COMMERCE DEPARTMENT
DIVISION OF ENERGY RESOURCES

Quality Installation and Retrocommissioning of High-Efficiency Condensing Boilers

Although high-efficiency condensing boilers have been available to consumers for a long time, they have yet to fully penetrate the market. Consumer acceptance continues to be a barrier, as well as lack of confidence by many contractors and utilities related to energy savings, cost-effectiveness, and quality installation.

The Center for Energy and Environment (CEE) received a CARD grant to address these uncertainties. The CEE research team monitored 13 condensing boilers in Minnesota homes to characterize installed performance. Six of these boilers were installed up to seven years before the project began and seven were installed during it, using a project-developed quality installation protocol.

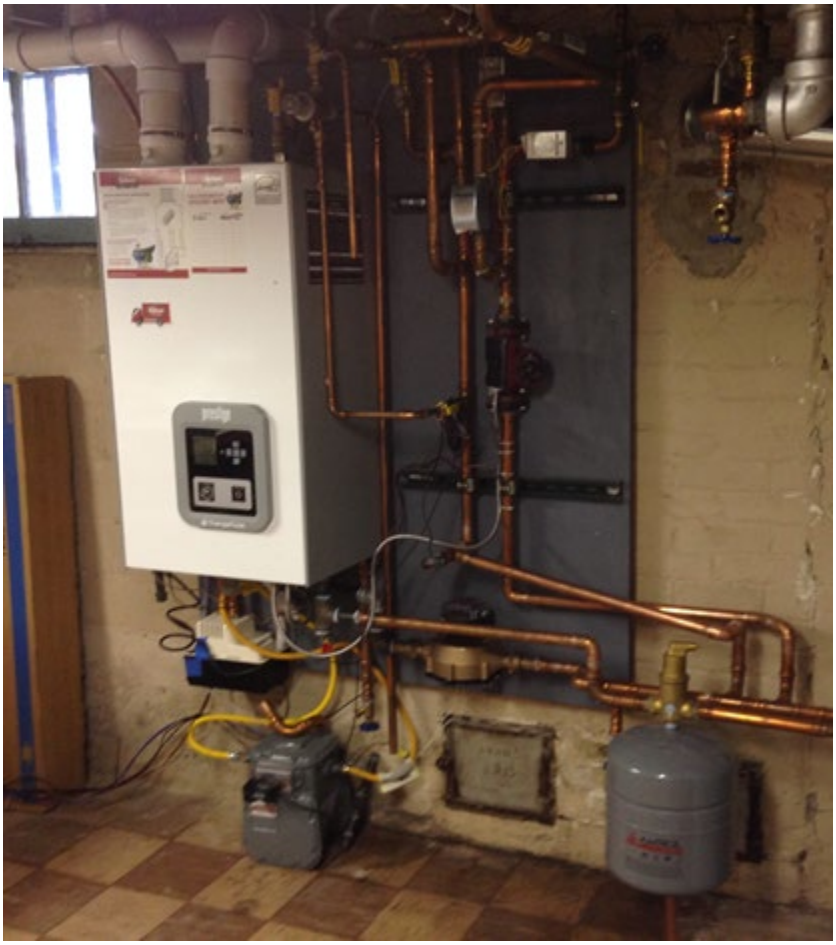
The team collected data on supply and return water temperature, flow rates, incidence of condensing, and energy use across all 13 systems, which represent a wide range of single-family installations with different brands, emitter types, zone set-ups, and outdoor reset control installation and set points. In addition, the team conducted interviews with contractors/distributors and homeowners, and performed an economic analysis.

Field research

The project's field research was conducted in two phases: Phase I in six homes where a non-condensing boiler had been replaced with a condensing boiler within the last seven years, and Phase II for seven customers with an interest in replacing their non-condensing boiler with a condensing boiler.

