Multifamily Domestic Hot Water Demand Controls Demonstration

Final Report

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NYSERDA Report XXX NYSERDA Contract 40266 July 2019

Notice

Acknowledgments

The authors would like to express their gratitude to the owners and staff of the test site buildings. We also would like to thank Lee Butler who oversaw this work on behalf of NYSERDA. Finally, we would like to acknowledge the invaluable technical support provided by Gabriel Ayala and Derek Zobrist of Enovative Group, Inc.

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Acronyms and Abbreviations List

CT	Current Transformer
DHW	Domestic Hot Water
NYSERDA	New York State Energy Research and Development Authority
SIR	Savings-to-Investment Ratio

Executive Summary

Water heating is typically the second largest energy end use in buildings, exceeded only by space conditioning (Sachs et al., 2011). In the United States, central domestic hot water (DHW) systems are commonly used in low and high rise multifamily buildings to provide domestic hot water. DHW distribution losses in multifamily buildings can account for 30% to 50% of the energy input to the system (Enovative Systems, 2010b) (Wendt, Baskin, & Durfee, 2004). In many multifamily buildings, recirculation pumps run continuously. However, several DHW control strategies have been developed to save energy.

One such control system is known as demand control. In this project, demand controls were installed in 40 multifamily buildings in New York City to provide insights and data from a wide range of buildings, resulting in practical advice for those interested in implementing this type of control strategy. Energy savings were evaluated by comparing boiler runtime during periods when the demand control system was operating against periods when it was not operating (baseline case). Based on boiler fuel input rating and/or fuel meter readings (and normalizing with respect to cold water make-up temperature), the difference in boiler energy consumption between the demand control and baseline cases was calculated. Savings-to-investment ratio, DHW fuel reduction, and pump kWh reduction were also calculated for each site based on the actual, installed costs of the installed systems, typical energy prices and measured reductions in boiler energy and pump energy.

The existing hot water distribution system needs to be functioning properly or the demand control systems can result in no savings, or even an energy penalty. Observations from monitoring revealed that many of the following potential problems were common:

- Failed check valves;
- Failed recirculation pumps;
- Pump oriented in the wrong direction;
- Improperly sized recirculation pumps;
- Severe cross over;
- Ghost flow;
- Tank stratification;

Nineteen of the 40 test sites were found to have one or more of the above issues. Most of these factors, excluding pump orientation, cannot be diagnosed by observation only and require thorough inspection. Nevertheless, annual savings projections for the 40 sites averaged about $1,000 and installed costs averaged $2,144 per site, resulting in a savings to investment ratio of more than nine.

While demand controls are a viable energy savings measure for many multifamily buildings, a careful evaluation of existing conditions is essential to assuring the intended impact and avoiding negative results. An experienced installer using guidance provided in this report can achieve success. In addition, post-installation monitoring of the DHW system temperatures and equipment runtimes is recommended to ensure that savings are achieved.

1 Background

This report presents the findings from the implementation of domestic hot water (DHW) demand controls in 40 multifamily buildings in New York City. It follows an earlier in-depth research project of four buildings, also supported by New York State Energy Research and Development Authority (NYSERDA), that was reported in ***Energy-Efficient Controls for Multifamily Domestic Hot Water Systems*** (The Levy Partnership, Inc., 2015). The 40-building implementation obtained results from a larger sample of buildings, but with fewer on-site measurements compared to the previous research study. The broader implementation provides insights and data from a wide range of buildings, resulting in practical advice for those interested in implementing DHW demand controls.

1.1 Building Stock and Systems Targeted by the Technology

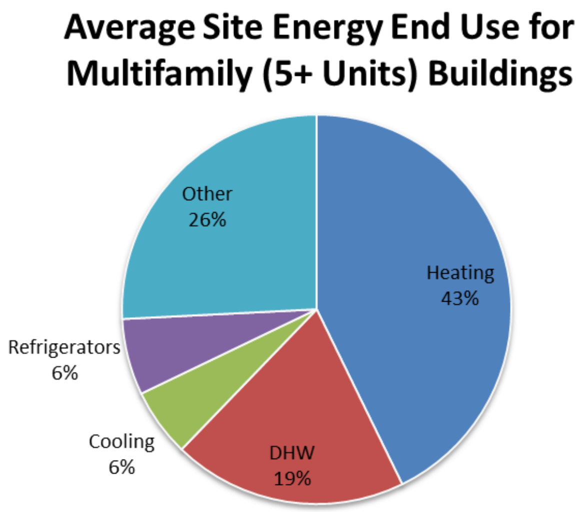
In buildings with intermittent hot water use, recirculation loops can increase energy consumption by exposing the supply and return line piping to continuous heat loss, even during periods when demand for hot water is low. In multifamily buildings distribution losses can account for 30% to 50% of the energy input to the DHW system (Enovative Systems, 2010b) (Wendt, Baskin, & Durfee, 2004). Research in California and elsewhere has shown that savings from controlling the DHW recirculation pump based on demand can significantly reduce distribution losses and overall energy use. DHW system energy savings of 15% to 25% have been shown to be possible with enhanced control strategies (Wendt, Baskin, & Durfee, 2004). Field studies have revealed that system configuration, return piping size and pipe insulation levels also impact the system energy use and opportunities for reducing fuel consumption.

1.2 Energy Waste from Existing Systems

In the United States, central DHW systems are commonly used in low and high rise multifamily buildings to provide domestic hot water. Water heating is typically the second largest energy end use in buildings, exceeded only by space conditioning (Sachs et al., 2011). Average breakdown of multifamily end use is shown in Figure 1.

Figure 1. Residential Energy Consumption Survey End Use for Multifamily Buildings

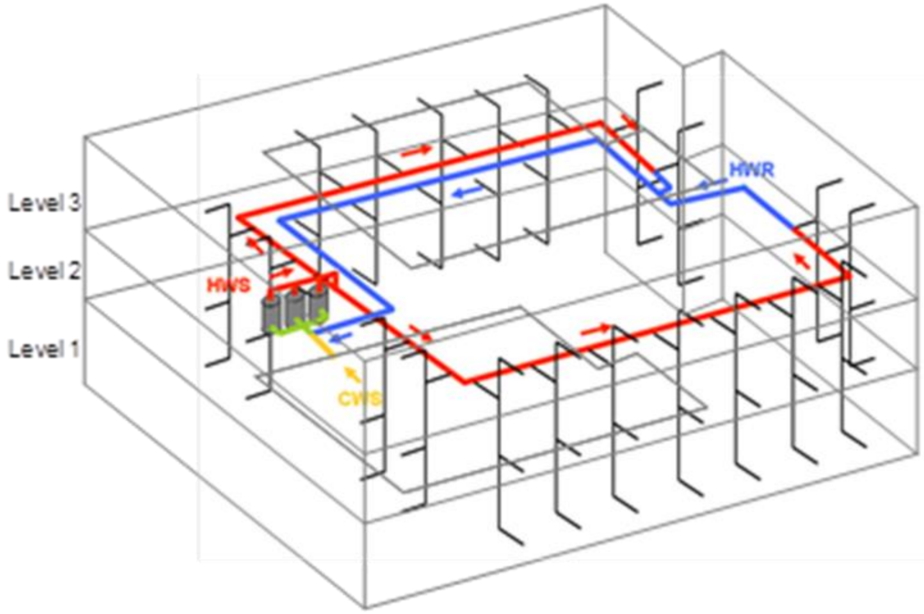
Energy Information Administration 2009



DHW recirculation loops are more common in larger buildings because of the need to quickly provide spaces far from the water heating plant with hot water. Most multifamily buildings with central domestic hot water systems and more than a handful of apartments generally have a recirculating system to enhance resident comfort. The recirculation pump keeps the DHW piping loop hot, reducing wait time at the faucets, however pipes gradually loses heat to the surrounding air. Without a recirculation pump, residents would have to run their faucet until the cool water between the faucet and the DHW plant is removed from the piping, wasting water in the process. Figure 2 shows a schematic of a central DHW system.

Figure 2. Schematic of Typical DHW Recirculation Loop in a Multifamily Building

Courtesy Heschong Mahone Group



1.2.1 Control Technologies

In many multifamily buildings, recirculation pumps run continuously. However, several DHW control strategies have been developed to save energy. The most common DHW control strategies are listed below. Some may be used in combination.

- *Temperature control* – an aquastat is used to switch the recirculating pump on and off to maintain a target temperature in the loop.
- *Timer control* – a timer is used to turn the recirculating pump on during peak usage times and off during off peak periods (typically nighttime).
- *Temperature modulation control* – the control system lowers the DHW tank or supply set-point temperature when hot water demand is expected to be low.
- *Demand control* – the recirculation pump is controlled based on demand (flow) and return water temperature.

Timer, temperature, and timer with temperature controls cost between $25 and $200 whereas demand and temperature modulation controls cost between $750 and $2,000 (Lutz, J.D. (Lawrence Berkeley National Laboratory), 2008). Timer and temperature controls are the most commonly used of these DHW control systems; however, they are less effective compared to demand and temperature modulation controls. A key limitation of timer control is that when a user demands hot water during a period when the pump is off, they may waste water and be inconvenienced as they wait for the temperature to increase.

Temperature control is limited by the fact that it only reduces pump electric use, and in keeping the recirculation piping hot even when there is no demand, does not reduce DHW fuel use.

1.3 Summary of Previous Research and Literature

A detailed literature review was included in Dentz, et. al., 2015 and is not repeated here, except for an updated summary table (Table 1). Note the wide variation in savings reported. This is an indication of the highly variable nature of DHW systems and usage patterns.

Table 1. Energy Savings by Control Techniques Compared to Continuous Pumping

Report	Location	Building Characteristics	Control Type	Savings Compared to Continuous Recirculation
The Levy Partnership (2015)	New York City	4 sites, 278 units	Demand	9% gas/99% pump
			Temperature modulation	4% gas
			Demand + Temperature modulation	14% gas
Benningfield Group (2009)	California	35 sites, 1,540 units	Demand	35 therms/unit/yr
Enovative (2008)	Los Angeles, CA	5 story, 50 units	Demand	30% gas/78% pump
Enovative (2009)	Los Angeles, CA	5 story, 189 units	Demand	12% gas/ 96% pump
Enovative (2010a)	Escondido, CA	2 story, 8 units	Demand	18% DHW electric/97% pump
Enovative (2010b)	Irvine, CA	3 story, 21 units	Demand	16% gas/ 98% pump
Enovative (2011a)	Malibu, CA	30 units	Demand	15% gas/95% pump
Goldner (1999)	New York City	6 sites, 5-6 stories, 25-103 units	Timer (nighttime off)	6%
			Timer (peak hours off)	6%
			Return temperature	11%
HMG (2008)	Saint Helena, CA	2 story, 8 units	Demand	44%
			Temperature modulation	35%
			Timer (late evening off)	1%
	Oakland, CA	3 story, 121 units	Demand	5%
			Return temperature	-5%
			Timer (late evening off)	-1%

2 Methods

2.1 Project Plan

Forty multifamily buildings, owned by eight entities served as demonstration sites. A site agreement was executed with each entity specifying the responsibilities and expectations of researchers and building owners. Among other terms, it specified access to the building and authorization to install, operate, and monitor the DHW distribution system. It also specified the monetary incentive that would be provided to the building owners – this amounted to 50% of the cost of the installed system.

Researchers then conducted a site survey to document the existing DHW system and confirm suitability for demand controls. For suitable sites, an installation plan was developed indicating the locations of equipment and any other plumbing modifications necessary for the installation of the controls.

A plumbing contractor was selected either through competitive bidding or based on the building owner's preference. Researchers briefed the contractors as necessary on system installation and typically were present during the installation, which generally took two to six hours depending on existing conditions and crew experience. Following controller installation, data loggers and sensors for energy measurements were installed. The measurement and analysis plan is described below. At the conclusion of the monitoring period for each building, monitoring equipment was removed and data was collected and analyzed.

Other project tasks included identifying market barriers and developing a plan to overcome market barriers. These documents are included in the Appendices. Furthermore, a program of dissemination of project results was undertaken. Selected dissemination materials are contained in Appendix A, including a case study from one building.

2.2 Energy Impact Analysis Method

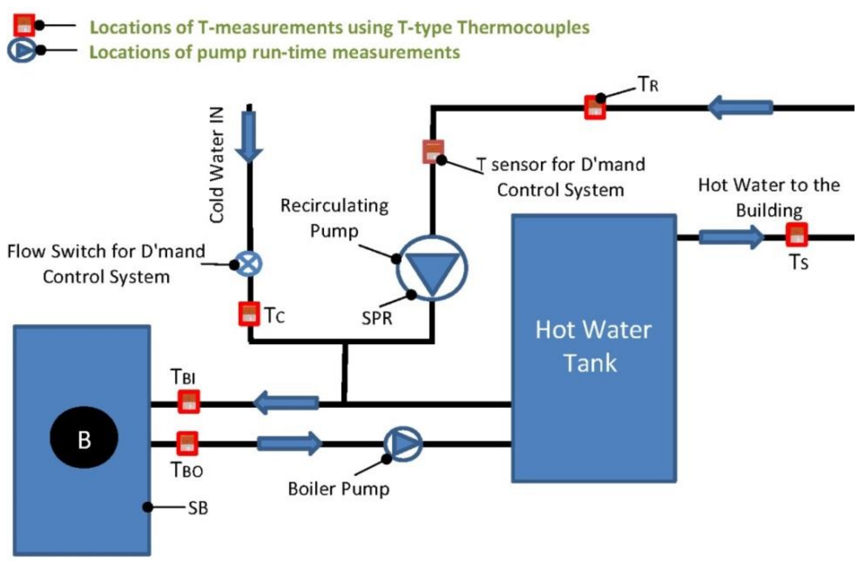
The following plan was executed to measure the effectiveness of the demand control retrofits at each participating building. Energy savings were evaluated by comparing boiler runtime during periods when the demand control system was operating against periods when it was not operating (baseline case). Based on boiler fuel input rating and/or fuel meter readings (and normalizing with respect to cold water make-up temperature), the difference in boiler energy consumption between the demand control and baseline cases was calculated. Because periods of demand control and baseline operation alternated close in time, it was assumed that environmental and occupancy changes were minimal (i.e., mains water temperatures and occupancy rates should not change dramatically over the course of a few weeks). Electricity savings from reduced pump operation were determined by monitoring pump runtime and noting pump rated power.

The total monitoring period was two to four weeks at each site: 1-2 weeks in continuous pump operation (baseline) followed by 1-2 weeks in demand control. The system was left in demand control after monitoring was complete.

2.3 Monitoring Points

A diagram of a typical system showing monitoring points is provided in Figure 3 and a list of monitoring point descriptions is in Table 2. T-type thermocouples and/or thermistors were surface mounted on pipes to measure cold and hot water temperatures at various locations as shown in Figure 3. Data was logged by Hobo data loggers (model U12-006) every 5 minutes, recorded as the average over that 5-minute interval.

Figure 3. Monitoring Points for a Typical System



Fuel consumption was measured in one of two ways depending on DHW system type.

Method A: Buildings with dedicated natural gas meters serving a DHW appliance only, and buildings with natural gas meters serving combo space-water heating boilers in summer when space heating boilers are off. Fuel consumption by the DHW appliances was measured by manually recording gas meter readings when switching between demand and continuous flow. Burner runtime (measured using Veris current transformers) and Hobo data loggers (model U12-006) recorded elapsed runtime over 5 minute intervals. This was combined with nominal firing rate where possible to ensure data quality.

Method B: Buildings with oil-fired DHW appliances and buildings with a dedicated gas DHW appliance that shares a meter with the space heating appliance during heating season. Burner runtime was used to calculate fuel consumption. Runtime was measured as described above and multiplied by nominal firing rate to calculate fuel consumption. Buildings with combination space-water heating boilers were monitored during summer when space heating was off.

Runtime of the recirculating pump and the runtime of the pumps connected to summer boilers was measured using Veris H300 current transformers (CT) and data was collected by a Hobo data logger (model UX90-001) every 5 minutes. Alternatively pump motor runtime was logged by a Hobo UX90-004.

Table 2. Data Points Collected During Monitoring Periods

Data Points	Description	Sensor	Unit
TC	Cold (City) Water Temp	Type-T TC/Thermistor	°F
TS	Hot Water Supply to Building	Type-T TC/Thermistor	°F
TR	Recirculation Return Water Temp	Type-T TC/Thermistor	°F
TBO	Supply Water Temperature of Boiler	Type-T TC/Thermistor	°F
TBI	Return Water Temperature of Boiler	Type-T TC/Thermistor	°F
SRP	Runtime/Status of Recirculation Pump	Veris CTH300/Hobo UX90-004	minutes
SP1	Runtime/Status of Boiler	Veris CT H300	minutes

2.4 Analysis Method

Savings-to-investment ratio, DHW fuel reduction, and pump kWh reduction were calculated for each site based on the actual, installed costs of the installed systems, typical energy prices and measured reductions in boiler energy and pump energy as calculated above. Note that, unlike in the 4-building detailed research study, DHW consumption was not monitored and therefore variations in usage between baseline and demand monitoring periods may impact results to an unknown degree. Over a large sample of buildings this impact is expected to even out.

2.5 Equations

Equation 1. Gas meter hundred cubic feet (CCF) to therms conversion

$$Therms = CCF / 1.026$$

Equation 2. Runtime-firing rate derived fuel consumption

$$DHW\ Fuel = Runtime \times Firing\ Rate$$

Equation 3. Makeup water temperature normalization

$$Test\ DHW\ Fuel_{norm} = DHW\ Fuel_{Test} \times \frac{Temp_{Test}}{Temp_{Base}}$$

where:

- *Test DHW Fuel*$_{norm}$ is in therms natural gas or gallons of fuel oil
- *DHW Fuel*$_{Test}$ is the total therms/gallons as calculated above
- *Temp*$_{Test}$ is average makeup water temperature during the demand control period, in degrees Fahrenheit
- *Temp*$_{Base}$ is average makeup water temperature during the baseline period, in degrees Fahrenheit

Equation 4. Annual DHW fuel reduction

$$\begin{aligned} &Annual\ DHW\ Reduction \\ &\qquad = 365 \\ &\qquad \times [(Total\ DHW\ Fuel_{Base} \div \#Days_{Base}) - (Total\ DHW\ Fuel_{norm} \div \#Days_{Test})] \end{aligned}$$

where:

- *#DaysTest* is the length of the demand control test period, in days
- *#DaysBase* is the length of the baseline period, in days

Equation 5. Annual pump kWh reduction

$$kWh = Average\ Daily\ Runtime \times 365 \times Measured\ kW$$

Equation 6. Annual cost savings (assumed $0.20/kWh, $1.00/therm, $3.25/gal #2 oil)

$$Annual\ Cost\ \text{Savings} = Pump\ Electric\ Reduction + DHW\ Fuel\ Reduction$$

Equation 7. Savings-to-investment ratio (assumed 15-year useful life, 3% discount rate, no utility escalator)

$$SIR = Present\ Value(3\%, 15, annual\ cost\ savings)\ /\ Total\ Installation\ Cost$$

Equation 8. Simple payback, in years

$$Simple\ Payback = Installed\ Cost \div Total\ Annualized\ Savings$$

3 Site Recruitment

Lists of property managers, building owners and energy consultants were used to contact prospective sites. Additionally, owners who were involved with previous demonstration projects were contacted. Recruitment of 40 sites was challenging and an ongoing process throughout the project. One of the major challenges at the beginning was the lack of local examples of buildings using the controls. This became less of an issue as initial sites were installed and began showing successful results. For reasons discussed in the market barriers report, affordable housing owners proved to be more receptive to the idea of installing the DHW controls than did market rate property owners. The best candidates were non-profit organizations that owned many small-to-mid sized buildings and who were interested in energy efficiency. In the end, eight owners provided the sites, most of which provided multiple buildings. One source provided thirteen sites; three others provided six each; one provided five; one provided two; and two provided one each.

4 Results by Site

A summary of sites and results is provided in Table 3. For each site, the number of floors and apartment units is listed, along with the DHW system type. An indirect storage system is a boiler with an unfired storage tank, and direct storage system is a fired storage tank. Sites with missing data have notes explaining why values are not recorded and additional detail on these issues is provided in Appendix B.

Boiler runtime reduction is the percent decrease in boiler runtime during demand control monitoring compared to boiler runtime during continuous monitoring. The term "boiler runtime" is used to describe burner operation for the water heater appliance, despite some systems not having boilers. Boiler runtime calculations are described above as "Annual DHW Reduction".

Pump Runtime reduction is the percent decrease in recirculation pump runtime during demand control monitoring compared to during continuous operation.

Savings are the calculated cost of energy savings described above in "Annual cost savings". Install costs are reported without incentives to represent the full cost of installation.

Savings to investment ratio (SIR) is a calculated value to describe the total energy savings cost over the lifetime of the controls lifespan divided by the installed cost. The control has an assumed 15-year lifespan. The equation used to calculate the SIR is listed above under as "Savings-to-Investment Ratio."

The note section is used primarily to provide a brief summary of why data is missing. An in-depth description of each site is available in Appendix B. Seven of the 40 sites had issues that prevented collection of complete data. Two sites had failed recirculation pumps that were diagnosed after installation but before metering completion, one site had one of their DHW boilers fail during metering, one with thermo-syphoning preventing proper functionality of the control, one with crossover preventing proper functionality of the control, and one where the data was lost.

Table 3. Summary of Results

Site #	County	Floors	Units	DHW System	Boiler Runtime Reduction	Pump Runtime Reduction	Savings	Install Costs	SIR	Note
1	New York	4	10	Indirect Storage	7.1%	24.6%	$3,281	$975	50.5	
2	Nassau	3	56	Indirect Storage	12.5%	32.5%	$1,365	$2,074	9.9	
3	Nassau	2	29	Direct Storage	16.2%	99.7%	$916	$2,074	6.6	
4	Queens	5	42	Indirect Storage	14.2%	98.0%	$1,777	$2,074	12.9	
5	Queens	6	42	Indirect Storage	12.6%	93.0%	$1,198	$2,074	8.7	
6	Queens	6	66	Indirect Storage	9.6%	91.6%	$949	$2,074	6.0	
7	Queens	4	54	Tank-less Coil	3.1%	81.0%	$273	$2,074	2.0	
8	Queens	6	49	Indirect Storage	-1.5%	99.7%	$127	$2,074	0.9	
9	Queens	4	32	Direct Storage	13.2%	99.5%	$555	$2,074	4.0	
10	Nassau	3	25	Indirect Storage				$2,074		Thermo-syphoning preventing proper function.
11	Nassau	3	40	Indirect Storage				$2,074		Crossover causing tenant complaints
12	Queens	6	66	Indirect Storage	-3.2%	100.0%	$6	$2,074	0.0	
13	Queens	6	66	Indirect Storage	-1.1%	97.4%	$130	$2,074	0.9	
14	Queens	6	44	Indirect Storage	16.1%	99.9%	$1,209	$2,074	8.7	
15	Queens	4	56	Indirect Storage				$2,074		Electrical issue preventing proper function
16	Kings	5	74		5%	61%	$216	$2,074	1.6	
17	New York	4	8	Direct Storage	18%	40%	$2,732	$1,350	30.4	
18	New York	6	41	Indirect Storage	19%	100%	$4,728	$1,150	61.7	
19	Kings	6	60	Indirect Storage	13.54%	96.04%	$4,280	$2,340	27.4	
20	Kings	6	38	Indirect Storage	11.70%	62.30%	$4,000	$2,340	25.6	

Site #	County	Floors	Units	DHW System	Boiler Runtime Reduction	Pump Runtime Reduction	Savings	Install Costs	SIR	Note
21	New York	6	17	Direct Storage	0%	99%	$89	$1,750	0.8	
22	New York	6	11	Direct Storage	14%	100%	$1,376	$1,750	11.8	
23	New York	6	19	Direct Storage	10%	93%	$2,174	$1,750	18.6	
24	New York	6	18	Direct Storage	7.55%	99.60%	$2,161	$1,750	18.5	
25	Kings	3	36	Indirect Storage				$2,074		Missing Data
26	Kings	6	62	Indirect Storage				$2,340		Boiler failure
27	Kings	6	93	Indirect Storage	-25%	4.86%	-$549	$2,340	-3.5	
28	Kings	6	93	Indirect Storage	-13%	0.00%	-$909	$2,340	-5.8	
29	New York	5	25	Indirect Storage	4%	91.89%	$830	$1,943	6.4	
30	Bronx	5	21	Direct Storage	3%	99.29%	-$44	$3,120	-0.2	
31	Bronx	5	46	Direct Storage				$3,120		Pump failure
32	Bronx	5	54	Direct Storage	3%	1.84%	$543	$3,120	2.6	
33	Bronx	3	6	Direct Storage	4.43%	98.41%	$266	$3,120	1.3	
34	Bronx	4	8	Direct Storage				$3,120		Pump failure
35	Bronx	3	2	Direct Storage	-27%	99.65%	-$370	$3,120	-1.8	
36	New York	6	19	Direct Storage	-56%	93.91%	-$938	$1,944	-7.2	
37	New York	6	22	Direct Storage	9%	93.85%	$1,380	$1,944	10.7	
38	New York	6	18	Indirect Storage	-10%	99.54%	-$733	$1,944	-5.7	
39	New York	5	10	Indirect Storage	-20%	100.00%	$219	$1,944	1.7	
40	New York	5	22	Indirect Storage	4%	99.94%	$1,183	$1,944	9.1	

4.1 Costs

Total actual retrofit costs for each building were recorded for labor and equipment separately. Where additional components necessary for the effective operation of the demand controls were installed (e.g. mixing valves, check and solenoid valves) these costs were also recorded. However, elective work done on the system that is completed concurrently with the controls retrofit, e.g. new isolation valves, insulation, new recirculation pumps etc., was not considered part of the controls costs. Engineering/consulting costs were not included in the financial analysis as a properly trained plumber, perhaps with manufacturer technical support, should be able to install and commission the controls successfully.

5 Discussion

Demand controls have been shown to work in numerous buildings and the control installation is relatively inexpensive given the savings available. The energy cost savings can be significant and quickly pay back the investment of installing the demand controls, however, the success of the controls is highly dependent on being mindful of and avoiding or resolving the potential technical and operational obstacles listed below.

5.1 Performance Concerns

The existing hot water distribution system needs to be functioning properly or the demand control systems can result in no savings, or even an energy penalty. Observations from monitoring revealed the following potential problems:

- Failed check valves;
- Failed recirculation pumps;
- Pump oriented in the wrong direction;
- Improperly sized recirculation pumps;
- Severe cross over;
- Ghost flow;
- Tank stratification;
- Very Large buildings.

Nineteen of the 40 test sites were found to have one or more of the above issues. Most of these factors, excluding pump orientation, cannot be diagnosed by observation only and require thorough inspection.

5.1.1 Failed/Absent Check Valves

Check valves failed in an open position were the most common observation that potentially led to decreased savings in the demonstration sites. A failed check valve allows water to flow opposite the intended direction. This can allow hot water from the DHW system to flow back towards the cold water city supply, wasting hot water and allowing it to flow into the cold water supply lines or to allow hot water from the DHW system to flow back up the recirculation return line in the wrong direction where it may cause the controller temperature sensor to believe the water in the lines is hot enough and not turn on when it detects flow. It is difficult to tell if a check valve is still operating properly. One possible way to tell if the valve has failed is by monitoring the pipe surface temperature on either side of the valve. Many building owners will not have the equipment to monitor pipe temperature and the best procedure may be to replace any old check valves with in-line spring loaded check valves at time of control installation. Additional check valve inspection procedures are described in below (Cambridge Brass, 2014).

1. Ensure there is flow and pressure supplied to the service and downstream distribution by operating a faucet or similar point of use device supplied through this check valve.
2. Ensure all point of use devices are closed within the system so there is no other pressure loss.
3. Slowly open the small test port cap on the top of the check valve until water starts to slowly bleed out.
4. Turn off the supply valve (inlet valve on a meter setter, or other valve upstream of the check valve). The flow should stop coming out of the test port within 2-5 seconds, relieving the pressure in the meter. Flow should stop at this point.
5. Verify the supply valve controls this flow by opening and closing it again to see flow from the test cap.
6. With the supply valve off, there should be no additional flow after 2-5 seconds, indicating the check valve is holding pressure on the downstream/distribution side.
7. If the test port continues to bleed water after 5 seconds, there is a possibility of debris or damage that could have fouled the check valve and service may be necessary to restore proper function of the check valve.

5.1.2 Failed Recirculation Pumps

Several sites had failed recirculation pumps. The two primary causes to this were the pump being clogged with scale or rust and pumps being air seized. Pumps should be checked for clogs or seizing and cleared during controls installation. Pumps that cannot be cleared or repaired should be replaced. Lack of a working pump in some (typically smaller) buildings is not a problem because water pressure alone is sufficient to deliver hot water to apartments and the distances are short enough that not much time is needed. However, even if complaints are not received, extended wait times for hot water due to lack of a working pump may lead to greater water and energy waste than with a working pump.

5.1.3 Pump Oriented in the Wrong Direction

Ensure that the recirculation pump is oriented the correct direction and pumping water in the intended direction. Pumps facing the wrong direction will eliminate energy savings from demand control and can risk sending cold water up the hot water risers, reduced hot water flow, or eliminate the functionality of the recirculation pump if a functioning check valve is in place.

5.1.4 Improperly Sized Recirculation Pumps

Recirculation pumps were undersized and not pumping enough water for the demand control to make a significant impact on boiler run time savings.

5.1.5 Crossover

Crossover is when hot water crosses over the cold water lines or vice versa through a failed mixing valve/cartridge or improperly plumbed fixture or appliance. It is common especially in older buildings. Crossover can foil demand controls in two ways. First, when demand controls deactivate the recirculation pump, pressure dynamics in the plumbing system are altered and this can exacerbate the crossover problem leading to substantially more occupant complaints and forcing the deactivation of the demand controller. Second, crossover can trick the demand control into unnecessarily running the recirculation pump if cold water leaks into the return line and reached the controller temperature sensor. In severe cases this can eliminate pump time reduction and boiler runtime reduction savings. Crossover can be resolved by installing check valves on the hot and cold water risers in each apartment or by replacing failed mixing cartridges in single-handle fixtures. Crossover is a notoriously difficult problem to track down. Crossover detection methods can be found in Appendix C.

5.1.6 Incompatible Tempering Valves

Some tempering valve manufacturers will not honor the warranty for valves that are subject to non-continuous water flow because of worries that the thermal cycling accelerates aging of the valve. If this is a concern, then owners may wish to contact their valve supplier.

5.1.7 Limited Pipe Sections Suitable for Measuring Makeup Water Flow

The demand flow sensor should be installed on a horizontal section of pipe, but can be installed vertically if the flow goes against gravity. The pipe can be either the make-up cold water to the system or on the main supply to the building off the DHW system before any branches. In some cases a suitable, accessible length of pipe might not be available. In those cases, a new pipe loop may need to be added on which to install the flow sensor.

