# energySMART
# Emerging Technology Program

# 1003: Demand-based domestic hot water recirculation

# Public project report

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### *Background*

Domestic hot water (DHW) recirculation systems in multi-family buildings ensure that hot water is present at the fixture in individual apartment units with minimal delay. This is accomplished by installing a hot water recirculation loop with a pump that constantly runs hot water throughout the system and back to the central boiler or water heater, preventing the water in the pipe from cooling. However, such systems waste energy. Typically the pump runs 24 hours a day, every day even when there is no call for hot water or the water in the pipes is sufficiently hot. As the water is circulated it loses heat which forces additional boiler or water heater firing to add heat back into the system.

A demand based recirculation system only runs the circulation pump when there is a call for hot water. Additionally, if the water in the return line is sufficiently heated it will shut the pump down even if there is a call for hot water. This results in significant gas and electric savings. This pilot project validates and quantifies those energy savings.

### *Results*

The pilot project results were very positive. Two apartment buildings were retrofitted with demand based DHW recirculation systems. The sites realized therm savings used for DHW of 28.2% and 19.9%, with simple payback periods of 1.46 and 1.06 years. Yearly therm savings at the two sites are expected to be 1,855 and 2,282 therms.

## Project background

### *Project overview*

This pilot assessment evaluated on-demand controls for recirculation pumps in central domestic hot water (CDHW) systems in multi-family housing as a method for reducing natural gas use. Demand controls operate by monitoring in real-time the demand for hot water. Unlike conventional continuous operation pumps, demand controls only activate the pump to circulate hot water when there is actual demand. This reduces unnecessary circulation of hot water throughout the recirculation loop, in turn reducing heat losses and needless firing of the boiler or water heater. The cumulative effect is natural gas savings. Additionally, the significantly reduced operation of the recirculation pump results in electric savings and less wear and tear on the equipment.

energySMART's Emerging Technology Program (ETP) executed a field-based pilot of this technology at two multi-family sites over 18 weeks. Although this was a limited number of sites, the availability of studies from other regions provided supporting data to further substantiate the findings in the Nicor Gas service territory. The energy savings at these two ETP sites were consistent with the results from existing field-based testing in California, and also provided valuable information on installation costs and best practices, assisted in the development of early market contractor support, and provided needed data to validate energy savings and cost-effectiveness.

### *Previous study results*

Previous research has been completed on this technology that supports this promising potential, including a 2008 work paper by PG&E, a 2009 report for Southern California Gas by Benningfield Group, and a report by Heschong Mahone Group as part of the 2008 California Building Energy Efficiency Standards development. The Benningfield Group documented therm savings for this technology in 35 multi-family sites in Southern California for four weeks in 2009. The 35 sites ranged in size from as small as 20 apartment units to as large as 189 units. Their report showed therm savings that ranged from 17.8 therms/apartment unit to 95.7 therms/apartment unit, with an average gas savings of 34.7 therms/apartment unit.

Much of the research to date on this technology has come out of California, though there are field installations in other states including Georgia and Washington, D.C. No installations before this Nicor Gas ETP pilot were known in the state of Illinois.

### *Technology*

The demand control system reduces recirculation piping heat losses and unnecessary firing of the natural gas boiler or water heater by only operating the hot water recirculation pump when there is an active demand for hot water (such as a tenant turning on a shower) and when the hot water return temperature falls below a certain setpoint. At times when there is no hot water demand – for example, during a weekday afternoon or when the water in the recirculation loop is still sufficiently hot the demand control system does not operate the recirculation pump. This eliminates electricity use from continuous operation of the pump while also minimizing the heat losses associated with moving hot water throughout the recirculation piping in a large building when there is no demand. Instead, the pump will run intermittently as needed throughout the day.

The baseline technologies for CDHW systems include no controls (e.g. a continuously operating recirculation pump), time clocks, aquastats, and temperature modulation controls. Each approach has advantages and disadvantages; for example, with a time clock the installer must estimate the times of day when hot water will be needed. In order to keep tenants satisfied and minimize complaints, time clocks are often set to only shut-off the pump in the middle of the night. Although this does save gas, it captures only a fraction of potential savings. Similarly aquastats and temperature modulation controls can save energy but may be limited in their ability to maximize savings.

An important benefit of demand control systems is that they consistently provide hot water when tenants require it while still being able to realize savings when there is no demand. Maintaining tenant satisfaction is critical for any CDHW controls to remain installed and operating efficiently. For example, many multi-family building owners have installed controls such as time clocks in their CDHW systems and then bypassed them in response to tenant complaints about lack of hot water at various times. The ability of demand controls to consistently provide hot water when needed minimizes the risk that they will be bypassed in response to tenant complaints. Based on preliminary review and analysis through the ETP, the relatively low cost of demand control systems and their high potential energy savings suggests they are cost-effective and have attractive payback periods. The intent was to validate this through the ETP field-based pilot assessment.

