# Evaluation of
# Potential Best Management Practices
# -
# Tankless Water Heaters

Prepared for

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NOTE: For a full introduction to the
Council's Potential Best Management Practice (PBMP) process,
refer to previous reports that detail the purpose and
status of that process since its inception in 2004:
http://www.cuwcc.org/products/pbmp-reports.aspx

# Tankless Water Heaters

## Introduction

Are tankless water heaters a water savings technology? In short, the answer is no. There are ways to install them so as to improve the water use efficiency of a hot water distribution system, but as manufactured, they do not save water. In fact, with two exceptions, all tankless water heaters available at the time of writing this paper waste more water than storage water heating technology. This paper provides the evidence.

### What is a Tankless Water Heater?

There are two Federal statutes that govern the efficiency of water heaters, the National Appliance Energy Conservation Act (NAECA) and the Energy Policy Act (EPAct). These statutes define a category of water heaters called instantaneous. Instantaneous water heaters have large firing rates relative to their small water capacities. By law, they are allowed to have an internal volume of up to 2 gallons of water. This volume limitation applies to all instantaneous water heating technology, regardless of the fuel source (natural gas, propane, electric or oil).

Up until January 2010, none of the water heaters sold under this legal category were, in fact, instantaneous. An instantaneous water heater is a water heater in which hot water leaves the water heater immediately once a tap is opened. For this to happen, there needs to be a stored volume of hot water before the tap is opened. In other words, the water heater must have some storage. Naming the category instantaneous caused some significant market confusion because customers thought that by installing one of these water heaters they would get hot water at their tap instantaneously, something they really want to have. Instead, it took longer for hot water to arrive at their hot water outlets, and more water was wasted too!

Over time, the market has come to call the instantaneous category tankless. In fact, these water heaters are not truly “tankless”, since as stated above, they are allowed to store up to 2 gallons of water internally. Most of the natural gas and propane tankless water heaters available in the U.S., however, have approximately one quart of internal capacity; one has 0.75 gallons (heat exchanger and a 0.5 gallon tank) and one has two gallons. See Figures 1 through 3 for examples of gas tankless water heaters. Electric tankless water heaters have volumes ranging from about one cup to one gallon. See Figures 4 through 6 for examples of electric tankless water heaters.

