EXECUTIVE SUMMARY

Energy and Water Efficiency Improvements for Dishrooms in Military Dining Facilities

ESTCP Project EW-201518

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ESTCP

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1.0 INTRODUCTION

Energy and water usage for commercial foodservice have a significant impact on the overall usage of a facility. Daily meal preparation and cleanup in a military dining facility (DFAC) represents more than 75% of the energy and water load. Within the foodservice facility itself, the dishwashing room or "dishroom" has the highest energy intensity compared to the other zones within a DFAC (ASHRAE, 2012). The dishroom has an intensity of 53.5 W/ft^2, compared to 29.3 W/ft^2 for the Carry Out zone, 27.1 W/ft^2 for the Server zone, and 13.5 W/ft^2 for the Kitchen zone. Up to 75% of the hot water in the kitchen is consumed in the dishroom. Many of the dishwashers installed in foodservice facilities and DFACs are older, use excessive volumes of hot water, and are being operated inefficiently. Preliminary field monitoring has shown significant water and energy savings potential by replacing outdated dishwashers with modern ENERGY STAR® qualified models. Recent findings have shown that these existing dishwashers (also called warewashers or dish machines) are not only consuming large volumes of hot water for the rinse operation, but also generating considerable additional water waste due to existing staff operating procedures. Water and energy savings of up to 90% have been experienced in unpublished dishwasher replacement field projects by Frontier Energy (formally known as Fisher Nickel, Inc). While energy-efficient cooking equipment, improved ventilation systems, and advanced space conditions systems have been developed and used for the kitchen, dining, and serving zones, the dishroom has experienced fewer improvements in energy and water usage for all types of foodservice facilities, including DFACs.

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2.0 OBJECTIVES

The objective of this project was to identify and demonstrate a comprehensive strategy of installing and analyzing new technologies to reduce the energy and water usage and energy intensity within a dishroom at a military installation used for cleaning and sanitizing of flatware, dishes, cooking vessels, and other foodservice utensils. Included are technologies to recover heat from waste water, to reduce waste water, to improve worker environmental conditions, to demonstrate reliability, and to reduce air conditioning loads. The specific Performance Objectives are: 60% energy savings for heating water to the dishwasher, 30% energy savings for the ventilation system (including fan power and energy to condition indoor air), and 75% savings in water use for washing. The results of this project were used for a Best Practices Guide and workshop presentation to assist energy managers, consultants, and commercial foodservice contractors at DoD locations to recognize the benefits of the dishroom technologies demonstrated. The ventilation results were used as the basis for establishing new dishroom ventilation standards for foodservice applications.

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3.0 TECHNOLOGY DESCRIPTION

To achieve the objective of reducing energy and water usage in dishroom installations, the project team led by Gas Technology Institute (GTI) demonstrated three types of technologies: waste water heat recovery, optimized ventilation system, and a low-water usage warewasher or dish machine. An optimal savings potential can be achieved from the three technologies based on the interrelationship between them. The dish machine cleans dishware and other items, producing steam and hot waste water at various rates depending on the load sizes. The ventilation system vents away the steam produced by the dish machine but is typically not set to ventilate at the correct rate to ensure an optimal working environment in terms of comfort. A waste water recovery system reuses heat from the waste water to preheat inlet water to the dish machine that would otherwise be literally poured down the drain. By recovering waste heat and making appropriate adjustments to the ventilation rate, less energy and water is used to clean the dishes and to maintain a comfortable work environment.

At the start of this project, two technologies existed to recover the heat from the drain. The Gravity-Film Heat Exchanger (GFX) is a vertical counterflow heat exchanger used to transfer heat from the drain water to the incoming water of the dish machine (Figure E1). Waste water flows through a 2–4-inch diameter central copper pipe with a ½ inch copper coil wrapped around it, which is the supply line to the dish machine. The coils are slightly flattened to increase surface area and thus improve heat transfer.

Figure E1. GFX Schematic and Novothermic NVX2060 (L to R)

The other technology was the Novothermic NVX2060 Heat Exchanger, also shown in Figure E1. This unit is also a heat exchanger for transferring heat from the drain to the supply water of the dishwasher. This is a standalone unit positioned next to or underneath the dish machine and requires a power source. After an initial evaluation of the proposed demonstration site at US Army Garrison Presidio of Monterey, the Novothermic was the leading candidate based on the type of dish machine and the layout of the dish room.