5.1.8 Branched Return Lines with Unequal Levels of Flow

Recirculation lines often multiple branches, especially in larger buildings. Unless the system is perfectly balanced (a rarity), the temperature of the water will vary from branch to branch. The demand control temperature sensor should be placed on the branch that is coolest when the recirculation pump is running in order to ensure that the apartments served by that branch receive adequate water temperature. This may require lengthening the sensor wire.

5.1.9 Ghost Flow

Ghost flow is DHW flow through the recirculation system in the absence of a pump or other intentional driving force. It can be driven by gravity or a boiler pump in a secondary loop. It can eliminate most of the savings potential of demand controls because water will continue to flow through the recirculation lines even when the controller shuts off the pump. Ghost flow can be halted by ensuring equal pressure across the boiler loop and/or installation of proper flow control valves (such as a solenoid valve) on the system to actively stop flow when the pump is deactivated. A solenoid valve can be installed on the recirculation line such that the demand controller powers the pump and opens the valve simultaneously.

5.1.10 Tank Stratification

DHW storage tank temperature stratification may be intensified by demand recirculation controls (Gifford, 2004). Temperature stratification within storage tanks is caused by the difference in density between the hotter, less dense water supplied to the tank by the boiler and cold, denser make-up water supplied to the tank from the municipal water main. Under conditions of continuous DHW recirculation with typical storage tank installations, some degree of mixing can be expected to occur as the recirculation water is drawn through the tank supply tapping at the top of the tank and returned to the tank's bottom section (where cold make-up water also enters). The degree to which the tank water temperature is homogenized by the mixing effect of the recirculation water depends on tank aspect ratio, recirculation pump horsepower, the speed and flowrate of the recirculation water, and so on. Gifford's research describes an optimal but not easily quantified balance between desirable system effects gained from some levels of both stratification and mixing: temperature stratification effectively increases the output of hot water (fed from the upper area) of the tank, while some mixing of the tank contents prevent un-tempered hot water from short-circuiting across the top of the tank from the boiler inlet tapping to the building supply pipe. Therefore, it is possible that when recirculation pumping is halted for periods of time by demand controls, scalding-hot water could be sent to faucets and showerheads.

Evidence of tank stratification was observed in some of the demonstration sites. Sites with tank stratification could realize more savings from a reduction in hot water set point to align the hot water delivery temperature with building needs and avoid overheating and unnecessary fuel use, as well as keeping water at safer tap temperatures. Storage tank set point should be evaluated and adjusted after controls have been operating for a short time. In the studied buildings a reduction of 5-10°F would be appropriate.

Further research should identify the prevalence of unintended, unsafe temperature supply spikes across different indirect-fired DHW storage tank installations. Similar to the potential solution proposed for mixing valve flow requirements, perhaps a low-energy pump and short piping loop could allow demand controls to operate safely if over-stratification remains a concern.

5.1.11 Very Large Buildings

Large buildings with long DHW supply runs might be unsuitable sites for demand controls. When the controls are in demand settings this can lead to unacceptably long wait times for hot water during off peak periods, i.e. the first person to turn on the hot water in the morning will have to wait for water to be pumped from the heater.

5.1.12 Contractor Training

Demand control installation is a light retrofit involving a single pipe tee installation, a surface-mounted temperature sensor, and re-wiring the existing recirculation pump to the control box, which itself is powered by a standard three-prong plug. Common issues involve the positioning of the temperature sensor and the flow switch tee along the piping network; as well compatibility with the existing mixing valve model, if one is installed. This typically takes a first-time installer less than a day to complete and is detailed in the product manual. That said, hands-on training is important in allowing installers to rapidly gain comfort with this product to ensure that at this early stage of adoption the retrofits provide use-case examples for statewide application. There are several common installation scenarios anticipated to be encountered in New York State multifamily building stock (e.g. incompatible tempering valves, limited pipe sections suitable for measuring makeup water flow, branched return lines with unequal levels of flow) in which novice installers would benefit from an onsite discussion with an experienced professional. Onsite orientations with the contractor and building staff followed by installation oversight for the first several installations conducted by each contractor is suggested.

5.1.13 Building Superintendent Support

Demand controls are unfamiliar to most superintendents. Building superintendents were given copies of the installation manual, including control operation, and the support contact information. During the demonstration pilots, superintendents were more likely to bypass the demand control or change operation to continuous flow rather than attempting to trouble shoot or fine tune the control settings. In many instances after being notified of hot water complaints, researchers were able to adjust the demand control settings to allow for the control to remain in demand mode. Increasing the superintendent’s familiarity and comfortability with the control so they can make setting adjustments rather than bypassing the control or setting it to continuous mode will increase the success of control installations.

In addition to the above, the following two concerns have been noted with demand controls but not directly observed in this study:

- Issues with electric mixing valves
- Legionella

5.1.14 Electronic Mixing Valves

Electric mixing valves are thought to be incompatible with demand controls. Electric mixing valves typically require a constant flow of water, driven by the recirculation pump, in order to properly sense temperature and mix water. Without a constant water flow the mixing valve can cause supply water temperature to fluctuate. Future electronic mixing valves may be designed to work with demand controls.

5.1.15 Legionella

DHW systems can be susceptible to contamination with legionella bacteria because temperatures between 77 and 108°F can provide favorable conditions for the growth of these bacteria (ASHRAE, 2000). OSHA discourages the use of demand recirculation control specifically out of concern for potential contamination of DHW systems with legionella bacteria, and recommends a constant minimum water temperature of 122°F throughout all DHW piping (OSHA, 2014). This conflicts with other government agency recommendations and requirements. The ENERGY STAR program recommends demand recirculation (US EPA & US DOE, 2014); California building code currently requires the use of demand recirculation controls in newly constructed multifamily buildings (California Code of Regulations Title 24 §150.1(c)8); New York City building code currently allows a minimum DHW discharge temperature of 110°F in buildings equipped with mixing valves (New York City Administrative Code §27-2031). Alternative means of legionella prevention in DHW systems are at various stages of development, implementation, and research. ‘Dead leg’ sections of domestic water piping where water can remain stagnant (regardless of recirculation pump operation) are highlighted as the most likely places for legionella to grow, and more research is needed to determine whether the frequent exchange of water that occurs in DHW recirculation loops places them at lower risk for bacterial establishment.

6 Market Barriers

During the course of the demonstration project interviews were conducted to identify market barriers to demand controls technology and potential strategies to overcome these barriers. The proposed plan for overcoming market barriers is divided into two initiatives; one for new construction and one for existing buildings. An initial focusing on New York City for both segments is suggested because of the density of buildings and professionals working on them. The market barriers report is contained in Appendix D. A summary is provided below.

New Construction

Educate and train code officials.

1. Get demand controls integrated into energy code training programs.
2. Build awareness among design professionals and specifiers.

Existing Buildings

1. Focus on the most suitable market – affordable multifamily rentals:
2. Get demand controls integrated into utility and other efficiency programs.
3. Reach out to software providers and trainers (e.g. eQuest trainers Karpman Consulting, PHIUS and PHI's North American certifiers) to ensure demand controls can be modeled and credited in their software.
4. Educate the consultants involved in these programs as they will be the ones to initiate demand controls in these buildings.
5. Train installation contractors working in this market segment as described in Table 4.

Table 4. Industry Member Adoption Approaches

Type	Adoption approaches
Building owner Building manager	Provide information that clearly describes how demand controls work and their benefits; i.e. case studies, manufacturer literature. Owners and managers will usually not initiate or drive demand controls implementation but will need to know enough to approve it.
Contractors (HVAC, plumbing)	Tradesperson training programs and sales calls by manufacturer reps. Contractors will not likely initiate or drive demand controls implementation but will need to know how to install it, as well as the more subtle skills of determining good building, candidates, diagnosing problems and adjusting control settings.

7 Conclusions and Recommendations

Demand controls are a viable energy savings measure for many multifamily buildings; however, a careful evaluation of existing conditions is essential to assuring the intended impact and avoiding negative results. An experienced installer using a set of guidelines or checklist similar to that provided in this report (see Appendix E) or a third-party consultant should oversee the work. The use of a third-party consultant will increase costs, but may be worthwhile, especially in larger buildings, where the impacts could be greater. In addition, post-installation monitoring of the DHW system temperatures and equipment runtimes is recommended to ensure that savings are achieved. Because of the complex and variable nature of recirculating DHW systems, oftentimes adjustments have to be made or additional components installed to achieve savings. This would not be known without post-installation data on runtimes and temperatures. New versions of demand control equipment that have integrated sensors and data collection/transmission capabilities is becoming available and will simplify this process and keep it affordable.

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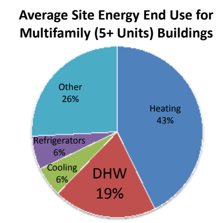
Appendix A. Technology Transfer Deliverables

Emerging Technology Demonstration: Multifamily Central Domestic Hot Water System Controls

2017 MPP Partner Summit
October 24, 2017

Water Heating
One of the Largest Residential Energy Uses

Water Heating is one of the largest multifamily energy users.



Source: U.S. Energy Information Administration, 2009 Residential Energy Consumption Survey

2

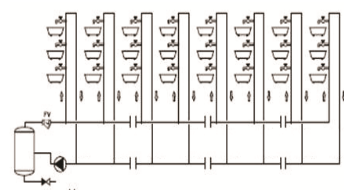
Metropolitan NYC Multifamily Stock

- Population 19 million
- 1 in 16 US citizens
- 2.1 million occupied apts.
- 77% of multifamily buildings are 5 units or more
- Vast majority of buildings have CDHW

3

What is a CDHW System?

A Central Domestic Hot Water distribution system moves hot water from the heater to the fixtures.



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Why is a Recirculation Pump Required?

- A recirculation pump quickly distributes hot water throughout a building to reduce wait time for DHW
- Without a recirculation pump, the wait time would depend on how far one is from the heating plant

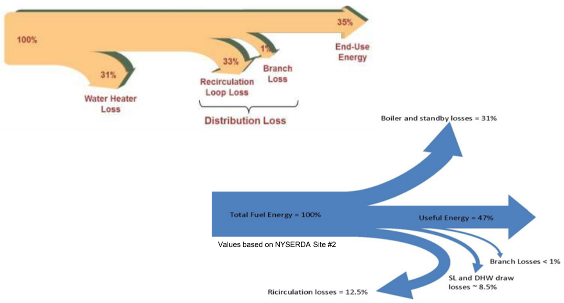
5

CDHW Energy Performance Problems

- Old boilers
- High temp set points
- Un-insulated pipes
- Un-controlled recirculation pumps
- Cross-over problems
- Poor or inefficient plumbing design
- Unbalanced distribution
- Lack of PM regimen

6

Typical CDHW Energy Waste with Continuous Pump Operation



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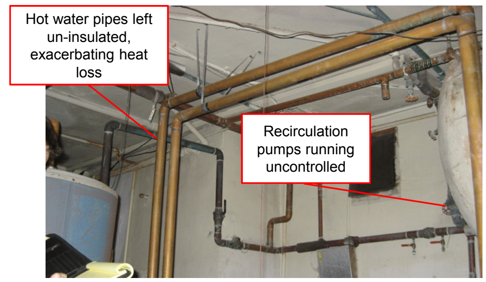
Distribution Losses



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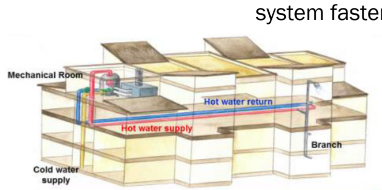
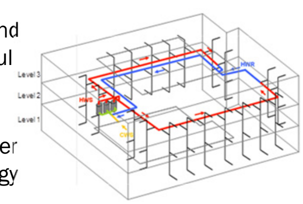
Hot Water Circulation Dilemma

- Too little circulation
  - Wastes Water
  - Frustrates tenants
- Too much circulation
  - Wastes energy
  - Deteriorates the system faster



Recirculation Loop Pump Controls

- Reduce thermal losses
- Reduce system wear and tear and increase useful life of mechanical equipment
- Maintain same hot water service using less energy



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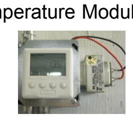
Types of DHW Control

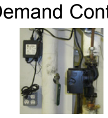
Timer Control

Temperature Modulation



Temperature Control

Demand Control



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Timer Control

- Turns pump on and off according to a schedule
- Off periods coincide with peak DHW usage
- When a user demands hot water during an "off" and no-demand period, water will be wasted as the temperature increases
- In larger buildings peak times are ill-defined or non-existent

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Temperature Control

- Controls pump based on temperature (usually 120˚F) via a sensor on the return line
- Reduces pump electricity, but maintains DHW loop temperature even without demand
- Often turned up past the supply temperature by building staff (effectively bypassing the control)

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Temperature Modulation Control

- Resets tank temp according to expected demand
- Lower demands require lower set point
- Reduces energy needed to keep tank hot when demand is low
- Does not control pump

Demand Control

- Controls pump based on demand and water temperature
- Measures demand via flow switch
- Measures return temperature
- The pump runs if there demand is detected AND return temperature is below ~105°F.

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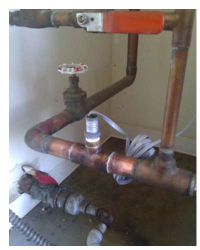
Demand Control: Sensing Demand



- Flow sensor: senses real time demand and sends signal to control board to activate pump
- Detects flow rates of less than 0.2 gpm
- May be put on CW make up or HW supply pipe

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Temperature Sensor

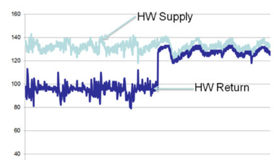
- Copper sensor indicates when the water in the pipes is not sufficiently hot (e.g., under 105°F)
- Resistance 10k, +/- 1%
- Sensors and pump communicate via a control box located on the pump

Benefits of Demand Controls

- Pump runs <1 hour per day
- Same level of hot water service
- Allows return pipe to cool during non-hot water usage
- Keeps high delta T from supply to return: very efficient

How Much Energy Can be Saved?

- Research demonstrates 10-30% reduction in total water heater fuel usage
- 90+% reduction in electricity used for pumping
- Cost payback 1/2 to 3 years



Previous Research

Study Source	Location	Building Characteristics	Control Type	Savings Compared to Continuous Pumping
CA Bldg. Engy. Eff. Standards	California	Low-rise, Two story, 44 units	Demand control	-
		Low-rise, four story, 88 units	Demand control	-
Benningfield Group	California	Total 35 sites (1540 units)	Demand control	1.78 MBtu/apt. to 9.57 MBtu/apt.
Enovative Kontrol Systems	California	Five story, 50 units	Demand control	30% gas, 78% pump
Enovative Kontrol Systems	California	30 units	Demand control	15% gas, 95% pump
Enovative Kontrol Systems	California	Two story, 8 units	Demand control	18% electricity for heater, 97% pump
Enovative Kontrol Systems	California	Five story, 189 units	Demand control	12% gas and 96% pump runtime
Enovative Kontrol Systems	California	Three story, 21 units	Demand control	16% gas, 98% pump
NYSERDA	New York	2 sites, less than 45 units 2 sites, less than 80 units 2 sites, more than 80 units 2 sites, less than 45 units	Timer control (night)	6%
			Timer control (morning and evening peak)	6%
			Temperature control	11%
HMG	California	Two story, 8 units	Temperature control	1%
			Temperature modulation	35%
			Demand control	44%
NYSERDA	New York	High Rise, 122 units	Demand control and Temp Modulation	8%
		Mid-rise, 54 units		12%
Building America/NYSERDA		Low-rise, 48 units		14%
		Low-rise, 54 units	Demand control	7%

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NYSERDA Research Buildings DHW Fuel Savings

Annual DHW Fuel…	A	B	C	D
Building characteristics	7 floors 66 br	15 floors 294 br	3 floors 81 br	3 floors 72 brs
Baseline Consumption (therms/br)	175	94	184	112
Reduction with Demand Control (therms/br)	12% (20.4)	9% (8.0)	6% (10.3)	7% (8.3)
Reduction with Temp. Modulation (therms/br)	2% (3.4)	8% (7.8)	-	2% (1.9)
Reduction with Demand Control & Temp. Modulation (therms/br)	15% (25.9)	12% (11.3)	-	15% (16.2)

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Research Buildings Simple Payback

Property	Building A	Building B	Building C	Building D
Annual DHW Cost (incl. pump electricity)	$15,900	$31,200	$16,400	$9,200
Installed Cost for Demand Control/Temp. Modulation	$3,000/ $2,000	$2,500/ $5,300	$3,000	$3,000/ $2,000
Demand Control Payback	2.1	1	3	3.7
Temp. Modulation Payback	11.2	3	-	18.5
Demand Control + Temp. Modulation Payback	3	2.5	-	4

Worst-case average payback:
- Demand control: <4 years
- Temp. modulation: 21 years

Average Annual $ Savings including interactive effects	
Demand Control	9%
Temp. Modulation	3%
Demand Control & Temp. Modulation	12%

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NYSERDA ETAC Project

- Install Demand Control Systems in 40 buildings
- Monitor the systems for 2-4 weeks
- Alternate demand control and continuous pumping weekly
- Estimate DHW energy use in each mode

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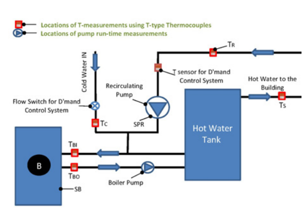
Measurements

- Temperatures:
  - Supply
  - Return
  - Make-up
  - Water to boiler
  - Water from boiler
- Run time
  - Boiler
  - Pump
- Calculations
  - Energy savings per day
- Document
  - Complaints
  - Implementation costs



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Demonstration Buildings Results

Site #	Floors	Apts.	% boiler run-time reduction	% pump run-time reduction
1	9	36	7.1%	25%
2	3	56	12.5%	33%
3	2	29	16.2%	99%
4	5	42	14.2%	98%
5	6	42	12.6%	93%
6	6	66	9.6%	91%
7	4	54	3.1%	81%
8	6	49	-1.5%	99%
9	4	32	13.2%	99%
10	6	66	-3.2%	100%
11	6	66	-1.1%	97%
12	6	44	16.1%	99%
13	5	74	5.2%	61%
14	4	8	17.7%	41%
15	6	41	18.9%	96%
16	6	60	13.5%	61%
17	6	38	11.7%	62%
18	6	17	0.3%	92%
19	6	11	13.6%	100%
20	6	19	10.5%	93%
21	6	18	7.6%	100%
Average for buildings with savings			**13%**	**79%**

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Demonstration Buildings Results

Site #	Installation costs ($)	Annual $ savings	Payback in years
1	975	3,281	0.3
2	2,074	1,365	1.5
3	2,074	916	2.3
4	2,074	1,777	1.2
5	2,074	1,198	1.7
6	2,074	949	2.2
7	6,206	273	22.7
8	2,074	n/a	n/a
9	2,074	555	3.7
10	2,074	n/a	n/a
11	2,074	n/a	n/a
12	2,074	1,209	1.7
13	2,074	216	9.6
14	1,350	2,704	0.5
15	1,150	6,306	0.2
16	2,340	4,206	0.6
17	2,340	4,000	0.6
18	1,750	85	20.5
19	1,750	1,376	1.3
20	1,750	2,174	0.8
21	1,750	2,161	0.8
Average for buildings with savings	**1,861**	**2,278**	**1.3**

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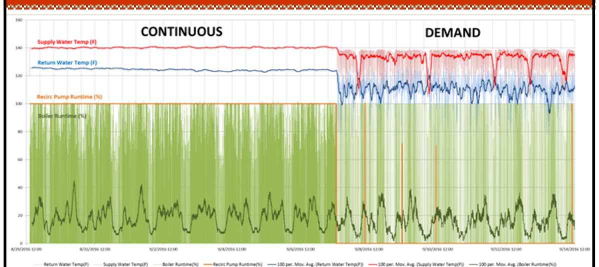
Site 12



Site #	Floors	Apts.	% boiler run-time reduction	% pump run-time reduction	Payback in years
12	6	44	16.1%	99%	1.7

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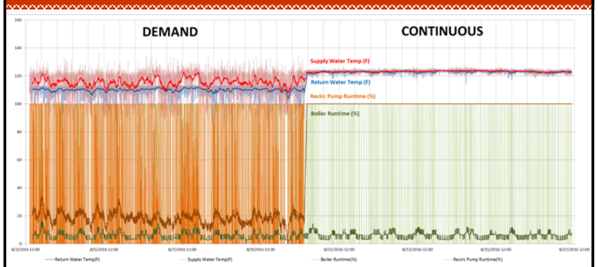
Site 7



Site #	Floors	Apts.	% boiler run-time reduction	% pump run-time reduction	Payback in years
7	4	54	3.1%	81%	22.7

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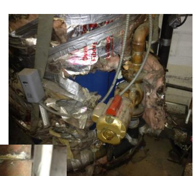
Issues

- **Balancing:** poorly balanced lines may limit savings potential
- Crossover: Can be exacerbated by discontinuous flow, requiring remediation
- **"Ghost" flow:** from gravity or driven by boiler pump must be halted
- **Old plumbing:** may increase installation cost



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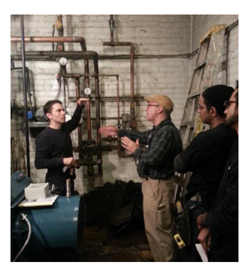
Issues

- **Tank stratification:** can be exacerbated by discontinuous flow, increasing supply temperature
- **Mixing valves:** many not rated for discontinuous flow, requiring replacement
- **Legionella:** conflicting regulatory guidance
- **Very large buildings:** may result in unacceptably long wait times during off peak



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Emerging Technology Demonstration: Multifamily Central Domestic Hot Water System Controls

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CASE STUDY - 2107 AMSTERDAM AVENUE, MANHATTAN

MULTIFAMILY – EXISTING BUILDINGS

Domestic Hot Water Recirculation Controls Retrofit

2107 Amsterdam Avenue, New York, NY; flow sensor and controller. Photo credit The Levy Partnership, Inc.

SNAPSHOT

Challenges

Innefficient gas-fired atmospheric water heater
Continuous recirculating domestic hot water loop

Solution

Added demand controller to recirculating pump with flow and temperature sensors so the pump runs only when needed

Benefits

18% reduction in domestic water heating fuel use
Annual energy savings of $2,700 per year
Reduced wear and tear on DHW pipes and pump

This eight-unit building in upper Manhattan was experiencing high domestic water heating costs and had a continuously recirculating domestic hot water loop. These factors made it a perfect candidate for the installation of DHW demand controls.

Opportunity

Planned boiler room work made this an easy project to install the demand control system on the domestic hot water lines. The plumber was able to cut in the flow sensor tee, mount the controls, mount the temperature sensor and wire the existing recirculation pump to the controls in about half a day. The controller includes a flow sensor installed in the make-up water pipe leading to the hot water tank and a temperature sensor on the recirculation system return line. If either there is no call for hot water (indicated by no flow at the flow sensor) OR the retiurn line temperature exceeds the setpoint (can be adjusted from 90°F-108°F) then the recirculation pump will not turn on. The control scheme maintains hot water service to residents, while minimizing pump run time. When the pump does not run, the return water line is allowed to cool, thereby reducing conductive heat losses from the pipe and the need to constantly add more heat to the recirculaitng water.

Payoff

With an estimated savings of $2,700 per year and total cost of only $1,350, this project will pay off in half a year. Furthermore, circulator pump runtime was cut by 40%, meaning the pump will last longer.

Appendix B. Measurement and Verification

MEASUREMENT AND VERIFICATION (M&V) COMPREHENSIVE REPORT

Prepared for: **NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY**

Title of project: **Demonstrating Central Domestic Hot Water System Demand Controls**

Agreement number: **40266** Purchase order: **52793 11/14/14**

Contract period: **September 1, 2014 through August 31, 2016 (24 months)**

Report date: **April 24, 2019**

This report provides a summary of results by site for the implementation of the M&V plan to measure the effectiveness of the demand control retrofits at each participating building.

Report Contents

Full List of Sites

	Address	Baseline data	Demand control data
1	125 West 76th Street, NY, NY	07/06/16 – 07/13/16	07/13/16 – 07/20/16
2	701 Prospect Ave, Westbury, NY	07/21/16 – 07/28/16	07/12/16 – 07/21/16
3	9 Chelsea Place, Great Neck, NY	07/21/16 – 07/28/16	07/12/16 – 07/21/16
4	142-09 Barclay Avenue, Flushing NY	07/27/16 – 08/03/16	07/20/16 – 07/27/16
5	142-12 41st Ave, Flushing NY	08/03/16 – 08/10/16	07/27/16 – 08/03/16
6	138-49 Barclay Avenue, Flushing NY	08/03/16 – 08/10/16	07/27/16 – 08/03/16
7	75-23 113th St, Forest Hills, NY	08/10/16 – 08/17/16	08/03/16 – 08/10/16
8	141-28 84th Drive Briarwood, NY	08/15/16 – 08/22/16	08/22/16 – 08/29/16
9	95-11/19 64th Road Rego Park, NY	08/22/16 – 08/29/16	08/15/16 – 08/22/16
10	206 Clinton Street, Hempstead, NY	Controls ineffective due to excessive ghost flow	
11	28 Gilchrest Road, Great Neck, NY	Data collection not possible due to excessive crossover discovered	
12	66-08 Austin Street, Rego Park, NY	08/22/16 – 08/29/16	08/15/16 – 08/22/16
13	65-84 Austin Street, Rego Park, NY	08/24/16 – 08/31/16	08/17/16 – 08/24/16
14	140-74 34th Avenue, Flushing NY	08/31/16 – 09/07/16	09/07/16 – 09/14/16
15	43-06 63rd Street, Woodside NY	08/07/16 – 08/14/16	08/14/16 – 08/21/16

16	710 Dumont, Brooklyn, NY	02/07/17 – 02/22/17	01/17/17 – 02/07/17
17	2107 Amsterdam Ave, NY, NY	06/19/17 – 06/26/17	06/26/17 – 07/05/17
18	676 St. Nicholas Ave., NY, NY	06/19/17 – 06/26/17	06/26/17 – 07/05/17
19	43 Central Ave., Brooklyn, NY	02/07/17 – 02/14/17	02/22/17 – 03/08/17
20	63 Central Ave., Brooklyn, NY	02/22/17 – 03/16/17	03/16/17 – 03/31/17
21	426-428 East 11th Street, NY, NY	05/19/17 – 05/31/17	05/08/17 – 05/19/17
22	410 East 11th Street, NY, NY	03/31/17 – 04/13/17	04/13/17 – 05/08/17
23	617 East 9th Street, NY, NY	04/13/17 – 05/08/17	03/31/17 – 04/13/17
24	212 East 7th Street, NY, NY	04/13/17 – 05/08/17	03/31/17 – 04/13/17
25	472 and 458 Ruby St., Brooklyn, NY	1/24/2018 - 02/03/2018	02/06/2018 - 02/26/2018 02/26/2018 - 03/06/2018
26	10 Forrest St, Bklyn, NY	3/19/2018 - 4/2/2018	Pending replacement of broken pump
27	533 Bushwick Ave., Bklyn, NY	4/2/2018 - 4/10/2018	4/10/2018 - 4/19/2018
28	555 Bushwick Ave., Bklyn, NY	4/19/2018 - 4/27/2018	4/27/2018 - 5/1/2018
29	234 Bradhurst Ave, NY, NY	6/13/18 - 6/21/18	6/21/18 - 7/1/18
30	1111 Westchester Ave., NY, NY	10/26/18 – 12/11/18	12/11/18 – 12/18/18
31	770 Bryant Ave, Bronx NY	10/26/18 - 11/12/18	11/12/18 - 11/20/18
33	1018 Fox St, Bronx NY	12/18/18 - 1/3/19	1/3/2019 - 1/11/2019
35	1111 Hoe Ave, Bronx NY	12/18/18 - 1/3/19	1/3/2019 - 1/11/2019
32	760 Bryant Ave, Bronx NY	2/27/19 - 3/11/19	3/11/19 – 3/18/19
34	931 Ave St John, Bronx NY	11/29/18 - 12/11/18	Pending replacement of broken pump
36	310 West 153rd St., New York, NY	1/17/2019 - 1/24/19	2/20/19 - 2/27/19
37	301 West 152nd St., New York, NY	1/17/2019 - 1/24/19	2/20/19 - 2/27/19
38	308 West 151st St., New York, NY	2/1/19 - 2/13/19	2/13/19 - 2/20/19
39	230 Bradhurst Ave., New York, NY	2/1/19 - 2/13/19	2/13/19 - 2/20/19
40	2809 8th Ave., St., New York, NY	2/27/19 – 3/11/19	3/11/19 – 3/18/19

Site	Address	Pump savings	Boiler savings	Annual cost savings	Note
1	125 West 76th, New York	24.6%	7.1%	$3,281	
2	701 Prospect, Westbury	32.5%	12.5%	$1,365	
3	9 Chelsea Pl, Great Neck	99.7%	16.2%	$916	
4	142-09 Barclay, Flushing	98.0%	14.2%	$1,777	
5	142-12 41st St, Flushing	93.0%	12.6%	$1,198	
6	138-49 Barclay Ave, Flushing	91.6%	9.6%	$949	
7	75-23 113th St., Forest Hills	81.0%	3.1%	$273	
8	141-28 84th Dr, Briarwood	99.7%	-1.5%	$127	
9	95-11/19 64th Rd., Rego Park	99.5%	13.2%	$555	
10	206 Clinton, Hempstead				See site specific page
11	28 Gilchrest Rd, Great Neck				See site specific page
12	66-08 Austin St, Rego Park	100.0%	-3.2%	$6	
13	65-84 Austin St., Rego Park	97.4%	-1.1%	$130	
14	140-74 34th Ave, Flushing	99.9%	16.1%	$1,209	
15	43-06 63rd St, Woodside				See site specific page
16	710 Dumont, Brooklyn	61%	5%	$216	
17	2107 Amsterdam Ave, New York	40%	18%	$2,732	
18	676 St. Nicholas Ave., New York	100%	19%	$4,728	
19	43 Central Ave, Brooklyn	96.04%	13.54%	$4,280	
20	63 Central Ave, Brooklyn	62.30%	11.70%	$4,000	Data missing
21	426-428 East 11th Street, New York	99%	0%	$89	
22	410 East 11th Street, New York	100%	14%	$1,376	
23	617 East 9th Street, New York	93%	10%	$2,174	
24	212 East 7th Street, New York	99.60%	7.55%	$2,161	
25	472 & 458 Ruby Street, Brooklyn				See site specific page
26	10 Forrest St, Brooklyn				See site specific page
27	533 Bushwick Ave., Brooklyn	4.86%	-25%	-$549	
28	555 Bushwick Ave., Brooklyn	0.00%	-13%	-$909	
29	234 Bradhurst Ave, New York	91.89%	4%	$830	
30	1111 Westchester Ave., New York	99.29%	3%	-$44	
31	770 Bryant Ave, Bronx				See site specific page
32	760 Bryant Ave, Bronx	1.84%	3%	$543	
33	1018 Fox St, Bronx	98.41%	4.43%	$266	
34	931 Ave St John, Bronx				See site specific page
35	1111 Hoe Ave, Bronx	99.65%	-27%	-$370	
36	310 West 153rd St, New York	93.91%	-56%	-$938	
37	301 West 152nd St, New York	93.85%	9%	$1,380	
38	308 West 151st St, New York	99.54%	-10%	-$733	
39	230 Bradhurst Ave, New York	100.00%	-20%	$219	
40	2809 8th Ave, New York	99.94%	4%	$1,183	

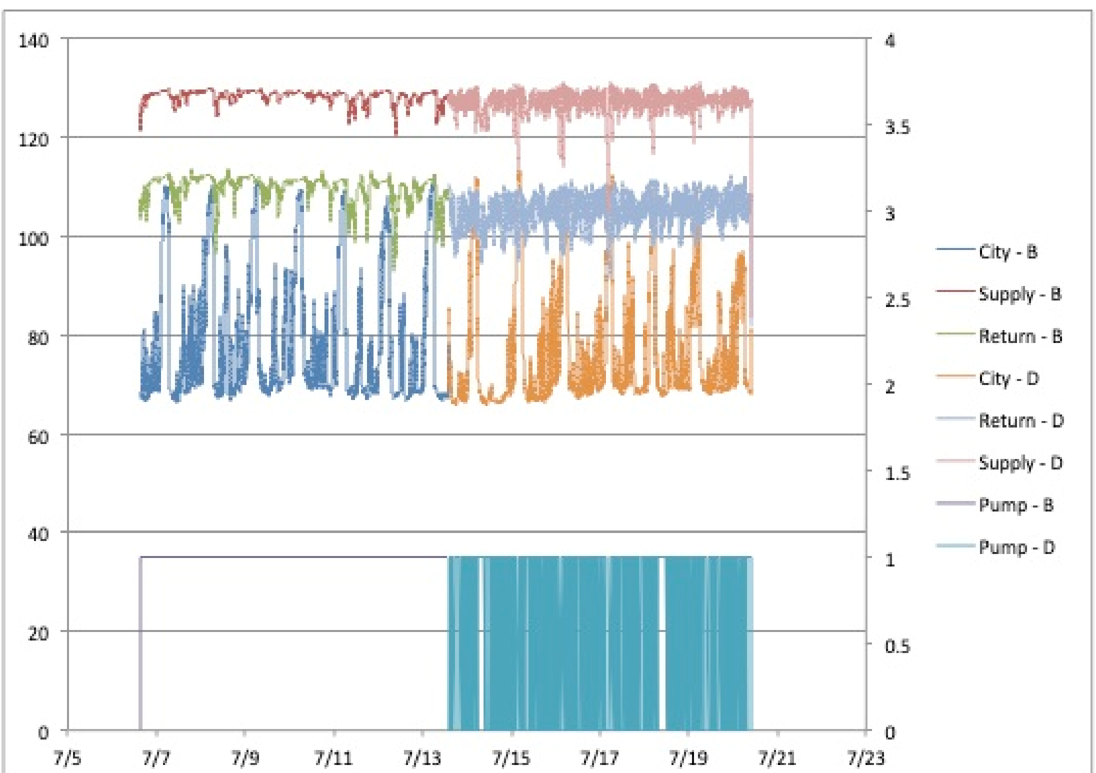
Site#1

125 West 76th Street, NY, NY

Term	Unit	Quantity	Source
Baseline Period	date	7/6/16 - 7/13/16	M&V Schedule
Demand Period	date	7/13/16 -7/20/16	M&V Schedule
Pump power	kW	0.030	Equipment specifications
Boiler runtime_baseline	hr	7.03	Data Logger
Boiler runtime_demand	hr	6.36	Data Logger
Pump runtime_baseline	hr	167.8	Data Logger
Pump runtime_demand	hr	123.1	Data Logger
#days_baseline	d	7.0	Data Logger
#days_demand	d	6.8	Data Logger
Ave City Water Temp_baseline	F	78.2	Data Logger
Ave City Water Temp_demand	F	76.5	Data Logger
Ave Return Water Temp_baseline	F	109.8	Data Logger
Ave Return Water Temp_demand	F	105.5	Data Logger
Input/Firing rate(oil_gallon)	gallon/hr	30.0	Equipment specifications
DHW fuel_baseline(oil)	gallon	210.9	Calculation
DHW fuel_normalized demand(oil)	gallon	186.6	Calculation
Annual DHW Reduction(oil)	gallon/yr	1006	Calculation
Annual pump electrical reduction	kWh/yr	64.7	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_oil	$/gallon	$3.25	M&V Plan
Boiler runtime saving	%	7.1%	Calculation
Pump runtime saving	%	24.6%	Calculation
Annual cost savings(oil+electricity)	$/yr	**$3,281**	Calculation

Notes:

Control return water threashold temperature raised in response to tenant complaints. Return and supply water temps reduced under demand control. XX unit building. Spikes in city water temp.



