Pumped Rinse Dishmachine Field Evaluation Report

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Test Sites:
Danville Brewing Company, Comal Berkeley, La Tapatia Martinez

Food Service Technology Center Background

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Executive Summary

Project Overview

The purpose of this project was to highlight the water and energy savings potential of pumped rinse door-type dishmachines. This was done by monitoring 3 non-pumped rinse dishmachines for water and energy use as well as performance in the field and replacing the worst performing machine with a pumped rinse machine, then calculating the real-world savings. Then, the results from this field study were compared to previous similar field studies where door-type dishmachines were similarly directly submetered, and this comparison was used to estimate the savings potential of a California statewide replacement program for door-type dishmachines.

Background

Door-type dishmachines have three main rinse categories: pressure-fed, dump-and-fill, and pumped rinse. Pressure-fed machines depend on the building's hot water pressure and a pressure regulator to deliver rinse water, and typically use increasing amounts of water per rinse throughout the machine's lifetime due to maintenance issues. Technicians will sometimes purposefully increase the rinse pressure (and therefore the water consumption) to allow for better performance, as a rinse with higher pressure will help get wares visibly cleaner. Dump-and-fill machines have a small internal tank (sump) that gets filled between rinse events, then the entire volume of the tank gets dumped on the dishes, typically at a much lower pressure than pressure-fed machines and use the wash pump to provide the rinse pressure. They typically consume more water per rack than pressure-fed machines to make up for the lower rinse pressure. Pumped rinse machines work similarly to pressure-fed machines, but the final rinse pressure is set by the pump speed and is not field adjustable. This project showed that a pumped rinse is the most water efficient rinse strategy.

Results

Of the three baseline machines monitored in this study, the pressure-fed machine found at Danville Brewing was the worst performer in terms of how much water it consumed compared to its specifications sheet, so Frontier Energy researchers decided to replace it with a Hobart AM15VLT-2 with pumped rinse and heat recovery. The new machine functioned much closer to its specifications and used 70 less gallons of water per day for the same throughput. Table 1 summarizes these findings.

Table 1: Project Water Monitoring Results Summary

Facility	Rinse Type	Age (y)	Number of Racks per Day	Daily Water Use (gal)		Water Use Per Rack (gal/R)		Rated Water Use (gal/R)	Difference (%)
La Tapatia - Low Temp tankless	Pumped Rinse Dump and Fill	10	265	313		1.18		1.09	8%
Comal - Low Temp tankless	Pumped Rinse Dump and Fill	5	311	482		1.40		1.09	28%
Danville Brewing - Baseline High Temp	Pressure Fed with wash tank	3	178	244 including fills*	226	1.37 including fills*	1.27	0.83	53%
Danville Brewing - Replacement High Temp	Pumped Rinse with wash tank	New	180	174 including fills*	135	0.97 including fills*	0.75	0.74	2%
Danville Brewing Savings				70		0.40			

*includes one to two tank fills per day for high temp machines

The results from this study and the set of data from previous Frontier Energy monitoring projects yielded the statewide replacement program savings numbers reported in Table 2. Overall, a 100% market transformation would save 1.7 million HCF per year, as well as 9.6 million therms, and would save ratepayers a total of $30 million, or an average of $750 per replacement per year.

Table 2: Savings Potential of a Statewide Replacement Program

Types	Estimated Number of Units in California	Average Water Use Per Year (million HCF)	Average Gas Use Per Year (million therms)	Average Cost Per Year (million $)
Dump and Fill	28,000	4.6	22.7	$76.7
Pressure Fed	10,000	1.3	6.5	$21.7
Pumped Rinse	2,000	0.2	1.1	$3.5
Savings From 100% Market Transformation		1.7	9.6	$30.0

Recommendations

Ultimately, the data analyzed by this project left some gaps in understanding that should be filled. The relatively small data set did not allow for a thorough analysis of the age at which non-pumped rinse dishmachines begin to drift out of the manufacturer's specifications and could not determine what percentage of machines are properly commissioned. These parameters would only be able to be determined by a long term longitudinal study which was not feasible or within this project's scope. For utility customers with smart water meters, it is possible to determine the rinse water use per rack with the smart metering data, so it is recommended that a study be conducted with a large sample of sites. In this study, the customer would be asked to shut off all other uses of water for a short period of time and to wash a predetermined number of racks of dishes. The water consumption at the utility meter could then be used to determine the water use per rack and compared to the manufacturer's specification sheet, and it would be simple to generate a large enough data set comparing machine age to the degree of drift. This pilot study also needs to be repeated for undercounter commercial dishmachines to determine the savings potential for that product category.

Another major recommendation from this project would be to make submetering of dishmachines mandatory in all commercial kitchens for new construction and major retrofits. When integrated into existing smart metering infrastructure, this would allow customers and utilities to better understand dishmachine water consumption and would improve current maintenance practices because it would arm technicians with more diagnostic information.

Finally, a targeted educational program for facility operators, maintenance personnel and dishroom designers is needed. A major finding from these submetering field studies was that part of the reason so many dishmachines are in such poor repair was a basic lack of understanding on the part of the operator in terms of when to call maintenance and what ideal dishmachine performance looked like. This educational program would be designed to give facility operators the tools to diagnose operating problems with their dishmachines and would also train maintenance personnel on how to resolve problems without simply dialing up the rinse pressure. This program would also stress to dishroom designers the importance of specifying ENERGY STAR® rated pumped rinse dishmachines to reduce dishroom water and energy use.

Abstract

Dishmachines in commercial kitchens use water to complete two main tasks; to wash the stuck-on food debris from dishes and then to sanitize the dish with either low-temperature chemical-infused rinse water or high temperature rinse water. For properly commissioned, maintained and operated dishmachines operating to their manufacturers' specifications, the rinse water drives water and energy consumption. There are three main ways of controlling the rinse flow rate: to depend entirely on the building's hot water system through a pressure regulator, to fill a small tank with fresh rinse water for every rinse event (i.e. dump-and-fill,) or to use a pump on the rinse arm. In California, most door-type dishmachines are pressure-fed, there are a significant number of dump-and-fill machines, and pumped rinses have low market share. Door-type dishmachines are usually rated to consume on the order of a gallon of water per rack, but pressure-fed dishmachines tend to consume more water throughout their lives as different components of the machines break down and can sometimes use up to twice their rated rinse. Because the average lifespan of a door-type dishmachine is 15 years, this phenomenon can lead to significant water and energy waste. Controlling the rinse flow rate with a pump can eliminate this waste.