**Figure 1. Gas Tankless Water Heater**
**Internal volume is approximately 1 quart (Rinnai)**

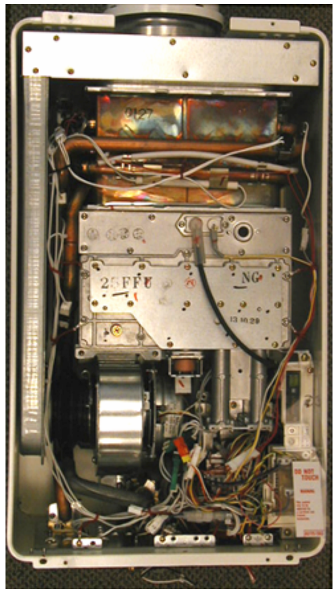


**Figure 2. Gas Tankless Water Heater**
**Internal volume is approximately 3 quarts (Navien)**

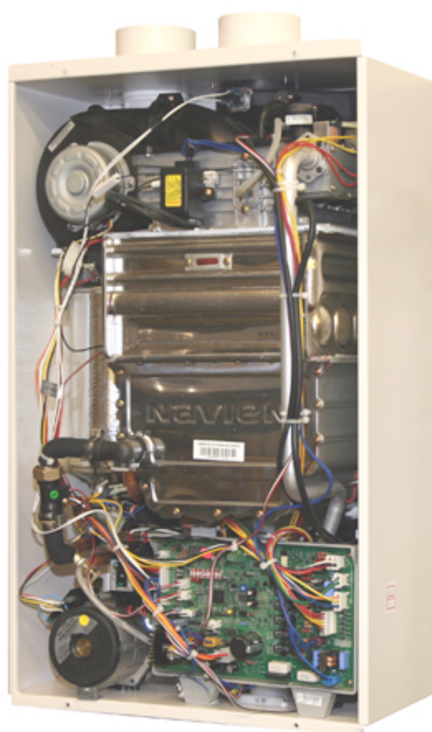


**Figure 3. Gas Tankless Water Heater**
**Internal volume is approximately 2 Gallons (Grand Hall)**

**Figure 4. Electric Tankless Water Heater**
**Internal volume is less than 1 Cup (Skye)**

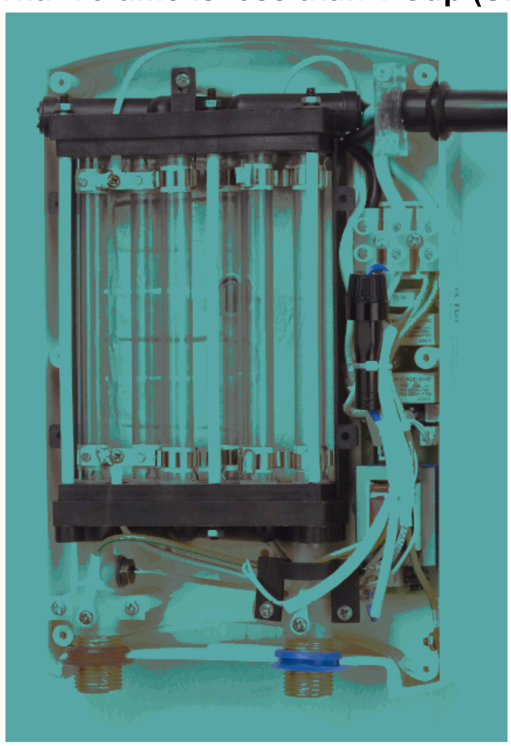


**Figure 5. Electric Tankless Water Heater**
**Internal volume is approximately 2 cups (Stiebel Eltron)**

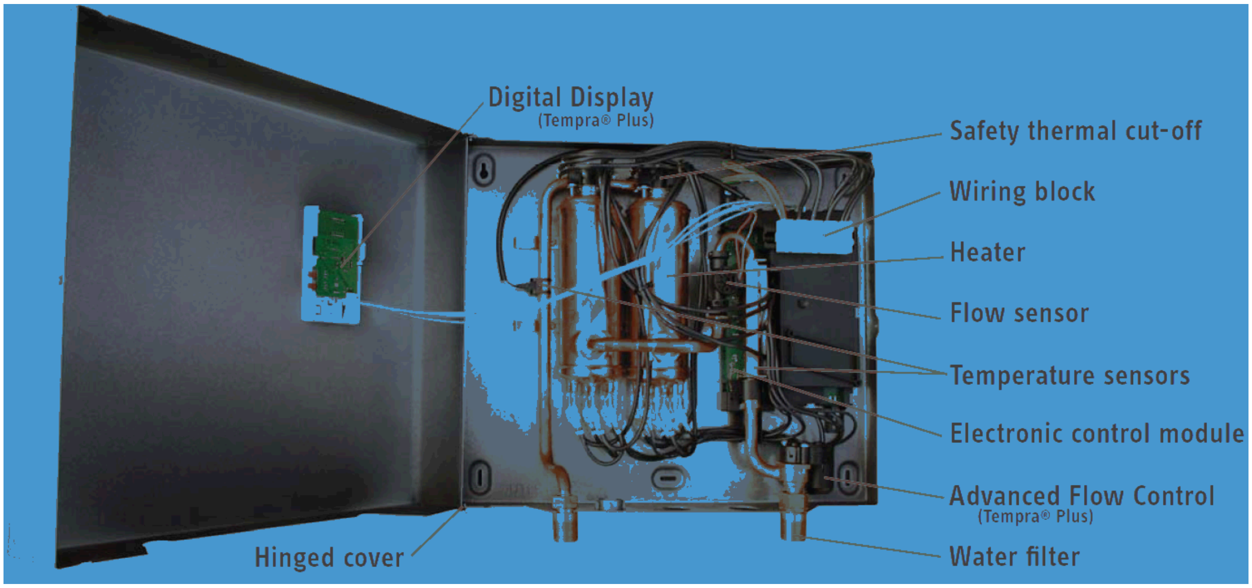
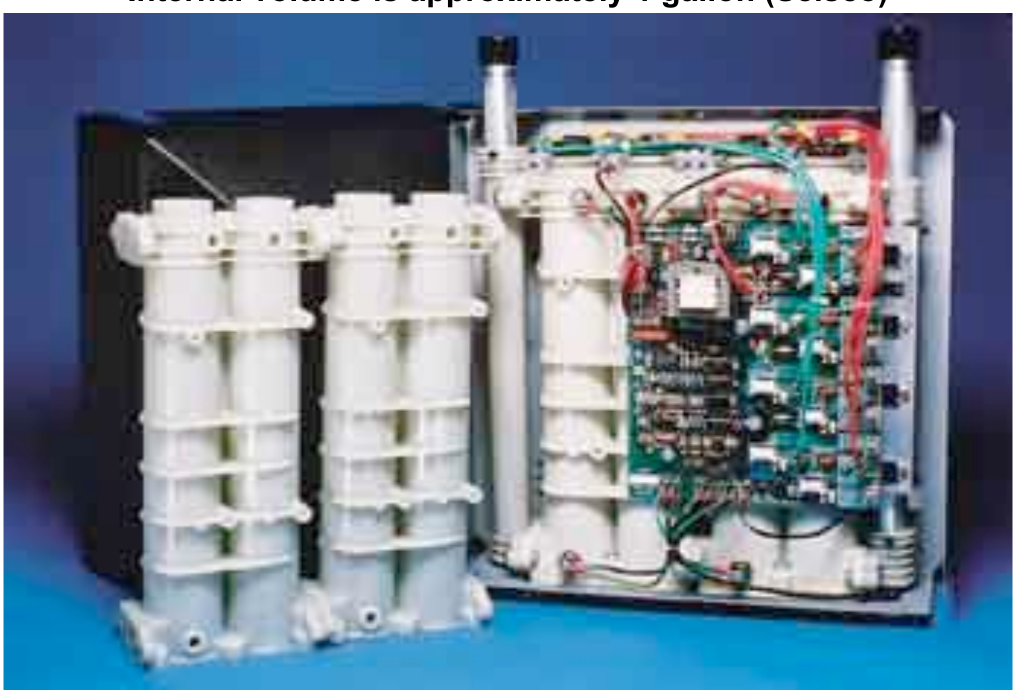



**Figure 6. Electric Tankless Water Heater**
**Internal volume is approximately 1 gallon (Seisco)**

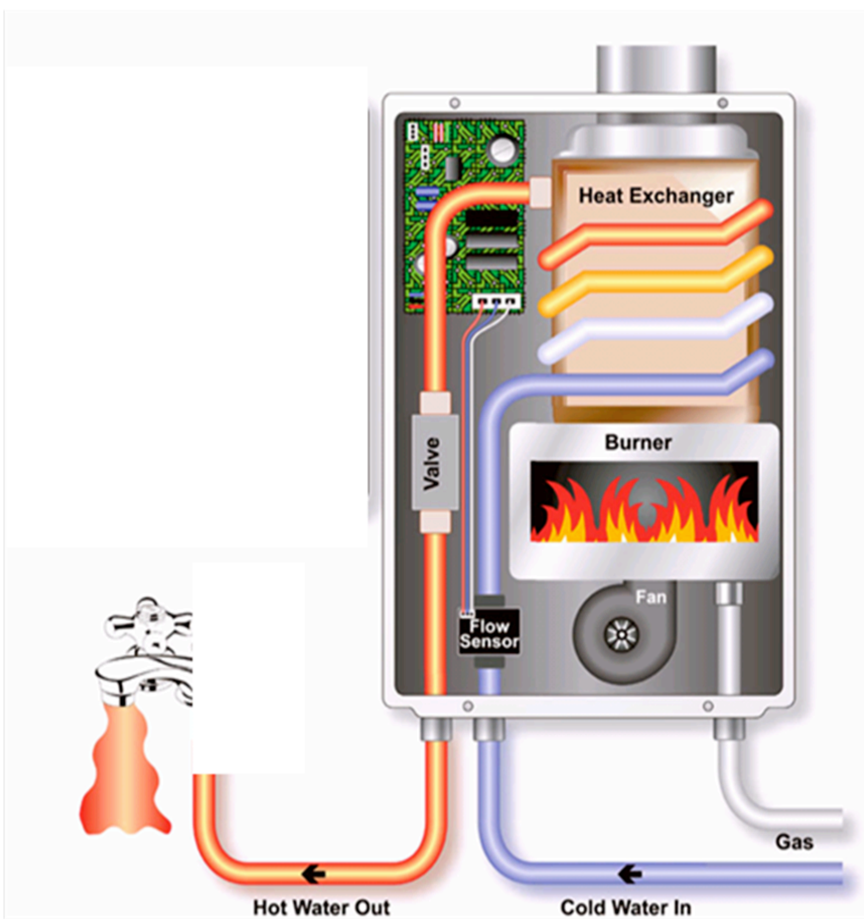


## How Do Tankless Water Heaters Work?

This paper focuses primarily on the performance of whole-house gas tankless water heaters (meaning both natural gas and propane) and, secondarily, on electric tankless water heaters.

Figure 7 shows a schematic of a typical gas tankless water heater. When a hot water outlet (e.g., faucet or shower) is opened, cold water starts flowing through the water heater. When the flow is greater than the trigger point for the device, typically 0.75 gallons per minute (gpm), the flow switch sends a signal to the heater's computer. At this point, the heater's fan comes on to clear any residual combustion byproducts from the combustion chamber. Next, the gas valve opens and the burner modulates the firing rate in an amount proportional to the flow rate. The water is heated as it travels through the heat exchanger. This continues throughout the duration of the hot water event. When the hot water event is completed, the flow switch signals the computer that flow has stopped and the gas valve is turned off. The fan continues operating to clear any combustion byproducts from the combustion chamber and to cool down the heat exchanger.

**Figure 7. Schematic of a Gas Tankless Water Heater**



Electric tankless water heaters operate in a similar fashion (See Figure 5 for details). When a hot water outlet is opened, cold water begins flowing through the water heater. When the flow is greater than the trigger point for the device (typically in the range of 0.25 – 0.75 gpm), the flow switch sends a signal to the internal computer. At this point, electricity is fed to the elements in an amount proportional to the flow rate. Water is heated as it travels through the water heater. This continues throughout the duration of the hot water event. When the hot water event is completed, the flow switch signals the computer that flow has stopped and the electric power to the elements is turned off. The basic method of operation is very similar to that of a gas tankless water heater. Most manufacturers have a mechanical flow switch that senses flow in a similar fashion to the flow switch in a gas tankless water heater. One company uses temperature difference to determine flow and can operate at very low flow rates.