The project team developed site selection criteria to identify and select sites that were representative of Minnesota homes and boiler systems (see Figure 1 for condensing boiler example). Data from both phases was used to determine annual energy consumption and seasonal operating efficiency. Annual performance between operation modes and phases was compared and an estimated baseline boiler established. In addition, annual energy performance, runtimes, and installed efficiencies were also examined.

Figure 1: Existing Boiler at Site Exist_07



Overall, the as-found operation had better than expected space heating performance. The vast majority of days showed space heating efficiencies of 85% and above—ranging between 86% and 95%, with an average annual efficiency of 90%. While slightly lower than the rated AFUE (average AFUE was 94%), these installed efficiencies are in line with the expected efficiencies of well-installed systems.

Based on these findings, the as-found condensing boilers would expect to save 14% annual heating energy consumption over a baseline boiler rated at 82% efficiency.

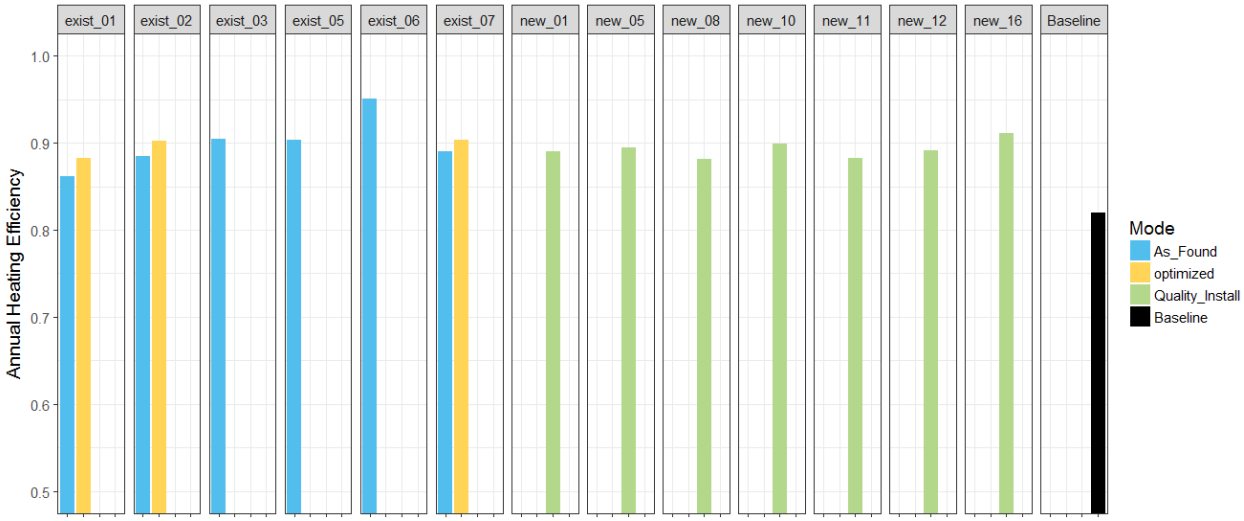
Optimization

Space heating optimization was conducted at three of the seven as-found sites. One site had very high as-found efficiency, and optimization was not possible. Two other sites were used to look at domestic water heating optimization instead. The final three sites were optimized for space heating. While time consuming to do, the optimization did show improved efficiency and reduced energy consumption in all cases. However, the effort, time, and measurements needed to make these optimizations did not justify the amount of energy savings they delivered. This was because the improvement was relatively small at an average of 1.9%, but also because these systems already had very good energy efficiency performance without optimization, limiting the opportunity for impact.

Phase II monitoring and results had nearly identical performance to Phase I boilers after retrocommissioning. For Phase II, the average annual space heating efficiency was 89.3%, compared to 89.9% for Phase I after retrocommissioning. This characterization validates the quality installation measures developed in Phase I for ensuring installed performance capable of achieving the expected

savings above baseline for new installations. Figure 2 shows the measured results for boilers in each phase, including optimized efficiency (Phase I) and an 82% rated efficiency baseline boiler.

