Nicor Gas Emerging Technology Program

1036: Commercial Dryer Modulation Retrofit

Public Project Report

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Pilot Summary
Natural Gas & Electricity
#1036 Commercial Dryer Modulation Retrofit

Technology Concept/Rational:

1. Majority of commercial gas clothes dryers have one burner firing rate.
2. Exhaust temperature sensor regulates the on/off operation of the burner.
3. In initial drying stages, the single firing rate is properly sized for highest heat settings.
4. In later drying stages, less heat is needed and the firing rate is now oversized.
5. As a result, burner cycles on/off frequently, with less efficient drying and wasted gas.

Adding modulating capabilities allows the firing rate to adjust to the changing heat demand. The piloted technology is a two stage modulating gas valve retrofit kit to convert a standard non-modulating dryer to a modulating dryer. The installed cost is about $525 per dryer.

Target Market Summary: Target markets are the commercial and institutional sectors, such as:

- Laundromat
- Dry cleaning
- Hospitality
- Healthcare

Any other facilities with on premise laundry may be a suitable fit, such as health clubs or multi-family housing. These facilities have commercial dryers with capacities between 30 and 250 pounds and typically no modulating capabilities.

Test Site Summary: The technology was evaluated at 5 pilot sites on a total of 11 dryers to account for savings from a variety of targeted market end uses and dryer capacities.

- 2 hotels (50-150 lb. dryers), 4 monitored dryers
- 1 laundromat (30-70 lb. dryers), 4 monitored dryers
- 1 healthcare facility (50-150 lb. dryers), 2 monitored dryers
- 1 dry cleaner (30-70 lb. dryers), 1 monitored dryer

Test Methodology: The gas savings were derived by comparing monitored data from:

- 3 months of non-modulating, baseline dryer operation
- to 3 months of modulating dryer operation at each site (long-term monitoring)

A standardized test was also conducted at each site with the dryers operated in non-modulating and modulating modes while drying the exact same laundry load.

Cost Assumptions:

Installed cost per dryer:	$525
Natural Gas cost per therm:	$0.725/therm
Electricity cost per kWh:	$0.075/kWh

Pilot Results: Results from the pilot are summarized in the table below based on the findings from 8 of the 11 dryers, with 3 dryers being excluded due to baseline equipment issues.

	Long-Term Monitoring	Standardize Test
Average Annual Gas Savings	333 therms	286 therms
% Annual Gas Savings	13.8%	12.4%
Average Annual Electric Savings	N/A	N/A
% Annual Electric Savings	N/A	N/A
Annual Cost Savings	$250	$215
Payback Period	2.10 years	2.44 years

EEP Potential: The pilot demonstrated around 300 therms on average of annualized gas savings per dryer resulting from the retrofit of the gas modulation technology. In practice at the pilot sites, the gas savings were more dependent on the number of dryer cycles (loads of laundered items that are dried and the resulting gas use) and not the dryer size. For implementation as a measure in an energy efficiency program, it may be best to provide a flat rebate per dryer based on the average gas savings as opposed to a rebate based on the capacity of the dryer.

Key adoption barriers and their respective solutions are highlighted below:

1. Voiding of dryer warranty: Addition of non-original equipment manufacturer parts can void the dryer warranty, which usually covers the first 3 years. Since the typical equipment life is 10-15 years, there is still ample time for an attractive payback.
2. Emerging status: Most laundries have never seen a conversion technology like this before and may be hesitant to adopt it. Education and outreach, including sharing results and experiences from early adopters will ease concerns about efficacy and reliability.
3. Equipment and safety standards: The retrofit nature of this technology isn't directly covered by prevailing new equipment standards. And even if the retrofit was compliant with the necessary standards, standards organizations and/or code authorities could still require additional tests of the retrofit on particular gas dryer models. Nicor Gas should encourage the manufacturer to engage with code officials in their target markets to obtain guidance and approval. Additionally, when each dryer is retrofitted, the installing contractor should verify the flame and combustion are stable. It might also be appropriate for the installing contractor to conduct an emissions test to verify good combustion below the required carbon monoxide ppm threshold.

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Executive Summary

Background

The majority of commercial, gas clothes dryers have only one burner firing rate. A temperature sensor in the dryer exhaust regulates the on/off operation of the burner to meet the drying cycle settings ranging from low to high heat (low to high temperature).The single firing rate for the burner is sized large enough to warm up the clothes and drive off moisture quickly during the initial stages of drying at the highest heat (temperature) setting. In the later stages of drying that firing rate is oversized, since not as much heat is needed when there is not as much moisture remaining in the clothes. The burner must then turn on/off frequently. This can result in less effective drying of the clothes as the temperature fluctuates along with the significant waste of gas during the repeated thermal cycling. Adding modulating capabilities to the gas dryer allows the firing rate to adjust to the changing demand for heat over the drying cycle.

There are modulating dryers available directly from laundry equipment manufacturers, but that would require a large capital investment by users to replace their existing non-modulating dryers. The manufactured product utilized in this pilot is a modulating (actually two stage) gas valve retrofit kit with an installed cost around $525 per dryer, that converts a standard non-modulating dryer to a modulating dryer. Initial demonstrations by the manufacturer indicate up to 40% savings on dryer gas use.