## Why Tankless Water Heaters Cannot Save Water

There are two main reasons why tankless water heaters are not water saving devices when compared to storage water heaters installed in the same location.

1. At the beginning of a hot water event, tankless heaters start with cold water. The water passing through the heat exchanger needs to ramp-up to the desired temperature. During this time, cold water runs through the water heater and enters the plumbing system (trunk line) on its way to the hot water outlet (e.g., faucet or shower). This is true for both gas and electric tankless water heaters, although we have only found data on this event for gas tankless water heaters.
2. When sized properly (as they should be!), tankless water heaters allow for “continuousness”, or “never running out of hot water in my shower”. The question is whether people will take advantage of this capability and how much this will affect their overall water usage. There are some indications that with this attribute, users change their habits and take longer showers, thereby potentially offsetting expected “savings”.

The next two sections of this paper discuss these two issues.

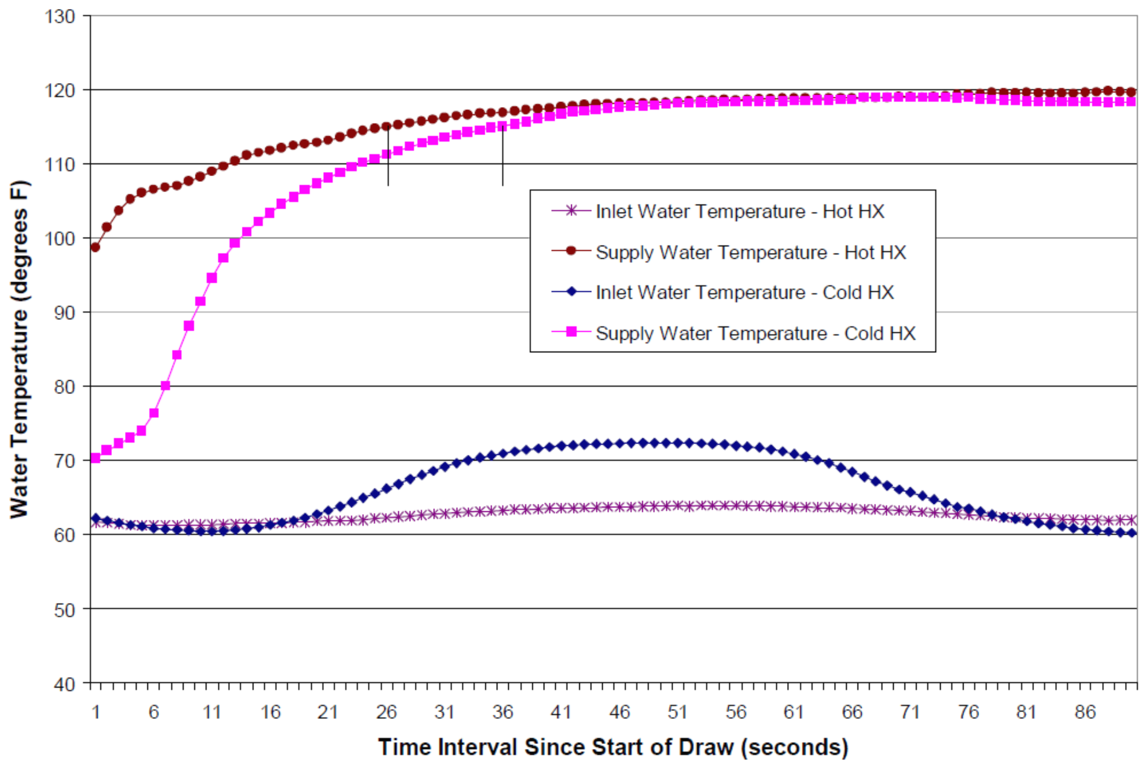
### Wait Time and Water Waste at the Beginning of a Hot Water Event

When the user opens a hot water faucet valve, the typical tank-type storage water heater immediately sends hot water into the piping system. With a tankless water heater, on the other hand, water first begins to pass through the cold heat exchanger, which heats up quickly. However, there is still a delay before the full temperature is reached and, as such, cold or lukewarm water is delivered by the heater into the plumbing system. Several studies document the waste of water and time.

*California Energy Commission (CEC)*

Tankless water heater manufacturers claim that there is a small delay (about three to four seconds) before the burner ignites when activated by the internal computer. This claim is reasonably accurate. However, the Davis Energy Group, under the auspices of a study funded by the CEC, found that it took significantly longer before hot water actually exited the water heater[1]. Figure 8 shows that, with a flow rate of 1.9 gpm (typical of the total flow rate for a water-efficient faucet or shower or the portion that is hot in a standard faucet or shower), it took 26 seconds to reach 115°F supply water temperature when a previous draw had been taken 5 minutes before (heat exchanger was still relatively hot, or Hot HX). It took 36 seconds when hot water had not been drawn for 45 minutes (heat exchanger was relatively cold, or Cold HX). The impact was negligible (29 and 37 seconds, respectively) when the same test was conducted at a flow rate of 3.3 gpm.

**Figure 8. Hot and Cold Start-up Performance of a Tankless Water Heater**




The time it takes for the temperature to ramp up to the desired delivery temperature results in additional water waste. Using the flow rates and times from the Davis Energy Group's study findings for the CEC, Table 1 shows the volumes wasted for both hot and cold heat exchangers.

[1] Davis Energy Group, 2006. *"Field and Laboratory Testing of Tankless Gas Water Heater Performance"* prepared for Lawrence Berkeley National Laboratory, April 14.

**Table 1. Water Wasted During Temperature Ramp-Up**

| Flow Rate (gpm) | Hot Heat Exchanger (Hot HX) 5 minutes between hot water events | | Cold Heat Exchanger (Cold HX) 45 minutes between hot water events | |
|---|---|---|---|---|
| | Time to 115°F supply water temperature (seconds) | Volume of Water Wasted (gallons) | Time to 115°F supply water temperature (seconds) | Volume of Water Wasted (gallons) |
| 1.9 | 26 | 0.82 | 36 | 1.14 |
| 3.3 | 29 | 1.60 | 37 | 2.04 |

The waste of water is proportional to the flow rate since the heater controls adjust the burner firing rate to match the flow rate. That is, doubling the flow rate doubles the water waste. The reason it takes more time, with the additional water waste when the time between hot water events is longer, is because the heat exchanger has had more time to cool down and the ramp-up process starts from a lower temperature. Figure 8 presents data on the ramp-up time for heat exchanger temperatures (at the start of the burner firing) at 70°F and just under 100°F. When the heat exchanger is located in a colder environment, such as in a garage, basement or on an outside wall during the winter, the heat exchanger will be significantly colder (perhaps as low as 40°F) and the ramp up times and water waste will be even larger.

How significant is this 0.8-2.0 gallons of water wasted per hot water event? Davis Energy Group stated, "The added time delay may or may not be a concern for homeowners, depending upon their expectations and the type and configuration of their hot water distribution system."[2] However, the importance of the additional time delay and water waste really depends on the length of the hot water event and on the volume of water that is in the hot water distribution system. At the low end, if the duration of the hot water event after the hot water has arrived at the fixture is 30 seconds, the additional delay ramping up to temperature doubles the length of the hot water event. If the duration of the hot water event is 300 seconds (say for a five minute shower), the ramp-up time adds 10 percent to the length of the hot water event. While the volume of water wasted waiting for the hot water to arrive is the same in both cases, the time impact could vary from significant (for a 30 second event) to trivial (for a 300 second event).

