Emerging Technology Program

1008: Combi Systems (Combined Domestic Hot Water & Space Heating Systems)

Public Project Report – Executive Summary

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Executive Summary

Introduction

The Nicor Gas Emerging Technology Program (ETP), a part of the utility's ongoing energySMART Energy Efficiency Program (EEP), assesses new or underutilized technologies that have the potential to provide natural gas savings for the 2.2 million Nicor Gas customers in Northern Illinois. The Gas Technology Institute (GTI) implements the ETP for Nicor Gas. This report summarizes the findings from an evaluation of a combined water and space heating systems and their potential to provide a new energy efficiency measure to Nicor Gas residential and commercial customers.

Background

Combined water and space heating systems, referred to herein as combis, use a single gas-fired process or thermal engine to provide both domestic hot water (DHW) and space heating (SH) for a building. The combination of a hydronic air handling unit (AHU) and tankless water heater in pre-engineered or engineered applications can potentially improve the energy efficiency of meeting these combined heating needs in residential applications.

Although combi systems have been applied in residential buildings for two decades or more, the technology is underutilized and its market share barely exceeds two percent. However, new housing construction practices and present day retrofit measures are leading to more thermally efficient building envelopes and the decline of average home SH loads. This makes combi systems more applicable, especially as tankless water heater manufacturers have begun offering higher capacity systems to meet both loads with on-board integrated DHW and SH controls.

Multiple major manufacturers are entering or expanding in the marketplace with competitively priced, integrated, pre-engineered combi systems with advanced controls for enhanced operability and national product support and training. New systems offer improved reliability and cost-effectiveness while reducing system design and installation errors, a historic challenge for this and other emerging technologies.

This field demonstration of five combi systems was conducted to help document installation, performance, and cost effectiveness issues that needed to be addressed through pilot activities in Nicor Gas service territory. The project put commercially available combi systems into the field through local contractors that were trained by the participating manufacturer and the Nicor Gas Emerging Technology Program (ETP).

With support from members of the Partnership for Advanced Residential Retrofit (PARR) team, a Department of Energy (DOE) Building America (BA) initiative, the limited five system Nicor Gas pilot in northern Illinois had its reported results supplemented by a 10 system demonstration in New York state with the New York State Energy Research and Development Administration (NYSERDA). Moreover, the project

provided the foundation for two additional utilities to launch combi pilots: one with Southern California Gas Company (SoCal), and the other with United Illuminating Company (UIL). Those pilots are underway with an additional 29 of 36 planned combi units installed. While performance monitoring data were not available for those additional units, other tangible information collected from the sites contributed to some of the conclusions in this report.

Results

Contractor Training

Combi system training sessions for a dozen HVAC contractors in Illinois, California, and New York were conducted as a part of this and complementary combi system projects. Six of those contractors were Nicor Gas trade allies. All of the contractors were identified through utility partners, and most of them were utility trade allies working with the utilities and their implementation contractors to support their ETPs/EEPs.

Most of the contractors that participated in training sessions were heating, ventilation, and air conditioning (HVAC) contractors. While water heaters are typically installed by plumbing contractors, those contractors often lack HVAC expertise for installing combis. On the other hand, some HVAC contractors, particularly small shops, do not have licensed plumbers on staff required to install the water and gas piping. The multi-trade expertise required to install combis is an installation barrier that needs to be overcome through widespread training. One way to accomplish extensive training would be at the program-level through utility EEP implementation contractors. The implementation contractors are responsible for executing individual energy efficiency measures and as part of their work they link end users to installing contractors. Bulk installing contractor training via “combi system workshops” could be provided by the manufacturer/distributor in support of an EEP measure implementation.

Code Misperception and a Barrier Broken Down

In early dialogue with one of the major water heater manufacturer’s distribution channels in Nicor Gas service territory, a perceived code barrier was identified. The perception was that combi systems were not being installed in homes because inspectors were prohibiting them. The problem stemmed from past installations in the region where resourceful contractors were field engineering makeshift combi systems with off-the-shelf components. While those systems may have served the purpose, two specific code violations where cited and then ingrained in the trade.

