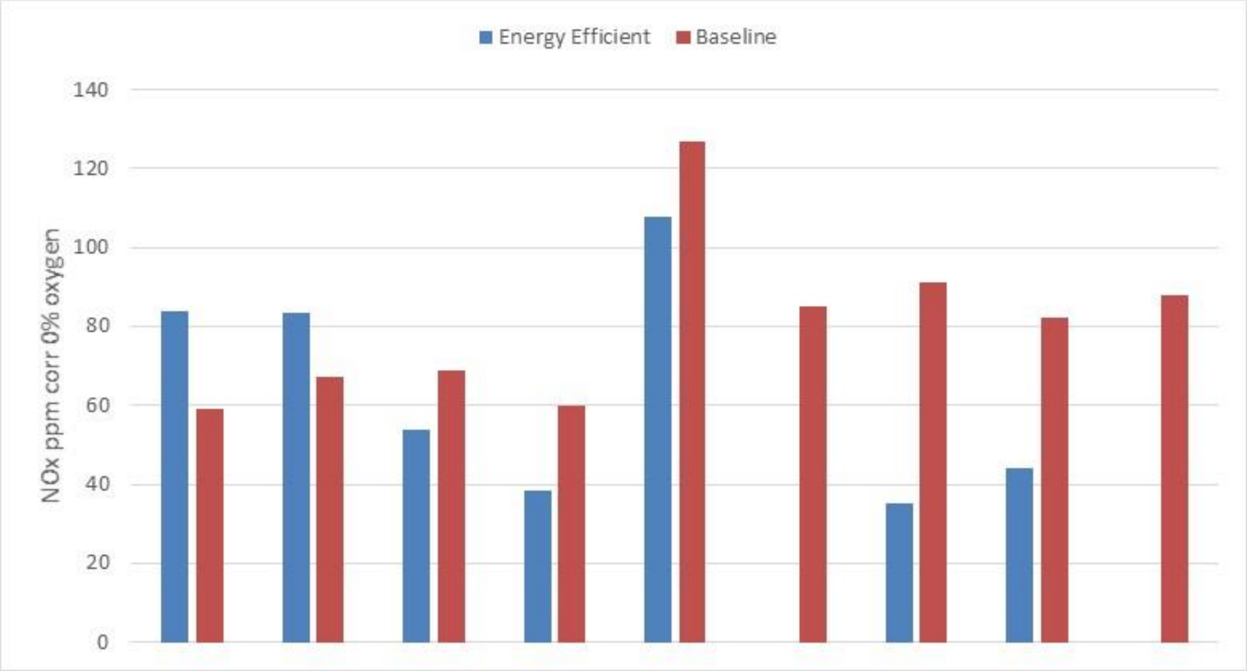
Appliances exhibited varying NO_x levels in each category with no noticeable correlation between appliance efficiency and NO_x measured values. Annual appliance NO_x generation depends on measured NO_x values and total burner on-time. Measurement uncertainty was higher for broilers and ranges due to the open burner without a defined flue.

Figure 344: Measured Fryer NO_x Results



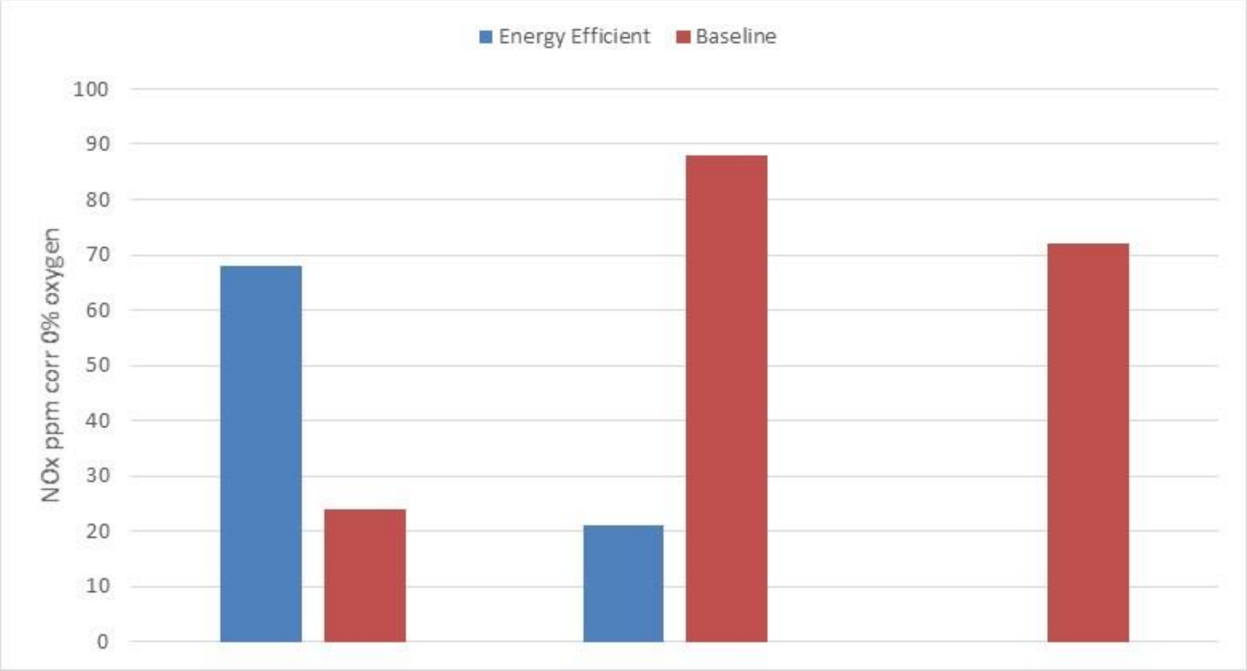
Source: Frontier Energy, Inc.

Figure 345: Measured Oven NO_x Results



Source: Frontier Energy, Inc.

Figure 346: Measured Broiler NO_x Results



Source: Frontier Energy, Inc.

Annual NO_x Generation Model

NO_x values generated in the results portion of this report show the average NO_x values at 0% oxygen when the burner is on and fully stabilized. The concentration (ppmv) values alone do not show how much NO_x an appliance generates annually; however, the values are directly tied to the annual energy consumption of the appliance. Energy data collected in this project can be paired with NO_x values to estimate the annual NO_x impact. Unlike snap action thermostats where an appliance generates consistent NO_x amounts at regular intervals, modulating valve thermostats will generate NO_x continuously at levels corresponding to burner input rates. This methodology assumes snap action thermostat control for an annual NO_x generation model since NO_x was only measured during preheat.

Annual burner on-time was extrapolated from measured daily energy consumption and average maximum input rates of all appliances.

Table 27: Appliance Burner Annual Hours of Operation

Value	Fryer	Broiler	Griddle	Oven	Range
Therms/day	3.3	11.7	4.8	5.4	4.0
Therms/yr	1,201	4,259	1,747	1,966	1,456
Input Rate (kBtu/h)	80/per vat	100	70	60/per cavity	25/per burner
Burner Hours On per year	1,500	4,200	2,500	3,300	5,800

Source: Frontier Energy, Inc.

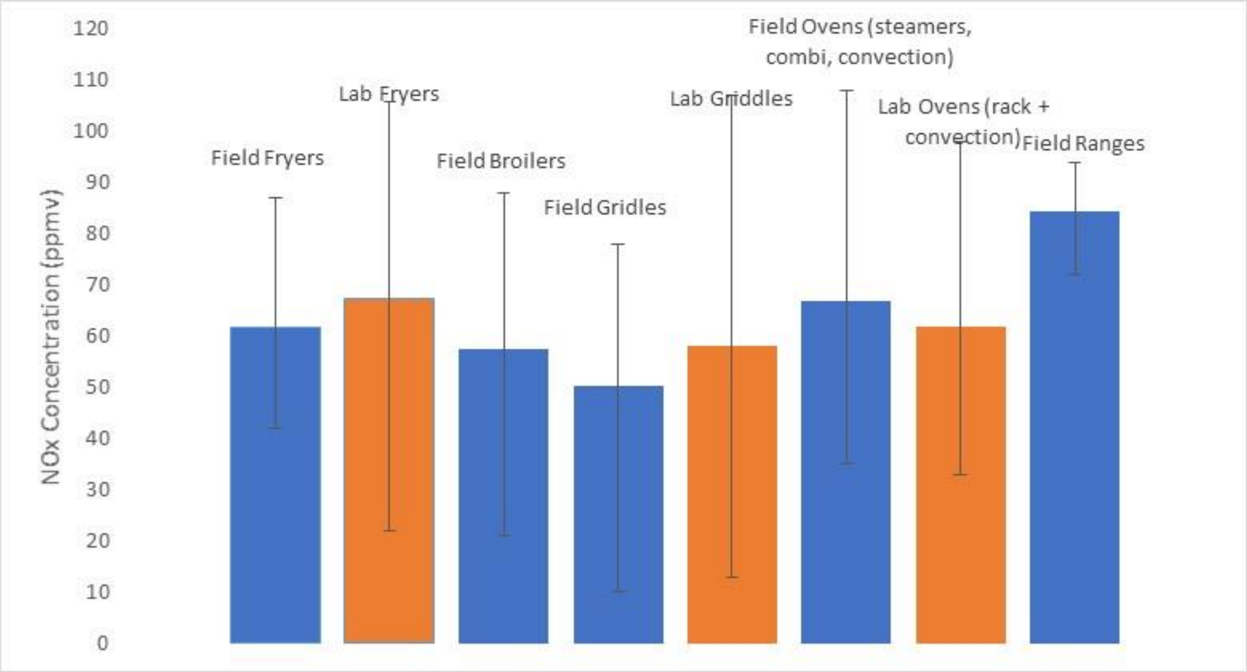
NO_x concentration corrected to 0% Oxygen ranged from 10 to 110 ppm during preheat for appliances tested. Final NO_x measurements less than 10 ppm were recorded as 10 ppm due to the high uncertainty of the portable analyzer measurements under 10 ppm. Eight fryers were tested in the lab, half of which were ENERGY STAR fryers and the other half standard-efficiency fryers. Five griddles were tested in the lab, three of which were ENERGY STAR. Four convection ovens were tested in the lab, three of which were ENERGY STAR. Three rack ovens were tested, all of which were ENERGY STAR ovens.

Table 28: Average NO_x Generation for Different Appliances (ppm 0% corr)

Site / Appliance	Fryer	Broiler	Griddle	Oven	Range
Average – All Sites	62	58	50	67	85
Lab	67	N/A	58	62	N/A

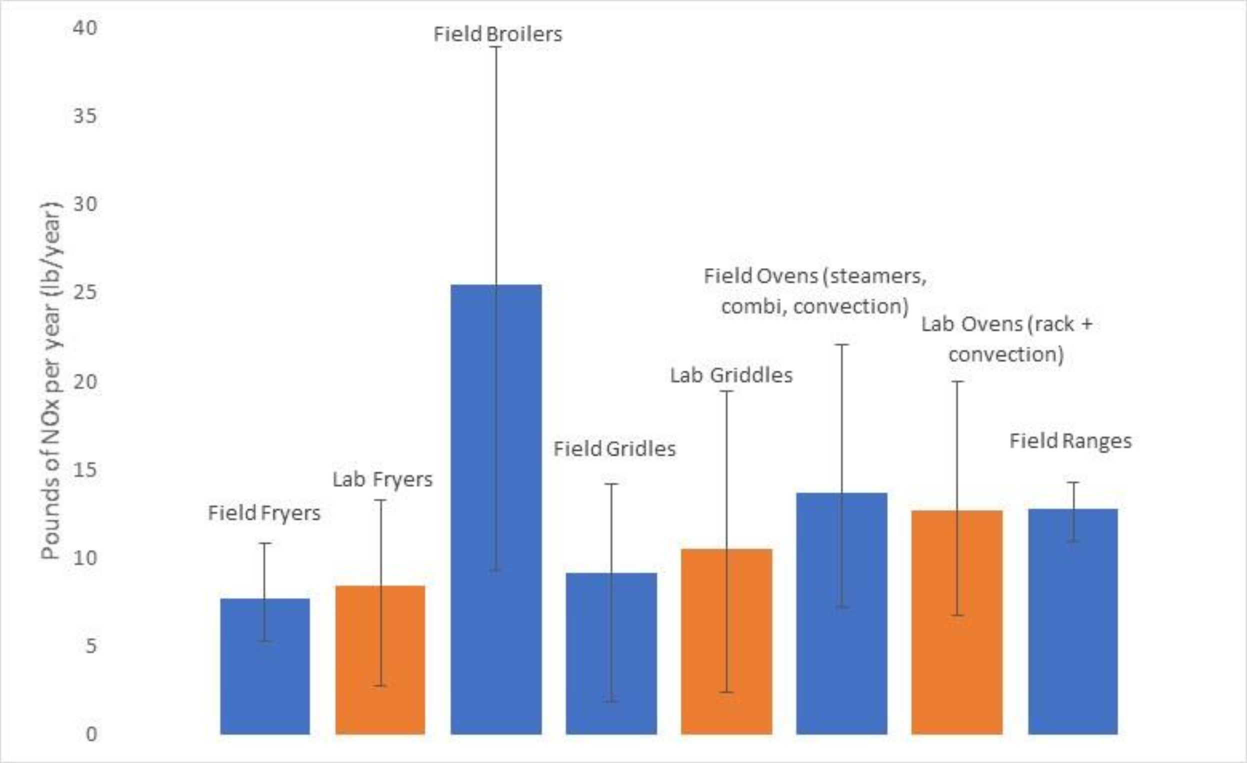
Source: Frontier Energy, Inc.

Figure 347: Measured Appliance NO_x Ranges PPM



Source: Frontier Energy, Inc.

Figure 348: Estimated Annual NO_x Generation per Appliance Type lb/year



Source: Frontier Energy, Inc.

Calculating pounds of NO_x generated per year from concentration of NO_x measured:

Assumptions:

- Method 19 F-Factors

- Natural Gas F-Factor (Fd) = 8710 dscf/106 Btu
- Molar Volume (Vn) = 385.5 dscf/lbmol @ standard conditions 68F (20°C) and 29.92 in Hg (760 mmHg)
- NOx molecular weight (MW) = 46.01 lb/lbmol

$$NOx\left(\frac{lb}{therm}\right) = NOx_{ppm}\ x\ F_{d,natural\ gas}\ x\ \frac{1}{V_n}\ x\ MW_{NOx}\ x\ \frac{1\ MMBtu}{10\ therms}$$

$$NOx\left(\frac{lb}{year}\right) = NOx\left(\frac{lb}{therm}\right) x\ Energy\ Rate\ (\frac{therms}{year})$$

Table 29: Average NO_x Generation for Different Appliances (lb/yr)

Site / Appliance	Fryer	Broiler	Griddle	Oven	Range
Average – All Sites	7.7	25.5	9.1	13.7	12.8
Lab	8.4	N/A	10.5	12.6	N/A

Source: Frontier Energy, Inc.

Some appliance models within the same category (e.g. fryers, griddles) and with similar burner designs generated different NO_x values. Burner input rate, primary and secondary air flow rates, and number of burners also affect NO_x generation. For this reason, NO_x concentration and mass flow rates are model specific and no generalizations can be made about relationships between energy efficiency and NO_x or burner type and NO_x. This calculation methodology of pounds of NO_x generated per year represents the highest NO_x concentration observed from testing different models and the average monitored energy usage of the different appliance categories (see Appendix).

NO_x Measurement Conclusions

There are many different appliance types used in commercial kitchens, but the focus of this study was to evaluate NO_x from five appliance types: fryers, broilers, griddles, ovens, and ranges. NO_x concentration ranged from 10 to 110 ppm across these appliance categories. NO_x has not yet been thoroughly characterized in commercial foodservice and Frontier Energy continues to expand the foundation of NO_x emissions testing, improving the methodology based on different flue geometries and including more challenging open burner arrangements as seen in broilers and ranges. Measurement uncertainty was higher for broilers and ranges due to more diluted air samples found in appliances with no defined flue.

Appliances exhibited varying NO_x concentration in each category with no noticeable correlation between appliance and burner type. Annual appliance NO_x generation depends on measured NO_x values and total burner on-time. Comparing the NO_x ppm values during preheat is not solely representative of total NO_x emitted by the appliance. Appliances with high NO_x ppm values and low burner on-times may generate less NO_x annually than appliances with low NO_x ppm values and high burner on-times. Energy data generated from laboratory or field testing can be used in conjunction with NO_x ppm values to estimate the annual NO_x generated by an appliance. Although ENERGY STAR appliances did not prove to have lower NO_x ppm values, their low energy consumption usually is characterized by shorter burner on-times to achieve similar cooking results.

For lab testing, ASTM D6522 is a good guide and method for understanding analyzer calibration for sub-10 ppm and extended measurement, but it is most suitable for continuous burner operation and emissions analyzers with extraordinary stability. The biggest challenge in applying ASTM D6522 criteria to commercial kitchen appliances is that these appliances typically employ non-continuous burner processes (apart from broilers, ranges, and modulating burners during idle). Seldom does the burner reach steady state conditions; therefore, the stability and linearity requirements need to be flexible enough to accommodate the duration and range of NO_x and CO generated by the burner.

The biggest challenge with field emissions measurement was working in an uncontrollable environment. When measuring emissions in the field, the tests are run according to existing conditions of the appliance and kitchen. Although these uncontrolled conditions increase measurement uncertainty, flue probe placement showed the greatest impact on the NO_x measurement due to air dilution. Samples taken under 16% oxygen concentration exhibited repeatable results. It is not recommended to rely on a NO_x value taken with a diluted sample over 19% oxygen. Portable field analyzers provided consistent results between the same appliance models tested in the lab and at different field sites. With estimated uncertainties around ±10ppm and the wide range of NO_x results between different appliance models within the same category (22-106ppm for fryers), portable NO_x analyzers have shown to be an effective way of measuring NO_x in foodservice. Field test energy data collected throughout this project proved to be instrumental in extrapolating annual NO_x generation.

It is important to emphasize that portable analyzers are not designed to sample for long durations as specified in ASTM D6522 stability tests without experiencing drift. When conducting replicates on the same fryer model, the NO_x emissions for each test showed consistency despite not always meeting ASTM stability criteria. It is recommended that an ASTM NO_x test method be developed specifically addressing foodservice appliances and respective burner cycles with these considerations.

