WATER HEATER TEST PROCEDURE RULEMAKING: DEVELOPMENT TESTING PRELIMINARY REPORT

ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS AND CERTAIN INDUSTRIAL EQUIPMENT:

Residential and Light Commercial Water Heaters

November 2013

U.S. Department of Energy
Assistant Secretary
Office of Energy Efficiency and Renewable Energy
Building Technologies Program
Appliances and Commercial Equipment Standards
Washington, DC 20585

This Document was prepared for the Department of Energy
by staff members of
Navigant Consulting, Inc. and
The National Institute of Standards and Technology

WATER HEATER TEST PROCEDURE RULEMAKING: DEVELOPMENT TESTING PRELIMINARY REPORT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

WATER HEATER TEST PROCEDURE RULEMAKING: DEVELOPMENT TESTING PRELIMINARY REPORT

1. INTRODUCTION

The American Energy Manufacturing and Technical Corrections Act (AEMTCA) requires DOE to establish a uniform efficiency descriptor for covered water heaters. (42 U.S.C. 6295(e)(5)) Consequently, the U.S. Department of Energy (DOE) initiated a rulemaking to consider amendments to its existing test procedures for covered residential and commercial water heaters. As part of this effort, DOE conducted a series of tests to assess the impact of proposed revisions and additions to the current DOE test procedures for residential water heaters and certain commercial water heaters. The purpose of the testing is to validate the proposed test method (78 FR 66201) and examine the impact of the proposed test procedure revisions on the first-hour rating of storage water heaters, maximum gallons per minute rating of instantaneous water heaters, and energy factor of both storage and instantaneous water heaters. In addition, the test results were used to assess the variability in the energy factor based on the draw profile selected, as well as the impact of the proposed amendments on different types of water heaters. DOE collected and analyzed data on the energy factor, first hour rating (for storage water heaters), and maximum gallon per minute (max gpm, for instantaneous water heaters) of a number of different types of water heaters for this report, and considered the following impacts:

- Impact of test procedure revisions and additions on first hour rating of residential storage water heaters
- Impact on maximum gallon per minute of instantaneous water heaters
- Impact on energy factor of all water heaters
- Effects on different categories of water heater (*e.g.*, gas-fired storage, electric storage, gas-fired instantaneous, etc.)
- Variance in energy factor ratings of water heaters tested under different draw profiles (*e.g.*, point of use, low usage, etc.)

1.1. CURRENT TEST PROCEDURE

Residential Water Heaters

The current DOE test procedure for residential water heaters (10 CFR 430, Subpart B, Appendix E) provides test protocols for storage water heaters to be tested for a first-hour and energy factor rating, and for instantaneous residential water heaters to be tested for a maximum gpm and energy factor rating. The first-hour rating test measures the volume of hot water that can be delivered by a storage water heater in a single hour, while the maximum gpm rating reflects the maximum flow rate at which an instantaneous water heater can continuously deliver hot water at a useful temperature. The energy factor rating test measures overall water heater efficiency (including active, standby, and cycling operation) over a 24-hour period at a specific set of rating conditions and single draw profile.

Under current testing procedure, the ambient air temperature during all tests (first hour, max gpm, and energy factor) must be maintained between 65°F and 70°F, the inlet water temperature must be 58°F ± 2°F, and the thermostat must be adjusted to a setting that achieves a mean internal storage tank temperature of 135°F ± 5°F.

For the first-hour rating test, the storage water heater is allowed to operate until it is at an average internal tank temperature of 135°F ± 5°F. Once the target tank temperature is achieved, the test begins and hot water is drawn at a rate of 3.0 gpm until the outlet temperature of the water exiting the storage tank decreases to 25°F less than the maximum observed outlet temperature. Subsequent draws begin when the thermostat acts to reduce the supply of heat energy to the storage tank and continue until the outlet temperature of the water exiting the storage tank decreases to 25°F less than the maximum observed outlet temperature for the given draw. This process is repeated for a total time of one hour. At the end of the hour, if a draw is in progress, that draw is allowed to complete normally (i.e., until the outlet temperature of water exiting the storage tank decreases to 25°F less than the maximum observed outlet temperature). If a draw is not occurring, a final draw is initiated and then terminated when the outlet water temperature reaches the same outlet temperature that the previous draw was terminated at. The first-hour rating is then calculated as the total volume of hot water drawn over this period (in gallons), and is a function of both the storage volume and water heater recovery rate.

In the maximum gpm test, after the thermostat is adjusted to a set point that achieves an outlet temperature of 135°F ± 5°F, water is drawn from the instantaneous water heater for a total time of 10 minutes at the maximum possible flow rate while maintaining the target set point temperature. The maximum gpm rating is calculated as the total volume of water drawn over this period (in gallons) divided by ten minutes.

The energy factor rating is determined from a 24-hour simulated use test. In this test a total of 64.3 gallons of water are removed from the water heater at a rate of 3.0 gpm over six equal draw periods.[a] Initially, the water heater is operated at a set point that achieves an average internal temperature of 135°F ± 5°F for storage water heaters or provides an outlet temperature of 135°F ± 5°F for instantaneous water heaters. At the start of the test, a volume of water equal to one-sixth of 64.3 gallons is drawn. Another draw equal to one-sixth of 64.3 gallons is drawn at the start of the each subsequent hour and continues for a total of six draws. After the sixth draw, the water heater is left in standby mode until 24 hours have elapsed from the start of the test. The energy factor of the water heater is then calculated as the total energy contained in the delivered hot water divided by the total energy the water heater consumed during the 24-hour test period. The energy factor is a function of several intermediate metrics, such as recovery efficiency and

[a] If an instantaneous water heater cannot deliver water at 3.0 GPM and a temperature of 135°F±5°F, then the water flow rate is reduced such that the discharge temperature is 135°F±5°F and heater firing rate is maximized.

standby loss, and is normalized for differences from the nominal test parameters that occur during testing.[b]

Commercial Water Heaters

The current test procedure for commercial water heaters is specified at 10 CFR 431.106 and references the American National Standards Institute (ANSI) Z21.10.3-2011, "Gas Water Heaters, Volume III, Storage Water Heaters with Input Ratings above 75,000 Btu per Hour, Circulating and Instantaneous." The DOE test procedure provides a method to determine the thermal efficiency and standby loss for gas-fired and oil-fired storage and instantaneous water heaters, and to determine the standby loss for electric storage and instantaneous water heaters.

For determining thermal efficiency, the DOE test method requires that the thermostat first be adjusted so that the maximum mean tank temperature after cut-out is 140°F ± 5°F. Inlet water is supplied at 70°F ± 2°F and the ambient air temperature is maintained 75 °F ± 10°F. Water is drawn from the water heater and the flow rate of the water being drawn is adjusted until the temperature is a constant 70°F ± 2°F above the supply water temperature. Once the outlet temperature becomes constant, as determined by no variation in excess of more than 2°F over a 3 minute period, the outlet water is diverted to a weighing container for exactly 30 minutes. Gas or oil and/or electrical consumption are metered over the 30 minute period, and the water is weighed at the end of the test. In addition, inlet and outlet water temperature measurements are recorded during the test, as well as the temperature, pressure, and heating value of the fuel and barometric pressure. Thermal efficiency is then calculated as the ratio of the energy in the delivered hot water to the total fossil fuel and electrical energy consumed during the test period.

For determining standby loss, the DOE test method requires that the water heater be set up as described for the thermal efficiency test. The water heater is then put into operation and after the second cut-out the test begins. The test continues until either (1) the first cutout after 24 hours or (2) 48 hours if the water heater is not in the heating mode at that time, whichever happens first. Every 15 minutes during the test, the ambient air temperature and mean tank temperature are recorded, and at the end of the test the total fuel and/or electrical consumption is recorded. The standby loss (as a percent) is then calculated as the ratio of average hourly energy consumption to the heat content of the stored water above room temperature. For gas and oil water heaters, the standby loss percentage is then tabulated in Btu per hour.

---

[b] Adjustments are made to account for the fact that the temperature difference between the storage tank and surrounding ambient air may not be the nominal 67.5°F due to the 10°F allowable variation in storage tank temperature (for storage water heaters) or discharge temperature (for instantaneous water heaters) and the 5°F allowable variation in ambient air temperature. Another adjustment is made to take into account that the temperature difference between the outlet and supply water may not be equivalent to the nominal value of 77°F due to tolerances in the inlet water temperature and allowable variation in the storage tank temperature (for storage water heaters) or discharge water temperature (for instantaneous water heaters).

1.2. THE PROPOSED TEST PROCEDURE

DOE has expanded the test procedure scope to include electric instantaneous water heaters, water heaters with between 2 and 20 gallons of storage volume, and gas-fired and oil-fired storage water heaters with storage volumes up to 120 gallons. The test method also covers certain commercial equipment that meet the definition of “light commercial” water heaters proposed in the notice of proposed rulemaking. Additionally, the proposed DOE method would lower the set point temperature to 125°F, rather than 135°F, while requiring water flow rates to vary for each draw during the 24-hour simulated use test. Test conditions for inlet water and ambient air temperature are still prescribed as 58°F and 67.5°F, respectively.

For storage water heaters, the proposed first-hour rating test is generally conducted in the same manner as the current test procedure, but the target set point temperature is now 125°F and water draws are terminated when the outlet water temperature drops 15°F from its maximum value instead of 25°F. In addition, the result of the first-hour rating is then used to select the draw pattern used for the 24-hour simulated use test, summarized in Table 1 below.

Table 1: 24-hour simulated use test draw profile criteria for storage water heaters

First hour rating greater than or equal to:	***… And First Hour Rating less than…***	***Draw pattern to be used in 24-hour simulated use test***
0 gal	20	Point of use
20	55	Low usage
55	80	Medium usage
80	No limit	High usage

For instantaneous water heaters, the proposed maximum gpm rating test is generally the same as the current test, except for the decrease in water discharge temperature from 135°F to 125°F.[c] As in the first-hour rating test for storage water heaters, the result of the maximum gpm test is now used to select the draw pattern for the 24-hour simulated use test, summarized in Table 2 below.