Therefore, where there are a large number of small duration hot water events, such as at lavatory sinks in public restrooms, which can experience actual hot water use of less than 10 seconds, the waste of water and time are proportionally much larger and perceptually more noticeable.

The time delay due to ramping up the temperature must be added to the time delay in delivery of hot water through the water distribution system. Assuming that there is one gallon of water in the hot water distribution system piping between the water heater and a given hot water outlet (a very typical amount), and assuming a 1.9 gpm faucet or shower outlet, it will take more than

[2] Ibid

30 seconds to clear out the "not hot" water in the piping. Adding 15 seconds in wait time and 0.5 gallons of water, the time-to-tap and volume-to-hot increases by 50 percent, which is significant in both quantity and perception.

Figure 8 also shows that if the desired or needed hot water supply temperature is lower (say 105°F), the time delay decreases to 5 seconds with a hot heat exchanger and to 17 seconds with a cold heat exchanger. This leads to the conclusion that locating the water heater as close to the hot water outlets as possible, or insulating the hot water distribution system, or both, would be beneficial from both the time delay and water waste perspectives. The reason to do this is to minimize the temperature drop in the piping between the water heater and the hot water outlets. In addition, the smaller the volume in the hot water distribution system, the smaller the energy losses in the piping will be. Moving the water heater closer to the hot water outlets and insulating the hot water distribution system would be a benefit for storage water heaters as well. As such, these strategies are not inherent to the type of water heater and cannot be claimed as a water use efficiency measure solely for tankless water heaters.

*Water Efficiency Labelling and Standards (WELS) Scheme*

The Australian Government funded a study[3], conducted under the auspices of the Water Efficiency Labelling and Standards (WELS) Scheme[4], that looked at whether gas tankless water heaters wasted water and, if so, how much. In this study, the water wastage was the volume of water that flowed through the unit from the time the burner of the unit was activated until the temperature of the water (as recorded by the data logger) reached, on the first occurrence, the temperature differentials of 5°C (9°F) and 1°C (1.8°F) from the average steady state temperature. This test procedure is different from that used by the Davis Energy Group, which measured wasted water from the time the flow sensor registered flow. From the perspective of the customer who turns on a tap, the WELS test procedure underestimated the waste of water and time.

The pattern shown in Figure 9, which is derived from the Szann study, is very similar to the one developed by the Davis Energy Group. The X-axis is in seconds. The water heater set point is equivalent to 140°F, which is 18 degrees higher than the one tested by the Davis Energy Group. The red line shows the temperature at the outlet of the water heater. From the time the burner ignited, it took 10 seconds for the water to reach 115°F (45°C in the figure), 15 seconds to get within 5°C of the set point and more than 30 seconds to get within 1°C. The green line shows the temperature at a discharge point (hot water outlet). It takes 26 seconds to reach 115°F (45°C in the figure), 34 seconds to get within 5°C of the set point and more than 70 seconds to get within 1°C. This highlights the additional waste of water and time to clear out the "not hot" water in the hot water piping.

[3] Szann, Aleksander, "Water Wastage of Instantaneous Gas Water Heaters", Department of the Environment, Water, Heritage and the Arts, Australian Government, 2008.
[4] http://www.waterrating.gov.au/about/index.html

## Figure 9. Water Heater Profile – Time

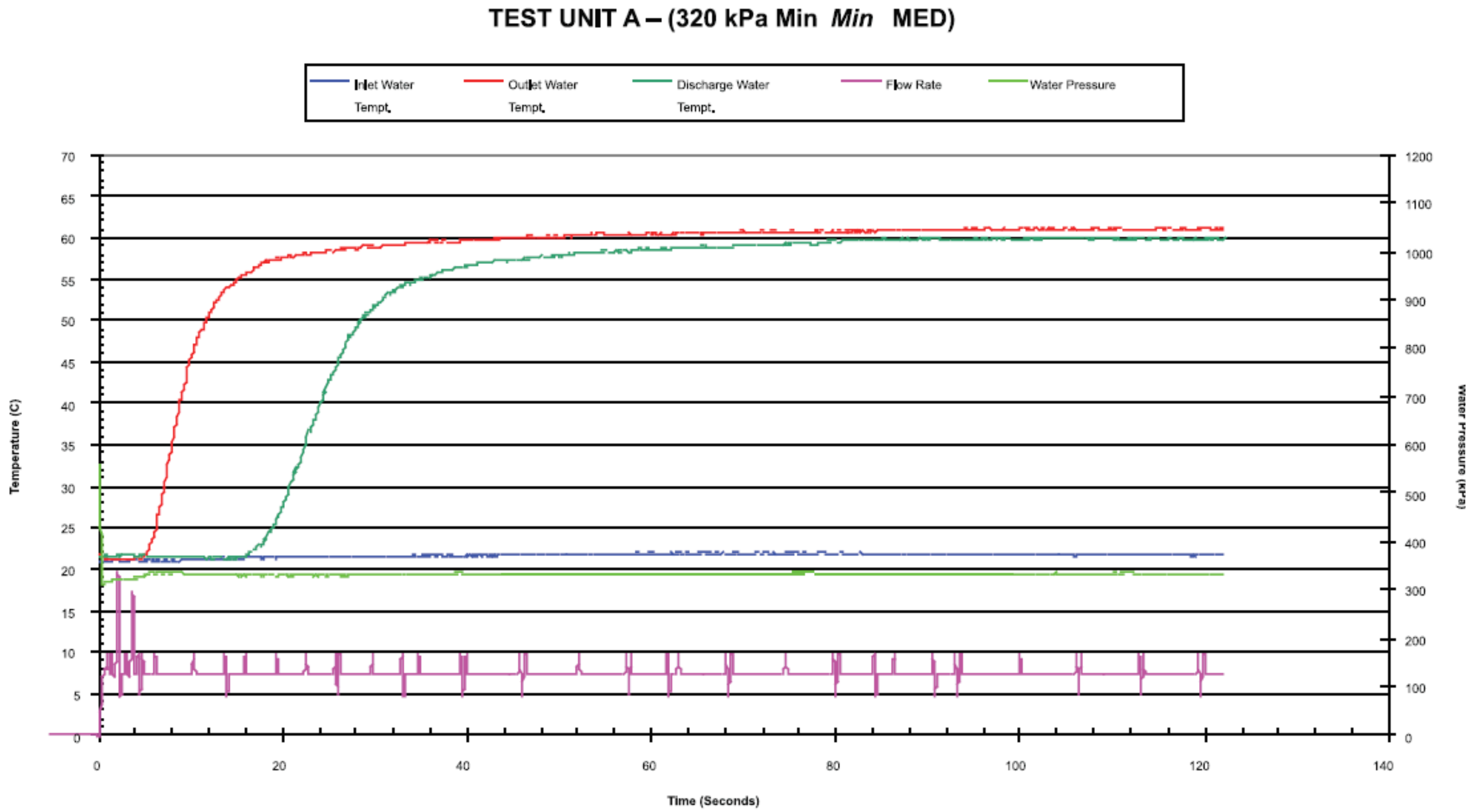
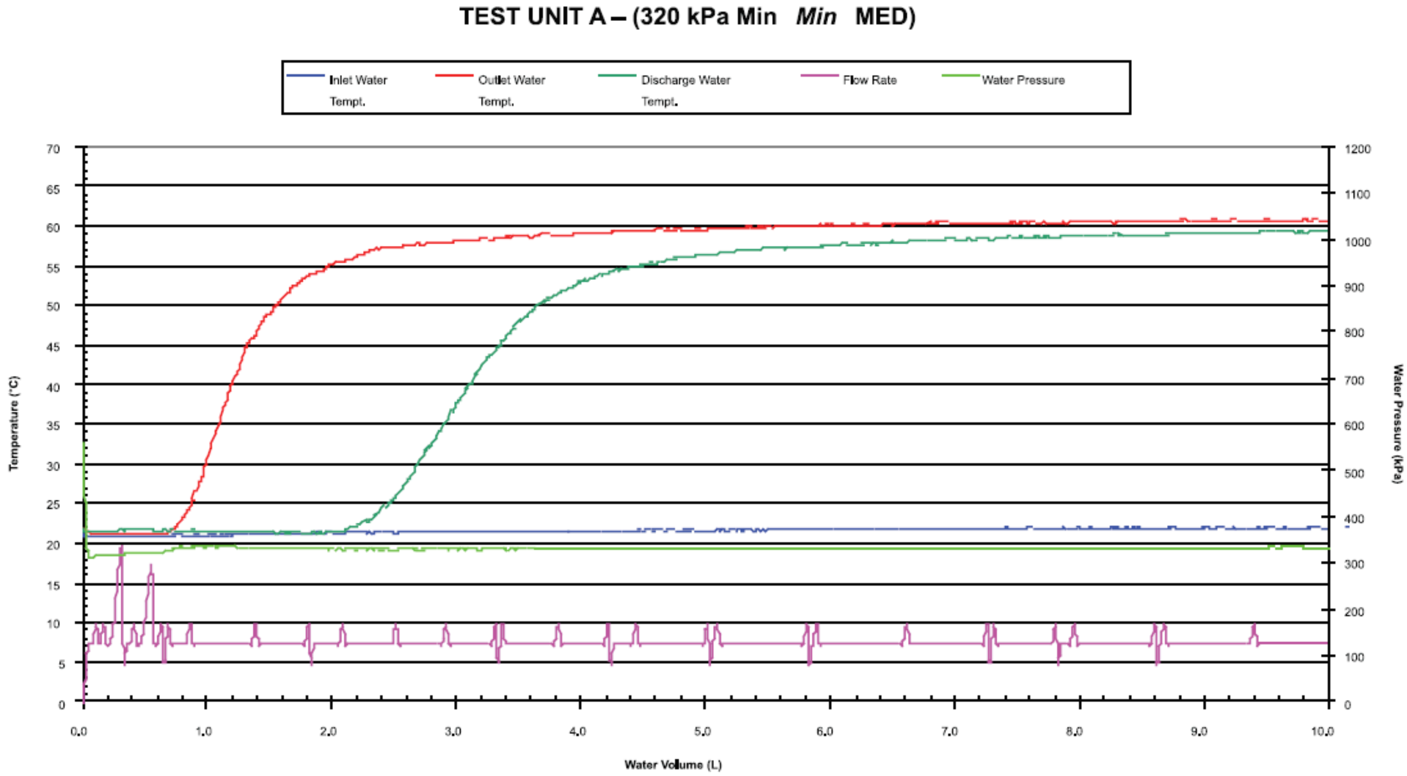



