Nicor Gas | Energy Efficiency Program

Emerging Technology Program

#1008-RE: Combination Space Heating and Domestic Hot Water Heating System - Public Laboratory Evaluation Report

05/2/2025

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Executive Summary

Introduction

As part of the Nicor Gas Energy Efficiency Program, the Emerging Technology Program (ETP) assesses new technologies that have the potential to realize natural gas savings for the 2.3 million Nicor Gas customers in northern Illinois. GTI Energy provides program implementation services for the Nicor Gas ETP. This report summarizes the findings of a laboratory evaluation conducted to assess the space and water heating performance of a combination space heating and domestic hot water heating system sized for an average residential home in the Nicor Gas territory.

Background

As building envelope performance for new homes continues to improve, low-capacity electric-driven heat pump technologies are facing off against over-sized gas-fired forced-air systems. Low-capacity furnaces in the U.S. are limited to 40 kBtu/h input. Yet, gas-fired forced-air technologies, such as combination systems (combis) with on-demand modulating water heating with minimum firing rates of 20 kBtu/h, are very competitive, if not better, options for low-load homes. Combi systems can provide both space and water heating with a single condensing appliance, providing a single energy efficiency (EE) measure that can improve the net cost of an energy conservation program. Moreover, the single-vent solves the dual-condensing-vent problem in multi-family residential applications.

While the potential for highly efficient combis exists, lab and field research has proven that poorly designed forced-air combis can result in non-condensing efficiency levels, leading to insufficient energy savings to qualify for EE programs. Recently, however, innovative manufacturers have developed combi systems with hardware and controls that enable condensing efficiency. These improvements include properly sized hydronic coils and blower modulation, along with controls that adjust water and air flow rates, as well as delivered water and air temperatures. By incorporating an outdoor reset controller, these systems can modulate heating capacity while maintaining comfort and achieving condensing efficiency.

A Canadian combi manufacturer, Manufacturer 1, developed a single-package combi system for low-load applications which is evaluated in this laboratory evaluation. It integrates a condensing boiler and air handler in one unit and comes in both low- and high-velocity versions with four rated output capacities between 55 and 99 kBtu/h. With reported high-efficiency results from CSA P9.11 – *Test Method for Determining the Performance of Combined Space and Water Heating Systems (Combos)*, the combi system, optimized and evaluated at GTI Energy's laboratories, could provide a comparable alternative to other combi systems in the North American market.

GTI Energy developed a test plan to evaluate Manufacturer 1's combi system unit sized for the Nicor Gas territory's average house, roughly 2,000 square feet. GTI Energy's Virtual Test Home (VTH) methods previously have demonstrated insightful assessments of HVAC, water heating and power generation equipment. Unlike standard rating-point test methods, such as Annual Fuel Utilization Efficiency (AFUE) and Heating Seasonal Performance Factor (HSPF) for space heating equipment, the VTH can be used to evaluate and characterize the performance of complex systems in a wide range of as-installed operating conditions to estimate annual greenhouse gas (GHG) emissions and operating cost via building energy modeling.

Results

VTH assessment of the combi system water and space heating produced efficiency performances in the low 90% range. These results are some percentage points below other efficient combi systems that have been previously evaluated in the VTH. These other combi systems achieved high space and water heating performances by implementing on-demand gas-fired tankless with 97% combustion efficiencies and by controlling air- and water-flows and supply water temperatures. Manufacturer 1's combi system, on the other hand, has limited controls to modulate space heating capacities that results in delivered air temperatures similar to air-source heat pumps, which are at least 25 °F lower than furnaces. Optimizing controls may increase the comfort and efficiency of the combi system operating in both space and water heating modes.

Water and space heating performance curves were developed based on a series of tests conducted by GTI Energy. The following test results are based on one system configuration shown in Table 1 to achieve the highest efficiency and required heating capacity. Manufacturer 1 does not have specific configuration guidelines to set their combi system, and GTI Energy, together with Manufacturer 1, selected and optimized these parameters based on laboratory evaluation.