Table 2: 24-hour simulated use test draw profile criteria for instantaneous water heaters

Max GPM rating greater than or equal to:	***… And max GPM rating less than…***	***Draw pattern to be used in 24-hour simulated use test***
0 GPM	1.7	Point of use
1.7	2.8	Low usage
2.8	4.0	Medium usage
4.0	No limit	High usage

[c] Under the proposed test, if an instantaneous water heater cannot deliver water at 2.0 GPM and 125°F ± 5°F, then its flow rate is reduced such that the discharge temperature is 125°F ± 5°F and its heater firing rate is maximized.

Based on the performance of the storage water heater in the first-hour rating test or the instantaneous water heater in the maximum gpm test, the unit is classified into one of four categories to reflect its expected use in the field–point of use, low usage, medium usage, and high usage. Each category is subject to a unique draw profile, summarized in Table 3.

Table 3: 24-hour simulated use test draw profiles for proposed test procedure

1. Point of Use Draw Pattern

Draw Number	Time During Test (hh:mm)	Volume (gallons)	Flow Rate (GPM)
1*	0:00	2.0 (7.6)	1 (3.8)
2*	1:00	1.0 (3.8)	1 (3.8)
3*	1:05	0.5 (1.9)	1 (3.8)
4*	1:10	0.5 (1.9)	1 (3.8)
5*	1:15	0.5 (1.9)	1 (3.8)
6	8:00	1.0 (3.8)	1 (3.8)
7	8:15	2.0 (7.6)	1 (3.8)
8	9:00	1.5 (5.7)	1 (3.8)
9	9:15	1.0 (3.8)	1 (3.8)
Total Volume Drawn Per Day: 10 gallons (38 L)			

* Denotes draws in first draw cluster.

2. Low Usage Draw Pattern

Draw Number	Time During Test (hh:mm)	Volume (gallons)	Flow Rate (GPM)
1*	0:00	15.0 (56.8)	1.7 (6.5)
2*	0:30	2.0 (7.6)	1 (3.8)
3*	1:00	1.0 (3.8)	1 (3.8)
4	10:30	6.0 (22.7)	1.7 (6.5)
5	11:30	4.0 (15.1)	1.7 (6.5)
6	12:00	1.0 (3.8)	1 (3.8)
7	12:45	1.0 (3.8)	1 (3.8)
8	12:50	1.0 (3.8)	1 (3.8)
9	16:15	2.0 (7.6)	1 (3.8)
10	16:45	2.0 (7.6)	1.7 (6.5)
11	17:00	3.0 (11.4)	1.7 (6.5)
Total Volume Drawn Per Day: 38 gallons (144 L)			

* Denotes draws in first draw cluster.

3. Medium Usage Draw Pattern

Draw Number	Time During Test (hh:mm)	Volume (gallons)	Flow Rate (GPM)
1*	0:00	15.0 (56.8)	1.7 (6.5)
2*	0:30	2.0 (7.6)	1 (3.8)
3*	1:40	9.0 (34.1)	1.7 (6.5)
4	10:30	9.0 (34.1)	1.7 (6.5)
5	11:30	5.0 (18.9)	1.7 (6.5)
6	12:00	1.0 (3.8)	1 (3.8)
7	12:45	1.0 (3.8)	1 (3.8)
8	12:50	1.0 (3.8)	1 (3.8)
9	16:00	1.0 (3.8)	1 (3.8)
10	16:15	2.0 (7.6)	1 (3.8)
11	16:45	2.0 (7.6)	1.7 (6.5)
12	17:00	7.0 (26.5)	1.7 (6.5)
Total Volume Drawn Per Day: 55 gallons (208 L)			

* Denotes draws in first draw cluster.

4. High Usage Draw Pattern

Draw Number	Time During Test (hh:mm)	Volume (gallons)	Flow Rate (GPM)
1*	0:00	27.0 (102)	3 (11.4)
2*	0:30	2.0 (7.6)	1 (3.8)
3*	0:40	1.0 (3.8)	1 (3.8)
4*	1:40	9.0 (34.1)	1.7 (6.5)
5	10:30	15.0 (56.8)	3 (11.4)
6	11:30	5.0 (18.9)	1.7 (6.5)
7	12:00	1.0 (3.8)	1 (3.8)
8	12:45	1.0 (3.8)	1 (3.8)
9	12:50	1.0 (3.8)	1 (3.8)
10	16:00	2.0 (7.6)	1 (3.8)
11	16:15	2.0 (7.6)	1 (3.8)
12	16:30	2.0 (7.6)	1.7 (6.5)
13	16:45	2.0 (7.6)	1.7 (6.5)
14	17:00	14.0 (53.0)	3 (11.4)
Total Volume Drawn Per Day: 84 gallons (318 L)			

* Denotes draws in first draw cluster.

As with the current test method, the energy factor of the water heater is calculated as the total heat energy of delivered water divided by the total energy the water heater consumes throughout the 24-hour simulated use test. Energy consumption rates are also modified to take into account that the difference between storage tank and ambient temperature may not be the nominal 57.5°F, and the difference between inlet and outlet water temperature may not be the nominal value of 67°F.

1.3. TESTED PRODUCTS

To validate the proposed test method and explore the impacts of the proposed test procedure on first-hour rating, DOE tested fifteen storage water heaters and six instantaneous water heaters. Table 4 lists the twenty-one units along with their relevant attributes used in this analysis.

Table 4: Products used in residential water heater test report

Water Heater ID	***Heater Type***	***Energy Source***	***Rated Storage Volume (gal)***	***Rated Input***	***Notes***
S-NG-1	Storage	Natural gas	40	40 kBtu/h	
S-NG-2	Storage	Natural gas	29	60 kBtu/h	
S-NG-3	Storage	Natural gas	75	70 kBtu/h	
S-NG-4	Storage	Natural gas	40	40 kBtu/h	
S-NG-5	Storage	Natural gas	40	40 kBtu/h	
S-O-1	Storage	Oil	32	104 kBtu/h	
S-O-2	Storage	Oil	32	104 kBtu/h	
S-E-1	Storage	Electric	30	4.5 kW	
S-E-2	Storage	Electric	50	4.5 kW	
S-E-3	Storage	Electric	80	4.5 kW	
S-E-4	Storage	Electric	4	1.5 kW	Not covered by the current DOE test procedure
S-E-5	Storage	Electric	6	2 kW	Not covered by the current DOE test procedure
S-E-6	Storage	Electric	2.75	1.5 kW	Not covered by the current DOE test procedure

S-E-7	Storage	Electric	80	4.5 kW	
S-HP-1	Storage	Heat pump*	50	4.5 kW	
I-NG-1	Instantaneous	Natural gas	0	199 kBtu/h	
I-NG-2	Instantaneous	Natural gas**	0	150 kBtu/h	
I-NG-3	Instantaneous	Natural gas	0	175 kBtu/h	
I-E-1	Instantaneous	Electric	0	3.5 kW	
I-E-2	Instantaneous	Electric	0	12 kW	
I-E-3	Instantaneous	Electric	0	28.8 kW	Not covered by the current DOE test procedure

* Water heater S-HP-1 is electric- and heat pump-powered, and includes storage tank.
** Note that propane gas is an alternative energy source for water heater I-NG-2.

2. IMPACT ON FIRST-HOUR RATING OF STORAGE WATER HEATERS

DOE tested fifteen storage water heaters for first hour rating under the proposed amended test procedure, including five natural gas-fired, two oil-fired, seven electric resistance-powered, and one heat pump-powered. For the twelve storage water heater models that are covered by the current DOE test procedure, DOE compared the measured first-hour ratings under the existing test procedure to the first hour ratings observed under the proposed revised test procedure, as shown in Figure 1 below.[d] Five out of the twelve saw their first-hour rating decrease from the current to the proposed test procedure, while the remaining seven water heaters saw their first-hour rating increase. On average, storage water heater measured first-hour ratings under the proposed test procedure are 103% of their current measured value. From Figure 1 below, the majority of water heaters see their measured first-hour rating change to between approximately 90% and 110% of their measured rating under the current test method.

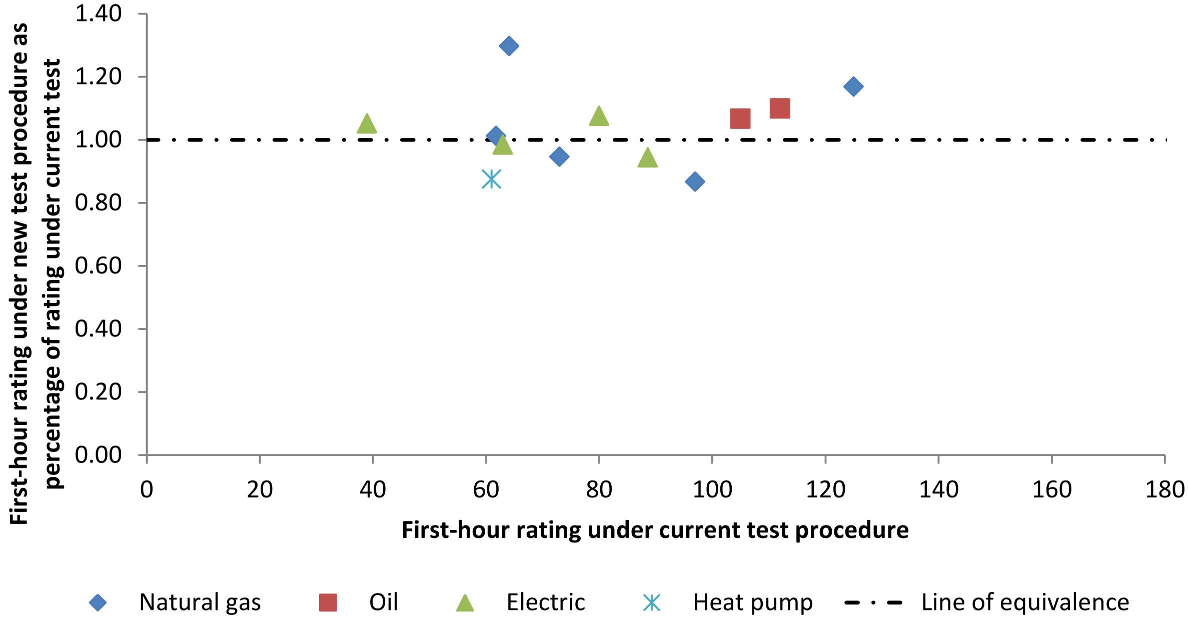

Figure 1: First-hour rating of storage water heaters under proposed test procedure as percentage of current first-hour rating, as function of current first-hour rating

DOE also investigated the change in measured first-hour rating of water heaters in different draw profile categories. Figure 2 below categorizes the twelve applicable storage water heaters into their corresponding draw profile based on first-hour rating test results under the proposed test procedure. It appears from Figure 2 that the measured first-hour rating of high usage water heaters increases from the current to proposed test procedure, while low usage and medium usage water heaters see their measured first-hour rating either drop or remain relatively constant.