The target market for this new technology is the commercial/institutional sector, specifically laundromat, dry cleaning, hospitality, and healthcare facilities. Additionally, any other facilities with on-premise laundry (OPL) may be a suitable fit, such as a health clubs or multi-family housing. These facilities often have commercial dryers with capacities between 45 and 250 pounds (lbs.) with no modulating capabilities typically.

Results

The modulating dryer technology was evaluated at 5 pilot sites to account for savings from a variety of targeted market end uses and dryer capacities. The monitored data from the pilot sites showed an overall trend of gas savings with the technology. The gas savings were derived by comparing monitored data from 3 months of non-modulating, baseline dryer operation to 3 months of modulating dryer operation. Overall the results show an average, annualized gas savings per dryer of 13.8%, equating to 333 therms. At $0.752/therm cost for gas, that yields $250 in annual cost savings and a 2.10 year payback at an installed cost of $525 for the dryer modulation retrofit technology.

In addition, a standardized test was conducted at each site with the dryers operated in non-modulating and modulating modes while drying the exact same load of laundry. On average, the results were very similar to the long-term monitoring with an average, annualized gas savings of 12.4%, equating to 286 therms. At $0.752/therm cost of gas, that yields $215 in annual cost savings and a 2.44 year payback at an installed cost of $525 for the dryer modulation retrofit technology.

Project Background

Project Overview

This pilot assessment evaluated the potential gas savings from the conversion of standard, non-modulating, commercial gas clothes dryers with on-off operation of a single, high firing rate burner to a modulating (two stage) burner operation with high and low firing rates. This emerging retrofit technology comes in a kit form that allows a single stage gas valve to be replaced in an existing dryer with a two stage gas valve and associated controls to provide the low fire and high fire burner operation.

The Nicor Gas Emerging Technology Program (ETP) applied these retrofit kits in an evaluation of the technology at 5 pilot sites covering a variety of targeted market end uses and dryer capacities. Pilot sites included 2 hotels (50-150 lb. dryers), 1 laundromat (30-70 lb. dryers), 1 healthcare facility (50-150 lb. dryers), and 1 dry cleaner (30-70 lb. dryers). Two dryers were monitored per site, with the exception of the laundromat, where 4 dryers were monitored, and the dry cleaner, where 1 dryer was monitored. In all, 11 dryers were monitored. Monitoring was conducted for 3 months of non-modulating, baseline dryer operation and 3 months of modulating dryer operation. In addition, a standardized test was conducted at each site where the dryers were operated in non-modulating and modulating modes while drying the exact same load of laundry.

Previous Study Results

There appear to be no other previous, independent third party studies that have been completed to date on this modulating dryer valve retrofit. On the manufacturer's website it is claimed to achieve "average energy savings of 15% to 25% (often more, depending on local conditions)". The manufacturer has conducted some of its own demonstrations of the technology that show the following energy savings:

- Hotel Large Chain – 42.5%
- Laundromat – 25+%
- Rehabilitation Center – 33%

Technology and Market Overview

The investment of $525 per dryer for the installed cost of this technology is estimated to pay back in less than 3 years, so it could achieve widespread market adoption based on its economics alone. The manufacturer expects to get the installed cost down to $475 once the market has matured with higher production levels, product cost reductions, and installing contractor experience. After installation, the technology should not require any incremental maintenance by the end user for the life of the dryer. However, installation would most likely occur after the original warranty coverage has expired since this retrofit could void the dryer manufacturer's warranty if installed. Most warranties usually cover only the first 3 years, so the typical commercial dryer life expectancy of 10 to 15 years (depending on duty cycles and maintenance levels) still provides ample time for an attractive return on this investment.

However, there are significant barriers to the adoption of this technology due to its emerging status, retrofit nature, and uncertain standard/code treatment. Most end users in the commercial/institutional laundry sector have never seen a conversion technology like this before. They may be hesitant to adopt it given the lack of familiarity as well as the uncertainty regarding the technology and its ability to provide the intended gas modulation and resulting savings for their dryers. Perhaps the greatest barrier though will be its treatment by standard organizations and code authorities.

Making changes to an original equipment manufacturer (OEM) burner system (gas train) raises potential safety and liability issues. Are the burners still operating within their original certified specifications over the modulating gas flow range (high to low fire); do the burners perform acceptably at low fire under existing high fire combustion airflow; and are there any issues with altered combustion performance and emissions at low fire? Generally, burner systems are designed for a specific firing rate and excess air ratio, and then are tested to certify their performance and safety under those conditions. Changing the firing conditions could raise concerns about the need to prove standard/code performance and safety of the gas train with each OEM dryer. Although it is worth noting that OEM dryer burners must already handle changes in excess air ratios as venting issues (lint buildup, clogging, etc.) could lead to variances in airflow and combustion processes under normal operation.