### *Market overview*

Perhaps the largest barrier to implementation is in pump replacement opportunities. Prime targets for adoption are retrofit opportunities in existing buildings due to the large number in Nicor Gas service territory. However, existing pumps are placed well out-of-sight in boiler rooms and are typically only replaced upon failure. Landlords do not proactively replace them. Once the pump fails it becomes an emergency situation since tenants are lacking hot water. Speed becomes critical so the responding contractor replaces the existing pump with the quickest available option. The responding technician will use the pump he can obtain the fastest in order to satisfy the tenants. In such a situation there is little time to propose energy savings measures.

The on demand control system used by ETP for this pilot costs $1,500.00 with an estimated installation cost of $600.00. The total system cost to replace an existing pump is $2,100.00. This contrasts with a standard recirculation pump without controls at $400.00 for the pump and $500.00 for installation. The total installed cost of a standard system is $900.00. Therefore, the incremental cost of the demand based recirculation system over the standard is $1,200.00.

energySMART will need to address this issue by possibly providing some form of incentive to stock these on-demand pumps along with contractor training and supporting literature to upsell the more energy efficient product to the landlord at the time of replacement. Some form of preceding promotional campaign aimed at multi-family building owners and operators could also educate the target market in advance. Similarly, energySMART may want to emphasize early retirement options for existing continuous operation pumps. With promising low paybacks, offering the demand controls with a financial rebate could spur early replacement of working pumps thereby avoiding the emergency replacement issue.

## Objectives

The following objectives were established as the goal of this project:

- Validate gas (and electricity) savings
- Determine installation costs and best practices
- Validate the cost effectiveness
- Establish potential deemed savings value
- Develop early market contractor support

### *Research questions*

The following questions are intended to be answered by this project:

- Will the result of Benningfield Group report be duplicated in the Midwest?
- Is there a basis to normalize the savings, i.e. per boiler/water heater firing rate, DHW storage gallon, per apartment unit, etc.?
- Can any barriers to implementation be determined?
- How can Nicor Gas best implement this product as a therm savings measure through energySMART?

## Methodology

### *Experimental design and procedure*

ETP identified two vintage walk-up multi-family buildings in Nicor Gas territory with CDHW systems and dedicated return lines – multi-family building #1 and multi-family building #2 both within Nicor Gas service territory. Both buildings were owned and operated by the same management company. The details are below:

| | **Multi-family building #1** | **Multi-family building #2** |
|---|---|---|
| **Units** | 51 units, 3 stories | 23 units, 3 stories |
| **Boiler** | (1) Laars Mighty Therm<br>Model PW0500 | (1) Laars Mighty Therms<br>Model PW0325 |
| **Storage** | (2) 119 gallon tanks | (1) 119 gallon tank |
| **Insulated DHW pipe** | Yes | No |

The following relevant data was collected:
1. Domestic hot water boiler gas valve firing time
2. Recirculation pump run time
3. Domestic hot water flow rate (consumption)

The gas valve firing time was used with the nameplate input rating of the DHW bolier to determine gas consumption. The recirculation pump run time in conjunction with the pump input rating was used to determine electric usage.

ETP worked with a manufacturer  that makes on-demand control systems for multi-family/commercial applications to develop a data acquisition system (DAS) that was able to remotely transmit collected data on a daily basis.

### *Site requirements*

Each multi-family building site was required to meet the following criteria:

- Multifamily dwelling with at least 20 apartment units
- Central domestic hot water system with recirculation pump and loop
- Copper distribution pipe (to eliminate occluded pipe common with galvanized systems)
- Readily measureable DHW gas input (excludes modulating systems)

### *Installation and commissioning requirements*

The demand control system requires the existing recirculation pump be replaced and a flow switch be installed in the domestic cold water makeup line into the hot water heater. Additionally, two water meters, one for cold water makeup and one for the recirculation pump were installed at each site. The water meters were required for the pilot program data acquisition only; they are not required for operation of the demand control system. Since the installation of these items requires cutting into the potable water system, a licensed plumber is required to perform such work.

The new pump and flow switch need to be tied into a control box along with a return water temperature sensor. While outside the scope of what many plumbers perform, the instructions are clear and this work can be performed without formal training. At both sites, this work was performed by the licensed plumber executing the installation.

### *Analytical methods*

The on-demand recirculating pump was installed with an automatic switching timer for the pilot test period. This timer would switch the system from operating in demand mode to continuous mode (the pump running 24 hours a day, as it would under conventional, baseline conditions) on an alternating one week cycle. A weekly rather than daily cycle was selected since usage patterns vary significantly during weekdays vs. weekends. Additionally, weekly switching followed the protocol established in the Benningfield

Group study. Matching their switching protocol allows for comparison of datasets. This method was used to compare the savings between the on-demand mode being investigated and industry standard continuous operation.