This field project aims to determine the savings potential of a pumped-rinse dishmachine. The project involved monitoring the baseline water and energy usage of three door-type dishmachines with various rinse schemes at three medium-sized full-service restaurants, replacing the worst baseline performer with a high-efficiency pumped rinse dishmachine, and determining the savings. These results were then compared to past field studies performed by Frontier Energy to yield a realistic savings estimate for a statewide replacement program in terms of water and energy. The major recommendations from this study are that more research is needed in this area to include other types of dishmachines and to correct the small sample size which was used in this report, that utilities need to support a mid-life replacement program for poor-performing door-type dishmachines, and that dishmachines should be subject to mandatory submetering to help customers identify operating problems and correct waste.

Keywords: Dishmachine, commercial foodservice, kitchen, dishroom, rinse, dump-and-fill, pumped rinse, commissioning, maintenance, operation, training, workforce education and training, water, energy, savings

Introduction

Frontier Energy (FE) has been operating the Food Service Technology Center (FSTC) since the center's inception in 1987. The FSTC's mission statement is to support the foodservice industry by evaluating energy and water saving technologies and operating practices, and to educate the industry to help realize the savings potential. To that end, the center has completed a wealth of laboratory and field testing and has disseminated the findings through workforce education and training. This research project was intended to characterize the lifetime savings potential of pumped rinse door-type dishmachines and to estimate the savings potential of state-wide replacement programs. This project was made possible by funds from the Innovative Conservation Program (ICP).

Background

Sanitation for commercial foodservice uses a significant portion of a facility's energy and the lion's share of its water. Frontier Energy has completed various laboratory and field research in the last 16 years to characterize the water and energy use of common equipment such as pre-rinse spray valves, dipper wells, hot water systems including water heaters, and dishmachines. Dishmachines are typically the highest user of hot water in a commercial foodservice facility and the most structurally complex piece of sanitation equipment, and as such, they have been subject to the most research. Dishmachines offer myriad ways to improve water and energy efficiency as especially in the last decade, manufacturers have developed multiple design advancements such as a pumped rinse.

Dishmachines have two general functions: to wash the soiled or stuck-on food debris off of cooking implements, dishes and utensils, and to sanitize wares with a final rinse. Dishmachines generally have two main cycles to accommodate these two events. The wash cycle pumps warm water from the machine's tank onto the dishes. This water then falls back in the tank and usually goes through a filtration system before it gets recycled for the next wash event. During each wash event, some water is lost down the drain and made up with make-up water, and at the end of the shift, the tank is drained entirely. The rinse cycle generally drives water use, as fresh water enters the machine for each cycle. Manufacturers usually list a 'water use per rack' figure on their specification sheets, and this number is usually only based on the rinse water consumption.

During many prior dishmachine research projects, it was found by FE researchers that the amount of water consumed per rack washed was almost always higher than what was advertised on the dishmachine manufacturer's specification sheet, and generally, the older a machine was, the more water would be consumed. The range of rinse water rates varied from 110% of the manufacturer's specification to almost 300% of the manufacturer's specification. A common finding from site surveys and audits was that the rinse pressure regulator would be maxed out in most sites, regardless of the type of dishmachine or the foodservice market subsegment or site type. This is surprising because part of the normal commissioning process for these machines is to set the operating pressure within the boundaries noted by the manufacturer, typically between 15 and 20 psi. There seemed to be a disconnect between manufacturing, commissioning, operations and maintenance which led to the overuse of water.

The current efficiency and incentive programs for commercial dishmachines are based around the manufacturer's rating for rinse flow rate during a specific laboratory test where a machine has been commissioned according to a manufacturer's specification. Many of the dishmachines in the field which were found to be out of specification were recognized for efficiency through the ENERGY STAR® program. A longitudinal study tracking how different methods of rinsing in dishmachines impacted water consumption over time has not been done. Without this kind of research, it is difficult to say when a dishmachine starts falling out of its specification. Dishmachines have typical lifespans around 15 years.

An important aspect of dishmachine sales to note is the advent of leased dishmachines. There are multiple companies, who lease low temperature chemical-sanitizing rinse dishmachines. The business model is that the customer pays a monthly fee for the maintenance and chemicals to the machine. Many facilities opt for this instead of owning a dishmachine because of the perceived convenience. The machines which get leased are generally conventional-efficiency dump-and-fill machines, which are specified to use more water per rack than other rinse models. At the time of writing, there is at least one water agency in California offering significant rebates to incentivize customers to replace leased dishmachines with lower flow owned dishmachines. The purchased machines will still need chemicals from the same companies as the leased machines.

Door-type dishmachines can retail for anywhere between $5,000 and $20,000 depending on the model, its features (tank and booster heaters) and whether or not it qualifies for an ENERGY STAR ® classification. The cost of a new machine is generally prohibitive to mid-life replacements, so most facilities will try to get as much use out of a machine as possible before replacing it, even if it is known to be inefficient. This high cost effectively leads to a replace-on-burnout system for most facilities. Because less efficient low temp machines are also typically cheaper, replacement typically means the new machine will be less efficient out of the box.

For customers who own dishmachines, maintenance is a constant issue. The dishroom staff experiences high turnover, so keeping staff continuously trained on how to identify problems and properly use dishmachines is difficult for many facilities. Maintenance is usually not called until the dishmachine has experienced a catastrophic failure and won't operate at all or until dishes are exiting the dishmachine still dirty. Maintenance is also sometimes called at the behest of a health inspection because the tank and rinse temperatures are both things that most county health departments will check on inspections. A common solution to remedy those problems is to increase setpoint temperature of the water heater and or to increase rinse pressure which lead to energy and water use increase. Because maintenance is sometimes not called to remedy small problems with root cause analysis, big water and energy wastes are common with dishmachines.

Types of Dishmachines

Many kinds of commercial foodservice facilities simply cannot function without a dishmachine. Generally, cafés and some quick service restaurants can get away without one because they generate such a small number of soiled wares that staff can be reasonably expected to wash and sanitize the wares manually in a three-compartment sink. Modern dishmachines are ultimately labor savers: dishroom staff just has to scrap, pre-rinse and load a rack of dishes as opposed to taking a sponge and a scouring device to each ware. When dishmachines break down, facilities generally shut down until the dishmachine can be serviced.