Figure 2: Space Heating Efficiency For All Sites



Contractor and homeowner interviews

Barriers to widespread market adoption of condensing boilers, as well as general practice and attitudes, were examined through interviews with heating, ventilation and air-conditioning contractors and one distributor from across the Twin Cities metro area. About 2% to 30% of these companies' retrofit business was replacement hydronic systems ranging from 15 to 50 installations per year. These interviews focused on installation costs and individual opinions about system performance and reliability, operations, and maintenance. All the contractors interviewed reported that they make decisions about replacement equipment based on reliability, affordability, and installer familiarity.

Most contractors cited use of outdoor reset control as an external control device installed on condensing boilers. In addition, most contractors stated some sort of adjustment to the reset curve at installation, either according to manufacturers' recommendations or their own experience. None of the contractors use emitter capacity calculations on a regular basis unless there is a capacity concern. No particular attempt was being made by installers to ensure condensing actually occurs most of the time.

In addition, 13 participant homeowners were interviewed to assess their experience with installed condensing boilers. These homeowners had either replaced their non-condensing boiler within seven years of the project's start or as part of the project. Most systems were replaced at time of failure or as part of a larger remodel/retrofit. Some homeowners were motivated by energy savings potential while others were sold by contractors on advantages of condensing, including sealed combustion safety. Two participants had minor issues with performance, which were remedied after installation; other participants had no issues.

For participants that had experience with the older systems, all had a sense that they are saving energy with the new system and that comfort was either improved or the same. Eleven of the 13 homeowners rated their satisfaction at 5, on a scale of 1–5 (with 5 being the most satisfied).

Cost-effectiveness

CEE analyzed costs for condensing boilers by looking at 83 boiler replacement bids/invoices (45 non-condensing, 38 condensing) for 32 different homes. We found that the average difference in cost between condensing and non-condensing boiler installation is around $2,300. This is taking all 83

bids/invoices and comparing the average non-condensing price, $6,658, and the average condensing price, $8,944.

The study also looked at the price difference when both were bid by the same contractor on the same job (10 homes); this average price difference was around $2,500. However, the range in price difference when looking at cost comparison for these 10 homes was between $550 and $5,000. CEE also looked at installations that included indirect water heaters. The average price for including domestic hot water was around $2,800.

All monitored systems had space heating efficiencies near 90% and showed annual energy savings between 10% and 18% over a baseline non-condensing boiler with an assumed efficiency of 82%. The average heating savings for the participant households with condensing systems over non-condensing systems is 13%, with an average yearly cost savings of $97 (Table 1). To have a simple payback of 25 years or less (typical lifetime of boilers), the price difference between condensing and non-condensing boilers needs to be around $2,500. To have a 10-year payback, the price difference needs to be around $1,000.

Table 1: Summary of Annual Results

Site	Design Load (Outdoor Temp of -11 ^{0}F)	Annual Savings over Average Non-condensing Boiler($/year)	Percent Savings over Average Non-condensing Boiler
exist_01 – as found	49,123	$108	10%
exist_02 – as found	32,581	$95	12%
exist_03 – as found	23,606	$69	14%
exist_05 – as found	19,762	$59	14%
exist_06 – as found	29,490	$117	18%
exist_07 – as found	27,670	$82	12%
new_01	46,230	$122	12%
new_05	25,492	$81	13%
new_08	26,397	$88	12%
new_10	25,727	$74.	13%
new_11	31,746	$88	12%
new_12	32,354	$100	12%
new_16	43,332	$185	14%
Average	30,366	$97	13%

The cost analysis showed that, on average, the difference in installation price ($2,300) was close to the 23-year simple payback mark. However, equipment costs, contractor labor estimates, and national numbers demonstrate that increased market penetration can lower installation costs; in that scenario, a simple payback period of less than 10 years is possible. This payback can be reduced further through rebate programs and other market incentives.

A webinar titled “Increasing Residential Boiler Efficiency” is available and covers findings from this CARD project. The project final report (pdf) is available online. Please email project manager Mary Sue Lobenstein for questions about this project and the CARD program.