[d] Water heaters S-E-4, S-E-5, and S-E-6 do not have current first-hour or energy factor ratings since they have a storage volume between 2 and 20 gallons, and fall in a category not currently addressed by the DOE test procedure.

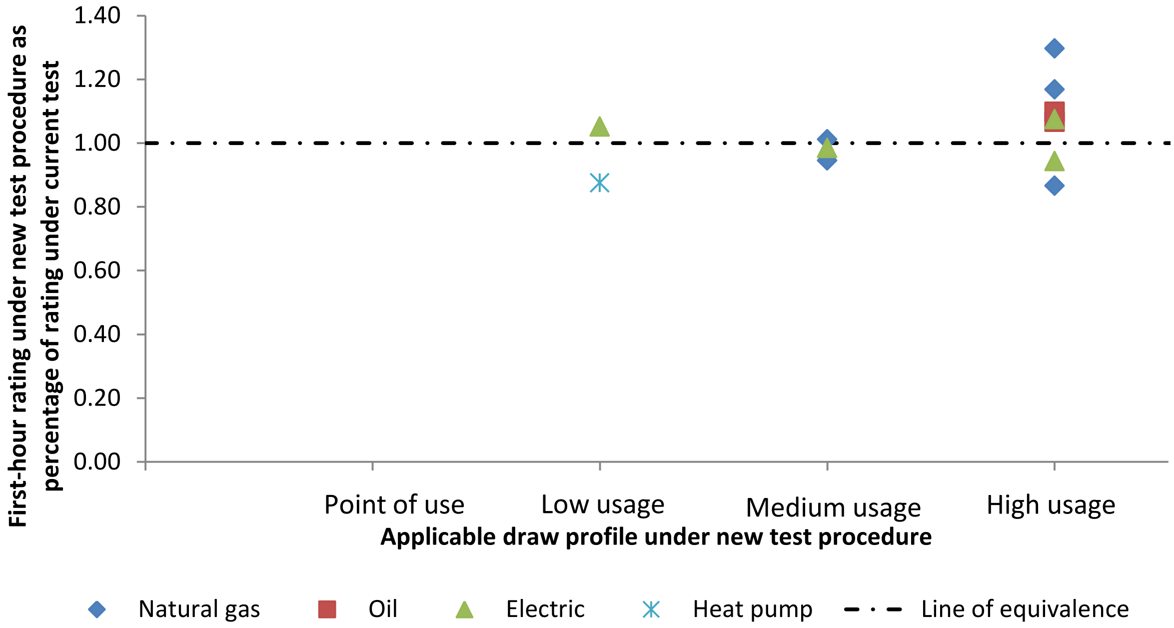

Figure 2: First-hour rating of storage water heaters under proposed test procedure as percentage of current first-hour rating, as function of applicable draw profile

3. IMPACT ON MAXIMUM GPM RATING OF INSTANTANEOUS WATER HEATERS

To determine the impact of the differences between the current and the proposed test procedures on the measured max gpm, DOE tested six instantaneous water heaters including three natural gas-powered and three electric-powered. Although one of the electric water heaters (I-E-3) is currently outside of the scope of the DOE test method for residential water heaters, DOE was able to perform the current max gpm test on that water heater without modification, and as such, included that unit in the comparison between the current and proposed test method.[e] Similar to the analysis of first-hour ratings of storage water heaters in Section 2, DOE compared the change in measured maximum gpm of instantaneous water heaters under the proposed test procedure to the measured maximum gpm under the current test procedure. Figure 3 below plots the measured maximum gpm under the proposed test procedure as a percentage of the measured maximum gpm under the current test procedure. From this figure, the three electric instantaneous water heaters saw an increase in their measured maximum gpm rating of 14% on average, while the three natural gas instantaneous water heaters saw an increase of 13%.

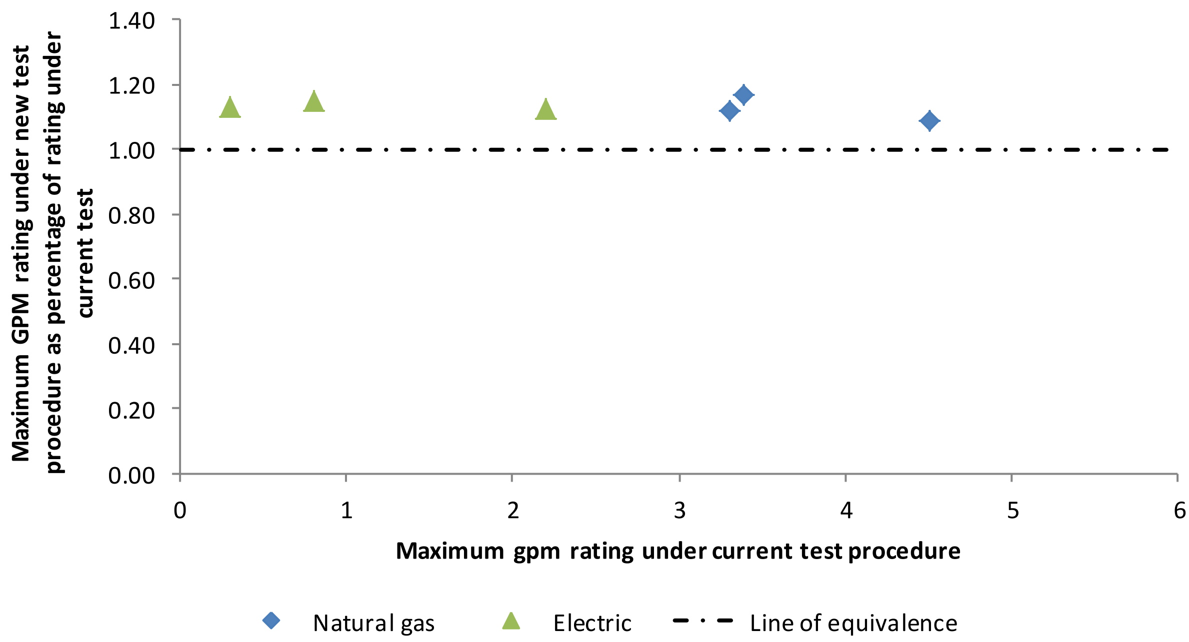

Figure 3: Maximum gpm rating of instantaneous heaters under proposed test procedure as percentage of current maximum gpm rating, as function of current maximum gpm rating

The instantaneous water heaters observed in this study are also categorized into their applicable draw pattern based on maximum gpm test results. The measured maximum gpm under the

---

[e] The unit I-E-3 would be covered under the proposed revised test method.

proposed test procedure as a percentage of the measured maximum gpm under the current test procedure is plotted as a function of the draw profile in Figure 4 below. As expected, the measured maximum gpm of instantaneous water heaters increases as the set point temperature drops from 135°F to 125°F from the current to proposed test procedure.

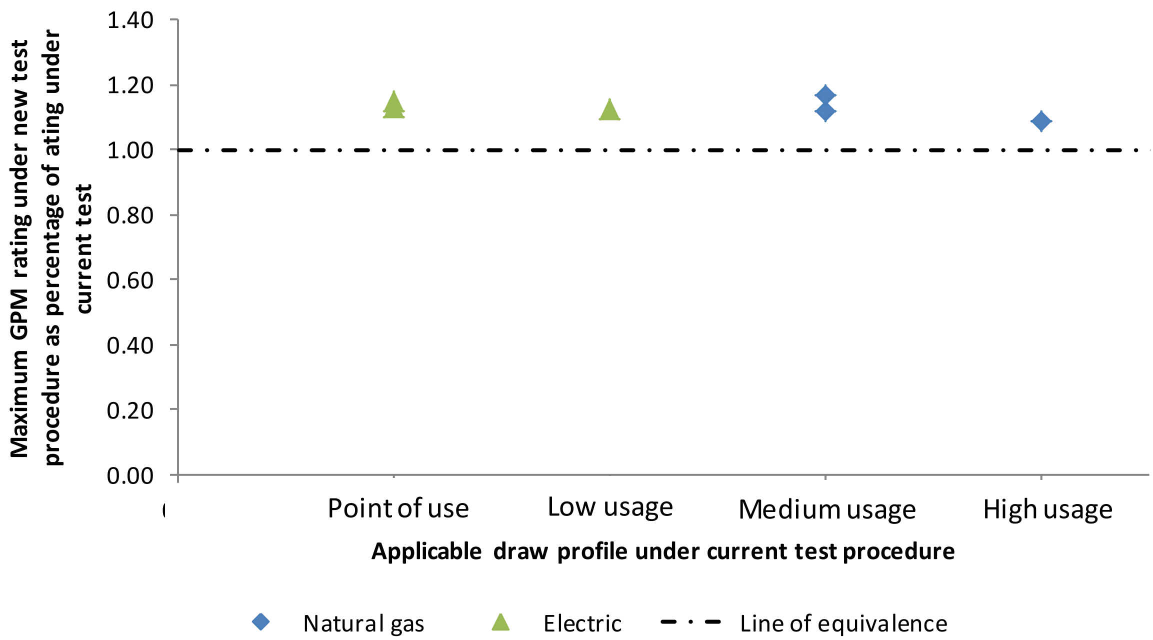

Figure 4: Maximum gpm rating of instantaneous water heaters under proposed test procedure as percentage of current maximum gpm rating, as function of draw profile established by the proposed maximum gpm rating test

