Evaluation of Smart Water Heater Controller

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LEGAL NOTICE

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EXECUTIVE SUMMARY

This report describes the energy performance benefits of installing smart water heater controllers on residential storage water heaters. Included in this report is information about the types of heaters used for this evaluation, the draw profiles used, and the data collected for evaluating the impact of using smart controllers on the energy performance of the heaters.

PG&E's Applied Technologies Services (ATS) monitored and collected energy consumption data for one gas and one electric residential storage water heater then collected the same data after installing smart controllers on the heaters. ATS's findings do not show substantial savings in energy consumption as a result of using smart controllers.

PROJECT GOAL

When a user selects a temperature setpoint for a storage water heater, the heater intermittently works to maintain its storage tank temperature close to the user setpoint at all times whether or not there is user demand for hot water. The heat exchange that happens between the hot water stored in the storage tank and the atmosphere, at times of no hot water demand, is considered wasted energy (convective losses). This is also known as standby losses.

There are various strategies to reduce convective losses. For example, one can increase the insulation of the storage tanks or manually reduce the temperature setpoint of the heater during times of no hot water demand. One smart water heater controller, on the market, claims to reduce this wasted energy. It does so by automatically reducing the setpoint of the heater during times of no hot water demand and then raising the temperature setpoint to heat the water shortly prior to the user's hot water demand; per the manufacturer, persistent reduction in the setpoint is amongst the control strategies used by the controller. In this way, the smart controller attempts to reduce the standby losses.

The goal of this project is to evaluate the impact of one such controller on energy consumption by one gas and one electric residential storage water heater.

PROJECT DESCRIPTION

This project attempts to evaluate the reduction in energy usage as a result of using a smart controller, on one gas and one electric storage residential water heater.

This evaluation was done in a lab environment. ATS monitored and collected the overall energy consumption data for one gas and one electric residential storage water heater. ATS then installed the controllers on the heaters, and, in a similar fashion, collected the overall energy consumption data of the heaters with the controllers installed.

PROJECT FINDINGS/RESULTS

Within the confines of this lab setting, and with the heaters that were used for this test, the controllers provide minimal energy savings.

Once the controllers were installed, and the heaters were put to go through pre-determined draw profiles, ATS observed that the controllers functioned in two modes. One was a learning/monitoring mode and another was control mode.

In the learning/monitoring mode, the controller did not have a visible impact on the operations of the heaters and the heaters were functioning in a baseline mode (no controller impact). In the control mode, the temperature setpoint of the heaters were automatically reduced or increased. This resetting of the temperature setpoint was not driven by ATS. It is ATS' understanding that the controller increases or decreases the temperature setpoint based on its anticipation of the hot water demand. That is, the controller learns user behavior, in this case it learns the pre-determined draw profile, and anticipates user hot water demand. It then reduces or increases the temperature setpoint of the heater with the goal of reducing wasted energy.

ATS observed instances during which the controller reduced the temperature setpoint of the heaters but did not reset the temperature to accommodate the original test setpoint; therefore, resulting in cooler water to be delivered to the user during demand periods.

At times during which the controller did heat up the water to a temperature at or close to the user setpoint, energy consumption was similar to the energy consumption of the heaters in baseline/no control mode.

PROJECT RECOMMENDATIONS

While no energy saving was observed during this test, the smart controller may better serve the goal of limiting wasted energy on older heaters with no pilot gas valve; please refer to the Background Section of this document for additional heater selection criteria. Additional study including testing older heaters and field trials accounting for seasonal temperature variances would be necessary to establish a more accurate picture of overall energy savings for this product.

INTRODUCTION

This document reports the findings of a laboratory test conducted on a smart water heater controller. The controller under test claims the ability to reduce the energy used by storage water heaters; these heaters must meet manufacturer's heater selection criteria.

In most storage water heaters, the heater operates to maintain the storage tank temperature at or close to the user determined setpoint, at all time whether there is or isn't demand for hot water. This behavior could result in convective losses, or wasted energy, between the storage tank and the atmosphere. This kind of loss is dependent on a variety of factors, including the insulation of the storage tank, the ambient temperature and thermostat setpoint. If the storage tank is well insulated, then these losses are low. In addition to insulation, one can reduce standby losses by reducing the temperature setpoint of the water heater at times of no demand. For example, a user can lower the water heater temperature setpoint before leaving to work, or before leaving for a vacation.

There is at least one smart controller on the market to claim the ability to automate this function of reducing the temperature setpoint of a storage heater, at times of no hot water demand. This controller claims the ability to monitor and learn user behavior, once installed on a storage hot water heater. It can then adjust temperature setpoint, at various time periods, with the goal of lowering energy waste. ATS tested this technology and findings are reported in this report.

BACKGROUND

The controller under study is a smart water heater controller that claims to reduce the wasted energy in storage water heaters. Per the manufacturer, this controller is designed to learn user behavior, and then use that information to adjust heater setpoint and heating time. In this manner, the controller limits heating during periods of non-use and reduces wasted energy.

The controller can be purchased directly from the manufacturer and installed on a residential storage water heater by the user.

The following heater selection criteria, provided by the manufacturer, were considered during the heater selection phase for this test:

- The controller is suitable for use with gas and electric storage water heaters.
- The heater must be smaller than 120 gallons in capacity.
- The heater must be less than 15 years old.
- The storage gas water heaters must have electronic gas control valve, and no pilot gas valve.
- The controller is not suitable for use with heat pump water heaters, tankless water heaters, boiler-fed water heaters, and combination space and water heating systems.

For the installation of the controller, the ATS team followed the installation guidelines provided by the manufacturer. The installation of the controller did not require specialized skills.

The smart controller communicates through Wi-Fi. ATS is supported by PG&E's secured Wi-Fi. PG&E's Wi-Fi was not functional for the controller due to security issues. An independent Wi-Fi connection was established for this test.

EMERGING TECHNOLOGY/PRODUCT

The smart water heater controller claims the ability to reduce wasted heat during standby time periods.

