RESEARCH HIGHLIGHT

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Monitoring Performance of Retrofitting from Tank to Tankless Water Heaters

BACKGROUND

Domestic hot water energy consumption represents the second largest energy end-use point in houses after space heating. Until recently, most homes have been equipped with storage-type hot water systems. Storage-type systems receive cold potable water in a storage tank where it is then heated by electric elements or fuel-fired (gas or oil) heat exchangers. Heat can also be added to the tank from solar, geothermal or air source heat pump systems. In the last several years, "tankless" water heaters (Figure 1) (also known as "on-demand" or "instantaneous" water heaters), a common hot water heating technology in Europe and Asia, have been introduced into the North American market. As the name implies, tankless heaters do not heat hot water in storage tanks. Rather, they use high inputs of gas or electricity to instantaneously heat water as it flows through the unit. Some tankless water heaters have features that can condense moisture from the combustion gases to increase energy efficiency. As water heating only occurs on demand, tankless heaters do not heat hot water when it is not needed and they do not incur standby heat losses typically associated with conventional storage-type hot water heaters. Tankless units are more compact than storage-type water heaters and they are typically wall-hung and therefore require less floor space.

Figure 1 Tankless Water Heater installed at Avalon Discovery 3

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HOME TO CANADIANS

Though the heat-on-demand, no standby energy loss features of tankless water heaters can be expected to reduce hot water-related energy consumption, little data is available about the actual energy savings of tankless water heaters compared to conventional hot water tanks. Notwithstanding the energy-efficient features of tankless heaters, there are certain operational aspects of such systems that may affect their overall performance. For instance, when a hot water tap is opened, a clothes washer is activated or a dishwasher is started, tankless water heaters may allow water to flow through them for some short period of time before they start heating water. Once started, it may also take the heating unit some finite time to become fully operational. This can result in a delay of hot water arriving at the tap which can be frustrating for the user and may also result in the waste of water as the user waits for the hot water to arrive. Additionally, the capacity of tankless water heaters to provide "endless" hot water for showers may lead some users to consume more hot water than they otherwise would (or could) with storage-type water heaters given their reduced capacity to instantaneously heat water.

To better understand the relative performance of storage and tankless water heaters, Canada Mortgage and Housing Corporation (CMHC) initiated a research project to answer the following questions:

1. Do gas-fired tankless water heaters result in less gas being used for water heating than their storage tank alternatives? If so, how much?
2. Is there a difference in the amount of water used by a family with a new tankless water heater, compared to the family's old usage with the storage-type heaters? If so, how much?
3. Are there any other notable differences in how occupants perceive the performance of tankless and storage-type water heaters?

To provide answers to these questions, Enbridge Gas and Canada Mortgage and Housing Corporation (CMHC) collaborated on a project to investigate the impact that replacing conventional gas-fired water heaters with gas-fired tankless water heaters had on gas and water consumption and homeowner perceptions of performance.

METHODOLOGY

The overall approach for the research involved the characterization of water heating energy use and hot water consumption in houses before and after the conversion of the water heating system from storage-type water heaters to tankless water heaters. Thirty-one houses, in various cities in Ontario, were initially identified as candidate test houses given the intentions of the homeowners to convert from storage-type to tankless heaters. Twenty-three houses continued through the full length of the project while the other eight houses were removed from the project as, in most cases, the homeowners did not end up installing the tankless water heaters for varying reasons. The number of occupants in the houses ranged from 1 to 5, with an average of 3.5. The pre-retrofit storage-type heaters ranged in age from 2 years to over 25 years with an average age of 10.2 years. Just over 70 per cent of the storage tanks were being rented by the homeowners.

Hot water use was measured with water meters installed on the inlets to the water heaters and natural gas meters were installed to measure the natural gas consumed by the water heaters. After a three-month monitoring period, the storage-type heaters were removed and replaced with tankless water heaters and monitoring then continued for another three months. Hourly gas and hot water use data, pre- and post-installation of the tankless water heaters, were then analyzed.