1. There must be system provisions that preclude potable water from standing in the heat transfer unit when not in use.
2. Each water heater must bear a statement on the rating plate indicating that it is suitable for potable water heating and space heating.

Theses perceived barriers coupled with the lack of knowledge regarding the manufacturer’s tankless water heater and hydronic air handler operation prevented the manufacturer from initially implementing its equipment discount plan through a distributor; thus hindering release of the new technology within the trade. In reality, the manufacturer's combi package did address both code issues by employing automatic circulation of water in the furnace and by identifying on the National Sanitation Foundation (NSF) certificate that the system was suitable for potable water heating and space heating.

Through training, the code misperception was alleviated within the manufacturer's distribution channels in Nicor Gas service territory. With that barrier broken down, the manufacturer was able to develop an equipment discount and contractor rebate program with its local distributor in Nicor Gas service territory.

Energy Savings and Economic Performance

After the combi systems were installed at the five sites, ETP visited each site to install a Logic Beach data logger that was connected to a cell modem. The arrangements allow for downloading of data at any time, changes to the program at any time, and live looks at the system to monitor performance. Sensors were monitored and recorded every five seconds during DHW draws. When DHW was not being drawn, sensors recorded every 30 seconds. Data were transmitted via cell phone modem and downloaded weekly for one year nominally for each site. Monthly and cumulative performance calculations included the following:

- Gas energy consumed
- Electric energy consumed
- Energy delivered to domestic hot water
- Energy delivered to space heating
- System efficiency
- Hot water consumed by volume

Two methods were considered for determining energy savings: utility billing and baseline nameplate efficiency savings calculations. The first method is often used because it is based on the site's actual baseline gas usage. However, given the very small size of the Nicor Gas pilot and the lack of historic billing information for some of the pilot sites retrofitted with combi systems, the nameplate method was used exclusively.

Baseline gas usage was determined by dividing the SH and DHW energy delivered during the combi system operation by the nameplate efficiencies of baseline equipment. For this pilot, the baseline gas usage was determined using a conventional non-condensing furnace at 80% AFUE and a water heater at 0.59 EF. An additional baseline comparison was also calculated using a condensing furnace at 90% AFUE and a water heater at 0.59 EF. Combi system gas savings were determined by subtracting the monitored gas use for combi system operation from the calculated baseline gas use. It is important to note that this methodology simplifies pre-retrofit appliance gas usages by assuming the appliances operate at name-plate efficiencies all of the time.

Combi system installations at the Nicor Gas pilot sites occurred between January 2013 and October 2013. There were 45 site-months of data acquired across the five Nicor Gas sites. All of the pilot sites in the Nicor Gas pilot utilized the same integrated appliance tankless-AHU combi systems. Nicor Gas Sites 1, 2, 3, and 5 were installing contractor’s homes, and those contractors were provided formal combi training by the manufacturer and ETP. Nicor Gas Site 4 was an HVAC shop that was used to evaluate the combi system and to allow the HVAC contractor to showcase the technology.

The combi field test installations for this study were monitored “as-is” to ascertain contractor knowledge, installation practices, and performance of combi systems. While the contractors were encouraged to adhere to the installation and operation practices provided to them during the training session, certain deviations did occur. Most notably, some contractors raised the delivered hot water temperature to the AHU in order to provide higher heating rates and/or enhanced comfort. This higher temperature setting makes it more challenging to achieve condensing efficiencies and contributes in practice to the lessening of the combi system efficiency gains. Combi system manufacturers have indicated they are working to develop condensing tankless systems that can rely on lower temperature hot water to the AHU to boost their system efficiency, while still ensuring both comfort during space heating as well as hot water of sufficient temperature to meet health and safety standards for domestic use.