This controller can be installed on a gas or an electric storage water heater. The controller claims to monitor and learn user usage patterns. Once it has learned user behavior and hot water usage patterns, the controller can reset the temperature setpoint of the heater in a way that reduces energy usage of the heater.

In general, by not storing hot water in the storage tank at the normal setpoint at all times, the heat exchange (wasted energy) between a hot water storage tank and atmosphere is reduced, and some energy is saved.

ASSESSMENT OBJECTIVES

The objective of this assessment is to compare the energy usage of a storage water heater (both gas and electric) when used without and then with the controller.

It is important to review data relevant to the amount of energy saved as a result of using the controller. Also, any impact on the water temperature delivered to the delivery point (we will use "showerhead" as an example of the delivery point) at times of hot water demand should be evaluated. In other words, how quickly would the heater run out of hot water if lower temperature water is being delivered to the showerhead? If the temperature of the hot water delivered to the showerhead is far below the original setpoint of the heater, then a larger volume of hot water may be drawn from the storage tank to compensate for the cooler water at the showerhead, and to accommodate a temperature that is satisfactory to the user. This scenario may result in the tank/user running out of hot water quicker than normal. In other words, the impact of an active controller on user experience when it comes to how quickly the user runs out of hot water needs to be evaluated. In addition, delivering water at a temperature lower than the setpoint at time of use, inevitably results in energy saving relative to the times at which the delivered water is close to the original user setpoint.

TECHNOLOGY/PRODUCT EVALUATION

This product was evaluated at ATS's water heater lab. The water heater lab environment is temperature controlled. The heaters were exposed to the same draw patterns on a daily basis. Variable draw patterns and their impact on the controller were not evaluated for this report. The heater baseline temperature was set when the heaters were first commissioned. The baseline temperatures were not changed throughout the test period. The data collected on a day-to-day basis are comparable when it comes to initial conditions. Daily heater energy consumption data was used to compare heater energy consumption without the controller and with the controller.

TECHNICAL APPROACH/TEST METHODOLOGY

LABORATORY TESTING OF TECHNOLOGY

All testing was performed within ATS' water heater lab. For this study, two residential storage water heaters were installed in the water heater lab. See Table 1 for heater specifications.

TABLE 1: HEATER SPECIFICATIONS

	GAS	ELEC.
Manufacturer	Rheem	Rheem
Serial #	M311600708	M281615518
MFG Date:	1-Aug-16	13-Jul-16
Model:	XG40T12DU36U0	XE40M06ST45U1
Storage Capacity	40 Gal.	40 Gal.

A specific medium usage draw profile (see Table 2) was selected from Department of Energy's Code of Federal Regulation, *DOE 10CFR430"Energy Conservation Program for Consumer Products".* The draw profile was presented to the manufacturer and then selected as an appropriate draw profile to be used for this test.

Both water heaters went through a minimum 3 day period of logging baseline data before connecting the controllers to the heaters. That was to collect energy consumption information for the heaters without the controllers.

Per the manufacturer, after the controller has been installed on the heater and with heater's normal operation, the controller requires a minimum of around 3 weeks to learn user behavior. Shorter learning times may be considered. It is ATS' understanding that a longer learning period may improve the learning behavior of the controller. For this test, ATS monitored and logged data for the heater/controller for a minimum period of around four weeks.

The Test Plan section of this report provides details about the general test plan, methodology and the measurements obtained for this report.

TEST PLAN

GENERAL TEST PLAN

- Test two different residential storage water heaters:
    - One electric storage water heater.
    - One gas storage water heater with electronic ignition.
- Run each water heater for a specified period of time and under specified conditions without the controller.
- Log various data points as shown in tables 3 to 6
- With the controller installed on each water heater, run each water heater for a specified period of time and under specified conditions.
- Log various data points as shown in tables 3 to 6.

TEST METHODOLOGY

Below is a general description of the test preparation steps and methodology:

a) Purchase and install heaters. Once the heaters are installed in the lab, set the outlet discharge temperature:
Initiate normal operation of the heaters at the maximum flow. Monitor the discharge temperature. Adjust setting as necessary to ensure water heater is able to provide approx.. 125±5°F.

b) Draw Pattern – without smart controller
   1. Run each of the residential storage water heaters (gas and electric) through the draw patterns shown in Table 2 for a 24-hour simulated test (assume medium usage pattern). Note that each test (draw profile) spans 24 hours.
   2. Repeat steps 1 for a minimum of 3 days.

c) Draw Pattern – with smart controller:
   1. Run each of the residential storage water heaters (gas and electric) through the draw patterns shown in Table 2 for a 24-hour simulated test (assume medium usage pattern). Note that each test (draw profile) spans 24 hours.
   2. Repeat step 1 for a minimum of 3 weeks.

TABLE 2: DOE MEDIUM USAGE DRAW PROFILE

DRAW #	TIME DURING TEST [HH:MM]	VOLUME (GALLONS)	FLOW RATE (GPM)
1	0:00	15	1.7
2	0:30	2	1
3	1:40	9	1.7
4	10:30	9	1.7
5	11:30	5	1.7
6	12:00	1	1
7	12:45	1	1
8	12:50	1	1
9	16:00	1	1
10	16:15	2	1
11	16:45	2	1.7
12	17:00	7	1.7

Instrumentation Plan

Various temperatures, pressure, gas, electricity data points as listed in tables 3-6 were collected on an absolute time scale.

Temperature Instrumentation

All temperature instrumentation underwent a two-point calibration (ice bath and isothermal block) to ensure measurement accuracy. Below is a list of data points collected:

d) Ambient temperature

e) Gas temperature (gas heater only)

f) Two separate temperature instrumentation setups for the gas and electric heaters:

- City water temperature into the heater.
- Water temperature out of the heater.
- Six different thermocouples for the interior of the storage tank.
- Temperature of the water entering the flow control valve.
- Temperature of the water at the drain point.