There are four main types of commercial dishmachines: undercounter machines which are commonly found in bars and juice shops, door-type machines which are found in most quick or full-service restaurants and are the subject of this study, rack conveyor machines which use a conveyor belt to send machines from the dirty side of the machine to the clean side and are typically found in large full-service restaurants and some cafeterias, and flight-type machines which use plastic fingers on a conveyor belt and are typically found in very large facilities such as universities and prisons. These types are pictured in figures 1 through 4. These machines have various throughputs and rates at which they can wash dishes. Dishmachines are generally sized based on the perceived highest necessary throughput at a facility, so they tend to be somewhat oversized.

Figure 1: Undercounter Dishmachine at Bridges Restaurant

Figure 2: Door-Type Dishmachine at Bridges Restaurant

Figure 3: Rack Conveyor Dishmachine at Tadich Grill

Figure 4: Flight Conveyor Dishmachines at Gate Gourmet

Figure 5 shows the breakdown of new units sold nationwide by size of dishmachine. Door-type and undercounter dishmachines are the most common units sold. In 2009, about 40,000 units were sold in the US according to NAFEM State of the Industry Report.

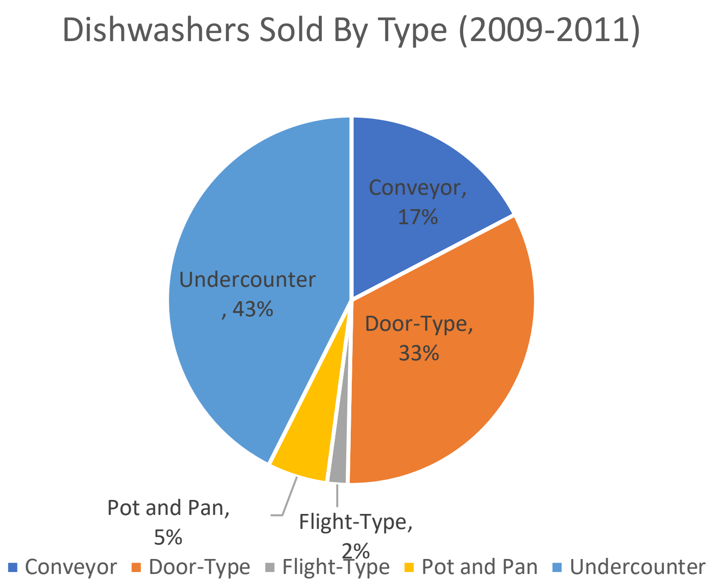

Figure 5: Types of Dishmachines sold in the US

Rinse Method Technology Descriptions

For all sizes of dishmachine, there are two broad categories of how to achieve a sanitizing rinse. There is a low temperature rinse that uses a chemical sanitizing agent and 140˚F water and a high temperature 180˚F rinse that is hot enough to not need the sanitizing agent. Dishmachines usually consume hot water from the building's hot water system, so they represent a sizeable gas load (most commercial foodservice facilities in California are heated by gas tank water heaters). High temperature sanitizing rinse machines also have a booster heater to achieve the final rinse temperature. The booster heater can be either electric or gas. This fuel choice is usually driven by the type of energy available in the dishroom (most booster heaters for high temp door type machines are electric and integrated into the machine). Most high-temp dishmachines also have an internal tank heater which makes up for energy transferred to room temperature wares in the wash cycle.

There are three main ways of delivering rinse water to dishes. The first is through a pressure regulator, where water is fed from the building into the machine either directly or through a booster heater. These are Pressure-Fed machines. The pressure regulator can be adjusted to increase or decrease the rinse flow rate depending on the site's specific needs and the current maintenance status of the machine. Rinse is usually timed for 10-15 seconds depending the machine model, so the water consumption is directly related to the incoming pressure. Water is usually routed to rinse nozzles and sprayed with some pressure onto the wares.

The second method is to fill a small internal tank with a volume typically between 1 and 1.5 gallons with rinse water, then dump the entire rinse tank onto the dishes. This is a dump-and-fill machine. These machines typically do not have a separate wash tank. The last method considered in this report is through a pump, which essentially behaves like a pressure-fed machine, except it can't be easily adjusted and forces the rinse flow rate to remain constant with the pump speed. This is a pumped-rinse machine. The tank temperatures and respective rinse types associated with sites monitored are summarized in Table 3.

Table 3: Summary of Rinse Types Monitored

Rinse Temp	Tank Type	Rinse Type	Site Monitored
Low Temp 140°F Rinse	Dump and Fill, 1 gal sump	Pumped Rinse using the same pump as the wash pump	Comal La Tapatia
High Temp 180°F Rinse	Heated 10-15 gal tank between 150-160F	Pressure Fed Rinse	DBC Baseline
		Pumped Rinse on a separate pump from the wash pump	DBC Replacement

Market

The majority of foodservice subsegments utilize dishmachines. It is estimated that there are 100,000 of these such facilities in California. NAFEM State of the Industry Report data from 2009-2011 shows that 30-40% of the dishmachines sold are door type nationwide, which translates to 40,000 facilities in California including subsegments such as quick service restaurants, small to medium full-service restaurants and fine dining establishments.

Purpose

The goal of this project was to evaluate the water savings potential of pumped rinse dishmachines compared to other rinsing methods. Then, researchers and utilities could use this information to design replacement programs and realize statewide savings around a research-based estimate as opposed to back-of-the-envelope estimates.

Objectives and Scope

The objective of this project was to monitor and analyze the water and energy use of 3 dishmachines various kinds of rinses in the field, then to replace the worst performing dishmachine with an efficient pumped rinse model to analyze the savings. The project scope included the selection of field testing sites, the installation of instrumentation to monitor and log the dishmachine water and energy use and to perform the replacement installation and commissioning.

Hypothesis

Frontier Energy estimates that a pumped rinse dishmachine can save over 30% of a dishmachine's rinse water and is the most reasonable retrofit option of the three rinse options considered in this study.

Project Limitations and Challenges

This project is limited in its analysis in the size of the ultimate data set and the number of pumped rinse dishmachines represented. From the study, there was only one pumped rinse machine considered, only one pressure-fed machine and only two dump-and-fill machines. From prior field research that Frontier has completed, there is only one additional pumped rinse machine and three pressure fed machines for a total of 3 pumped rinse, 4 pressure fed machines and 1 dump-and-fill machines in the final data set. It is also limited because the age of the machines prior to this study was not ascertained, so it's difficult to correlate machine age and rinse water consumption. This would ultimately be very useful information to have accurate data for with utility replacement programs, as it could be used to target customers with older machines to maximize savings. This study is also limited in that it could not take into account the additional chemical cost or environmental impact of the additional sanitizing rinse chemicals for low-temperature rinse dishmachines. This is critical information for determining accurate ROIs, but the data set is so limited that this was omitted in the cost analysis.