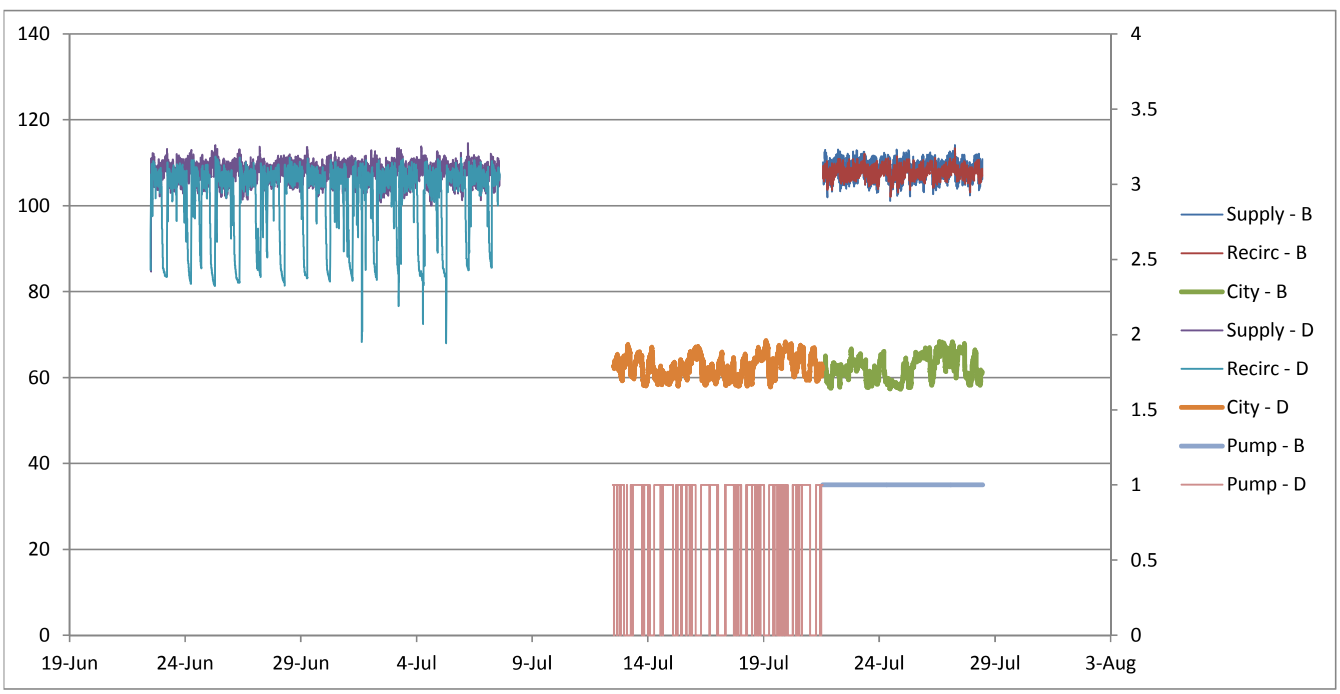
Site#2

701 Prospect Ave, Westbury, NY

Term	Unit	Quantity	Source
Baseline Period	date	7/21/16 - 7/28/16	M&V Schedule
Demand Period	date	7/12/16 - 7/21/16	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler2 runtime_baseline	hr	25.52	Data Logger
Boiler2 runtime_demand	hr	27.14	Data Logger
Boiler3 runtime_baseline	hr	29.60	Data Logger
Boiler3 runtime_demand	hr	36.61	Data Logger
Pump runtime_baseline	hr	164.83	Data Logger
Pump runtime_demand	hr	147.07	Data Logger
#days_baseline	d	6.87	Data Logger
#days_demand	d	9.08	Data Logger
Ave City Water Temp_baseline	F	62.23	Data Logger
Ave City Water Temp_demand	F	62.46	Data Logger
Ave Return Water Temp_baseline	F	107.84	Data Logger
Ave Return Water Temp_demand	F	101.46	Data Logger
Input/Firing rate(gas_therm)	therm/hr	3.78	Equipment specifications
DHW fuel_baseline(gas)	therm	208.23	Calculation
DHW fuel_normalized demand(gas)	therm	241.69	Calculation
Annual DHW Reduction(gas)	therm/yr	1348.17	Calculation
Annual pump electrical reduction	kWh/yr	85.40	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving	%	12.5%	Calculation
Pump runtime saving	%	32.5%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$1,365**	Calculation

Notes:

Data meets expectations - return water temperature is lower on average during demand; supply and city water temperature is consistent.
Demand period supply and return water temperature offset in time - does not impact savings calculations.



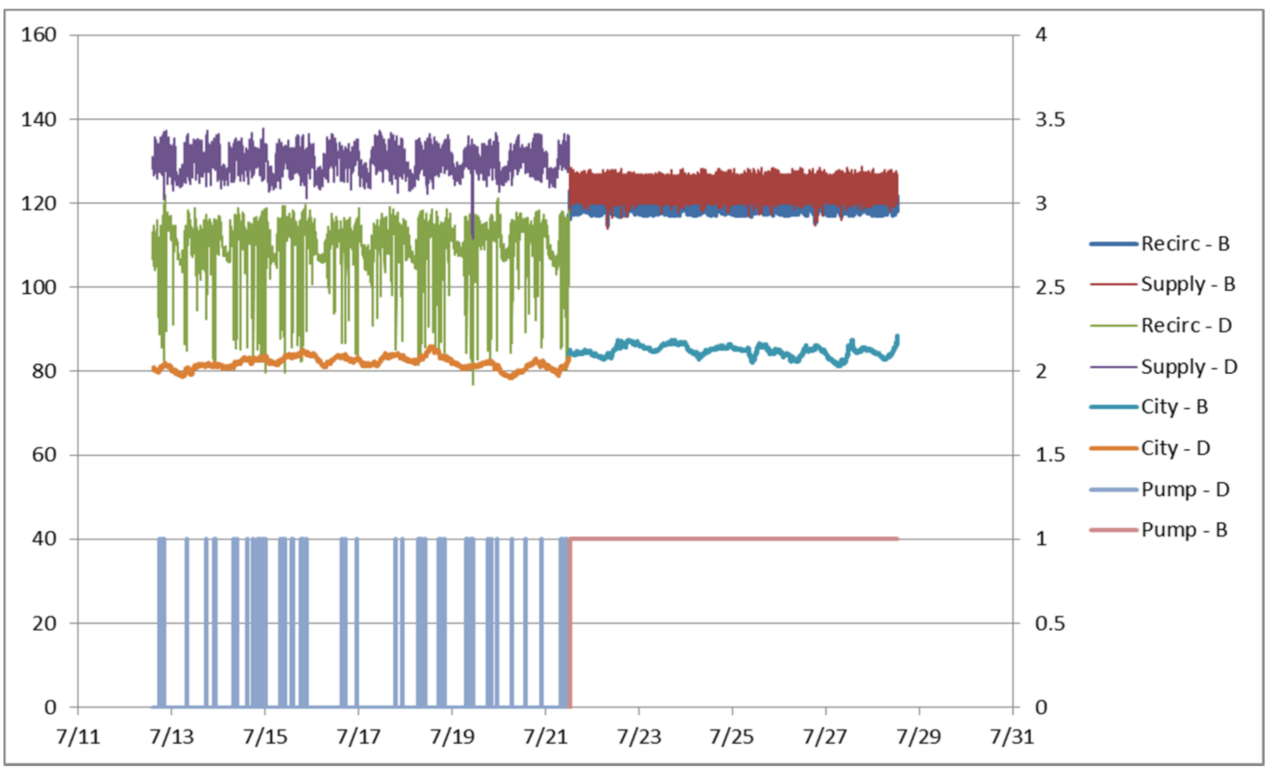
Site#3

9 Chelsea Place, Great Neck, NY

Term	Unit	Quantity	Source
Baseline Period	date	7/21/2016 - 7/28/2016	M&V Schedule
Demand Period	date	7/12/2016 - 7/21/2016	M&V Schedule
Pump power	kW	0.06	Equipment specifications
Boiler runtime_baseline	hr	17.38	Data Logger
Boiler runtime_demand	hr	18.45	Data Logger
Pump runtime_baseline	hr	168.18	Data Logger
Pump runtime_demand	hr	0.70	Data Logger
#days_baseline	d	7.01	Data Logger
#days_demand	d	8.88	Data Logger
Ave City Water Temp_baseline	F	84.83	Data Logger
Ave City Water Temp_demand	F	82.01	Data Logger
Ave Return Water Temp_baseline	F	119.62	Data Logger
Ave Return Water Temp_demand	F	111.18	Data Logger
Input/Firing rate(gas_therm)	therm/hr	4.72	Equipment specifications
DHW fuel_baseline(gas)	therm	82.06	Calculation
DHW fuel_normalized demand(gas)	therm	84.23	Calculation
Annual DHW Reduction(gas)	therm/yr	811.44	Calculation
Annual pump electrical reduction	kWh/yr	523.88	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	16.20%	Calculation
pump runtime saving(%)	%	99.67%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$916**	Calculation

Notes:

Reasonable savings. Supply water temp increase in demand may indicate tank stratification. Recommendation - reduce supply setpoint approx. 5F to match supply water temp during continuous mode.



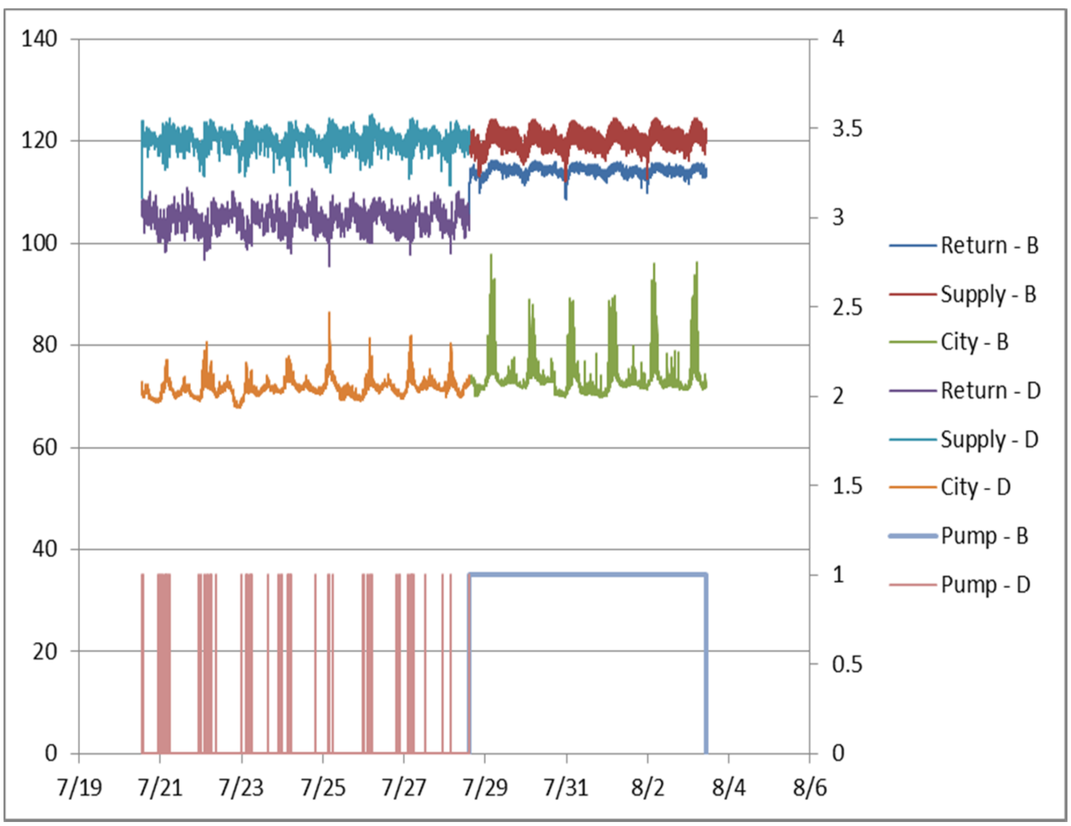
Site#4

142-09 Barclay Avenue, Fushing NY

Term	Unit	Quantity	Source
Baseline Period	date	7/27/16 - 8/3/16	M&V Schedule
Demand Period	date	7/20/16 -7/27/16	M&V Schedule
Pump power	kW	0.030	Equipment specifications
Boiler runtime_baseline	hr	44.95	Data Logger
Boiler runtime_demand	hr	53.06	Data Logger
Pump runtime_baseline	hr	140.17	Data Logger
Pump runtime_demand	hr	3.40	Data Logger
#days_baseline	d	5.84	Data Logger
#days_demand	d	8.03	Data Logger
Ave City Water Temp_baseline	F	73.31	Data Logger
Ave City Water Temp_demand	F	71.55	Data Logger
Ave Return Water Temp_baseline	F	114.17	Data Logger
Ave Return Water Temp_demand	F	104.69	Data Logger
Input/Firing rate(gas_therm)	therm/hr	3.78	Equipment specifications
DHW fuel_baseline(gas)	therm	169.80	Calculation
DHW fuel_normalized_demand(gas)	therm	195.61	Calculation
Annual DHW Reduction(gas)	therm/yr	1725.46	Calculation
Annual pump electrical reduction	kWh/yr	258.16	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	14.20%	Calculation
pump runtime saving(%)	%	98.24%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$1,777**	Calculation

Notes:

7/20/2016: 5 point temp sensors deployed and logging data



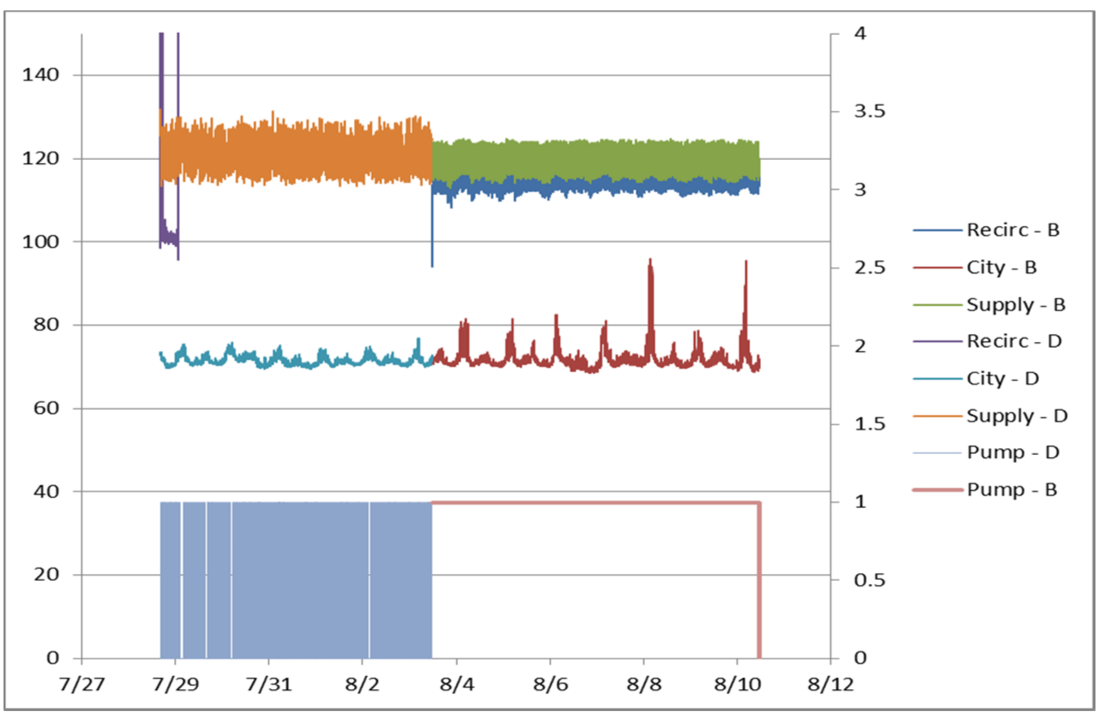
Site#5

142-12 41st Ave, Flushing NY

Term	Unit	Quantity	Source
Baseline Period	date	8/3/16 - 8/10/16	M&V Schedule
Demand Period	date	7/27/16 -8/3/16	M&V Schedule
Pump power	kW	0.06	Equipment specifications
Boiler runtime_baseline	hr	42.54	Data Logger
Boiler runtime_demand	hr	30.87	Data Logger
Pump runtime_baseline	hr	167.62	Data Logger
Pump runtime_demand	hr	9.15	Data Logger
#days_baseline	d	6.98	Data Logger
#days_demand	d	5.80	Data Logger
Ave City Water Temp_baseline	F	71.89	Data Logger
Ave City Water Temp_demand	F	71.51	Data Logger
Ave Return Water Temp_baseline	F	114.74	Data Logger
Ave Return Water Temp_demand	F	313.58	Data Logger
Input/Firing rate(gas_therm)	therm/hr	3.78	Equipment specifications
DHW fuel_baseline(gas)	therm	160.70	Calculation
DHW fuel_normalized_demand(gas)	therm	116.01	Calculation
Annual DHW Reduction(gas)	therm/yr	1099.98	Calculation
Annual pump electrical reduction	kWh/yr	491.05	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	12.64%	Calculation
pump runtime saving(%)	%	93.43%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$1,198**	Calculation

Notes:

Higher supply water temp in demand mode indicates minor tank stratification. Return water temp logger failed partway through monitoring, however initial data showed good temperature reduction. Good boiler savings. City water temperature spikes indicate back flow. Recommendations - install spring check valve on city water supply.



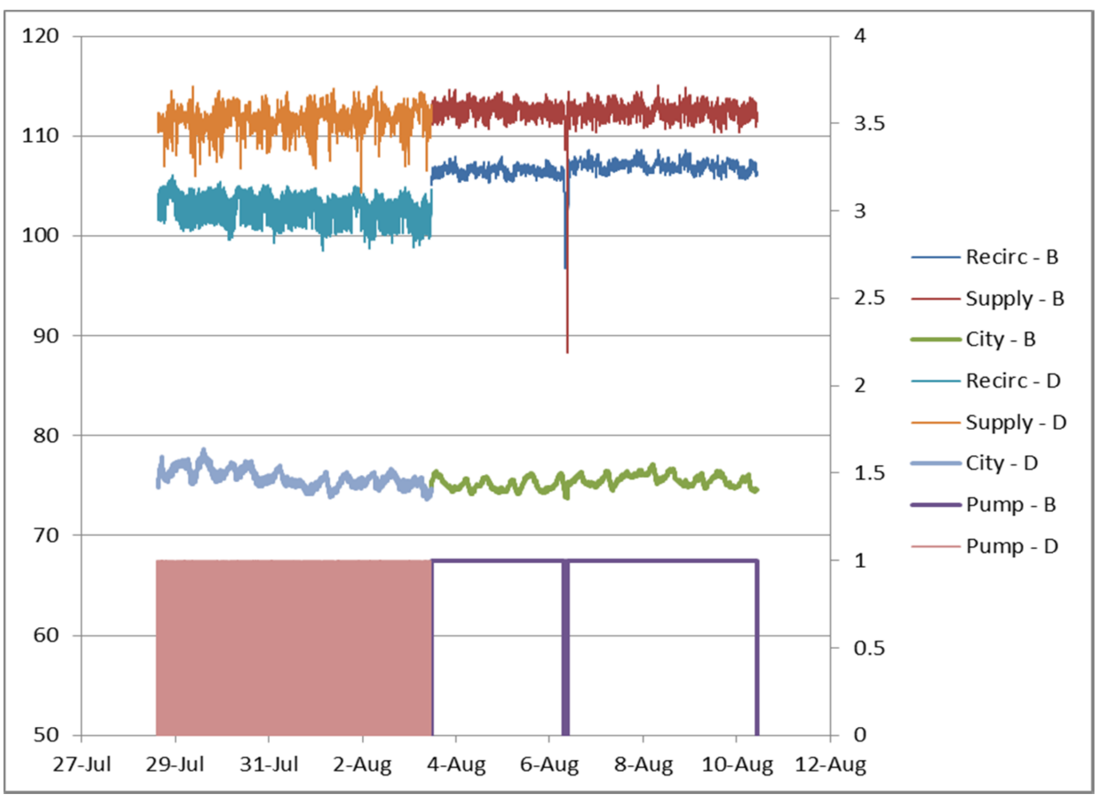
Site#6

138-49 Barclay Avenue, Flushhing NY

Term	Unit	Quantity	Source
Baseline Period	date	8/3/16 - 8/10/16	M&V Schedule
Demand Period	date	7/27/16 - 8/3/16	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler runtime_baseline	hr	13.95	Data Logger
Boiler runtime_demand	hr	10.55	Data Logger
Pump runtime_baseline	hr	167.21	Data Logger
Pump runtime_demand	hr	13.13	Data Logger
#days_baseline	d	6.97	Data Logger
#days_demand	d	5.83	Data Logger
Ave City Water Temp_baseline	F	75.39	Data Logger
Ave City Water Temp_demand	F	75.81	Data Logger
Ave Return Water Temp_baseline	F	106.73	Data Logger
Ave Return Water Temp_demand	F	102.90	Data Logger
Input/Firing rate(gas_therm)	therm/hr	13.51	Equipment specifications
DHW fuel_baseline(gas)	therm	188.45	Calculation
DHW fuel_normalized_demand(gas)	therm	143.29	Calculation
Annual DHW Reduction(gas)	therm/yr	901.06	Calculation
Annual pump electrical reduction	kWh/yr	238.14	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	9.63%	Calculation
pump runtime saving(%)	%	90.62%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$949**	Calculation

Notes:

Behaves as expected. Consistent supply temp. Return temp lower in demand. Good savings.



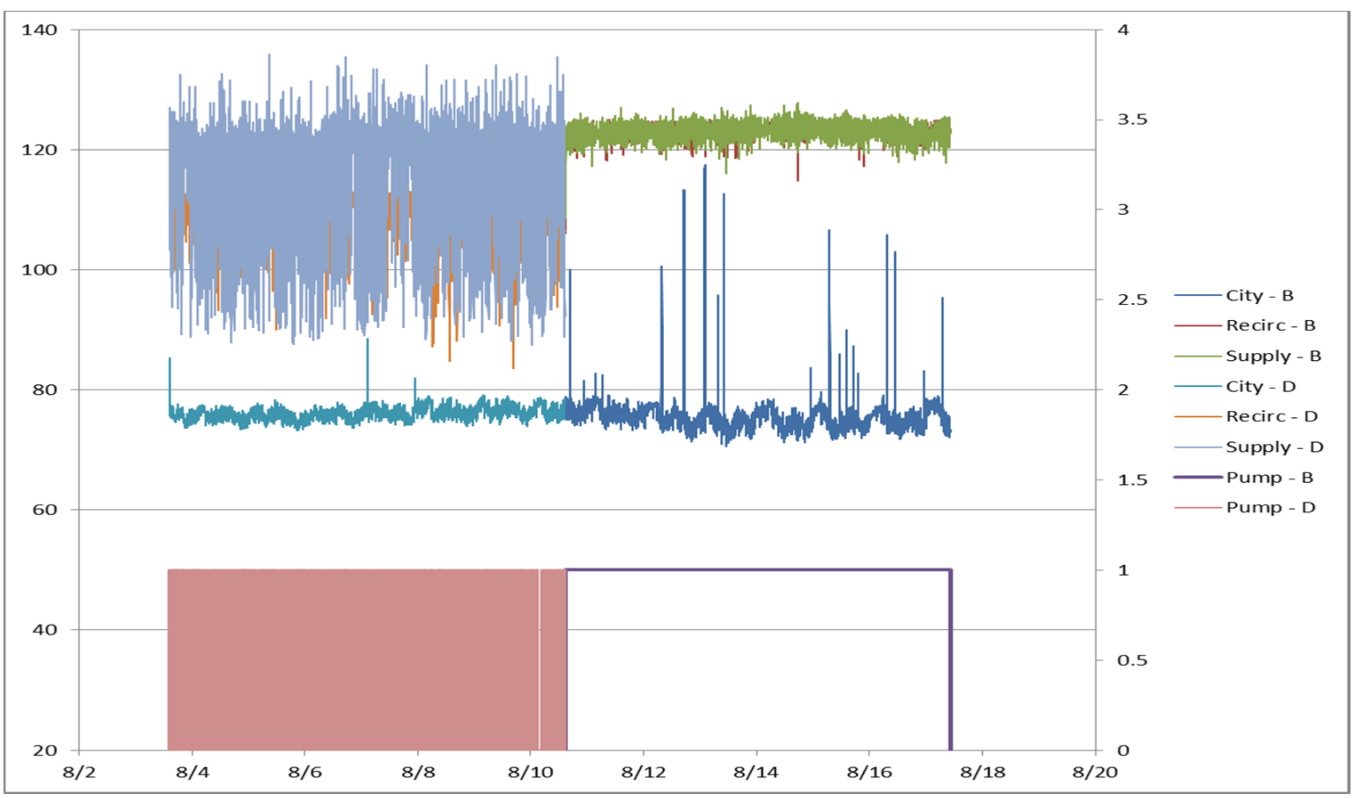
Site#7

75-23 113th St, Forest Hills, NY

Term	Unit	Quantity	Source
Baseline Period	date	8/10/2016 -8//17/2016	M&V Schedule
Demand Period	date	8/3/2016 - 8/10/2016	M&V Schedule
Pump power	kW	0.09	Equipment specifications
Boiler runtime_baseline	hr	10.02	Data Logger
Boiler runtime_demand	hr	10.00	Data Logger
Pump runtime_baseline	hr	163.68	Data Logger
Pump runtime_demand	hr	31.38	Data Logger
#days_baseline	d	6.82	Data Logger
#days_demand	d	7.02	Data Logger
Ave City Water Temp_baseline	F	75.47	Data Logger
Ave City Water Temp_demand	F	76.08	Data Logger
Ave Return Water Temp_baseline	F	122.89	Data Logger
Ave Return Water Temp_demand	F	110.02	Data Logger
Input/Firing rate(gas_therm)	therm/hr	11.60	Equipment specifications
DHW fuel_baseline(gas)	therm	116.21	Calculation
DHW fuel_normalized_demand(gas)	therm	116.85	Calculation
Annual DHW Reduction(gas)	therm/yr	144.81	Calculation
Annual pump electrical reduction	kWh/yr	641.58	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	3.11%	Calculation
pump runtime saving(%)	%	81.38%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$273**	Calculation

Notes:

At this site an ETV was installed. Fluctuating supply temp likely due to ETV unable to read water temperture in no-flow conditions.