As indicated, the retrofit nature of this technology falls into something of a gray area not directly covered by the prevailing new equipment standards. The American National Standards Institute (ANSI) is the governing organization that oversees a wide range of equipment standards, including those for gas valves and gas clothes dryers. ANSI Standard 21.21 Automatic Valves for Gas Appliances [ANSI 2012] provides “a basic standard for safe operation, substantial and durable construction, and acceptable performance of automatic valves for gas appliances.” The standard states it “applies to newly produced automatic valves … [however] compliance of an automatic gas valve with this standard does not imply that the automatic valve is acceptable for use on gas appliances without supplemental tests with the automatic gas valve applied to the particular appliance design.” So even if the manufacturer provides an ANSI Standard 21.21 compliant modulating (two stage) gas valve, standard organizations and/or code authorities could still require additional tests of its full retrofit kit to particular gas dryers.

Presently, the modulating valve retrofit kit provided by the participating pilot manufacturer has not been certified with individual dryers, but the gas valve itself has been certified under the applicable ANSI standard. None of the OEM dryer standard safety features are bypassed by the modulating (2 stage) valve retrofit. The high fire rate is the same as originally designed on the dryer and the addition of the low firing rate is the only difference in operation. It is anticipated that with an atmospheric (not premixed) burner system, additional excess air will not cause combustion problems. When the dryer is retrofitted, the installing contractor should verify that the flame and combustion are stable. It might be appropriate to recommend the installing contractor also conduct an emissions test to verify good combustion below the carbon monoxide (CO) ppm threshold required under the applicable ANSI standard.

The gas dryer OEMs themselves have their factory built products comply with ANSI Standard Z21.5.1 Gas Clothes Dryers – Volume 1, Type 1 Clothes Dryers [ANSI 2011] and/or ANSI Standard Z21.5.2 Gas Clothes Dryers – Volume 2, Type 2 Clothes Dryers [ANSI 2013]. Both of these standards provide "a basic standard for safe operation, substantial and durable construction, and acceptable performance of gas dryers" that are "factory-built packages, multiply produced", including the original automatic gas valve in the factory packaged dryer. Type1 gas dryers are intermittent duty appliances used in residential homes or multifamily buildings. Type 2 gas dryers are continuous duty appliances with public interface directly or through a hired attendant at the commercial/institutional OPL. Incorporation of a modulating burner and associated controls by OEMS in their factory built gas dryers would provide a direct pathway to standard compliance through ANSI standards Z21.5.1 and Z21.5.2.

At this time, the modulating dryer technology is a retrofit technology only available from the participating pilot manufacturer. However, new modulating dryers are becoming available directly from some dryer OEMs in the very large commercial or industrial market (>250 lb. capacity dryers), but at relatively high equipment cost. Although gas modulation has been around for decades in various appliances such as boilers and furnaces, and the technology itself is very mature, its application in clothes dryers is a more recent trend.

Objectives

The following objectives were established as the goals for this pilot project:

- validate gas savings
- determine cost effectiveness with estimated simple paybacks
- establish a dataset for generation of deemed savings value
- demonstrate the product in the field for the local market
- develop early market contractor support

Research Questions

The Following additional question was identified for this project:

- Are there any electricity consumption impacts – decrease or increase – due to this technology?

Methodology

Experimental Design and Procedure

A total of 5 pilot sites with 11 dryers in all were monitored, consisting of: two hotels with two 170 lb., one 120 lb. and one 75 lb. dryers; one laundromat with two 45 lb. and two 30 lb. dryers); one healthcare (nursing home) facility with two 75 lb. dryers; and one dry cleaner with one 50 lb. dryer. Table 1 lists the 5 pilot sites and the dryers that were monitored at each site.

The gas and electric usage of the dryer, number of dryer cycles, and dryer room makeup air temperature were monitored. The data was collected by a Logic Beach datalogger which recorded the energy usage, cycle count, and temperature every minute. The data was accessed remotely with a cell modem to periodically download the data and to look live at the sensor readings. One (1) month of baseline monitoring was conducted prior to the installation of the modulating dryer retrofit kit. Then 3 months of monitoring was conducted after the retrofit. It was determined during the monitoring that the dryer room makeup air temperature was largely influenced by the temperature of the outdoor air, which is the source of inlet air for the dryer. This in turn had a large effect on the gas energy usage as a result of greater heat input needed at lower dryer inlet temperatures. So an additional 2 to 3 months of baseline monitoring was conducted after the conclusion of the modulating dryer monitoring. At that time the dryers were placed back into baseline mode and operated at their original high firing rate. This revised approach provided months of data for comparable operating conditions where the dryer room makeup air temperature for the baseline dryer monitoring was similar to the months of data for the modulating dryer monitoring.