Table 3: Instrumentation, Temperature

Data Point	Unit	Manufacturer	Last Cal. Date	Cal. Cycle	Cal. Cycle Unit
Water Temperature, entering each heater	F	Burns	04/14/17	1	yr
Water Temperature, leaving each heater	F	Burns	04/14/17	1	yr
Water Temperature, at each flow meter	F	Burns	04/14/17	1	yr
Water Temperature, at each drain	F	Burns	04/14/17	1	yr
Ambient Temperature	F	Burns	04/14/17	1	yr
Gas Temperature, at gas meter	F	Burns	04/14/17	1	yr
Temp. inside each storage tank (6 points)	F	Therm-X - ATS	04/14/17	1	yr

Pressure

Calibrated instruments used to collect pressure related data:

- Barometric pressure.
- Natural Gas pressure (gas heater only)

TABLE 4: INSTRUMENTATION, PRESSURE

DATA POINT	UNIT	MANUFACTURER	LAST CAL. DATE	CAL. CYCLE	CAL. CYCLE UNIT
Atmospheric Pressure	PSI	Rosemount	08/20/15	2	yrs
Gas pressure, for the gas heater	Inch. H2O	Rosemount	08/20/15	2	yrs

POWER AND GAS METER

Calibrated gas and power meters used to collect the following data points:

- Gas meter, volume of the gas used by the gas water heater
- Power meter, power consumption
- Power meter, Volts
- Power meter, Current

TABLE 5: INSTRUMENTATION, POWER

DATA POINT	UNIT	MANUFACTURER	LAST CAL. DATE	CAL. CYCLE	CAL. CYCLE UNIT
Power, electric heater	Watts	Hioki	04/27/17	1	yr
Voltage, electric heater	V	Hioki	04/27/17	1	yr
Current, electric heater	I	Hioki	04/27/17	1	yr
Gas flow, gas heater	Cubic ft.	American Meter	04/23/15	5	yrs

FLOWMETERS

Calibrated water flow meters used to collect various flow data points.

- Draw (gpm and gallons) for the gas water heater
- Draw (gpm and gallons) for the electric water heater

Below is a tabulated format of all the collected points.

TABLE 6: INSTRUMENTATION, FLOW

DATA POINT	UNIT	MANUFACTURER	LAST CAL. DATE	CAL. CYCLE	CAL. CYCLE UNIT
Water volume, for each heater	Gallons	Badger	08/21/15	2	yrs
Water Flow meter, , for each heater	GPM	Badger	08/21/15	2	yrs

RESULTS

Figure 1 and Figure 2, show the results obtained from running a specific draw profile – described earlier in this report - on the water heaters (gas and electric).

Figures 1 and 2 show the following parameters:

- Tank avg, (°F): Tank Average Temperature
- THW_{out} (°F): Temperature of the hot water leaving the heater
- Control, control/monitor: Controller in control mode vs. controller in monitor mode
- $E_{Out}+E_{Stored}$ (Btu): Energy leaving the heater + Energy stored in the tank
- E_{Stored} (Btu): Energy stored in the tank

$$E_{Stored}(Btu) = \frac{Heater\ Volume(gallons) \times C_p \frac{BTU}{lb_m °F} \times Density(\frac{lbm}{ft^3}) \times \Delta T(°F)}{7.48055(\frac{gallons}{ft^3})}$$

- E_{out} (Btu): Energy leaving the heater

$$E_{Out}(Btu) = \Delta T(°F) \times Cp \times Draw\ Volume(gallons) \times 8.33$$

Where:

$$\Delta T(°F) = T_{water\ out\ of\ heater}(°F) - T_{water\ into\ heater}(°F)$$

$$Cp = 0.998 \frac{Btu}{lb_m °F}$$

The conversion factor to convert gallons of water to pounds of water: 8.33

- Energy entering the heater: Ein (Btu)

$$E_{in}(Btu) = \frac{Q_{std}\,(ft^3)}{HHV}$$

Where:

$$HHV = 1{,}041\ \frac{BTU}{ft^3}$$

$$Q_{std} = Q_{act}(ft^3) \times p_r \times t_r$$

Where:

p_r is pressure ratio

t_r is temperature ratio

**Data for Ein (Btu) for the electric heater was collected using a power-meter. Ein (Btu) for the gas heater was calculated using the equation above.*

Figures 1 and 2 show overall results obtained from the test. The plots contain two vertical scales reflecting temperature and energy. This is to visualize changes in temperature and changes in energy simultaneously. The horizontal axis shows various test dates. Note that each draw profile lasted for 24 hours. Energy consumption comparison can be done on a per day basis. Additional breakdown of data is provided later in this report.

When data was being logged for the heater/controller operation, ATS noticed that the controllers underwent periods of monitoring and periods of control. On each graph, the dotted redline is used to indicate monitoring period vs. control period. The control period is shown with +10,000 Btu mark, and the monitoring period is shown with -10,000 Btu mark. Note that the +/-10,000 Btu are only used as markers to indicate the controller's behavior - control vs. monitoring - which was not controlled by the lab staff.

Both heaters' thermostats were set to approximately 125°F at the beginning of the test. The average ambient temperature was kept at 69°F. The draw profile remained constant and ran on absolute time. Only a single draw profile was used and repeated for this report. Variation of the draw profile and its impact on the controller behavior was not evaluated in this report.

As shown on the plots, while there is a clear drop in the energy consumption, part of this drop is directly associated with the controller reducing the setpoint of each heater, and delivering water at a cooler temperature than the original setpoint. It was observed that the controller adjusted the temperature of the gas water heater to as low as 102.2°F and the electric water heater to as low as 100.4°F throughout the test period.

No information has been obtained on the insulation differences between the gas and the electric water heaters in this project.