The following relevant data was collected:

1. Domestic hot water heater gas valve firing time. This was recorded by measuring the time current flowed through the gas solenoid valve.
2. Recirculation pump run time. Like the gas valve, the time that current flowed through the pump motor was measured to determine run time.
3. Domestic hot water consumption. A flow meter with a reed switch was installed in the piping. Four pulses equals one gallon. Pulses were tallied and reported every fifteen minutes and the consumption was calculated.

The gas valve firing time was used with the nameplate input rating of the DHW bolier to determine gas consumption. The recirculation pump run time in conjunction with the pump input rating was used to determine electric usage. The rate of DHW consumption was measured to identify any trends and for normalizing purposes.

The gas valve and pump run times were documented as cumulative tallies. Therefore, the consumption for a given day is the difference between that day and the previous day.

The water flow measurement utilizes a reed switch which tallies 4 pulses per gallon. The data was gathered in 15 minute increments and that tally was recorded. The gallon flow rate per 15 minute increment is the number of pulses divided by 4. The gallon per hour flow rate is this number times 4. Therefore, the number of pulses equals the gallon per hour flow rate.

## Results

### *Installation and commissioning*

A local licensed plumbing contractor installed the necessary equipment at both sites. The on-demand controls manufacturer sent out a representative to assist ETP with the installation of the control panel and temperature sensor. The manufacturer verified proper installation of the system. Both multi-family sites were up and running on Thursday, December 4, 2012.

At multi-family building #1 the water meter measuring DHW consumption was non-operational upon installation. Delays in obtaining a replacement meter prevented measurement until February 14, 2013. The monitoring period was extended providing eight weeks of hot water flow data.

Switching from demand mode to continuous mode was intended to occur once a week, every Thursday. Unfortunately, switching errors occurred and at times switching did not occur properly. However, the data recorded was still large enough to provide an adequate sample. Multi-family building #1 recorded seven and a half weeks in demand mode and ten and a half in constant mode. Multi-family building #2 recorded ten weeks in demand mode and eight in constant mode. The initial goal was twelve total weeks of monitoring; six demand and six constant. The data collected exceeds those numbers.

The data was retrieved remotely via cellular modem. Occasionally the transmission failed and the data was lost or incomplete. Since the aggregate week was used in calculations, mid-week data loss did not affect calculations. When data loss occurred on a switching day, the missed data was averaged or extrapolated as necessary. The data set is large enough that the integrity of the calculations should not be affected.

Of utmost importance in this pilot project is that the tenants receive hot water as they were accustomed. To that end, the host site management company did not inform them of the change in recirculation system operation. The host site management company accurately records all tenant complaints for follow-up and resolution. Multi-family building #2 had no complaints concerning lack of hot water. Multi-family building #1 had three phone-in complaints due to excessive wait for hot water. Two of the complaints occurred when the pump was in constant mode and therefore are not attributed to the demand system. While one complaint did occur during demand mode, it was determined that all three complaints were caused by faulty shower mixing valves. The leaking valves led to bypass of the recirculation line preventing the system from operating properly.

### *Energy savings and economic performance*

The pilot project results were very positive. The two sites realized therm savings used for DHW of 28.2% and 19.9%, with simple payback periods of 1.46 and 1.06 years. Yearly therm savings at the two sites are expected to be 1,855 and 2,282 therms.

| | **Multi-family building #1** | **Multi-family building #2** |
|---|---|---|
| **Yearly gas savings therms** | 2,282 | 1,855 |
| **Yearly gas savings $** | $1,918 | $1,394 |
| **Yearly electrical savings kW-hr** | 725 | 578 |
| **Yearly electrical savings $** | $55 | $43 |
| **Total yearly cost savings $** | $1,973 | $1,438 |
| **Therm savings per apartment** | 44.75 | 80.64 |
| **Therm saving per input BTUH** | 0.004564 | 0.005299 |
| **Therm saving per storage gallon** | 9.58 | 15.59 |
| **Payback with a $2100 installation cost** | 1.06 years | 1.46 years |

### *Stakeholder acceptance*

The host site management company was impressed with the energy savings potential and is considering implementing this technology at more of their sites. Additionally, the effectiveness at which it continued to provide hot water, without complaints, further increased its appeal.

## Discussion and Conclusions

### *Implications for energySMART*

The strongest advantages of this technology lie in its ease of installation, rapid payback, and large therm savings throughout the territory. No formal training is required to install this system. Any plumber is capable of the pump installation and should be able to install the controls. Technical support is available, if necessary. Payback of between one and two years provides a very favorable return on investment. Finally, a deemed savings value can be readily obtained for the data obtained in this and the Benningfield Group pilot programs.