The project identified NO_x emission ranges in major appliance categories as well as measurement methodologies. There are multiple factors that can play into NO_x generation aside from burner type including the firing rate of an appliance, burner location, and configuration of the heat exchanger. For this reason, NO_x concentration and mass flow results are model specific and no generalizations can yet be made about relationships between energy efficiency and NO_x or burner type and NO_x. A regimented study including more appliance types and field sites needs to be conducted to determine which burner and flue designs will produce the least NO_x in each appliance category.

CHAPTER 9:
Technology/Knowledge Transfer Plan

Frontier Energy successfully implemented the technology/knowledge transfer activities outlined in the Technology/Knowledge Transfer Plan in August 2016.

Frontier Energy distributed technical information and knowledge gained from this demonstration project by leveraging Frontier Energy's long-standing workforce education, training and information outreach program for food service as well as the strategic industry partnerships it has forged over the past decades. The goal of the outreach was to educate the target audiences on best design practices while highlighting existing high-efficiency products and energy-efficient components. The outreach provided the benefits of high-efficiency commercial cooking equipment and the various energy-efficient options to educate clients on concepts that yield energy savings for their applications with an end goal to accelerate the adoption and implementation of energy-efficient commercial cooking equipment in the marketplace.

Frontier Energy leveraged its partnerships with established industry professional and trade entities, including the media, to relay the data to these memberships and/or trade allies. Information outreach was delivered through various modes and venues including short seminars, webinars, articles, papers, and interviews.

Additionally, the data filtered through to commercial foodservice industry using design consultations; energy efficiency site audits for local restauranteurs; routine interface with manufacturers and their representatives; and the Food Service Technology Center (FSTC) website at www.fishnick.com.

The targeted audience for the technology transfer activities included engineers, facility designers/consultants, equipment manufacturers, equipment dealers & representatives, equipment service agents, contractors and installers, commercial food service operators – larger and smaller chains, franchisees, and independent owner/operators, non-commercial (institutional) food service 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 – 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 executed by the following activities:

1. Project Webpage: Developed a comprehensive project webpage unique to the research project: https://fishnick.com/ceccook/
2. Project Case Studies: Developed four case studies showcasing the successes and lessons learned at four of the sites.
3. Project Fact Sheets: Developed two (2) 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.

4. California Energy Wise (CEW) Seminars – Conducted eight two-hour seminars highlighting results from the demonstration project.
5. Industry Outreach: Information and data were consistently disseminated via short, quick-time frame (typically 20- to 60-minute) seminars, 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.
6. Media/Media Events: Industry articles from Foodservice Equipment & Supplies magazine covering status updates and findings from project sites.
7. Project Showcases: Hosted two project showcase events to highlight the key successes and lessons learned from the work at each of the five 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.

View the full Technology/Knowledge Transfer Report in Appendix A

CHAPTER 10: Conclusions

Baseline Energy Use and Operating Hours

Table 33 shows gas and electric use for the six monitored sites. Frontier Energy analyzed ventilation systems at all the sites; however, only three sites could potentially be optimized because of the facility regulations. An energy feedback system could be implemented at three sites, informing the operators of their operation’s energy use.

Table 30: Energy Use at Different Sites

Site	Appliances Monitored	Optimized Ventilation Potential	Energy Information System Potential	Daily Energy Use (therms/day)	Daily Energy Use (kWh/day)
DoubleTree	12	Yes	Yes	39	222
UCSF Medical Center	4	No	Yes	32 (one cookline)	N/A
Airline Catering	12	No	No	115	N/A
Werewolf	8	Yes	Yes	22	64
Oliver’s Market	1	No	No	8 (one oven)	N/A
Versailles Cuban	10	Yes	Yes	46	101

Source: Frontier Energy, Inc.

The Airline Catering company had the highest total energy use of all sites because of its long operating hours and multiple cook lines. Werewolf Amercian Pub had the least energy use because of its small appliance line; however, it had the greatest energy reduction potential because of outdated appliances. DoubleTree Hotel had the greatest electric load because of the three electric steamers, large ventilation system, and a relatively low gas load. The UCSF Medical Center cookline had only two ovens as candidates for replacement; however, these appliances used the most energy providing an opportunity for substantial savings. Oliver’s Market grocery store only had one appliance monitored for rotisserie oven replacement. Versailles Cuban full-service restaurant had the entire cookline monitored and had the greatest electric energy savings due to the DCKV system implementation.

The monitored foodservice facilities had long operating hours with the most common appliances being on between 15 and 19 hours per day (Table 34). Fryers, broilers, griddles, and ovens were usually turned on when staff arrived in the morning and turned off after the dining room closed. The range was the only appliance that was turned on and off during service because range burners are manually adjusted when necessary by the operator resulting in shorter operating hours.

Table 31: Average Operating Hours for Different Appliances (h/day)

Site / Appliance	Fryer	Broiler	Griddle	Oven	Range
DoubleTree	15	17	12	19	15
UCSF Medical Center	17	N/A	N/A	15	N/A
Airline Catering	17	18	N/A	18	N/A
Werewolf	15	19	18	19	7
Oliver’s Market	N/A	N/A	N/A	10	N/A
Versailles Cuban	15	N/A	14	5	13
Average – All Sites	16	18	15	14	12

Source: Frontier Energy, Inc.

Broilers used the most energy followed by ovens and griddles (Table 35). Griddles used half the energy of broilers. A fractional reduction in broiler energy could overshadow higher percentage reductions in other appliances. Ovens had the most energy variation, making the higher consumers optimal replacement candidates. Range energy usage depended greatly on restaurant menu items and breakfast service. Fryers had the most consistent energy use due to standard oil vat size and temperatures.

Table 32: Average Energy Use for Different Appliances (therms/day)

Site / Appliance	Fryer	Broiler	Griddle	Oven	Range
DoubleTree	3.7	11.9	4.1	5.1	3.2
UCSF Medical Center	3.3	N/A	N/A	7.8	N/A
Airline Catering	3.4	18.0	N/A	4.8	5.6
Werewolf	2.6	5.3	4.9	3.5	3.1
Oliver’s Market	N/A	N/A	N/A	7.8	N/A
Versailles Cuban	3.7	N/A	5.4	3.6	4.2
Average – All Sites	3.3	11.7	4.8	5.4	4.0

Source: Frontier Energy, Inc.

Cookline Replacement Energy Reduction

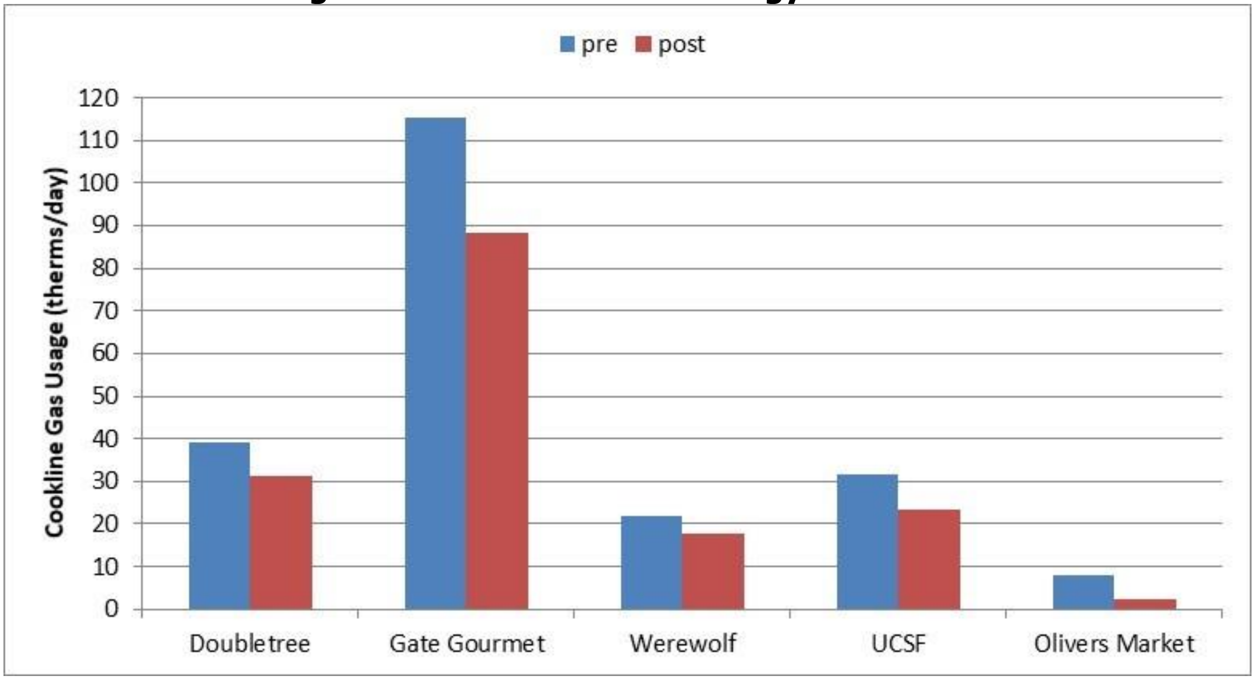
Frontier Energy measured the energy consumption of entire cooklines at five sites and a single rotisserie at another site (Table 36). After energy efficient appliance replacement, the entire cookline gas energy reduction ranged between 19 and 27% (Figure 348). The airline catering company had the highest energy ue with most savings coming from the steam kettle replacement with energy-efficient two-compartment steamers. The University hospital benefited from oven replacement, which resulted in 55% oven energy savings, but the rest of the cookline was not eligible for replacement resulting in 27% overall savings. The restaurant/bar benefited from the whole cookline replacement, which resulted in 19% savings. The hotel appliance replacement resulted in 29% savings mostly due to broiler replacement; large electric energy savings were attributed to compartment steamer replacement. The grocery store experience 68% savings from replacing its rotisserie oven with a combi oven. The full-service restaurant experienced 44% gas savings through replacing its four large vat fryers and convection oven.

Table 33: Cookline Gas Energy Reduction (therms/day)

Site	Gas Savings (therms/day)	Gas Savings	Electric Savings (kWh/day)	Electric Savings (replaced appliances only)
DoubleTree	11.4	29%	137	62%
UCSF Medical Center	8.5	27%	N/A	N/A
Airline Catering	27.1	23%	N/A	N/A
Werewolf	4.3	19%	32	49%
Oliver’s Market	5.3	68%	N/A	N/A
Versailles Cuban	17.5	43%	49	49%
Total – All Sites	74.1	35%	218	53%

Source: Frontier Energy, Inc.

Figure 349: Cookline Gas Energy Reduction



Source: Frontier Energy, Inc.

Researchers only replaced one appliance at the grocery store. The rotisserie oven was replaced by a combi oven resulting in 68% savings. Based on the savings, the grocery store is planning to replace their rotisserie ovens with combis at their other locations.

Researchers monitored electrical energy at three sites. DoubleTree Hotel had three electric two-compartment steamers which were replaced by a gas steamer, a gas combi, and an electric steamer. The steamer replacement resulted in over 137 kWh reduction and the two gas appliances only added two therms to the total gas load. Werewolf restaurant/bar had two kitchen ventilation hoods which were consolidated into one by moving the oven from the prep line to the main cookline. Researchers installed a demand control ventilation system on the main line hood, which resulted in an additional 30% savings. Versailles Cuban full-service restaurant experienced larger electric savings through DCKV system integration because it had more hood space.

Table 34: Cookline Electric Energy Reduction (kWh/day)

Site	Pre Electric	Post Electric	Electric Savings	Electric Savings
DoubleTree	219	85	137	71%
Werewolf	64	32	32	49%
Versailles Cuban	101	52	49	49%
Total – All Sites	384	169	218	56%

Source: Frontier Energy, Inc.

Ventilation: Energy Reduction

Frontier Energy assessed the ventilation requirements for three of the six foodservice facilities. Werewolf and Versailles Cuban restaurants were found to be viable candidates for Demand-Controlled Kitchen Ventilation (DCKV) systems. Initial attempts were made to improve the performance of the hoods, makeup air systems, distribution systems, and general indoor air quality.

The installation the DCKV system at the Werewolf restaurant saved 11,429 kWh/yr in exhaust and supply fan energy (i.e., 45%) annually. At Versailles Cuban, the annual savings were 17,836 kWh from monitoring the exhaust and supply fans (i.e., 49%) with an estimated annual heating savings of 1,200 therms/yr.

The component and installation prices on DCKV systems currently on the market are still high and pose a barrier to deep market penetration, which is currently only estimated to be 3 to 5%. Demand-Controlled Kitchen Ventilation is certainly the wave of the future as the field installations proved that constant volume ventilation systems are unnecessary for large parts of the day and waste tremendous amounts of energy. Simpler and less expensive systems are currently being developed to communicate directly between the appliance and ventilation system. These systems can be manufactured cost effectively and eliminate some of the shortcomings with temperature-based systems such as latency and slow response, which lead to poor hood performance and poor indoor air quality. Additional research is needed to develop cost-effective systems that respond quickly to changes in the cooking operation by anticipating ventilation rates through direct communication with the appliance’s control system.

In a similar progressive approach, research can be done to harvest and redirect the large amount of waste heat being released through the exhaust system of every foodservice facility. Commercial kitchen ventilation heat recovery systems are used to preheat water to offset demand by the water heater or to provide a source of heat for equipment utilizing makeup air heating. The research needs to be initiated to develop and evaluate many exhaust air heat recovery systems that are currently in various stages of development.

Barriers to Adoption and Market Potential

Most restaurant operators do not replace a piece of equipment until it breaks down. With most commercial cooking equipment manufacturers focusing on reliability over efficiency, it is common to see 20-year old operating appliances. Often facility gas meters are located on the supply line for the entire building, so it is difficult for an operator to determine which appliances consume the most energy. If operators were aware of the annual energy cost of each appliance, they would be more likely to replace them with energy-efficient alternatives. The high initial cost of commercial cooking appliances ($3,000 to $15,000) presents one of the biggest barriers to market adoption; however, energy-efficient appliance rebates and utility financing provide operators the tools necessary to ease the financial burden.

New restaurant operators are more likely to specify energy-efficient equipment in their kitchen because the incremental cost of energy-efficient equipment over standard equipment is lower than the initial purchase price. The biggest barrier to adoption for new restaurant operators is that commercial kitchen designers are often loyal to a single brand family of appliances. Although each major appliance brand has several energy-efficient options, specifying all new appliances from one brand will result in an inefficient kitchen. Most new restaurant construction projects run over budget due to unforeseen code challenges or mismatched dimension specifications. Cooking equipment is one of the last components specified for restaurants and its purchasing budget often gets reduced at the last moment because of these common construction budget issues. Reduced appliance purchasing budgets often lead to specification of inefficient equipment. Restaurant operators are also more likely to spend budget in the dining room than on the kitchen cookline.

With more restaurants empathizing with sustainable food purchasing strategies, their carbon footprint can further be reduced by specifying energy-efficient cooking equipment. It is estimated that independent establishments account for 70% of restaurants in California, which amounts to approximately 60,000 independent restaurants (referenced in the CHD-Expert foodservice report).

With roughly 100,000 foodservice facilities operating in California, with most having at least some combination of range, fryer, griddle, or oven, there is large market potential for implementing energy-efficient appliances. Sites in this project demonstrated up to 41% energy savings. Scaling the replacement model to all foodservice facilities in the state may not be practicable given initial equipment purchase expense; however, targeted appliance replacement is possible in any kitchen. Identifying the highest energy-consuming appliance and replacing it with an energy-efficient appliance could cost the operator less than $5,000 and have payback times of less than two years.

GLOSSARY

Term	Definition
Cooking Energy (kWh or kBtu)	The total energy consumed by an appliance as it is used to cook a specified food product.
Cooking Energy Consumption Rate (kW or kBtu/h)	The average rate of energy consumption during the cooking period.
Cooking Energy Efficiency (%)	The quantity of energy input to the food products; expressed as a percentage of the quantity of energy input to the appliance during the heavy-, medium-, and light-load tests.
Duty Cycle (%)	The average energy consumption rate (based on a specified operating period for the appliance) expressed as a percentage of the measured energy input rate. Also referred to as load factor.
Energy Input Rate (kW or kBtu/h)	The peak rate at which an appliance will consume energy, typically reflected during preheat. Also referred to as Energy Consumption Rate or Energy Rate.
Heating Value (Btu/ft^3)	The quantity of heat (energy) generated by the combustion of fuel. For natural gas, this quantity varies depending on the constituents of the gas. Also referred to as Heat Content.
Idle Energy Rate (kW or Btu/h)	The rate of appliance energy consumption while it is holding or maintaining a stabilized operating condition or temperature. Also referred to as Idle Rate.
Idle Temperature (°F, Setting)	The temperature of the cooking cavity/surface (selected by the appliance operator or specified for a controlled test) that is maintained by the appliance under an idle condition.
Idle Duty Cycle (%)	The idle energy consumption rate expressed as a percentage of the measured energy input rate. Also referred to as Idle Energy Factor.
Measured Input Rate (kW or Btu/h)	The maximum or peak rate at which an appliance consumes energy, typically reflected during appliance preheat (i.e., the period of operation when all burners or elements are″on″).
Pilot Energy Rate (kBtu/h)	The rate of energy consumption by the standing or constant pilot while the appliance is not being operated (i.e., when the thermostats or control knobs have been turned off by the food service operator).

Term	Definition
Preheat Energy (kWh or Btu)	The total amount of energy consumed by an appliance during the preheat period
Preheat Rate (°F/min)	The rate at which the cook zone heats during a preheat.
Preheat Time (minute)	The time required for an appliance to ″pre-heat″ from the ambient room temperature (75 ± 5°F) to a specified (and calibrated) operating temperature or thermostat set point
Production Capacity (lb/h)	The maximum production rate of an appliance while cooking a specified food product in accordance with the heavy-load cooking test
Production Rate (lb/h)	The average rate at which an appliance brings a specified food product to a specified″cooked″ condition
Rated Energy Input Rate (kW, W or Btu/h, Btu/h)	The maximum or peak rate at which an appliance consumes energy as rated by the manufacturer and specified on the nameplate. Also referred to as Nameplate Energy Input Rate
Recovery Time (minute, second)	The average time from the removal of the cooked food product until the appliance has returned to a specified ready-to-cook condition.
Test Method	A definitive procedure for the identification, measurement, and evaluation of one or more qualities, characteristics, or properties of a material, product, system, or service that produces a test result.
Typical Day	A sampled day of average appliance usage based on observations and/or operator inter-views, used to develop an energy cost model for the appliance.