Methodology

Data Acquisition and Instrumentation Setup

The FE team installed instrumentation and data logging equipment at the test sites to measure and record the water and energy use of the dishmachine. All sites required the almost the same instrumentation, which was the temperature and flow rate of the water inlet to the dishmachine, the temperature of the final rinse, the tank temperature, the drain temperature, and the final rinse pressure where appropriate. Commercial-grade water meters, thermocouples and pressure gauges were used. In all cases, the water meters were connected to the dishmachine with flexible hoses.

Electric meters were installed to measure the energy consumption of all dishmachines which consumed electric power. The energy draw on the building's hot water system was determined by taking the amount of hot water consumed and assuming the water heater had an 80% thermal efficiency. The data loggers were installed in water-proof enclosures. Some were installed with cell modems, but there was a firmware issue between the loggers and the cell modems that researchers felt was unresolvable, so the cell modems were decommissioned and data was collected manually. The power for the data loggers was usually tapped from inside the dishmachine but there were a few instances where power could be drawn from an open wall socket.

Figure 6: Enclosure with data logger and cell modem

The water meters and electric meters provided a pulse per unit output to the data logger. The rinse pressure gauge had a voltage output, as did the thermocouples. All data was collected at 5 second intervals.

Instrumentation Specifications

Water Meters

Omega Engineering FTB-4607 1/2″ single-jet turbine meter with 151.4 pulses/gal output, accuracy 1% of full scale, flow range of 0.2 to 11 gpm, maximum temperature of 190°F (Figure 7). www.omega.com

Figure 7: Omega FTB-4607

Power Metering

Dent Instruments ELITEpro XC portable power data logger, single- and three-phase capability, accuracy ±1% (Figure 8). www.dentinstruments.com

Figure 8: DENT ELITEpro XC

Dent Instruments mini hinged split-core current transformers, 20A and 50A, low voltage 0.333 Vac out, accuracy ±1%.

Continental Control Systems Acuu-CT split-core current transformers, CTL-0750 Opt C0.6, 20A and 50A, low voltage 0.333 Vac out, accuracy ±0.5%. www.ccontrolsys.com

Dataloggers

DataTaker DT80, ten isolated analog inputs and twelve pulse counter inputs (Figure 9). www.datataker.com

Campbell Scientific CR300, six universal input channels and four pulse counter channels (Figure 10). www.campbellsci.com

Figure 10: DataTaker DT-80

Figure 9: Campbell Scientific CR300

Data Analysis

The data was compiled to yield the average daily water and energy use of each dishmachine as well as the average rinse temperature, flow rate and pressure where applicable. The performance of each machine was compared to the specifications sheet to yield a percentage of how different the actual water consumption was from the specifications.

The following parameters were also calculated in the analysis. Some were not important enough to discuss in the report:

- Operating time (h)
  - Hot/cold water flow time
- Water flow rate (gpm, gph)
- Hot water supply temperature (°F)
- Cold water supply temperature (˚F)
- Water use (gal)
  - Rinse water use (gal)
  - Rinse water use per gallon specified (%)
- Electrical energy use (kWh)
- Domestic water heater gas use (therms)
- Misc. parameters
  - Electricity cost ($/kWh)
  - Water and sewer cost ($/HCF)
  - Gas cost ($/therm)
  - Annual operating cost ($/year)

Monitoring Results

The following section presents the compiled energy and water consumption data and the operating characterizations for the four dishmachines monitored in the field. All operations were at medium sized full-service restaurants. Baseline machines were monitored at Comal in Berkeley, CA, at La Tapatia in Martinez, CA, and at Danville Brewing Company in Danville, CA. The replacement machine was installed at Danville Brewing Company.

These sites had somewhat similar menus. Comal and La Tapatia are taquerias and Danville Brewing Company offers some traditional pub fares as well as some Tex Mex options. Part of the reason these sites were chosen for this study was that it was hypothesized by FE researchers that these sites would have similar warewashing needs both in terms of throughput and soil level. All machines were downstream of a pre-rinse spray valve and had no other pre-rinse operation equipment, although the sites all did some level of dry scrapping.

The monitoring took place for at least 30 days at each site and in each phase of the project. The data from these sites was compared with the manufacturers' specifications sheets and then was aggregated with data from 2 previous sites for a total comparison of 8 door-type dishmachines. The costs of each operation were compared for the final ROI estimates. The baseline machines found in the field were not altered in any way by the researchers, especially with regards to their operating parameters in order to get a clear picture of any water use that could be attributed to maintenance problems. The replacement machines were installed and commissioned as per the manufacturers' guidelines.

Comal Berkeley

Site Overview

Comal is an upscale Mexican restaurant in Berkeley, CA that has been operating since 2012. They are open for dinner on weekdays and for brunch and dinner on weekends. Comal also operates a burrito bar next door called "Comal Next Door" which serves lunch and dinner daily. Between the two restaurants, they typically serve around 2,000 meals per day. This restaurant runs multiple dishmachines. They have 3 undercounter machines spread throughout bar areas and a main door-type dishmachine in the kitchen.

The dishmachine the site used for its back of house operation was an AutoChlor A4-L door-type dishmachine. It was new when the restaurant started operating, so this machine had experienced near daily use for roughly seven years, which is just about the average age of a door-type dishmachine in the field. Door-type dishmachines can be in use for up to 15 years if properly maintained, but the median age of machines in the field is between 5 and 7 years. The machine at Comal had a pumped rinse. This machine was selected for monitoring to examine whether pumped rinse machines keep the rinse flow rate consistent throughout their lifetimes. The data was collected from March to April of 2019.

The machine at Comal (Figure 11) was fed with hot water and had a low temperature rinse. The water entered the booster heater at 118˚F and got boosted to a final rinse temperature of 160˚F. This was a higher rinse temperature than most low temperature chemical sanitizing machines which typically operate around 140˚F. This design temperature was likely chosen by the manufacturer to accommodate a detergent that is more effective at higher temperatures.

Figure 11: AutoChlor A4-L as Installed at Comal

Results

The manufacturer's specifications sheet indicates that this machine should have used 1.09 gallons per rack, this machine uses 28% more rinse water than specified. While clearly not ideal, this could be attributed to wear and tear on the pump itself, an undiagnosed operating issue such as worn rinse nozzles, or it could be an error in the initial commissioning of the machine. Without knowing anything about the commissioning, it's difficult to identify where the discrepancy actually lies. Still, based on other machines of a similar age, this is far less of a difference between the actual and specified rinse flow rates.