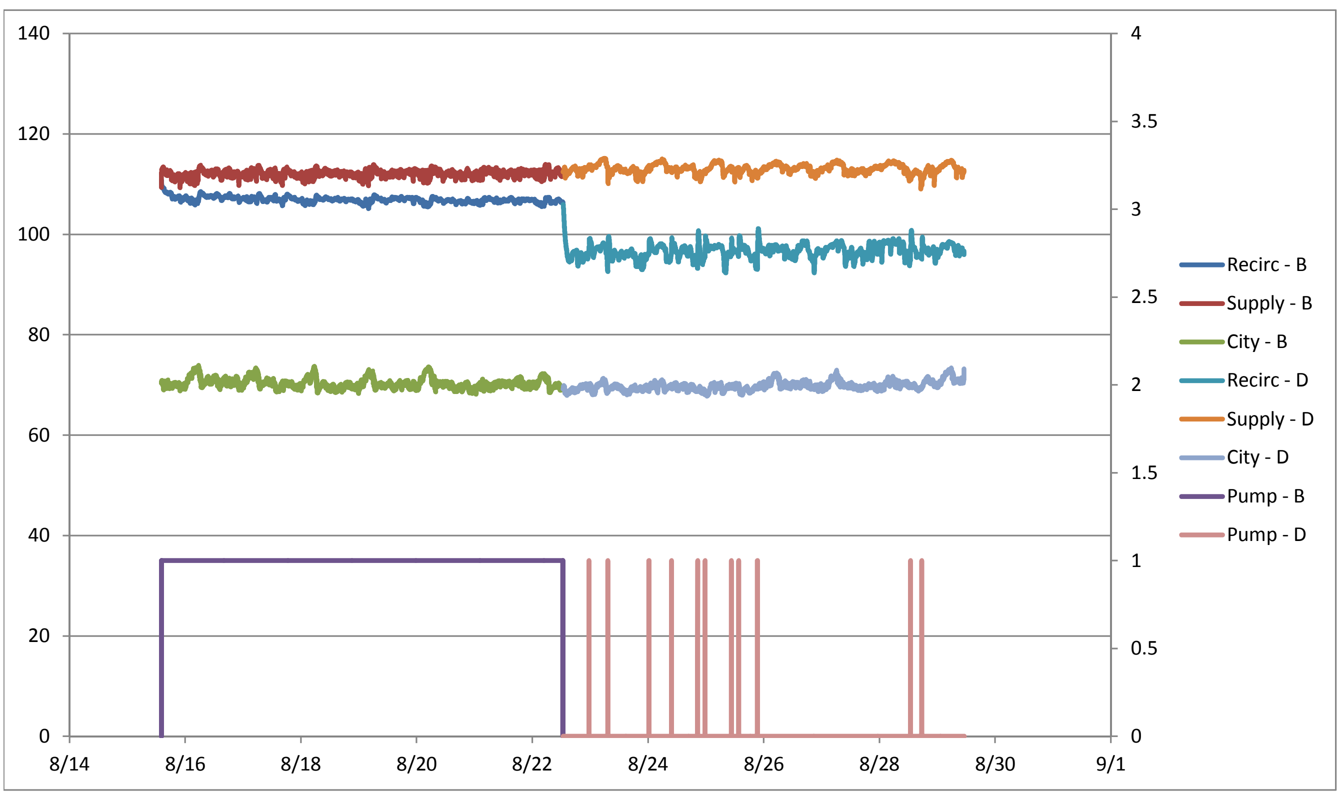
Site#8

141-28 84th Drive Briarwood, NY

Term	Unit	Quantity	Source
Baseline Period	date	8/15/2016 - 8/22/2016	M&V Schedule
Demand Period	date	8/22/2016 -8/29/2016	M&V Schedule
Pump power	kW	0.09	Equipment specifications
Boiler runtime_baseline	hr	16.06	Data Logger
Boiler runtime_demand	hr	16.26	Data Logger
Pump runtime_baseline	hr	166.74	Data Logger
Pump runtime_demand	hr	0.56	Data Logger
#days_baseline	d	6.95	Data Logger
#days_demand	d	6.93	Data Logger
Ave City Water Temp_baseline	F	70.39	Data Logger
Ave City Water Temp_demand	F	69.88	Data Logger
Ave Return Water Temp_baseline	F	106.95	Data Logger
Ave Return Water Temp_demand	F	96.68	Data Logger
Input/Firing rate(gas_therm)	therm/hr	4.72	Equipment specifications
DHW fuel_baseline(gas)	therm	75.83	Calculation
DHW fuel_normalized_demand(gas)	therm	76.24	Calculation
Annual DHW Reduction(gas)	therm/yr	-29.94	Calculation
Annual pump electrical reduction	kWh/yr	785.73	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	-1.48%	Calculation
pump runtime saving(%)	%	99.66%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$127**	Calculation

Notes:

Very good graph. All temperatures as expected. Unclear why savings was minimal unless consumption varied significantly. Likely alterations in consumption.



Site#9

95-11/19 64th Road Rego Park, NY

Term	Unit	Quantity	Source
Baseline Period	date	8/22/2016 -8/29/2016	M&V Schedule
Demand Period	date	8/15/2016 -8/22/2016	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler1 runtime_baseline	hr	17.72	Data Logger
Boiler1 runtime_demand	hr	19.34	Data Logger
Boiler2 runtime_baseline	hr	21.47	Data Logger
Boiler2 runtime_demand	hr	14.59	Data Logger
Pump runtime_baseline	hr	166.37	Data Logger
Pump runtime_demand	hr	0.80	Data Logger
#days_baseline	d	6.93	Data Logger
#days_demand	d	6.91	Data Logger
Ave City Water Temp_baseline	F	72.46	Data Logger
Ave City Water Temp_demand	F	72.64	Data Logger
Ave Return Water Temp_baseline	F	120.96	Data Logger
Ave Return Water Temp_demand	F	103.23	Data Logger
Input/Firing rate(gas_therm)	therm/hr	1.88	Equipment specifications
DHW fuel_baseline(gas)	therm	73.65	Calculation
DHW fuel_normalized demand(gas)	therm	63.92	Calculation
Annual DHW Reduction(gas)	therm/yr	502.88	Calculation
Annual pump electrical reduction	kWh/yr	261.54	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving	%	13.18%	Calculation
Pump runtime saving	%	99.52%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$555**	Calculation

Notes:

Good runtime savings. Unusual pattern in temperature data - unexplained offset daily bumps in supply and city water temps. Unclear why return temps higher than supply. Possible faulty mixing valve. The high return line temperatures indicate that the pump is running in reverse.

Site#10

206 Clinton Street, Hempstead, NY

Term	Unit	Quantity	Source
Baseline Period	date		M&V Schedule
Demand Period	date		M&V Schedule
Pump power	kW		Equipment specifications
Boiler runtime_baseline	hr		Data Logger
Boiler runtime_demand	hr		Data Logger
Pump runtime_baseline	hr		Data Logger
Pump runtime_demand	hr		Data Logger
#days_baseline	d		Data Logger
#days_demand	d		Data Logger
Ave City Water Temp_baseline	F		Data Logger
Ave City Water Temp_demand	F		Data Logger
Ave Return Water Temp_baseline	F		Data Logger
Ave Return Water Temp_demand	F		Data Logger
Input/Firing rate(gas_therm)	therm/hr		Equipment specifications
DHW fuel_baseline(gas)	therm		Calculation
DHW fuel_normalized_demand(gas)	therm		Calculation
Annual DHW Reduction(gas)	therm/yr		Calculation
Annual pump electrical reduction	kWh/yr		Calculation
Rate_electricity	$/kWh		M&V Plan
Rate_gas	$/therm		M&V Plan
Boiler runtime saving(%)	%		Calculation
pump runtime saving(%)	%		Calculation
Annual cost savings(gas+electricity)	$/yr		Calculation

Notes:

Control installed, Thermosyphoning Issue detected , likely casued in part by boiler transfer loop pump adjacent to the the re-circ line, data loggers showed that re-circ line was not cooling when the pump was off.
Solenoid valve and relay control is required for control to be effective.

Site#11

28 Gilchrest Road, Great Neck, NY

Term	Unit	Quantity	Source
Baseline Period	date		M&V Schedule
Demand Period	date		M&V Schedule
Pump power	kW		Equipment specifications
Boiler runtime_baseline	hr		Data Logger
Boiler runtime_demand	hr		Data Logger
Pump runtime_baseline	hr		Data Logger
Pump runtime_demand	hr		Data Logger
#days_baseline	d		Data Logger
#days_demand	d		Data Logger
Ave City Water Temp_baseline	F		Data Logger
Ave City Water Temp_demand	F		Data Logger
Ave Return Water Temp_baseline	F		Data Logger
Ave Return Water Temp_demand	F		Data Logger
Input/Firing rate(gas_therm)	therm/hr		Equipment specifications
DHW fuel_baseline(gas)	therm		Calculation
DHW fuel_normalized_demand(gas)	therm		Calculation
Annual DHW Reduction(gas)	therm/yr		Calculation
Annual pump electrical reduction	kWh/yr		Calculation
Rate_electricity	$/kWh		M&V Plan
Rate_gas	$/therm		M&V Plan
Boiler runtime saving(%)	%		Calculation
pump runtime saving(%)	%		Calculation
Annual cost savings(gas+electricity)	$/yr		Calculation

Notes:

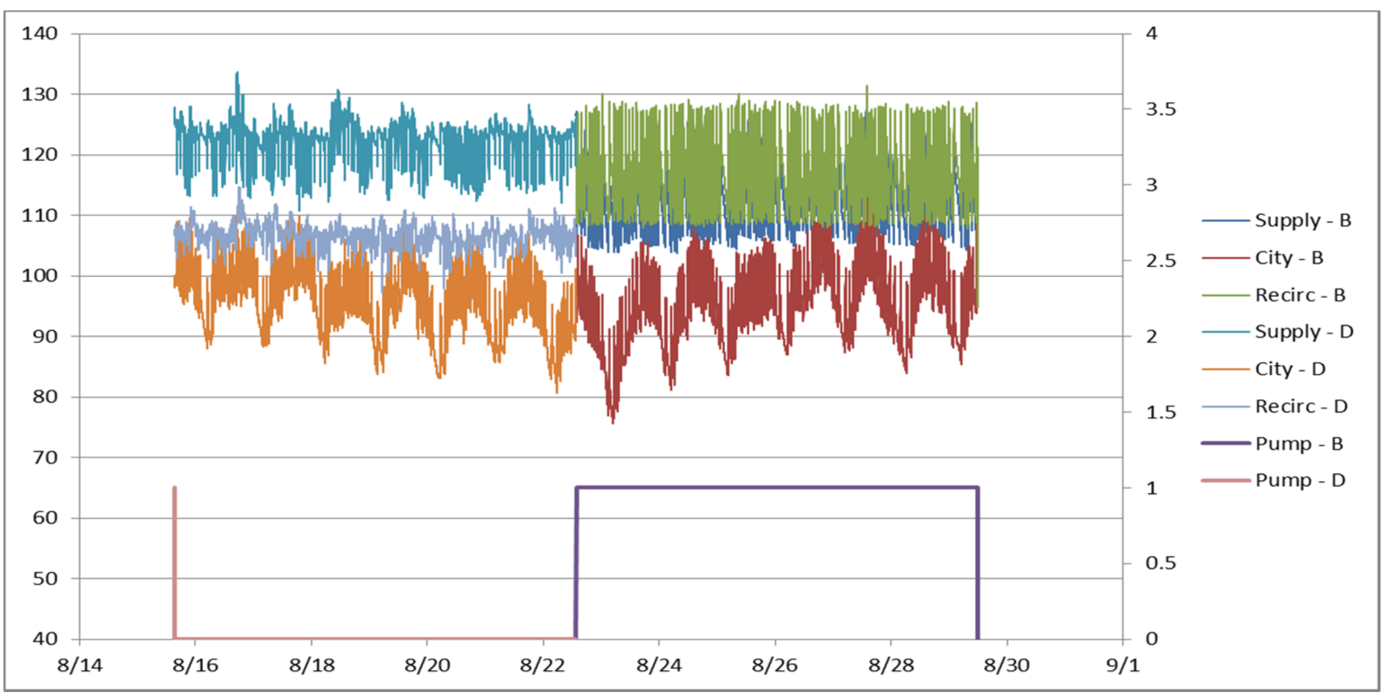
Issues with crossover detected when in demand mode, intermiitent hot and cold when showering, complaints received from Bluestone and tenants, control adjusted twice issue with crossover could not be resolved.
From visit: Crossover here is huge problem. Completed crossover test on site (starts at 40, drops down to 22 when hot water is called, jumps back immediately after HW shut-off).
Upshot: Control was switched to 4 minute demand mode, which should work better in building with crossover issues.

Site#12 **66-08 Austin Street, Rego Park, NY**

Term	Unit	Quantity	Source
Baseline Period	date	8/22/2016 - 8/29/2016	M&V Schedule
Demand Period	date	8/15/2016 - 8/22/2016	M&V Schedule
Pump power	kW	0.06	Equipment specifications
Boiler runtime_baseline	hr	12.46	Data Logger
Boiler runtime_demand	hr	12.90	Data Logger
Pump runtime_baseline	hr	166.10	Data Logger
Pump runtime_demand	hr	0.00	Data Logger
#days_baseline	d	6.92	Data Logger
#days_demand	d	6.95	Data Logger
Ave City Water Temp_baseline	F	95.05	Data Logger
Ave City Water Temp_demand	F	95.79	Data Logger
Ave Return Water Temp_baseline	F	116.73	Data Logger
Ave Return Water Temp_demand	F	106.67	Data Logger
Input/Firing rate(gas_therm)	therm/hr	3.78	Equipment specifications
DHW fuel_baseline(gas)	therm	47.08	Calculation
DHW fuel_normalized_demand(gas)	therm	49.13	Calculation
Annual DHW Reduction(gas)	therm/yr	-98.83	Calculation
Annual pump electrical reduction	kWh/yr	525.60	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	-3.17%	Calculation
pump runtime saving(%)	%	100.00%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$6**	Calculation

Notes:

Significant tank stratification evidenced by higher dupply temp in demand. Failed city cold water check valve, hot supply water running back through city cold water causing high cold water temperatures. Lowering tank setpoint could improve savings. Recommendation - install solonoid or spring check valve on the return line and a spring loaded check valve on city cold water supply.



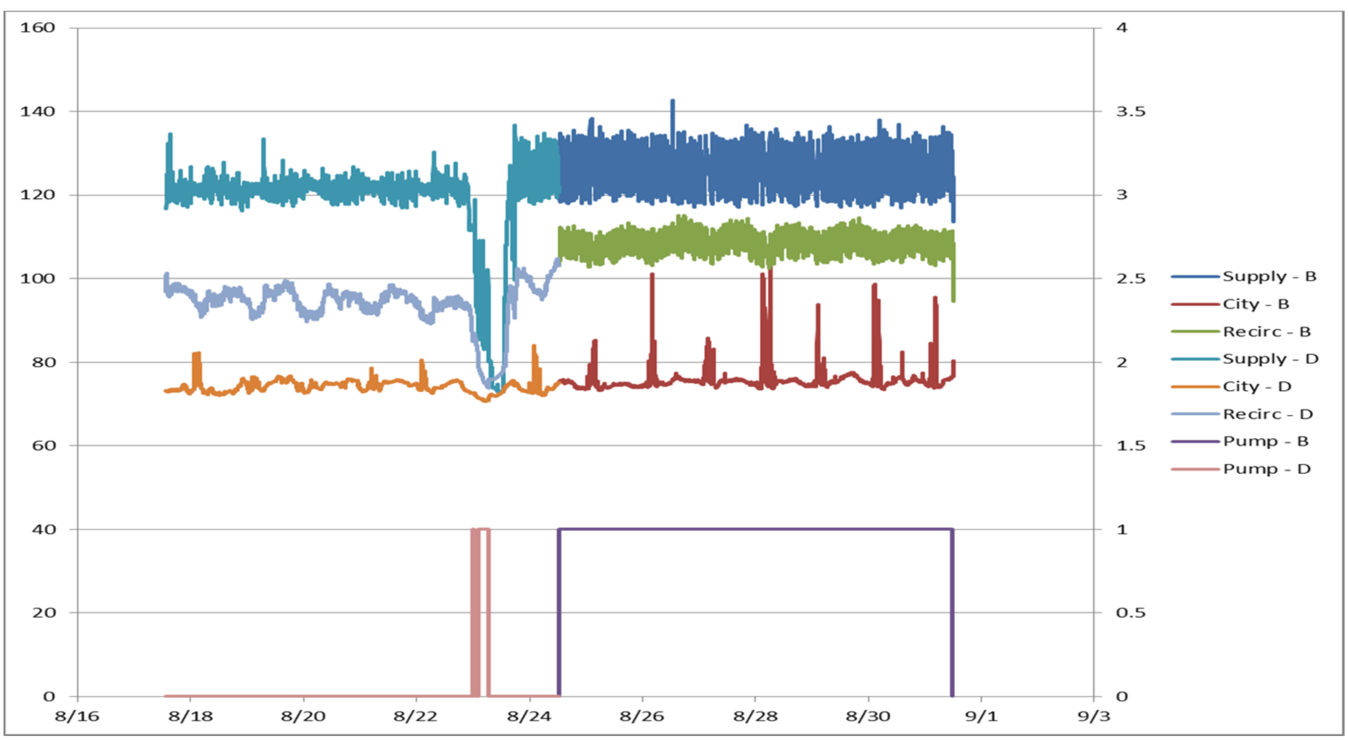
Site#13

65-84 Austin Street, Rego Park, NY

Term	Unit	Quantity	Source
Baseline Period	date	8/24/2016 - 8/31/2016	M&V Schedule
Demand Period	date	8/17/2016 - 8/24/2016	M&V Schedule
Pump power	kW	0.06	Equipment specifications
Boiler runtime_baseline	hr	12.29	Data Logger
Boiler runtime_demand	hr	8.37	Data Logger
Pump runtime_baseline	hr	167.12	Data Logger
Pump runtime_demand	hr	0.00	Data Logger
#days_baseline	d	6.96	Data Logger
#days_demand	d	5.31	Data Logger
Ave City Water Temp_baseline	F	75.80	Data Logger
Ave City Water Temp_demand	F	74.37	Data Logger
Ave Return Water Temp_baseline	F	108.38	Data Logger
Ave Return Water Temp_demand	F	94.90	Data Logger
Input/Firing rate(gas_therm)	therm/hr	3.78	Equipment specifications
DHW fuel_baseline(gas)	therm	46.42	Calculation
DHW fuel_normalized_demand(gas)	therm	31.00	Calculation
Annual DHW Reduction(gas)	therm/yr	303.53	Calculation
Annual pump electrical reduction	kWh/yr	525.60	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	10.79%	Calculation
pump runtime saving(%)	%	100.00%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$409**	Calculation

Notes:

Supply water temp in demand more consistent and slightly lower. Return water temp lower as expected. Unusual dip in supply and return water temp during only pump activation time in demand mode likely for DHW shut down (this period excluded from analysis). Reason for daily early morning spike in city water temp unknown, but reduced in demand mode.



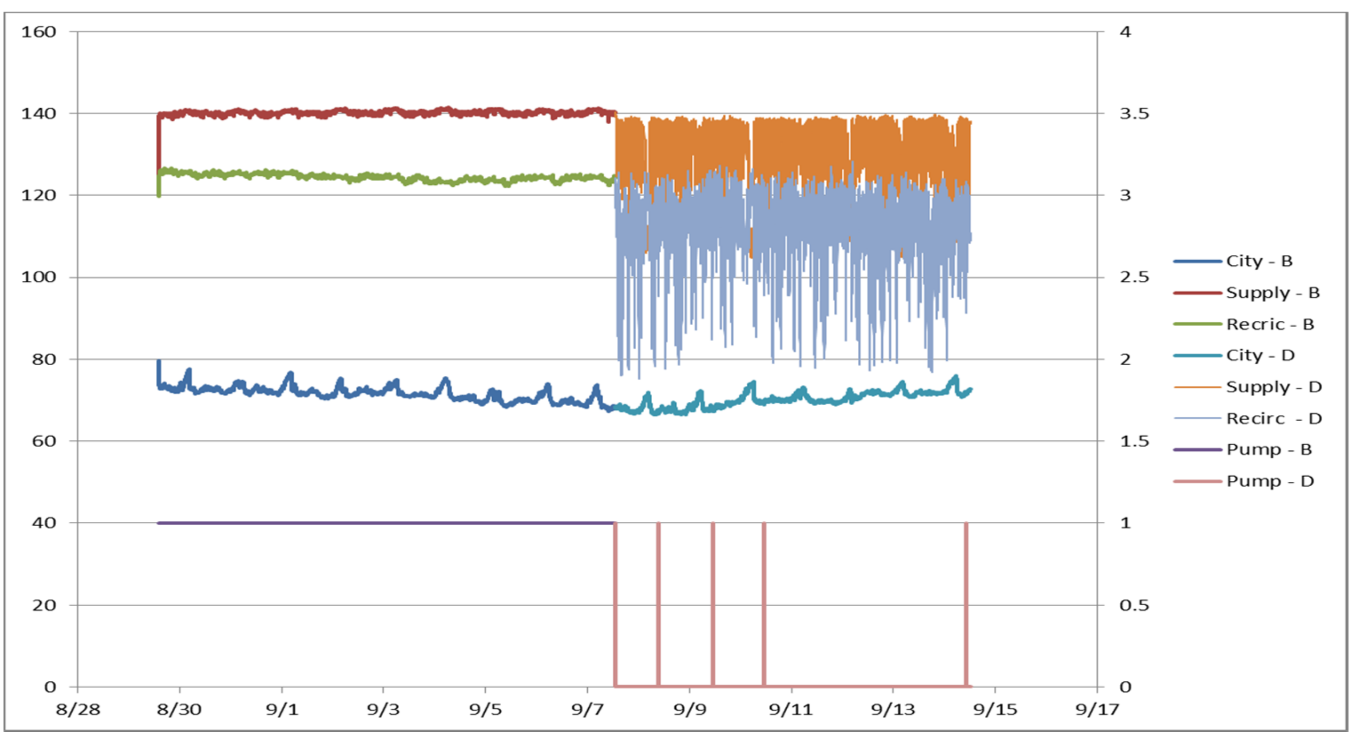
Site#14

140-74 34th Avenue, Fushing NY

Term	Unit	Quantity	Source
Baseline Period	date	8/31/2016 -9/07/2016	M&V Schedule
Demand Period	date	9/07/2016 - 9/14/2016	M&V Schedule
Pump power	kW	0.06	Equipment specifications
Boiler runtime_baseline	hr	40.38	Data Logger
Boiler runtime_demand	hr	26.38	Data Logger
Pump runtime_baseline	hr	214.82	Data Logger
Pump runtime_demand	hr	0.21	Data Logger
#days_baseline	d	8.95	Data Logger
#days_demand	d	6.97	Data Logger
Ave City Water Temp_baseline	F	71.54	Data Logger
Ave City Water Temp_demand	F	70.15	Data Logger
Ave Return Water Temp_baseline	F	124.43	Data Logger
Ave Return Water Temp_demand	F	110.45	Data Logger
Input/Firing rate(gas_therm)	therm/hr	3.78	Equipment specifications
DHW fuel_baseline(gas)	therm	152.54	Calculation
DHW fuel_normalized_demand(gas)	therm	97.71	Calculation
Annual DHW Reduction(gas)	therm/yr	1104.30	Calculation
Annual pump electrical reduction	kWh/yr	524.93	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	16.12%	Calculation
pump runtime saving(%)	%	99.87%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$1,209**	Calculation

Notes:

Good savings. City and return temps as expected. Return temp in continuous lower than expected, given supply temp. Supply temp shows fluctuation for unknown reasons.



Site#15

43-06 63rd Street, Woodside NY

Term	Unit	Quantity	Source
Baseline Period	date		M&V Schedule
Demand Period	date		M&V Schedule
Pump power	kW		Equipment specifications
Boiler runtime_baseline	hr		Data Logger
Boiler runtime_demand	hr		Data Logger
Pump runtime_baseline	hr		Data Logger
Pump runtime_demand	hr		Data Logger
#days_baseline	d		Data Logger
#days_demand	d		Data Logger
Ave City Water Temp_baseline	F		Data Logger
Ave City Water Temp_demand	F		Data Logger
Ave Return Water Temp_baseline	F		Data Logger
Ave Return Water Temp_demand	F		Data Logger
Input/Firing rate(gas_therm)	therm/hr		Equipment specifications
DHW fuel_baseline(gas)	therm		Calculation
DHW fuel_normalized_demand(gas)	therm		Calculation
Annual DHW Reduction(gas)	therm/yr		Calculation
Annual pump electrical reduction	kWh/yr		Calculation
Rate_electricity	$/kWh		M&V Plan
Rate_gas	$/therm		M&V Plan
Boiler runtime saving(%)	%		Calculation
pump runtime saving(%)	%		Calculation
Annual cost savings(gas+electricity)	$/yr		Calculation

Notes:

Polarity issue with control, short circuiting and sparks when control plugged in, absestos on pipe elbows, plumbers re-visited to assess electric work, polarity issue should be resolved, new control or new male pigtail may be required on control
Relay/control kicks on but the pump doesn’t turn off, it is hardwired electronically. Electrical needs to be solved.

Site#16

710 Dumont, Brooklyn, NY

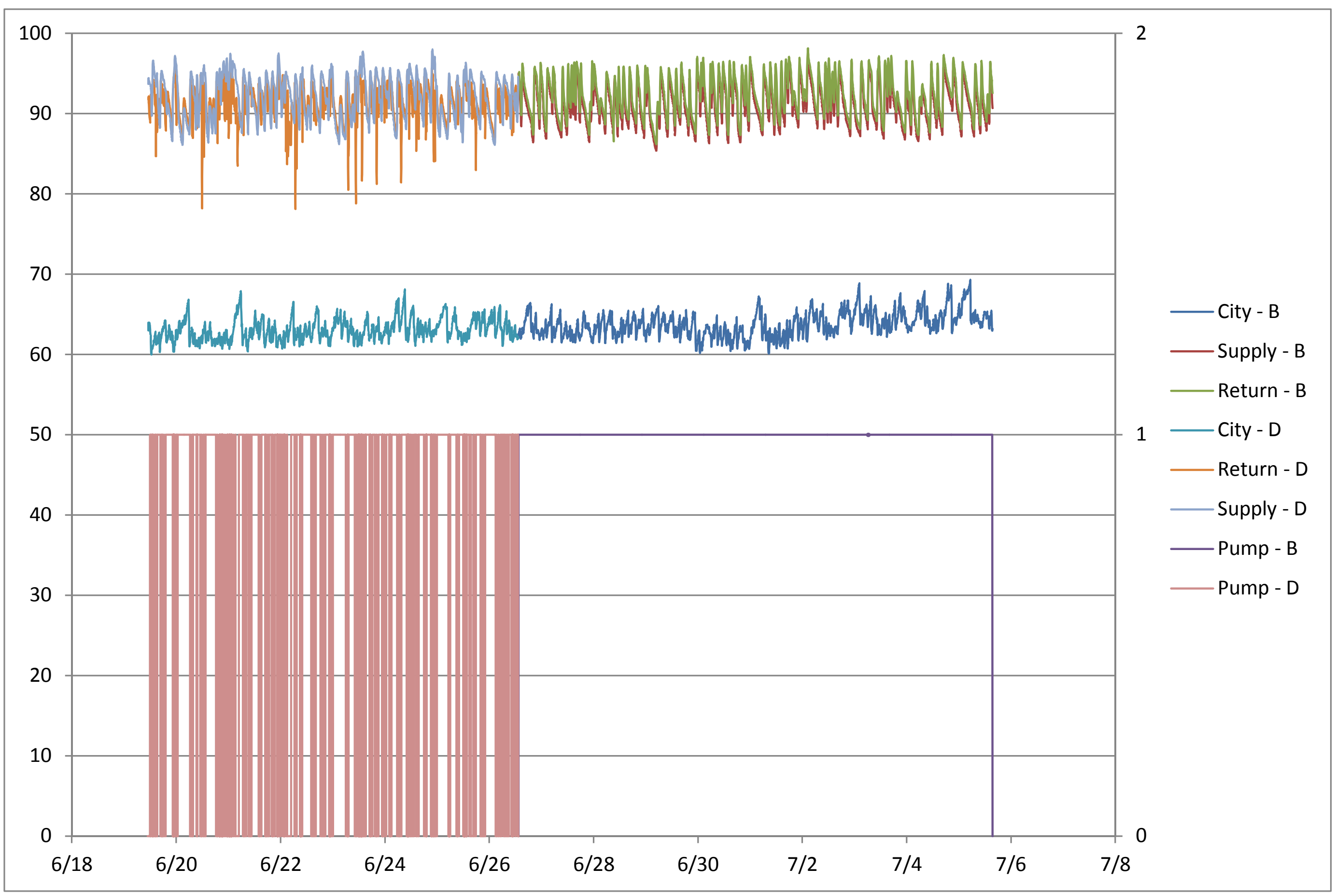
Term	Unit	Quantity	Source
Baseline Period	date	2/7/2017 - 2/14/2017	M&V Schedule
Demand Period	date	1/17/2017 - 2/7/2017	M&V Schedule
Pump power	kW	0.06	Equipment specifications
Boiler runtime_baseline	hr	72.88	Data Logger
Boiler runtime_demand	hr	67.57	Data Logger
Pump runtime_baseline	hr	171.79	Data Logger
Pump runtime_demand	hr	65.38	Data Logger
#days_baseline	d	7.16	Data Logger
#days_demand	d	7.00	Data Logger
Ave City Water Temp_baseline	F	48.03	Data Logger
Ave City Water Temp_demand	F	50.11	Data Logger
Ave Return Water Temp_baseline	F	96.11	Data Logger
Ave Return Water Temp_demand	F	96.27	Data Logger
Input/Firing rate(gas_therm)	therm/hr	3.78	Equipment specifications
DHW fuel_baseline(gas)	therm	275.32	Calculation
DHW fuel_normalized_demand(gas)	therm	266.32	Calculation
Annual DHW Reduction(gas)	therm/yr	151.77	Calculation
Annual pump electrical reduction	kWh/yr	321.06	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	5.19%	Calculation
pump runtime saving(%)	%	61.08%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$216**	Calculation

Notes:

Term	Unit	Quantity	Source
Baseline Period	date	6/19/2017 - 6/26/2017	M&V Schedule
Demand Period	date	6/26/2017 - 7/5/2017	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Pump runtime_baseline	hr	218.03	Data Logger
Pump runtime_demand	hr	10.19	Data Logger
#days_baseline	d	9.08	Data Logger
#days_demand	d	7.07	Data Logger
Ave City Water Temp_baseline	F	63.79	Data Logger
Ave City Water Temp_demand	F	63.09	Data Logger
Ave Return Water Temp_baseline	F	92.31	Data Logger
Ave Return Water Temp_demand	F	91.21	Data Logger
DHW fuel_baseline(gas)	therm	359.85	Calculation
DHW fuel_normalized_demand(gas)	therm	228.17	Calculation
Annual DHW Reduction(gas)	therm/yr	2682.29	Calculation
Annual pump electrical reduction	kWh/yr	247.02	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	17.65%	Calculation
pump runtime saving(%)	%	39.95%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$2,732**	Calculation

Notes:

Unknown why temps are low and why no change in return water temp. Good boiler runtime reduction in demand.