During the baseline testing, a new dish machine manufactured by Hobart became available that had built-in heat recovery. The Hobart CLPS86ER is a conveyor style dish machine that has an internal heat exchanger for recovering heat from the waste water to reuse for heating new wash water. After discussions with the manufacturer and host site, the project team requested and was granted a change of scope to switch to this unit. The advantages of on-board vs. external heat recovery are that technical support would be consolidated with a single manufacturer for both the heat recovery unit and the dish machine, and additional floor space in the already tight dish room would not be needed for an external unit.

In accordance with ASTM F1920, *Standard Test Method for Performance of Rack Conveyor Commercial Dishwashing Machines* with canopy exhaust, hoods shall use a 3-foot by 6-foot configuration for operating at the dish machine manufacturer's specified ventilation rate. Typically, the exhaust hood operates at too high a ventilation rate, resulting in more air being removed from the dishroom and pulling excess air from the rest of the DFAC. This results in energy waste because the excess air typically has been heated or air-conditioned for the comfort of the occupants.

Warewashers or dish machines are available in three designs for the washing and sanitizing of items including plates, eating utensils, and cooking utensils: flight type, rack conveyor, and stationary door. The designs vary to meet cleaning volumes and cleaning rates. Preliminary field monitoring has shown significant water and energy savings potential by replacing outdated dish machines with modern ENERGY STAR® qualified models. Recent findings have shown that not only are these existing dish machines consuming large volumes of hot water for the rinse operation, but also the staff operating practices are greatly adding to additional water waste. Water and energy savings of up to 90% have been experienced in unpublished dishwasher replacement field projects by Frontier Energy. The most common design for dish machine is the use of electric heating elements to heat the water. Despite a majority of most commercial foodservice appliance types using natural gas as the fuel source, dish machines are over 95% electric. The main reason for this is that electric dish machines are easier to design and manufacture, there being limited space available within the confines of the unit for positioning a gas-fired water heating system (including a burner, tank, gas train, and vent). The current state of the art for natural gas dish machines is to use an external gas-fired booster heater to preheat the water to the dish machine, with an electrical heating element to heat the water to the final rinsing and washing temperatures.

4.0 PERFORMANCE ASSESSMENT

Figure E2 shows the existing (baseline) carousel machine and the replacement (demonstration) machine installed in the dish room at the test site.

Figure E2. Baseline and Demonstration Dish Machines (L to R)

The key to acquiring accurate data for assessing the quantitative and qualitative performance objectives was establishing several difference performance characteristics of how the dish room was currently operating during the early stages of the baseline testing. Once the baseline data acquisition equipment was installed, data was measured to determine two key performance characteristics: identify the major sources of water usage and determine the operation load in terms of meals served per day.

Performance Characteristic: Operational Loads in Meals Per Day

An important issue when comparing baseline with demonstration data was assuring the usage rates during these test periods were the same or about the same for the number of meals being served. A consistent number of meals served correlated to a similar number of racks being washed for each meal for daily, weekly and yearly time frames. Data was recorded for the total headcount for each day and divided up into breakfast, lunch, and dinner for six months during the baseline testing. There were some variations in the headcount for different days of the week and due to DFAC closures but compared with other similar-sized facilities the usage rate was very consistent on a weekly or greater timeframe basis. The average meals served per day was 984.

The consistent meal usage rate was expected to have a consistent water usage rate because the water usage rate per rack is the same for the dish machine, which is typically the largest water usage source in a DFAC. However, this was not the case as discussed in the Water Usage Profile section.

Performance Characteristic: Water Usage Profile

Water usage in a dishroom is not limited to the dish machine. Different water usage locations in the dishroom that were monitored during the project including the tank fill, rinse, pre-rinse, and sink. Data showed a significant water usage came from pre-rinse, which is done to remove food items and large stains on the dishware before entering the dish machine for cleaning and sanitation.

Compared with the total water usage, the pre-rinse usage rate was higher than expected and led to a deeper investigation of the water usage in the dishroom besides the dish machine. Figure E3 showed significant variations for low and high-water use. Most daily use was 1.5 to 1.7 gallons of water per meal to pre-rinse, but very significant numbers of days used less than 1 gallon and more than 3.4 gallons. The gap in the data from 2.8 to 3.5 shows that different methods were being used at the pre-rinse area.

