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Dr. Mr. Karney,

Applied Energy Technology Company appreciates this opportunity to comment on the draft proposed inclusion of water heating technologies in the Energy Star Program.

Applied Energy Technology Company (AET) is a private research and consulting organization headed by Dr. Carl Hiller, P.E. – principal. AET, through Dr. Hiller, has extensive experience on water heating matters. Clients include the U.S. Department of Energy, several state energy agencies, water heating equipment manufacturers and electric and gas utilities to name a few. Dr. Hiller was a participant and significant contributor/commenter on both the U.S. and ASHRAE water heater test procedures and energy efficiency standards.

We have comments relating to the following subjects:

1. Heat pump water heaters
2. National energy impacts and market penetration assumptions
3. Electric storage water heaters
4. Fossil-fuel fired storage water heaters
5. Tankless fossil-fired water heaters
6. Tankless electric water heaters
7. Warranties
8. First hour rating
9. Piping/distribution system effects

Heat Pump Water Heaters (HPWHs)

We are happy to see that the Energy Star program seeks to include hpwhs, but we are concerned about how the program proposes to do this. Unfortunately, hpwh market success in the U.S. remains elusive for many of the same reasons as in the past. Chief among them are reliability, cost, and lack of adequate manufacturing, marketing, installation, and maintenance infrastructure (1). For these reasons, the Energy Star program should recognize that hpwhs cannot be relied upon as the only electric water heating option to be promoted. Significant national energy impacts due to hpwhs will remain limited for many years to come due to the problems noted above, and while Energy Star labeling will help, it alone will not solve the problems limiting hpwh use. Specifically, we recommend the following:

1. Other more conventional electric water heating options should remain in the Energy Star program mix because they hold promise of much larger overall national energy savings impact than hpwhs in the near term.

2. The proposed minimum required 2.0 energy factor (EF) for hpwhs in the Energy Star program is too high and could inhibit development of other slightly less efficient, but potentially much lower cost hpwh alternatives. An example might include thermoelectric hpwhs. Additionally, thermally-driven fossil-fired hpwhs are under development in other countries, with reported efficiencies on the order of 120%. For these reasons, we recommend that for hpwhs, the minimum required EF to qualify for the Energy Star rating be set at no more than 1.05. This value could be raised with time as successful products penetrate the market place.

3. The latest Energy Star proposal is to include "drop-in" or "integrated" hpwhs only. First of all, there is no specific definition of either of those terms (they are marketing terms not technical terms), so those terms should not be used. The implication is that only hpwh systems that are integrally built with a storage tank (correct technical term is "with-tank" unit) would be included. We strongly recommend against this for several reasons. First of all, even if the hpwh components are still operational, they must all be discarded at the time of a tank failure, limiting the useful life of the equipment. While "without-tank" units may be a bit more site-labor intensive to install, they offer several benefits over with-tank units, such as applications flexibility (due to remote-from-tank mounting ability), hpwh life independent of tank life, and ability to independently size the hpwh and storage tank. If the Energy Star proposal that only with-tank units be accepted was done because of a belief that they would be easier to install, this belief is misguided. The above noted attributes of without-tank units means that they can be applied in a far greater number of installations. Moreover, without-tank units can be made to install as simply as with-tank units simply by installing them with a new tank that has been pre-plumbed and pre-wired to accept the hpwh, prior to delivery to the job site. Additionally, the current reality is that the installed costs of with-tank and without-tank hpwhs are about the same.

National Energy Impacts and Market Penetration Assumptions

The overall goal of the Energy Star program is to decrease national energy use through the promotion of high-efficiency alternatives – that is to say, of appliances that have efficiencies higher than the norm. We find it disturbing that in the Energy Star draft proposal on water heaters that arbitrary and inconsistent assumptions are used regarding potential market penetration of the different higher-than-normal-efficiency water heating options. In some cases there is no discussion at all of the potential market penetration of certain efficiency levels (e.g. electric storage water heaters) and the impact that can have on national energy savings, and in other cases market penetration assumptions of 10% are proposed with no discussion or justification (e.g. high performance gas storage water heaters, whole-home tankless water heaters, heat pump water heaters). In yet other cases market penetration assumptions for various water heating alternatives vary from 1% to 5%. These market penetration assumptions are arbitrary, yet have a huge impact on the national energy savings that could be obtained. We feel it is important that the Energy Star proposal adopt a more consistent method of comparing the national benefits of the different high-efficiency water heating options. This is important because the potential market penetration percentages are in reality vastly different for the different approaches, especially as they relate to incremental costs, cost effectiveness, ease of installation, and adequacy of support infrastructure.