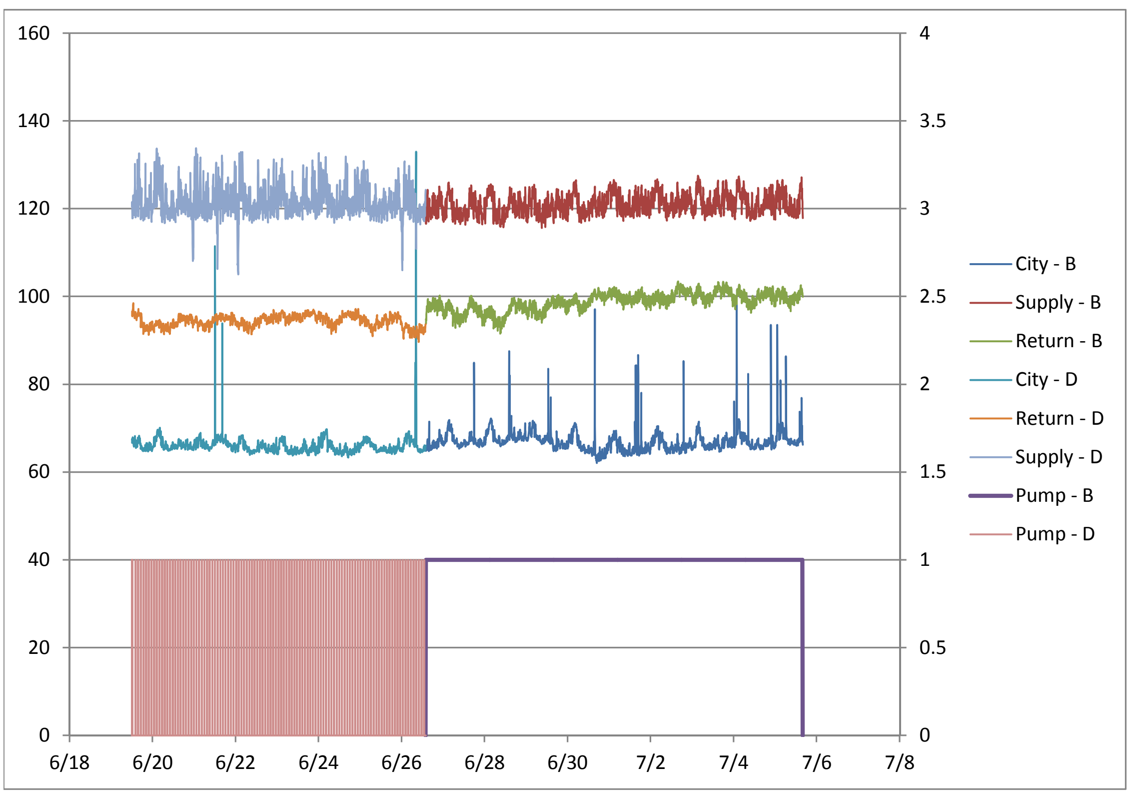
Site#18

676 St. Nicholas Ave., NY

Term	Unit	Quantity	Source
Baseline Period	date	6/19/2017 - 6/26/2017	M&V Schedule
Demand Period	date	6/26/2017 - 7/5/2017	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler runtime_baseline	hr	24.66	Data Logger
Boiler runtime_demand	hr	15.58	Data Logger
Pump runtime_baseline	hr	217.98	Data Logger
Pump runtime_demand	hr	0.66	Data Logger
#days_baseline	d	9.08	Data Logger
#days_demand	d	7.07	Data Logger
Ave City Water Temp_baseline	F	67.00	Data Logger
Ave City Water Temp_demand	F	70.25	Data Logger
Ave Return Water Temp_baseline	F	99.06	Data Logger
Ave Return Water Temp_demand	F	94.49	Data Logger
Input/Firing rate(gas_therm)	therm/hr	31.64	Equipment specifications
DHW fuel_baseline(gas)	therm	780.10	Calculation
DHW fuel_normalized_demand(gas)	therm	516.85	Calculation
Annual DHW Reduction(gas)	therm/yr	4675.33	Calculation
Annual pump electrical reduction	kWh/yr	261.77	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	18.85%	Calculation
pump runtime saving(%)	%	99.61%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$4,728**	Calculation

Notes:

Low return water temperature suggests undersized pump. Slight increase in return line temperature during the baseline period is to be expected. Tank stratification occuring during demand period.



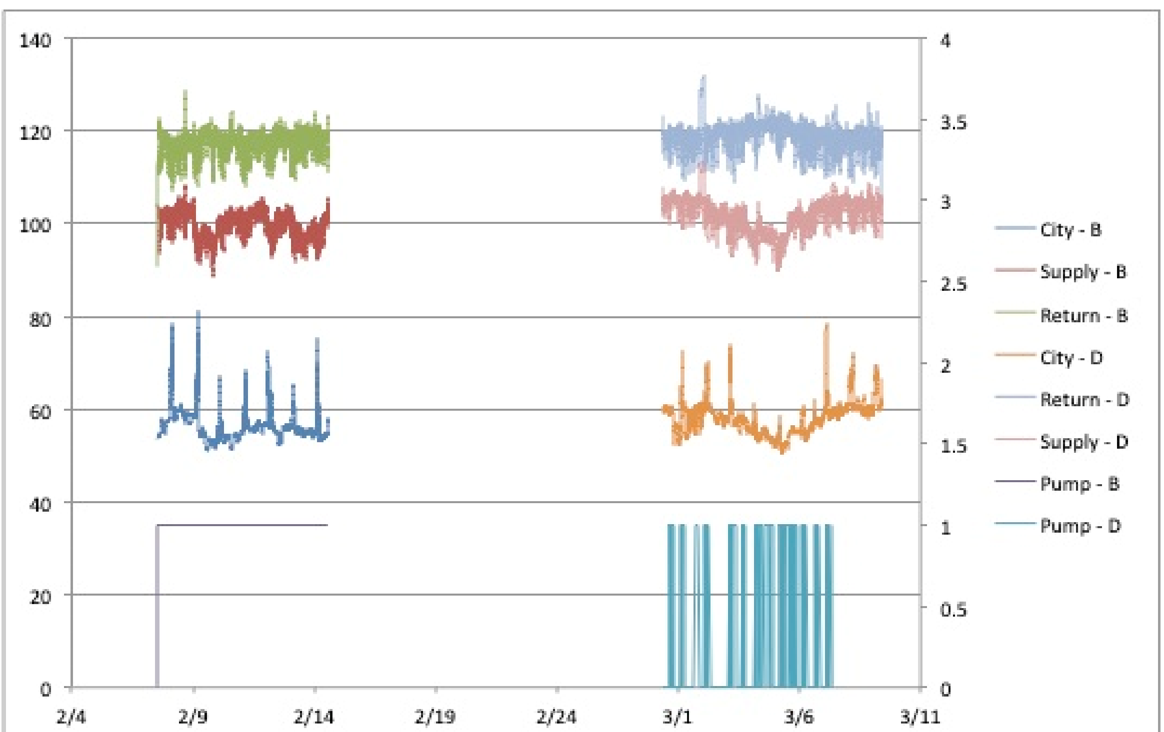
Site#19

43 Central Avenue, Brooklyn NY

Term	Unit	Quantity	Source
Baseline Period	date	2/7/2017 – 2/14/2017	M&V Schedule
Demand Period	date	2/22/2017 – 3/08/2017	M&V Schedule
Pump power	kW	0.12	Equipment specifications
Boiler1 runtime_baseline	hr	59.91	Data Logger
Boiler1 runtime_demand	hr	50.12	Data Logger
Boiler2 runtime_baseline	hr	48.72	Data Logger
Boiler2 runtime_demand	hr	44.19	Data Logger
Pump runtime_baseline	hr	168.83	Data Logger
Pump runtime_demand	hr	6.71	Data Logger
#days_baseline	d	7.03	Data Logger
#days_demand	d	7.06	Data Logger
Ave City Water Temp_baseline	F	56.07	Data Logger
Ave City Water Temp_demand	F	57.90	Data Logger
Ave Return Water Temp_baseline	F	117.59	Data Logger
Ave Return Water Temp_demand	F	119.01	Data Logger
Input/Firing rate(gas_therm)	therm/hr	6.75	Equipment specifications
DHW fuel_baseline(gas)	therm	733.52	Calculation
DHW fuel_normalized_demand(gas)	therm	657.63	Calculation
Annual DHW Reduction(gas)	therm/yr	4078.58	Calculation
Annual pump electrical reduction	kWh/yr	1009.57	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	13.54%	Calculation
pump runtime saving(%)	%	96.04%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$4,280**	Calculation

Notes:

Good boiler runtime reduction; but does not correlate with expected reduction in return water temp. City water spikes.



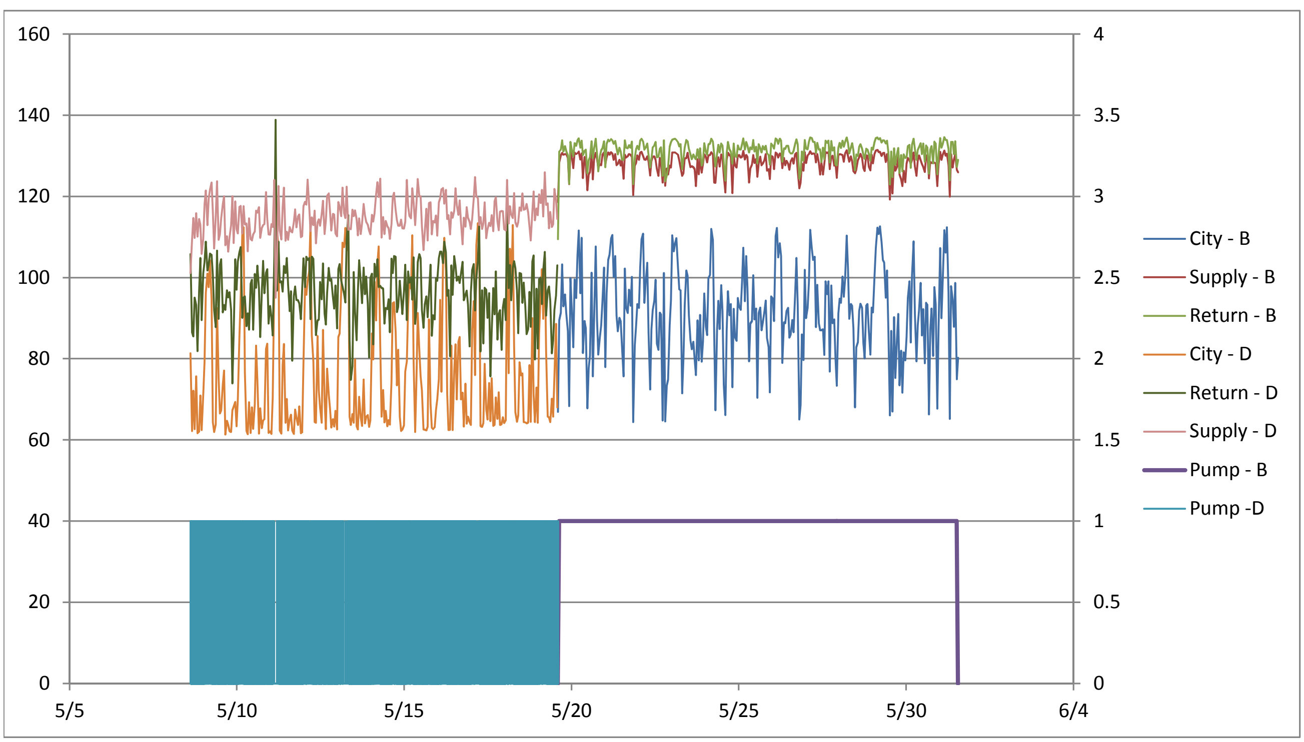
Site#21

426-428 East 11th Street, NY

Term	Unit	Quantity	Source
Baseline Period	date	05/19/2017 - 05/31/2017	M&V Schedule
Demand Period	date	05/08/2017 - 05/19/2017	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler1 runtime_baseline	hr	71.45	Data Logger
Boiler1 runtime_demand	hr	76.34	Data Logger
Boiler2 runtime_baseline	hr	28.37	Data Logger
Boiler2 runtime_demand	hr	14.51	Data Logger
Pump runtime_baseline	hr	288.54	Data Logger
Pump runtime_demand	hr	3.74	Data Logger
#days_baseline	d	12.02	Data Logger
#days_demand	d	10.98	Data Logger
Ave City Water Temp_baseline	F	91.14	Data Logger
Ave City Water Temp_demand	F	75.98	Data Logger
Ave Return Water Temp_baseline	F	131.09	Data Logger
Ave Return Water Temp_demand	F	96.50	Data Logger
Input/Firing rate(gas_therm)	therm/hr	3.78	Equipment specifications
DHW fuel_baseline(gas)	therm	377.09	Calculation
DHW fuel_normalized_demand(gas)	therm	343.22	Calculation
Annual DHW Reduction(gas)	therm/yr	36.89	Calculation
Annual pump electrical reduction	kWh/yr	259.06	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	0.33%	Calculation
pump runtime saving(%)	%	98.58%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$89**	Calculation

Notes:

Adjusted the pot nob to from 90F to 108F in response to complaint. Temperatures in demand are lower than in baseline - unknown why this did not result in savings.



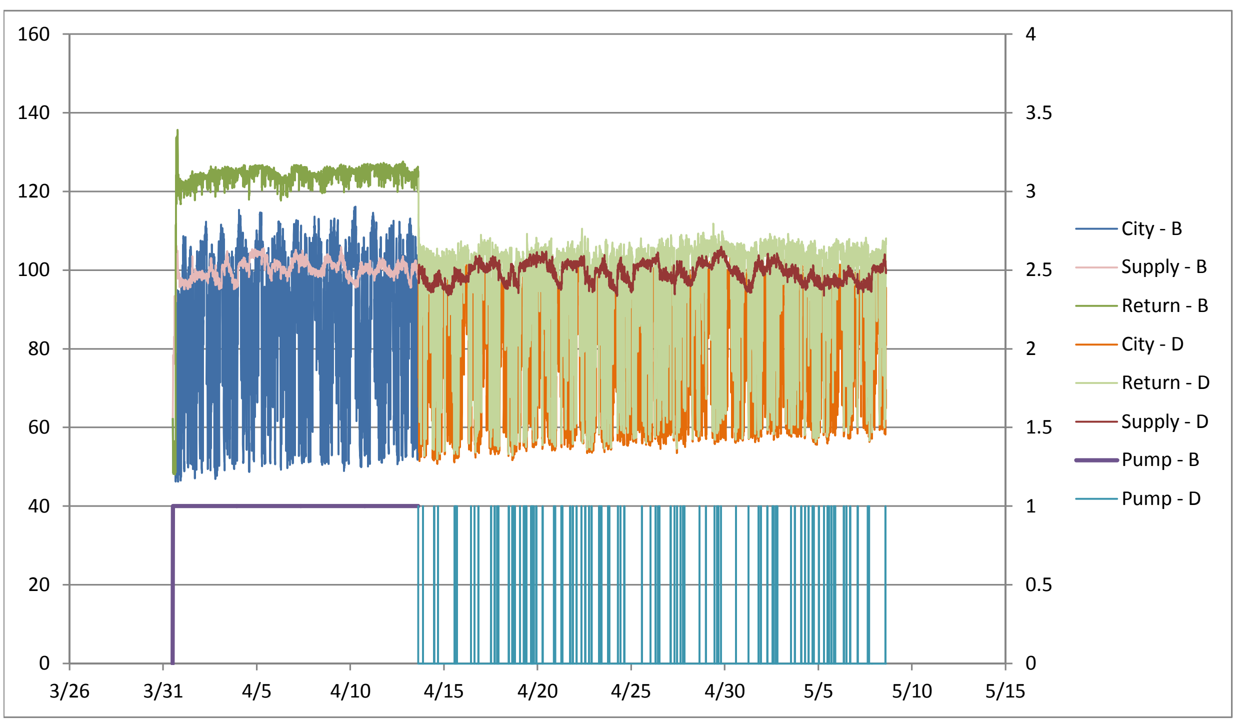
Site#22

410 East 11th Street, NY

Term	Unit	Quantity	Source
Baseline Period	date	03/31/2017 - 04/13/2017	M&V Schedule
Demand Period	date	04/13/2017 - 05/08/2017	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler1 runtime_baseline	hr	29.31	Data Logger
Boiler1 runtime_demand	hr	51.70	Data Logger
Boiler2 runtime_baseline	hr	26.63	Data Logger
Boiler2 runtime_demand	hr	40.36	Data Logger
Pump runtime_baseline	hr	314.76	Data Logger
Pump runtime_demand	hr	0.07	Data Logger
#days_baseline	d	13.12	Data Logger
#days_demand	d	24.98	Data Logger
Ave City Water Temp_baseline	F	86.49	Data Logger
Ave City Water Temp_demand	F	77.56	Data Logger
Ave Return Water Temp_baseline	F	123.46	Data Logger
Ave Return Water Temp_demand	F	95.70	Data Logger
Input/Firing rate(gas_therm)	therm/hr	3.78	Equipment specifications
DHW fuel_baseline(gas)	therm	211.30	Calculation
DHW fuel_normalized_demand(gas)	therm	311.90	Calculation
Annual DHW Reduction(gas)	therm/yr	1323.18	Calculation
Annual pump electrical reduction	kWh/yr	262.77	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	13.58%	Calculation
pump runtime saving(%)	%	99.99%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$1,376**	Calculation

Notes:

Return temp drops in demand mode. Unclear why return temp higher than supply in baseline - possible reversed recirc pump. Low supply temps in both modes, but no complaints.



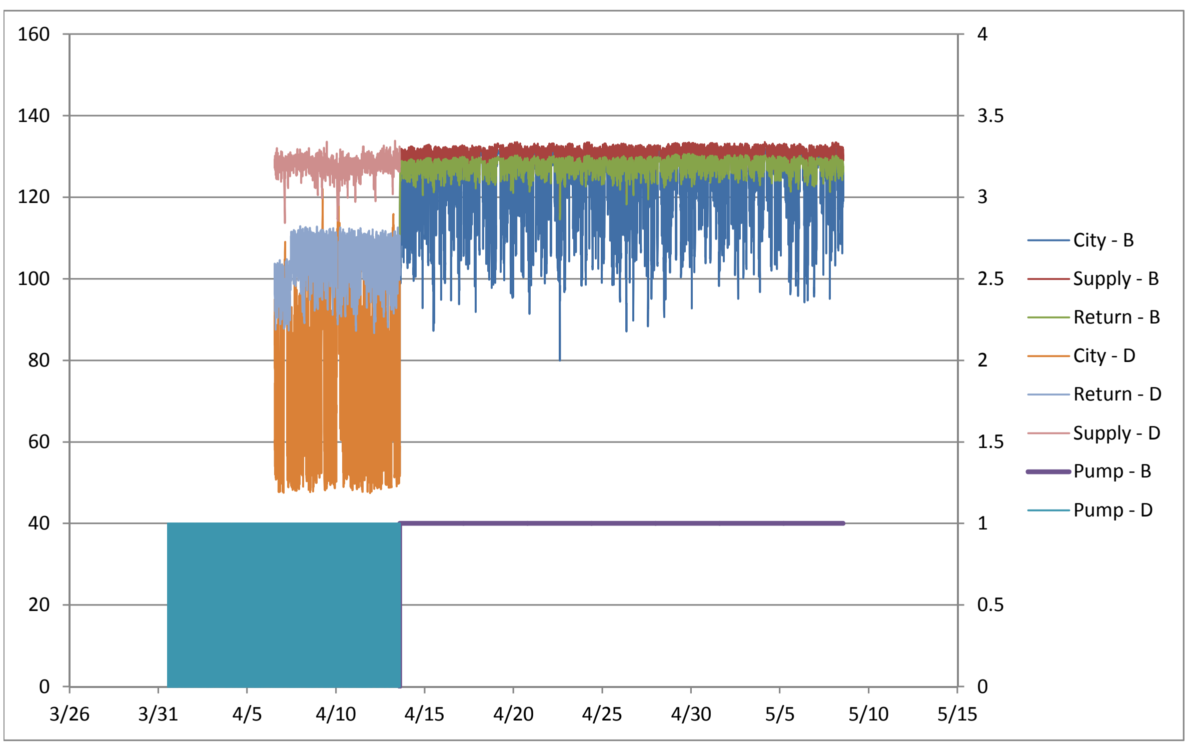
Site#23

617 East 9th Street, NY

Term	Unit	Quantity	Source
Baseline Period	date	04/13/2017 - 05/08/2017	M&V Schedule
Demand Period	date	03/31/2017 - 04/13/2017	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler1 runtime_baseline	hr	46.95	Data Logger
Boiler1 runtime_demand	hr	9.53	Data Logger
Boiler2 runtime_baseline	hr	158.43	Data Logger
Boiler2 runtime_demand	hr	86.57	Data Logger
Pump runtime_baseline	hr	599.20	Data Logger
Pump runtime_demand	hr	21.53	Data Logger
#days_baseline	d	24.97	Data Logger
#days_demand	d	13.05	Data Logger
Ave City Water Temp_baseline	F	67.00	Data Logger
Ave City Water Temp_demand	F	70.25	Data Logger
Ave Return Water Temp_baseline	F	127.68	Data Logger
Ave Return Water Temp_demand	F	102.39	Data Logger
Input/Firing rate(gas_therm)	therm/hr	6.75	Equipment specifications
DHW fuel_baseline(gas)	therm	1386.88	Calculation
DHW fuel_normalized_demand(gas)	therm	648.92	Calculation
Annual DHW Reduction(gas)	therm/yr	2124.65	Calculation
Annual pump electrical reduction	kWh/yr	245.54	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	10.48%	Calculation
pump runtime saving(%)	%	93.13%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$2,174**	Calculation

Notes:

Pump cycles on and off for short periods of time causing the graph to appear that it is running more than reality. City water temps deemed unreliable - results not normalized for city water temp.



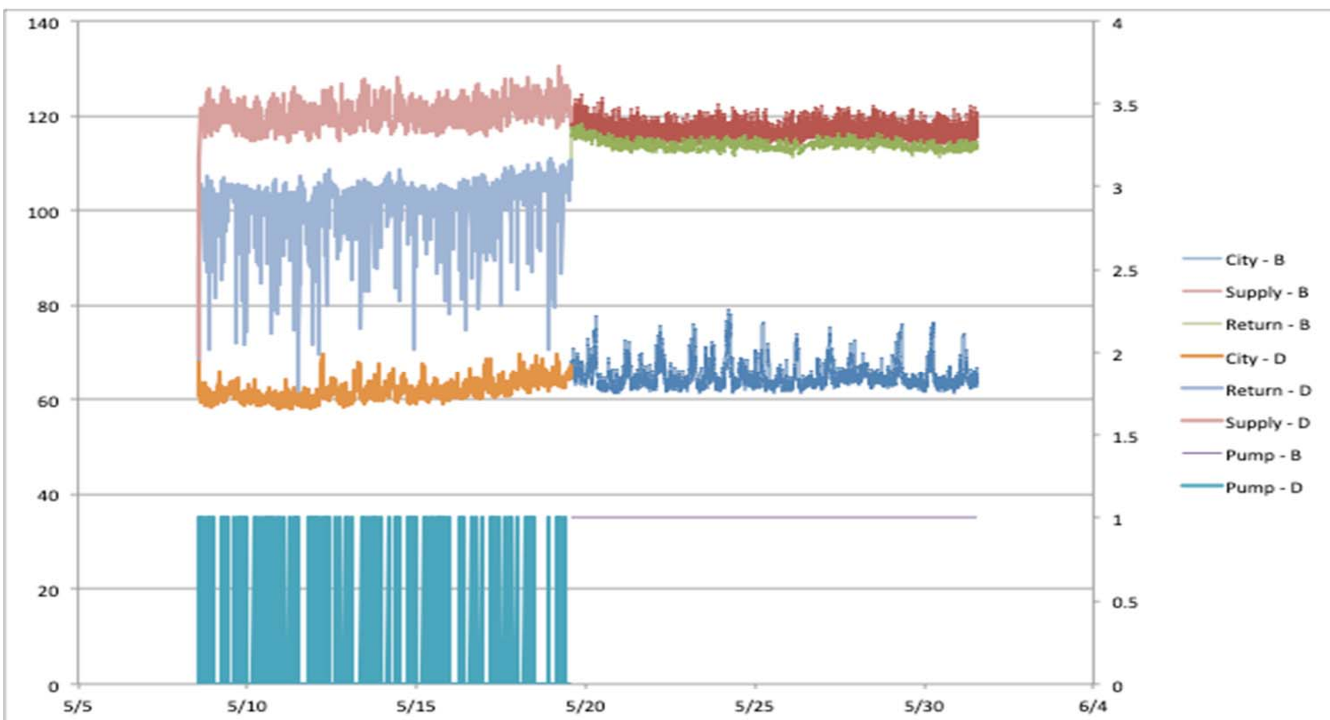
Site#24

212 East 7th Street, NY

Term	Unit	Quantity	Source
Baseline Period	date	04/13/2017 - 05/08/2017	M&V Schedule
Demand Period	date	03/31/2017 - 04/13/2017	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler1 runtime_baseline	hr	48.18	Data Logger
Boiler1 runtime_demand	hr	36.54	Data Logger
Boiler2 runtime_baseline	hr	38.10	Data Logger
Boiler2 runtime_demand	hr	36.03	Data Logger
Pump runtime_baseline	hr	289.43	Data Logger
Pump runtime_demand	hr	1.04	Data Logger
#days_baseline	d	12.06	Data Logger
#days_demand	d	10.97	Data Logger
Ave City Water Temp_baseline	F	64.94	Data Logger
Ave City Water Temp_demand	F	61.84	Data Logger
Ave Return Water Temp_baseline	F	113.73	Data Logger
Ave Return Water Temp_demand	F	102.34	Data Logger
Input/Firing rate(gas_therm)	therm/hr	6.75	Equipment specifications
DHW fuel_baseline(gas)	therm	582.62	Calculation
DHW fuel_normalized_demand(gas)	therm	466.69	Calculation
Annual DHW Reduction(gas)	therm/yr	2108.80	Calculation
Annual pump electrical reduction	kWh/yr	261.76	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	7.55%	Calculation
pump runtime saving(%)	%	99.60%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$2,161**	Calculation

Notes:

Demand control almost eliminated pump runtime. Return water temp dropped as intended. Slight supply water temp increase due to stratification - could lower setpoint. Good boiler savings.



Site#25

472 and 458 Ruby St., Brooklyn, NY

Term	Unit	Quantity	Source
Baseline Period	date		M&V Schedule
Demand Period	date		M&V Schedule
Pump power	kW		Equipment specifications
Boiler runtime_baseline	hr		Data Logger
Boiler runtime_demand	hr		Data Logger
Pump runtime_baseline	hr		Data Logger
Pump runtime_demand	hr		Data Logger
#days_baseline	d		Data Logger
#days_demand	d		Data Logger
Ave City Water Temp_baseline	F		Data Logger
Ave City Water Temp_demand	F		Data Logger
Ave Return Water Temp_baseline	F		Data Logger
Ave Return Water Temp_demand	F		Data Logger
Input/Firing rate(gas_therm)	therm/hr		Equipment specifications
DHW fuel_baseline(gas)	therm		Calculation
DHW fuel_normalized_demand(gas)	therm		Calculation
Annual DHW Reduction(gas)	therm/yr		Calculation
Annual pump electrical reduction	kWh/yr		Calculation
Rate_electricity	$/kWh		M&V Plan
Rate_gas	$/therm		M&V Plan
Boiler runtime saving(%)	%		Calculation
pump runtime saving(%)	%		Calculation
Annual cost savings(gas+electricity)	$/yr		Calculation

Notes:

Severe hot/cold crossover prevented implementation of demand controls. Many complaints of crossover in demand mode.

Site#26

10 Forest St, bklyn

Term	Unit	Quantity	Source
Baseline Period	date		M&V Schedule
Demand Period	date		M&V Schedule
Pump power	kW		Equipment specifications
Boiler runtime_baseline	hr		Data Logger
Boiler runtime_demand	hr		Data Logger
Pump runtime_baseline	hr		Data Logger
Pump runtime_demand	hr		Data Logger
#days_baseline	d		Data Logger
#days_demand	d		Data Logger
Ave City Water Temp_baseline	F		Data Logger
Ave City Water Temp_demand	F		Data Logger
Ave Return Water Temp_baseline	F		Data Logger
Ave Return Water Temp_demand	F		Data Logger
Input/Firing rate(gas_therm)	therm/hr		Equipment specifications
DHW fuel_baseline(gas)	therm		Calculation
DHW fuel_normalized_demand(gas)	therm		Calculation
Annual DHW Reduction(gas)	therm/yr		Calculation
Annual pump electrical reduction	kWh/yr		Calculation
Rate_electricity	$/kWh		M&V Plan
Rate_gas	$/therm		M&V Plan
Boiler runtime saving(%)	%		Calculation
pump runtime saving(%)	%		Calculation
Annual cost savings(gas+electricity)	$/yr		Calculation

Notes:

Pump failed upon controls installation, monitoring resumed when pump replaced. Flue then disconnected from boiler so monitoring halted, awaiting boiler repairs to continue monitoring.