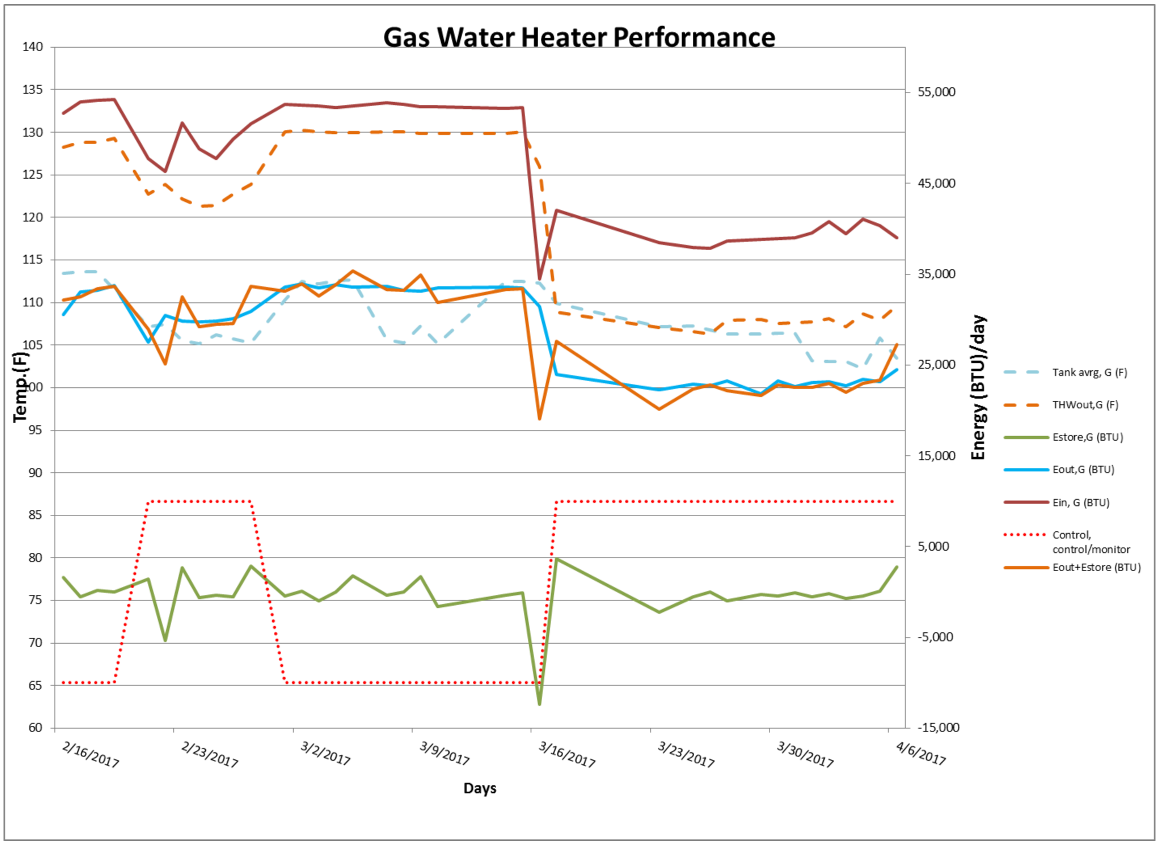

FIGURE 1: TEST SPAN DATA, GAS HEATER

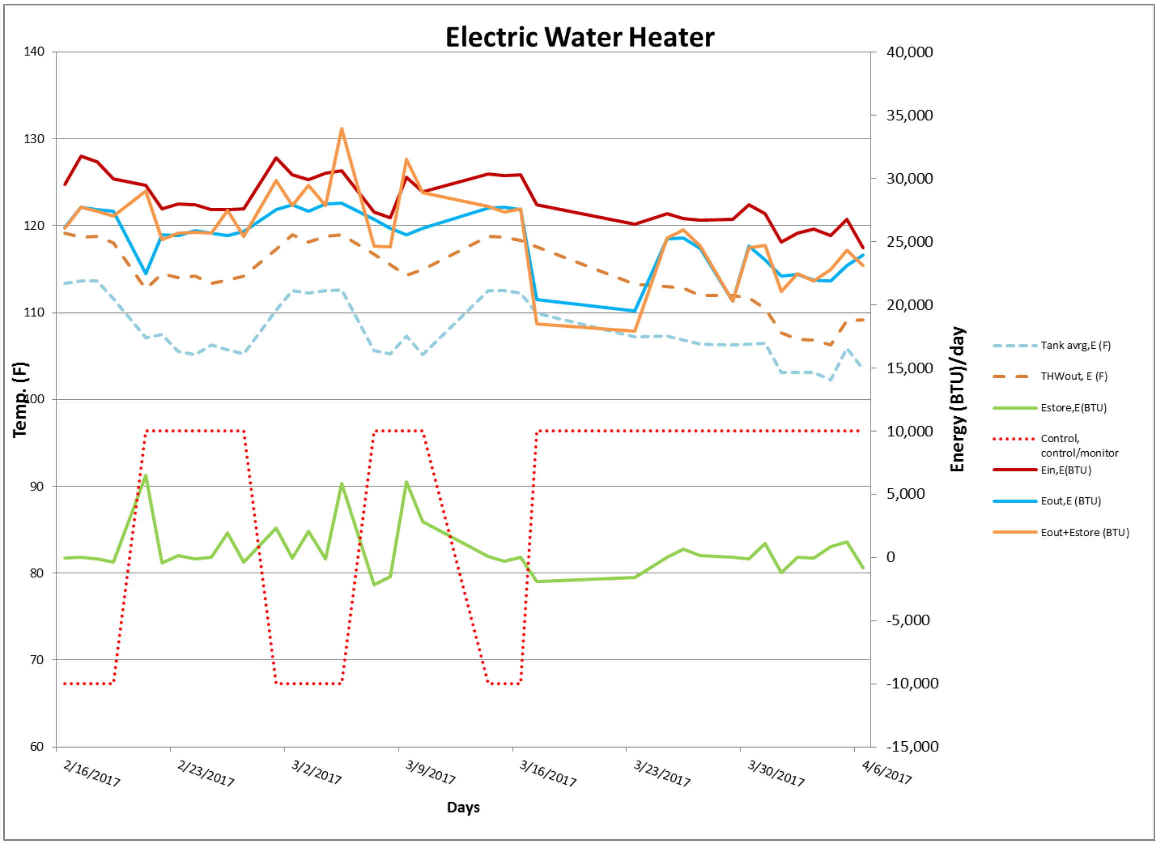

FIGURE 2: TEST SPAN DATA, ELECTRIC HEATER

Tables 7 and 8 below show the average daily energy consumption and flow-weighted heater outlet temperatures over various controller monitor/control periods. When comparing monitor/control periods during which the outlet temperatures remained similar, significant energy saving is not realized.