Table 4: Baseline Monitoring Results at Comal

Daily Water Use	
Total Water Use (gal/d)	481.7
Rated Water Use Per Rack (gal/rack)	1.09
Actual Water Use per Rack (gal/rack)	1.40
Flow Pressure	
Rinse Pressure (psi)	N/A (pump)
Specified Rinse Pressure (psi)	N/A (pump)
Water Temperatures	
Inlet (˚F)	118.3
Booster Outlet/Final Rinse (˚F)	160.1
Tank (˚F)	148.2
Operating Time	
Dishwasher Operating Span (h)	5.6
Number of Racks Per Day	311
Energy Use and Efficiency	
Booster Heater Energy (kWh/d)	206
Total Dishwasher Energy (incl. BWH) (kWh/d)	303
Booster Heater Efficiency	92%
Overall Dishmachine Efficiency	43%
Energy Use Per Rack (kWh/rack)	0.97

La Tapatia Martinez

Site Overview

La Tapatia is a Mexican restaurant in Martinez, CA that has been operating for over 20 years. They are open for lunch and dinner on weekdays and for breakfast, lunch and dinner on weekends. They typically serve about 200 meals per day, and also run a fairly popular catering service which serves the Martinez, Concord and Benicia areas.

The dishmachine onsite was a CMA EST-AH (Figure 12) which was first purchased and installed in 2008. Because the median age of door-type dishmachines is between 5 and 7 years, the machine at La Tapatia represents an older machine. The machine was chosen for monitoring because it was a dump-and-fill machine, which needed to be represented in the final data set. This was a low temperature machine with a final rinse temperature at 140°F. It did not have its own booster heater and was fed entirely with hot water from a standard efficiency tank-type water heater. The dishmachine and its pre-rinse spray valve are the only two appliances fed by this water heater, and the heater is located very close to the dishroom.

Figure 12: CMA EST-AH as installed at La Tapatia

Results

This machine only uses 8% more rinse water than the manufacturer's specification. After 10 years of daily use, wear and tear and maintenance problems, this is a clear win for non-adjustable rinses. Operators at the site did not report any performance problems. These results are important because they show that through a non-adjustable rinse, it is possible to be operating close to the manufacturer's specification, and for machines to perform well even after heavy usage and 10 years in the field.

Table 5: Monitoring Results at La Tapatia

Daily Water Use	
Total Water Use (gal/d)	312.5
Rated Water Use Per Rack (gal/rack)	1.09
Actual Water Use per Rack (gal/rack)	1.18
Flow Pressure	
Rinse Pressure (psi)	N/A (pump)
Specified Rinse Pressure (psi)	N/A (pump)
Water Temperatures	
Inlet (˚F)	140.9
Operating Time	
Dishwasher Operating Span (h)	8.8
Number of Racks Per Day	265
Energy Use and Efficiency	
Total Dishwasher Energy (incl. BWH) (kWh/d)	258
Overall Dishmachine Efficiency	64%
Energy Use Per Rack (kWh/rack)	0.97

Danville Brewing Company

Site Overview

Danville Brewing Company (DBC) is a brewery and taproom in Danville CA that has been operating since mid-2016. Their taproom serves lunch and dinner throughout the week and has brunch/lunch/dinner service on Saturdays and Sundays. The restaurant serves traditionally American fare. During the week, they serve about 500 meals per day, and during the weekends they typically serve about 750 meals per day.

The dishmachine the site used for its back of house operation is a Champion DH5000-VHR with heat recovery. It was the 2012 model and was new when the restaurant started operating. The data was collected from November to December of 2018, so this represents a relatively new machine.

The baseline machine at DBC (Figure 13) had an exhaust heat recovery system and was fed entirely with cold water. The building had a cold water pressure around 45 psi, and the dishmachine itself had a pressure regulator for a final rinse pressure between 15 and 20 psi. When the instrumentation was installed, it was found that the pressure regulator was set to its highest setting. The dishmachine's rinse pressure gauge was not properly functioning, and it was also hidden from plain view by the heat exchanger for the heat recovery system. The temperature information display and the dishmachine controls were hidden by a compost bin. Overall, it was somewhat difficult for an operator to get any real information about how the machine was operating. This is potentially problematic for dishmachine maintenance, because it means the only way an operator would know that the machine needs attention is when dishes come out of the machine still dirty. Another interesting note about this machine was that it was still installed under a hood even though heat recovery machines are generally ventless. This could indicate improper equipment specification on the part of the designer, although at the time of monitoring instrumentation installation, the ventilation hood was turned off entirely, so it's possible that the original machine specified was not a ventless model and there was a change made in the specification before purchasing the dishmachine. This is possible because the dishmachine is often one of the last pieces to be installed in a commercial kitchen.

Figure 13: Champion DH5000-VHR as Installed at Danville Brewing Company

Baseline Results

Overall, the dishmachine used 1.65 times as much water as was indicated on the manufacturer's specification sheet, and used 1.53 times as much rinse water. Typically, manufacturers don't count tank fill and top off water as a part of their specification, but even if only the DBC machine's rinse water use was counted, it still used substantially more water than specified. This is because the pressure regulator was maxed out. It's difficult to say why this was the case, but it is more likely that this was a commissioning error than a maintenance issue due to the age of the machine. It would be interesting to turn down the final rinse pressure to determine what the minimum acceptable pressure would be for this site. If the pressure gets too low, staff would complain that the dishmachine doesn't clean dishes adequately, or they will wash the same rack of dishes multiple times to achieve results. The minimum acceptable pressure can be found by incrementally decreasing pressure until dishes begin to come out of the machine still soiled, and then slightly increasing the rinse pressure. Table 6 lists the monitoring results.