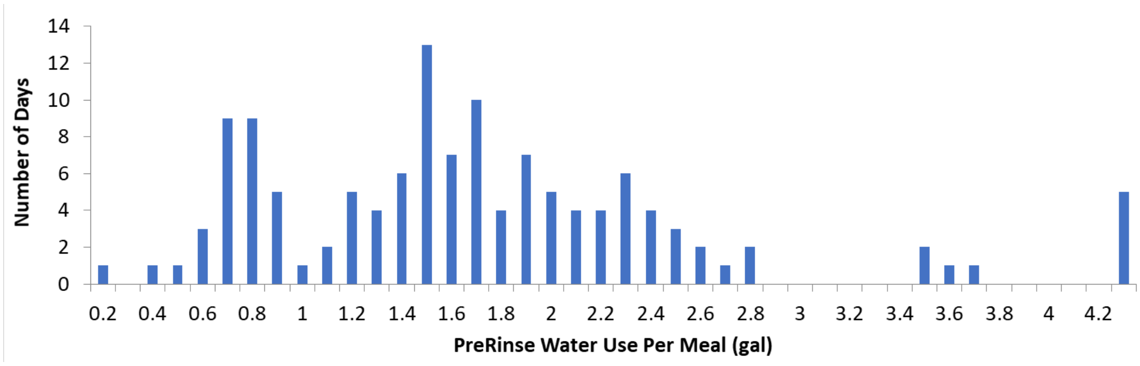

Figure E3. Water Usage for Pre-Rinse Area

The data showed that the variations in water usage were not a weekly or monthly trend but could occur on consecutive days. After discussions with the site energy manager and observations of dishroom operations over several days of dish washing, the problem was identified. A garden hose without a nozzle was being used to "wash out" the trough where the scraps collected below the pre-rinse station. On some days, the hose would be left on to continuously wash out the trough. The days with the hose left on were the data points for the Pre-Rinse Water Use Per Meal that were greater than 3.5 gallons per meal. On a different day, a single employee was observed to only use the hose to rinse the trough periodically and was using a dry scrapping method to remove the excess food and stains from the dishware. The water usage on these days was less than 1.0 gallons per meal as shown in Figure E3. After identifying this, the project team added a nozzle to the hose and recommended using a dry scrapping method to remove larger food items from the dishware. Information for pre-rinse operations was added to the Best Practices Guide for the project.

Quantitative Performance Objective: Water Heating Energy Usage

Once the water usage sources within the dishroom were identified, the baseline water usage was monitored for the total volume of water used and the energy required to heat the water for over six months. These values were compared with six months of water and energy data for the demonstration dish machine. In terms of energy use, the main difference from the baseline to the demonstration unit was that steam generated in the boiler room was the sole source of water heating for the DFAC including the dish machine, but a natural gas booster heater was used as the primary heat source for the demonstration machine. The goal for the host site was to replace the steam boiler system with a natural gas system for dish washing and a smaller boiler for hot water in the sinks in the kitchen and bathrooms. During the demonstration, once the new dish machine and booster heater had established the ability to function as required, the larger boiler in the DFCA was decommissioned. Table E1 summarizes the energy usage for baseline operations and demonstration operations before and after decommissioning of the boiler system.

Table E1. Results for Energy Use for Dish Washing

Performance Objective	Baseline	Demonstration	Savings	Savings
Total Natural Gas Use	6.7 MMBtu/day	4.7 MMBtu/day 3.3 MMBtu/day*	2.1 MMBtu/day 3.5 MMBtu/day*	31% 51%
Electricity (Conveyor, Pumps, Motor)	28 kWh/day	17 kWh/day	11 kWh/day	41%

* After decommissioning of boiler system

As Table E1 shows, the use in natural gas in the DFAC was reduced by 31% once the new dish machine with the natural gas booster was put into operation. During the initial months of the demonstration, the natural gas boiler was still in operation for the hot water supply for the kitchen and bathroom sinks and heating. Eventually the large boiler was replaced with a smaller one because of the reduced capacity requirements. Once the boiler system was decommissioned, the total energy savings for water heating for washing dishes was a 51% reduction. The goal was to achieve a 60% reduction in water heating energy usage and the project team has determined that if the existing boiler system in the DFAC was optimized for the new loads in the DFAC after the demonstration, that further savings could be achieved.