Since the pre- and post-installation periods were at different times of the year, the gas consumption data were adjusted to remove the impact of typical changes in water heater energy consumption due to changes in the water temperature delivered from the water mains. This was accomplished by normalizing the gas consumption for each day to an August reference using monthly seasonality factors that have been developed by Enbridge based on five years of internal load research information from separately metered water heaters. The monthly seasonality factors were applied to each day's gas consumption, corresponding to the month in which each day fell. Water consumption data were not adjusted.

Surveys were conducted to gauge homeowner impressions of the performance of their new tankless water heaters and to determine if there had been any changes in the households during the study period that would have impacted on hot water consumption during the pre- and post-retrofit monitoring periods. Based on the results, two houses were removed from the study and two other houses had specific time periods removed from the analysis that corresponded to homeowner absences. Given the possibility that the number of days participants were absent from their homes may not have been consistent over both the pre- and post-installation periods, individual days that showed less than 4 ℓ (1 U.S. gallon) of hot water usage during either period were removed from the data set that was used for analysis.

Note that the methodology did not consider the impact that the hot water heaters may have had on space heating and cooling energy consumption. The storage-type heater standby heat losses could partially offset some space heating requirements in winter and add to air-conditioning loads in the summer. Therefore, overall household natural gas savings resulting from a conversion from storage-type to tankless water heaters may not be as large as the natural gas savings reported in this study.

RESULTS

The daily water and gas consumption (normalized to August) data for each site were tabulated and compared for the "before" and "after" installation periods. To investigate how the rated efficiency level of the new water heaters might influence the results, the data were separated into two categories, representing the "non-condensing" and "condensing" tankless water heaters. Non-condensing water heaters were installed in four homes, while condensing water heaters were installed in the remainder (19).

The results of the analysis of the energy and water consumption pre- and post-retrofit are shown in Figure 2. Table 1 provides more detailed information for each house including the average daily normalized gas consumption of the water heater at each site before and after the retrofits and provides an analysis of the extent of the changes. Sites A to D in Table 1 (and 2) have non-condensing tankless units, whereas sites E through W have condensing tankless units.