Site, Installation, and Commissioning Requirements

The selected site was required to meet the following criteria:

- site is representative of the target markets for this technology
- gas fired commercial clothes dryers are on site
- site owners/operators will allow dryer retrofits and installation of data acquisition equipment for baseline and modulating dryer monitoring periods

Table 1: Dryer Pilot Site and Dryer Make/Model List

	Dryer #1	**Dryer #2**	**Dryer #3**	**Dryer #4**
Hotel Site #1	170 lb – UniMac Model #UT170NRMF6 G1W01	170 lb – UniMac Model #UT170NRMF6 G1W01		
Hotel Site #2	120 lb – UniMac Model #UT120NRMF6 G1W01	75 lb – UniMac Model #UTF75NRMF6 G1W04		
Healthcare Site	75lb -Huebsch – Model #HTO75EQTB1 G1W01	75lb -Speed Queen – Model #STB75CG		

Laundromat Site	30lb - Huebsch Model #STT45NBCG2G2N03	30lb - Huebsch Model #STT45NBCG2G2N03	45 lb -Speed Queen Model #STT45NBCG2G2N03	45 lb -Speed Queen Model #STT45NBCG2G2N03
Dry Cleaner Site	50lb – Cissell Model #CT050NQTB1G1W01			

Analytical Methods

In baseline mode the gas usage was calculated by monitoring the dryer gas valve on time with a current switch and multiplying by the nameplate (high) firing rate of the dryer. For the modulating dryer valve both the high fire and low fire on times were monitored with separate current switches. The low firing rate was determined by measuring the manifold pressure setting of the gas valve with a digital manometer and using the following flow calculation:

New (Low) Firing Rate (Btu/hr) $Q_N = Q_O * \sqrt{(P_N/P_O)}$

Where Q_N = *Low Firing Rate (Btu/hr)*

Q_O = *High Firing Rate (Btu/hr)*

$\sqrt{}$ = *Square Root*

P_N = *Low Firing Rate Manifold Pressure (inch water column – "WC)*

P_O = *High Firing Rate Manifold Pressure (inch water column – "WC)*

A diagram of the monitoring equipment is provided in Figure 2 and a list of the instrumentation is provided in Table 2 . Referring to Figure 2, as explained before, two current switches were used to monitor the retrofitted modulating (low and high fire) gas valve. The makeup air temperature in the dryer room was monitored with a thermocouple to allow comparisons between baseline and modulating monitoring data at similar dryer room makeup air temperatures. Data collected at a lower makeup air (lower outdoor air) temperature will show a higher gas use for the dryer as a result of the greater heat input needed at the lower dryer inlet temperature.

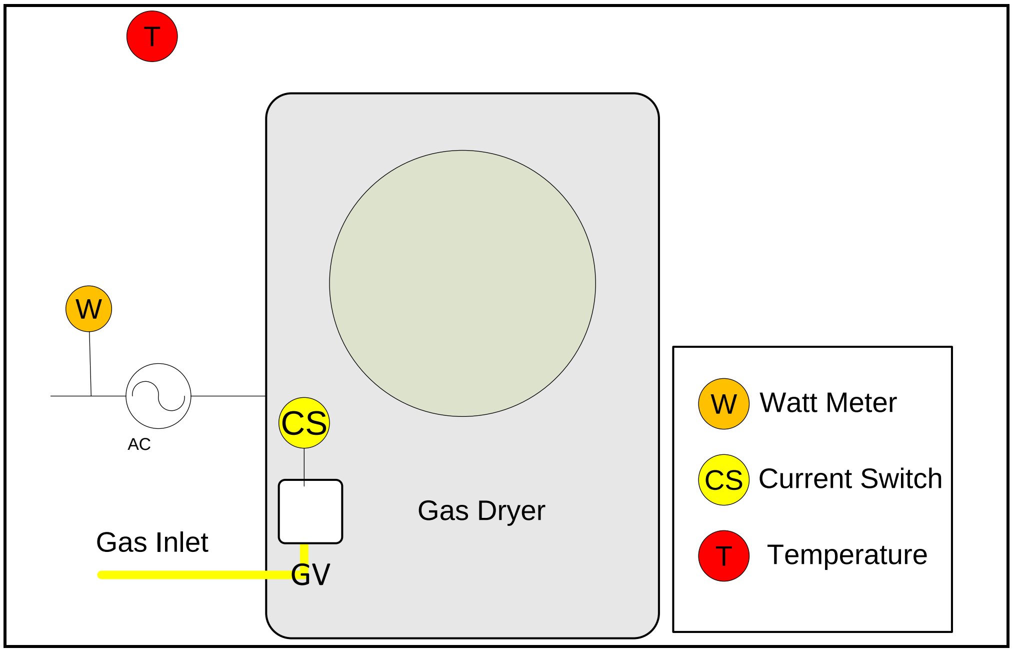

Figure 1: Data Collection Monitoring Diagram

Table 2: Data Collection Monitoring Equipment

Sensor	Description	Equipment	Manufacturer/Model	Accuracy	Webpage link
T	Dryer room makeup air temp	Thermocouple	Omega / 5TC-TT-T-24-72	± 1 ^{o}F	http://www.omega.com/Temperature/pdf/5TC.pdf
W	Dryer electric use	Watthour Meter	Continental Controls/ WNB-3D-240-P	± 1%	http://www.ccontrolsys.com/w/Advanced_Pulse_WattNode
CS1	Dryer gas use –	Current Switch	Setra/ CSCGFN015NN	-	http://www.setra.com/ProductDetails/CSC_HVAC.htm
Data Logger	Records and sends data for dryers	Intellilogger	Logic Beach / IL-80		http://www.logicbeach.com/
Cell Modem	Connects logger to internet	Cell Modem	Sierra Wireless / Raven XE		http://www.sierrawireless.com/

For this long term monitoring, the percent gas savings was determined for each individual dryer by comparing gas use of the baseline dryer operation to modulating dryer operation for month long periods with comparable average dryer room makeup air temperature conditions. Once the percent gas savings was determined, an annual therm savings was estimated for each individual dryer based on the gas use and number of dryer cycles seen in the long term monitoring which were extrapolated to a full year of operation.