The original performance objective for energy use for water heating did not include energy associated with operating the baseline and demonstration dish machines, including electric motors to operate the conveyor, pump and motors. Table E1 shows that an additional 41% of electrical energy was saved using the demonstration dish machine. Combining the savings for the two energy types in Table E1 results in a total energy savings of 54% for replacing the baseline dish machine with the demonstration unit.

Waste Water Heat Recovery

The dish machine chosen for the demonstration had a built-in heat exchanger that uses the waste water to preheat the cold water at the inlet of the booster heater. External heat exchangers have been used over that past few years for applications including dish machines, showers, laundries, and other waste hot water applications. The disadvantages of these types are clogging from grease or other matter in the waste stream and requiring addition floor space. For these reasons, the project used the Hobart dish machine with on-board heat recovery. This is first design of a commercial dish machine to include this technology. Data from the demonstration showed that the heat exchanger averaged a 42.4 °F increase in water temperature (63.2 °F to 105.6 °F). Based on the usage rates in gallons per day, the heat exchanger saved on average 2.2 therms (or 0.22 MMBtu) per day of natural gas energy. This equates to about 800 therms (or 80 MMBtu) per year or 10.4% percent of the total savings of energy for the heating of dish washing water.

Quantitative Performance Objective: Ventilation System Energy Usage

Past projects by Frontier Energy have shown that typically the ventilation systems in dishrooms are oversized and remove excessive room air from the dishroom and pull conditioned air from other parts of the facility. The objective for this project was to resize the fan for the ventilation system to properly vent the dishroom to maintain a comfortable work environment and minimize the loss of conditioned air. However, as identified early in the baseline testing, the existing ventilation system was undersized and not properly venting heat and humidity. The baseline carousel machine used a snorkel hood on the exit of the dish machine. This style of hood is effective on removing heat and moisture at the exit of the machine but does not capture heat and moisture within the dishroom. This would not be a problem if all the heat and moisture were being generated at only the exit of the machine. However, significant heat is added to the work space by the heated steam lines to the dish machine, leaks in the steam line, and directly from the outer shell of the dish machine that heats up during operation. Also, moisture is added to the work space from the cleaned dishware once it exits the machine, from the steam leaks, and from other processes in the dish room such as cleaning the floor or pre-rinsing. The demonstration conveyor machine is designed to work with a standard hood that is open over the entire machine including the inlet, outlet, and pre-rinse area. This style of hood is much more effective on removing heat and moisture from the dish room to maintain a comfortable working environment. However, this style requires a higher ventilation rate with the same or more fan power than the baseline. Because of this change in hood design, there were no savings on the project by properly sizing the ventilation system.

Quantitative Performance Objective: Space Conditioning Energy Usage

Because of the change in the hood system design, there was no reduction in ventilation rate from the baseline. Because of this, the volume of conditioned air from other parts of the facility being ventilated did not change from the baseline to the demonstration.

Quantitative Performance Objective: Water Usage

As detailed in earlier sections, there were many sources of water usage in the dishroom besides the dish machine. Before the start of the project, it was expected almost all the savings would be from the dish machine, with a performance objective of saving 75%. However, additional water savings was achieved by making changes on how dishes were pre-rinsed. These changes included using a low flow water nozzle, dry scrapping, and minimizing rinsing of the food scraps trough. Table E2 list the water savings for only the dish machine and for the entire dish room, including the pre-rinse station. Replacing the baseline carousel dish machine with the demonstration conveyor dish machine saved approximately 89% of water usage or 5,185 gallons per day. Most of the savings is due to the newer machine using much less water to wash a single rack of dishware. However, additional water savings was realized because the design of the baseline carousel machine would allow a cleaned rack to go back through the machine again if not removed once it exited the machine. The demonstration conveyor machine is a once through machine preventing racks from being rewashed. An additional 1,190 gallons per day were saved due to the changes in the operation of the pre-rinse area. The total savings of 6,375 gallons per day equates to approximately 2.33 million gallons of water saved per year in the DFAC.