TABLE 7: AVERAGE DAILY ENERGY CONSUMPTION AND FLOW-WEIGHTED OUTLET TEMPERATURES, GAS HEATER

CONTROLLER MONITOR/CONTROL	AVRG EIN (BTU)/DAY	FLOW-WEIGHTED HEATER OUTLET TEMPERATURE (F)
Monitor	54,136	129.0
Control	49,100	122.6
Monitor	51,934	129.6
Control	39,427	107.8

TABLE 8: AVERAGE DAILY ENERGY CONSUMPTION AND FLOW-WEIGHTED OUTLET TEMPERATURES, ELECTRIC HEATER

CONTROLLER MONITOR/CONTROL	AVRG EIN (BTU)/DAY	FLOW-WEIGHTED HEATER OUTLET TEMPERATURE (F)
Monitor	31,021	118.5
Control	27,935	113.8
Monitor	30,581	118.4
Control	28,332	115.4
Monitor	30,282	118.6
Control	26,450	110.6

For the gas heater, data for four different test days (two days with the controller in a control mode and two with the controller in a monitor mode) are presented in Table 9. Data for 2/17/17 and 3/29/2017 are plotted and shown in Figures 3 and 4.

Note that while the original heater setpoint was not changed by the user, the temperature of the hot water leaving the tank as a response to a hot water draw, during the days that the controller was in a control mode, was lower than the days on which the controller was in a monitor mode. This scenario must be evaluated for user impact as it may result in the tank/user running out of hot water quicker than normal. In other words, the impact of an active controller on user experience when it comes to how quickly the user runs out of hot water needs to be evaluated, as described under the Assessment Objective section.

TABLE 9: GAS HEATER

	AVERAGE TANK TEMP (F)	HOT WATER TEMP.(F) AT HEATER OUTLET	CONTROLLER MONITOR/CONTROL
2/17/17	124	129	Monitor
3/3/17	125	130	Monitor
3/29/17	100	108	Control
4/2/17	102	108	Control

Figures 3 below shows a plot with average tank temperature and flow data for the gas heater on 2/17/2017 while controller is in a monitor mode. Note that the storage tank temperature is kept relatively close to setpoint, to help satisfy the user setpoint upon draw.

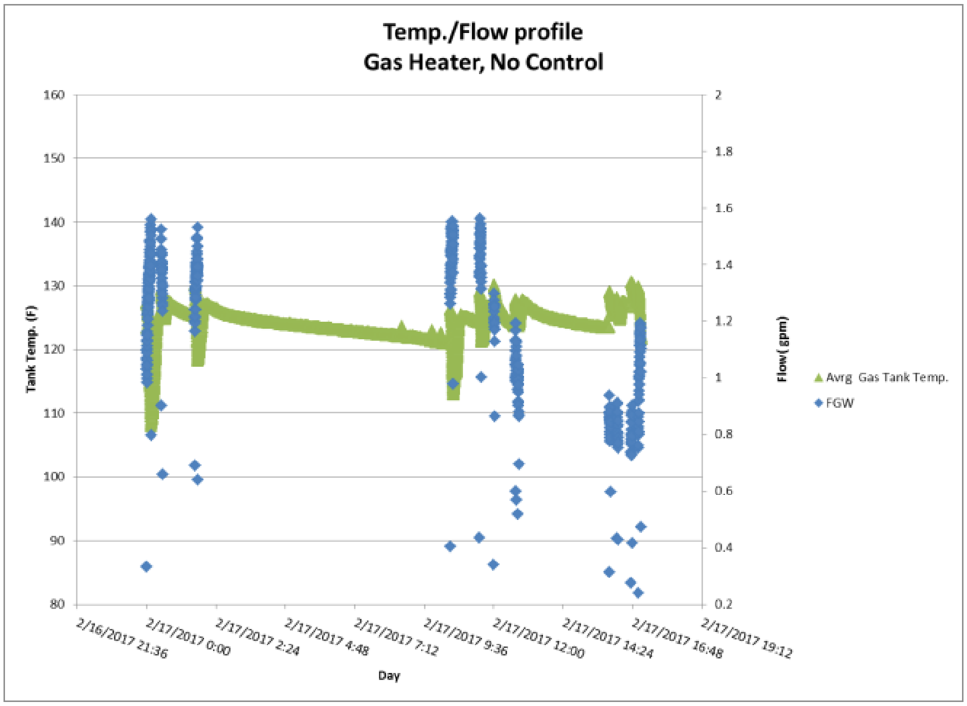

FIGURE 3: AVERAGE TANK TEMPERATURE AND FLOW PROFILE ON 2/17/2017/ MONITOR MODE, GAS HEATER

Figures 4 below shows a plot with the average tank temperature and flow data for the gas heater on 3/29/2017 while controller is in a control mode. Note that the storage tank temperature is kept at a lower temperature relative to the setpoint.