Table 3: Standard Test Loads

	Dryer #1	Dryer #2	Dryer #3	Dryer #4
Hotel Site #1	101 lb wet, 61 lb dry Rags/Mops	164-179 lb wet, 92-93 lb dry Hotel Towels		
Hotel Site #2	29-30 lb wet, 21 lb dry Hotel Sheets	29-30 lb wet, 17 lb dry Hotel Towels		
Healthcare Site	42-43 lb wet, 27 lb dry Misc. Clothes	35-36 lb wet, 24 lb dry Misc. Clothes		
Laundromat Site	16 lb wet, 8 lb dry Cotton towels	16 lb wet, 8 lb dry Cotton towels	24 lb wet, 12 lb dry Cotton Towels	24lb wet, 12 lb dry Cotton Towels
Dry Cleaner Site	15 lb wet, 9 lb dry Cotton towels			

In addition to the long term monitoring, a more standardized, short term test was also conducted where the exact same load of laundry was washed and dried twice, once in baseline dryer mode and once in modulating dryer mode. Although the load was washed in the exact same washer there is still some variance in the moisture content of the clothes between each drying. This was accounted for by measuring the Btus of gas used per lb of moisture removed during the drying process. The clothes were weighed before and after drying for each mode. The load size was varied with each dryer and its respective capacity. For the laundromat and dry cleaner, a standard load of plain white cotton towels was laundered. At the hotels and healthcare site, the load that was being laundered at the time of the short term test was just washed again. The loads dried in the standard test are provided in Table 3. Once the percent gas savings was determined from this short term test, an annual therm savings was estimated based on the number of dryer cycles from the long term monitoring annual gas usage calculation.

Results

Installation and Commissioning

Per the monitoring equipment listed in Table 2, electric meters were installed at the pilot sites by Climate Pros, a local HVAC and plumbing contractor, and the current switches and thermocouples were installed by ETP staff. All of the sensors were connected to the data logger by ETP staff. Pictures of the dryers at all 5 sites are provided in Figure 3 - Figure 7.

Figure 2: Hotel Site #1 Dryers

Figure 3: Hotel Site #2 Dryers

Figure 4: Healthcare Facility Dryers (2 on left were monitored and retrofitted)

Figure 5: Laundromat Dryers (2 leftmost and 2 rightmost dryers were monitored and retrofitted)

Figure 6: Dry Cleaner Dryer (right dryer was monitored and retrofitted)

Energy Savings and Economic Performance

Table 4 shows the annualized results from the long term monitoring of the 11 dryers at the 5 pilot sites. The monitored data showed an overall trend of gas savings with the modulating retrofit technology. The gas savings were derived by comparing monitored data from 3 months of non-modulating, baseline dryer operation to 3 months of modulating dryer operation. Overall the results show an average, annualized gas savings per dryer of 13.8%, equating to 333 therms. At $0.752/therm cost for gas, that yields $250 in annual cost savings and a 2.10 year payback at an installed cost of $525 for the dryer modulation retrofit technology.

Table 5 shows the annualized results from the short term, standardized testing that was conducted at each site with the dryers operated in non-modulating and modulating modes while drying the exact same load of laundry. On average, the results were very similar to the long-term monitoring with an average, annualized gas savings of 12.4%, equating to 286 therms. At $0.752/therm cost of gas, that yields $215 in annual cost savings and a 2.44 year payback at an installed cost of $525 for the dryer modulation retrofit technology.

Some issues were encountered in both the long term monitoring and short term, standardized testing that affected the calculations of these average gas savings outcomes.

At the Dry Cleaner site, originally both dryers shown in Figure 7 were to be monitored but Dryer #1 was found to be in need of significant maintenance to provide reliable operation, so it was dropped from consideration and only Dryer #2 was monitored.

Table 4: Long Term Monitoring Annualized Results

Site	Dryer	Annual Gas Use Baseline (therms)	Annual Gas Use Modulation (therms)	Annual Gas Savings (therms)	Annual Gas Savings (%)	Annual Cost Savings	Payback (years)	Dryer Size (lb)
Dry Cleaner	Dryer #2	2,410	2,373	37	1.5%	$27.60	19.02	50
Healthcare Site	Dryer #1	4,738	4,176	562	11.9%	$422.46	1.24	75
	Dryer #2	4,519	4,222	298	6.6%	$223.97	2.34	75
Hotel #1	Dryer #1	2,678	2,668	10	0.4%	$7.44	70.52	170
	Dryer #2	4,011	3,619	391	9.8%	$294.25	1.78	170
Hotel #2	Dryer #1	Inconsistent results						120
	Dryer #2	2,354	2,267	87	3.7%	$65.42	8.02	75
Laundromat	Dryer #1	1,903	1,697	205	10.8%	$154.50	3.40	30
	Dryer #2	1,163	1,007	155	13.4%	$116.81	4.49	30
	Dryer #3	2,035	1,321	714	35.1%	$536.97	0.98	45
	Dryer #4	1,320	1,070	249	18.9%	$187.51	2.80	45
Average				**333**	**13.8%**	**$250.24**	**2.10**	