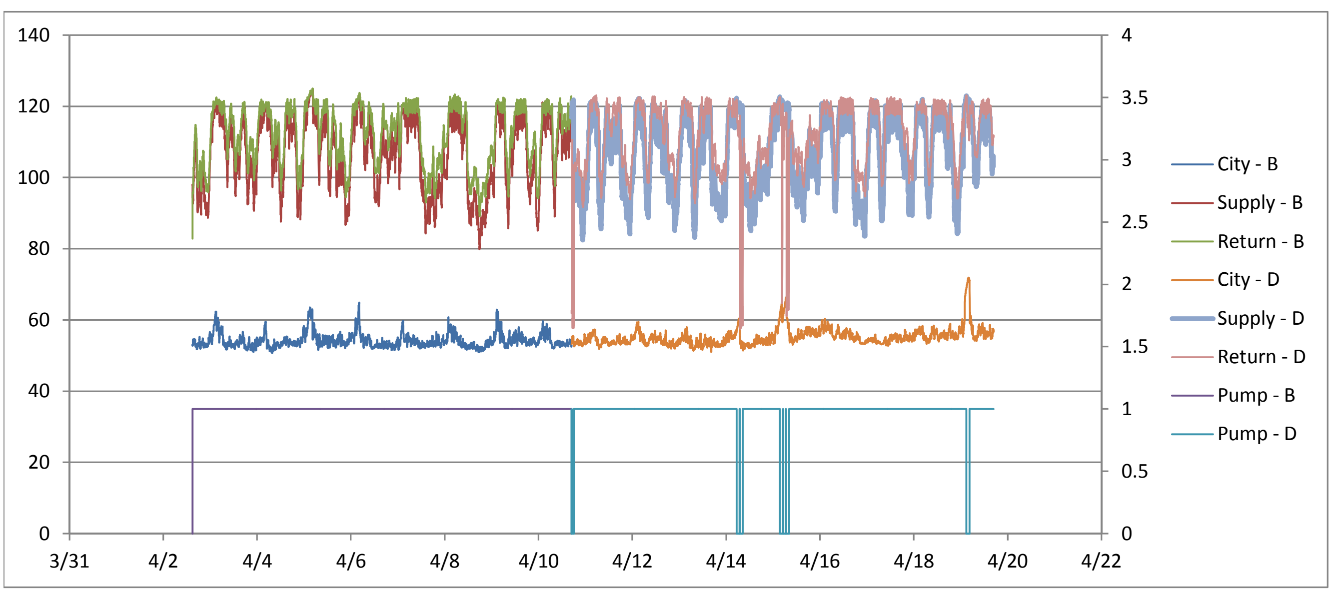
Site#27

533 Bushwick Ave., Bklyn

Term	Unit	Quantity	Source
Baseline Period	date	4/2/2018 - 4/10/2018	M&V Schedule
Demand Period	date	4/10/2018 - 4/19/2018	M&V Schedule
Pump power	kW	0.37	Equipment specifications
Boiler runtime_baseline	hr	0.82	Data Logger
Boiler runtime_demand	hr	1.15	Data Logger
Pump runtime_baseline	hr	194.01	Data Logger
Pump runtime_demand	hr	20.54	Data Logger
#days_baseline	d	8.08	Data Logger
#days_demand	d	8.99	Data Logger
Ave City Water Temp_baseline	F	54.15	Data Logger
Ave City Water Temp_demand	F	55.28	Data Logger
Ave Return Water Temp_baseline	F	112.10	Data Logger
Ave Return Water Temp_demand	F	171.94	Data Logger
Input/Firing rate(gas_therm)	therm/hr	15.81	Equipment specifications
Input/Firing rate(oil_gallon)	gallon/hr	30.00	Equipment specifications
DHW fuel_base(gas)	therm	13.02	Calculation
DHW fuel_norm(gas)	therm	18.51	Calculation
DHW fuel_base(oil)	gallon	24.70	Calculation
DHW fuel_norm(oil)	gallon	35.13	Calculation
Annual DHW Reduction(gas)	therm/yr	-163.50	Calculation
Annual DHW Reduction(oil)	gallon/yr	-310.26	Calculation
Annual pump electrical reduction	kWh/yr	158.66	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Rate_oil	$/gallon	$3.25	M&V Plan
Annual cost savings(gas)	$/yr	-$131.77	Calculation
Annual cost savings(oil)	$/yr	-$417.26	Calculation
Boiler runtime saving(%)		-25.20%	Calculation
pump runtime saving(%)		4.86%	Calculation
Annual savings(combined)	$/yr	**-$549**	Calculation

Notes:

High pump runtime explains low temperature differential between supply and return. Recommendations are that the pump control threshold is reduced.



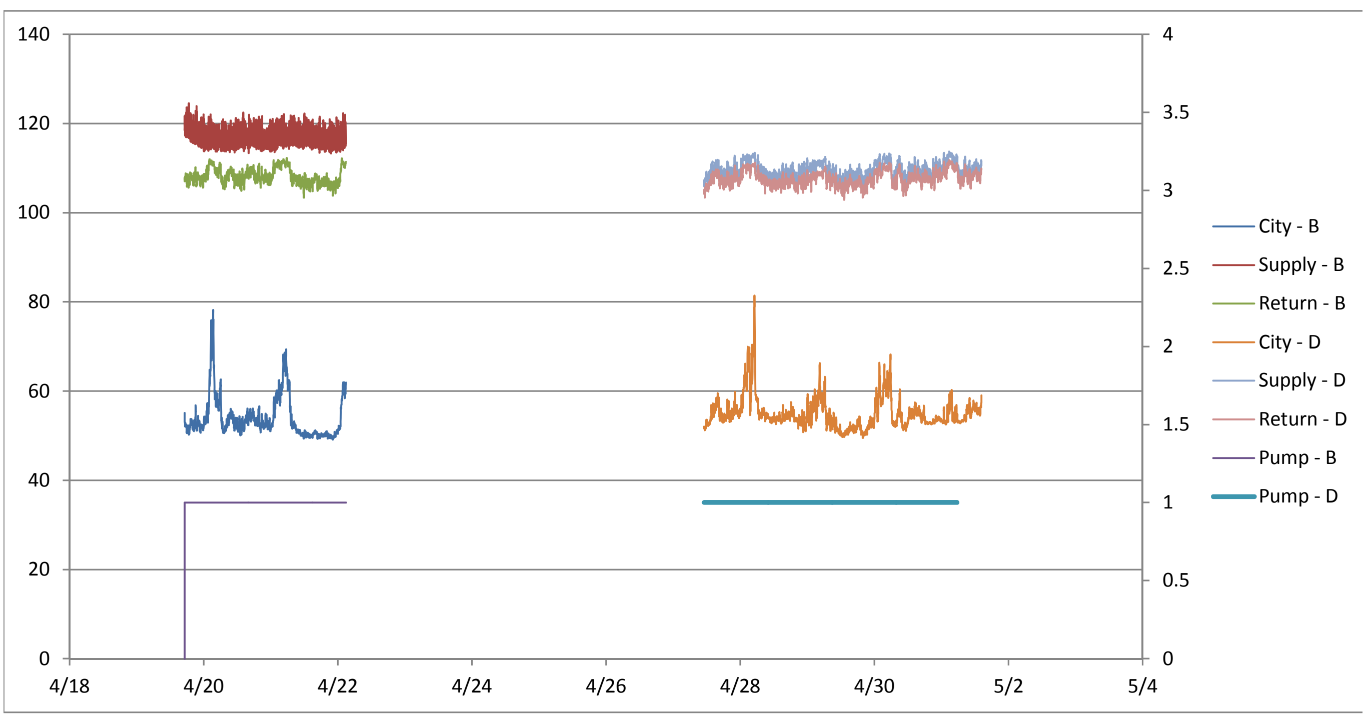
Site#28

555 Bushwick Ave., Bklyn

Term	Unit	Quantity	Source
Baseline Period	date	4/19/2018 - 4/27/2018	M&V Schedule
Demand Period	date	4/27/2018 - 5/1/2018	M&V Schedule
Pump power	kW	0.37	Equipment specifications
Boiler1 runtime_baseline	hr	10.32	Data Logger
Boiler1 runtime_demand	hr	4.87	Data Logger
Boiler2 runtime_baseline	hr	19.97	Data Logger
Boiler2 runtime_demand	hr	11.87	Data Logger
Pump runtime_baseline	hr	185.74	Data Logger
Pump runtime_demand	hr	90.50	Data Logger
#days_baseline	d	7.74	Data Logger
#days_demand	d	3.77	Data Logger
Ave City Water Temp_baseline	F	53.94	Data Logger
Ave City Water Temp_demand	F	54.92	Data Logger
Ave Return Water Temp_baseline	F	108.25	Data Logger
Ave Return Water Temp_demand	F	109.48	Data Logger
Input/Firing rate(gas_therm)	therm/hr	6.75	Equipment specifications
DHW fuel_baseline(gas)	therm	204.52	Calculation
DHW fuel_normalized_demand(gas)	therm	115.11	Calculation
Annual DHW Reduction(gas)	therm/yr	-1496.90	Calculation
Annual pump electrical reduction	kWh/yr	2939.54	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	-13.46%	Calculation
pump runtime saving(%)	%	0.00%	Calculation
Annual cost savings(gas+electricity)	$/yr	**-$909**	Calculation

Notes:

Unsure of why there is such a high pump runtime in demand mode. Temperature difference between supply and return being larger is also unexplained. The same pump runtime in demand and continuous indicates that boiler runtime is independent of the control and pump runtime.



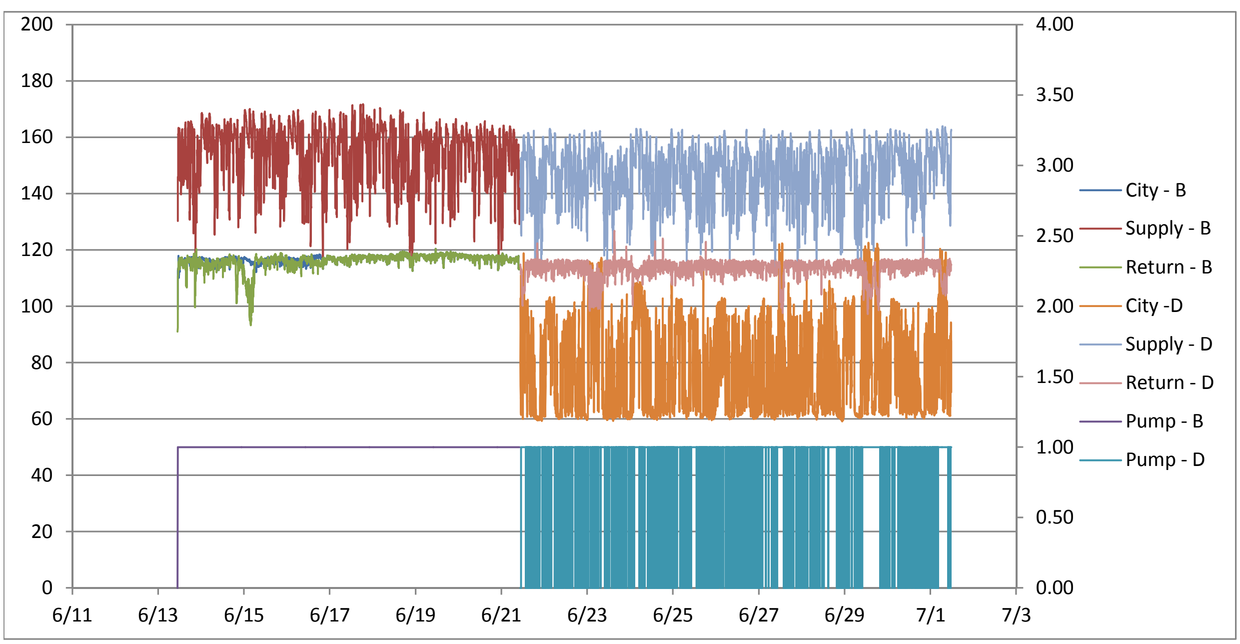
Site#29

234 Bradhurst Ave, NY, NY

Term	Unit	Quantity	Source
Baseline Period	date	6/13/18 - 6/21/18	M&V Schedule
Demand Period	date	6/21/18 - 7/1/18	M&V Schedule
Pump power	kW	0.25	Equipment specifications
Boiler runtime_baseline	hr	5.28	Data Logger
Boiler runtime_demand	hr	6.40	Data Logger
Pump runtime_baseline	hr	191.26	Data Logger
Pump runtime_demand	hr	19.54	Data Logger
#days_baseline	d	7.97	Data Logger
#days_demand	d	10.04	Data Logger
Ave City Water Temp_baseline	F	116.79	Data Logger
Ave City Water Temp_demand	F	78.15	Data Logger
Ave Return Water Temp_baseline	F	114.87	Data Logger
Ave Return Water Temp_demand	F	113.38	Data Logger
Input/Firing rate(gas_therm)	therm/hr	15.81	Calculation
Input/Firing rate(oil_gallon)	gallon/hr	30.00	Equipment specifications
DHW fuel_baseline(gas)	therm	83.48	Calculation
DHW fuel_normalized_demand(gas)	therm	101.22	Calculation
DHW fuel_baseline(oil)	gallon	158.42	Calculation
DHW fuel_normalized_demand(oil)	gallon	128.53	Calculation
Annual DHW Reduction(gas)	therm/yr	144.73	Calculation
Annual DHW Reduction(oil)	gallon/yr	2584.10	Calculation
Annual pump electrical reduction	kWh/yr	2012.45	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Rate_oil	$/gallon	$3.25	M&V Plan
Boiler runtime saving(%)	%	3.8%	Calculation
pump runtime saving(%)	%	91.9%	Calculation
Annual cost savings(gas,oil,electricity)	$/yr	**$830**	Calculation

Notes:

Frequent pump cycling makes pump appear to be on more than actuality in graph. Measured city water temperature was unrealistically high and was removed.



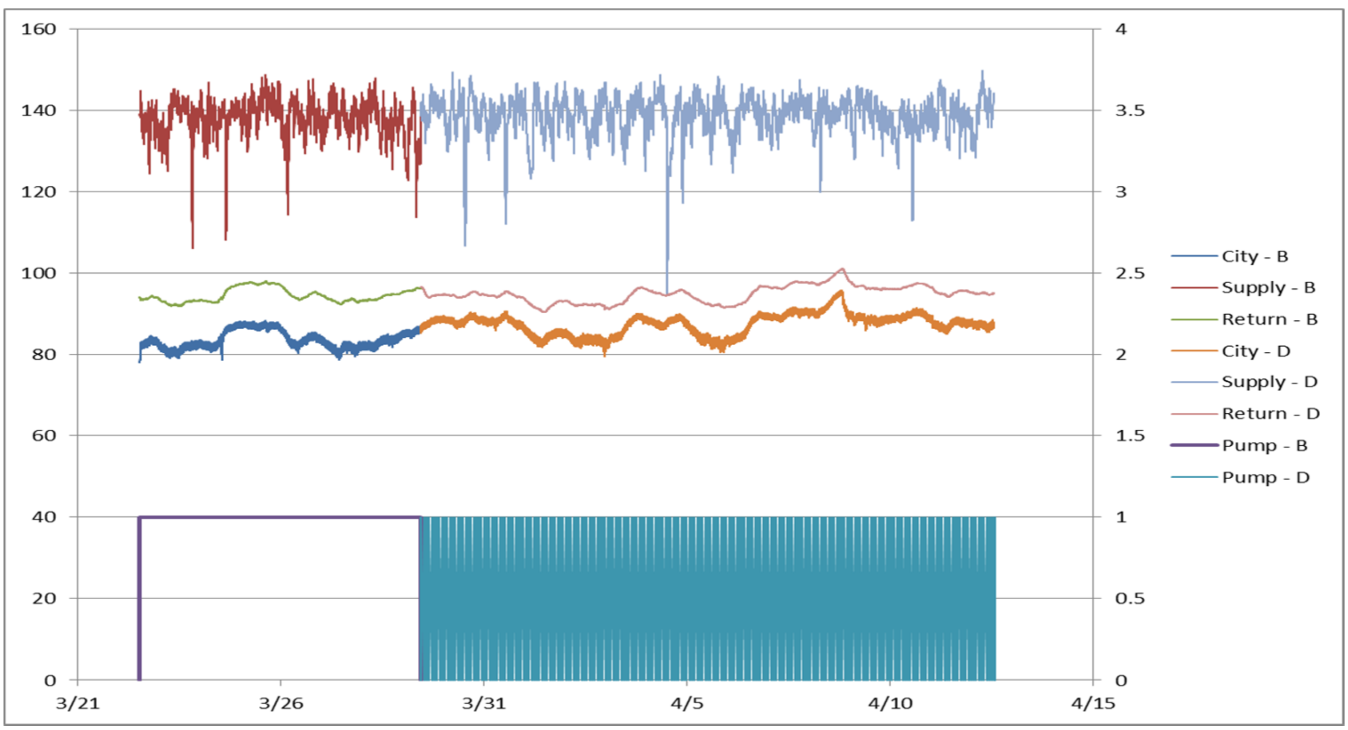
Site#30

1111 Westchester Ave., NY, NY

Term	Unit	Quantity	Source
Baseline Period	date	3/22/19-3/29/19	M&V Schedule
Demand Period	date	3/29/19 - 4/12/19	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler1 runtime_baseline	hr	0.00	Data Logger
Boiler1 runtime_demand	hr	0.00	Data Logger
Boiler2 runtime_baseline	hr	83.56	Data Logger
Boiler2 runtime_demand	hr	44.43	Data Logger
Pump runtime_baseline	hr	165.97	Data Logger
Pump runtime_demand	hr	2.41	Data Logger
#days_baseline	d	6.92	Data Logger
#days_demand	d	14.15	Data Logger
Ave City Water Temp_baseline	F	83.62	Data Logger
Ave City Water Temp_demand	F	87.55	Data Logger
Ave Return Water Temp_baseline	F	94.50	Data Logger
Ave Return Water Temp_demand	F	94.88	Data Logger
Input/Firing rate(gas_therm)	therm/hr	2.36	Equipment specifications
DHW fuel_baseline(gas)	therm	197.28	Calculation
DHW fuel_normalized_demand(gas)	therm	109.82	Calculation
Annual DHW Reduction(gas)	therm/yr	-95.40	Calculation
Annual pump electrical reduction	kWh/yr	259.44	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	2.56%	Calculation
pump runtime saving(%)	%	99.29%	Calculation
Annual cost savings(gas+electricity)	$/yr	**-$44**	Calculation

Notes:

Return and supply temperatures unaffected by control - indicates broken pump. Minimal fluctuation in city water temp indicated likely working check valve.

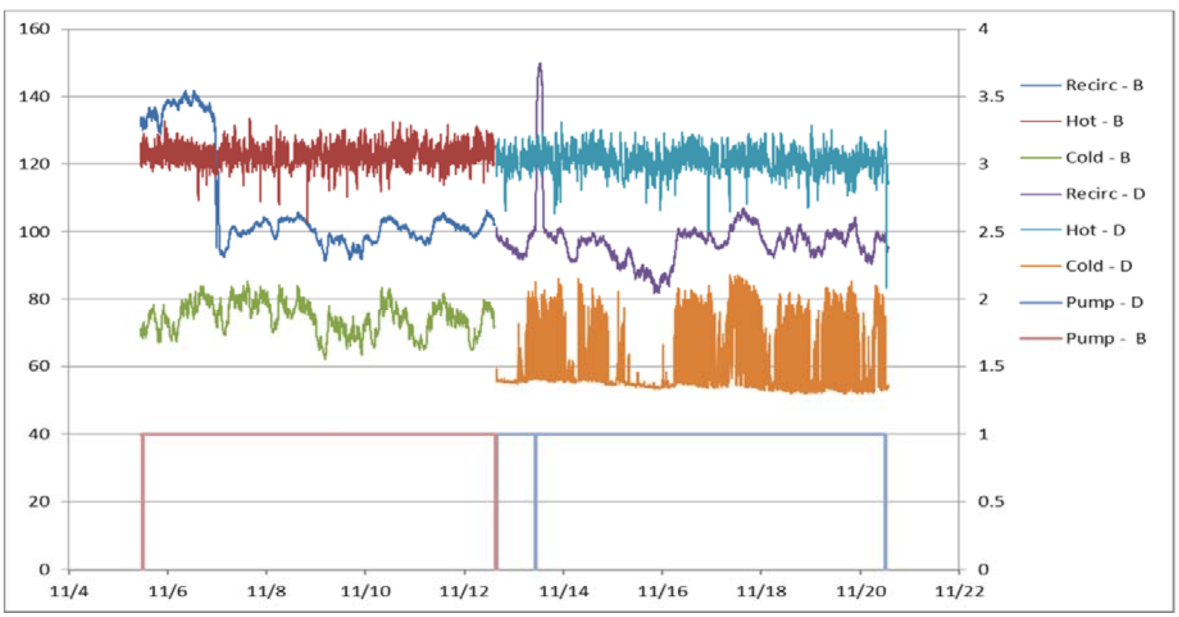


Site#31 **770 Bryant Ave, Bronx NY**

Term	Unit	Quantity	Source
Baseline Period	date	10/26/18 - 11/12/18	M&V Schedule
Demand Period	date	11/12/18 - 11/20/18	M&V Schedule
Pump power	kW	0.09	Equipment specifications
Boiler1 runtime_baseline	hr		Data Logger
Boiler1 runtime_demand	hr		Data Logger
Boiler2 runtime_baseline	hr		Data Logger
Boiler2 runtime_demand	hr		Data Logger
Pump runtime_baseline	hr		Data Logger
Pump runtime_demand	hr		Data Logger
#days_baseline	d		Data Logger
#days_demand	d		Data Logger
Ave City Water Temp_baseline	F		Data Logger
Ave City Water Temp_demand	F		Data Logger
Ave Return Water Temp_baseline	F		Data Logger
Ave Return Water Temp_demand	F		Data Logger
Input/Firing rate(gas_therm)	therm/hr	2.60	Equipment specifications
DHW fuel_baseline(gas)	therm		Calculation
DHW fuel_normalized_demand(gas)	therm		Calculation
Annual DHW Reduction(gas)	therm/yr		Calculation
Annual pump electrical reduction	kWh/yr		Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%		Calculation
pump runtime saving(%)	%		Calculation
Annual cost savings(gas+electricity)	$/yr	**$0**	Calculation

Notes:

The recirculation return during the baseline period, labeled "recirc - B" on the graph, has a higher temperature than the return line temperature for a few days and then dramatically plumets and does not arrise again. We are unsure of what causes the higher return line temperature, but it appears that the pump fails when the recirculation line temperature drops despite the fact that is running, indicated by the "Pump - B" line being at 1 rather than if it were off indicated by being at 0. The pump has been confirmed to have failed from on site visits. The pump motor is running but moving a minimal amount of water, the pump is also visibly leaking. We also see a drop in the average cold water temperature being supplied to the water heaters, despite an increase in temperature variability. This drop in cold water temperature is what is driving the savings at this site. The pump was always on during the demand control period, indicating that this is a high use building or that there is another leak in the line causing the control to believe there is always a call for hot water.



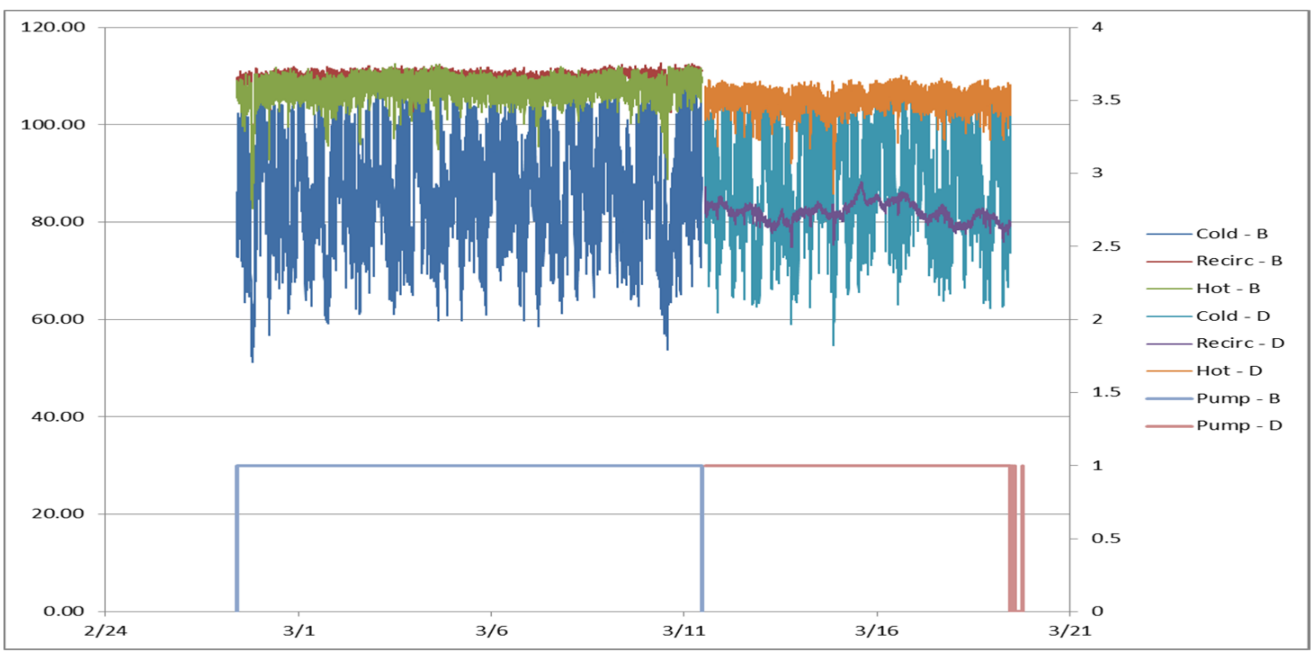
Site#32

760 Bryant Ave, Bronx NY

Term	Unit	Quantity	Source
Baseline Period	date	2/27/19 - 3/11/19	M&V Schedule
Demand Period	date	3/11/19-3/19/2019	M&V Schedule
Pump power	kW	0.06	Equipment specifications
Boiler1 runtime_baseline	hr	123.03	Data Logger
Boiler1 runtime_demand	hr	80.60	Data Logger
Boiler2 runtime_baseline	hr	133.27	Data Logger
Boiler2 runtime_demand	hr	85.88	Data Logger
Pump runtime_baseline	hr	289.06	Data Logger
Pump runtime_demand	hr	190.38	Data Logger
#days_baseline	d	12.04	Data Logger
#days_demand	d	8.08	Data Logger
Ave City Water Temp_baseline	F	85.94	Data Logger
Ave City Water Temp_demand	F	86.37	Data Logger
Ave Return Water Temp_baseline	F	109.67	Data Logger
Ave Return Water Temp_demand	F	81.67	Data Logger
Input/Firing rate(gas_therm)	therm/hr	2.57	Equipment specifications
DHW fuel_baseline(gas)	therm	659.60	Calculation
DHW fuel_normalized_demand(gas)	therm	430.58	Calculation
Annual DHW Reduction(gas)	therm/yr	541.13	Calculation
Annual pump electrical reduction	kWh/yr	10.01	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	3.19%	Calculation
pump runtime saving(%)	%	1.84%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$543**	Calculation

Notes:

The savings from this site is likely driven by what appears to be a reduction in hot water temperature from the baseline, "Hot - B", and the demand period, "Hot - D". The pump appears to have failed in between metering periods. This is suggested due by the recirculation line baseline temperature, "recirc - B", dropping dramatically between periods while the pump is stilll on, and that the pump is on while the recirculation line temperature, "Recirc. - D" is dramatically lower than the hot water supply, "Hot - D".



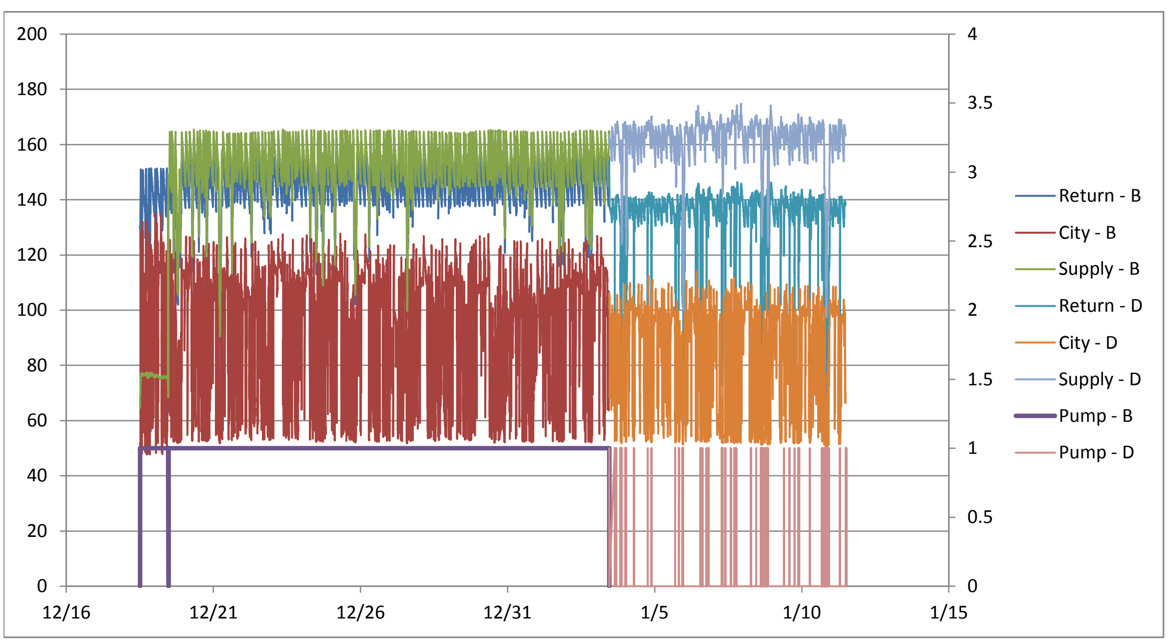
Site#33

1018 Fox St, Bronx NY

Term	Unit	Quantity	Source
Baseline Period	date	3/25/19 - 4/12/19	M&V Schedule
Demand Period	date	4/12/19 - 4/19/19	M&V Schedule
Pump power	kW	0.09	Equipment specifications
Boiler runtime_baseline	hr	73.2	Data Logger
Boiler runtime_demand	hr	27.9	Data Logger
Pump runtime_baseline	hr	336.5	Data Logger
Pump runtime_demand	hr	2.7	Data Logger
#days_baseline	d	14.0	Data Logger
#days_demand	d	7.0	Data Logger
Ave City Water Temp_baseline	F	141.0	Data Logger
Ave City Water Temp_demand	F	133.3	Data Logger
Ave Return Water Temp_baseline	F	141.1	Data Logger
Ave Return Water Temp_demand	F	135.0	Data Logger
Annual pump electrical reduction	kWh/yr	803.6	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Therms consumed_baseline	therm	232	Gas meter
Therms consumed_demand	therm	200	Gas meter
Space Heat boiler(gas_therm)	therm/hr	2.36	Equipment specifications
Space Heat fuel_base(gas)	therm	172.8	Calculation
Space Heat fuel_test(gas)	therm	65.9	Calculation
DHW fuel_baseline(gas)	therm	59.2	Calculation
DHW fuel_demand(gas)	therm	134.1	Calculation
DHW fuel_normalized(gas)	therm	126.8	Calculation
Annual DHW Reduction(gas)	therm	105	Calculation
Boiler runtime saving(%)	%	4.43%	Calculation
pump runtime saving(%)	%	98.41%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$266**	Calculation

Notes:

The increase in supply water temperature indicates tank stratification. Recommend reducing setpoint. Demand mode has an expected drop in return temperature. City water temperature fluctuations could be due to a failed check valve, decrease in temperature fluctuations in city temperature during demand control period also support this conclusion.