Table 6: Danville Brewing Monitoring Results

Daily Water Use	
Wash Tank Fill and Top-Off Water Use (gal/d)	18.1
Rinse Water Use (gal/d)	225.7
Number of Fills per day	1.27
Gallons per Fill	9.5
Total Water Use (gal/d)	243.8
Rated Water Use Per Rack (gal/rack)	0.83
Actual Water Use per Rack (gal/rack)	1.37
Flow Pressure	
Rinse Pressure (psi)	22.6
Specified Rinse Pressure (psi)	15 - 20
Water Temperatures	
Heat Exchanger Inlet (˚F)	60.2
Heat Exchanger Outlet/Booster Inlet (˚F)	121.2
Booster Outlet/Final Rinse (˚F)	181.7
Tank (˚F)	153.5
Operating Time	
Dishwasher Operating Span (h)	8.7
Number of Racks Per Day	178
Energy Use and Efficiency	
Tank Heater Energy (kWh/d)	82
Booster Heater Energy (kWh/d)	133
Total Dishwasher Energy (kWh/d)	215
Booster Heater Efficiency	73%
Overall Dishmachine Efficiency	36%
Energy Use Per Rack (kWh/rack)	1.02

Replacement Results

The Hobart AM15VLT-2 door-type dishmachine with heat recovery (Figure 14) was donated to this project by Hobart. It was brand new except for a few tests performed at FSTC before its installation in the field. There were a few features of note with this machine, including an exhaust heat recovery system which worked similarly to the system on the baseline Champion DH5000-VHR. The pump which controls the rinse flow rate is located between the outlet of the heat exchanger and the inlet to the machine's internal booster heater. This machine was the 'tall' model, which was designed such that an operator can fill a rack with standard-sized sheet pans and easily wash many sheet pans in a single wash. Shorter machines only have the capacity to wash a single sheet pan at a time, so this theoretically would reduce the number of racks washed per day.

Figure 14: Hobart AM15VLT-2 as installed at Danville Brewing Company

Of the baseline machines monitored, the dishmachine at Danville Brewing Company was the worst performer in terms of the amount of rinse water used compared to the manufacturer's specification. Ultimately, this replacement option had the best potential for saving the most water. Also, because the baseline machine was an exhaust heat recovery machine, the replacement at DBC represents a better like-for-like replacement so researchers could evaluate the incremental impact of a pumped rinse without as much conflation of other design differences in the two machines. One major operating difference between dishmachines with and without exhaust heat recovery is that heat recovery machines have longer wash/rinse cycles to allow time for the exhaust vapor to pass through the heat exchanger. This increases the time between racks washed. Restaurants transitioning from a conventional machine to one with heat recovery can experience a disruption to their workflow, and researchers avoided this so that the new machine wouldn't be rejected by the site.

The replacement machine saved 70 gallons per day (40%) from the total water consumption and washed a similar number of racks per day as the baseline machine. When subtracting the number of fills per day the machine operated within 2% of its specifications. If the tank fills are included in the per rack consumption, they add 30% to the rinse per rack rating. The energy per rack was also reduced significantly due to a lower water consumption than the baseline machine.

These results are listed in Table 7.

Table 7: Replacement Results at Danville Brewing Company

Daily Water Use	
Wash Tank Fill and Top-Off Water Use (gal/d)	40.6
Rinse Water Use (gal/d)	133.5
Number of Fills per day	1.25
Gallons per Fill	14.0
Total Water Use (gal/d)	174.1
Rated Water Use Per Rack (gal/rack)	0.74 (final Rinse water)
Actual Water Use per Rack (gal/rack)	0.75 (final Rinse water) / 0.97 total
Flow Pressure	
Rinse Pressure (psi)	N/A (pump)
Specified Rinse Pressure (psi)	N/A (pump)
Water Temperatures	
Hot Inlet (˚F)	116.3
Cold Inlet (˚F)	72.3
Booster Inlet (˚F)	110.1
Booster Outlet/Final Rinse (˚F)	179.6
Operating Time	
Dishwasher Operating Span (h)	8.9
Number of Racks Per Day	180
Energy Use and Efficiency	
Tank Heater Energy (kWh/d)	50
Booster Heater Energy (kWh/d)	23
Total Dishwasher Energy (kWh/d)	73
Booster Heater Efficiency	97%
Overall Dishmachine Efficiency	48%
Energy Use Per Rack (kWh/rack)	0.41

Summary of Results and Comparison Analysis with Previous Data

Door Type Dishmachine Field Monitoring Dataset

The data set from this study was enhanced with 5 additional machines from previous monitoring studies for a total of 9 machines. The additional dishmachines included an Ecolab ES2000 dump and fill machine found at Bridges restaurant in Danville, CA, which was replaced with a Hobart AM15VL with heat recovery and pumped rinse. Also represented are three machines at The Counter in San Mateo, CA: a CMA180 high temperature pressure-fed dishmachine, a Champion DH5000-VHR high temperature pressure-fed dishmachine with exhaust heat recovery (replacement 1,) and a Meiko DV80.2 WAHRS pumped rinse machine (replacement 2) (figure 15) with exhaust heat recovery.

Figure 15: Meiko DV80.2 WAHRS as installed at The Counter

The 9 dishmachines' water use is displayed in table 8, as are the average water uses for each rinse type. The average water use was determined by taking the average water use per rack for each category, then multiplying by the average number of racks from the study. The water use per rack for each dishmachine reflects the total amount of water consumed by the dishmachine during the field test period, including tank fills and top-offs. The table is organized by the rinse type.

Table 8: Water Use of all Field Monitored Door-Type Dishmachines

Facility	Rinse Type	Machine Age (y)	Number of Racks per Day	Daily Water Use (gal)	Water Use Per Rack (gal/R)	Rated Water Use (gal/R)	Percentage Difference Including Tank Fills (%)
La Tapatia Low Temp	Dump and Fill	10	265	313	1.18	1.09	8%
Bridges Low Temp	Dump and Fill	7	165	352	2.13	1.02	109%
Comal Low Temp	Dump and Fill	5	311	481	1.40	1.09	28%
Average Dump and Fill			**211**	**349**	**1.66**		
Danville Brewing Baseline	Pressure Fed with a Wash Tank	3	178	244	1.37	0.83	65%
The Counter Baseline High Temp	Pressure Fed with a Wash Tank	10	227	318	1.40	0.96	46%
The Counter Replacement 1 High Temp	Pressure Fed with a Wash Tank	New	192	230	1.20	0.83	44%
Average Pressure Fed			**211**	**279**	**1.32**		
Bridges High Temp	Pumped Rinse with a Wash Tank	New	185	208	1.12	0.94	20%
Danville Brewing Replacement High Temp	Pumped Rinse with a Wash Tank	New	180	174	0.97	0.74	30%
The Counter Replacement 2 High Temp	Pumped Rinse with a Wash Tank	New	201	149	0.74	0.74*	0%*
Average Pumped Rinse			**211**	**230**	**1.09**		

*Manufacturer's spec sheet gal per rack figure includes estimated daily tank fill water consumption actual water consumption per rinse cycle was less than the figure listed in the spec sheet.