From the five Nicor Gas sites, 45 site-months of data were collected over consecutive months (for up to 12 full months) as shown in Table 2. An additional 90 site-months of data were collected from 8 supplemental NYSERDA sites shown in Table 1 as well. For months where representative site-month data were not collected (as shown in red in Table 1), linear regression techniques were used to estimate annualized energy consumptions and efficiencies using data from other months for that site. For energy delivered to SH, HDDs and corresponding monthly data were used to generate estimates for the months that were missing. For energy delivered to DHW, historical ground water temperatures and corresponding monthly data were used to generate estimates for the months that were missing.

Energy savings for the Nicor Gas sites and supplemental NYSERDA sites are shown in Table 2. It can be seen that there is a wide range of savings across pilot sites. Table 5 summarizes the monthly performances of the combi systems at the Nicor Gas sites only.

Per the Nicor Gas pilot data in Table 1 (with the non-residential Site 4 excluded) an annualized average of 127.5 therms per year, or 9.4% of DHW and SH gas use, was saved with the combi system when compared to a conventional furnace at 80% AFUE and water heater at 0.59 EF. However, average therm and % savings per year were near zero against a 90% AFUE furnace and 0.59 EF water heater. Table 5 shows cumulative combi system efficiencies for the Nicor Gas pilot sites ranged from 82.8% to 88.0%.

Table 1 – Annualized Pilot Site Energy Usage and Therm Savings

Host Site	Delivered Energy		Combi Energy Consumed		Baseline Energy Consumed			Therm Savings Combi vs. Baselines		% Savings 0.59 DHW 80% SH	% Savings 0.59 DHW 90% SH
	DHW	SH	DHW	SH	0.59 DHW	80% SH	90% SH	0.59 DHW 80%SH	0.59 DHW 90%SH		
Nicor Gas 1	59.1	733.1	73.3	886.0	100.2	916.3	814.5	57.3	-44.5	5.6%	-4.9%
Nicor Gas 2	121.9	1052.1	139.0	1195.0	206.6	1315.2	1169.0	187.8	41.6	12.3%	3.0%
Nicor Gas 3	182.0	770.3	213.2	902.4	308.5	962.9	855.9	155.7	48.8	12.2%	4.2%
Nicor Gas 4	4.6	104.4	5.2	121.9	7.9	130.5	116.0	11.2	-3.3	8.1%	-2.7%
Nicor Gas 5	138.7	1001.8	166.2	1212.0	235.0	1252.3	1113.2	109.2	-29.9	7.3%	-2.2%
Nicor Gas Avg w/o Site 4								**127.5**	**4.0**	**9.4%**	**0.0%**
w/Site 4								104.2	2.5	9.1%	-0.5%
NYSERDA 2	61.6	584.3	83.6	752.4	104.4	730.3	649.2	-1.3	-82.4	-0.2%	-10.9%
NYSERDA 3	212.0	652.9	250.4	710.4	386.3	816.1	725.4	241.7	151.0	20.1%	13.6%
NYSERDA 4	96.5	489.8	122.4	592.5	163.6	612.3	544.2	60.9	-7.1	7.8%	-1.0%
NYSERDA 6	165.1	1217.8	201.3	1476.8	279.9	1522.2	1353.1	124.0	-45.1	6.9%	-2.8%
NYSERDA 7	122.8	614.8	137.6	662.7	208.2	768.5	683.1	176.4	91.0	18.1%	10.2%
NYSERDA 8	52.8	488.4	62.6	523.9	89.5	610.5	542.7	113.4	45.6	16.2%	7.2%
NYSERDA 9	251.6	482.6	272.5	527.8	426.5	603.3	536.3	229.5	162.4	22.3%	16.9%
NYSERDA 10	72.9	483.0	84.8	551.2	123.6	603.7	536.6	91.3	24.2	12.6%	3.7%
NYSERDA Avg								**129.5**	**42.5**	**13.0%**	**4.6%**