LIST OF ACRONYMS

Term	Definition
ASTM	Formerly known as the American Society for Testing and Materials
Btu	British thermal units
CEM	Continuous emission monitor
CEUS	California Commercial End-Use Survey
Cfm	Cubic feet per minute
CFS	Commercial food service
CKV	Commercial kitchen ventilation
CO	Carbon monoxide
CO_2	Carbon dioxide
DCKV	Demand-controlled kitchen ventilation
EIS	Energy information system
°F	Degrees Fahrenheit
F^2	Square feet
FSEC	SoCal Gas Food Service Equipment Center
FSTC	Food Service Technology Center
Gpm	Gallons per minute
GTI	Gas Technology Institute
HP	Horsepower
inWC	Inches of water column
IR	Infrared
kBtu/h	Kilo British thermal units per hour
kW	Kilowatts
kWh	Kilowatt-hour

Term	Definition
Lb/hr	Pounds per hour
NO_2	Nitrogen dioxideC
NOx	Nitrogen oxides
O_2	Oxygen
PG&E	Pacific Gas and Electric Company
PIER	Public Interest Energy Research Program
RPM	Revolutions per minute
Scf	Standard cubic foot
SDG&E	San Diego Gas & Electric Company
SoCal Gas	Southern California Gas Company
SPPM	Single point probe measurement
UCSF	University of California, San Francisco
VFD	Variable frequency drive
W	Watts
Wh	Watt-hours

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APPENDIX A:
Technology Transfer Plan

Technology Transfer Plan Execution

Frontier Energy 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 on August 2016.

Frontier Energy disseminated technical information and knowledge gained from this demonstration project by leveraging Frontier Energy's long-standing workforce education, training and information outreach program (www.fishnick.com) for food service as well as the strategic industry partnerships it has forged over the past decades. The goal of the outreach was to educate the target audiences on best design practices while highlighting existing high efficiency products and energy efficient components. The objective of the outreach was to communicate the benefits of high efficiency commercial cooking equipment and the various energy efficient options to educate clients on concepts that yield energy savings for their applications, with an end goal to accelerate the adoption and implementation of energy efficient commercial cooking equipment in the market place.

Workforce Education and Training (WE&T) is an ongoing program offered to the food service sector by California's four Investor Owned Utilities (IOUs) through the statewide *California Energy Wise* seminar program. Energy Efficiency (EE) food service seminars (at least two or more hours) and/or webinars (a minimum of 30 minutes) 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 so as to increase seminar participant knowledge on how to improve operations and practices. Frontier Energy 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 and deliverance of these seminars with the FSTC in PG&E's service territory and in collaboration with SDG&E and SoCalGas in southern California to reach targeted audiences in those service areas, respectively.

Frontier Energy leveraged its partnerships with established industry professional and trade entities, including the media, to relay the data to these memberships and/or trade allies. Information outreach was delivered through various modes and venues including short seminars, webinars, articles, papers and interviews. These types of outreach activity provided a forum in which a group was delivered extensive information on energy efficient technology and/or the application of energy efficient technology in a quick-time frame (typically 20- to 45-minute), industry-hosted venues, most often by invitation and/or ideation proposals.

Additionally, the data filtered through to commercial foodservice industry actors via design consultations; energy efficiency site audits for local restauranteurs; routine interface with manufacturers and their representatives; and the FSTC website at www.fishnick.com. Four (4) case studies were developed highlighting the key findings, one for each of the demonstration sites and were distributed through existing FSTC and CEC outreach channels.

Targeted Audience

- Engineers
- Facility designers/consultants
- Equipment manufacturers
- Equipment Dealers & Representatives
- Equipment Service Agents
- Contractors and installers
- Commercial food service operators – larger and smaller chains, franchisees, and independent owner/operators
- Non-commercial (institutional) food service operators such as hotel, hospital, business, commissary kitchens and campus kitchen/dining facilities
- 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)
- Media – articles, technical features and/or interviews
- 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)
- Utilities – Energy Centers, CA Statewide IOU Advisory Council Meetings, Codes & Standards, Incentives and Emerging Technologies groups
- Other Research Organizations

Technology Transfer Platform

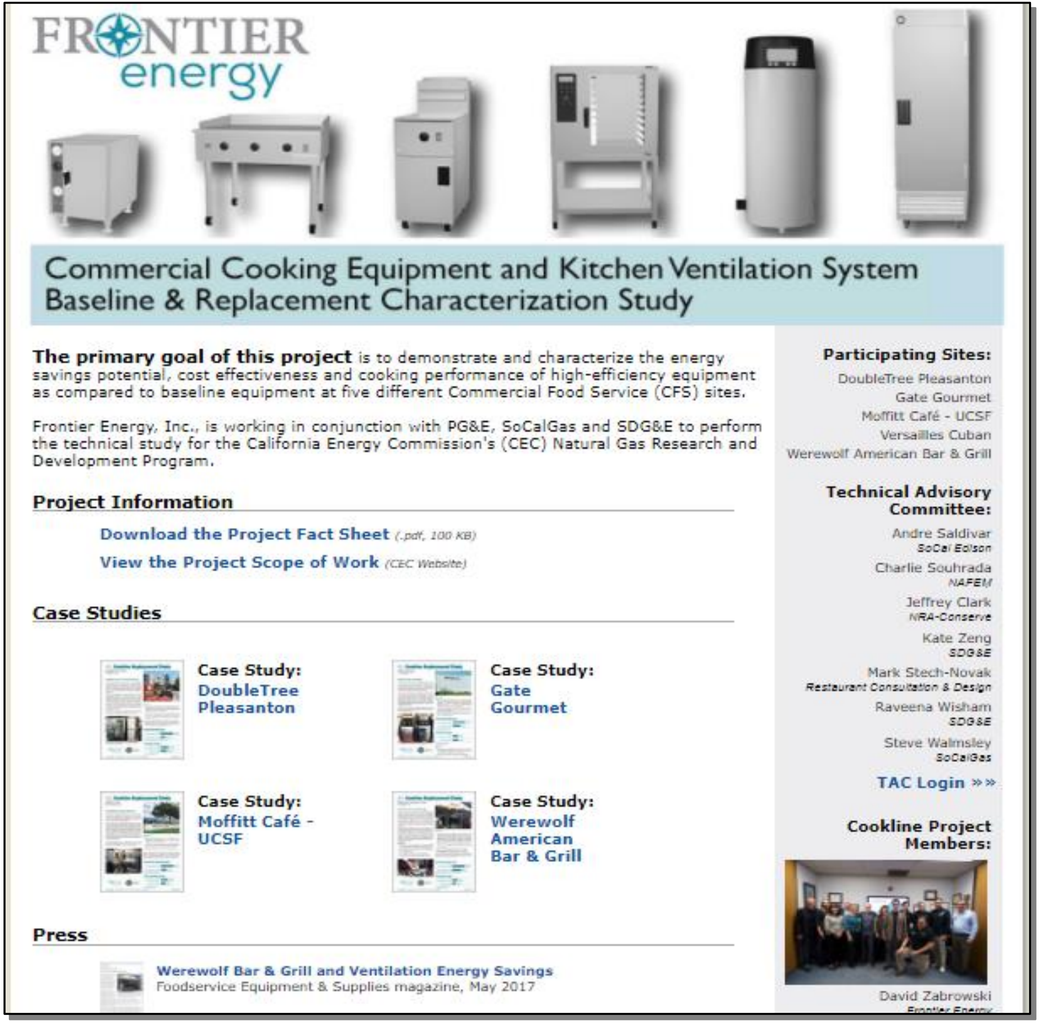
Project Webpage

Developed a comprehensive project webpage unique to the research project (Figure A-1). https://fishnick.com/ceccook/

- 04/01/2015 – 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.

- 11/7/2017 – 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.

Figure A-1: Project Webpage



Commercial Cooking Equipment and Kitchen Ventilation System Baseline & Replacement Characterization Study

The primary goal of this project is to demonstrate and characterize the energy savings potential, cost effectiveness and cooking performance of high-efficiency equipment as compared to baseline equipment at five different Commercial Food Service (CFS) sites.

Frontier Energy, Inc., is working in conjunction with PG&E, SoCalGas and SDG&E to perform the technical study for the California Energy Commission's (CEC) Natural Gas Research and Development Program.

Project Information

Download the Project Fact Sheet *(.pdf, 100 KB)*

View the Project Scope of Work *(CEC Website)*

Case Studies

Case Study: DoubleTree Pleasanton

Case Study: Gate Gourmet

Case Study: Moffitt Café - UCSF

Case Study: Werewolf American Bar & Grill

Press

Werewolf Bar & Grill and Ventilation Energy Savings
Foodservice Equipment & Supplies magazine, May 2017

Participating Sites:

DoubleTree Pleasanton
Gate Gourmet
Moffitt Café - UCSF
Versailles Cuban
Werewolf American Bar & Grill

Technical Advisory Committee:

Andre Saldivar
SoCal Edison
Charlie Souhrada
NAFEM
Jeffrey Clark
NRA-Conserve
Kate Zeng
SDG&E
Mark Stech-Novak
Restaurant Consultation & Design
Raveena Wisham
SDG&E
Steve Walmsley
SoCalGas

TAC Login »»

Cookline Project Members:

David Zabrowski
Frontier Energy

Project Case Studies

Developed four (4) case studies showcasing the successes and lessons learned at four of the sites.

- Cookline Replacement Study - DoubleTree Hotel – Pleasanton, CA
- Cookline Replacement Study - Gate Gourmet – Los Angeles, CA
- Cookline Replacement Study - Moffitt Café, UCSF – San Francisco, CA
- Cookline Replacement Study - Werewolf Café – San Diego, CA

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

Depending on the remaining budget, a fifth case study may be developed in 2018 highlighting the successes and lessons learned from the Versailles Cuban site.

Cookline Replacement Study

Gate Gourmet

Los Angeles, CA

Energy savings take flight...

Cookline Replacement Study

DoubleTree Hotel

Pleasanton, CA

Doubling down on energy efficiency...

Cookline Replacement Study

Moffitt Café

San Francisco, CA

Committed to energy efficiency...

Cookline Replacement Study

Werewolf American Pub

San Diego, CA

Out with the old and in with the new...

Project Fact Sheets

Developed two (2) 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/ceccook/

California Energy Wise (CEW) Seminars

Conducted two-hour (2 h) seminars highlighting results from the demonstration project. Presentation materials were developed for a new seminar (Putting the Kitchen of the Future to the Test) and were incorporated into an existing seminar (Fast, Small, Flexible). CEW seminars are directed at a wide variety of market actors including, but not limited to, commercial and non-commercial food service 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: Fast, Small & Flexible: Maximizing Your Kitchen Space

- Outcome: Participants learned about new state of the art technology that can optimize efficiency, functionality and performance while reducing the overall footprint to meet the evolving demands of the 21st century commercial kitchen.
- Date: August 2, 2016
    - Location:Energy Innovation Center, SDG&E – San Diego, CA
    - Audience: Industry Professionals: equipment reps, account managers, designers/consultants, environmental health and operators
    - Number of Attendees: 25
    - Speaker: Mark Finck, Frontier Energy Lab Manager
    - Presentation available at: https://fishnick.com/handouts/08022016/
- Date: August 16, 2016
    - Location: Food Service Technology Center, PG&E – San Ramon, CA
    - Audience: Industry Professionals: equipment reps, account managers, designers/consultants, environmental health plan checkers and operators
    - Number of Attendees: 21
    - Speaker: Mark Finck, Frontier Energy Lab Manager
    - Presentation available at: https://fishnick.com/handouts/08162016/

Topic: Clearing the Air on Kitchen Ventilation

- Outcome: Participants learned about the results and data from DCKV Werewolf report.
- Date: 04/25/2017
    - Location: Food Service Technology Center, PG&E
    - Audience: Foodservice industry professionals: equipment dealers, consultants, environmental health plan checkers and foodservice operators
    - Number of Attendees: 18
    - Speakers: Don Fisher, Fisher Consultants Principal and Rich Swierczyna, Frontier Energy Sr. Engineer
    - Presentation available at: https://fishnick.com/handouts/04252017/

Topic – Putting the Kitchen of the Future to the Test

- Outcome: Participants learned how energy efficient foodservice equipment performed in a real kitchen, the impacts to the bottom line including cost justification for new equipment and when it makes sense to change the cooking platform.
- Date: July 18, 2017
    - Location: Energy Innovation Center, SDG&E – San Diego, CA
    - Audience: Foodservice industry professionals: operators, consultants/designers and utility representatives
    - Number of Attendees: 24

    - Speaker: Denis Livchak, Frontier Energy Engineer and Guest Speakers: Justin Hoehn, Rational Corporate Chef and Rocky Nichols, Werewolf Owner/Operator.
    - Presentation available at: https://fishnick.com/handouts/07182017/
- Date: November 9, 2017
    - Location: Food Service Technology Center, PG&E – San Ramon, CA
    - Audience: Foodservice industry professionals: operators, consultants/designers and utility representatives
    - Number of Attendees: 45
    - Speakers: David Zabrowski, Frontier Energy VP, Denis Livchak, Frontier Energy Engineer, Richard Young, Frontier Energy Director of Education
    - Presentation available at: https://fishnick.com/handouts/11092017/

Topic – *Build a Better Burger*

- Outcome: Participants learned about new innovative technologies that were showcased in the Cookline project and how they equated to substantial energy savings in the foodservice sites
- Date: September 12, 2017
    - Location: Food Service Technology Center, PG&E – San Ramon, CA
    - Audience: Restaurant operator/owners, manufacturer reps, consultants, and culinary schools.
    - Number of Attendees: 21
    - Speaker: Mark Finck, Frontier Energy Lab Manager
    - Presentation available at: https://fishnick.com/handouts/09122017/
- Date: September 14, 2017
    - Location: Foodservice Technology Center, SoCal Edison – Irwindale, CA
    - Audience: Restaurant operators/owners, manufacturer reps and consultants
    - Number of Attendees: 15
    - Speaker:Mark Finck, Frontier Energy Lab Manager
    - Presentation available at: https://fishnick.com/handouts/09142017/

Delivered Webinars:

Topic - What You Need to Know Before NRA – 05/08/2018

- Outcome: Participants learned about the innovative equipment being showcased in the Cookline project that would be on display at the NRA Show. Highlighted data from the energy efficient cooking equipment replacements in the Cookline project.
- Date: May 8, 2017
    - Audience: Cross-section of Commercial Food Service industry professionals: dealers, manufacturers, utilities, equipment reps, and designers
    - Number of Attendees: 55

    - Speakers: Mark Finck, Frontier Energy Lab Manager, Richard Young, Frontier Energy Director of Education, David Zabrowski, Frontier Energy VP
    - Recorded webinar available at: http://www.fishnick.com/education/webinars/2017/nrashow/

Topic: Reduce Frying Costs While Optimizing Food and Oil Quality

- Outcome: Participants learned about best practices for their frying operation: from the learn the importance of filtering, tips to prolong the life and quality of the oil and how fryer selection and maintenance play a key role in the success of their frying program. Highlighted data from the fryer replacements in the Cookline project.
- Date: July 12, 2017
    - Audience: Cross-section of Commercial Food Service industry professionals: dealers, manufacturers, utilities, equipment reps, consultants and designers
    - Number of Attendees: 45
    - Speakers: Mark Finck, Frontier Energy Lab Manager; Guest Speaker Corby Stow, Oil Solutions Groups
    - Recorded webinar available at: https://fishnick.com/education/webinars/2017/fryingcosts/

Topic: LEED and the Hotline: Using LEED Guidelines to Create a High Performance Cookline

- Outcome: Participants learned how to use LEED as a guideline to create a high-performance energy efficient cookline.
- Date: September 19, 2017 - webinar in partnership with FCSI
- Audience: Cross-section of Commercial Food Service industry professionals: dealers, manufacturers, utilities, equipment reps, consultants and designers
- Number of Attendees: 107
- Speakers: Richard Young, Frontier Energy Director of Education and Bret Daniels (Camacho)
- Recorded webinar available at:https://attendee.gotowebinar.com/register/4785324575510843395

Industry Outreach

Information and data were consistently disseminated via short, quick-time frame (typically 20- to 60-minute) seminars, 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. 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

FCSI the Americas – Foodservice Consultants Society International

Topic - Lab Meets the Real World: Case Studies of Energy Efficient Upgrades that Saved Money.

- Outcome: Participants learned about energy and water efficient equipment might and how the savings held up in the tough and unpredictable environment of a real-world kitchen compared to the lab. This presentation shared energy and cost comparison data from two of the CEC project monitoring sites – Gate Gourmet (SoCalGas service territory) and Werewolf (SDG&E) where existing standard foodservice appliances (broilers, fryers, steamers, combination ovens, convection ovens, griddles and ice machines) were replaced by energy efficient units.
- Date: April 16, 2016
- Location: Nashville, TN
- Audience: Foodservice consultants/designers, manufacturers, industry media, directors of other industry associations
- Number of Attendees: 300
- Speaker: Richard Young, Frontier Energy, Director of Education
- Presentation available at: https://fishnick.com/handouts/04162016/

Rational & Halton Foodservice Design Workshop

Topic: Fast, Small & Flexible: Maximizing Productivity with Fewer Resources

- Outcome: This presentation shared energy and cost comparison data from the Werewolf (SDG&E) where existing standard foodservice appliances (broilers, fryers, steamers, combination ovens, convection ovens, griddles and ice machines) were replaced by energy efficient units and product was gradually shifted from standard cooking equipment to the combi oven. Participants learned how using new technology such as combi ovens could reduce overall equipment energy use and space requirements while improving performance.
- Date: May 3-4, 2016
    - Location: San Diego
    - Audience: Consultants
    - Number of Attendees: 25
    - Speaker: David Zabrowski, Frontier Energy VP
    - Presentation available at: https://fishnick.com/handouts/05042016/

National Restaurant Association Annual Trade Show / Educational Sessions / Panel Discussion

Topic: The Future of Restaurant Design

- Outcome: Participants learned about the future of restaurant design and what the restaurant of the future will look like and how it will differ from today. This session explored how evolving customer expectations will impact the restaurant of the future.
- Date: May 22, 2016
    - Location: McCormick Convention Center – Chicago, IL
    - Audience: Foodservice Industry
    - Number of Attendees: 100

    - Speaker: David Zabrowski, Frontier Energy VP
    - Presentation: No PowerPoint available as this was a panel discussion.