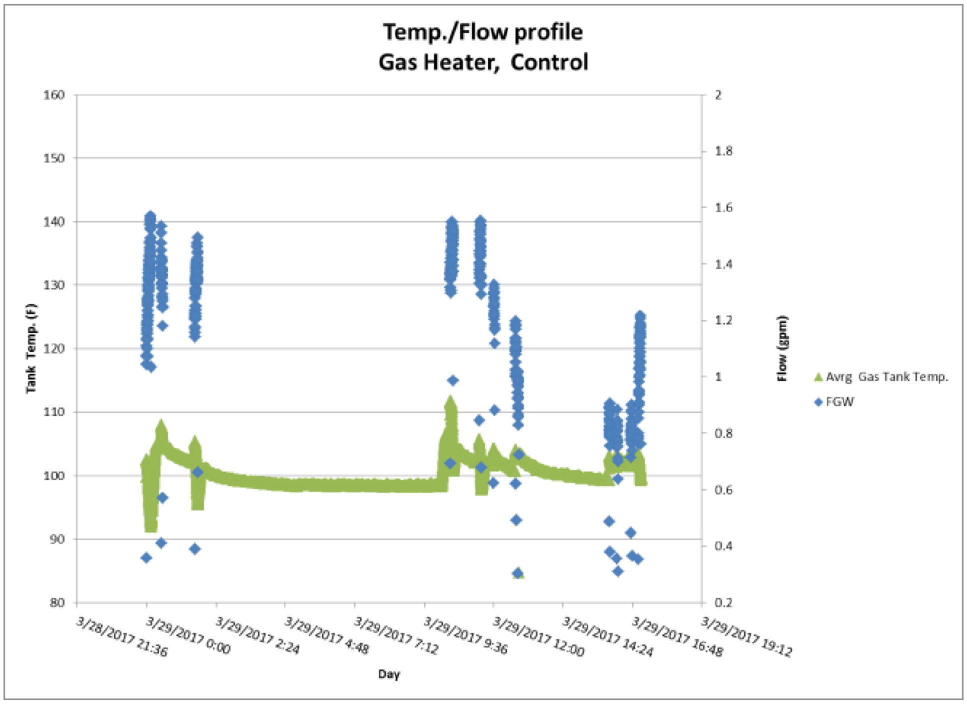

FIGURE 4: AVERAGE TANK TEMPERATURE AND FLOW PROFILE ON 3/29/2017, CONTROL PERIOD, GAS HEATER

For the electric heater, data for four different test days (two days with the controller in a control mode and two with the controller in a monitor mode), are presented in Table 10. Data for 2/17/17 and 3/29/2017 are plotted and shown in Figures 7 and 8.

Note that while the original heater setpoint (user setpoint) was not changed by the user. The temperature of the hot water leaving the tank, as a response to a hot water draw during the days that the controller was in a control mode, was lower than the days on which the controller was in a monitor mode. This scenario must be evaluated for user impact as it may result in the tank/user running out of hot water quicker than normal. In other words, the impact of an active controller on user experience when it comes to how quickly the user runs out of hot water needs to be evaluated, as described under the Assessment Objective section.

TABLE 10: ELECTRIC HEATER

	AVERAGE TANK TEMP (F)	HOT WATER TEMP.(F) AT HEATER OUTLET	CONTROLLER MONITOR/CONTROL
2/17/17	114	119	Monitor
3/3/17	112	118	Monitor
3/29/17	106	112	Control
4/2/17	103	107	Control

Figures 5 and 6 below each show a plot with the average tank temperature and flow data for the electric heater on 2/17/2017 while controller is in a monitor mode. The average tank temperature does not see substantial change between draw and no draw time.

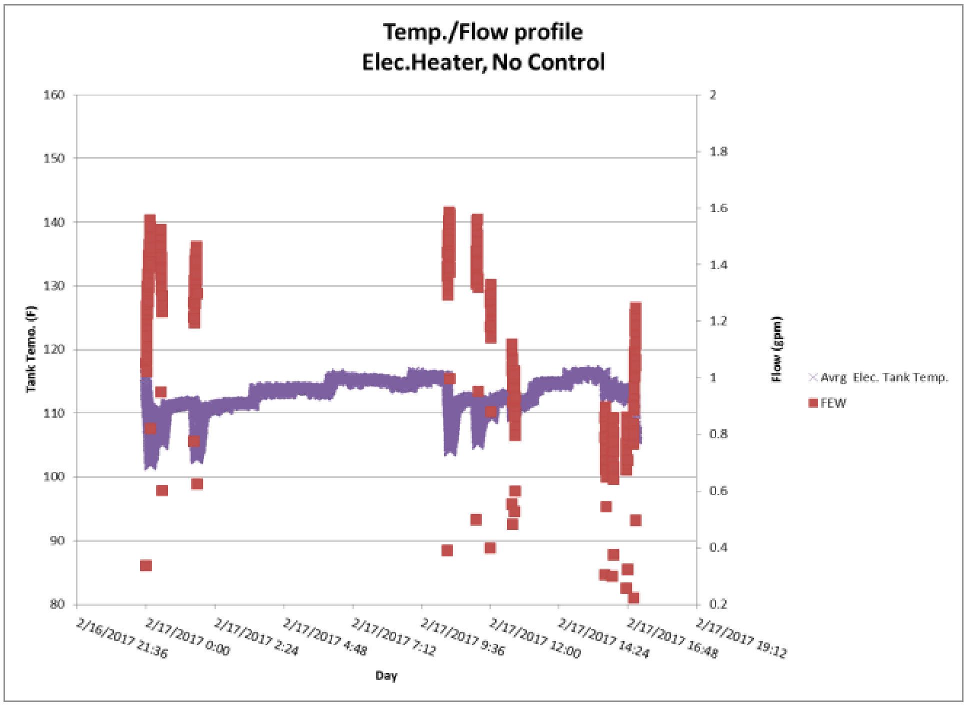

FIGURE 5: AVERAGE TANK TEMPERATURE AND FLOW PROFILE ON 02/17/2017, NO CONTROL (MONITOR) PERIOD, ELECTRIC HEATER

Figures 6 below shows a plot with average tank temperature and flow data for the Electric heater on 3/29/2017, while controller is in a control mode. Note that the storage tank temperature is kept at a lower temperature relative to the setpoint. ATS observed that this point is more pronounced in the gas heater than in the electric heater.