Dry Cleaner had pressure supply problem where the supply pressure to the dryer would vary and make results unreliable
Dryer was found later to have low pressure less than 1" WC on low fire (when it had been set at 1.45" WC)
Dryer was found to have a flame sense problem later where it would shut off the dryer when low fire was engaged

Table 5: Short Term, Standardized Testing Annualized Results

Site	Dryer	Annual Gas Use Baseline (therms)	Annual Gas Use Modulation (therms)	Annual Gas Savings (therms)	Annual Gas Savings (%)	Annual Cost Savings	Payback (years)	Dryer Size (lb)
Dry Cleaner	Dryer #2	2,410	2,265	145	6.0%	$109.28	4.80	50
Healthcare Site	Dryer #1	4,738	4,678	60	1.3%	$45.25	11.60	75
	Dryer #2	-	-	-	-	-	-	-
Hotel #1	Dryer #1	2,678	2,613	65	2.4%	$48.53	10.82	170
	Dryer #2	4,011	3,255	755	18.8%	$567.92	0.92	170
Hotel #2	Dryer #1	1,384	1,392	-8	-0.6%	-$6.24	Never	120
	Dryer #2	2,354	2,219	135	5.8%	$101.79	5.16	75
Laundromat	Dryer #1	1,903	1,728	174	9.2%	$131.07	4.01	30
	Dryer #2	1,163	1,019	144	12.4%	$108.10	4.86	30
	Dryer #3	2,035	1,425	610	30.0%	$458.83	1.14	45
	Dryer #4	1,320	1,199	121	9.2%	$90.90	5.78	45
Average				**286**	**12.4%**	**$214.84**	**2.44**	

Dry Cleaner had pressure supply problem where the supply pressure to the dryer would vary and make results unreliable
Dryer was found later to have low pressure less than 1" WC on low fire (when it had been set at 1.45" WC)
Dryer was found to have a flame sense problem later where it would shut off the dryer when low fire was engaged

Later, it was determined that Dryer #2 was subject to inconsistent gas pressures, with the supply pressure dropping severely at times, most likely due to another operation on site using a large amount of gas. With inconsistent gas pressures, the long term monitoring was determined to be inaccurate because gas use was calculated based on the gas valve on time and needs a consistent pressure to provide accurate gas flow. The data is highlighted in orange in both Table 4 and Table 5 and was excluded from the average gas savings calculation.

The short term, standardized testing on Dryer #2 at the Healthcare Site was performed incorrectly when the washed load in each mode was dried for different amounts of time. So those results were not used and not included in Table 5.

Dryer #1 at Hotel #1 showed very little gas savings in the long term monitoring and a longer payback period in the short term, standardized testing. The site was visited by ETP and manufacturer staff after the monitoring and it was found that the gas pressure on low fire had been reduced to under 1" WC when it had been set at 1.45" WC initially. How the gas pressure was changed has not been determined, but gas pressures over time are normally very consistent once they are set initially on the valve. This change in pressure makes the data inaccurate as the amount of gas used during the testing is dependent on the assumed gas pressure and it is uncertain when the pressure was changed. The data was marked in yellow in both Table 4 and Table 5 and was excluded from the average gas savings calculation.

Dryer #1 in Hotel #2 showed inconsistent results in the long term monitoring that did not provide adequate data for trend analysis due to variances in dryer cycles and resulting gas usage during comparable periods of dryer room makeup air temperatures. This site was also visited by ETP and manufacturer staff to determine what the nature of the problem. The visit found that the dryer was having a problem with the flame sensor. When the dryer would switch to low fire the flame sense would lose the signal and shut the gas valve off. This was fixed by cleaning and repositioning the flame sense, but the monitoring/testing data was not accurate do to this problem and was not used in the average gas savings calculation. The data is highlighted in red in both Table 4 and Table 5.

Despite these problems on site, the modulating dryer retrofit did show average gas savings sufficient for paybacks periods in the 2 -3 year range. More detailed tables of these results can be seen in Appendix A: Detailed Analyses of Energy Savings and Economic Performance. It should be noted that although the detailed tables show the electric usage, there was basically no difference between dryer electric energy use before and after the modulating retrofit. Some dryers showed slightly higher electric use and some dryers slightly lower electric use, with no clear, consistent, or significant trend showing a decrease or increase in electric use.

Stakeholder Acceptance

In general test sites were happy with the modulating dryer operation and users did not notice any differences in the laundering processes with the modulating dryers. Completed end user surveys are in Appendix B: End User Survey and Results.