Table 1 – Manufacturer 1 Combi System Configuration

Variable	Target
Water Heating Setpoint	125 °F
Low Outdoor Air Temperature (OAT)	65 °F
Peak OAT	-40 °F
Pump Speed	Low
Minimum Entering Water Temperature (EWT)	110 °F
Maximum Entering Water Temperature (EWT)	150 °F
Minimum Blower RPM	500
Maximum Blower RPM	1200

Water Heating

Manufacturer 1's combi system can be configured to water heating temperatures up to 140 °F. For this test, the system was set to 125 °F as shown in Table 1. Figure 1 shows the resulting water heating performance curve of Manufacturer 1's combi system. These results indicated that the integrated boiler system at city water temperatures of 60°F has thermal and combustion efficiencies of 90%.

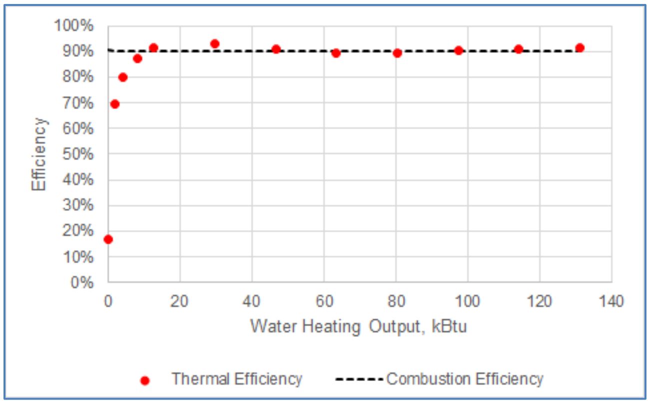

Figure 1 – Manufacturer 1's Combi System Water Heating Performance Curve

Space Heating

Manufacturer 1's combi system can modulate space heating output using an outdoor reset approach. This outdoor reset approach needs a low and peak OAT, minimum and maximum blower RPM, and entering temperatures as shown in Table 1. The user can set the on-board pump to either low-, mid- or high- speed using the speed switch. Figure 2 and Figure 3 show the space heating performance of Manufacturer 1's combi system as a function of OAT and part-load. The part-load is defined as the ratio of building load over the system maximum heating capacity. Test results demonstrated that:

- Both combustion and thermal efficiencies above 40% part-load or OAT below 20 °F are between 88 and 90%. These results indicate that this system operates 70% of the time of the heating season at low 90%+ efficiencies.
- The maximum system supply air temperatures (SAT) are below 100 °F, which are 15 °F less than condensing furnace operating at high airflow rates. Furnaces' typical temperature rises are between 45 to 70 °F, which corresponds to 115 and 140 °F SATs with a 70 °F return air temperature.
- Leaving water temperatures (LWT) in the hydronic coil are below 95 °F.

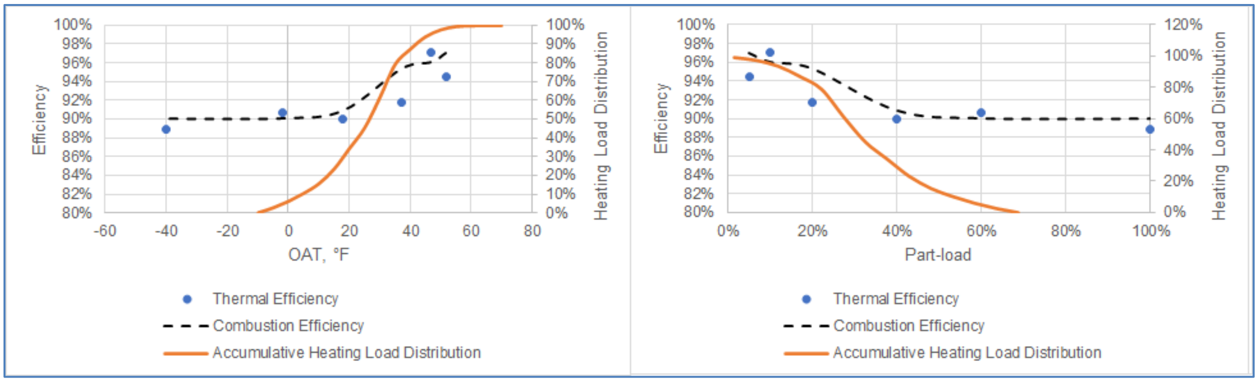

Figure 2 – Manufacturer 1's Combi System Space Heating Efficiency as a Function of OAT (left) and Part-load (right) Relative to Annual Heating Distribution