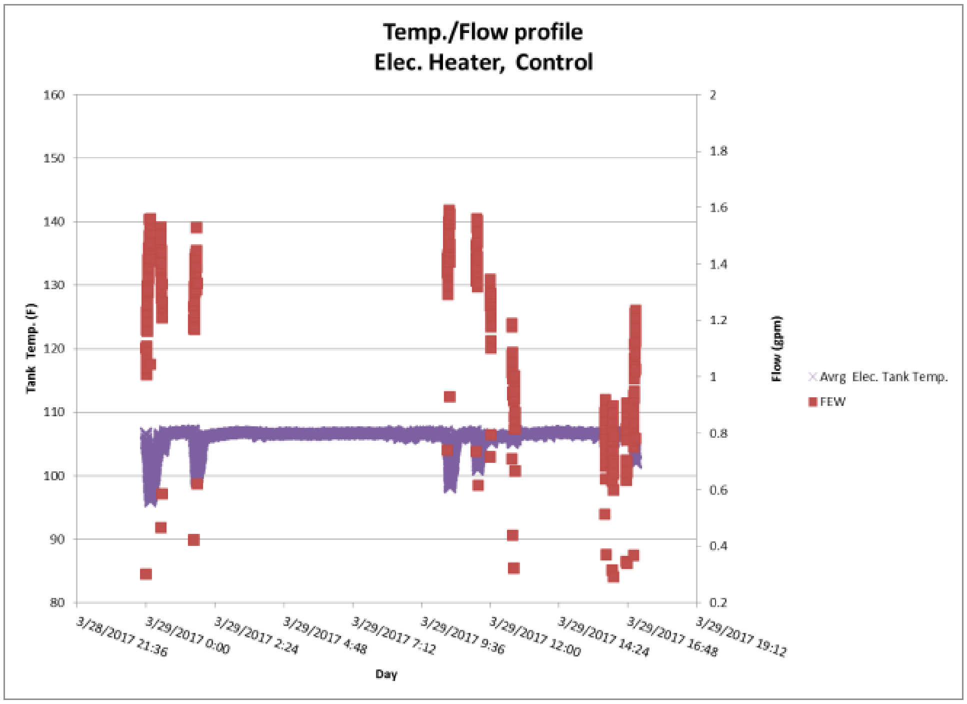

FIGURE 6: TEMPERATURE OF WATER LEAVING THE TANK AND FLOW PROFILE, CONTROL PERIOD, ELECTRIC HEATER

To better evaluate the energy savings as a result of using the controller, a set of test dates with almost identical hot water temperatures, both while the controller is in a control mode and in a monitor mode, were selected. In the gas and electric water heater graphs shown in Figures 7 and 8, no energy saving was substantiated. In addition, most of the available data obtained at the end of the controller's learning period show substantial temperature drop in the temperature of the hot water leaving the heater - relative to the user setpoint. Ideally, to compare energy usage during monitor period versus energy usage during control period, one would require similar temperature output during both monitor and control periods.

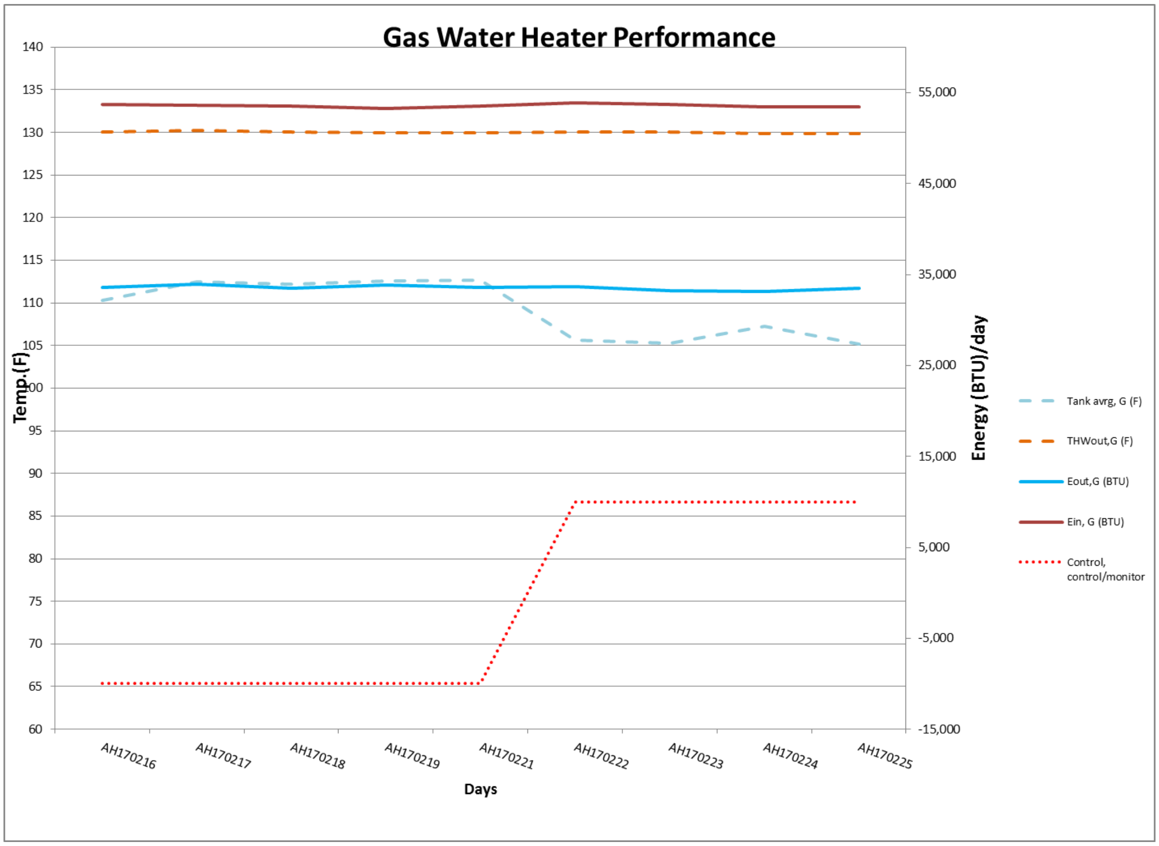

FIGURE 7: CONTROLLER IN CONTROL MODE VS. CONTROLLER IN MONITOR MODE, CONSTANT WATER TEMPERATURE FOR WATER LEAVING TANK, GAS HEATER