Site#34

931 Ave St John, Bronx NY

Term	Unit	Quantity	Source
Baseline Period	date		M&V Schedule
Demand Period	date		M&V Schedule
Pump power	kW		Equipment specifications
Boiler1 runtime_baseline	hr		Data Logger
Boiler1 runtime_demand	hr		Data Logger
Boiler2 runtime_baseline	hr		Data Logger
Boiler2 runtime_demand	hr		Data Logger
Pump runtime_baseline	hr		Data Logger
Pump runtime_demand	hr		Data Logger
#days_baseline	d		Data Logger
#days_demand	d		Data Logger
Ave City Water Temp_baseline	F		Data Logger
Ave City Water Temp_demand	F		Data Logger
Ave Return Water Temp_baseline	F		Data Logger
Ave Return Water Temp_demand	F		Data Logger
Input/Firing rate(gas_therm)	therm/hr		Equipment specifications
DHW fuel_baseline(gas)	therm		Calculation
DHW fuel_normalized_demand(gas)	therm		Calculation
Annual DHW Reduction(gas)	therm/yr		Calculation
Annual pump electrical reduction	kWh/yr		Calculation
Rate_electricity	$/kWh		M&V Plan
Rate_gas	$/therm		M&V Plan
Boiler runtime saving(%)	%		Calculation
pump runtime saving(%)	%		Calculation
Annual cost savings(gas+electricity)	$/yr		Calculation

Notes:

had clogged pump, motor spinning

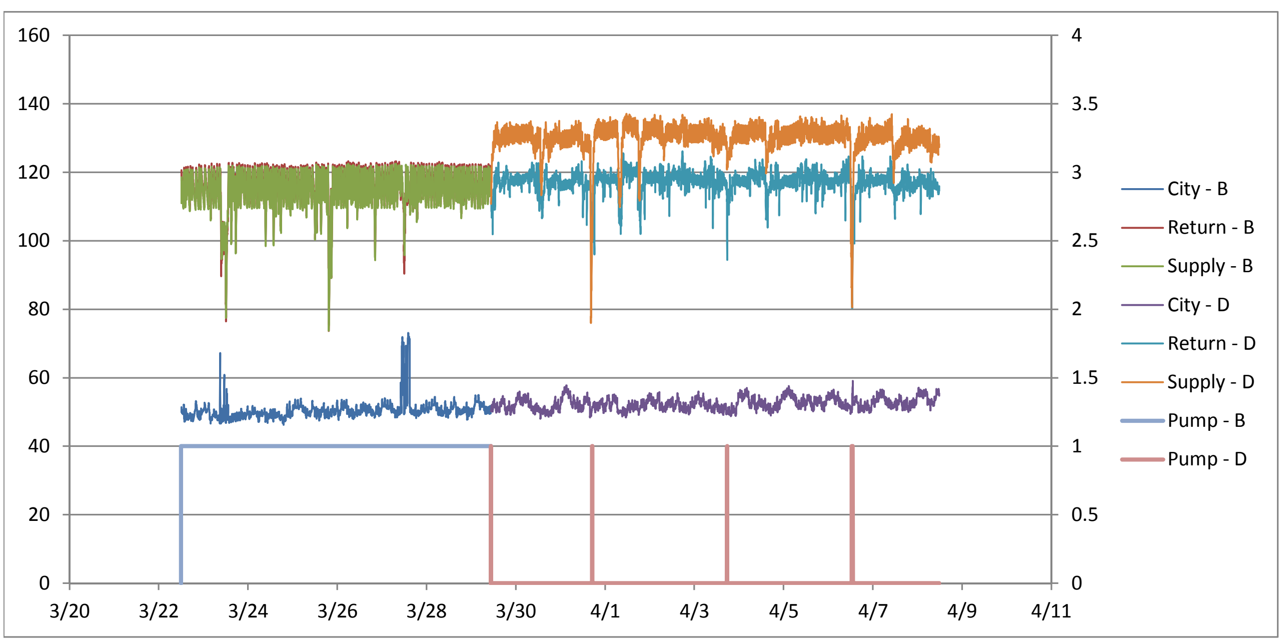
Site#35

1111 Hoe Ave, Bronx NY

Term	Unit	Quantity	Source
Baseline Period	date	3/22/19-3/29/19	M&V Schedule
Demand Period	date	3/29/19 - 4/8/12	M&V Schedule
Pump power	kW	0.04	Equipment specifications
Boiler runtime_baseline	hr	35.94	Data Logger
Boiler runtime_demand	hr	46.51	Data Logger
Pump runtime_baseline	hr	166.58	Data Logger
Pump runtime_demand	hr	0.84	Data Logger
#days_baseline	d	6.94	Data Logger
#days_demand	d	10.04	Data Logger
Ave City Water Temp_baseline	F	50.47	Data Logger
Ave City Water Temp_demand	F	52.21	Data Logger
Ave Return Water Temp_baseline	F	114.81	Data Logger
Ave Return Water Temp_demand	F	117.27	Data Logger
Annual pump electrical reduction	kWh/yr	325.48	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Therms consumed_baseline	therm	171	Gas meter
Therms consumed_demand	therm	93	Gas meter
Space Heat boiler(gas_therm)	therm/hr	1.42	Equipment specifications
Space Heat fuel_base(gas)	therm	50.9	Calculation
Space Heat fuel_test(gas)	therm	82.0	Calculation
DHW fuel_baseline(gas)	therm	26.1	Calculation
DHW fuel_demand(gas)	therm	48.0	Calculation
DHW fuel_normalized(gas)	therm	49.7	Calculation
Annual DHW Reduction(gas)	therm	-434.6	Calculation
Boiler runtime saving(%)	%	-27.30%	Calculation
pump runtime saving(%)	%	99.65%	Calculation
Annual cost savings(gas+electricity)	$/yr	**-$370**	Calculation

Notes:

Boiler runtime increased in demand mode - recommend reducing setpoint which should reduce boiler runtime. Likely tank stratification in demand mode.



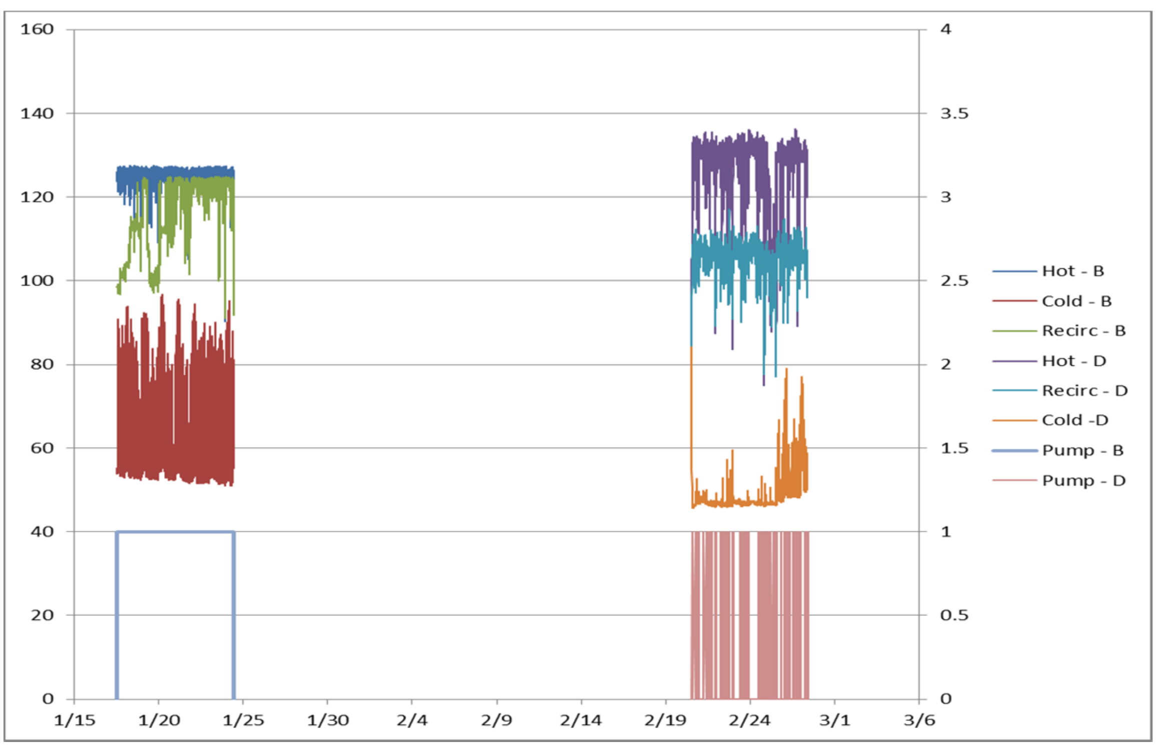
Site#36

310 West 153rd St

Term	Unit	Quantity	Source
Baseline Period	date	1/17/2019 - 1/24/19	M&V Schedule
Demand Period	date	2/20/19 - 2/27/19	M&V Schedule
Pump power	kW	0.09	Equipment specifications
Boiler runtime_baseline	hr	65.38	Data Logger
Boiler runtime_demand	hr	94.54	Data Logger
Pump runtime_baseline	hr	178.07	Data Logger
Pump runtime_demand	hr	10.06	Data Logger
#days_baseline	d	7.42	Data Logger
#days_demand	d	6.89	Data Logger
Ave City Water Temp_baseline	F	64.53	Data Logger
Ave City Water Temp_demand	F	48.91	Data Logger
Ave Return Water Temp_baseline	F	114.52	Data Logger
Ave Return Water Temp_demand	F	105.51	Data Logger
Input/Firing rate(gas_therm)	therm/hr	1.88	Equipment specifications
DHW fuel_baseline(gas)	therm	122.87	Calculation
DHW fuel_normalized_demand(gas)	therm	134.66	Calculation
Annual DHW Reduction(gas)	therm/yr	-1090.91	Calculation
Annual pump electrical reduction	kWh/yr	766.85	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	-55.77%	Calculation
pump runtime saving(%)	%	93.91%	Calculation
Annual cost savings(gas+electricity)	$/yr	**-$938**	Calculation

Notes:

This site had no savings, this is likely due to what appears to be an increase in hot water temperature. No complaints were recorded but the hot water temperature visibly increased in the graph. The recirculation return line temperature is as we would expect given no pump run time, and appears that the system is otherwise working properly, excluding the variable cold water temperature.



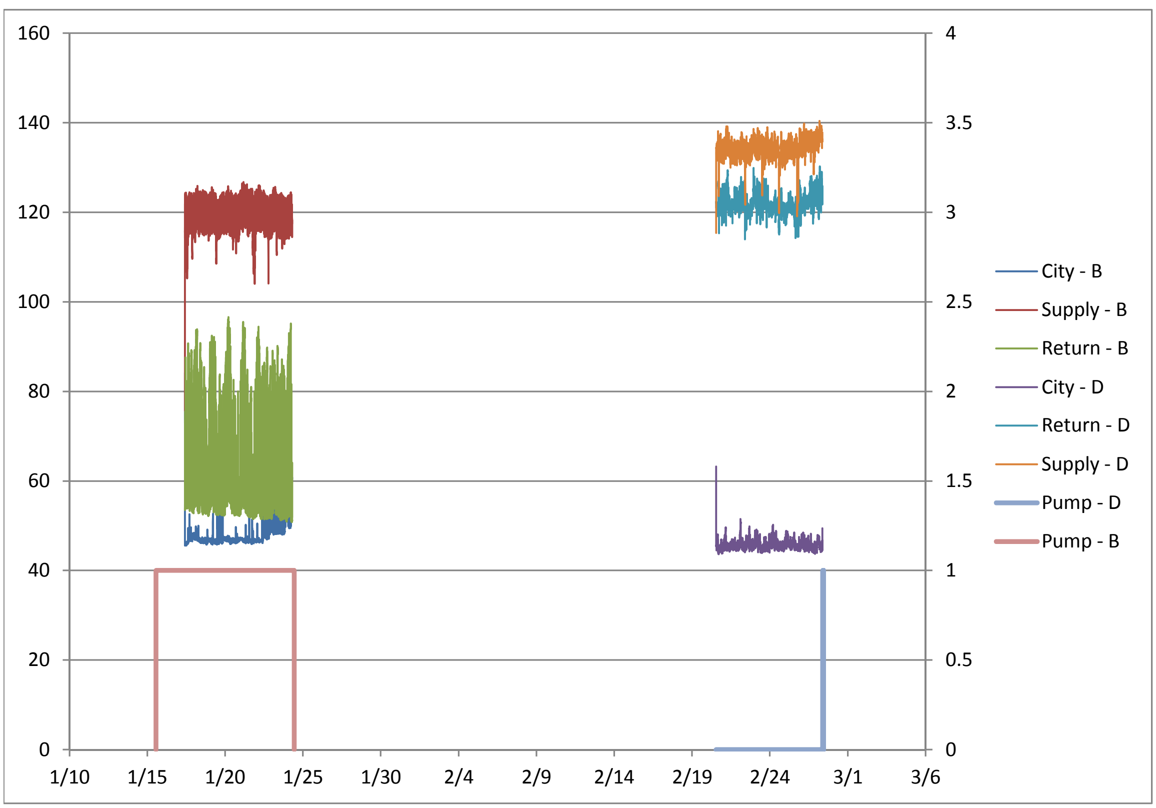
Site#37

301 West 152nd St

Term	Unit	Quantity	Source
Baseline Period	date	1/17/2019 - 1/24/19	M&V Schedule
Demand Period	date	2/20/19 - 2/27/19	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler runtime_baseline	hr	71.03	Data Logger
Boiler runtime_demand	hr	63.83	Data Logger
Pump runtime_baseline	hr	165.32	Data Logger
Pump runtime_demand	hr	10.06	Data Logger
#days_baseline	d	6.89	Data Logger
#days_demand	d	6.82	Data Logger
Ave City Water Temp_baseline	F	48.91	Data Logger
Ave City Water Temp_demand	F	45.83	Data Logger
Ave Return Water Temp_baseline	F	64.35	Data Logger
Ave Return Water Temp_demand	F	122.36	Data Logger
Input/Firing rate(gas_therm)	therm/hr	2.36	Equipment specifications
DHW fuel_baseline(gas)	therm	167.71	Calculation
DHW fuel_normalized_demand(gas)	therm	141.21	Calculation
Annual DHW Reduction(gas)	therm/yr	1330.60	Calculation
Annual pump electrical reduction	kWh/yr	245.24	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	9.26%	Calculation
pump runtime saving(%)	%	93.85%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$1,380**	Calculation

Notes:

Unknown reason for increase in return temperatures, possibly due to interactions between boiler loop pump and recirculation pump. Supply tem increase possibly due to tank stratification.



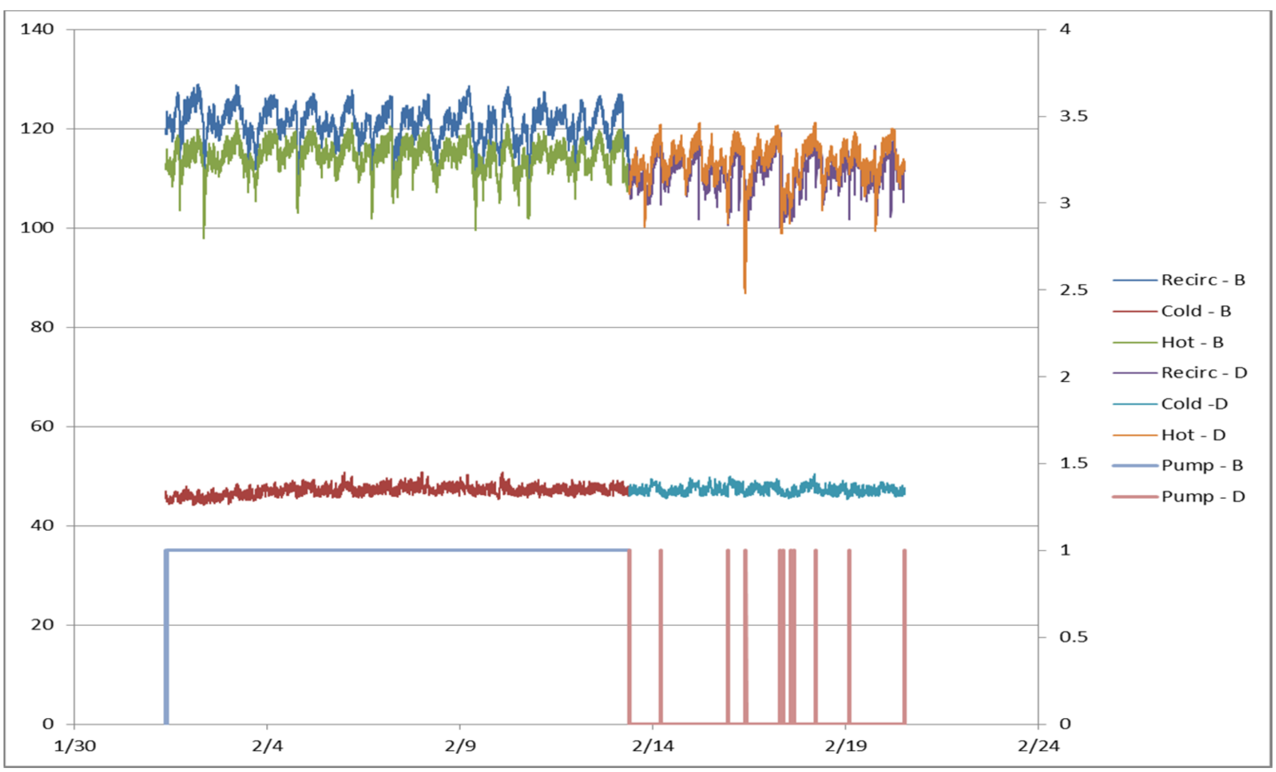
Site#38

308 West 151st St

Term	Unit	Quantity	Source
Baseline Period	date	2/1/19 - 2/13/19	M&V Schedule
Demand Period	date	2/13/19 - 2/20/19	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler runtime_baseline	hr	107.53	Data Logger
Boiler runtime_demand	hr	70.47	Data Logger
Pump runtime_baseline	hr	287.97	Data Logger
Pump runtime_demand	hr	0.80	Data Logger
#days_baseline	d	12.00	Data Logger
#days_demand	d	7.17	Data Logger
Ave City Water Temp_baseline	F	47.08	Data Logger
Ave City Water Temp_demand	F	47.28	Data Logger
Ave Return Water Temp_baseline	F	121.19	Data Logger
Ave Return Water Temp_demand	F	111.10	Data Logger
Input/Firing rate(gas_therm)	therm/hr	2.36	Equipment specifications
DHW fuel_baseline(gas)	therm	253.88	Calculation
DHW fuel_normalized_demand(gas)	therm	167.10	Calculation
Annual DHW Reduction(gas)	therm/yr	-785.01	Calculation
Annual pump electrical reduction	kWh/yr	260.08	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	-9.70%	Calculation
pump runtime saving(%)	%	99.54%	Calculation
Annual cost savings(gas+electricity)	$/yr	**-$733**	Calculation

Notes:

This site saw no savings. A possible explanation is that the circulation pump is installed backward. This is supported by the drop in recirculation line temperature below the hot water supply temperature when the pump is in demand mode.



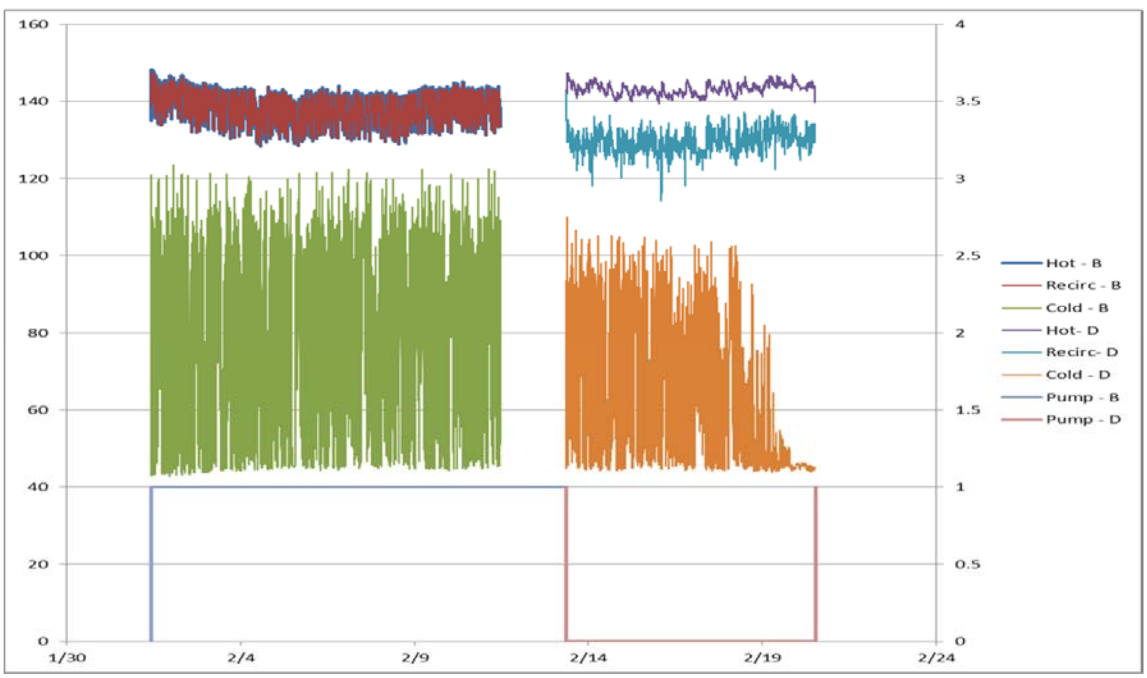
Site#39

230 Bradhurst Ave

Term	Unit	Quantity	Source
Baseline Period	date	2/1/19 - 2/13/19	M&V Schedule
Demand Period	date	2/13/19 - 2/20/19	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler runtime_baseline	hr	35.08	Data Logger
Boiler runtime_demand	hr	25.26	Data Logger
Pump runtime_baseline	hr	286.62	Data Logger
Pump runtime_demand	hr	0.00	Data Logger
#days_baseline	d	11.94	Data Logger
#days_demand	d	7.17	Data Logger
Ave City Water Temp_baseline	F	80.69	Data Logger
Ave City Water Temp_demand	F	63.61	Data Logger
Ave Return Water Temp_baseline	F	138.04	Data Logger
Ave Return Water Temp_demand	F	129.33	Data Logger
Input/Firing rate(gas_therm)	therm/hr	2.83	Equipment specifications
DHW fuel_baseline(gas)	therm	99.36	Calculation
DHW fuel_normalized_demand(gas)	therm	56.40	Calculation
Annual DHW Reduction(gas)	therm/yr	166.54	Calculation
Annual pump electrical reduction	kWh/yr	261.29	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	-19.90%	Calculation
pump runtime saving(%)	%	100.00%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$219**	Calculation

Notes:

This site had no boiler runtime savings but a total cost savings. This is likely due to the normalizing of the incoming city water temperatures. The colder measured city water temperature during the baseline period likely drives the savings. The pump never ran in demand mode and yet return tempertrure reamined high. No complaints were reported. The supply water temperature increase by 4.9F during the demand period may be explained by tank stratification increading when the pump is off and not acting to mix the tank water. The high city water temperature and variability seen in both the baseline and demand period indicates that hot water may be escaping into the city water supply line, although this was somewhat diminished during the demand period. This could be caused by a faulty check valve. Recommendations at this site would be to confirm check valve operation and reduce tank setpoint.



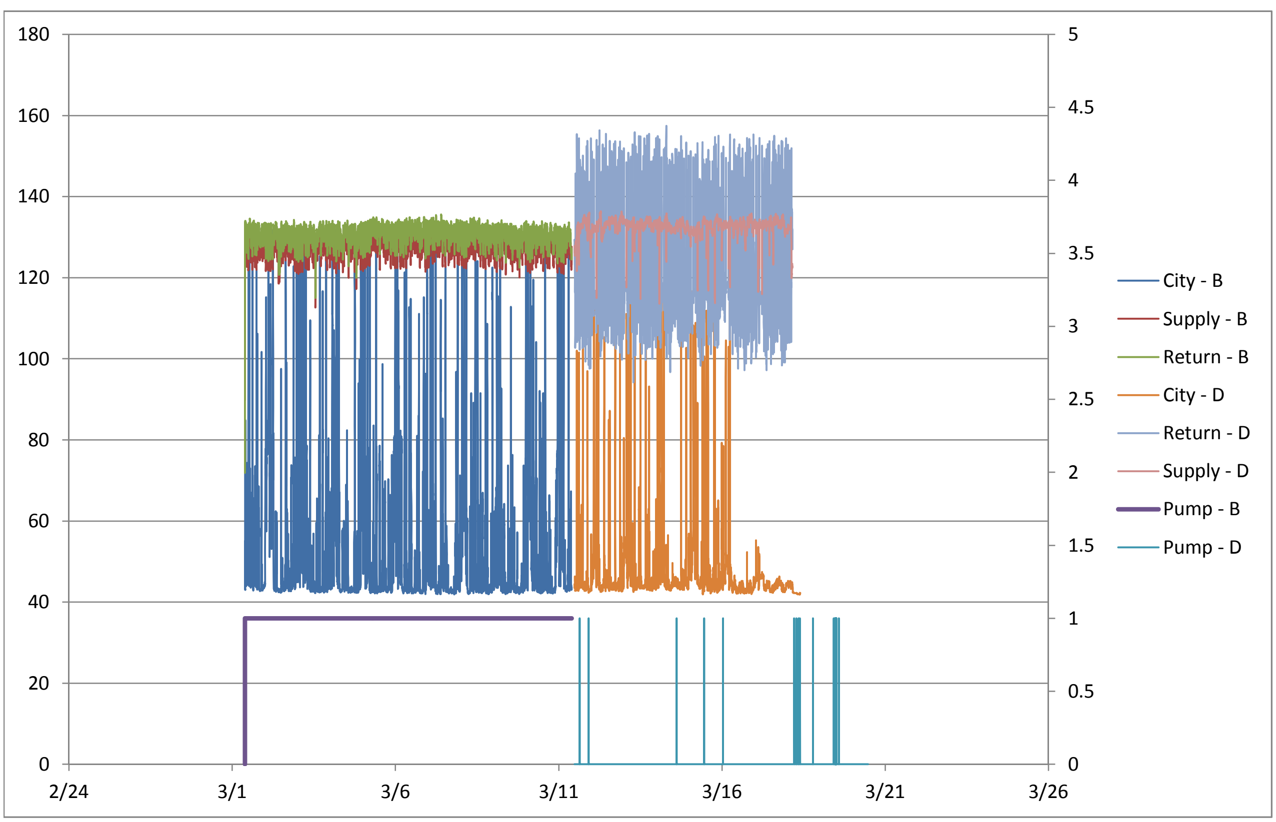
Site#40

2809 Frederick Douglass Blvd

Term	Unit	Quantity	Source
Baseline Period	date	2/27/19 - 3/11/19	M&V Schedule
Demand Period	date	3/11/19-3/19/2019	M&V Schedule
Pump power	kW	0.03	Equipment specifications
Boiler runtime_baseline	hr	52.56	Data Logger
Boiler runtime_demand	hr	45.50	Data Logger
Pump runtime_baseline	hr	240.16	Data Logger
Pump runtime_demand	hr	0.13	Data Logger
#days_baseline	d	10.01	Data Logger
#days_demand	d	8.99	Data Logger
Ave City Water Temp_baseline	F	53.32	Data Logger
Ave City Water Temp_demand	F	47.08	Data Logger
Ave Return Water Temp_baseline	F	130.48	Data Logger
Ave Return Water Temp_demand	F	118.58	Data Logger
Input/Firing rate(gas_therm)	therm/hr	3.97	Equipment specifications
DHW fuel_baseline(gas)	therm	208.47	Calculation
DHW fuel_normalized_demand(gas)	therm	159.36	Calculation
Annual DHW Reduction(gas)	therm/yr	1131.05	Calculation
Annual pump electrical reduction	kWh/yr	261.14	Calculation
Rate_electricity	$/kWh	$0.20	M&V Plan
Rate_gas	$/therm	$1.00	M&V Plan
Boiler runtime saving(%)	%	3.59%	Calculation
pump runtime saving(%)	%	99.94%	Calculation
Annual cost savings(gas+electricity)	$/yr	**$1,183**	Calculation

Notes:

High city water temperature indicates that the cold water check valve has failed. Return temp higher than supply. Supply temp in demand mode higher - likely tank stratification. Reduce setpoint to increase savings.



Appendix C. Crossover Detection

CROSSOVER DETECTION

Instruction Manual for Detecting and Locating Crossover in a Central Domestic Hot Water System

www.enovativegroup.com

CROSSOVER DETECTION METHODS

Introduction

Crossover is the result of a faulty mixing valve that allows cold water into the hot water pipes and/or hot water into the cold water pipes.

This type of mixing valve is usually found wherever a hot and cold pipe meet at a fixture in a central heating system. The most common fixtures are sink faucets, shower valves, and laundry machines.

Its presence often goes unnoticed and is commonly referred to as "the ghost flow." Its negative impact on water and energy is staggering.

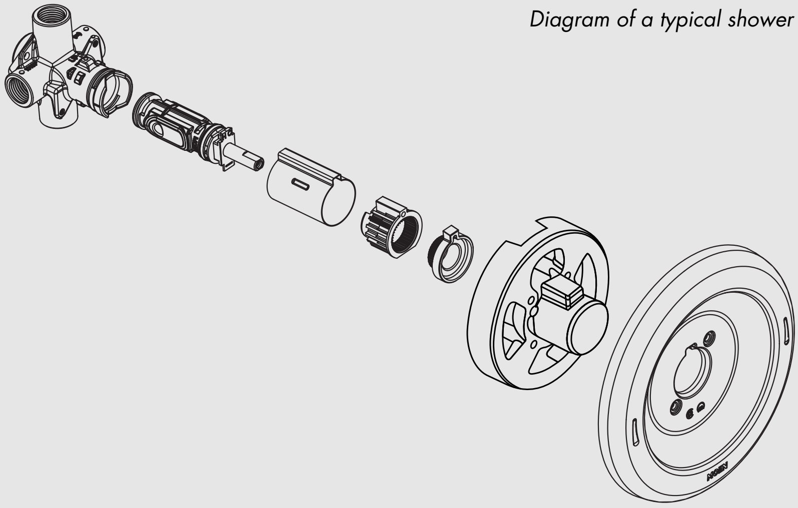
If left undetected, Crossover has the potential to waste a significant amount of energy and water, while degrading the quality of hot water experience to the end user.

Various studies conducted in California have found that only 1/3 of the energy consumed in order to produce hot water is utilized in a typical central heating system, while the other 2/3 is lost or wasted.

This amount of energy lost per building when added up across California results in millions of wasted therms and an un-sustainable level of lost water.

Previously, little data existed about Crossover. It was known mostly through word of mouth without any established industry practice for detection.

Diagram of a typical shower valve



CROSSOVER DETECTION METHODS

This instruction manual describes the best methods for detecting Crossover in a multifamily central domestic hot water system, and how to pinpoint the bad mixing valve.

The three methods covered in this instruction manual are:

- **Pressure Gauge Method**
- **Eatherton Method**
- **Water Flow Method**

Brief Descriptions

The Pressure Gauge Method is best for diagnosing Crossover for an entire building.

The Eatherton Method is best for pinpointing the specific valve causing Crossover.

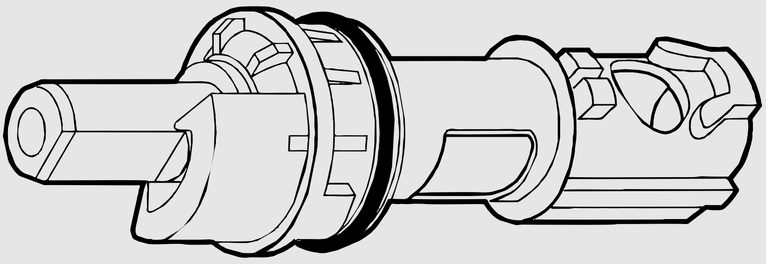
The Water Flow Method is best used as a back up test in place of the Pressure Gauge Method and is also able to locate a faulty valve when the Eatherton Method is not used.