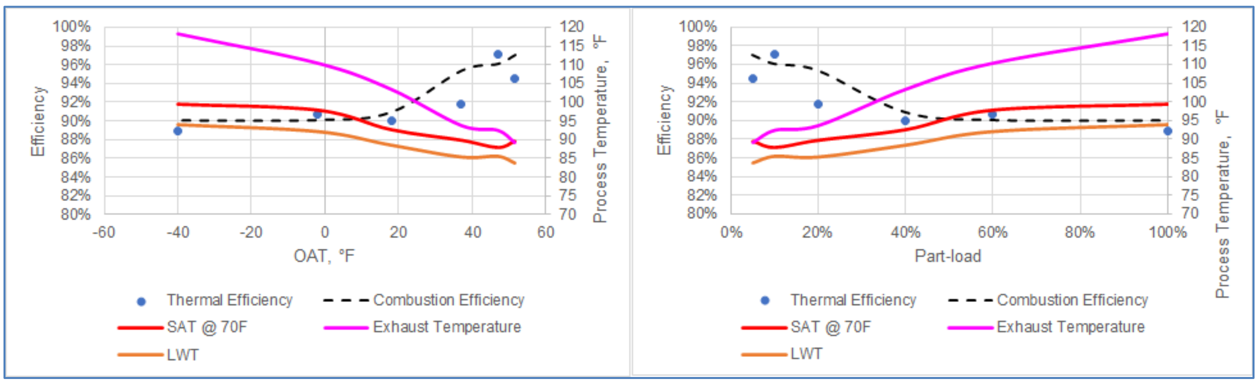

Figure 3 – Manufacturer 1's Combi System Space Heating Performance Curves as a Function of OAT (left) and Part-load (right)

Water Heating Comparison

Manufacturer 1's combi system water heating performance was compared to two other combis systems as shown in Figure 4. One of the two combi systems is an advanced combi system (*Adv Combi)* with a 97 UEF tankless and an air handler with control airflow, water flow and leaving water temperatures. The second combi system is a traditional combi (*Traditional Combi*) with a 92 UEF tankless and an air handler with single airflow, water flow, and supply water temperature. These performance curves demonstrate that the Manufacturer 1's combi system thermal efficiency achieves a combustion efficiency at a similar rate to the advanced and the traditional combi systems do with similar combustion efficiencies.

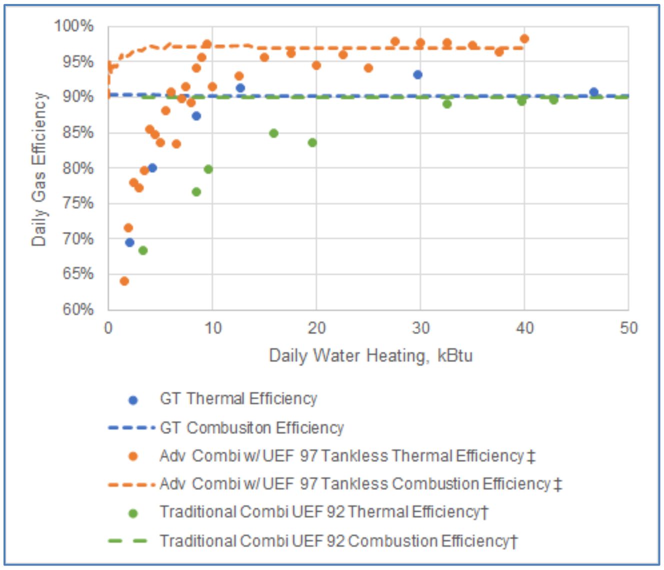

Figure 4 – Water Heating Performance Among Combi Systems (‡ Evaluated with UTD Funding, † Evaluated with Funding from a California Gas Utility)

Space Heating Comparison

A similar comparison was performed for the space heating operation of the three systems. Figure 5 shows the thermal and combustion efficiencies of these systems as a function of part-load. Operating characteristics between the advanced combi and Manufacturer 1's combi system are shown in Figure 6.The following observations were made:

- Critical features to provide comfortable heat (similar to furnaces) at high gas efficiency in combis are hydronic coil heat transfer area, variable hot water set point and pre-configured airflow and water flows as a function of load.
    - Despite having manual waterflow and airflow controls and hot water setpoints, the combi system can't reach gas efficiencies similar to the advanced combis (shown in Figure 5) due to the hydronic coil surface area and lack of preconfigured settings as a function of load.
- The advanced combi can provide similar supply air temperatures close to a furnace without affecting its gas efficiency unlike Manufacturer 1's combi system as shown in the right of Figure 6.
- Despite Manufacturer 1's combi system providing a higher gas efficiency at very low part-loads (shown in Figure 5) relative to the advanced combi, it delivered very low supply air temperature (as shown in the right of Figure 6). The advance combi controls also consider supply air temperature as part of its operating scheme as shown on the left of Figure 6.

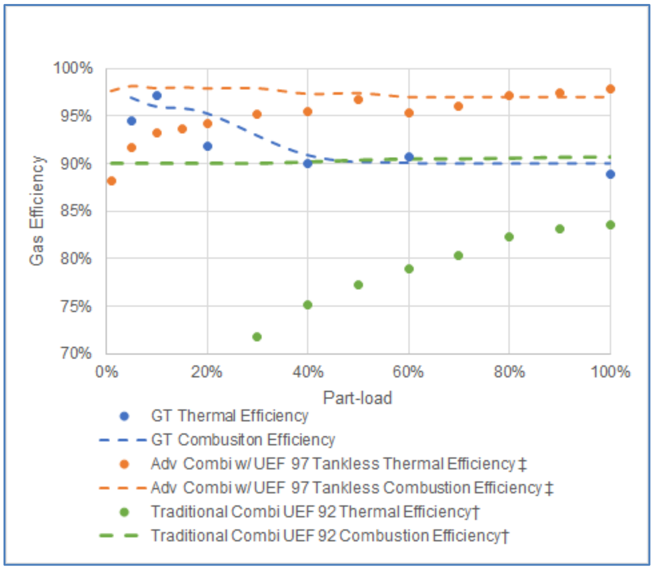

Figure 5 – Space Heating Performance Among Combi Systems (‡ Evaluated with UTD Funding, † Evaluated with Funding from a California Gas Utility)

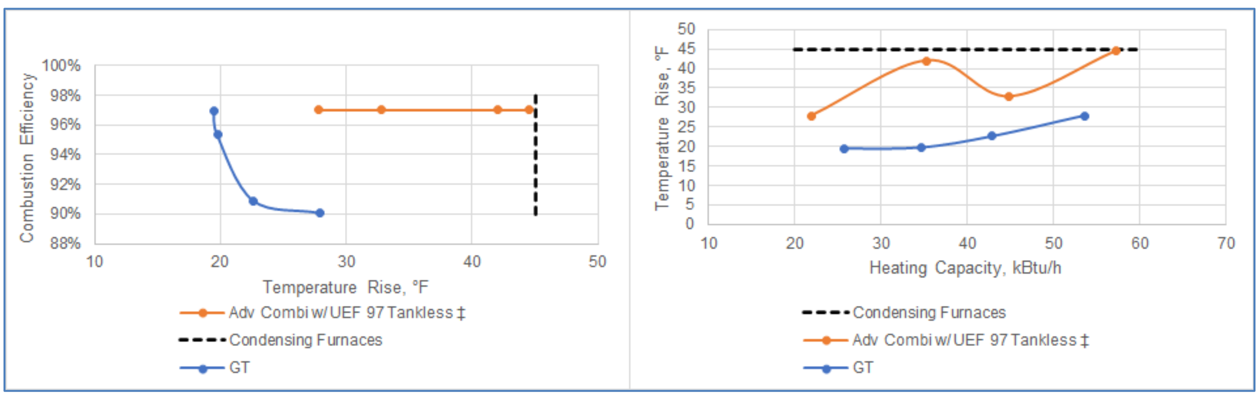

Figure 6 – Combustion Efficiency as a Function of Air Temperature Rise (left) and Air Temperature Rise as a Function of Heating Capacity (right). ‡ Evaluated with UTD funding.