Discussion and Conclusions

Implications for Nicor Gas Energy Efficiency Programs

The pilot demonstrated around 300 therms on average of annualized gas savings per dryer resulting from the retrofit of the modulation technology. In practice at the pilot sites, the gas savings were more dependent on the number of dryer cycles (loads of laundered items that are dried and the resulting gas use) and not the dryer size. In Figure 8, the annualized gas savings for the 8 dryers used to calculate the average gas savings in Table 4 (non-colored data rows) are plotted versus their respective dryer capacity. The plot shows significant diversity in the potential annual therm savings for a given capacity dryer. For instance, the 75 lb capacity Dryer #2 at the Healthcare Site used more therms annually than the 170 lb Dryer #2 and Hotel #1.

For implementation as a measure in an energy efficiency program, it may make the most sense to provide a flat rebate per dryer based on the average gas savings as opposed to a rebate based on the capacity of the dryer.

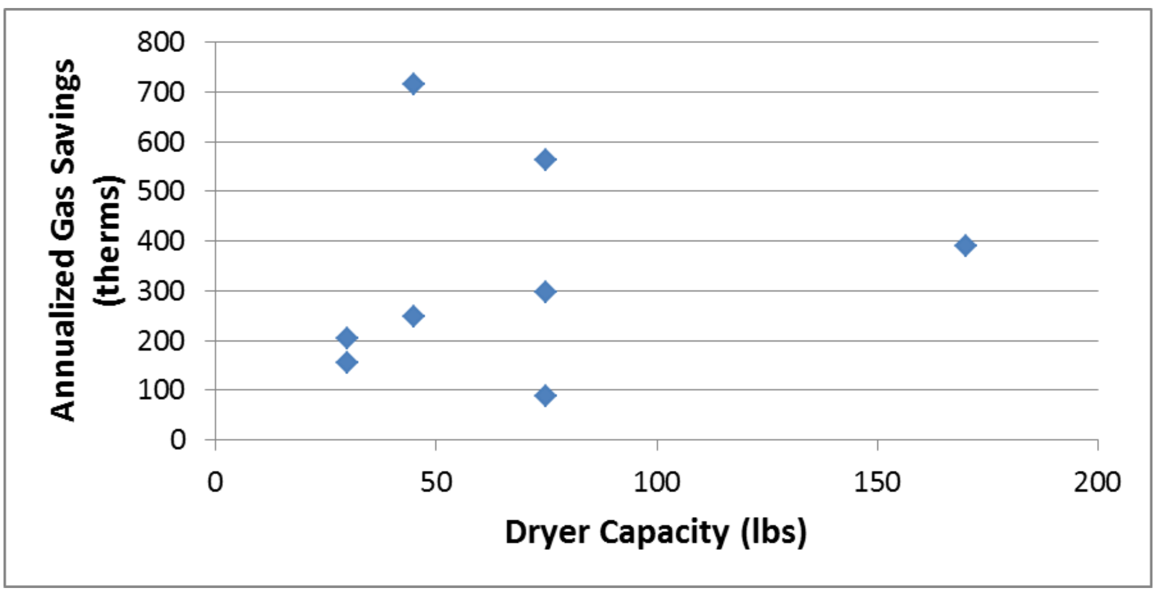

Figure 7: Annualized Gas Savings versus Dryer Capacity

Lessons Learned

It became apparent during the testing that the outdoor air temperature was having a large effect on the energy usage patterns of certain dryers. As outdoor air temperature decreases, the makeup air in the dryer room is cooler and needs to be heated more to dry the laundered items. The monitoring began with baseline operation in the Fall with very moderate temperatures and then shortly after the modulating operation was initiated, outdoor temperatures plummeted. This led to the need to conduct additional baseline monitoring after the modulating monitoring period was completed so that similar outdoor air temperatures could be compared. Both hotels had very small dryer access rooms with a lot of makeup air and the effect of colder outdoor temperatures was greatest for those sites. The dry cleaner had their dryers installed in a very large open room and the temperature did not vary much. For the healthcare site and Laundromat, small temperature differences were seen but they didn't seem to have a large effect on the gas usage. The laundromat seemed to stay relatively warm most likely do to the fact that so many dryers were in operation with significant heat spilling over into the dryer room. The healthcare site seemed to stay relatively warm even in the winter.

Recommendations for Further Study

Gathering additional gas savings data from dryers retrofitted with modulation capability in the future would help better quantify the range of savings and the average savings for various capacity dryers. That additional information would in turn lead to a more robust basis for a deemed savings to further facilitate establishment of a prescriptive measure. This additional data could possibly be gathered as part of early rebated installations under the Nicor Gas Energy Efficiency Program.

Additional field work by other researchers to establish the effect of outdoor temperature on the gas usage of dryers in general would be helpful in understanding the role that makeup air plays in the gas usage patterns of dryers in different building end use applications as well.

References

ANSI 2011. ANSI Standard Z21.5.1 Gas Clothes Dryers – Volume 1, Type 1 Clothes Dryers. American National Standards Institute (ANSI). Washington, D.C. www.ansi.org.

ANSI 2012. ANSI Standard 21.21 Automatic Valves for Gas Appliances. American National Standards Institute (ANSI). Washington, D.C. www.ansi.org.