ASHRAE – ASHRAE Annual Conference

Topic – Thermal Comfort in Commercial Kitchens: A Real-World Perspective.

- Outcome: This presentation shared kitchen temperature data from the Werewolf site. This seminar session demonstrated how extreme the thermal environment can be in a commercial kitchen and explained the challenge faced by engineers trying to improve thermal comfort through better CKV-HVAC system design.
- Date: June 26, 2016
    - Location: St. Louis, MO
    - Audience: ASHRAE Members, engineers, manufacturers, codes and standards officials, government education and research organizations
    - Number of Attendees: ~80
    - Speaker: Don Fisher, Fisher Consultants, LLC, ASHRAE Member

RFMA - Restaurant Facility Management Association Annual Conference

Topic - Kitchenology: Tales of Transformation and Efficient and Effective Operations

- Outcome: Participants learned why it is important to choose equipment wisely as they learned about the results and findings from real-world applications of these technologies in the field during the Cookline project.
- Date: March 6, 2017
    - Location: Nashville, TN
    - Audience: RFMA members, Facility Managers from national restaurant chains, equipment manufacturers and industry media.
    - Number of Attendees:
    - Speaker: Mark Finck, Frontier Energy Lab Manager
    - Presentation available at: https://fishnick.com/handouts/03062017/

CIA Summit – Culinary Institute of America Flavor Summit

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

- Outcome: Participants learned about highlights from the Cookline project and energy efficient cooking equipment can result in significant energy savings.
- Date: March 10, 2017
    - Location: CIA Greystone Campus, Sonoma, CA
    - Audience: Executive Chefs
    - Number of Attendees: 50
    - Speaker: Richard Young, Frontier Energy Director of Education

GFEN Conference – Gas Foodservice Equipment Network

Topic: Foodservice Equipment Innovations

- Outcome: Participants learned about highlights from the Cookline project.
- Date: April 4, 2017
    - Location: Natural Gas Technology Center in Charlotte, NC
    - Audience: Utility representation from across the US looking to either add foodservice programs to their existing portfolios or increase their existing foodservice programs.
    - Number of Attendees: 50
    - Speaker: Richard Young, Frontier Energy Director of Education

MISE Conference: (MISE refers to the setup chefs do for service)

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

- Outcome: Participants learned why it is important to choose equipment wisely as they learned about the results and findings from real-world applications of these technologies in the field during the Cookline project.
- Date: August 22, 2017
    - Location: Atlanta, GA
    - Audience: Hotel chefs representing national hotel chains
    - Number of Attendees: ~70
    - Speaker: Mark Finck, Frontier Energy Lab Manager
    - Presentation available at: https://fishnick.com/handouts/08222017/

ACFSA Annual Conference - Association of Correctional Food Service Affiliates

Topic: Food Service Equipment Panel: How Can Technology Help?

- Outcome: Participants learned about some of the findings from the Cookline project during the session.
- Date: September 26, 2017
    - Location: San Diego, CA
    - Audience: ACFSA members, facility management, manufacturers and food service directors
    - Number of Attendees: 30
    - Speakers: Richard Young, Frontier Energy Director of Education participated in a panel moderated by Robin Ashton – Foodservice Equipment Reports

Topic: Equipment Productivity, LEED and Professional Training

- Outcome: Participants learned about some of the findings from the Cookline project during the session.
- Date: September 27, 2017
    - Location: San Diego, CA

    - Audience: ACFSA members, facility management, manufacturers and food service directors
    - Number of Attendees: 25
    - Speaker: Richard Young, Frontier Energy Director of Education
    - Presentation available at: https://fishnick.com/handouts/09272017/

ESC TMAF Conference - Energy Solutions Center Technical Marketing Forum

Topic: Putting the Kitchen of the Future to the Test

- Outcome: Presented an overview of the cookline project and highlighted key outcomes to attendees at the fall conference.
- Date: October 3, 2017
    - Location: Los Angeles, CA
    - Audience: Representatives from GFEN's utility members
    - Number of Attendees: 30
    - Speaker: Richard Young, Frontier Energy Director of Education

Other Industry Outreach Event Platforms included the following venues:

National and State Conferences

- ASTM F26 Committee Meetings - Chicago, IL – May 2017
    - Participated in the meetings and provided updates on the Cookline project to approximately 20 attendees representing commercial foodservice equipment manufacturers (broilers, combis and steamers)
- ACFSA – American Correctional Foodservice Association – San Diego, CA – October 2017
    - Participated in two presentations and shared highlights from the Cookline project with attendees.
- CEE – Consortium for Energy Efficiency – San Francisco, CA - January 2017
    - Conference attendees participated in a field trip to the Food Service Technology Center and were given overview of the Cookline project
- CEHA – California Environmental Health Association
    - Provide education to CEHA members on innovative cooking equipment that has entered the market. Shared data from the Cookline project with members and plan checkers.
- CEW EPC – California Energy Wise Executive Planning Council Meetings
    - Provided quarterly updates during the Spring, Summer, Fall and Winter meetings to Executive Planning Council members representing SoCalGas, SDG&E, SoCal Edison and PG&E.
- CFESA – Commercial Foodservice Equipment Service Association – Austin, TX - October 2017
    - Shared overview and highlights from the project with attendees at the annual conference, October 15-16 in Austin, TX

- CIA – Culinary Institute of America
    - Presented at the annual flavor summit in Sonoma, CA
- CRA – California Restaurant Association
        - CRA participates in our California Energy Wise seminars and helps promote our events and research to its customers.
- CSNA – California School Nutrition Association – Sacramento, CA – November 2017
    - Exhibited at the CSNA show and shared case studies from the cookline project with attendees.
- GFEN – Gas Foodservice Equipment Network
    - Participated and presented at the April workshop in Charlotte, NC. Provided attendees with an overview of the Cookline project
    - Participated in the TMAF Conference in October – Los Angeles, CA and shared results and lessons learned from the research project
    - Participated in monthly member calls and shared updates and information on the project as needed.
- GGRA – Golden Gate Restaurant Association
- NAFEM – North American Association of Food Equipment Manufacturers
    - Charlie Souhrada with NAFEM serves on the TAC for the cookline project. Through Charlie we were able to share updates on the project.
- NAFEM TLC (Technical Liaison Committee) – Washington, DC – November 2017
- NAFEM TLC, - Denis Livchak shared information about the cookline project during the broiler, steamer and combi oven ASTM test standards discussion during the meetings Nov 1-3 in Washington D.C. He spoke to how the measured results from Doubletree and Werewolf allowed us to understand steamer and combination oven water consumption as well as hours of operation which was conveyed to the meeting attendants to understand real life equipment energy usage and to persuade manufacturers to develop more energy efficient broiler models. Participants: 30; Attendees: from the industry including manufacturers and end users
- NRA Show– National Restaurant Association – Chicago, IL –May 2017
    - Shared updates on the research and data from the CEC Cookline projects with industry associations, trade magazines, manufacturers and more.
- RFMA – Restaurant Facility Management Association – March 2017
    - Exhibited at the conference and shared some of the lessons learned with attendees.
    - Presented session to the members that provided the opportunity to share some of the results from the Cookline project.
- SoCalGas Foodservice Equipment Expo – Downey, CA – October 24-25, 2017
    - Discussed the cookline project and promoted the showcase event to attendees and vendors at the 7th Annual Foodservice Equipment Expo.

Media / Media Events

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

- *Foodservice Equipment & Supplies (FE&S)* covered the progress of the project throughout its entirety via numerous Press Releases:
    - Press Release – 07/10/2015
        - Frontier Energy (formerly Fisher-Nickel)
        - Technical Advisory Committee Announced
    - Press Release – 08/02/2015
        - Foodservice Equipment & Supplies
        - Case Study: Researching the Kitchen of the Future
        - By: Amelia Levin, Contributing Editor
    - Press Release – 09/30/2015
        - Foodservice Equipment & Supplies
        - Werewolf Cookline Project: An Update
        - By: Amelia Levin, Contributing Editor
- Press Release – 04/01/2016
    - Foodservice Equipment & Supplies
    - PG&E Cookline Project Update: Gate Gourmet
    - By: Amelia Levin, Contributing Editor
- Press Release – 10/03/2016
    - Foodservice Equipment & Supplies
    - *Energy Reduction Kitchen Plan Saves Double Tree Money*
    - By: Amelia Levin, Contributing Editor
- Press Release – 05/01/2017
    - Foodservice Equipment & Supplies
    - *Werewolf Bar & Grill and Ventilation Energy Savings*
    - By: Amelia Levin, Contributing Editor
- Press Release – 07/10/2017
    - Foodservice Equipment Reports
    - Fisher-Nickel Changes Name to Frontier Energy Report – 07/2017
- SFIA Master's Thesis
    - *Energy Reduction in Commercial Kitchens*
    - By: Denis Livchak, Engineer III

Project Showcases

Hosted two Project Showcase events to highlight the key successes and lessons learned from the work at each of the five 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 SDG&E, focused on the work performed at the Werewolf in San Diego, CA

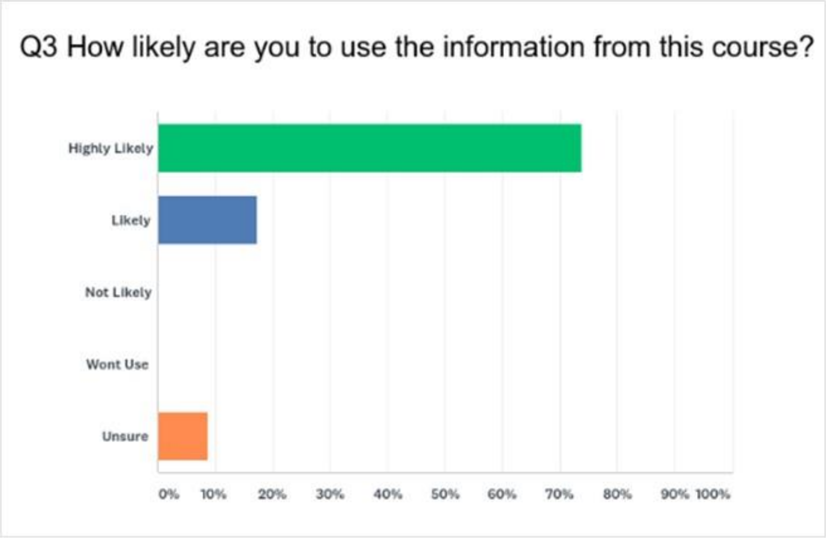
- Date: July 18, 2017 Location: SDG&E Energy Innovation Center Audience: Foodservice industry professionals: operators, consultants/designers and utility representatives
- Number of Attendees: 24 Speakers: Denis Livchak, Frontier Energy Engineer and Guest Speakers: Justin Hoehn, Rational Corporate Chef and Rocky Nichols, Werewolf Owner/Operator.
- Presentation available at: https://fishnick.com/handouts/07182017/
- This seminar served as a showcase for results from the Werewolf site and shared the steps taken to upgrade the Werewolf to an energy efficient cookline and highlighted the key outcomes from the research project. The seminar included a combi cooking demonstration by Justin Hoehn, Rational and concluded with a Q&A session with Werewolf owner, Rocky Nichols.
- According to Rocky Nichols – Werewolf Owner, "...it was tough bringing new equipment in an already designed kitchen, we were excited by the opportunity to install a combi oven, but the technology was outside of our comfort level. However, the chicken is better from the combi oven."
- 

Showcase 2: Putting the Kitchen of the Future to the Test Showcase Event

Partnership with PG&E Food Service Technology Center, focused on the work performed at all five sites.

- Date: November 9, 2017
- Location: Food Service Technology Center in San Ramon, CA
- Audience: Wide cross section of foodservice industry professionals Manufacturers, Equipment Reps, Dealers, Utility Representatives, Operators, Media, Designers, Industry Association Representatives, and TAC Members.
- Number of Attendees: 45
- Speakers: David Zabrowski, Frontier Energy VP, Denis Livchak, Frontier Energy Engineer, Richard Young, Frontier Energy Director of Education
- Presentation available at: https://fishnick.com/handouts/11092017/

- Presentations: provided an overview of the project followed by key successes, highlights and lessons learned. A panel discussion consisting of project participants: Dan Henroid (UCSF), Ted Mayorquin (DoubleTree) and Stacey Turek (Vulcan) rounded out the presentation.
- Hands-On Equipment Demonstrations: guests were invited to participate in the hands-on demonstration featuring the equipment showcased in the project.
- Rational Combi Oven, Vulcan Steamer & Griddle, Market Forge Steamer and Cleveland Combi Oven
- Evaluations & Feedback: Attendees were asked to participate in a short survey following the close of the showcase event.
- “Fantastic overview of project” – Melisa Marks, SoCalGas
- “Very well done. Thanks for your major contribution to foodservice!” – Mickey Craddock, Georgia Power
- “Enjoyed the class very much. Great, knowledgeable speakers.” – Brant White, ICF
- “Excellent – Great content!” – Gayle Massey, School Nutrition Magazine


Q3 How likely are you to use the information from this course?

Future Technology Transfer

Technology transfer is ongoing into 2018.

Scheduled Seminars – 2018:

Topic - Fast, Small & Flexible: Maximizing Your Kitchen Space

- Outcome(s) to be achieved: Participants will learn about new state of the art technology that can optimize efficiency, functionality and performance while reducing the overall footprint to meet the evolving demands of the 21st century commercial kitchen.
- Location / Date:
- Food Service Technology Center, PG&E – San Ramon, CA - May 8, 2018
- Energy Innovation Center, SDG&E, CA – May 9, 2018

Topic – Tools for Efficient Kitchen Design

- Outcome(s) to be achieved: Participants will learn about many ways to save money in a food service operation and energy efficiency is one of the best; both from a business as well as a sustainability standpoint. Foodservice professionals will learn how to reduce operating costs for their facilities in areas such as lighting, HVAC, food preparation equipment, sanitation, and refrigeration.
- Food Service Technology Center, PG&E – San Ramon, CA – August 9, 2018

Confirmed Industry Events - 2018

MAFSI Conference – Manufacturers Agents for the Food Service Industry
Topic: Survival Guide to Energy Efficiency in Foodservice

Outcome(s) to be achieved: Create a better understanding of the non-energy benefits to energy efficient foodservice equipment to help encourage equipment reps to become more comfortable with specifying energy efficiency cooking equipment on a national level by providing case study data from the Cookline project.

- Date: January 25, 2018
- Location: Naples, FL
- Audience: Foodservice equipment representatives, equipment manufacturers and industry professionals
- Number of Attendees: TBD
- Speaker: Janel Rupp, Frontier Energy Communications

RestaurantSpaces
Topic: NetZero

Outcome(s) to be achieved: Participants will learn about how development, design, construction and operations effect NetZero.

- Date: February 26, 2018
- Location: Palm Springs, CA
- Audience: Foodservice equipment representatives, equipment manufacturers and industry professionals

- Number of Attendees: TBD
- Speaker: Richard Young, Frontier Energy Director of Education

Consultant Summit –Alto Shaam and Unified Brands

Topic: CKV Presentation: Applying State of the Art Commercial Kitchen Ventilation Technologies for Maximum Comfort and Performance

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: June 22, 2018
- Location: Montreal, CA
- Audience: Foodservice Consultants
- Number of Attendees: TBD
- Speaker: Rich Swierczyna, Frontier Energy Sr. Engineer

National and State Conferences – 2018

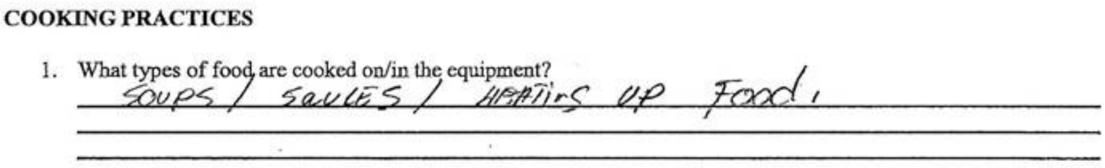
- ACFSA – American Correctional Foodservice Association
- ACF – American Culinary Federation – Newport Beach, CA – March 2018
- ASTM F26 Committee Meetings – Spring and Fall 2018
- CAND – California Academy of Nutrition and Dietetics – Pomona, CA - May 2018 CEE – Consortium for Energy Efficiency – San Francisco, CA – January 2018
- CEHA – California Environmental Health Association – Sacramento, CA – March 2018
- CEW EPC – California Energy Wise Executive Planning Council - Quarterly
- CIA – Flavor Summit – Sonoma, Ca – March 2018
- CRA – California Restaurant Association Western Restaurant Show
- CSNA – California School Nutrition Association
- Energy Efficiency Exchange NW – Portland, OR – May 2018
- FCSI – Foodservice Consultant Society International – Denver, CO- April 2018
- GFEN- Charlotte, NC – February 2018
- GGRA – Golden Gate Restaurant Association
- Menus of Change – Hyde Park, NY – June 2018
- NACUFS – National Association of College and University Foodservice – Salt Lake City, UT – March 2018
- NAFEM/FEDA/CFESA Joint Conference – North American Association of Food Equipment Manufacturers/ Foodservice Equipment Dealers Association / Commercial Foodservice Equipment Service Association - Palm Desert, CA – March 2018
- NRA Show– National Restaurant Association – Chicago, IL – May 2018
- RestaurantSpaces – Annual Conference – Palm Springs, CA – February 2018

- RFMA – Restaurant Facility Management Association – Phoenix, AZ - March 2018
- SoCalGas Foodservice Equipment Expo – Downey, CA – October 2018
- MAFSI – Manufacturers Agents for the Food Service Industry – January 2018
- MUFES - Multi-Unit Foodservice Equipment Symposium – Austin, TX – January 2018
- Utility Energy Forum – Santa Rosa, CA – April 2018