Figure 10 shows another test of the same water heater, but now the X-axis is in liters of water. The ramp-up rate is similar but not identical to the one in Figure 9. As before, the red line shows the outlet temperature and the green line shows the discharge temperature. From the time the burner ignited, 0.34 gallons (1.3 liters) were wasted until the water reached 115°F (45°C in the figure), 0.53 gallons (2.0 liters) until the water was within 5°C of the set point and more than 1 gallon (4.0 liters) until the water was within 1°C.

## Figure 10. Water Heater Profile – Volume




The results of tests on eight water heaters are shown in Table 2. The volume of water wasted at the outlet of the water heater ranged from about 0.3 gallons to more than 2.5 gallons per hot water event. More water was wasted at the discharge. As mentioned above, the WELS methodology understates the waste of water and time.

## Table 2. Water Wasted Per Hot Water Event

| Water heater | Water wasted | | | |
|---|---|---|---|---|
| | At outlet | | At discharge | |
| | $t_{\Delta 5}$ (L) | $t_{\Delta 1}$ (L) | $t_{\Delta 5}$ (L) | $t_{\Delta 1}$ (L) |
| Test Unit A | 2.1 | 4.4 (max 8.0) | | |
| Test Unit B | 1.2 | 1.4 (max 9.7) | 3.2 | 3.4 (max 11.6) |
| Test Unit C | 2.5 | 3.4 | 3.9 | 4.9 |
| Test Unit D | 1.3 | 1.4 (max 5.6) | | |
| Test Unit E | 2.2 | 3.3 | | |
| Test Unit F | 1.4 | 2.3 | | |
| Test Unit G | 2.0 | 2.8 | | |
| Test Unit H | 2.0 | 2.4 | | |

*Consumer Reports Magazine (CRM)*

As reported in 2008, CRM ran comparison tests between Takagi and Noritz gas-fired tankless water heaters and three storage water heaters[5]. They chose not to test electric tankless water heaters due to perceived capacity limitations. Their evaluation simulated the use of 76 to 78 gallons of hot water per day, the equivalent of taking three showers, washing one load of laundry, running the dishwasher once (six cycles) and turning a faucet on nine times, a total of 19 draws. CRM also ran more than 45,000 gallons of very hard water through the water heaters to simulate about 11 years of hot water use.

CRM found that users they polled reported getting a “cold water sandwich” at the beginning of some hot water events. In addition, users also reported that at low flow rates, such as when running a trickle of water for shaving, the gas-fired tankless water heater would not ignite, so only cold water would be delivered into the plumbing system.

They also reported that the water heaters they tested did not deliver water instantaneously, since it takes time to heat the water up to the target temperature. The volume of water that was wasted during temperature ramp-up was not reported.

*Center for Energy and Environment*

The Center for Energy and Environment in Minneapolis, MN is currently in the middle of a study comparing the performance of natural gas tankless water heaters with typical gas storage water heaters. Ben Schoenbauer, a research engineer with the Center provided information on the overall project and some of their preliminary results[6].

The study involves 10 homes. Two or three water heaters have been installed in each home and each is tested for one month to evaluate how each performs over a full range of seasons. The houses range in size from 1,000 to 2,500 square feet and the number of occupants ranges from one to five. Incoming cold water temperatures range from a low of 36$^{o}$F in February to a high of 74$^{o}$F in August. Temperature measurements are being taken approximately six inches away from the water heater on the hot pipe to determine the amount of time it takes to reach 95% of the way to the heater’s set point.

Several different types of tankless water heaters have been installed. The Center has observed two control strategies. One is a gradual ramp-up to the desired temperature, as shown in Figures 8, 9 and 10. The other is an overshoot – undershoot strategy that eventually settles down to the set point temperature. At flow rates between 1.0 and 2.5 gpm, they found that the overshoot – undershoot strategy is somewhat quicker (10 – 12 seconds) at reaching the set point than the gradual ramp-up strategy (approximately 20 seconds), but note that this strategy puts significantly hotter water into the hot water distribution system, thereby increasing the

[5] Consumer Reports Magazine, 2008. *“Tankless Water Heaters – They’re efficient but not necessarily economical”*, Posted September 2008 – Consumer Reports Magazine issue, October 2008.
[6] Personal Communication, 2010. Ben Schoenbauer, Research Engineer, Center for Energy and Environment, Minneapolis, MN, February.

potential risk of scalding. At flow rates greater than 2.5 gpm, the overshoot – undershoot ramp-up strategy can be as long as 20 seconds. When the flow rate is less than 1.0 gpm, it takes twice as long to reach 95% of the set point temperature.