This data is obviously limited in terms of the number of units per category. The two dump and fill machines operated wildly differently, so it's difficult to say that the average from this data set reflects the average dump and fill machine in the field with sufficient accuracy. Similarly, the only aged pumped rinse machine, found at Comal, was low temp, which has a pronounced effect on the water consumption and specifications of a dishmachine. In contrast, the three high-temp pressure-fed machines behaved similarly in terms of water use per rack and the percentage difference between the actual and rated water uses. This method of comparison is somewhat flawed, but there are still some useful conclusions to be drawn from this data set.

The closest performing dishmachine to its original specifications was the Meiko DV80.2 WAHRS at The Counter, whose specification sheet per rack consumption already included the estimated daily tank fill consumption. All the new pumped rinse machines were more water efficient than all other dishmachines in terms of water use per rack, but the dump and fill machine at La Tapatia was closest to its specifications. The highest water consumer was the dump and fill machine at Bridges, which used over twice what it was supposed to according to its spec sheet. Meiko also reports its tank fill water as a part of its water use per rack, so the similarity with its specifications sheet is more directly related to its specifications sheet than its performance. The Hobart replacement machine at Danville Brewing has a higher total water usage than its specifications sheet because its specifications sheet only considers rinse water usage. The rinse flow rate was found to be very close to the specifications sheet. The measured rinse water use per rack was 0.75 gallons per rack, only 1% different than the specification.

Dishmachine Average Daily Water Use Analysis

From the averages in table 7, the daily water use is lowest with pumped rinse dishmachines compared to the other rinse categories. Pumped rinse machines have a savings potential of 119 gallons per day and 49 gallons per day for an average restaurant which washes 211 racks per day compared to dump and fill machines and pressure fed machines, respectively. The pumped rinse machines also largely performed closest to their specification sheets out of any category.

Annual Savings Potential per Rinse Type

Table 9 lists the annual savings for switching to pumped rinses from dump and fill and pressure fed machines. There were multiple assumptions made to develop this table. The utility rates were $11.25/HCF, $1.10/therm, and 350 operating days per year were assumed as is typical for full-service restaurants. The machines were assumed to be fed by 140°F incoming water supplied by a gas domestic water heater operating at 80% efficiency. No differentiation is shown between low and high temp machines that may result in increased electric consumption at the machine itself.

Table 9: Annual Savings Potential of Pumped Rinse Dishmachines

	Average Water Use Per Year (HCF)	Average Gas Use Per Year (therms)	Average Cost Per Year
Dump and Fill	163	814	$2,730
Pressure Fed	130	651	$2,179

Pumped Rinse	108	536	$1,805
Dump and Fill to Pumped Rinse Savings	55	278	$925
Pressure Fed to Pumped Rinse Savings	22	155	$418

Savings Potential from Market Transformation

Because there are roughly 100,000 commercial foodservice facilities in California and because of the relative prevalence of door-type dishmachines, it is estimated that there are 40,000 door-type dishmachines in the state. A large portion of door-type dishmachines are pressure-fed. Table 10 estimates the savings potential of replacing all door-type dishmachines in California with pressure-fed dishmachines. While estimating electricity savings from pressure fed machines to pumped rinse machines would be straightforward, the dump and fill to pumped rinse electricity savings are quite complicated because of the number of possible baseline and replacement scenarios. For high-temperature pressure fed machines, the electricity savings would be the water savings per machine multiplied by the temperature rise at the booster heater with a factor for the booster heater's efficiency. For the constraints of table 10, this is on the order of 10 GWh for a total market replacement. The dump and fill to pumped rinse could be a transition from a low-temp machine to a low-temp machine with a wash tank, or could be a medium-temp (i.e. the Autochlor A4) which uses a booster heater to a high temp machine. Last scenario could be a low-temp machine to a high-temp machine which may increase electrical usage of the added booster heater, but reduce water and primary gas heating usage. All 3 possibilities imply different electricity usages at the booster and tank heaters for each machine, and it is impossible to estimate how many of each changeout would be required for a total market transformation, so the electricity usage is omitted. The gas usage is included because for all changeouts, gas is only being consumed at the water heater, so the gas usage scales directly with the water usage.

Table 10: Market-wide Replacement Savings Potential of Pumped Rinse Door-Type Dishmachines

Types	Estimated Number of Units in California	Average Water Use Per Year (million HCF)	Average Gas Use Per Year (million therms)	Average Cost Per Year (million $)
Dump and Fill	28,000	4.6	22.7	$76.7
Pressure Fed	10,000	1.3	6.5	$21.7
Pumped Rinse	2,000	0.2	1.1	$3.5
Savings From 100% Market Transformation		1.7	9.6	$30.0

A mid-life market transformation program is totally justified because of the high utility savings, but most of the statewide cost savings would be achieved through electricity savings, so water and energy utilities would need to partner to be most effective.

Because of the significant number of pressure-fed machines in California and the perceived technical feasibility, one avenue available for a retrofit program is to have a manufacturer develop an add-on pumped rinse for a dishmachine. With a technology like this, utility savings would be possible without incurring the high cost of replacing a dishmachine. Ideally, a pumped rinse widget could be added onto a pressure-fed machine for less than $1000 per unit as opposed to the retail price of a door-type dishmachine, between $5,000 and $20,000 plus the cost of installation and commissioning. Currently there are no pumped rinse retrofit options on the market.

Table 10 does not take into account undercounter, rack conveyor or flight type dishmachines because of the lack of available field monitoring data. Undercounter dishmachines are particularly good candidates for rebate and replacement programs because they generally have shorter lifespans and smaller initial equipment costs than other categories of dishmachine, but the water and energy savings per replacement would be smaller than that for door-types. There are also many more undercounter dishmachines in California than any other category of dishmachine, so a replacement program designed around them would have the potential to save as much or more water than the door-type program proposed in table 9. There are several pumped rinse undercounter dishwashers currently available on the market.

Discussion on Commissioning, Operations, and Maintenance of Dishmachines

Commissioning

The way a dishmachine is commissioned has a pronounced effect on how much water and energy it will consume throughout its lifetime. When the first replacement was performed at The Counter, the dishmachine was set up such that the rinse flow rate matched the minimum water consumption from the specifications sheet would be achieved. This was done by setting this pressure-fed dishmachine's pressure regulator to its minimum setting. This was found to be unacceptable by the staff because the dishmachine failed to adequately wash wares because the rinse pressure was too low to provide adequate coverage to every dish on a rack, so dishes were coming out of the dishmachine still visibly soiled. The machine was recommissioned to its maximum pressure setting, which greatly increased its water and energy usage per rack. From this experience, FE researchers learned that the commissioning of the rinse arm is critically important. A possible low-hanging-fruit joint utility program might be to simply recommission pressure-fed dishmachines to restore them to their factory settings and to diagnose any operating problems. This has the benefits of being relatively low-cost and providing the opportunity for some workforce education and training: if the program implementer is also armed with some educational materials regarding the proper operation and maintenance of a dishmachine, the restaurant owner and staff could better understand the water, energy and cost impacts. A major benefit of pumped-rinse dishmachines is that they are less sensitive to commissioning errors leading to poor performance or water and energy waste.