APPENDIX B:
Appliance Operator Surveys

Doubletree

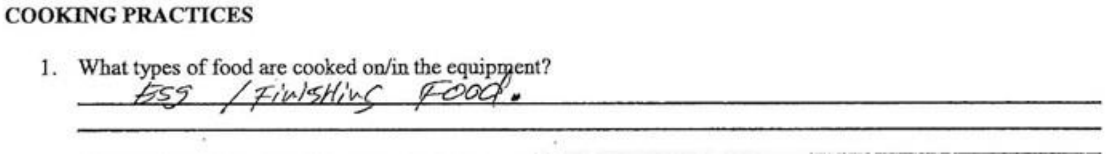
Figure B-1: Prep Range Operator Survey



COOKING PRACTICES

1. What types of food are cooked on/in the equipment?
SOUPS / SAUCES / HEATING UP FOOD.

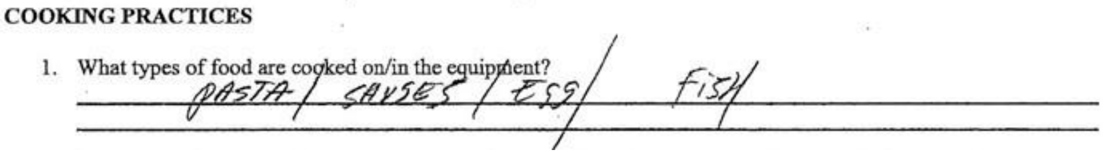
Range with Salamander:



COOKING PRACTICES

1. What types of food are cooked on/in the equipment?
EGG / FINISHING FOOD.

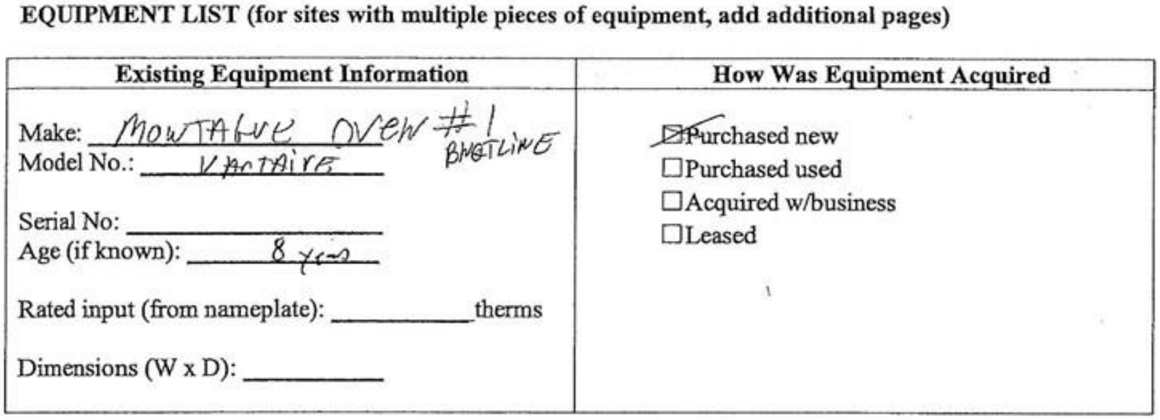
Cook-to-order Range:



COOKING PRACTICES

1. What types of food are cooked on/in the equipment?
PASTA / SAUSES / EGG / FISH

Figure B-2: DoubleTree Convection Oven Operator Survey Results

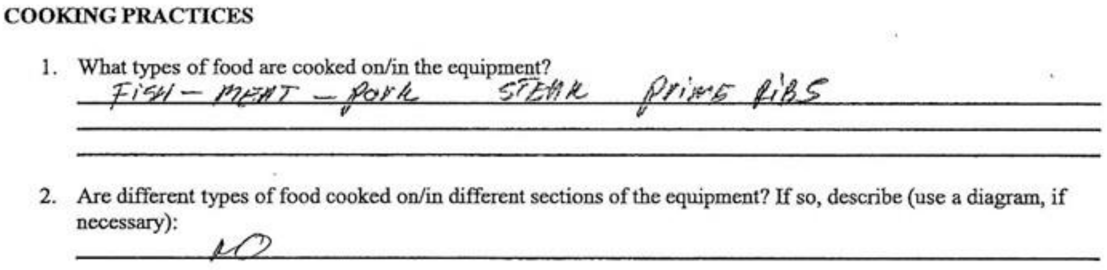


EQUIPMENT LIST (for sites with multiple pieces of equipment, add additional pages)

Existing Equipment Information	How Was Equipment Acquired
Make: MONTAGUE OVEN #1 BNGTLINE Model No.: VACTAIRE Serial No: ________ Age (if known): 8 yrs Rated input (from nameplate): ________ therms Dimensions (W x D): ________	☒ Purchased new ☐ Purchased used ☐ Acquired w/business ☐ Leased

The convection ovens are mostly used to cook different meats. The steaks are initially cooked on the underfired broiler, and then they are finished in the oven. Slow cooked items such as pork and prime ribs also get cooked in the convection ovens.

Left Oven:

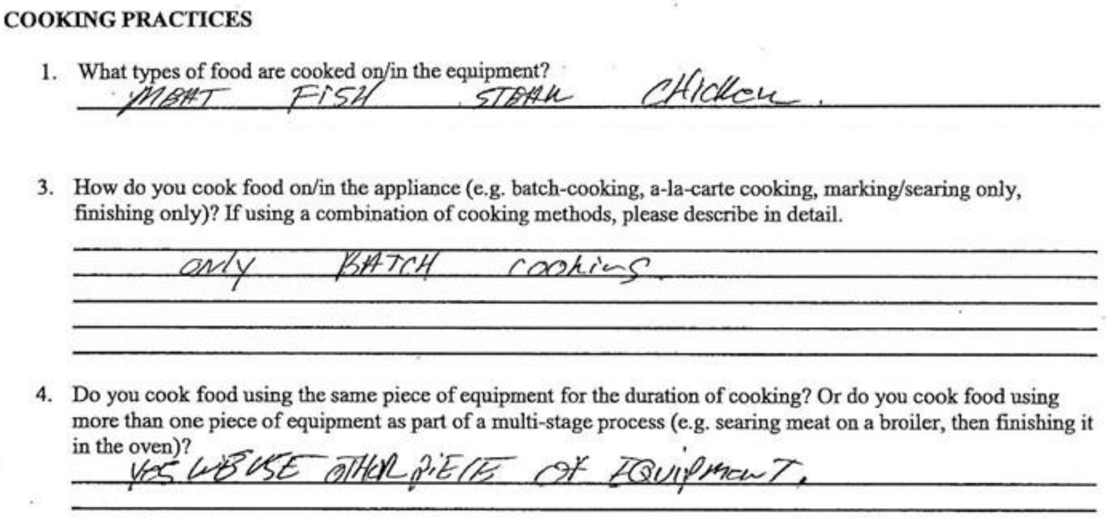


COOKING PRACTICES

1. What types of food are cooked on/in the equipment?
FISH – MEAT – pork STEAK prime RIBS

2. Are different types of food cooked on/in different sections of the equipment? If so, describe (use a diagram, if necessary):
NO

Right Oven:



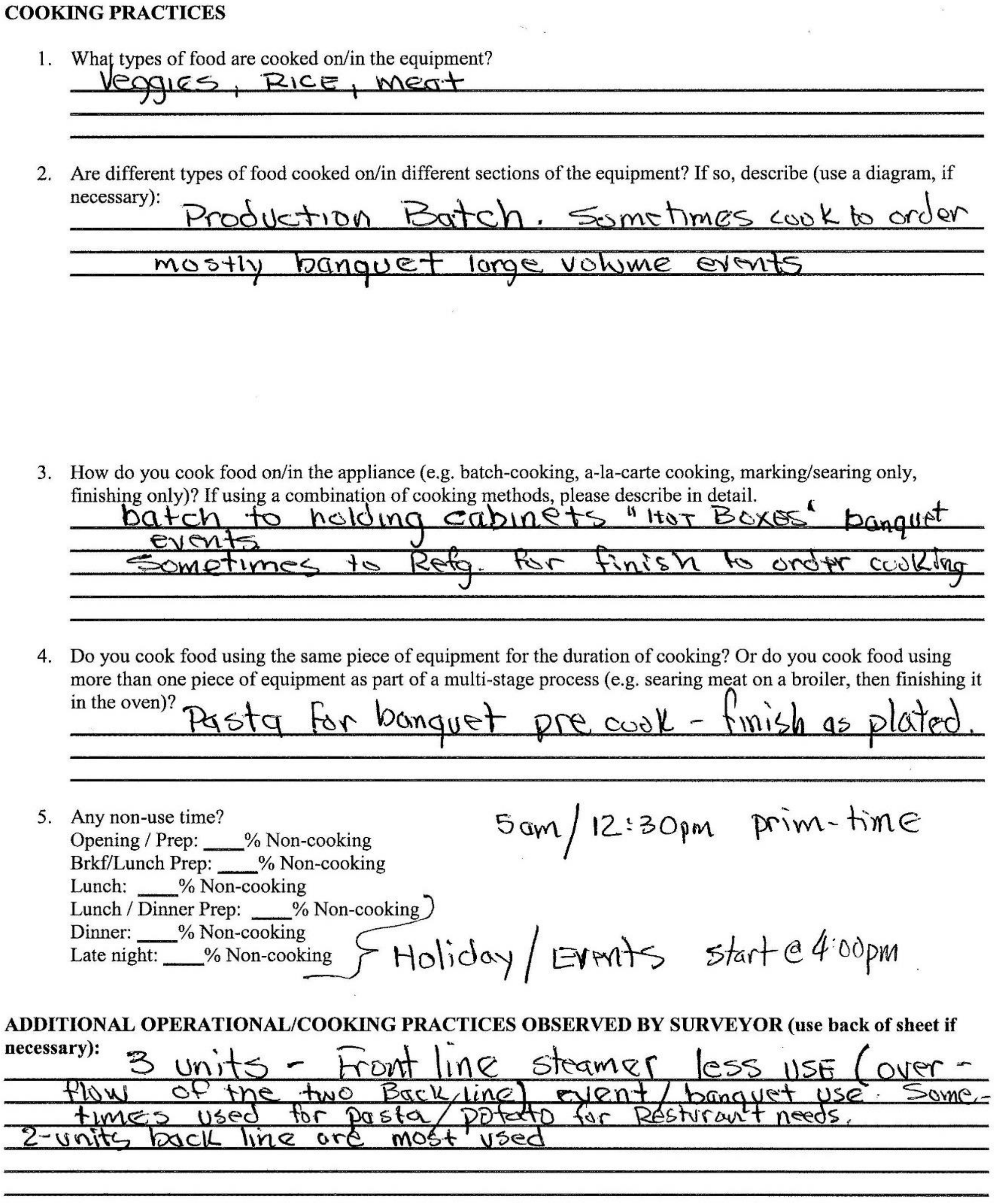
COOKING PRACTICES

1. What types of food are cooked on/in the equipment?
MEAT FISH STEAK Chicken.

3. How do you cook food on/in the appliance (e.g. batch-cooking, a-la-carte cooking, marking/searing only, finishing only)? If using a combination of cooking methods, please describe in detail.
only BATCH cooking.

4. Do you cook food using the same piece of equipment for the duration of cooking? Or do you cook food using more than one piece of equipment as part of a multi-stage process (e.g. searing meat on a broiler, then finishing it in the oven)?
YES WE USE OTHER PIECE OF EQUIPMENT.

Figure B-3: DoubleTree Steamer Operation Survey



COOKING PRACTICES

1. What types of food are cooked on/in the equipment?
Veggies, Rice, meat

2. Are different types of food cooked on/in different sections of the equipment? If so, describe (use a diagram, if necessary):
Production Batch. Sometimes cook to order
mostly banquet large volume events

3. How do you cook food on/in the appliance (e.g. batch-cooking, a-la-carte cooking, marking/searing only, finishing only)? If using a combination of cooking methods, please describe in detail.
batch to holding cabinets "Hot Boxes" banquet events
Sometimes to Refg. for finish to order cooking

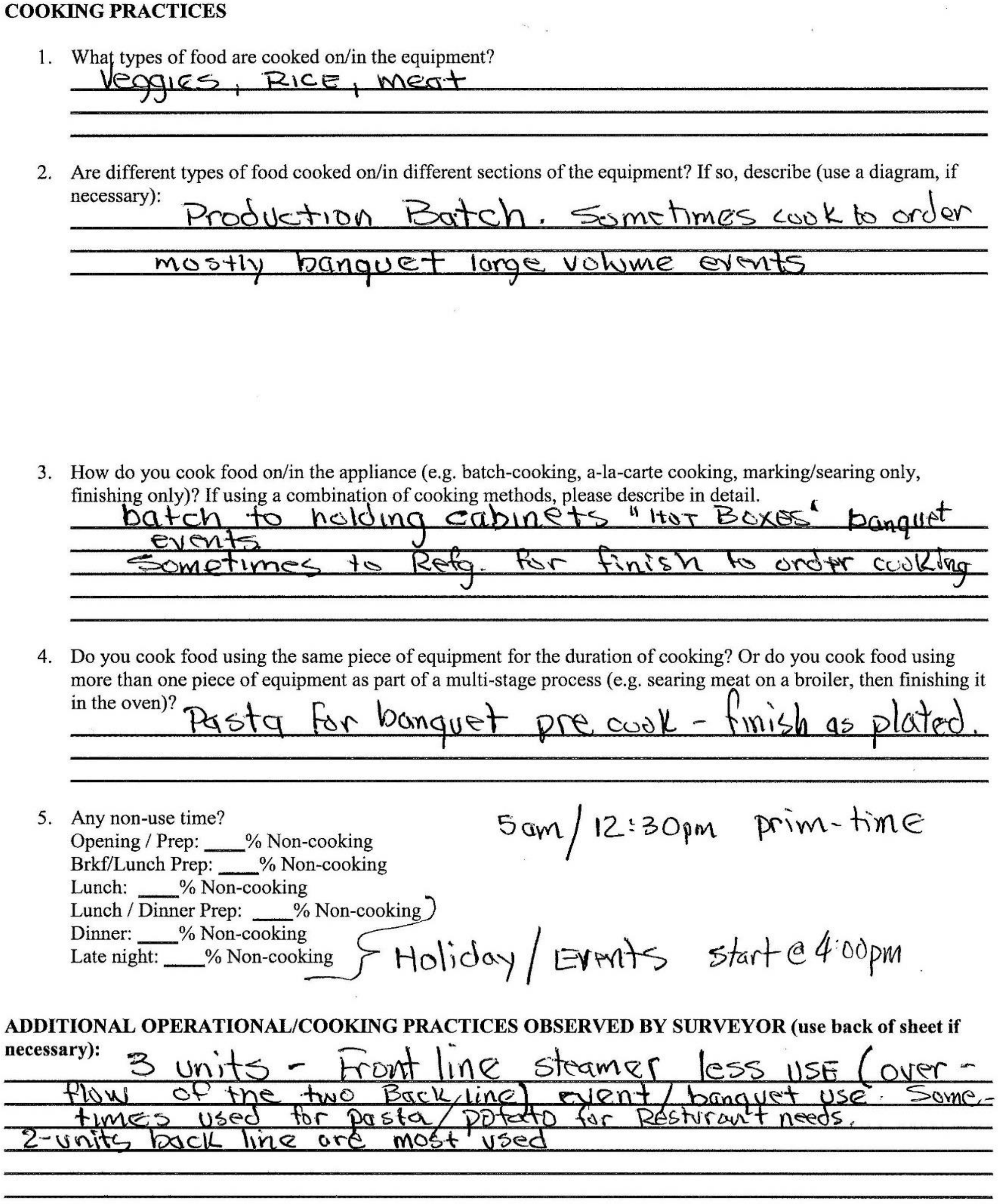
4. Do you cook food using the same piece of equipment for the duration of cooking? Or do you cook food using more than one piece of equipment as part of a multi-stage process (e.g. searing meat on a broiler, then finishing it in the oven)?
Pasta for banquet pre cook - finish as plated.

5. Any non-use time?
5am/12:30pm prim-time
Opening / Prep: ____% Non-cooking
Brkf/Lunch Prep: ____% Non-cooking
Lunch: ____% Non-cooking
Lunch / Dinner Prep: ____% Non-cooking
Dinner: ____% Non-cooking
Late night: ____% Non-cooking
Holiday / Events start @ 4:00pm

ADDITIONAL OPERATIONAL/COOKING PRACTICES OBSERVED BY SURVEYOR (use back of sheet if necessary):
3 units - Front line steamer less USE (overflow of the two Back line) event/banquet use. Sometimes used for pasta/potato for Resturant needs.
2-units back line are most used

Airline Catering

Figure B-4: Airline Catering Replacement Fryer Survey



COOKING PRACTICES

1. What types of food are cooked on/in the equipment?
Veggies, Rice, meat

2. Are different types of food cooked on/in different sections of the equipment? If so, describe (use a diagram, if necessary):
Production Batch. Sometimes cook to order
mostly banquet large volume events

3. How do you cook food on/in the appliance (e.g. batch-cooking, a-la-carte cooking, marking/searing only, finishing only)? If using a combination of cooking methods, please describe in detail.
batch to holding cabinets "Hot Boxes" banquet events
Sometimes to Refg. for finish to order cooking

4. Do you cook food using the same piece of equipment for the duration of cooking? Or do you cook food using more than one piece of equipment as part of a multi-stage process (e.g. searing meat on a broiler, then finishing it in the oven)?
Pasta for banquet pre cook - finish as plated.