Although the Center has not yet reported the amount of water wasted during ramp-up, it is possible to estimate this from the time information they have provided. At flow rates from 1.0 – 2.5 gpm, the volume wasted during ramp-up ranges from 0.17 – 0.83 gallons. This is lower than that reported by the Davis Energy Group, but still significant.

The Potential for Endless Hot Water

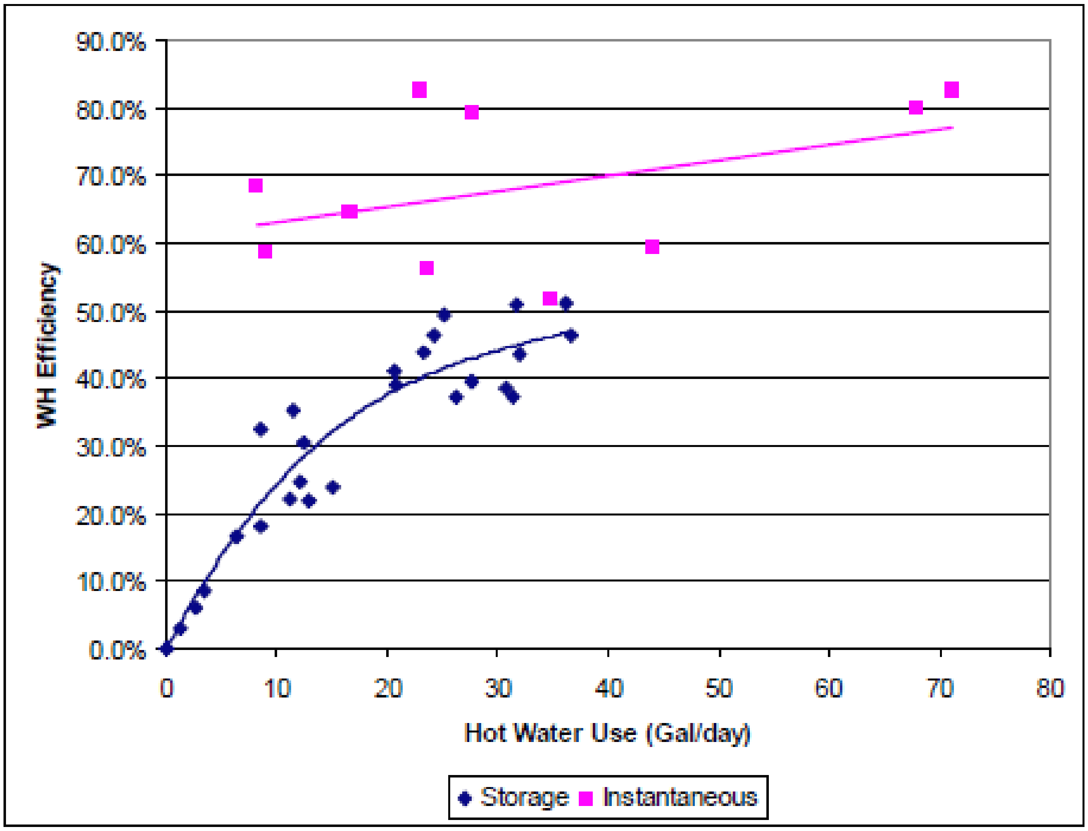
If people have the ability to take an extended or even an endless shower, will they do so?

*California Energy Commission (CEC)*

The Davis Energy Group, under the auspices of a study funded by the CEC, reported on a field test they had conducted for the Building America program in 2003[7]. Figure 11, which was originally used to compare the efficiency of a storage water heater with a tankless water heater, can also be used to compare water consumption. This figure shows the before (storage – one month) and after (tankless – two weeks) consumption of hot water for a two person household. When the storage water heater was in use, hot water consumption never exceeded 40 gallons per day. During the first two weeks after installation of the gas tankless water heater, daily hot water consumption was greater than 40 gallons three times, twice over 65 gallons.

[7] Davis Energy Group, 2006. *"Field and Laboratory Testing of Tankless Gas Water Heater Performance"* prepared for Lawrence Berkeley National Laboratory, April 14.

**Figure 11. Comparison of Daily Water Heater Efficiency**




Since this figure shows data only for the period of time immediately after the change-out of the water heater, it remains uncertain if the additional hot water use is a “trying out my new toy” phenomenon <u>or</u> if the increased hot water consumption will persist.

*The Center for Energy and Environment*

The Center is also measuring hot water usage. So far, the study has found that there appears to be no correlation between the type of water heater and the consumption of hot water. They have not yet reported on whether or not they have seen the “new toy” phenomenon.

## What Can Be Done to Reduce the Waste of Water from Typical Tankless Water Heaters?

This paper has shown that the most widely sold gas tankless water heaters waste between 0.3 and more than 2 gallons of water ***for each hot water event*** while they ramp-up to the set point temperature. This waste is in addition to the waste of the cold water that must be purged from the hot water distribution system when a hot water event is initiated.

There are two ways to reduce this waste: (1) add a tank to the tankless water heater or (2) move the water heater closer to the hot water outlets. Combining both of these strategies is the best option.

Adding a Tank to the Tankless Water Heater

It is not necessary to add a large tank. The tank can be integral to the water heater or it can be added externally to the tankless water heater. Two gas tankless water heaters currently existing that provide tanks integral to the unit.

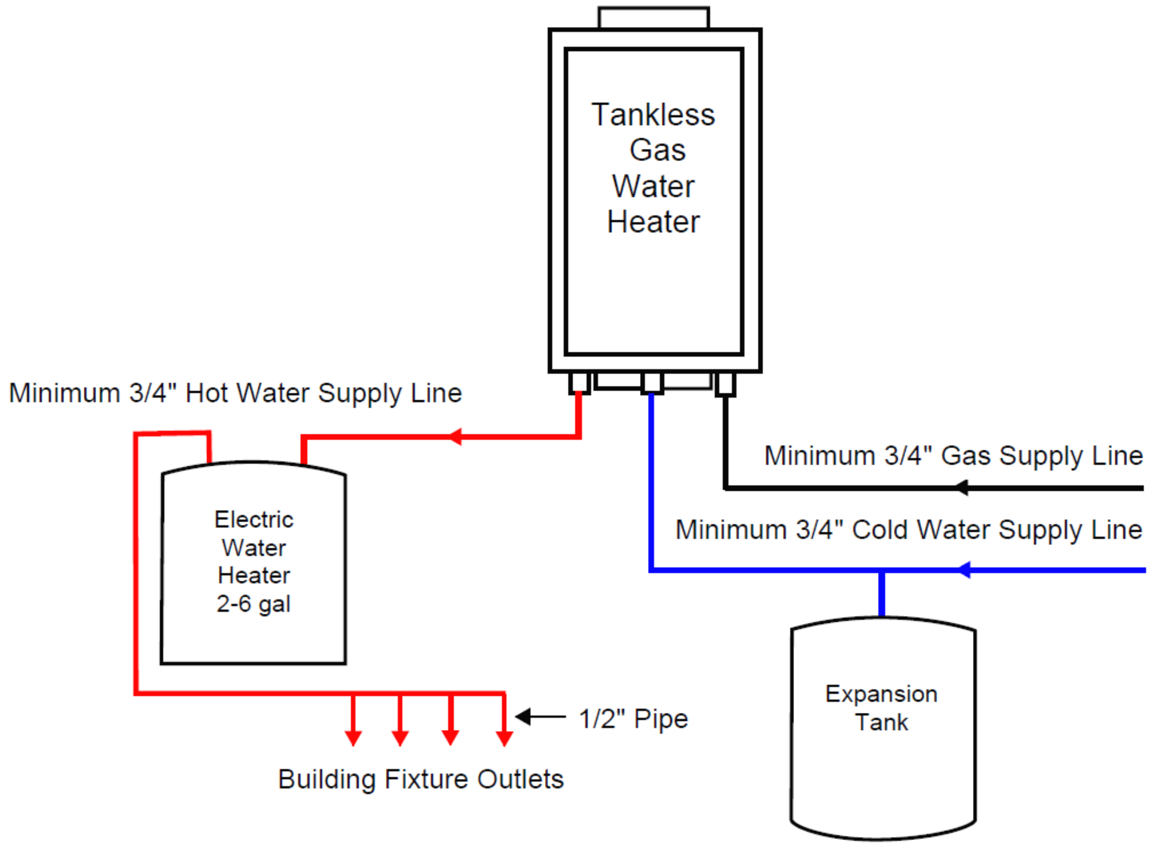
One of Navien's gas tankless models uses an integral tank located after the heat exchanger. It is located to the left in Figure 2. The tank contains approximately 0.5 gallons of water, which is kept hot by circulating water through the heat exchanger when the tank cools down. During operation, cold water enters the tank, which buffers its temperature. The mixed temperature water then passes through the heat exchanger where it gets heated to the set point.