4. IMPACT ON ENERGY FACTOR

DOE investigated the impact of the proposed test procedure on the energy factor of both storage and instantaneous water heaters. Based on the performance of the water heater in the proposed first-hour rating or maximum gpm test (as shown in Sections 2 and 3), DOE subjected each water heater to the appropriate draw profile as specified by the proposed test method . DOE also subjected each water heater to at least one other draw profile to better understand how the energy factor of a specific water heater model varies across different draw profiles, the analysis of which is presented in Section 6. The additional draw profile(s) tested were the pattern directly above and/or below the nominal usage pattern that the unit would qualify for. For example, if a unit qualified for the high usage pattern based on its first hour rating, it was also tested using the medium usage pattern. In several cases, DOE performed additional experimental testing at draw patterns two levels above the nominal pattern (*e.g.*, for a unit with a low usage nominal pattern, DOE also performed testing at the high usage pattern) to analyze the trend in the impact on measured energy factor across multiple draw patterns.[f]

4.1. STORAGE WATER HEATERS

The impact of the differences between the current and proposed test procedure on the measured energy factor was examined for all twelve of the storage water heaters to which the current test procedure is applicable.[g] As shown in Figure 5 below, the measured energy factor of six of the twelve storage water heaters increased under the proposed test method, while the measured energy factor of five water heaters decreased and one stayed constant.

Results for storage water heaters are also categorized by their applicable draw profile identified using the measured first-hour rating under the proposed test procedure. From Figure 6, all water heaters subject to a low or medium usage draw profile experience a decrease in measured energy factor, while the majority of those water heaters subject to a high usage draw profile experience an increase in measured energy factor. This is to be expected, as the energy factor of storage water heaters is correlated to the total volume drawn from the 24-hour simulated use test. Since the high usage test under the proposed procedure draws a higher total volume of water than the current test procedure, one would expect the energy factor to rise. Conversely, the low and medium usage tests under the proposed procedure draw less water than required by the current test method, and one would expect their energy factors to fall.

---

[f] Additionally, some water heaters were originally grouped into different draw profile bins than they are currently. This is because DOE adjusted the draw profile first-hour and maximum gpm limits after analyzing data made available mid-testing. Thus, more energy factor ratings were produced than necessary for some water heaters. For example, water heater S-NG-2 was tested under low, medium, and high usage draw patterns even though it currently qualifies for the high usage test, since it originally qualified for the medium usage test before DOE adjustments.
[g] This analysis excludes the change in energy factor for water heaters S-E-4, S-E-5, and S-E-6 since their small storage volumes (greater than 2 and less than 20 gallons) limit them to point of use applications and cannot be appropriately tested under the current test procedure.

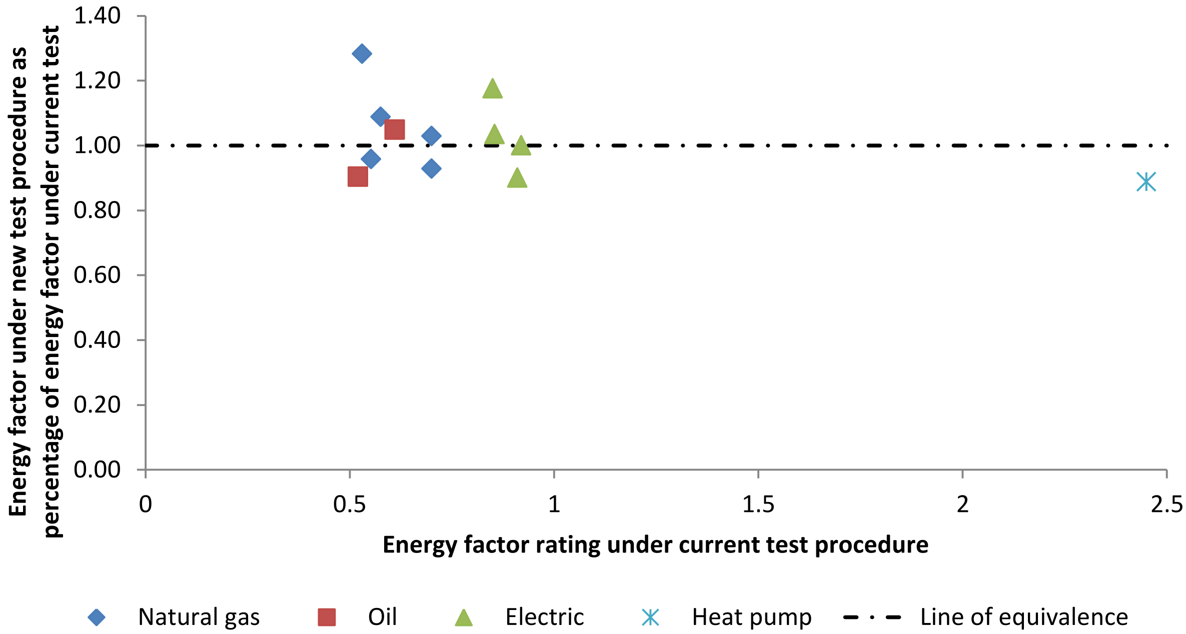

Figure 5: Energy factor of storage water heaters under proposed test procedure as percentage of current energy factor, as function of current energy factor

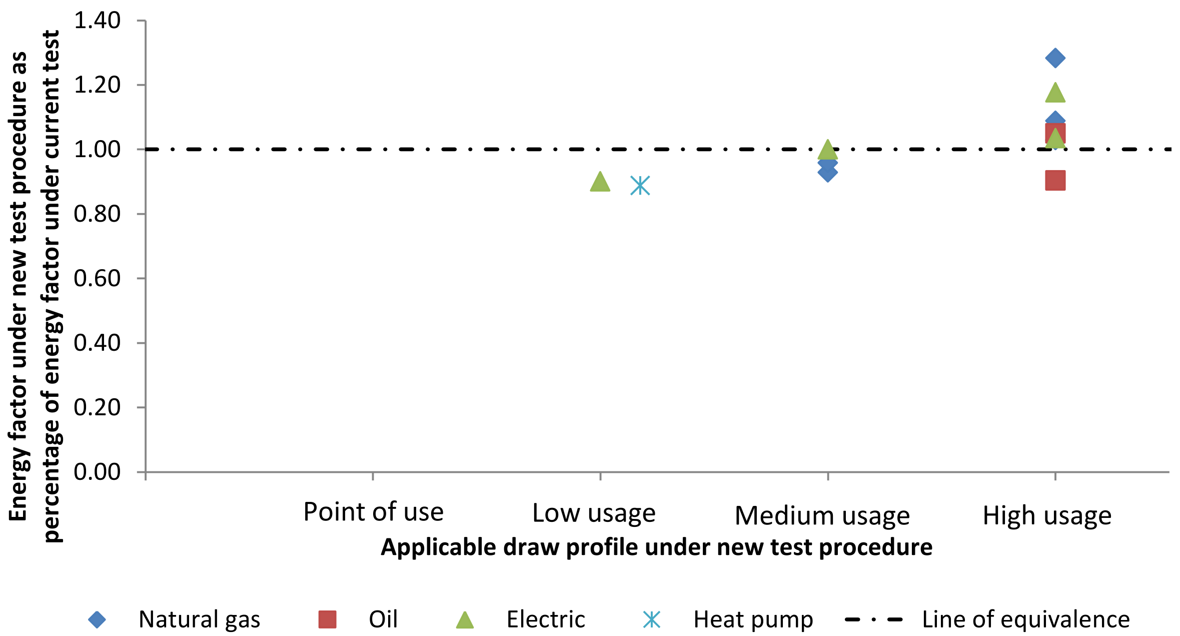

Figure 6: Energy factor of storage water heaters under proposed test procedure as percentage of current energy factor, as function of applicable draw profile

4.2. INSTANTANEOUS WATER HEATERS

The change in energy factor for instantaneous water heaters due to the differences between the current and proposed test procedures is evaluated for the six available instantaneous water heaters. As noted previously, one of the instantaneous water heaters tested (I-E-3) is outside of the scope of the current test method. However, since the current test method could be run on that unit without modification, and since the unit is covered by the proposed revised test method, DOE included that unit for comparison. Two of the three gas-fired instantaneous water heaters saw a slight increase in their measured energy factor under the proposed test procedure, while all three electric-powered instantaneous water heaters saw a decrease, as shown in Figure 7. When isolated by applicable draw pattern in Figure 8 the results are more easily assessed, as the point of use water heater category shows a clearer decrease in measured energy factor than the low, medium, and high usage categories, which tend to instead stay relatively constant from the current to proposed test procedure.