Important notes to consider when testing for Crossover:

often the symptoms of Crossover go unnoticed or are masked by other hot water issues such as a leaky pipe, a blown valve or a weak continuous recirculation pump.

If tenants are complaining about temperature fluctuations, uneven water, pressure or long waits for hot water testing for Crossover is a smart place to start.

Image of mixing cartridge



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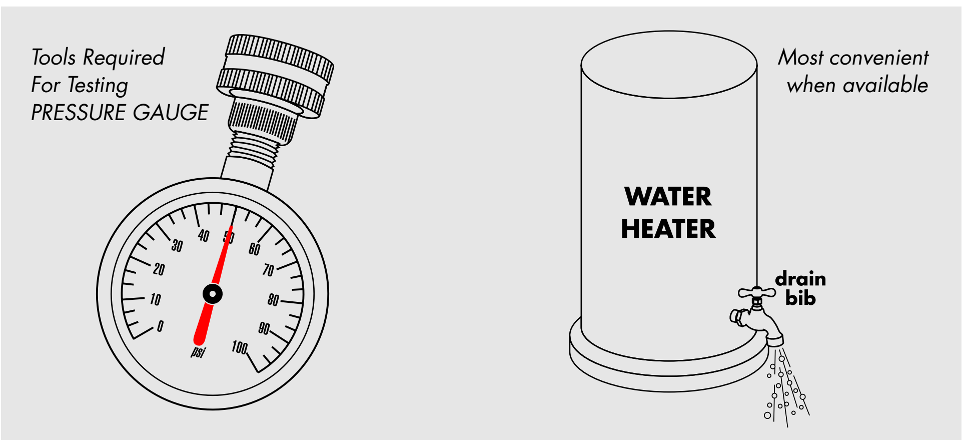
THE PRESSURE GAUGE METHOD

The Pressure Gauge Method is best used to determine if Crossover is present in a building or not. It is not an effective method for pinpointing the faulty valve.

The Pressure Gauge Method tests for Crossover by recording water pressure in the pipes. All that is required to perform this method is a standard pressure gauge shown below.



The Pressure Gauge Method is an easy test to implement once the pressure gauge is in place, takes less than 5 minutes to record the water pressure and doesn't require access to tenant apartments nor a lengthy interruption of hot water service.

A pressure gauge must be applied to the hot water pipe. It is suggested to use a hose or drain bib connected to the water heater when available.

Once the pressure gauge is in place it should read the normal pressure of the system. Take note of where the needle is pointing.

The next step is to isolate the hot water pressure by closing the cold water valve that feeds the water heater. Then drain the hot water pressure by opening a release valve or hot water faucet. As the hot water pressure falls, take note of the pressure gauge needle.

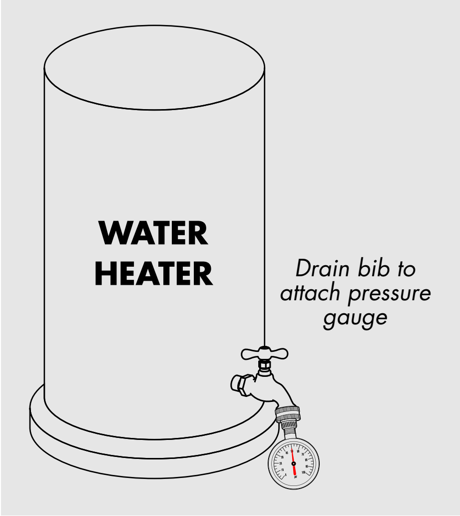
After a few minutes, if the water pressure in the hot water pipe falls, and rebuilds to normal, then crossover is occurring.

If the water pressure falls and remains low or close to zero, then the mixing valve is healthy, and Crossover is not present.

THE PRESSURE GAUGE METHOD

1. Attach pressure gauge to hot water pipe

A pressure gauge may already be installed which can be used or one may be added to a drain bib on the water tank itself, but it should be attached to the hot water piping or tank.



2. Check the pressure gauge for the normal pressure when the hot water pipe is fully pressurized

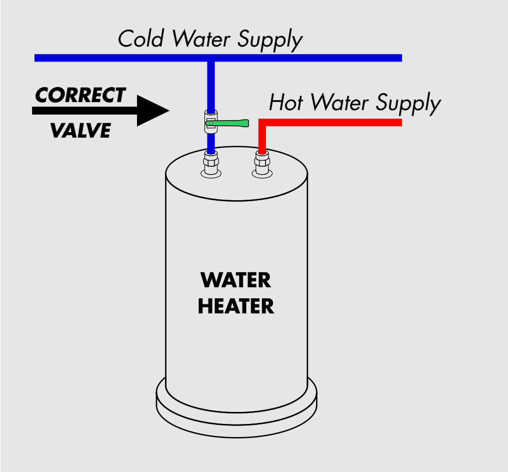
NOTE: if the gauge is installed on a hose bib you would now open the bib faucet and wait for the gauge to stabilize.

Take note of the pressure reading of the hot water pipe once it is stable.

Watch the needle for steadiness.

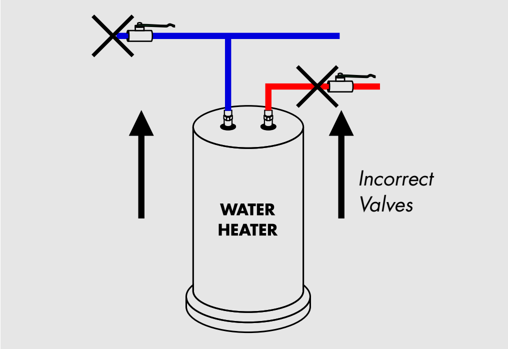
3. Close a valve on the cold water supply to the water heater.

The correct cold water supply valve is usually found on a pipe segment just above the water heater as shown below.



IMPORTANT NOTE:

Do not close the valve on the hot water supply from the heater and do not close the valve to the main cold water supply

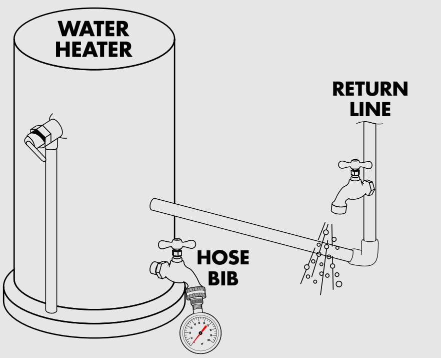


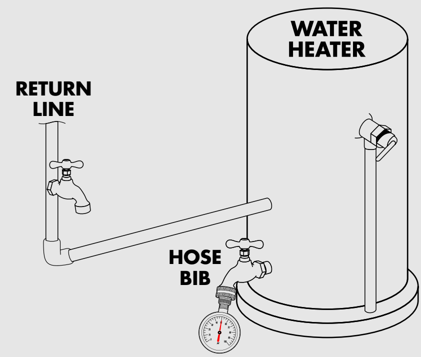
THE PRESSURE GAUGE METHOD

PRESSURE GAUGE

4. Relieve water pressure from the hot water pipe by opening a hose bib on the return line or TPR valve on the water heater.

6. Lastly, shut off the open fixture and watch the pressure gauge react (allow a few minutes to pass)



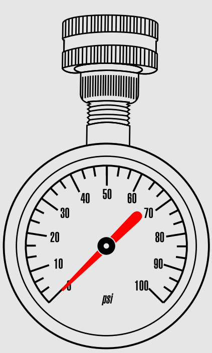


Make sure the fixture is set to run hot water only. Pressure can be released by the TRP Valve on the water heater, but only if it is in good condition. The best option is draining from the hose bib on the return line as shown above.

5. Now take a record of the water pressure reading on the gauge. It should begin to fall towards zero.

If the pressure gauge remains below normal, then there isn't any Crossover and the mixing valves are healthy.

After a few minutes, if the pressure gauge rebuilds to normal, then a mixing valve is worn out in the building and is creating Crossover.



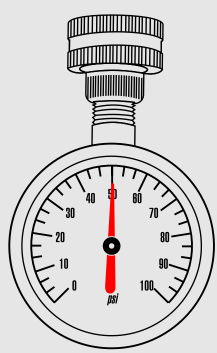
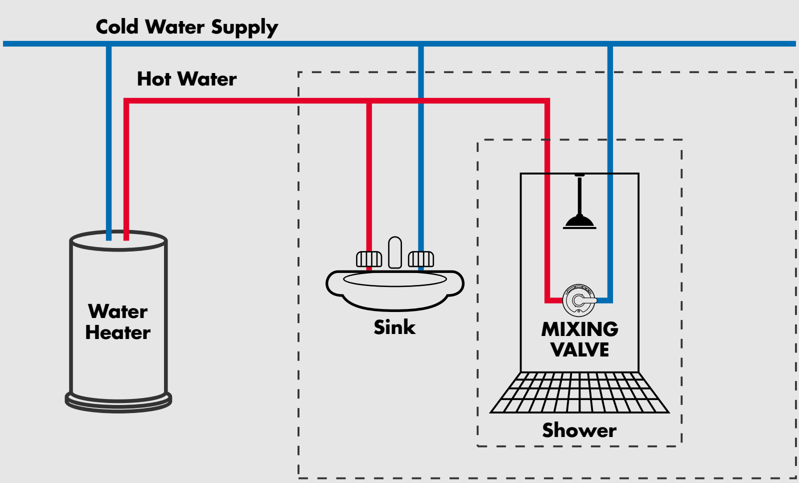


Image of a shower valve exposed when the faceplate is removed **(Step 2)**

The Eatherton Method is best used for locating the exact mixing valve that is allowing Crossover to occur.

The Eatherton Method is most effective in situations when a specific fixture such as a shower is producing temperature fluctuations or a long wait time for hot water.

The Eatherton Method requires access to the unit or apartment, but is very easy to implement. The tools needed for the Eatherton Method are a regular screwdriver, standard allen wrench and a pair of channel locks.



NOTE: *If the Crossover occurrence isn't revealing any obvious symptoms, which is often the case, then the Eatherton Test will have to be conducted in a unit by unit, floor by floor rollout.*

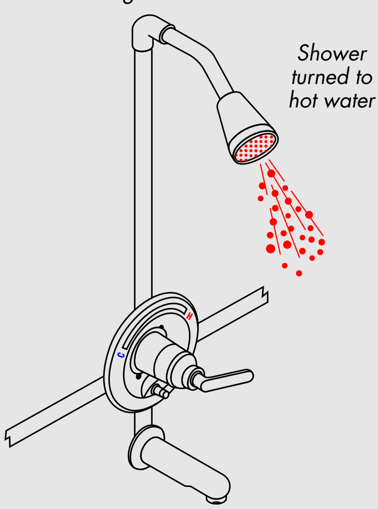
THE EATHERTON METHOD

1. **If possible, identify the unit or apartment with hot water complaints like fluctuating water temperature or long waits for hot water.**

2. **Remove the shower handle with an allen wrench and then the faceplate should slide off.**

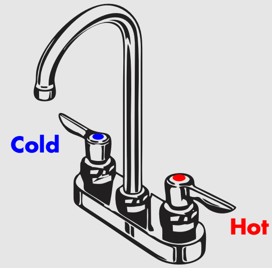
3. **Reattach the shower handle and turn on the hot water until the mixing valve is fully heated.**

Heated mixing valve after a few minutes



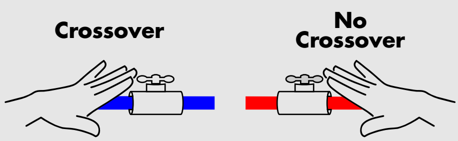
4. **Turn off the hot water once the shower valve is at hottest temperature.**

5. **With the shower turned off, but the mixing valve still hot to touch, turn on the hot water in a nearby fixture like a sink or lavatory faucet.**



The purpose of this step is to cause the water pressure released from the sink to test the strength of the mixing valve in the shower.

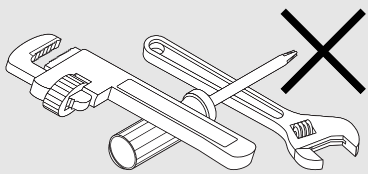
6. **Lastly, while the sink faucet is still open and running hot water, go back and feel the shower valve.**



If the shower valve has cooled down quickly it is because cold water has leaked through from the cold pipe and is an indication of Crossover.

THE WATER FLOW METHOD

The Water Flow Method is also known as the alternative method because it can be used to diagnose the entire building for Crossover, when the Pressure Gauge Method isn't available. Also, if there is access to the hot and cold pipes at the fixture level it can also be used in place of the Eatherton Method.



The Water Flow Method does not require any tools for the Building Test.

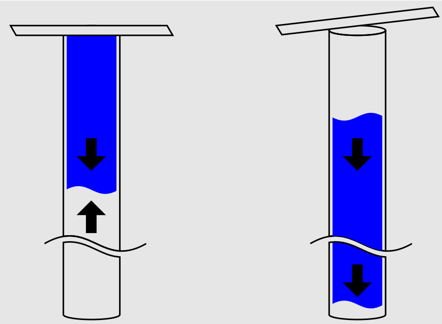
The Water Flow Method is very easy to implement, much like the Pressure Gauge Method. There needs to be a working shut off valve on the hot water supply. The main difference being the indicator for Crossover is based on water flow instead of water pressure.

There are a few special caveats and suggestions to follow if using the Water Flow Method.

One scenario to mention is that due surface tension, water in pipes will act like liquid in a straw with one end closed.

THE STRAW EFFECT

Like water in a hot water distribution system will act liquid trapped in a straw that has one end closed.



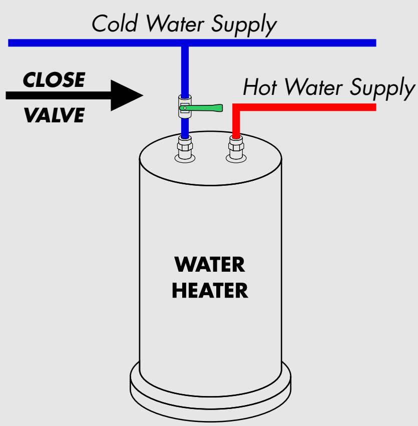
When using the Water Flow Method it is advised to open a 2nd faucet in order to allow air into the system and release any extra water trapped in the pipes.

Another consideration is that when draining water from the pipes it is suggested to drain from a high point (rooftop when possible) in the building in order to save water in the process.

Lastly, and most importantly it must be noted that when ever hot water is drained from the system and re-filled with large amounts of new water, if not re-pressurized correctly, air compressed in the pipes can cause critical damage to the shower mixing valve.

THE WATER FLOW METHOD

1. Close the cold water supply valve that feeds into the water heater (shown below)



NOTE: Do not close the valve on the hot water pipe nor on city supply (cold water main)

2. Close any valves on the hot water pipes (if operational) and any valves around the heater or storage tank.

SEGMENT THE HOT WATER PIPE

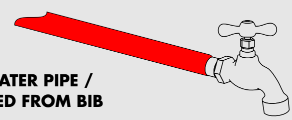
Whenever possible, if there are additional valves in position to further segment the hot water pipe, close every valve and test each segment with the following steps.

3. Open a fixture on the hot water pipe, preferably a hose bib, and allow the hot water to drain from the pipe.

NOTE: It is always better to drain the hot water supply from the highest point in the building versus the lowest point in order to save water and time.

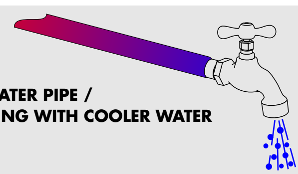
4. Once the water has drained from the pipe wait a couple of minutes and observe the water flow:

HOT WATER PIPE / DRAINED FROM BIB



If the water flow has ceased completely and the pipe is empty, then Crossover Is not present and the mixing valve is ok.

HOT WATER PIPE / RE-FILLING WITH COOLER WATER



If the water flow slows and then rebuilds to a steady rate and most importantly turns from hot to cool or ambient temperature, then the mixing valve is faulty and Crossover is occurring.

THE WATER FLOW METHOD:
UNIT TEST

After Crossover has been detected in the building, the next step is to locate the mixing valve causing the issue.

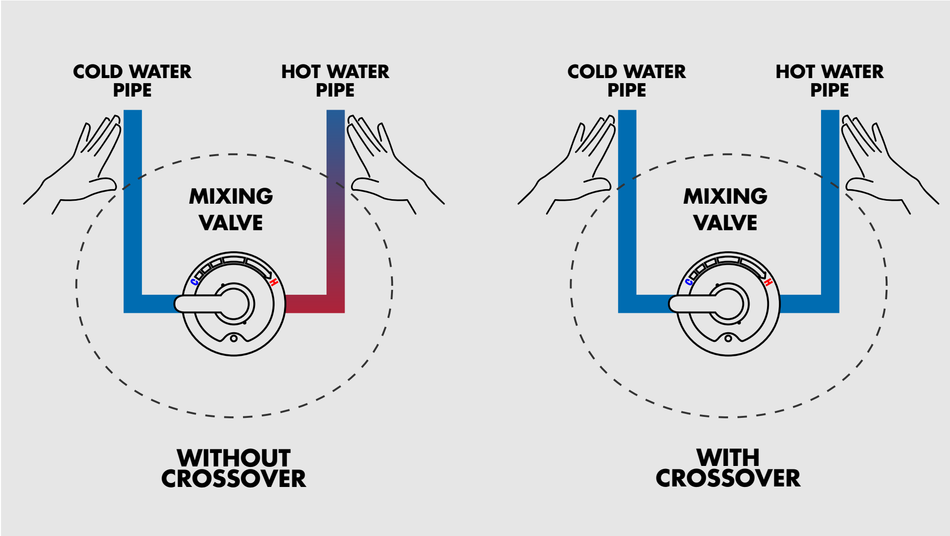
The user of this method will have to go unit by unit and feel the hot and cold water pipes.

1. Remove the shower handle and faceplate in order to expose the hot and cold water pipes.

2. Touch both pipes directly.

If the hot pipe is cooler than ambient temperature or equal to the cold water pipe, then this is where the Crossover is occurring and the mixing valve needs to be replaced.

If the hot pipe feels equal to ambient temperature or slightly warmer compared to the cold pipe, then the mixing valve is working correctly.



THE CROSSOVER DECTECTION METHODS SUMMARY CHART

DETECTION METHOD

DETECTION METHODS	WITH CROSSOVER	WITHOUT CROSSOVER
Pressure Gauge For Building Test	Water pressure rebuilds in the pipe	Water pressure remains low or at zero
Eatherton For Fixture Test	Mixing valve drops from hot to cold temp	Mixing valve remains hot to warm temp.
Water Flow For Building Test	Water flow rebuilds to steady stream	Water flow ceases and does not rebuild
Water Flow For Fixture Test	Hot water pipe will feel cool as cold water pipe	Hot water pipe will feel warm or hotter than cold water pipe

Appendix D. Plan to Overcome Market Barriers

EMERGING TECHNOLOGIES ACCELERATED COMMERCIALIZATION

Prepared for: **NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY**

Title of Project:	**Task 7 - Develop a Plan to Overcome Market Barriers**		
Agreement Number:	**40266**	Purchase Order:	**52793 11/14/14**
Contract Period:	**September 1, 2014 through August 31, 2016 (24 months)**		
Deliverable Date:	**December 31, 2018**		

This document describes a plan to overcome market barriers that impede DHW demand controls from achieving maximum multifamily market share in New York State. It is structured as follows:

1. List of market barriers
2. Discussion of market segments
3. Characteristics of an ideal building candidate
4. Decision makers and influencers
5. Plan to overcome market barriers

Market Barriers Summary

The Market Barrier Identification Report lists the primary market barriers to implementing multifamily DHW demand controls in New York, with a focus on New York City. Following is a table with a brief summary of each barrier and an approach to addressing that barrier.

Table 1 Summary of Primary Market Barriers and Plan for Overcoming them

Barrier	**Approach**
Lack of understanding and awareness by contractors	• Training on DHW controls provided to trades via unions or other programs, perhaps via NYSERDA workforce training initiative.
Lack of awareness by building designers	• Reaching the engineering community through manufacturer's reps • For new construction, NYC building code enforcement and integration into energy code training classes such as by Urban Green Council, NYSERDA and online DOB modules.
Lack of understanding and belief in system benefits	• Publicity of demonstration project results and other examples of successful use of DHW demand controls. • Integration into incentive programs such as: o NYC HPD through their IPNA programs for affordable housing o NYSERDA through their MPP programs for new and existing buildings

	o Utilities through incentive programs
Technical issues (see Table 2) making some buildings unsuitable	• Contractor training to be able to identify these issues and guidance on avoiding buildings with these problems; ideally the training would also include ways to correct these problems • Targeting the correct building stock • Local technical support in the form of manufacturer reps and knowledgeable energy consultants.

Discussion

Following is a discussion of strategies by market segment and by industry ally type. They are presented in order from most to least promising segments.

Market segment – New Residential Construction

Demand controls are now required by the NYC building code, which is a powerful lever to use with design professionals not only in New York City, but elsewhere in the State as the implied endorsement by the City of this technology can boost its acceptance by design professionals statewide. The primary means of penetrating this market is through building awareness by design professionals and specifiers either in one-on-one sales calls, code training, conferences, industry meetings and other outreach by manufacturer representatives. Manufacturer reps must provide guidance regarding benefits, proper system design, and proper installation in addition to the usual product information. Educating building code officials should also be on the agenda as this technology will be new to many of them.

This segment is most promising because of the code requirement and because new buildings are likely (although not guaranteed) to have fewer technical issues such as imbalanced systems and crossover and should not have corroded pipes or failed valves that complicate installation.

Market segment – Existing residential buildings, affordable rentals

This is a high-priority segment due to the following reasons:

- Large number of buildings statewide, especially in NYC
- Often relatively simple DHW system types and small building sizes
- High degree of control by owners over upgrade decisions
- High interest in reducing operating costs

However this segment also has some of the barriers noted above, particularly;

- Technical issues making some buildings less suitable or higher risk (such as with corroded pipes and/or imbalanced plumbing systems and crossover)
- Tight budgets to use for upgrades
- Awareness

To overcome the technical barriers in this segment, it is important to have knowledgeable contractors or other professionals assess viability and be available to diagnose and cure any problems that crop up during installation and commissioning.

Building awareness and overcoming budgetary barriers in this segment can be done through the many programs that these buildings participate in such as NYSERDA's MPP program, and HPD/HDC financing programs that require energy audits and upgrades as a condition of financing. In order for this to work, the technology must be accepted by these programs and credited with energy savings – something that the evidence from this study can help with.

Market segment – Existing residential buildings, market rate rentals

Many of these buildings are good candidates because they share some of the same attributes as affordable rentals; however a greater proportion of them are larger buildings which are not as good candidates. More importantly, however they are sometimes less motivated to pursue energy conservation measures because of perceived risk to building services and the proportionally smaller impact the savings have on larger operating budgets.

Market segment – Existing residential cooperative or condominium buildings

While some of these buildings may be technically good candidates, a greater proportion of them are larger buildings which are not. Their more complicated ownership structure can make the sales and decision process more uncertain and drawn out, making this the least attractive residential building segment.

Non-residential buildings

Non-residential buildings such as office and institutional buildings are outside of the scope of this project. In general they are more variable with some types having very low domestic hot water requirements.

Characteristics of an ideal candidate building

Table 2 Characteristics of an ideal candidate building

Type	**Ideal**	**Avoid**
Building size	Small to mid-size buildings up to 10-12-floors in height and with at least four apartments.	To prevent excessive wait times when the pump turns on, there should be no more than about a hundred or so linear feet of piping from water heater to farthest apartment hot water fixture and buildings should be no more than 10-12-floors high. For building exceeding these dimensions, the control may need to be set to "autoprime" which will maintain the recirc line at a higher temperature, providing more reliable service but reducing energy savings potential.
DHW	Recirculating DHW system with	If the residents are served

distribution system	recirc. pump that operates at least 6-12 hours per day.	satisfactorily without recirculation, then pump controls are unnecessary and the pump should be turned off.[1] Avoid systems that are severely unbalanced.
Water heater		Combi systems where the recirculation pump is used for circulating both DHW and hot water for space heating. CHP will have lower paybacks because the CHP system utilization will be reduced.
Water heating fuel	High cost fuels such as oil, propane or electric resistance offer shorter payback than natural gas.	
Mixing valve	None, or valves that are rated for discontinuous flow	Electronic valves that are not programmed for discontinuous flow
DHW system issues	Well maintained system without significant resident complaints about DWH.	Avoid buildings with fixture crossover problems; this will be exacerbated by demand controls. Corroded pipes and broken valves may increase installation costs. Buildings that have known existing issues getting hot water to all the units

Decision makers

This section describes decision makers and influencers and approaches to getting them to adopt DHW demand controls.

Table 3 Industry member adoption approaches

Type	Adoption approaches
Building owner	Provide information that clearly describes how demand controls work and their benefits; i.e. case studies, manufacturer literature. Owners and managers will usually not initiate or drive demand controls implementation but will need to know enough to approve it.
Building manager	
Contractors (HVAC,	Tradesperson training programs and sales calls by manufacturer reps.

[1] Note that before determining that recirculation is not needed to provide satisfactory DHW service, confirm that secondary (or "ghost") flow is not present in the recirc system even with pump deactivated. If ghost flow is present then demand controls should be installed in conjunction with a solenoid valve that prevents flow when the pump is off.

plumbing)	Contractors will not likely initiate or drive demand controls implementation but will need to know how to install it, as well as the more subtle skills of determining good building, candidates, diagnosing problems and adjusting control settings.
Energy consultants	Once programs endorse demand controls, disseminate that information to this group through channels made available by these programs as well as conferences and webinars. Consultants must have a deep knowledge of the technical issues related to demand controls. Energy code trainings will also reach this group.
Design professionals	Energy code trainings and sales calls by manufacturer reps will be important methods to reach this group.
Building code officials	Through building departments and energy/plumbing code trainings.
Energy modeling software providers	It will be necessary to ensure that consultants have an accurate way to model demand controls in energy modeling software commonly used for programs such as NYSERDA MPP, ENERGY STAR multifamily high-rise, Passive House and Enterprise Green Communities; and that software training classes cover demand controls.
Program managers	Direct outreach to managers of the following programs to encourage them to incentivize or otherwise recognize in their programs the benefits of demand controls: • HPD through their IPNA requirements for affordable housing • NYSERDA through their MPP programs for new and existing buildings • Utilities through incentive programs

Plan to overcome market barriers

The plan is divided into two initiatives; one for new construction and one for existing buildings. Focusing initially on New York City for both segments makes sense because of the density of buildings and professionals working on them.

New Construction

1. Educate and train code officials as described in Table 3.
2. Approach conduct energy code training programs and get demand controls integrated into those programs
3. Build awareness among design professionals and specifiers as described in Table 3.

Existing Buildings

Focusing on the most suitable market – affordable multifamily rentals – take the following steps:

1. Reach out to program managers to get demand controls integrated into their programs as described in Table 3.
2. Reach out to software providers and trainers (e.g. eQuest trainers Karpman Consulting, PHIUS and PHI's North American certifiers) to ensure demand controls can be modeled and credited in their software.
3. Educate the consultants involved in these programs as they will be the ones to initiate demand controls in these buildings.
4. Train installation contractors working in this market segment as described in Table 3.

Market penetration

Currently there is minimal (less than 1%) market penetration of demand controllers in both the new and existing building sectors in New York. By following the above plan, the following 5-year market penetration goals are possible:

- New Construction: With the code requirements now in place, at least 50% of new systems should include demand controls in this timeframe.
- Existing buildings: Using data from the 2014 NYC Housing and Vacancy Survey it can be estimated that there are nearly 50,000 potentially suitable buildings in NYC (in the most attractive market segment), with suitability defined as a regulated rental building with between 3 and 99 units; but not including public housing. These buildings often go through financing cycles of 15 years at which point upgrades are considered. This yields about 3,000 candidates per year. By year 2 of the 5-year outlook we would expect that a 5% market penetration could be achieved with that number increasing by 5% each year as consultants and others start implementing demand controls as a standard. This would yield a 20% market share of buildings undergoing retrofit in this market segment at the end of year 5 with market share continuing to increase and starting to spill over into other segments.

Appendix E. Demand and Controls Installation Checklist

Item	Procedure / Guidance	
1. Functioning city water inlet pipe check valve	Test check valves (see next page); plan to replace swing gate valves with spring loaded or solenoid valves.	
2. Functioning recirculation return line check valve	Test check valves (see next page); plan to replace swing gate valves with spring loaded or solenoid valves.	
3. Functioning recirculation pump	Verify that pump is not clogged with scale, rust, sediment, or air seized. Pump's function can be verified by checking if pipe temperature is similar on both sides of the pump.	
4. Recirculation pump oriented in the correct direction	Verify that pump is returning water to the DHW heater in the recirculation line.	
5. Properly sized recirculation pump	Consult pump manufacturer sizing guidelines to ensure that pump moves water rapidly enough to minimize wait times.	
6. Ensure no cross over	Confirm that building super has not received complaints about cross over. See Appendix C.	
7. Ensure no ghost flow / thermosyphoning	Check if return line remains hot even when recirculation pump is off for extended periods of time.	
8. Building / Recirculation system size	If loop is very long, then wait times may exceed acceptable limits when the pump turns on (check pump sizing guidelines).	
9. Mixing valves are compatible with disrupted flow	Verify with valve manufacturer.	
10. Old isolation valves	Plan to replace old isolation valves with new ball valves.	
11. Location for flow switch	Sufficient horizontal length of pipe on cold water inlet pipe or on hot water supply. Flow switch location close enough to control location for wiring.	
12. Cold water inlet and hot water supply pipe diameter	Note pipe diameter for sizing of flow switch tee.	
13. Location for controller temperature sensor	Temperature sensor location on recirculation line is close enough to control location for wiring.	
14. Recirculation pump HP size	Check electrical requirements of controller to confirm compatibility.	

Check Valve Inspection Procedure

1. Ensure there is flow and pressure supplied to the service and downstream distribution by operating a faucet or similar point of use device supplied through this check valve.

2. Ensure all point of use devices are closed within the system so there is no other pressure loss.

3. Slowly open the small test port cap on the top of the check valve until water starts to slowly bleed out.

4. Turn off the supply valve (inlet valve on a meter setter, or other valve upstream of the check valve). The flow should stop coming out of the test port within 2-5 seconds, relieving the pressure in the meter. Flow should stop at this point.

5. Verify the supply valve controls this flow by opening and closing it again to see flow from the test cap.

6. With the supply valve off, there should be no additional flow after 2-5 seconds, indicating the check valve is holding pressure on the downstream/distribution side.

7. If the test port continues to bleed water after 5 seconds, there is a possibility of debris or damage that could have fouled the check valve and service may be necessary to restore proper function of the check valve.

(Cambridge Brass, 2014)