One approach that might be considered is to treat the water heating efficiency upgrades as being done from an assumed available pot of “upgrades” money, rather than assuming arbitrary market penetrations. With this approach, the number of units to be installed would vary depending on their costs, thus affecting their potential market penetration. Under this approach, it would be obvious that the relatively low cost of electric storage water heater efficiency improvements, raising the EF from say 0.90 to 0.95, would result in far larger national site and source energy savings than more expensive options that save more energy per unit, but would result in far fewer units (see electric storage water heater discussion below).

Electric Storage Water Heaters

The latest Energy Star proposal is to exclude storage electric water heaters because the potential energy savings are “insignificant”. In fact the national energy savings that could result from promoting EF ratings of, say, 0.95 vs a DOE minimum efficiency level of 0.90, would be among the largest available of all the water heating options. This is due to the large market penetration probable due to the low cost increment and established product and infrastructure. The Energy Star proposal failure to recognize the large potential market penetration for this efficiency option will result in discarding of one of the most promising energy savings options.

Analysis done by AET shows that the cost increment for, say, a 50 gallon electric storage water heater, to raise its efficiency level to EF = 0.95 from the minimum required EF = 0.904, would be $90 or less. The Energy Star proposal estimates $50. The annual energy savings of this approach, assuming DOE EF test conditions as done in the Energy Star program proposal, would be approximately 235 kWh/yr per unit (2).

An estimate of the amount of potentially available water heater efficiency upgrades monies can be made by looking at the average installed cost of gas tankless water heaters and their current market sales volume. According to the Energy Star proposal, the current (2006?) sales volume for gas tankless water heaters is approximately 254,600 units per year. With an average incremental installed cost of $1500 (we are sure this cost varies substantially but the argument remains valid whether the incremental cost is $1000 or $2000), the available water heater upgrades money would be ($1500/unit)(254,600 units/yr) = $381.9x10^6/yr. If this money were instead spent on upgrading the efficiency of electric storage water heaters from EF=0.904 to EF=0.95, the number of units upgraded would be: ($381.9x10^6/yr)/($90/unit) = 4.243x10^6 units per year, or (4.24x10^6)/(4.8x10^6) = 0.883 or 88.3 % market penetration. Resultant national energy savings would be (4.243x10^6 units/yr)(235 kWh/yr/unit) = 9.97x10^8 kWh/yr = 3.4x10^{12} Btu/yr in the first year, and continuing sales every year would grow the annual savings by that same amount every year until older units reached their end-of-life. Hence the savings would grow by a similar annual amount for approximately 10-15 years. Clearly the net result would be huge national energy savings – one of the largest available energy savings potentials of all the water heating options (see discussions below for other similar savings estimates of some of the other options).

We therefore recommend that electric storage water heaters be included in the Energy Star program, and that the minimum EF level required to receive the Energy Star rating be set at approximately 0.05 EF points above the DOE mandated minimum efficiency for the respective tank size. Note that smaller tanks have lower heat loss, insulation levels and other tanks construction details being equal, just because they have lower surface area. It would be appropriate, therefore, to vary the required increment slightly with tank volume; otherwise impractical limits would be required on the smaller tanks. We recommend threshold EF ratings for 20, 30, 40, and 50 gallon electric storage water heaters to qualify for the Energy Star label be set at an incremental EF value of 0.03, 0.03, 0.04, and 0.05 respectively (yielding EF = 0.974, 0.96, 0.957, and 0.954 respectively), and at 0.06 for tanks larger than 50 gallons.