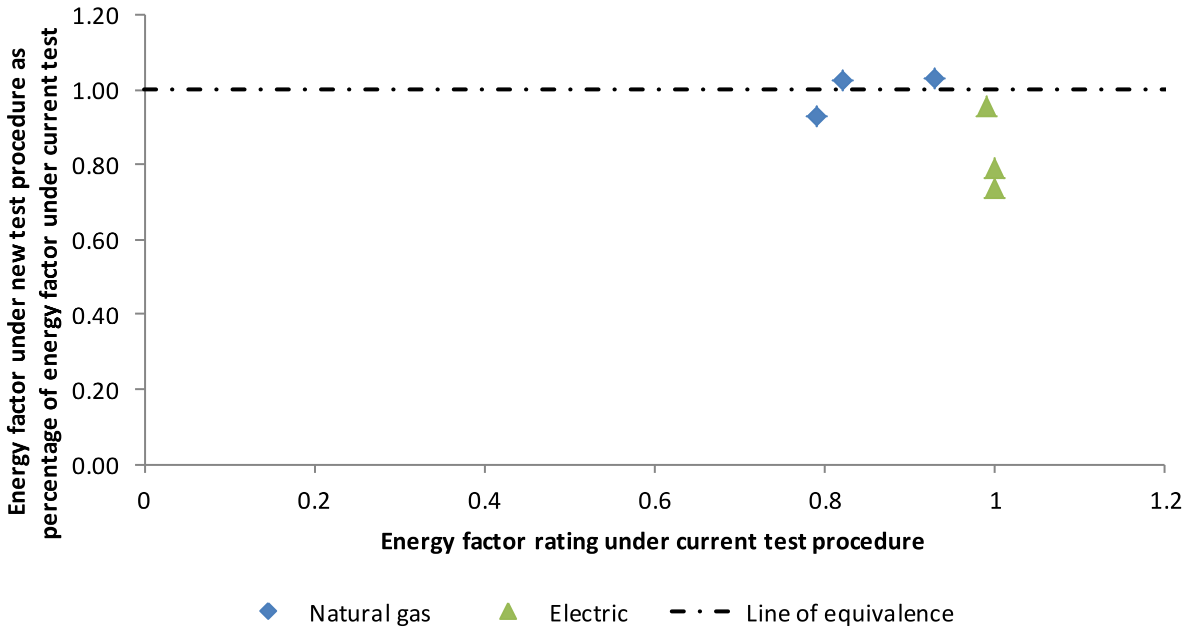

Figure 7: Energy factor of instantaneous water heaters under proposed test procedure as percentage of current energy factor, as function of current energy factor

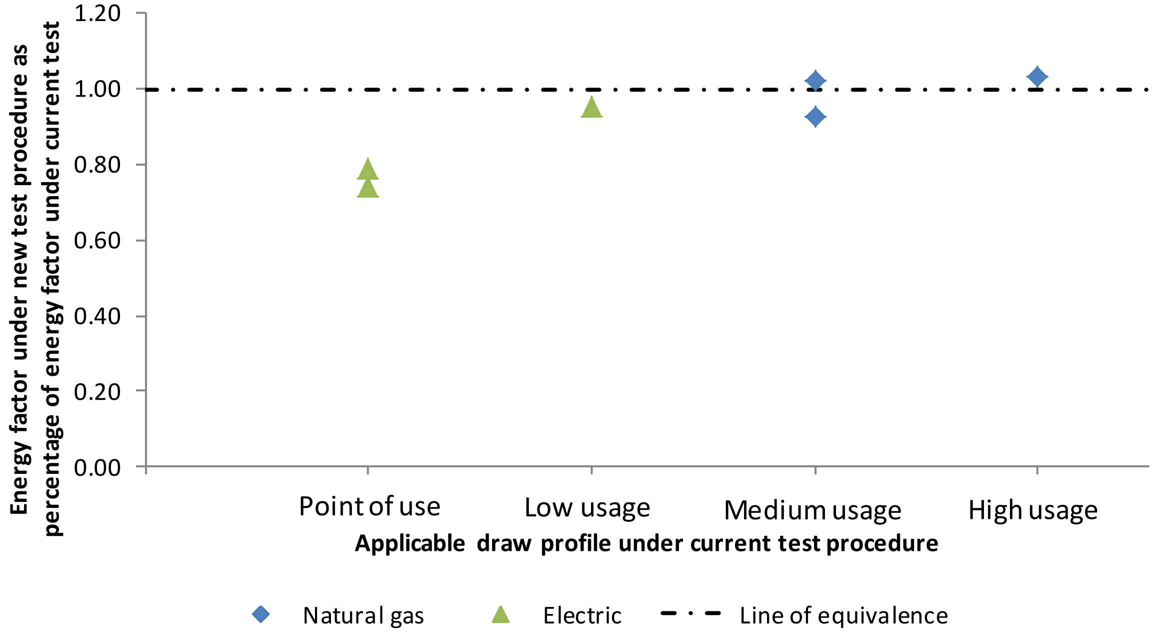

Figure 8: Energy factor of instantaneous water heaters under proposed test procedure as percentage of current energy factor, as function of applicable draw profile

5. EFFECTS OF PROPOSED TEST PROCEDURE ON DIFFERENT CATEGORIES OF WATER HEATER

Since DOE expects the proposed changes in the test method to likely affect different categories of water heaters in different ways, DOE is presenting the average change in first-hour, maximum gpm, and energy factor ratings separately by type, applicable draw profile, and energy source.

5.1. STORAGE WATER HEATERS

Table 5 below shows the average change in measured first-hour rating of the twelve storage water heaters evaluated. The measured first-hour ratings for storage water heaters on average increased by 3%, with water heaters tested under the high usage draw pattern experiencing the most significant increase in measured first-hour rating and water heaters tested under the low usage draw pattern experiencing the most significant decrease.

Table 5: Averaged first-hour rating of storage water heaters under proposed test procedure as percentage of current first-hour rating, categorized by energy source and applicable draw profile

		First-Hour Rating by Energy Source				
		Natural gas	**Oil**	**Electric**	**Heat pump**	***All***
Draw Profile	**Point of use**	N/A	N/A	N/A	N/A	N/A
	Low usage	N/A	N/A	105%	87%	96%
	Medium usage	98%	N/A	98%	N/A	98%
	High usage	111%	108%	101%	N/A	107%
	All	106%	108%	101%	87%	103%

The average change in measured energy factor for the twelve storage water heaters is shown in Table 6 below. On average, the measured energy factor of water heaters tested under the high usage draw pattern increased by 8%, while water heaters tested under the medium and low usage draw patterns decreased by 4% and 11% on average, respectively. Again, this is expected as the energy factor is correlated to the total volume drawn during the 24-hour simulated use test for storage water heaters.

Table 6: Averaged energy factor of storage water heaters under proposed test procedure as percentage of current energy factor, categorized by energy source and applicable draw profile

		Energy Factor by Energy Source				
		Natural gas	**Oil**	**Electric**	**Heat pump**	***All***
Draw Profile	**Point of use**	N/A	N/A	N/A	N/A	N/A
	Low usage	N/A	N/A	90%	89%	89%
	Medium usage	94%	N/A	100%	N/A	96%
	High usage	113%	98%	111%	N/A	108%
	All	107%	98%	100%	89%	102%

5.2. INSTANTANEOUS WATER HEATERS

Table 7 below shows the average change in the measured maximum gpm rating of instantaneous water heaters for different categories of applicable draw profile and energy source. The point of use and low usage electric categories saw increases of 14% and 13% on average for the measured maximum gpm, respectively, while the medium and high usage natural gas categories saw increases in measured maximum gpm of 14% and 9%, respectively.

Table 7: Averaged maximum gpm rating of instantaneous water heaters under proposed test procedure as percentage of current maximum gpm rating, categorized by energy source and applicable draw profile

		Maximum GPM Rating by Energy Source		
		Natural gas	**Electric**	***All***
Draw Profile	**Point of use**	N/A	114%	114%
	Low usage	N/A	113%	113%
	Medium usage	114%	N/A	114%
	High usage	109%	N/A	109%
	All	113%	114%	113%

The average change in energy factor for instantaneous water heaters is shown in Table 8 below. The electric point of use, electric low usage, and natural gas medium usage categories experience decreases in energy factor of 23%, 4%, and 2% on average, respectively. The natural gas high usage category experienced a 3% increase in its energy factor, on average.

Table 8: Averaged energy factor of instantaneous water heaters under proposed test procedure as percentage of current energy factor, categorized by energy source and applicable draw profile

		Energy Factor by Energy Source		
		Natural gas	**Electric**	***All***
Draw Profile	**Point of use**	N/A	77%	77%
	Low usage	N/A	96%	96%
	Medium usage	98%	N/A	98%
	High usage	103%	N/A	103%
	All	100%	83%	91%

6. VARIANCE IN ENERGY FACTOR RATINGS FOR WATER HEATERS UNDER DIFFERENT DRAW PROFILES

The water heaters tested by DOE in this report were subjected to at least one other draw profile that did not match its applicable draw pattern prescribed by the proposed test procedure based on the tested first hour rating (storage water heaters) or maximum gpm rating (instantaneous water heaters). As explained above, the additional draw profile(s) tested were the pattern(s) directly above and/or below the nominal usage pattern that the unit would qualify for. This allowed DOE to evaluate how different 24-hour simulated use test draw patterns affect the performance of different categories of water heaters. In this section, the variance in measured energy factor for water heaters tested under different draw profiles is observed for appropriate water heater categories. These include water heater type, energy source, and applicable draw pattern.

6.1. BY WATER HEATER TYPE

The observed water heater energy factor under the proposed test procedure is filtered by storage water heaters in Figure 9 and by instantaneous water heaters in Figure 11. Additionally, Figure 10 shows the energy factor ratings of the storage heat pump water heater S-HP-1 under different draw profiles in a separate chart, since its energy factor is so much greater than normal heat pump water heaters that it would make trends observed in Figure 9 less obvious. From Figure 9 and Figure 10 below, the measured energy factor of storage water heaters (including heat pump water heater S-HP-1) increases as the draw profile moves from point of use through high usage. From Figure 11, the measured energy factor of instantaneous water heaters appears to follow a similar trend as storage water heaters, though potentially experiences a plateau from the low through high usage draw profiles.