The location of the tank after the heat exchanger means that when a tap is opened, hot water leaves the water heater immediately. This is good from the water use efficiency perspective. However, the tank is very poorly insulated. This means that it loses heat rather quickly, causing the recirculating pump to come on and the burner to fire roughly every 30 minutes or so. This significantly degrades the overall energy efficiency, dropping it to approximately 72 percent compared to the 95 percent claimed. When they complete their research, the Center for Energy and Environment will report on how well this technology performs compared to the other tankless water heaters they tested.

The newest gas tankless water heater manufactured by Grand Hall has a two gallon tank integral to the unit. A schematic of this water heater, the Eternal, is shown in Figure 3. The tank surrounds the burner, which maintains the tank at a preset temperature. During operation, cold water enters the tank, which buffers its temperature, while hot water leaves the tank. There is no delay while the water temperature ramps up to the set point. Performance at the beginning of each hot water event should look similar to that of a typical storage water heater. The Energy Factor of this water heater is claimed to be 0.96, which indicates that the storage tank is rather well insulated. However, these claims have yet to be verified based upon field performance measurements.

Alternatively, a tank can be installed external to the water heater. Figure 12 shows a schematic of a gas tankless water heater where a small electrically heated tank has been added after the water heater. An expansion tank has been added to accommodate any expansion that may occur when the water is heated during periods of no water use.

**Figure 12. Gas Tankless Water Heater with an External Electric Storage Water Heater**




*Drawing by Anne Hess*

This configuration is what the gas tankless water heater manufacturers recommend when customers experience a "cold water sandwich". The "sandwich" occurs when hot water is demanded at a hot water outlet when the temperature of the water in the pipes has not yet cooled down, such as in the 5 minutes between hot water events studied by the Davis Energy Group. For example, imagine a morning where someone takes the second shower following soon after the first shower is taken. They turn on the shower valve and feel that the water is hot (the water in the pipe having not yet cooled down), so they get in and start their shower. After the hot water in the piping has passed through the showerhead, the cold water that went through the water heater during the initial ramp-up arrives. This slug of cold or lukewarm water can be quite a surprise (potential for thermal shock)! If the problem is annoying enough, the customer will either learn to wait long enough for the "sandwich" to pass through, which wastes even more water, or they install a post-heater tank.

The electric energy required for the tank is mostly needed to overcome the standby heat losses of the tank itself. During operation with the tank in place, when a tap is opened, hot water leaves the tank. Cold water enters the heat exchanger and passes through to the electric tank that buffers the temperature. In the meantime, the gas tankless water heater has ramped up to the desired temperature and hot water passes through the small tank on the way to the hot water outlet (e.g., faucet or shower). When the event is complete, the valve is turned off, and the tank is full of hot water, which has been heated by the gas tankless water heater.

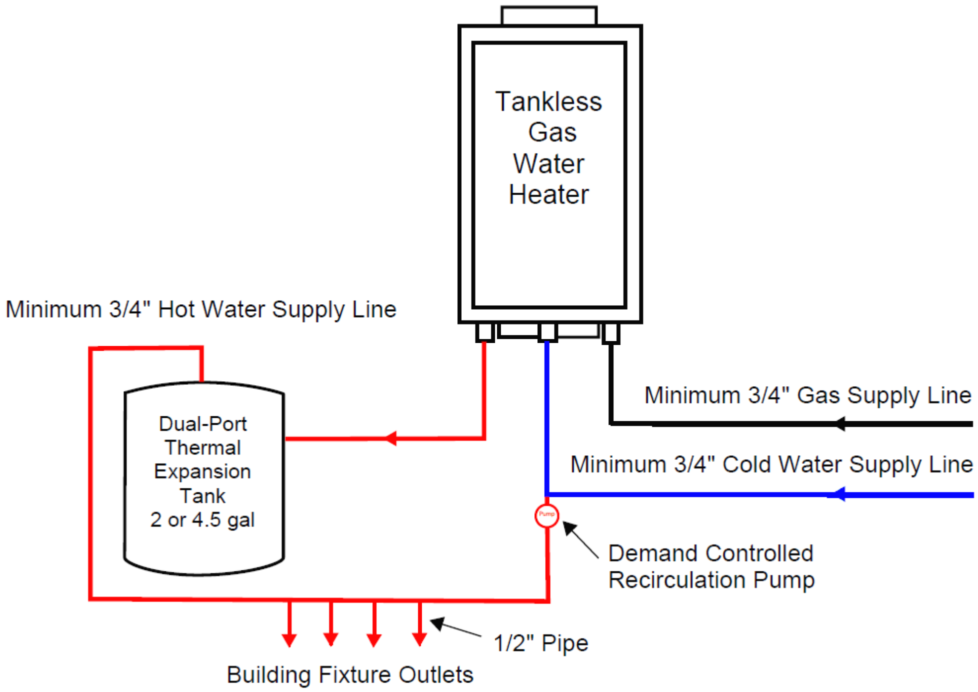
While the previous strategy solves the "cold water sandwich" problem and makes the waste of water no greater than would occur with a storage water heater in the same location, many people incorrectly believe that they are buying "instantaneous hot water". To accommodate that desire, the gas tankless water heater manufacturers recommend the installation of a recirculation pump in addition to the electric storage water heater. The pump is installed to run through the tank, maintaining the hot water distribution system at the desired temperature for many hours of the day. This strategy will save water, but it is <u>very</u> energy intensive. Running a recirculation loop continuously, assuming a 1.0 gpm flow rate and only a 5$^{o}$F temperature drop around the loop, will consume more than 6,000 kwh in a year just to keep the loop warm, making it a very expensive approach. Beyond that, additional electricity is needed to run the pump.