ANSI 2013. ANSI Standard Z21.5.2 Gas Clothes Dryers – Volume 2, Type 2 Clothes Dryers. American National Standards Institute (ANSI). Washington, D.C. www.ansi.org.

United States Census Bureau, 2012 County Business Patterns: http://censtats.census.gov/cgi-bin/cbpnaic/cbpdetl.pl.

Appendix A: Supporting Data Spreadsheets

The complete summaries of the monitoring datasets and accompanying statistical analysis for the 5 pilot sites are contained in the Excel workbook "**1036 Dryer Modulation Retrofit Therm Savings for Nicor Gas ETP 9-16-14.xlsx**" that has been provided as a companion electronic deliverable with this report.

Of note in the companion analysis, it was previously indicated in the main body of this report that the makeup air (outdoor air) temperature had a large effect on the gas savings of both of the hotel sites. So for the hotel sites, the gas use per minute of dryer on time was graphed versus the makeup air temperature to show a very clear pattern of gas use with varying makeup air (outdoor air) temperatures. This data was then used with the average monthly outdoor temperature in the area to estimate annual gas usage and savings. Hotel #1 showed a very clear, statistically valid trend for gas use versus makeup air (outside air) temperature for both baseline and modulating mode. Hotel #2 showed a statistically valid trend for dryer #2, but dryer #1 had inconsistent data during modulating operation that could not be used further in the analysis. The inconsistent data was most likely caused by the flame sensing problem noted for dryer #1 that was discovered after the monitoring was complete.

To establish annualized gas use and savings for the two hotel sites, linear regression curve fits of gas use versus makeup air (outdoor air) temperature were utilized. The other sites were subjected to less variation in makeup air temperature, so data from similar months of dryer room makeup air temperatures, with and without dryer modulation, were used to establish annualized gas use and savings. The healthcare site baseline monitoring had a problem with the data acquisition equipment and only 8 days of baseline data were used rather than a month as originally planned.

Hotel #1 Survey

Nicor Gas Emerging Technology Program

July 18, 2014

Thank you so much for participating as a host site for the Nicor Gas Emerging Technology Program pilot for Modulating Dryer systems. As a host site, you have valuable insight into the technology that was being piloted. We would greatly appreciate it if you would complete the short survey that follows so we can hear about your experience.

1. How have your dryers performed? Doing well.

   In particular, has your staff noticed any changes in the dryer performance after the modulating retrofit? Quicker dry time.

2. Have you noticed any changes in how long laundered items take to dry? Quicker.

   If so, do the clothes dry faster or slower? Faster.

3. Have you noticed a reduction in your natural gas use and/or bill? Don't see bills.

4. Have there been any problems encountered with your dryers? No problems, working good.

5. Do you have any additional comments or feedback on the system? Not at this time.

6. Given your experience, would you consider implementing this modulating technology in other dryers at your facilities? Other dryers are quest dryers not sure if your equipment would be able to be attached.

Hotel #2 Survey

Nicor Gas Emerging Technology Program

July 18, 2014

Thank you so much for participating as a host site for the Nicor Gas Emerging Technology Program pilot for Modulating Dryer systems. As a host site, you have valuable insight into the technology that was being piloted. We would greatly appreciate it if you would complete the short survey that follows so we can hear about your experience.

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1. How have your dryers performed?

The dryers have performed well during the test, we have had minor repair issues that were corrected without incident. Adding the modulating system did not have any effect on our dryers performance.

   In particular, has your staff noticed any changes in the dryer performance after the modulating retrofit?
   The staff has not noticed a difference.

2. Have you noticed any changes in how long laundered items take to dry?

It seems that the items are drying quicker and require less of a cool down cycle.

   If so, do the clothes dry faster or slower?

3. Have you noticed a reduction in your natural gas use and/or bill?

Yes, but it was a difficult cold winter so the dryers were more efficient, however our overall bills were high

4. Have there been any problems encountered with your dryers?

No

5. Do you have any additional comments or feedback on the system?

I think this technology can save resources and money in the long run.

6. Given your experience, would you consider implementing this modulating technology in other dryers at your facilities?

Yes, but the ROI is a bit low and as always cost is a factor. The time to do it would be with the installation of new equipment not just mid life cycle.

Health Care Site Survey

Nicor Gas Emerging Technology Program

July 18, 2014

Thank you so much for participating as a host site for the Nicor Gas Emerging Technology Program pilot for Modulating Dryer systems. As a host site, you have valuable insight into the technology that was being piloted. We would greatly appreciate it if you would complete the short survey that follows so we can hear about your experience.

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1. How have your dryers performed?

Better than before

In particular, has your staff noticed any changes in the dryer performance after the modulating retrofit?

Positive changes only

2. Have you noticed any changes in how long laundered items take to dry?

Is the same time

If so, do the clothes dry faster or slower?

3. Have you noticed a reduction in your natural gas use and/or bill?

N/A

4. Have there been any problems encountered with your dryers?

No problems

5. Do you have any additional comments or feedback on the system?

Is better in general

6. Given your experience, would you consider implementing this modulating technology in other dryers at your facilities?

Yes