Operations and Maintenance

The dishroom staff is the first line of defense against water waste. Part of the reason so many dishmachines operate poorly is that dishroom staff has a hard time identifying and reporting operating problems until there are catastrophic failures, such as a dishmachine failing to turn on or failing to adequately wash dishes. Part of the issue is that the dishroom experiences extremely high turnover and it's often difficult to adequately train employees to identify operating problems. A simple thing to do would be to have the dishroom staff make a note once per shift of what the working rinse temperature and pressure are and to note the working tank temperature. Because these are three critical points during commissioning, if any of them drift, it can be a cause to have maintenance performed.

Another method to diagnose machines would be to install utility submeters on the water inlets to dishmachines. This data could be easily tracked, and if it was included as a line item on a water bill, the customer could make the decision to maintain or replace a dishmachine based on the monthly water usage. If the monthly usage spikes or drifts, this could be a useful diagnostic tool for the maintenance technician as well as serve as the impetus to call a technician in the first place. Another advantage to having a dedicated utility submeter would be that the water impact of any change to the machine's operating parameters or maintenance status would be immediately seen by both the utility and the customer, so it would be immediately known if the maintenance strategy remedied the problem. This would be useful information for the maintenance technician as well.

If the submeter was integrated into the utility's smart metering program, the utility would have the added benefit of having water metering data for a large sample of dishmachines. This data could be used to answer any number of standing questions surrounding dishmachines, such as which manufacturers' machines fall out of specification first, which maintenance companies do the best job, and which machines use the most and least water. One growing trend with dishmachines is the ability to track their own operating parameters natively. Utilities should encourage more manufacturers to adopt these technologies, as it is possible for this onboard tracking to be shared with utilities and customers.

Conclusions and Recommendations

Pumped rinse dishmachines have a high savings potential for both water and energy use. They subvert many of the commissioning and maintenance issues that are endemic to dishmachines. This project was successful in piloting this technology, but more research and work needs to be done in this area to fully realize these potential savings.

Need for Additional Research

The data presented in this report was very limited and cannot paint a full picture of door-type dishmachines. There are simply too many variables for a 9-machine dataset to adequately cover the permutations. The most important factors are the machine’s age, rinse type, sanitizing method (high-temperature or chemical sanitizing rinse), and the type and location of the host facility. A larger-scale study would be able to delve more deeply into the questions raised by this pilot project. A simple method of expanding the available data set would be to use existing utility metering data. For water utilities that use smart meters, the procedure would be to get a large number of commercial foodservice customers to isolate a small time of a single day–roughly fifteen minutes–where off all water consuming appliances other than the dishmachine could be temporarily shut off. This could be somewhat conveniently done at either the beginning or end of operation. With other water-consuming appliances off, the customer would wash back-to-back racks of dishes and count the number of racks washed. The meter output could then be compared to the dishmachine’s specifications sheet and age. This resulting data set would be useful because it could determine the average age and type of dishmachine that is running out of spec, as well as the and the ratio of dishmachines that get commissioned to the manufacturer’s specifications. This data could also be used to compare different rinse strategies to a much greater detail than is possible in a limited pilot study.

Overall, this project confirmed that there is a significant savings potential, but cannot rigorously answer what that savings potential would be for all operating scenarios. Further, this study was limited to upright door-type dishmachines. Undercounter dishmachines represent a large statewide water load that also needs to be characterized. Furthermore, there is significant opportunities to saves water and energy consumption for rack conveyors and flight type dishmachines. It is recommended that this study be repeated for other dishmachine types and at a higher number of sites to build a more robust data set.

Policy

Pumped rinses are simple and effective. The incremental cost of using a pumped rinse over a pressure-fed rinse is small compared to the retail cost of a dishmachine, and pumped rinses are very low-risk in that the pump can’t make a dishmachine consume more water on its own. Utilities need to start putting pressure on dishmachine manufacturers to discontinue using pressure-fed machines in favor of pumped rinse machines to realize some of these savings. This could be done simply through incentives which cover the incremental cost difference.

As discussed above, there are numerous benefits to requiring all dishmachines to be submetered by the water utility. It is a useful diagnostic tool to ensure the machines are running normally as well as a major asset in understanding dishmachines in much finer detail than is possible with a pilot or demonstration scale study. It is also recommended that the dishmachine submeters be included in any utility smart metering programs.

Education

Operators and designers don't understand the water and energy impacts of dishmachines as well as they could. It is recommended that utilities fund workforce education and training programs and do some outreach to their commercial foodservice customers to increase the level of awareness and to promote best practices. The lowest hanging fruit would be to design a flyer/bill insert documenting the results of this study in a case study format and sending those results to commercial foodservice customers. This would be especially important in the event of a utility-sponsored replacement or maintenance program as a way of explaining to the customer why the program is important. Other avenues for education and training would be to design webinars and classes for the commercial foodservice operator and to include pumped rinse dishmachines in these classes. Designers and equipment selectors need to be targeted in this outreach and encouraged to specify pumped rinse dishmachines.

Programs

The most direct way to achieve regional or statewide savings from this technology is to sponsor an early-retirement dishmachine program. A comprehensive program could theoretically save 1.7 million HCF per year but would be costly. A more cost-effective solution would be to develop a retrofit option where a non-pumped rinse machine could be upgraded into a pumped rinse machine after the initial installation. This would need to be an NSF-certified solution to satisfy EH&S departments. This would keep customers from having to purchase a new dishmachine and could still produce significant savings. Because the average lifespan of a dishmachine in the field is about 15 years and the average age of a door-type dishmachine in California is between 5 and 7 years, a retrofit program would prevent the decommissioning of many machines before their lifespan is reached compared to a true replacement program. It is recommended that utilities work together with manufacturers to develop this technology.

In the meantime, savings can still be achieved with a statewide re-commissioning program for pressure-fed machines. This would restore dishmachines to their factory settings and could save an average of 30% of the water consumed per machine. This program would only be effective if dishmachine maintenance bodies were educated on how to properly diagnose and resolve water and energy waste issues, as many of the current wasteful operations can be attributed to poor commissioning and improper maintenance practices.

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