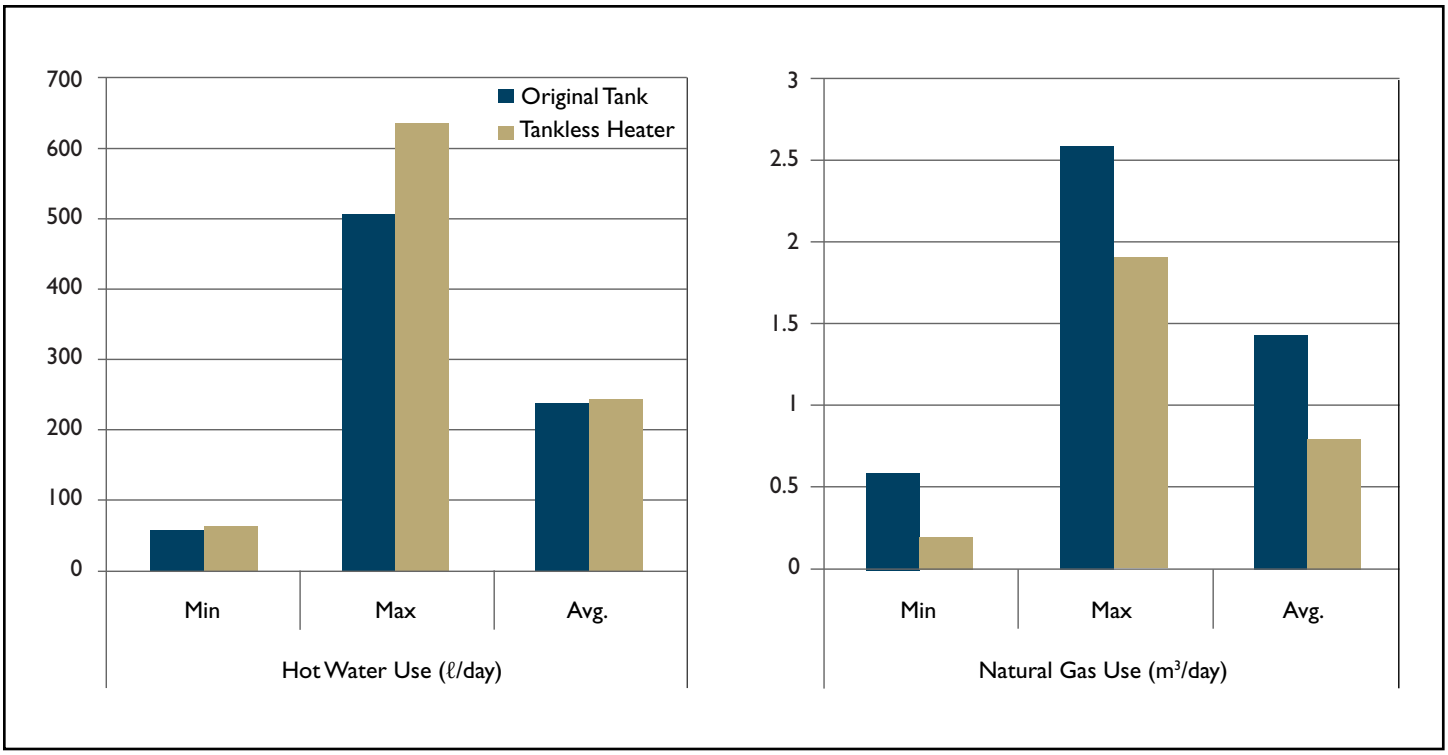

Figure 2 Post-and pre-retrofit natural gas and hot water consumption

Table 1 Daily natural gas consumption for water heating and analysis.

	Natural gas use with original water heater		Natural gas use with tankless heater		Analysis		
Site ID	**Monitored period (# days)**	**Average gas use (m^3/day)**	**Monitored period (# days)**	**Average gas use (m^3/day)**	**% Change in gas**	**Rated Energy Factor (EF) of tankless unit**	**Average reduction in gas use (%)**
A	118	1.30	102	0.78	-41%	0.82	54%
B	85	0.87	90	0.32	-64%	0.82	
C	73	1.39	90	0.70	-49%	0.82	
D	97	0.89	100	0.34	-62%	0.84	
E	117	1.67	93	1.02	-39%	0.90	44%
F	82	1.69	94	0.85	-50%	0.92	
G	90	1.70	89	0.75	-56%	0.94	
H	103	1.49	103	0.64	-57%	0.96	
I	103	1.74	104	1.00	-43%	0.98	
J	90	0.59	88	0.20	-66%	0.98	
K	80	1.90	89	0.99	-48%	0.98	
L	92	0.85	96	0.36	-58%	0.98	
M	95	1.20	104	0.53	-55%	0.98	
N	90	0.92	96	0.32	-65%	0.98	
O	77	1.28	153	0.78	-39%	0.98	
P	91	1.82	96	1.42	-22%	0.98	
Q	144	2.58	89	1.90	-26%	0.98	
R	103	0.75	85	0.59	-22%	0.98	
S	97	1.55	103	0.74	-52%	0.98	
T	81	1.10	96	0.65	-41%	0.98	
U	147	1.69	84	1.66	-2%	0.98	
V	147	1.44	82	0.98	-32%	0.98	
W	116	2.14	124	0.77	-64%	0.98	
Average	101	1.42	98	0.79	-46%	0.94	
Min	73	0.59	82	0.20	-2%	0.82	
Max	147	2.58	153	1.90	-66%	0.98	