Table E2. Results for Water Use for Dish Washing

Performance Objective	Baseline	Demonstration	Savings	% Savings
Total Water Usage of Dish Machine	5,805 gal/day	620 gal/day	5,185 gal/day	89%
Total Water Usage of Dishroom	7,587 gal/day	1,212 gal/day	6,375 gal/day	84%

Quantitative Performance Objective: Dish Machine Reliability

The key parameters for reliability is hours of operation and the rinse temperature. The demonstration has operated for over one year at the time of this report with the only issues being with adjustments to the conveyor system and ventilation hood. The dish machine itself has cleaned dishes and utensils as required by the Tri-Service Food Code TB MED 530 in terms of appearance. The Tri-Service Food Code also sets a requirement for the rinse water temperature to be at least 160 °F to ensure dishware is properly sanitized.

Qualitative Performance Objective: User Satisfaction in Terms of Thermal Comfort of Working Environment

The dishroom in a DFAC or any other foodservice facility is generally the most difficult and uncomfortable area to work in because of the heat and humidity generated by the dish machine. A properly size ventilation system removes heat and moisture from the dishroom to maintain a relatively comfortable work environment. After the installation of the demonstration equipment, the energy site manager expressed that the work environment was significantly improved with less visible water on the floor. Baseline data showed a consistent 10 degrees increase in temperature and 7% increase in relative humidity due to heat and humidity from the dish machine during operation. Data for the demonstration machine showed that the temperature and humidity in the room did not increase as much as with the baseline unit, thus confirming improved thermal comfort.

Qualitative Performance Objective: User Satisfaction in Terms of Cleaning Performance

According to Tri-Service Food Code TB MED 530, all dishware must be visibly clean and sanitized. The rinse water temperature was measured to be at least 160 °F during the demonstration, showing that the dishware was properly sanitized. Visual inspection of the dishware also meets with the requirements of the Tri-Service Food Code.

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5.0 COST ASSESSMENT

The cost assessment for the replacement of an existing dish machine with an energy and water savings unit depends on the type of machine being replaced. For this project, the existing machine was a carousel type that required a new dish room layout, conveyor feed system, energy supply and hood to be replaced with a conveyor dish machine. This type of replacement is more expensive compared to replacing an older machine with the same type of machine (conveyor, door, or flight).

The cost elements for implementing the change for an older carousel style dish machine to an energy efficient conveyor are listed in Table E3. The capital costs include the cost of the dish machine from Hobart, the gas booster from Hubbell, installation of a natural gas supply line and changes to the pre-rinse station, dish table, and conveyor system to accommodate the new machine. The last three would not be required if the baseline and demonstration dish machine were the same type. Installation costs include installation of the dish machine and the cost of a kitchen consultant. A kitchen consultant was needed for this project because of the extensive changes needed for the new layout of the dishroom due to changing to a conveyor machine. Consumables include the cost of compostable dishware that was used for meal service because the DFAC had to stay in operation during the installation. The estimated cost of $8,000 per year for washing detergent is based on the demonstration and other dish machine projects. Because the baseline and demonstration machines are high temperature units using hot water to sanitized dishes, chemical for sanitization are not needed. Table E3 includes an estimated cost for re-training the dish room staff to operate the new conveyor unit. As discussed in the Best Practices Guide for this project, the project team strongly suggests doing this during the baseline testing or before the installation of a new dish machine. Another cost is recommended annual maintenance including having qualified technicians perform an inspection and do tasks such as clean the filters, remove scale from heating elements, and replace seals if needed.

Table E3. Cost Model for an Energy Efficiency Dish Machine (Carousel to Conveyor)

Cost Element	Data Tracked During the Demonstration	Estimated Costs
Hardware capital costs	Dish Machine, Booster Heater, Hood, Conveyor, Pre-Rinse Station, Dish Table, Gas Line	$77,302
Installation costs	Kitchen Consultant, Dish Machine	$32,603
Consumables	Compostable Dishware: used during installation to keep DFAC operational	$16,000
	Dish Washing Detergent: $/year	$8,000
Facility operational costs	Reduction in energy required vs. baseline data	$14,248
	Reduction in water required vs. baseline data	$46,537
Maintenance	Frequency of required maintenance	yearly
	Labor and material per maintenance action	$500
Hardware lifetime	Estimate based on components degradation during demonstration	20 years
Operator training	Estimate of training costs	$2,500