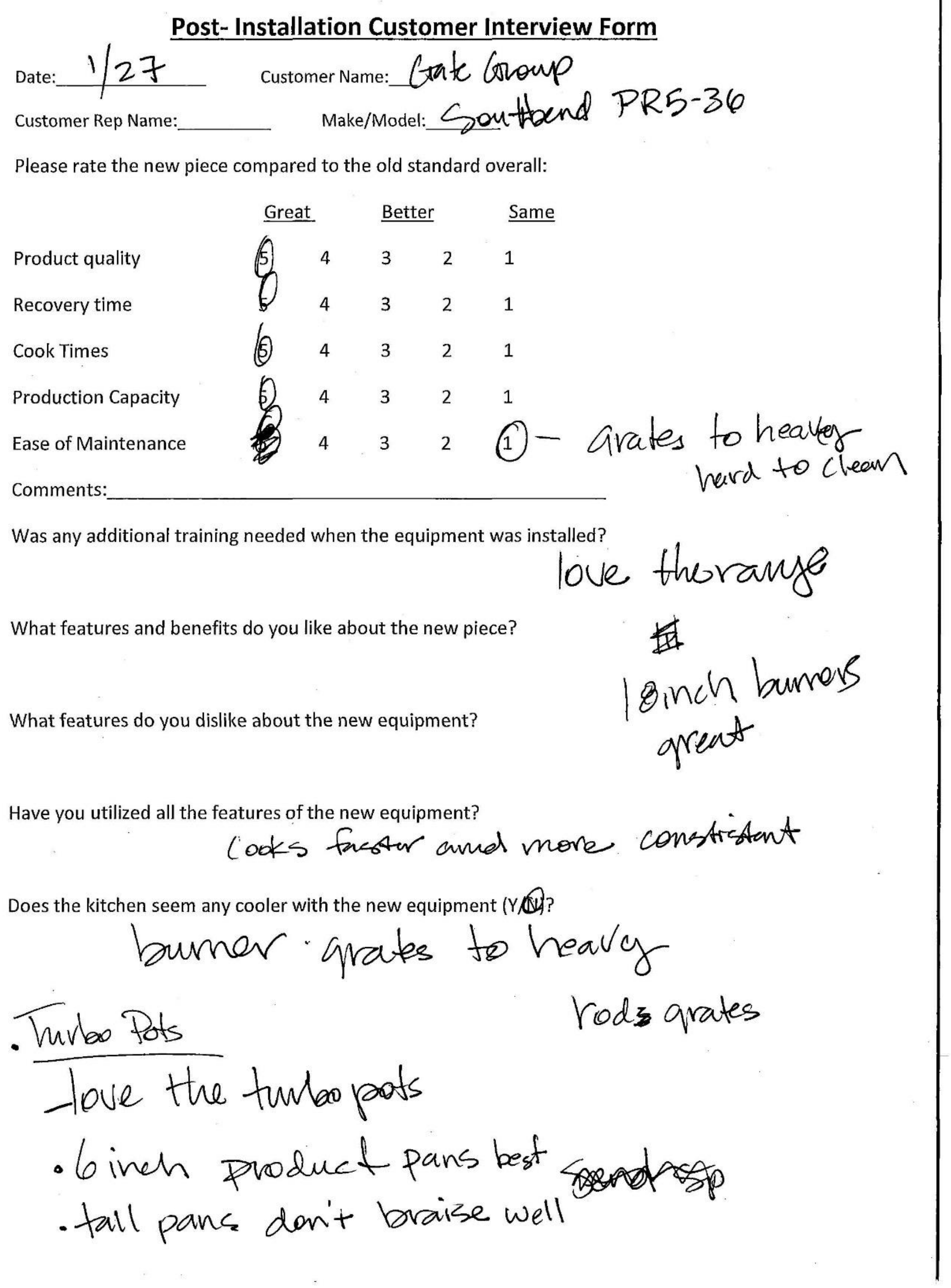
5. Any non-use time?
Opening / Prep: ____% Non-cooking
Brkf/Lunch Prep: ____% Non-cooking
Lunch: ____% Non-cooking
Lunch / Dinner Prep: ____% Non-cooking
Dinner: ____% Non-cooking
Late night: ____% Non-cooking

5am / 12:30pm prim-time

Holiday / Events start @ 4:00pm

ADDITIONAL OPERATIONAL/COOKING PRACTICES OBSERVED BY SURVEYOR (use back of sheet if necessary):
3 units - Front line steamer less USE (over-flow of the two Back line) event / banquet use. Some-times used for pasta / potato for Restrurant needs.
2-units back line are most used

Figure B-5: Airline Catering Range and Stockpot Operator Survey



Post- Installation Customer Interview Form

Date: 1/27 Customer Name: Gate Group

Customer Rep Name:__________ Make/Model: Southbend PR5-36

Please rate the new piece compared to the old standard overall:

	Great		Better		Same
Product quality	[✓ 5]	4	3	2	1
Recovery time	[✓ 5]	4	3	2	1
Cook Times	[✓ 5]	4	3	2	1
Production Capacity	[✓ 5]	4	3	2	1
Ease of Maintenance		4	3	2	[✓ 1] – grates to heavy hard to clean

Comments:____

Was any additional training needed when the equipment was installed?

love therange

What features and benefits do you like about the new piece?

18inch burners great

What features do you dislike about the new equipment?

Have you utilized all the features of the new equipment?

Cooks faster and more constistant

Does the kitchen seem any cooler with the new equipment (Y/[✓ N])?

burner grates to heavy

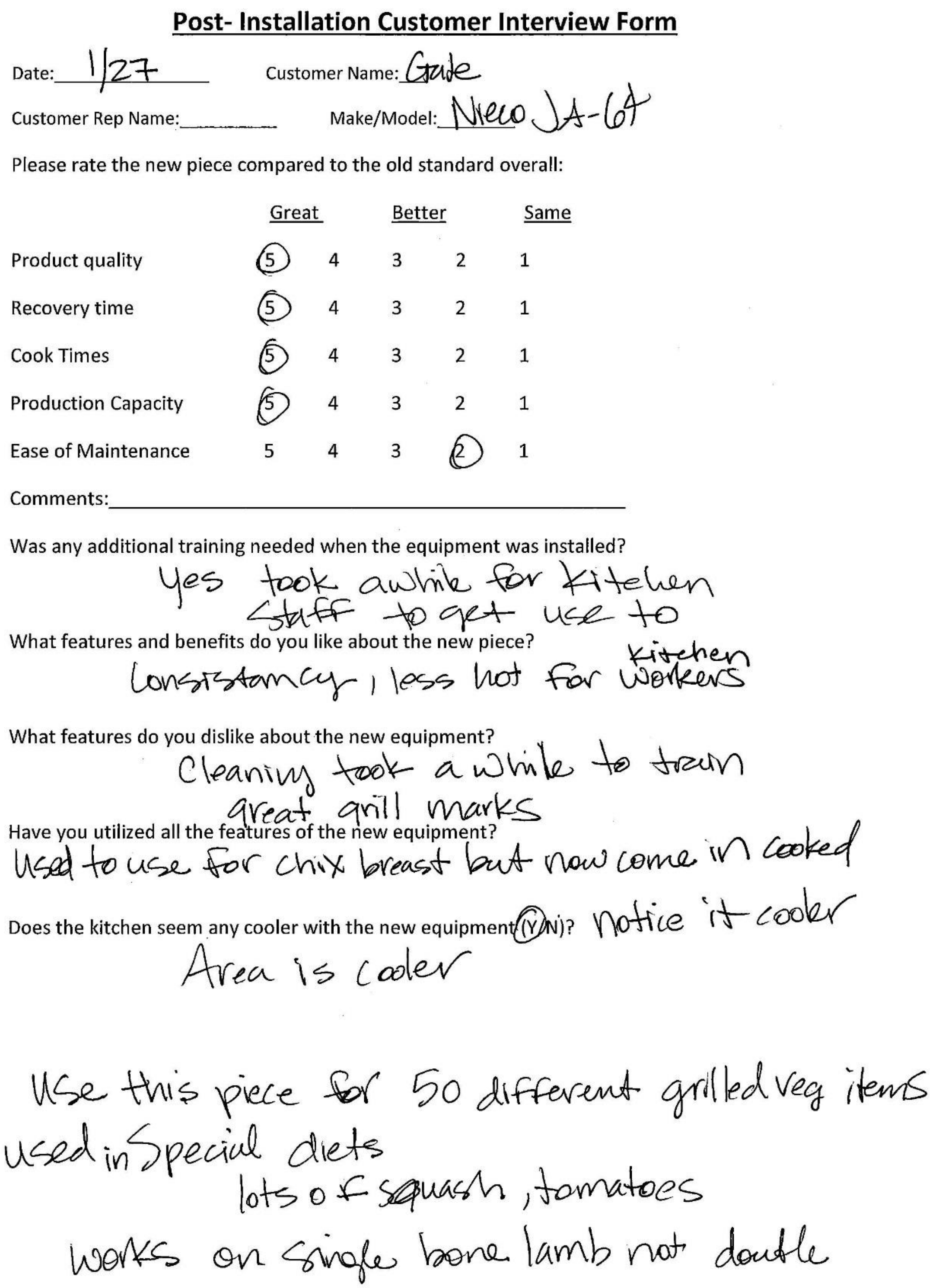
rods grates

- Turbo Pots

love the turbo pots

- 6 inch product pans best
- tall pans don't braise well

Figure B-6: Airline Catering Conveyor Broiler Operator Survey



Post- Installation Customer Interview Form

Date: 1/27

Customer Name: Gate

Customer Rep Name:__________

Make/Model: Nieco JA-64

Please rate the new piece compared to the old standard overall:

	Great		Better		Same
Product quality	[✓ 5]	4	3	2	1
Recovery time	[✓ 5]	4	3	2	1
Cook Times	[✓ 5]	4	3	2	1
Production Capacity	[✓ 5]	4	3	2	1
Ease of Maintenance	5	4	3	[✓ 2]	1

Comments:____

Was any additional training needed when the equipment was installed?

Yes took awhile for kitchen staff to get use to

What features and benefits do you like about the new piece?

Consistancy, less hot for kitchen workers

What features do you dislike about the new equipment?

Cleaning took a while to train

great grill marks

Have you utilized all the features of the new equipment?

Used to use for chix breast but now come in cooked

Does the kitchen seem any cooler with the new equipment ([✓ Y]/N)? notice it cooler

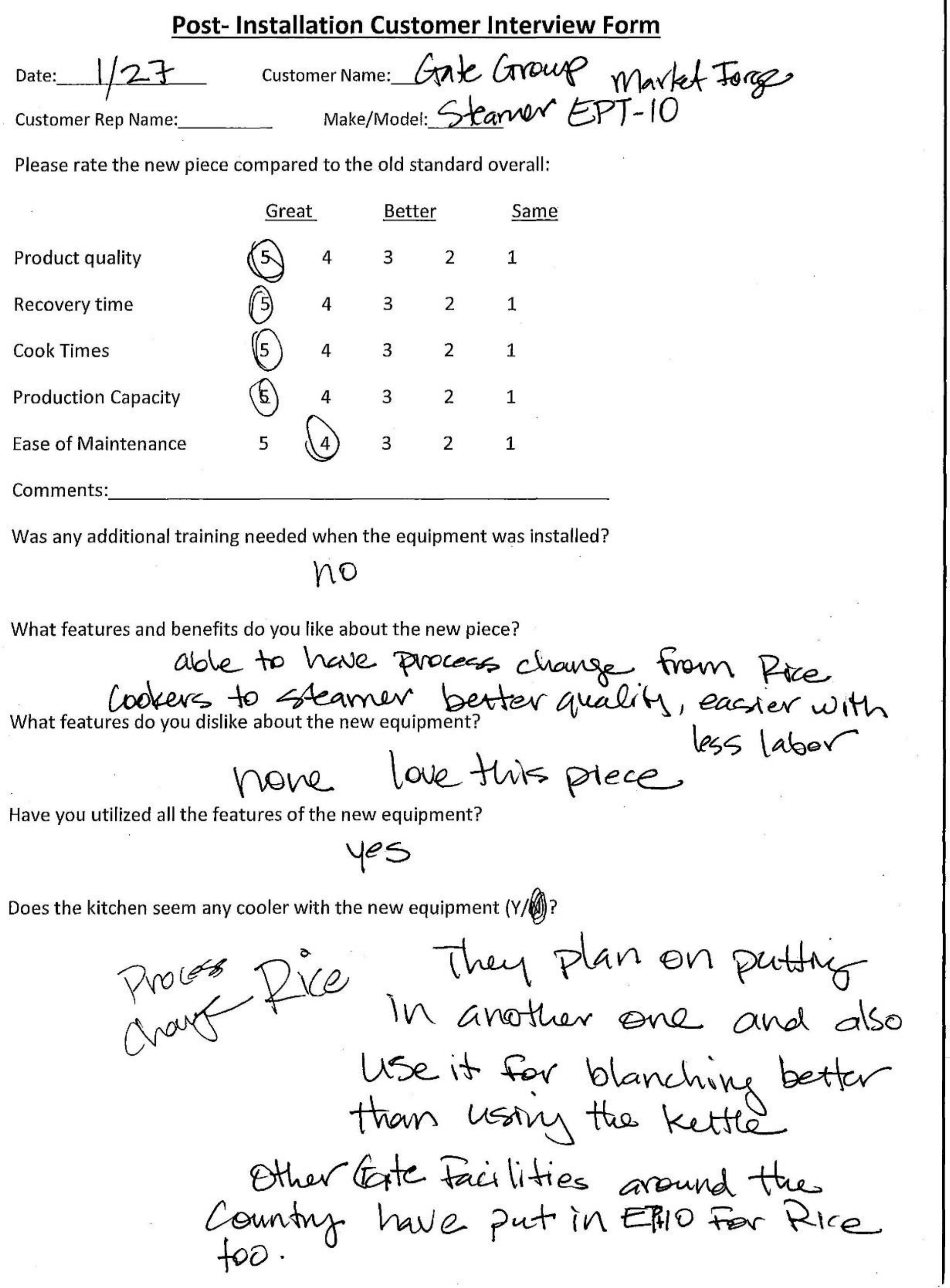
Area is cooler

Use this piece for 50 different grilled veg items used in Special diets

lots of squash, tomatoes

works on single bone lamb not double

Figure B-7: Airline Catering Replacement Steamer Survey Response



Post- Installation Customer Interview Form

Date: 1/27 Customer Name: Gate Group Market Forge

Customer Rep Name:_________ Make/Model: Steamer EPT-10

Please rate the new piece compared to the old standard overall:

	Great		Better		Same
Product quality	[✓ 5]	4	3	2	1
Recovery time	[✓ 5]	4	3	2	1
Cook Times	[✓ 5]	4	3	2	1
Production Capacity	[✓ 5]	4	3	2	1
Ease of Maintenance	5	[✓ 4]	3	2	1

Comments:____________________________________

Was any additional training needed when the equipment was installed?

no

What features and benefits do you like about the new piece?

able to have process change from Rice cookers to steamer better quality, easier with less labor

What features do you dislike about the new equipment?

none love this piece

Have you utilized all the features of the new equipment?

yes

Does the kitchen seem any cooler with the new equipment (Y/[✓ N])?

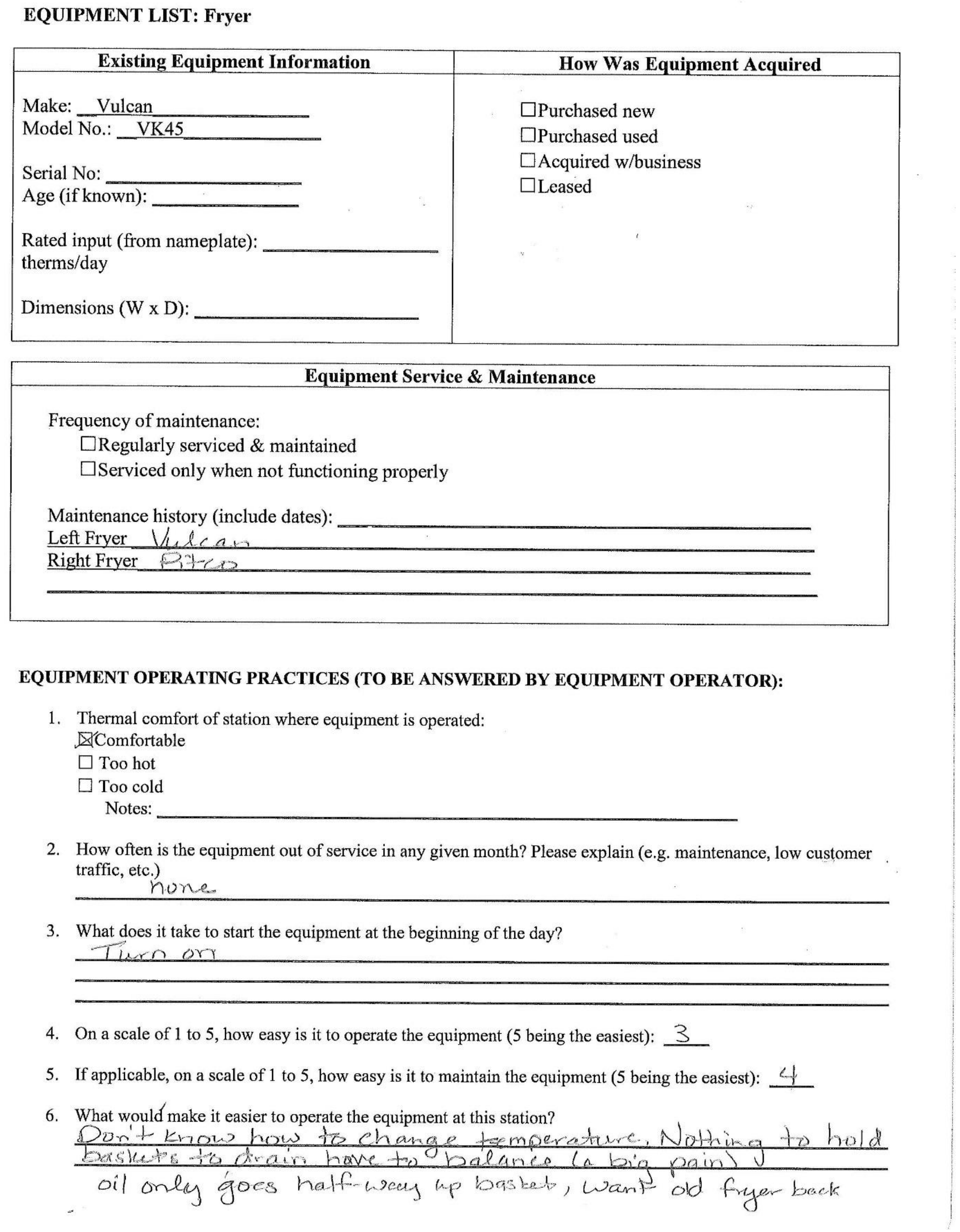
Process Change Rice

They plan on putting In another one and also Use it for blanching better than using the kettle

Other Gate Facilities around the Country have put in EPT10 for Rice too.