Table 2 Hot water consumption results and analysis

	Hot water use with original water heater		Hot water use with tankless water heater		Analysis		
Site ID	**Monitored period (# days)**	**Average water use (ℓ/day)**	**Monitored period (# days)**	**Average water use (ℓ/day)**	**% Change**	**Rated EF**	**Average change in water use**
A	118	200.8	102	194.6	-3%	0.82	-13%
B	85	107.7	90	87.9	-18%	0.82	
C	73	228.9	90	204.3	-11%	0.82	
D	97	114.2	100	92.7	-19%	0.84	
E	117	347.8	93	288.9	-17%	0.90	5%
F	82	426.7	94	321.6	-25%	0.92	
G	90	243.1	89	212.3	-13%	0.94	
H	103	167.5	103	189.1	13%	0.96	
I	103	263.4	104	275.4	5%	0.98	
J	90	58.6	88	62.2	6%	0.98	
K	80	276.6	89	308.3	11%	0.98	
L	92	100.4	96	96.3	-4%	0.98	
M	95	169.9	104	170.5	0%	0.98	
N	90	124.9	96	98.3	-21%	0.98	
O	77	240.9	153	296.6	23%	0.98	
P	91	366.8	96	367.7	0%	0.98	
Q	144	507.8	89	638.4	26%	0.98	
R	103	110.1	85	178.4	62%	0.98	
S	97	235.9	103	246.4	4%	0.98	
T	81	229.0	96	206.6	-10%	0.98	
U	147	360.0	84	544.9	51%	0.98	
V	147	221.2	82	263.0	19%	0.98	
W	116	343.6	124	236.4	-31%	0.98	
Average	101	236.8	98	242.6	2%	0.94	
Min	73	58.6	82	62.2	-31%	0.82	
Max	147	507.8	153	638.4	62%	0.98	

Overall, there was, on average, a 46-per-cent reduction in natural gas used for water heating after the installation of the tankless water heaters. Even though the condensing tankless units are designed to be more energy efficient, on average, the non-condensing tankless heaters saw the greatest energy savings. However, given the small sample size and the differences in the storage-type water heaters installed in the homes, no conclusions can be drawn concerning the performance of the condensing and non-condensing tankless heaters. One reason the homes with the non-condensing tankless heaters achieved greater natural gas savings is that the four houses that had these systems installed saw their usage of hot water decrease by an average of 13 per cent, compared to an average increase of 5 per cent for the houses with the condensing units. As shown in Table 2, considering all of the sites, there was an average increase in hot water use of 2 per cent after the installation of the tankless water heaters.

There was a large fluctuation in the pre- and post-installation hot water usage from house to house that was influenced both by how tankless water heaters heat and deliver hot water and changes in occupant usage. Some houses increased hot water usage after the installation of the tankless water heaters while other houses decreased usage. The availability of an endless supply of hot water might explain the 51-per-cent and 62-per-cent increases in hot water seen in two of the sites.

Fourteen of the 25 survey respondents expressed that the "endless" hot water was something they liked about the tankless system, while 10 respondents indicated that they enjoyed the energy savings. Fourteen of the 25 survey respondents expressed a dislike for the increase in the time it took to get hot water to the tap with the tankless heaters. The average increase in the time delay to get hot water at the tap was reported in the occupant survey to be around 20 seconds, although this didn't seem to have a significant impact on hot water consumption, as seen in Table 2. Three of the respondents (1 owner, 2 renters) commented that they disliked the high cost of the units. Although no costs are available for these three houses, two of the original houses that did not complete the study did not install tankless heaters due to high costs: one after receiving a quote of $4,000 for the purchase and installation of a tankless heater, and the other after being provided with an estimate of $1,000 to remove the existing rental storage-type heater.

CONCLUSIONS

Based on the results of the study, replacing the existing natural gas-fired, storage-type water heaters with gas-fired tankless water heaters can result in significant natural gas savings for water heating. On average, 0.63 m^3/day or 230 m^3/year of natural gas was saved. At \$0.30/m^3, this translates to an average savings of \$69 per year. It may also be concluded that, based on the study results, the installation of tankless water heaters may lead to an increase in hot water usage though the extent of any such increase would be highly dependent on how individual occupants respond to the availability of endless hot water. Homeowners tended to respond positively to the endless supply of hot water delivered by tankless water heaters. Some reservations were expressed regarding how long it took for hot water to arrive at the faucet and the cost of the units.

IMPLICATIONS FOR THE HOUSING INDUSTRY

The availability of tankless hot water heaters provides builders, renovators and consumers with a water heater option that can save energy and associated costs, reduce space needs, and provide "endless" hot water. Careful design and installation of tankless water heating systems may help overcome issues related to hot water delivery time.

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