Saving water at the expense of using electricity is not a good trade-off, so another strategy needs to be implemented. Figure 13 shows a dual-port expansion tank located in the same position as the electric storage water heater in Figure 12. The dual-port expansion tank allows water to pass through when a hot water outlet is open, only acting as an expansion tank when the water is turned off. Two openings means that gunk does not collect in the expansion tank, a problem with traditional one-port designs. A demand-controlled pump is located where the recirculation pump would normally be installed.

Shortly before hot water is desired, the occupants "tell" the pump to come on by means of a button or motion sensor. The demand controlled pump comes on, causing the gas tankless water heater to begin ramping up to the set point temperature. This primes the hot water supply line, including the dual-port expansion tank with hot water. When the pump's controls see a rise in temperature of approximately 5$^{o}$F, the pump shuts off. This process typically takes one to two minutes, depending on the volume of water in the hot water loop. When someone opens a tap, hot water comes out immediately, assuming that the volume between the hot water supply line and the hot water outlets is small (as it should be!). The gas tankless water heater has already fired so that the heat exchanger is still relatively warm. Any cold water that passes through during the ramp-up period of the actual hot water event is buffered by the hot water in the dual-port expansion tank, so no "cold water sandwich" results. It takes significantly less energy to prime the hot water supply line with hot water on-demand throughout the day than it does to keep a recirculation loop running all day. All of the water is heated by the gas tankless water heater and the only electricity needed is for the pump, which on a very busy day will run much less than one hour, probably less than 30 minutes.

It is necessary to install an on-demand pump in conjunction with the dual-port expansion tank. The reason is that the volume in the expansion tank adds its volume to the hot water distribution system, roughly 2 to 6 gallons depending on which expansion tank is installed. If the on-demand pump is not used to prime the hot water line before each event, it will be necessary to run this additional volume down the drain, significantly increasing the waste of water, energy and time.

**Figure 13. Gas Tankless Water Heater, Dual-Port Expansion Tank and Demand Controlled Pump**




Moving the Water Heater Closer to the Hot Water Outlets

How close to the hot water outlets does the tankless water heater need to be? To be a water use efficiency measure, the tankless water heater needs to reduce the waste that is due to the plumbing (i.e., the water "stored" in the pipes during non-event periods) by an amount that is greater than the amount of water than is wasted while the water heater ramps up to temperature. The waste of water during temperature ramp-up varies from 0.3 to more than 2.0 gallons (4.8 – 32 cups respectively) per hot water event. Not knowing what the water-wasted-during-ramp-up characteristics of the water heater will be, we need to assume that it will waste at the larger end of the range.

The volume of water between a water heater and the hot water outlets it serves varies from less than 1 cup (rare, but possible for water heaters under a sink) to much more than 2.0 gallons. The only way a tankless water heater installation can save water is by removing more than 2.0 gallons from the hot water distribution system. It can only do this if there is at least 2.0 gallons in the hot water distribution system that can be removed, which means it will need to be located very close to the hot water outlets it will serve. If the hot water distribution system would normally have less than 2.0 gallons in it, then a "water wasteful" tankless water heater can never be considered water saving device.

Table 3 shows the number of feet of pipe equal to one cup for four nominal pipe diameters and several typical types of pipe. The length per cup of a given nominal pipe diameter varies because the internal diameter is not the same for each material. CTS stands for copper tube size.

**Table 3. Feet of Piping Equal to 1 Cup of Water**

| | 3/8" CTS | 1/2" CTS | 3/4" CTS | 1" CTS |
|---|---|---|---|---|
| | ft/cup | ft/cup | ft/cup | ft/cup |
| **"K" copper** | 9.48 | 5.52 | 2.76 | 1.55 |
| **"L" copper** | 7.92 | 5.16 | 2.49 | 1.46 |
| **"M" copper** | 7.57 | 4.73 | 2.33 | 1.38 |
| **CPVC** | N/A | 6.41 | 3.00 | 1.81 |
| **PEX** | 12.09 | 6.62 | 3.34 | 2.02 |

In general, the closer the water heater is to the hot water outlets, the smaller the diameter the pipe can be. For purposes of this discussion, the most likely pipe diameters will be ½- and ¾-inch nominal (due to the requirements of prevailing plumbing codes). This means that the length of pipe equal to 1 cup varies between 4.8 and 6.6 feet for ½-inch nominal pipe and between 2.3 and 3.3 feet for ¾-inch nominal pipe. For simplicity in this analysis, we can assume that 1 cup equals 5 feet in ½-inch and 2.5 feet in ¾-inch pipe.

Using the smaller of the volumes wasted while ramping up to temperature, 4.8 cups, this means that the water heater must be no further from all of the hot water outlets it serves than 24 feet in ½-inch pipe and 12 feet in ¾-inch pipe.

There is usually a combination of these two diameter pipes between the water heater and the outlets (¾-inch on the trunks and branches and ½-inch on the twigs), but what is important is that the combination of lengths cannot exceed the volume represented by one of the lengths. Assuming that the split in materials is 50/50, the total maximum length is 18 feet.

This is approximately the length of pipe to get across one room in a typical home. The plumbing is in the walls, floor or ceiling so it has to go a longer distance than if it could go diagonally through the room. Such a hot water distribution system is buildable, but it requires careful planning. It will also mean recognizing the installation, operating costs and maintenance of multiple water heaters in most buildings. In addition, each distributed water heater needs to be sized for the hot water demand at the location it serves. A single hand sink needs a much smaller water heater than a master bathroom suite with two sinks, a shower and a large master tub, or a group of back-to-back or stacked bathrooms. As the distance (volume) between groups of hot water outlets and from the water heater gets large, say over 80 feet (approximately 2 gallons in ¾ inch nominal piping), the installation of multiple water heaters makes more sense from the perspective of saving water, energy, and time-to-tap. However, at the current cost of water and sewer in most municipalities, the energy cost savings will outweigh the water cost savings.

## Conclusion

In and of themselves, tankless water heaters are not a water saving technology and therefore, should not be recommended as a Best Management Practice for water utilities implementing water use efficiency programs. Locating water heaters closer to the hot water outlets they serve will save water, a design practice that could by implemented through building and plumbing codes as well as through “green building” mandates. Water heaters with some amount of stored water, located close to the hot water outlets, will save water because they do not need to ramp-up to temperature at the start of each hot water event. As noted earlier, there are only two legal gas tankless water heaters that have integral water storage at this time. These units will waste no more water than a storage water heater installed in the same location. If a storage tank is added externally to a tankless water heater, it will perform similarly to these units from a water use perspective (although their combined energy efficiency is likely to be less).

The only way for tankless water heaters without storage to yield water savings is to locate them close to the hot water outlets they serve, saving a quantity of water that is greater than that which would have been lost while ramping up to temperature. That is, these units need to be closer to the hot water outlets than the volume of water that is normally in the piping between these outlets and a remotely installed water heater. Given the amount of water that is wasted while ramping up to temperature, most tankless water heaters cannot save water using this strategy, since there is generally less volume in the piping than passes through the water heater while ramping up.

For tankless water heaters with either internal or external storage, as well as for storage water heaters, it is possible to improve water use efficiency (without decreasing energy efficiency) by installing an on-demand priming system which fills the hot water supply line with hot water just before hot water is needed at the outlets. This allows the water heater to be located relatively far from the hot water outlets. However, the improvement in water use efficiency is not due to the water heater. Instead, it is due to the improvement to the hot water distribution system.

Are tankless water heaters inherently a water savings technology? In short, the answer is no.

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