Werewolf

Figure B-8: Werewolf Fryer Operation Survey Results



EQUIPMENT LIST: Fryer

Existing Equipment Information	How Was Equipment Acquired
Make: Vulcan Model No.: VK45 Serial No: Age (if known): Rated input (from nameplate): therms/day Dimensions (W x D):	☐Purchased new ☐Purchased used ☐Acquired w/business ☐Leased

Equipment Service & Maintenance

Frequency of maintenance:

☐Regularly serviced & maintained

☐Serviced only when not functioning properly

Maintenance history (include dates):

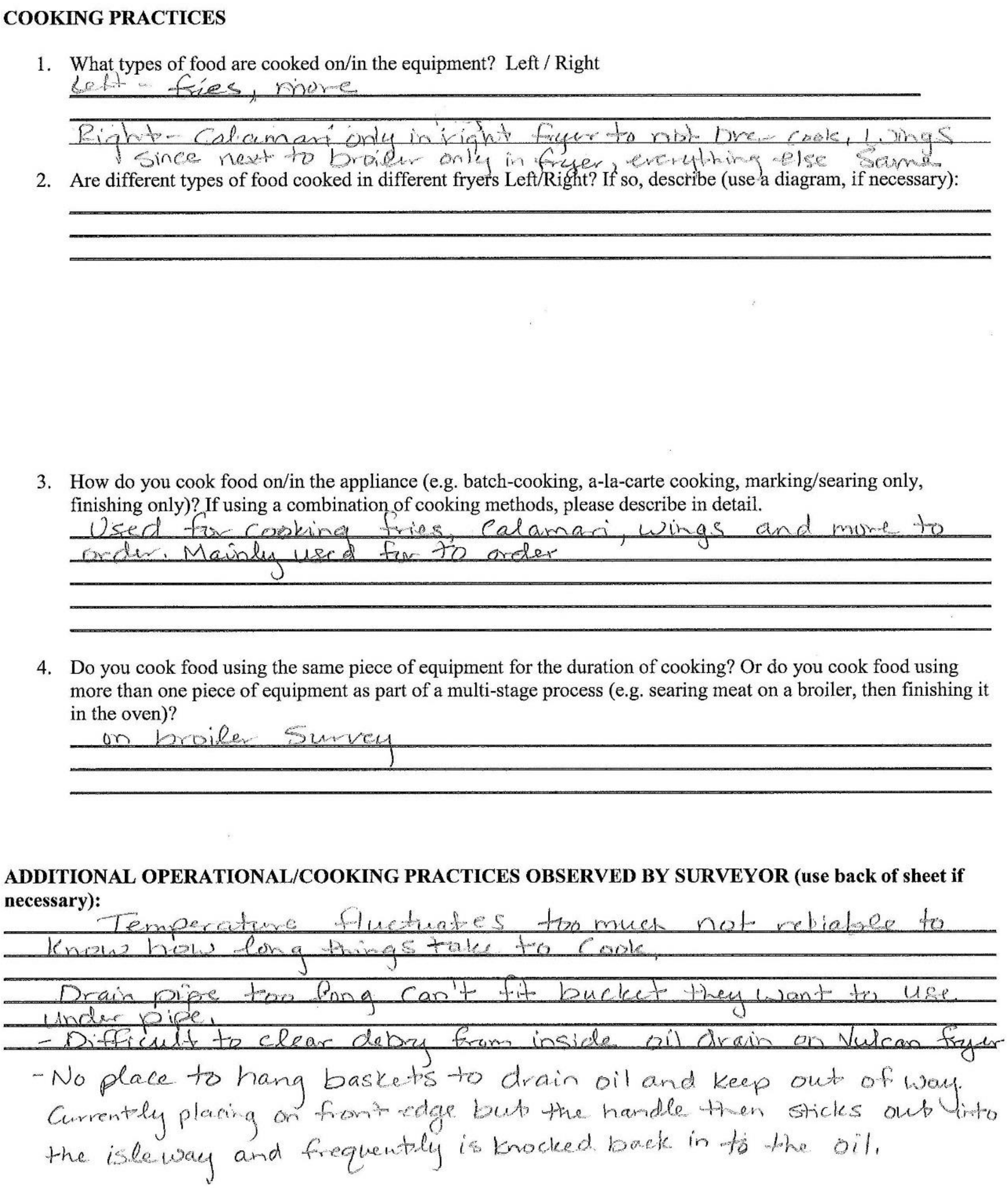
Left Fryer Vulcan

Right Fryer Pitco

EQUIPMENT OPERATING PRACTICES (TO BE ANSWERED BY EQUIPMENT OPERATOR):

1. Thermal comfort of station where equipment is operated:
   ☒Comfortable
   ☐ Too hot
   ☐ Too cold
   Notes:
2. How often is the equipment out of service in any given month? Please explain (e.g. maintenance, low customer traffic, etc.)
   none
3. What does it take to start the equipment at the beginning of the day?
   Turn on
4. On a scale of 1 to 5, how easy is it to operate the equipment (5 being the easiest): 3
5. If applicable, on a scale of 1 to 5, how easy is it to maintain the equipment (5 being the easiest): 4
6. What would make it easier to operate the equipment at this station?
   Don't know how to change temperature. Nothing to hold baskets to drain have to balance (a big pain) oil only goes half-way up basket, want old fryer back

Figure 350: Werewolf Fryer Cooking Survey Results



COOKING PRACTICES

1. What types of food are cooked on/in the equipment? Left / Right

Left - fries, more

Right - Calamari only in right fryer to not pre-cook, Wings since next to broiler only in fryer, everything else same

2. Are different types of food cooked in different fryers Left/Right? If so, describe (use a diagram, if necessary):

3. How do you cook food on/in the appliance (e.g. batch-cooking, a-la-carte cooking, marking/searing only, finishing only)? If using a combination of cooking methods, please describe in detail.

Used for cooking fries, Calamari, wings and more to order. Mainly used for to order

4. Do you cook food using the same piece of equipment for the duration of cooking? Or do you cook food using more than one piece of equipment as part of a multi-stage process (e.g. searing meat on a broiler, then finishing it in the oven)?

on broiler survey

ADDITIONAL OPERATIONAL/COOKING PRACTICES OBSERVED BY SURVEYOR (use back of sheet if necessary):

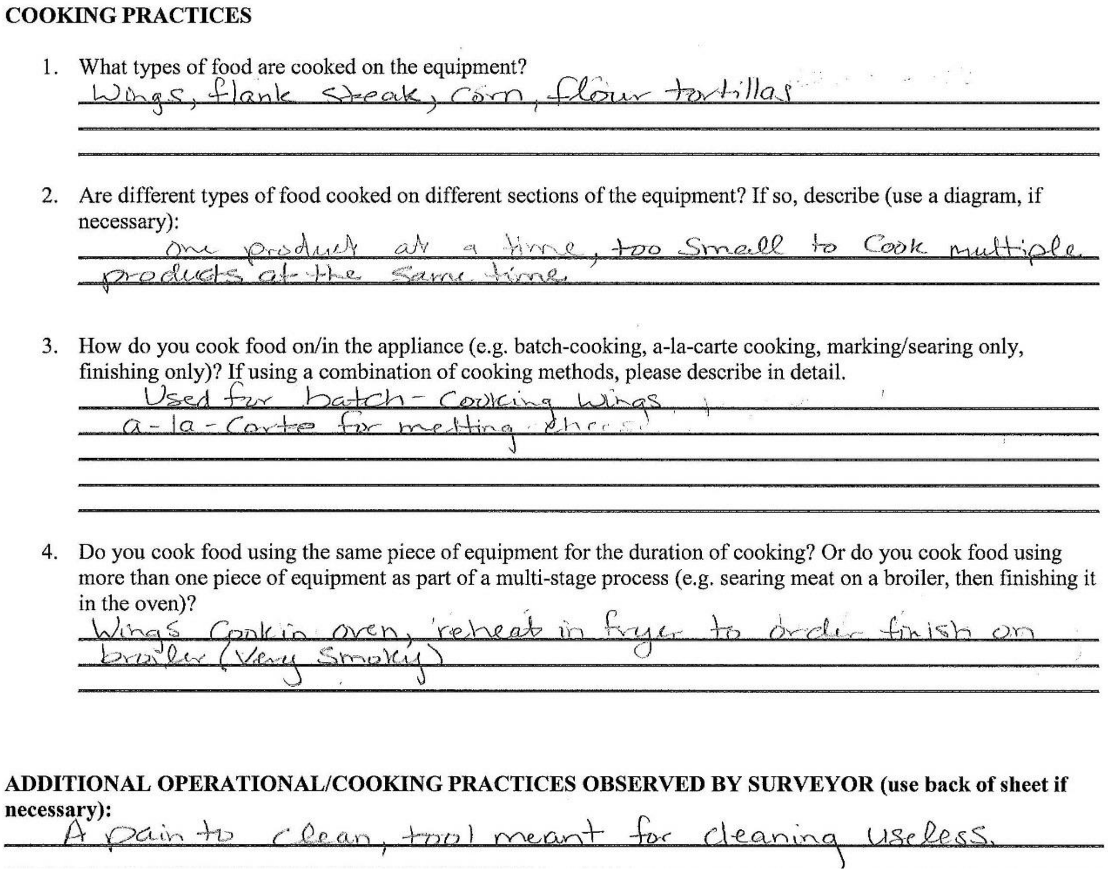
Temperature fluctuates too much not reliable to know how long things take to Cook.

Drain pipe too long can't fit bucket they want to use under pipe.

- Difficult to clear debry from inside oil drain on Vulcan fryer

- No place to hang baskets to drain oil and keep out of way. Currently placing on front edge but the handle then sticks out into the isleway and frequently is knocked back in to the oil.

Figure B-10: Werewolf Broiler Survey Results



COOKING PRACTICES

1. What types of food are cooked on the equipment?

Wings, flank steak, corn, flour tortillas

2. Are different types of food cooked on different sections of the equipment? If so, describe (use a diagram, if necessary):

One product at a time, too small to cook multiple products at the same time.

3. How do you cook food on/in the appliance (e.g. batch-cooking, a-la-carte cooking, marking/searing only, finishing only)? If using a combination of cooking methods, please describe in detail.

Used for batch-cooking wings

a-la-carte for melting cheese

4. Do you cook food using the same piece of equipment for the duration of cooking? Or do you cook food using more than one piece of equipment as part of a multi-stage process (e.g. searing meat on a broiler, then finishing it in the oven)?

Wings cook in oven, reheat in fryer to order finish on broiler (very smoky)

ADDITIONAL OPERATIONAL/COOKING PRACTICES OBSERVED BY SURVEYOR (use back of sheet if necessary):

A pain to clean, tool meant for cleaning useless.

Figure B-11: Werewolf Griddle Survey Results

COOKING PRACTICES

1. What types of food are cooked on/in the equipment?
2.

Left All meats (bacon, flank steak, chicken +) onions

Rignt breads (pancakes, buns, tortillas) no meat

3. Are different types of food cooked on/in different sections of the equipment? If so, describe (use a diagram, if necessary):

4. How do you cook food on/in the appliance (e.g. batch-cooking, a-la-carte cooking, marking/searing only, finishing only)? If using a combination of cooking methods, please describe in detail.

Used to prep onions only, Mainly used to cook food to order. Such as bacon, pancakes, tortillas,

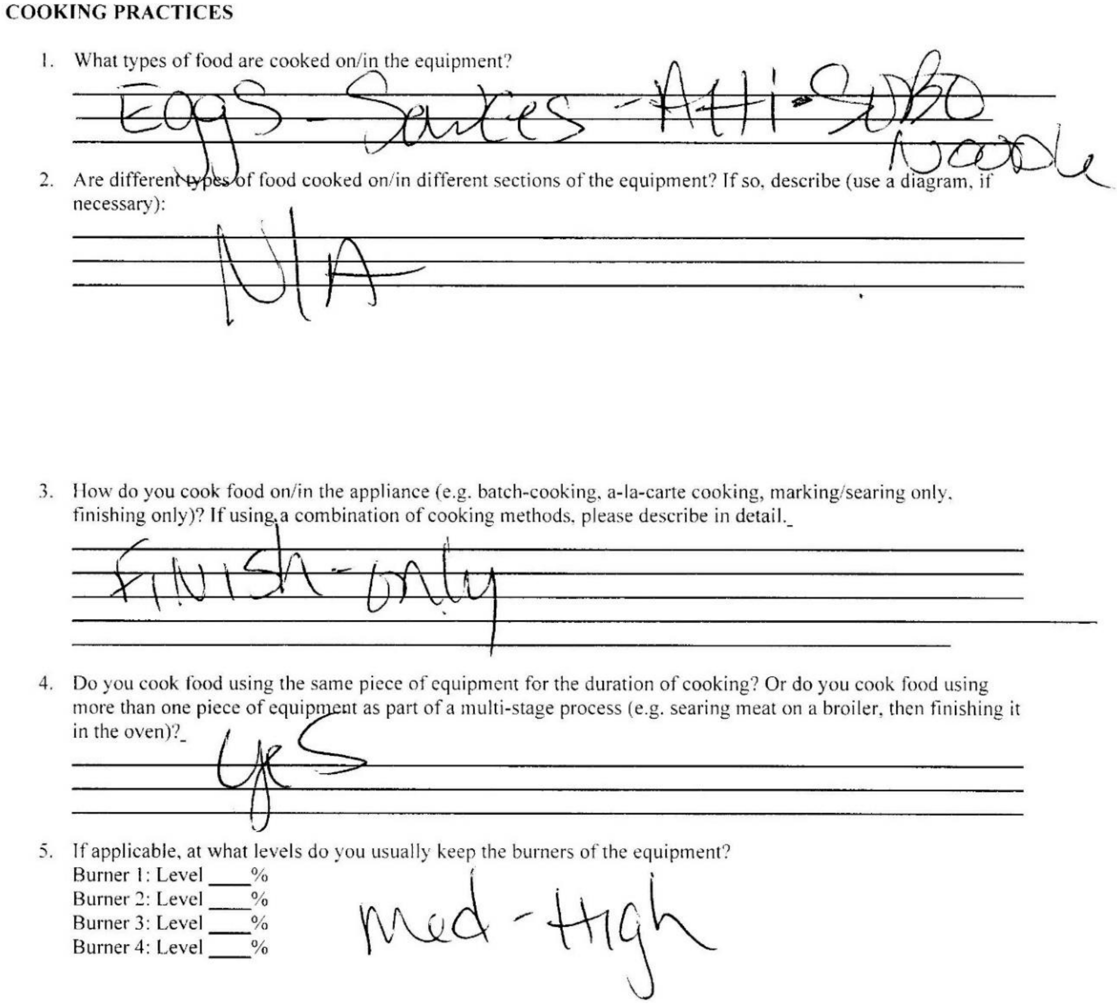
5. Do you cook food using the same piece of equipment for the duration of cooking? Or do you cook food using more than one piece of equipment as part of a multi-stage process (e.g. searing meat on a broiler, then finishing it in the oven)?

flank steak sear on broiler + finish on griddle to order.

ADDITIONAL OPERATIONAL/COOKING PRACTICES OBSERVED BY SURVEYOR (use back of sheet if necessary):

Griddles are not use for prep except to cook onions,
Both griddles are used equally during breakfast, lunch & dinner
-Left griddle runs warmer when set on same temp.

Figure B-12: Werewolf Six-Burner Range Survey Results



COOKING PRACTICES

1. What types of food are cooked on/in the equipment?

   Eggs - Sautes - Atti - Sobo Noodle

2. Are different types of food cooked on/in different sections of the equipment? If so, describe (use a diagram, if necessary):

   N/A

3. How do you cook food on/in the appliance (e.g. batch-cooking, a-la-carte cooking, marking/searing only, finishing only)? If using a combination of cooking methods, please describe in detail.

   Finish - only

4. Do you cook food using the same piece of equipment for the duration of cooking? Or do you cook food using more than one piece of equipment as part of a multi-stage process (e.g. searing meat on a broiler, then finishing it in the oven)?

   yes

5. If applicable, at what levels do you usually keep the burners of the equipment?

   Burner 1: Level ____%
   Burner 2: Level ____%
   Burner 3: Level ____%
   Burner 4: Level ____%

   Med - High

Figure B-13: Werewolf Convection Oven Survey Results

COOKING PRACTICES

1. What types of food are cooked on/in the equipment?
Potatoes, biscuits, Cheesy fries, mini pizzas, chicken wings

2. Are different types of food cooked on/in different sections of the equipment? If so, describe (use a diagram, if necessary); what food items have shifted from cook-line to Combi? :
- Only difference in use is now cooking rice with Steamer instead of rice cooker.
- Soap/detergent does not drain properly they don't know if it is bad for oven.
- Use same as oven before except for rice.
- Tried cooking wings but oven did not cook top/bottom trays at same rate.