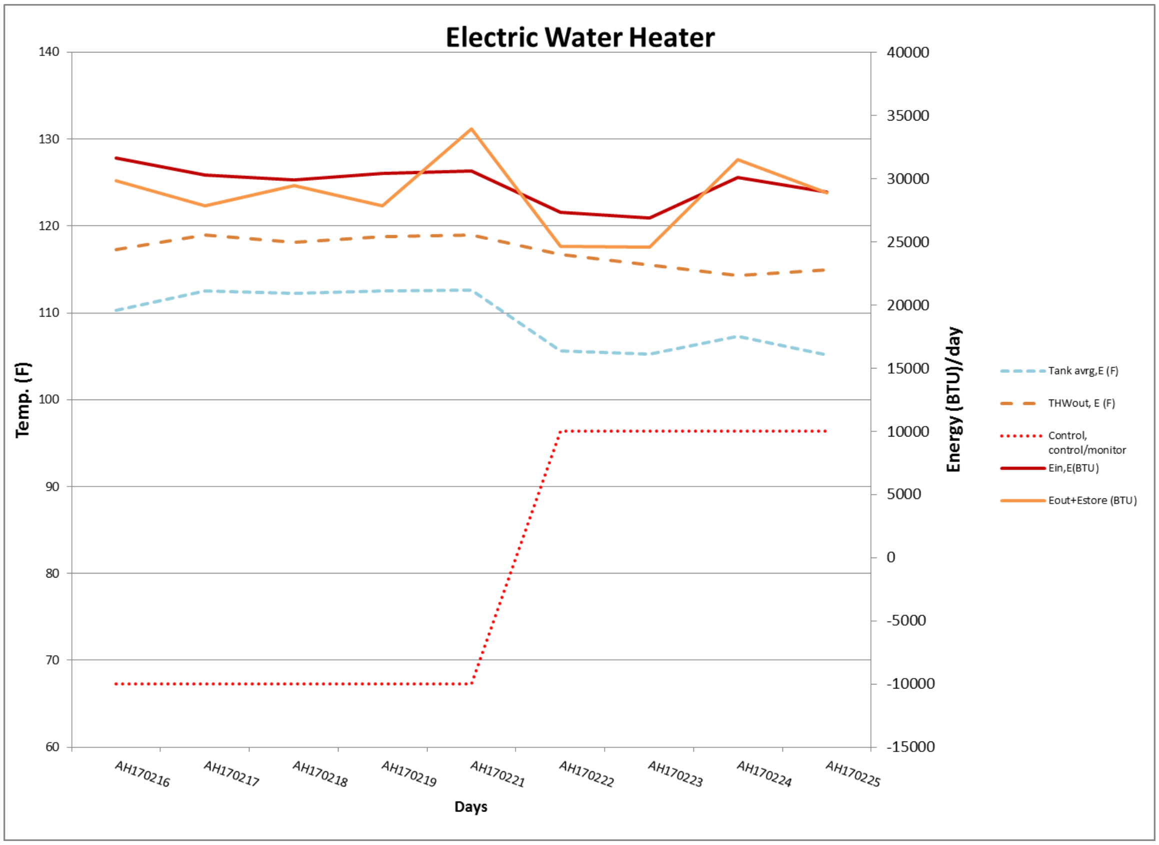

FIGURE 8: CONTROLLER IN CONTROL MODE VS. CONTROLLER IN MONITOR MODE, CONSTANT WATER TEMPERATURE FOR WATER LEAVING TANK, ELECTRIC HEATER

EVALUATIONS

The basic functionality of the controller is that it adjusts the temperature setpoint of the heater by learning user behavior and forecasting the time of demand or no demand for hot water. During no-demand periods, it decreases the temperature setpoint of the heater, which should eventually lead to lower heat loss to atmosphere, per the manufacturer, one of the controller's control strategies is to persistently reduce the temperature setpoint of the heater. While the total amount of energy required to heat up the water to the original setpoint remains unchanged, energy losses (energy not used to heat the water delivered to the user) is theoretically reduced due to the reduced contact time between the stored hot water and atmosphere.

Similar to an occupancy sensor, this product acts as a supplement to user behavior when it comes to manually readjusting the temperature setpoint of a water heater before leaving home for an extended period of time (low to no hot water demand time).

During this study, it was observed that:

a) During this evaluation, no substantial energy saving as a result of using the controllers were realized.

It is worth noting that NAECA (NAECAIII2015) made incremental increases in the minimum Energy Factor requirement for residential gas and electric water heaters, with less than 55 gallons capacity that were built after 4/15/2015. Given that the heaters under test were manufactured after the year 2016, they meet these higher energy factor requirements. Some new heaters obtain the new requirement by enhancing insulation; which may be the situation for the tested heaters. As such and given that the tested heaters likely have enhanced insulation, older heaters that did not have to meet the NAECA 2015 requirement may see higher gains from using the controller.

b) While the original heater setpoint was not changed by the user, the temperature of the hot water leaving the tank as a response to a hot water draw, during the days that the controller was in control mode, was lower than the days on which the controller was in monitor mode. Overall, where there was lower energy consumption associated with the active controller, the energy saving coincided with lower temperature hot water leaving the storage tank. It is important to evaluate the impact of this temperature reduction on user experience. For example, the user may draw a larger volume of hot water to compensate for the fact that it is cooler than the original setpoint, resulting in the tank quickly running out of hot water.

c) The smart controller communicates through Wi-Fi. On at least one occasion, during the test, the controller failed to automatically reconnect to Wi-Fi upon unintended disconnects. Although the reason for this disconnect was not determined, it is understood that the controller is capable of automatically reconnecting to Wi-Fi upon unintended disconnect.

RECOMMENDATIONS

Based on this study's limited scope and duration, the following recommendations are made:

- This assessment used the same draw profile, in absolute time, for a period of time. It is recommended to run additional tests with variable draw profiles on smart controllers. That is to more realistically model a residential scenario. It is also recommended to run some tests in non-absolute time to check the robustness of a smart controller.
- This assessment was performed in a controlled temperature environment for a relatively short period of time. It is recommended to evaluate the product in various ambient temperature scenarios.
- This assessment was evaluated on residential water heaters. It is recommended to perform a similar assessment on larger commercial heaters, with various draw profiles.
- It is recommended that a customer study be conducted into the impact of delivering "cooler" hot water (as mentioned in part b. of the evaluation section) on how quickly the tank runs out of hot water and how that impacts user experience.