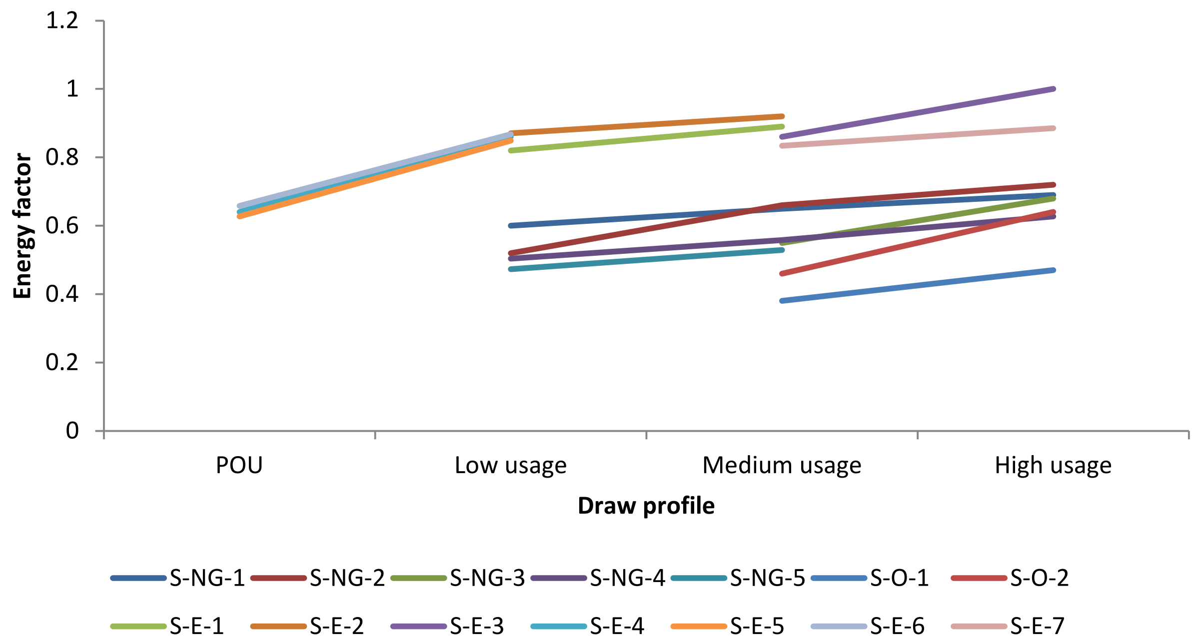

Figure 9: Energy factor ratings of storage water heaters tested with different draw profiles (heat pump water heater S-HP-1 excluded)

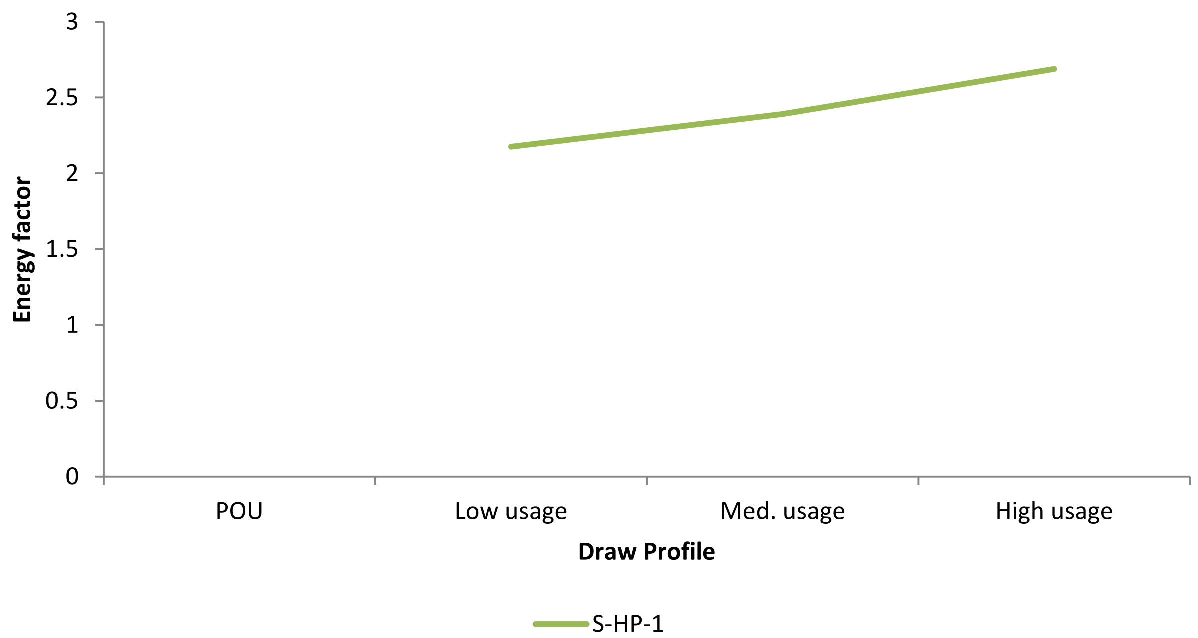

Figure 10: Energy factor ratings of storage heat pump water heater S-HP-1 tested with different draw profiles

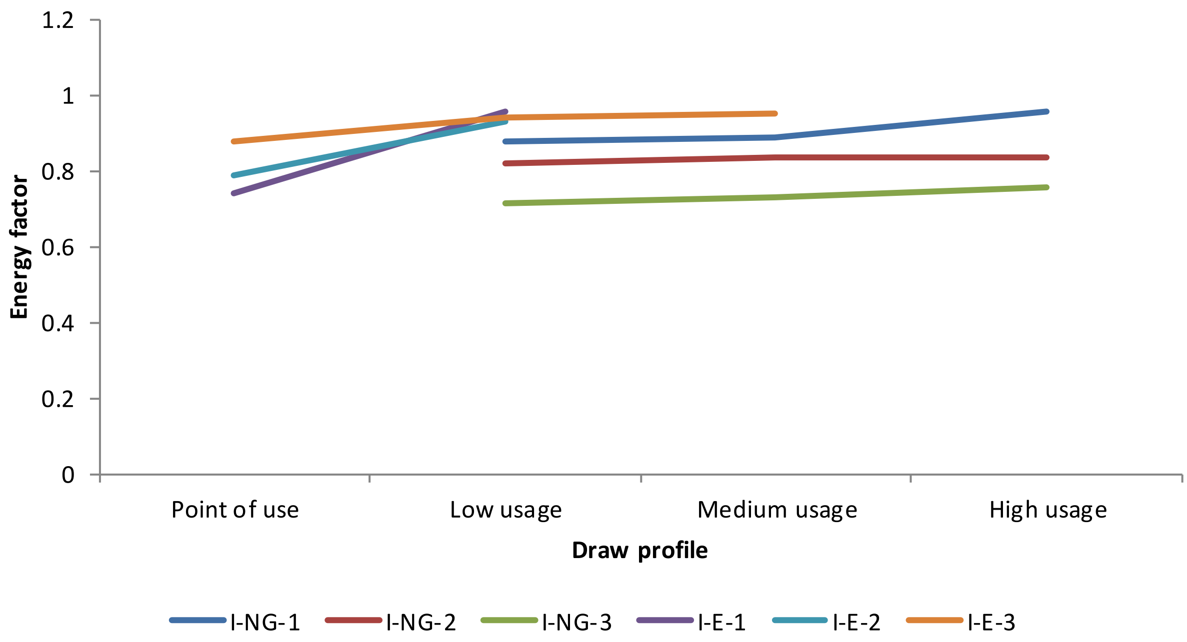

Figure 11: Energy factor ratings for instantaneous water heaters tested with different draw profiles

6.2. BY ENERGY SOURCE

Changes in the measured energy factor of water heaters were then filtered by energy source. Figure 12 below isolates the change in the measured energy factor by natural gas-powered water heaters, and shows an increase in the measured energy factor from low through high usage draw profiles, as expected. Figure 13 and Figure 14 filter by oil-fired and electric water heaters, respectively, and show a similar trend as natural gas-fired water heaters.[h] The same increasing trend is observed when isolating for the heat pump water heater S-HP-1, as shown previously in Figure 10 above.

[h] The oil-fired water heater sample only contains storage water heaters since no oil-fired instantaneous water heaters were tested.

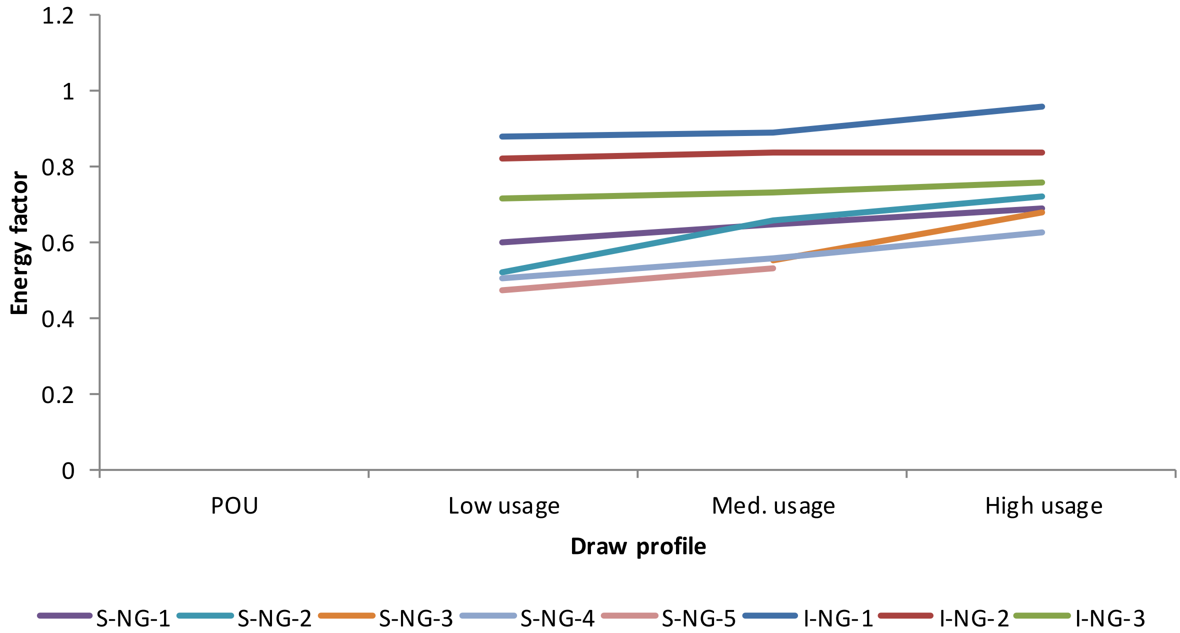

Figure 12: Energy factor ratings for water heaters using natural gas as an energy source