The cost model would change significantly if the baseline dish machine is the same type as the replacement. Cost elements like changes to the dish room layout and hood, operator training, installation, and kitchen consultant would not be needed or greatly reduced. Also, if the facility can be shut down during the installation, replacement dishware would not be needed. The total cost difference between replacing a conveyor with a conveyor and a carousel with a conveyor is estimated to be $54,572 or 27% less. An equal amount of savings (9% each) is from the difference in hardware and installation costs. Consumables (dishware used during installation) saves about 4% and training saves about 1%. Thus, most of the cost is associated with installation costs from changing to a new type of machine, including hiring a consultant to redo the dish room layout.

Lifetime costs are presented in Table E4. Equipment & Installation Costs includes costs of buying the equipment, purchasing compostable dishware to use during installation, installing a new hood, modifying the pre-rinse station, modifying the dish table and conveyor, adding a gas line, and hiring a kitchen consultant. Yearly Costs include cost of cleaning chemicals, maintenance, energy (gas and electric), and water. The natural gas savings includes approximately 800 therms of energy saved by the heat exchanger. The table also includes estimates for lifetime costs if the baseline carousel dish machine was replaced with a new machine of similar design. The estimates for equipment and installation costs are based on information from the kitchen consultant for the project. The only costs in the table that would vary based on location is the energy costs in the Yearly Costs. Compared to the energy costs in the region of California for the demonstration site, rates are generally 10-15% less expensive in the northeast US, 20-25% less expensive in the southeast and Midwest, and 25-30% less expensive in Texas.

Table E4. Replacement Dish Machine Lifetime Costs

Installation Type	Equipment & Installation Costs	Yearly Costs	Expected Equipment Operational Life	Lifetime Cost
New Machine w/ Extensive Layout Changes	$128,405	$31,208	20 years	$3,192,260
New Machine w/ Same Layout	$73,833	$31,208	20 years	$2,100,820
Baseline Machine	$150,000	$91,993	20 years	$4,839,860

Values from the new machine resulted in about $14,000 per year for energy savings (therms of natural gas and kWh of electricity) and $46,500 per year in water savings. Labor costs did not change from the baseline to the demonstration machine, except for the cost of training the staff on using the new type of machine in a new dish room layout.

6.0 IMPLEMENTATION ISSUES

The Presidio at Monterey was not required to acquire traditional building permits, but the proposed design of the dishroom for the demonstration with the new equipment was reviewed and approved internally to follow the required codes. All construction and installation activities were following local codes mandated by the City of Monterey Office of Plans and Public Works, thus any future sites should consult with local codes officials during the planning stages.

For installation in other DFAC locations, other various military codes that may apply include: Whole Building Design Guide (Section 11 48 00, Cleaning and Disposal Equipment for proper installation and operation) and the Tri-Service Food Code TM MED 350 (Construction and Installation section of Chapters 4, 5 and 6).

Because the basic methodology of operating the dish machine was not going to change from the baseline to the new machine, a kitchen designer was not used during the early stages of the project. The plan was to place a new machine into the existing footprint of the old machine and use the same conveyor system to move trays from the drop off location to the pre-rinse station to the dish machine. However, as the baseline testing was coming to an end, it was determined that existing layout of the dishroom and the location of the hoods would not work with the new machine. Also, the pre-rinse station needed to be relocated. After working with the site energy manager and existing staff, it was determined that an experienced kitchen designer was needed to meet the needs of the sites, to incorporate new plans of the usage of the dishroom, and to determine the dish machine and hood location. If a designer had been used in the early stages of the project, several issues and delays could have been avoided. The team eventually hired the original designer of the facility to assist with the new layout. Based on this experience, it is highly recommended before doing any changes to a dishroom to hire an experienced DFAC kitchen designer.

Another learned lesson was to use an experienced and local installer if possible. Several delays to the project occurred because the nearest installer was located over an hour away from the site. There also were issues with the installer on getting on-site and determining the correct location of the new equipment in the site. Including a kitchen designer in the early stages would have helped. The Best Practices Guide for this project further details some of the installation issues for this project.