Table 2 –Site-months of Data (Monitored in Blue)

Host Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Nicor Gas 1												
Nicor Gas 2												
Nicor Gas 3												
Nicor Gas 4												
Nicor Gas 5												
NYSERDA 2												
NYSERDA 3												
NYSERDA 4												
NYSERDA 6												
NYSERDA 7												
NYSERDA 8												
NYSERDA 9												
NYSERDA 10												

It is important to note the additional 90 site-months of data collected for 8 forced-air combi demonstrations in New York for NYSERDA. Three of those combi systems (NYSERDA Sites 7, 8, and 9) were installed with third-party AHUs specifically designed with condensing combi system applications in mind. These AHUs had hydronic coils designed to operate at lower hot water inlet temperatures to achieve condensing efficiencies (combi system efficiencies equal to or greater than 90%) while still providing comfortable supply air temperatures. Per the NYSERDA pilot data in Table 2, these three sites consistently achieved high annualized gas savings of 16.2% to 22.3% versus a 80% AFUE furnace and 0.59 EF water heater and 7.2% to 16.9% gas savings versus a 90% AFUE furnace and 0.59 EF water heater.

Based on the pilot results of five monitored, forced-air heating, tankless water heater combi systems in the cold climate of northern Illinois, the following major findings emerged in answer to the research questions posed in the project objectives:

What are expected combi system energy savings for weatherized/newer single-family detached homes?

- Data from this study indicate a wide range of savings across pilot sites due to varying DHW and SH energy consumptions. Per the Nicor Gas pilot data an average of 127.5 therms per year (or 9.4% of DHW and SH gas use) was saved with the combi system when compared to a conventional furnace at 80% AFUE and water heater at 0.59 EF.

What is the combined SH and DHW efficiency for installed combi systems?

- Cumulative combi system efficiencies averaged from 82.8% to 88.0% in the Nicor Gas pilot data, although NYSERDA pilot data showed combi system efficiencies as high as 92.3% with purpose built AHUs for combi system operation. Other research has shown, and both Nicor Gas and NYERDA pilot data confirm, that minimizing return water temperatures (to 105°F or lower) from the AHU back to the tankless water heater is the key to achieving condensing efficiency levels with combi systems. However, especially in colder climates, the temperature of the hot water delivered to the AHU is often set high (140°F – 160°F) in order to provide higher heating rates and/or enhanced comfort. This higher temperature setting makes it more challenging to achieve condensing efficiencies and contributes in practice to the lessening of the combi system efficiency gains noted above. Combi system manufacturers have indicated they are working to develop condensing tankless systems that can rely on lower temperature hot water to the AHU to boost their system efficiency, while still ensuring both comfort during space heating as well as hot water of sufficient temperature to meet health and safety standards for domestic use.

  Note that combi system efficiencies were calculated by dividing total energy delivered for domestic hot water (DHW) and space heating (SH) by total gas and electric energy consumed by the water heater (not including the air handling unit electricity). Although combi system testing and rating procedures have not been standardized, this efficiency calculation approach is consistent with the separate standardized testing and rating procedures for gas furnace efficiency (the Annual Fuel Utilization Efficiency or AFUE excludes the blower and other electricity consumption) and for gas water heater efficiency (the Energy Factor or EF includes electricity consumption). See Appendix A for details on the combi system efficiency calculation.

Pilot data is proving that energy savings from combi systems can be substantial versus code minimum or near code minimum furnaces and water heaters. However, incremental costs of combis are currently too high for generating positive utility TRCs. Installed costs for these systems need to come down by about 15% to 25% to meet utility TRCs of 1.0. Additionally, maintenance issues associated with keeping the tankless water heater free of mineral buildup (depending on local water hardness) to maximize combi system performance, need to be better delineated by the manufacturers and the cost implications quantified in TRCs to fully establish their cost effectiveness for any utility EEP.