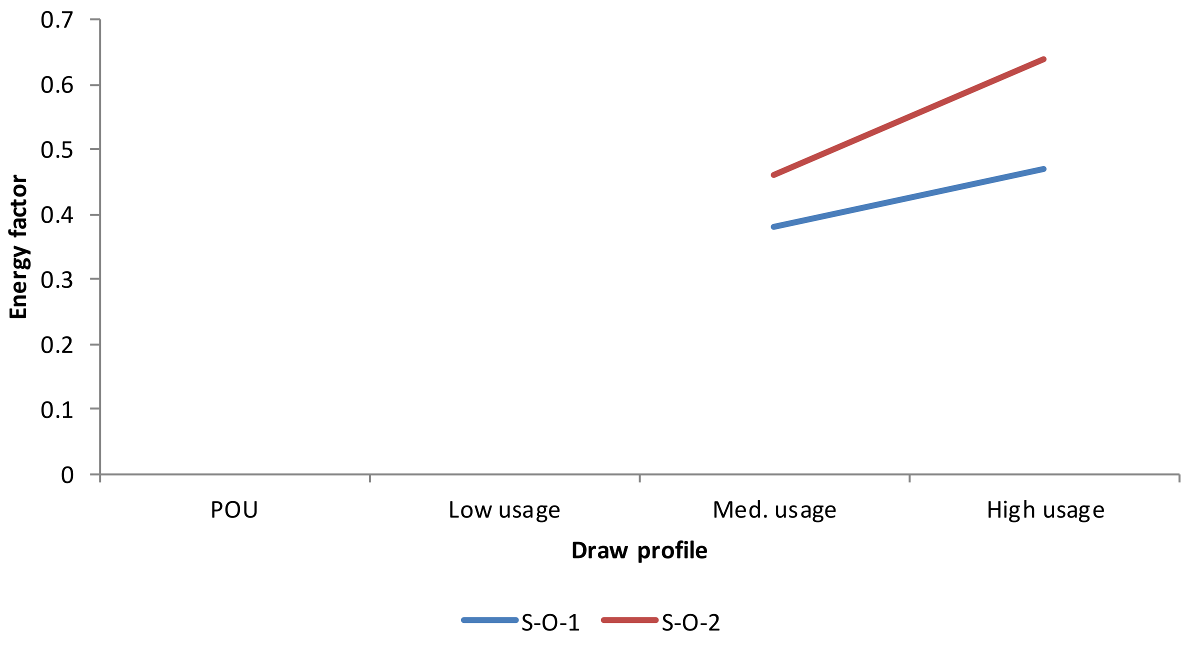

Figure 13: Energy factor ratings for water heaters using oil as an energy source

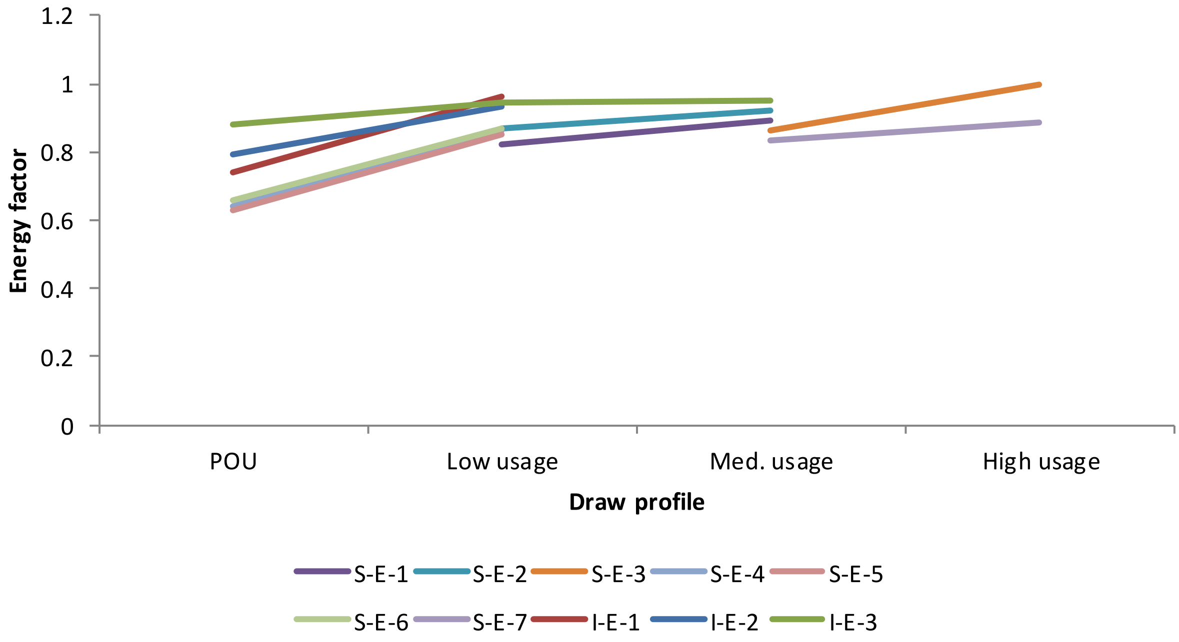

Figure 14: Energy factor ratings for water heaters using electricity as an energy source

6.3. BY APPLICABLE DRAW PROFILE

Lastly, changes in the measured energy factor for water heaters were filtered by applicable draw profile – that is, the specific draw profile that the water heater qualified for given its performance in the first-hour or maximum gpm rating test. For example, Figure 15 plots the five water heaters that qualified for the point of use draw profile, yet were also tested under low usage draw profile conditions. In this figure, all five water heaters see significant increases in their measured energy factor when placed under the low usage draw profile. Figure 16 filters for water heaters that qualified for the low usage test, showing a marginal increase from point of use to low usage and from low to medium usage.[i] In addition, the heat pump (S-HP-1) water heater was also tested at the high usage pattern and shows a significant increase from medium to high usage, as observed in Figure 9 shown previously. Figure 17 filters by medium usage, and shows five water heaters that experience relatively marginal gains in measured energy factor. Figure 18 filters by high usage, and shows an obvious increase in measured energy factor.

---

[i] Although the heat pump water heater S-HP-1 also qualified for the low usage draw profile, it is not included in Figure 16 since its energy factor ratings are so high that they would make trends observed for other water heaters less obvious. The energy factor ratings of the heat pump water heater at different draw profiles are instead available in Figure 9 above.

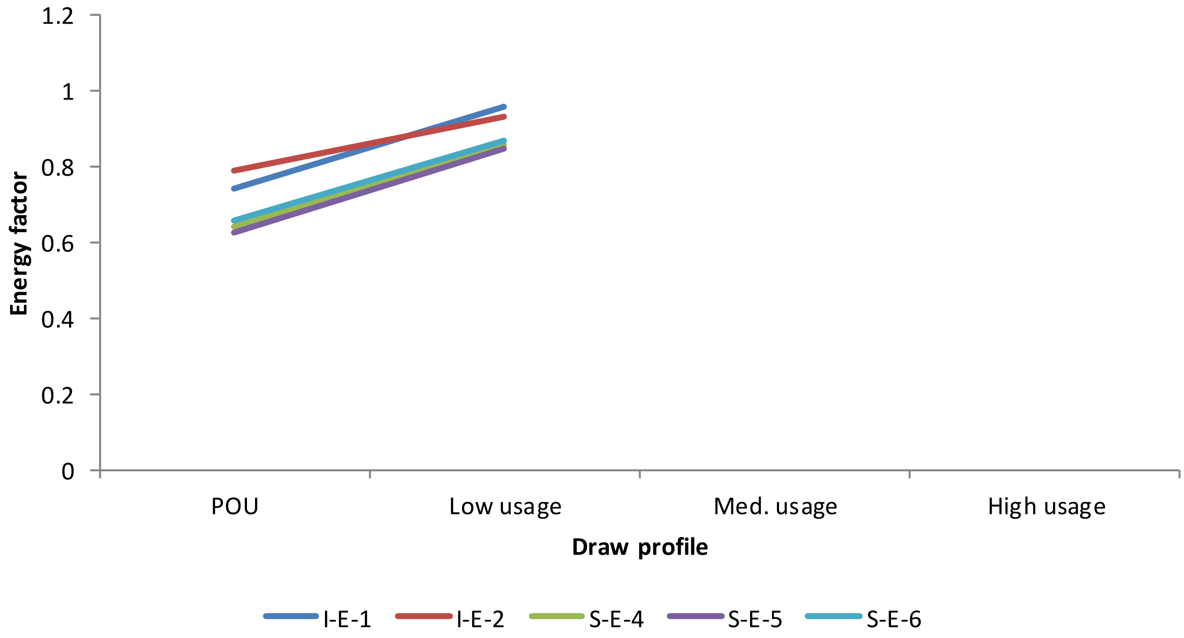

Figure 15: Energy factor ratings for water heaters testing for point of use draw profile