### *Lessons learned*

Multi-family building #1 had three distinct wings of the building, and three corresponding branches in the DHW return line. Installation requires the installation of a temperature sensor on the line in which the water takes the longest to return. In our original installation the wrong line was selected resulting in excessive wait time for one wing of the building. This was readily solved by relocating the temperature sensor. However, installing contractors must take care in properly selecting the correct branch.

The temperature sensor is hard wired to the control panel. The included wire has the sensor on one end and a molded plug on the other. At multi-family building #1 the wire was too short and longer wire needed to be spliced in. Installing contractors need to be prepared for such a possibility, or the manufacturer needs to offer longer line sensors.

### *Recommendations for further study*

Further discussion with knowledgeable parties needs to be conducted in order to determine the best route for program implementation in energySMART. Although the payback is short and the initial investment is low, Nicor Gas needs to overcome the fact that such recirculation pumps are only replaced upon failure. Additionally, while the therm savings per site are small, the potential savings throughout the territory is very attractive. A proactive measure needs to be created to facilitate product acceptance.

The Benningfield Group Report studied sites from 20 to 189 apartment units and our study sites fell within that range. Upon program rollout consideration should be placed on buildings larger and smaller than those. Perhaps energy consumption should be monitored at larger or smaller sites.

While this study was limited to multi-family residential buildings (and the manufacturer targets such structures as well) there is no reason to think that such a system would not be applicable in any CDHW system with a pumped recirculation loop that sees varied demand for hot water. Dormitories, 24-hour gymnasiums, laundromats, etc. can experience extended off periods but required random calls for hot water. Verifying suitability to other applications can increase therm savings.

Up for inclusion in the 2015 International Energy Conservation Code is the mandate that demand based recirculation be included in all buildings that require DHW recirculation. While this measure is yet to be voted on, and implementation is several years away, the application of this code needs to be monitored. Likely it will not apply to existing buildings, only new construction and substantial remodels. It is therefore unlikely to affect the large quantity of existing structures within Nicor Gas service territory. However, energySMART administrators will need to understand what impact future code changes may have on the rebate program.

## References

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*Emerging Hot Water Technologies and Practices for Energy Efficiency as of 2011*, revised February 2012, by Harvey Sachs, Jacob Talbot, and Nate Kaufman.

*Multifamily Central DHW and Solar Water Heating: 2013 California Building Energy Efficiency Standards*, October 2011 by California Utilities State Codes and Standards Team.

*Measure Information Template – Central Hot Water Distribution Systems in Multifamily Buildings: 2008 California Building Energy Efficiency Standards*, June 23, 2006 by the Heschong Mahone Group.

Nicor Gas Annual Report, 2010.
http://bib.kuleuven.be/files/ebib/jaarverslagen/NICOR_2010.pdf

*United States Census 2010* online map, www.census.gov/2010census/popmap.

Multifamily Rental Housing Inventory in Cook County Municipalities, 2010, Institute for Housing Studies, DePaul University.

Service Territory Baseline and Energy Efficiency Market Potential Study for Nicor Gas, August 2010 by 2010 Bass and Company Management Consultants, LLC.

## Appendix A: Detailed analyses of energy savings and economic performance

Upon request, GTI can provide:

1. The abbreviated dataset summary for the Navigant PY2 impact evaluation
2. The full detailed dataset from the two pilot sites

## Appendix B: Excerpts from end user survey and results

This survey was provided to the host site manager. The first 6 questions have been removed due to the sensitive nature of information they contained about the host sites. The remaining questions focused on satisfaction with the project, impressions of the results of the pilot, and interest in continued participation with the Nicor Gas ETP. The ETP questions are noted in black, with the host site's responses marked in blue.

7. How did you first hear about this pilot opportunity with the Nicor Gas Emerging Technology Program?

I was contacted through representatives of Nicor Gas Programs that had been previously working with through other energy programs.

8. What motivated you to participate?

The information gathered from the testing along with the incentive of free pump. The testing knowledge was a very large component though.

9. What did you think of the Nicor Gas ETP pilot process?

The program was a large success and worked smoothly with minimal errors or inconveniences. The data collected seemed to cover every aspect of the system. I don't think anything was overlooked at all.

10. Has your participation in this Nicor Gas ETP pilot benefitted your company? How?

The pilot gave the company the knowledge behind the pumping system to accurately plan paybacks at other buildings. It also allowed us to find any flaws the pump might have caused.

11. Would your management company consider participating in the Nicor Gas Emerging Technology Program again in the future?

[We] would be very interested in on going participation with the Emerging Technology Program.

12. Any other comments or feedback you'd like to share?

I just wanted to thank everyone that worked in the properties. They were all professional and willing to pass knowledge along. Special thanks to Tom for heading the project and coordinating everything to make it a seamless project.