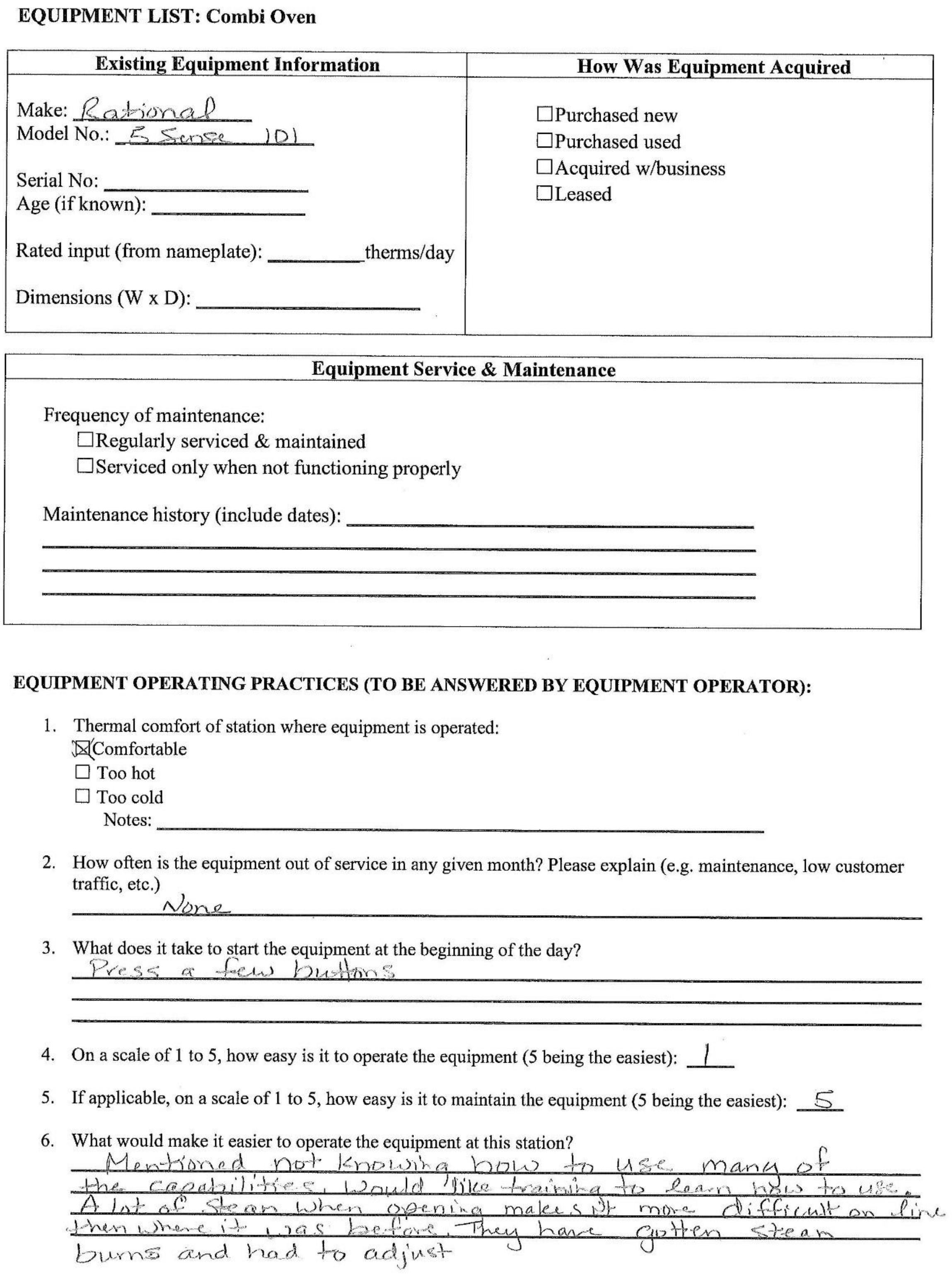
3. How do you cook food on/in the appliance (e.g. batch-cooking, a-la-carte cooking, marking/searing only, finishing only)? If using a combination of cooking methods, please describe in detail.
Use all types of Cooking batch, a-la-carte & finishing
batch Cook - potatoes, chicken, biscuits, rice
@ la carte - mini pizzas,
finishing - fries melt cheese (fries in fryer, melt cheese in Combi)

4. Do you cook food using the same piece of equipment for the duration of cooking? Or do you cook food using more than one piece of equipment as part of a multi-stage process (e.g. searing meat on a broiler, then finishing it in the oven)?
Many items use multi-stage process using multiple appliances.

used for Prep
5. Any non-use time?
Opening / Prep: ____% Non-cooking – used a good amount for breakfast prep
always cooking Brkf/Lunch Prep: ____% Non-cooking – always cooking
Lunch: ____% Non-cooking
Lunch / Dinner Prep: ____% Non-cooking
not as much Dinner: ____% Non-cooking
barely Late night: ____% Non-cooking
} barely use / not as much.

ADDITIONAL OPERATIONAL/COOKING PRACTICES OBSERVED BY SURVEYOR (use back of sheet if necessary):
In evening don't really use oven after 9pm but may begin to leave on until 1 or 2 am for mini pizza's and not use from 9pm - midnight. Using oven to melt cheese instead of Salimandir

Figure B-14: Werewolf Combi Oven Maintenance Survey



EQUIPMENT LIST: Combi Oven

Existing Equipment Information	How Was Equipment Acquired
Make: Rational Model No.: 5 Sense 101 Serial No: ________ Age (if known): ________ Rated input (from nameplate): ______therms/day Dimensions (W x D): ________	☐Purchased new ☐Purchased used ☐Acquired w/business ☐Leased

Equipment Service & Maintenance

Frequency of maintenance:
- ☐Regularly serviced & maintained
- ☐Serviced only when not functioning properly

Maintenance history (include dates): ________

EQUIPMENT OPERATING PRACTICES (TO BE ANSWERED BY EQUIPMENT OPERATOR):

1. Thermal comfort of station where equipment is operated:
   - ☒Comfortable
   - ☐ Too hot
   - ☐ Too cold

   Notes: ________
2. How often is the equipment out of service in any given month? Please explain (e.g. maintenance, low customer traffic, etc.)
   None
3. What does it take to start the equipment at the beginning of the day?
   Press a few buttons
4. On a scale of 1 to 5, how easy is it to operate the equipment (5 being the easiest): 1
5. If applicable, on a scale of 1 to 5, how easy is it to maintain the equipment (5 being the easiest): 5
6. What would make it easier to operate the equipment at this station?
   Mentioned not knowing how to use many of the capabilities. Would like training to learn how to use. A lot of steam when opening makes it more difficult on line then where it was before. They have gotten steam burns and had to adjust

APPENDIX C:
NO$_x$ Analyzer Comparison Test Results

Group 1 and 2 Data Summaries

Figure C-1: NO$_x$ Analyzer Group 1 Data Summary

		Standard Analyzer			Testo 350XL					Bacharach PCA3				
	Test Cond.	O2	NOX	NOXc	O2	NOX	cNOX (0% O2)	ppm off	% Off	O2	NOX	NOXc		% Off
	#	%	ppm	ppm	%	ppm	ppm	ppm	%	%	ppm	ppm	ppm	%
Morning Test	1	15.8	29	120	15.88	30	124.9004	1	-3%	15.7	28	118	-1	3%
	2	14.1	39	117	14.19	41	127.7049	2	-5%	14.2	38	122	-1	3%
	3	13.4	50	141	13.2	52	141.1429	2	-4%	13.3	52	144	2	-4%
	4	14.8	40	136	14.9	42	146.3	2	-5%	14.8	41	144	1	-2%
	5	12.5	58	146	12.7	63	160.5732	5	-9%	12.3	61	148	3	-5%
	6	13.4	42	117	13.7	45	130.625	3	-7%	13.4	44	122	2	-5%
	7	11.6	69	158	11.87	73	168.959	4	-6%	11.5	71	162	2	-3%
Afternoon Test (shut down and restart)	8	5.5	152	210	5.93	134	187.0808	-18	12%	5.2	142	198	-10	7%
	9	12.8	73	192	12.63	72	181.9589	-1	1%	13.3	74	189	1	-1%
	10	9.9	104	197	9.58	102	188.3216	-2	2%	9.7	101	193	-3	3%
	11	14.9	53	184	14.52	49	160.5172	-4	8%	15.3	51	184	-2	4%
	12	15.5	36	138	15.52	37	143.7361	1	-3%	15.7	34	143	-2	6%
	13	15.5	33	123	15.31	34	127.1199	1	-3%	15.6	33	128	0	0%
	14	9.3	100	178	9.13	99	175.7944	-1	1%	9	98	183	-2	2%
	15	10.9	82	170	10.71	83	170.2355	1	-1%	11.1	87	176	5	-6%
	16	9	108	192	8.6	105	178.4146	-3	3%	9.2	105	188	-3	3%
	17	10	95	182	10.1	90	174.1667	-5	5%	10.2	95	184	0	0%
	18	13.8	46	136	13.8	49	144.2394	3	-7%	13.9	49	140	3	-7%
	19	15.2	35	127	15.22	38	139.8239	3	-9%	15.3	36	132	1	-3%

Figure C-2: NO$_x$ Analyzer Group 2 Data Summary

	Standard Analyzer			Testo 350XL					Enerac M500				
Test Cond.	O2	NOX	NOXc	O2	NOX	cNOX (0% O2)	ppm off	% Off	O2	NOX	NOXc (no corrections on unit)		% Off
#	%	ppm	ppm	%	ppm	ppm	ppm	%	%	ppm	ppm	ppm	%
1	15.3	30	112	15.4	31	101	1	-3%	15.2	27	97.8	-3	10%
2	13.2	43	117	13.23	47	125	4	-9%	13.2	41	110.4	-2	5%
3	11.5	60	132	11.58	63	139	3	-5%	11.8	59	134.7	-1	2%
4	13.8	42	125	13.9	45	136	3	-7%	13.9	41	121.3	-1	2%
5	11.5	61	134	11.6	64	142	3	-5%	11.8	61	139.2	0	0%
6	10.3	75	150	10.39	75	151	0	0%	10.9	70	145.5	-5	7%
7	11.6	65	145	11.9	68	156	3	-5%	12.2	66	157.5	1	-2%
8	9.7	86	163	9.48	92	168	6	-7%	9.9	91	172.2	5	-6%
9	6.4	136	198	6.17	139	200	3	-2%	6.6	146	212.9	10	-7%
10	12.9	69	183	13.17	73	194	4	-6%	13.4	76	210.0	7	-10%
11	8.6	112	196	8.82	119	202	7	-6%	9	122	213.5	10	-9%
12	15.3	46	171	15.58	51	192	5	-11%	15.6	56	217.8	10	-22%
13	14.6	50	164	14.73	55	185	5	-10%	14.9	59	203.1	9	-18%
14	15.3	37	140	15.46	41	156	4	-11%	15.5	46	175.6	9	-24%
15	16.5	28	132	16.6	31	153	3	-11%	16.7	37	180.7	9	-32%

Group 1 and 2 Full Data Sets

Figure C-3: Group 1 Full Data Sets

							Analyzer Room								
	Test Cond.	Pgas_digital	Pgas_analog	Primary Air Damper	Flue Damper	Firing Rate Est.	O2	NO	NOc	NOX	NOXc	CO	COc	CO2	Tflue
	#	inwc	inwc	%open	Pos	Btu/hr	%	ppm	ppm	ppm	ppm	ppm	ppm	%	°f
Morning Test	1	2.32	2.2	100	2	10880	15.8	24	94	29	120	10	41	2.7	575
	2	2.32	2.2	100	3	10882	14.1	28	87	39	117	20	58	3.6	495
	3	2.33	2.2	0	3	10915	13.4	44	121	50	141	11	27	4.2	495
	4	4.08	4	0	2	11389	14.8	34	118	40	136	10	33	3.2	580
	5	3.99	4	0	3	11354	12.5	51	124	58	146	12	31	4.6	420
	6	3.99	4	100	3	11213	13.4	34	98	42	117	15	42	4	430
	7	6	5.52	0	3	12686	11.6	61	136	69	158	15	40	5	464
Afternoon Test (shut down and restart)	8	6.8	6.36	0	3	21897	5.5	138	204	152	210	10	13	8.7	631
	9	6.8	6	0	2	21266	12.8	65	173	73	192	16	46	4.1	765
	10	6.8	6.22	0	2.5	21387	9.9	83	149	104	197	21	43	6.2	762
	11	6.8	6.35	0	1	21258	14.9	48	172	53	184	13	45	3.2	693
	12	3.99	4	100	1.5	16204	15.5	28	101	36	138	12	44	2.9	695
	13	2.15	2	100	2	11426	15.5	28	111	33	123	11	44	2.9	615
	14	5.41	6	100	3	20324	9.3	90	169	100	178	8	12	6.5	538
	15	5.56	6	100	2.5	20104	10.9	70	154	82	170	31	68	5.3	750
	16	5.53	6	100	3	21000	9	101	177	108	192	8	15	6.6	480
	17	5.55	6	100	2.5	20213	10	84	158	95	182	22	43	5.8	704
	18	2.35	2	100	2.5	11903	13.8	38	112	46	136	14	40	3.8	594
	19	2.31	2	100	2	11904	15.2	31	115	35	127	13	46	3	622

							Testo 350XL										
	Test Cond.	Pgas_digital	Pgas_analog	Primary Air Damper	Flue Damper	Firing Rate Est.	O2	NO	cNO (3% O2)	cNO (0% O2)	NOX	cNOX (3% O2)	cNOX (0% O2)	CO	COc	CO2	Tflue
	#	inwc	inwc	%open	Pos	Btu/hr	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	°F
Morning Test	1	2.32	2.2	100	2	10880	15.88	23	82	95.75697	30	103	124.9004	9	37	3.03	623
	2	2.32	2.2	100	3	10882	14.19	29	74	90.32787	41	108	127.7049	17	43	3.92	539.6
	3	2.33	2.2	0	3	10915	13.2	42	103	114	52	125	141.1429	7	18	4.24	535
	4	4.08	4	0	2	11389	14.9	36	108	125.4	42	129	146.3	6	19	3.41	622
	5	3.99	4	0	3	11354	12.7	48	105	122.3415	63	130	160.5732	8	23	4.52	448
	6	3.99	4	100	3	11213	13.7	33	80	95.79167	45	106	130.625	13	31	4.17	456
	7	6	5.52	0	3	12686	11.87	59	114	136.5559	73	140	168.959	13	32	5.2	490
Afternoon Test (shut down and restart)	8	6.8	6.36	0	3	21897	5.93	124	145	173.1196	134	160	187.0808	13	17	8.56	673
	9	6.8	6	0	2	21266	12.63	61	125	154.1596	72	156	181.9589	16	41	4.75	844
	10	6.8	6.22	0	2.5	21387	9.58	81	133	149.5495	102	164	188.3216	32	38	6.48	833
	11	6.8	6.35	0	1	21258	14.52	45	138	147.4138	49	154	160.5172	10	23	3.47	756
	12	3.99	4	100	1.5	16204	15.52	29	99	112.658	37	121	143.7361	11	37	3.01	753
	13	2.15	2	100	2	11426	15.31	27	88	100.9481	34	114	127.1199	10	33	3.08	663
	14	5.41	6	100	3	20324	9.13	90	140	159.8131	99	148	175.7944	4	11	6.78	577
	15	5.56	6	100	2.5	20104	10.71	71	120	145.6232	83	146	170.2355	15	20	5.81	824
	16	5.53	6	100	3	21000	8.6	98	146	166.5203	105	154	178.4146	3	5	6.87	518
	17	5.55	6	100	2.5	20213	10.1	79	123	152.8796	90	146	174.1667	11	28	6.2	769
	18	2.35	2	100	2.5	11903	13.8	40	96	117.7465	49	121	144.2394	13	34	4.13	672
	19	2.31	2	100	2	11904	15.22	26	87	95.66901	38	117	139.8239	15	57	3.27	672

							Bacharach PCA3								
	Test Cond.	Pgas_digital	Pgas_analog	Primary Air Damper	Flue Damper	Firing Rate Est.	O2	NO	NOc	NOX	NOXc	CO	COc	CO2	Tflue
	#	inwc	inwc	%open	Pos	Btu/hr	%	ppm	ppm	ppm	ppm	ppm	ppm	%	°F
Morning Test	1	2.32	2.2	100	2	10880	15.7	25	98	28	118	10	51	2.9	628
	2	2.32	2.2	100	3	10882	14.2	27	89	38	122	16	54	3.9	536
	3	2.33	2.2	0	3	10915	13.3	44	121	52	144	10	27	4.2	532
	4	4.08	4	0	2	11389	14.8	36	125	41	144	8	28	3.4	620
	5	3.99	4	0	3	11354	12.3	53	129	61	148	8	26	4.8	451
	6	3.99	4	100	3	11213	13.4	33	97	44	122	19	44	4.1	460
	7	6	5.52	0	3	12686	11.5	61	137	71	162	12	28	5.2	494
Afternoon Test (shut down and restart)	8	6.8	6.36	0	3	21897	5.2	131	188	142	198	8	9	8.8	681
	9	6.8	6	0	2	21266	13.3	63	163	74	189	21	57	4.5	831
	10	6.8	6.22	0	2.5	21387	9.7	87	158	101	193	31	48	6.5	837
	11	6.8	6.35	0	1	21258	15.3	44	162	51	184	9	31	3.4	742
	12	3.99	4	100	1.5	16204	15.7	29	118	34	143	11	40	2.8	752
	13	2.15	2	100	2	11426	15.6	28	104	33	128	11	39	3	668
	14	5.41	6	100	3	20324	9	93	172	98	183	6	7	6.6	581
	15	5.56	6	100	2.5	20104	11.1	75	157	87	176	15	18	5.7	827
	16	5.53	6	100	3	21000	9.2	97	174	105	188	5	7	6.7	572
	17	5.55	6	100	2.5	20213	10.2	82	162	95	184	12	32	5.9	770
	18	2.35	2	100	2.5	11903	13.9	41	116	49	140	15	38	4.1	651
	19	2.31	2	100	2	11904	15.3	29	109	36	132	11	37	3.2	680

Figure C-4: Group 2 Full Data Sets

						Analyzer Room								
Test Cond.	Pgas_digital	Pgas_analog	Primary Air Damper	Flue Damper	Firing Rate Est.	O2	NO	NOc	NOX	NOXc	CO	COc	CO2	Tflue
#	inwc	inwc	%open	Pos	Btu/hr	%	ppm	ppm	ppm	ppm	ppm	ppm	%	°f
1	2.41	2	100	2	12104	15.3	24	88	30	112	15	56	3	565
2	2.41	2	100	3	12104	13.2	35	95	43	117	13	37	4.2	435
3	3.93	4	100	3	16035	11.5	56	123	60	132	13	30	5.1	475
4	3.99	4	100	2	16035	13.8	33	98	42	125	19	55	3.9	640
5	3.96	4	100	3	16035	11.5	55	123	61	134	10	23	5.1	480
6	5.56	6	100	3	19968	10.3	71	146	75	150	6	13	5.7	500
7	5.52	6	100	2.5	19968	11.6	59	132	65	145	13	27	5.1	690
8	5.48	6	100	3	19968	9.7	85	160	86	163	7	11	6.1	460
9	5.48	6	0	3	19968	6.4	134	196	136	198	14	22	8	460
10	5.48	6	0	2	19968	12.9	65	170	69	183	16	39	4.2	695
11	5.49	6	0	2.5	19968	8.6	106	180	112	196	20	34	7	635
12	5.38	6	0	1	19968	15.3	42	156	46	171	11	40	3	625
13	3.73	4	0	2	16404	14.6	46	154	50	164	10	34	3.4	620
14	2.16	2	0	2	11735	15.3	34	123	37	140	11	42	3.1	540
15	2.16	2	0	1.5	11735	16.5	25	118	28	132	11	49	2.3	515