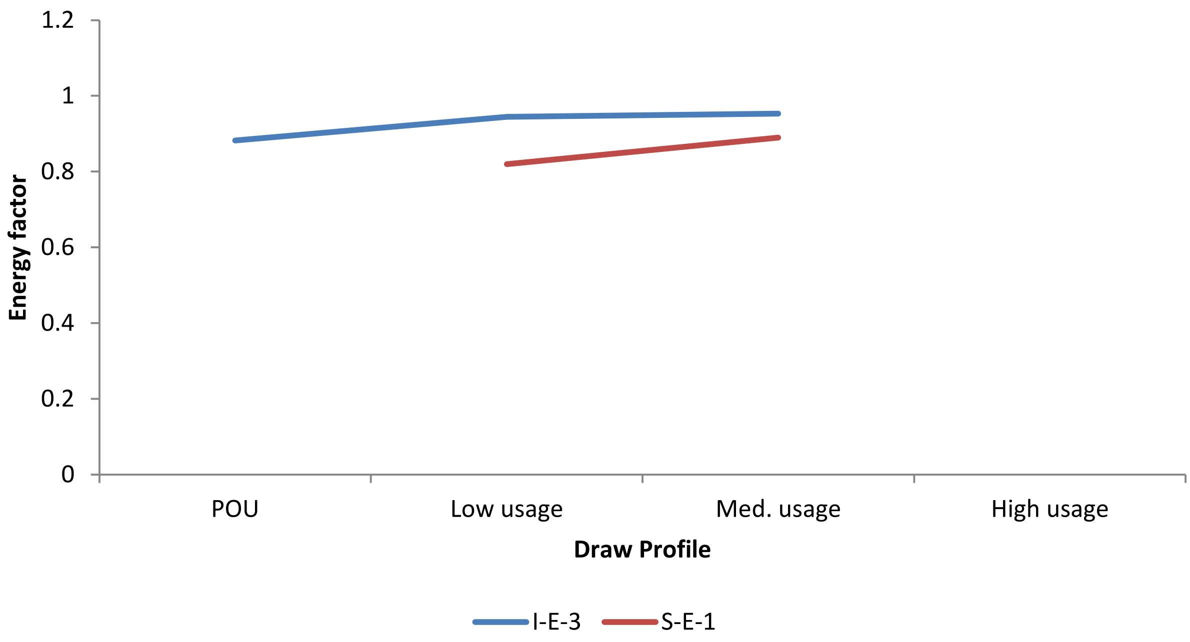

Figure 16: Energy factor ratings for water heaters testing for low usage draw profile (heat pump water heater S-HP-1 excluded)

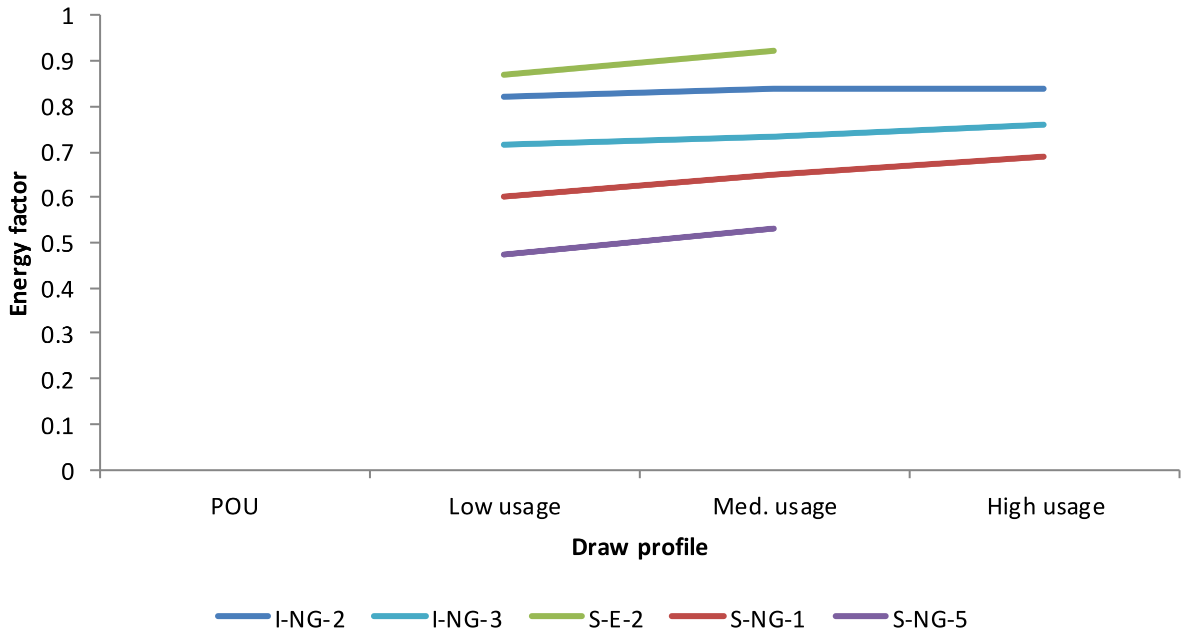

Figure 17: Energy factor ratings for water heaters testing for medium usage draw profile

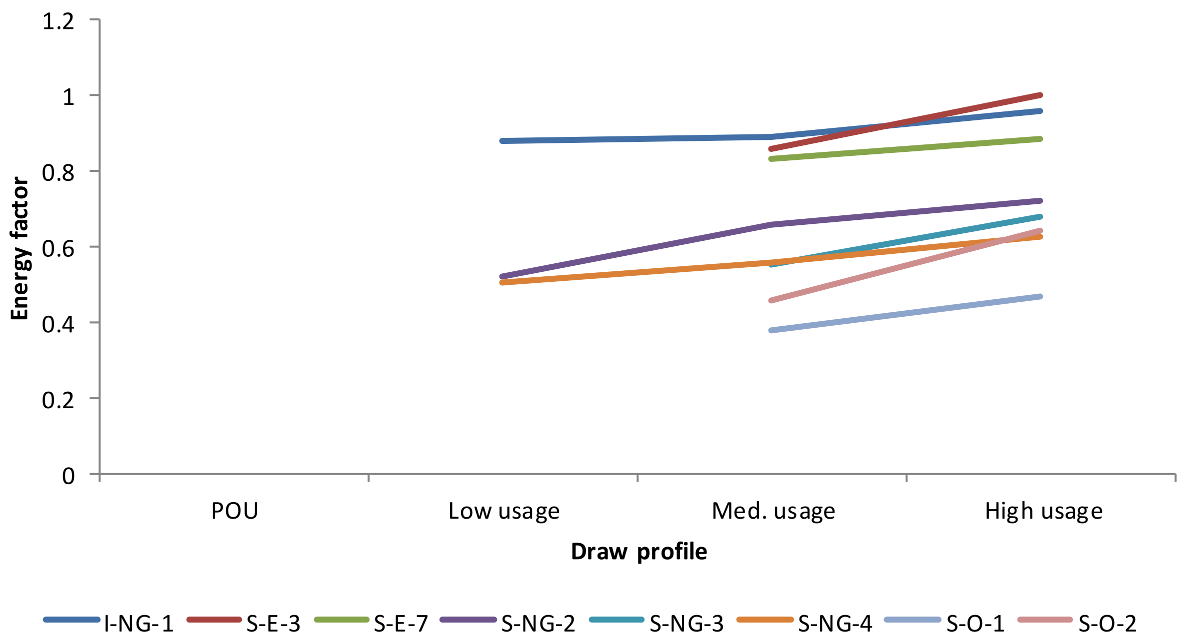

Figure 18: Energy factor ratings for water heaters testing for high usage draw profile

7. SUMMARY

This report provides a preliminary assessment of the impact of proposed additions and revisions to the current test procedure for residential water heaters. These additions and revisions also apply to light commercial water heaters, which are defined as a new category of water heater in the notice of proposed rulemaking. Specifically, the impacts analyzed for this report include:

- Impact of proposed test procedure revisions on measured first hour rating of storage water heaters, maximum gallon per minute of instantaneous water heaters, and energy factor of storage and instantaneous water heaters
- Effects of the proposed test procedure revisions on different categories of water heater
- Variance in measured energy factor ratings of units tested under different draw profiles

Twenty-one water heaters were tested under the proposed test procedure, including fifteen storage and six instantaneous water heaters. The energy factor and first hour rating tests specified by the current test procedure are not applicable for three small storage water heaters, labeled in this study as S-E-4, S-E-5, and S-E-6, and thus comparisons between their measured energy factors under the current test procedure and the proposed test procedure cannot be made.

For storage water heaters, DOE found that the measured first-hour rating under the proposed test procedure varied between 87 and 130% of the measured first-hour rating under the current test, with an average of 103%. The energy factor measured under the proposed test procedure as compared to that measured under the current test procedure varied by 89 to 128%, with an average of 102%. For instantaneous water heaters, DOE found that the maximum gpm rating under the proposed test procedure varied between 109 and 117% of the current rating, with an average of 113%. The energy factor measured by the proposed test procedure as compared to that measured under the current test procedure varied by 74 to 103%, with an average of 91%.

This report also analyzed effects of the proposed test procedure revisions on different categories of water heater. The type of water heater most affected by the change in test procedure as observed in this study was the instantaneous, electric, water heater that would be tested using the point of use draw pattern, which saw an average energy factor rating of 77% the current value. The majority of other water heaters had measured energy factor ratings of 90 to 110% of the measured energy factor under the current test method.

Lastly, this report evaluated how water heaters assigned to their nominal draw profile behaved when subject to different draw profiles. It was found in all cases that as the total volume of water drawn during the 24-hour simulated use test increased—that is, the draw profile increased from point of use through high usage—the measured energy factor of the water heater also increased. Different categories of water heaters experienced steeper climbs in energy factor from one test to another, the greatest being storage water heaters from medium to high usage, and both storage and instantaneous water heaters from point of use to low usage.

DOE will continue to conduct additional tests in order to better understand how the proposed test procedure affects the measured first-hour, maximum gpm, and energy factor ratings as compared to the values measured under the current test.