Note that by setting the increment as above the DOE minimum EF instead of at a fixed value, the required EF to qualify for the Energy Star program label rises automatically if the DOE minimum requirements rise. This will have the effect of removing the smaller units from the Energy Star program as DOE minimum EFs rise, because the incremental values will be impossible to meet. We also recommend that these Energy Star qualifying values be kept for a period of 10 years before being dropped, because after 10 years, most water heaters would have been replaced and the higher efficiency levels should have become the norm.

Fossil Fuel Fired Storage Water Heaters

The same arguments used above for electric storage water heaters apply to fossil-fuel fired storage water heaters, and we recommend that similar incremental EF requirements be established, but with slightly higher increments because of the initially lower baseline EF levels from which we start. The ratio of incremental EF requirement can be estimated from computing the baseline efficiency ratio for electric vs gas storage units as specified in the DOE minimum standards, e.g. (0.904/0.575) = 1.57 for 50 gallon tanks. The required incremental EF levels to qualify for the Energy Star program thus become (1.57)(0.05) = 0.078 for the 50 gallon gas storage water heater, (0.9172/0.594)(0.04) = 0.062 for the 40 gallon, (0.930/0.613)(0.03) = 0.046 for the 30 gallon, and (0.944/0.632)(0.03) = 0.045 for the 20 gallon. Similar computations should be done for the required incremental EF increase for tanks larger than 50 gallons, using the 0.06 factor times the ratio of minimum electric divided by minimum gas energy factors for each size. Required Energy Star gas water heater energy factor ratings for 20,30,40, and 50 gallon tanks would hence be 0.677, 0.0.659, 0.656, and 0.653 respectively.

A special note is worthwhile on oil-fired water heaters. If they are to be included in the Energy Star program, their required incremental EF values must be higher than for natural gas and propane units because their required minimum efficiency levels were not raised in the last round of DOE water heater energy efficiency standards – thus they are currently not required to do even the simplest energy efficiency measures, such as adding heat traps or insulation, or improving flues. An additional incremental EF value of 0.04 should be added, over and above the incremental valued discussed above for gas-fired units.

Tankless Fossil-Fired Water Heaters (Whole-Home Tankless Water Heaters)

We have no major disagreement with the Energy Star proposals for gas tankless water heaters, but would like to offer cautions regarding maximum and minimum flow rates and temperature rises. It should be recognized that as more information becomes available on the impact of hot water distribution systems on water and energy waste, it will become more likely that more than one water heater will be used in order to reduce water and energy waste compared to having longer piping runs. (Data is available that makes it clear that the heat loss from using additional storage water heaters is lower than that caused by even modest-length insulated piping runs (3, 4, 5, 6, 7), hence using multiple water heaters can often save energy). It will become more likely in the future that use of multiple smaller water heaters (both storage and tankless) will become the norm to improve energy efficiency. As that happens, the high flow rates specified in the Energy Star proposal for tankless units will be less important. Careful consideration should be given to this impact, and its potential resultant use of larger-than necessary tankless water heaters as more than one is used.

Additionally, the Energy Star labeling process should consider the minimum flow rates for firing of gas tankless water heaters in the decision making process. Some units require at least 0.5 to 0.8 gallons per minute flow rate before they fire, resulting in people using higher than needed flow rates and more water than necessary, just to get the unit to turn on. Specification of a minimum turn-on flow rate of no higher than 0.25 gpm would eliminate most of this concern.

It is informative to compare the national energy savings potential of whole-house tankless gas water heaters to that of high-efficiency electric storage water heaters, using realistic comparisons of potential market penetration. Using the 78 therms per year energy savings for tankless over storage gas water heaters estimated by Energy Star, and the current annual sales volume of tankless units of 254,600 units per year, which represents approximately ($254,600/4.7x10^6$) = 0.054 or 5.4% market penetration, we can estimate that the annual energy savings is (78 therms/yr)(100,000 Btu/therm)(254,600 units) = $1.986x10^{12}$ Btu/yr. Given the $1500/unit cost premium for tankless units (see electric storage water heater discussion above), for the same total cost outlay, raising electric storage water heater EF from 0.904 to 0.95 would result in over 88% market penetration and $3.4x10^{12}$ Btu/yr national energy savings, or almost double the national energy savings provided by the tankless whole-house units. This is another way of saying that while national energy savings from tankless gas water heaters may be significant, savings from improved electric storage water heaters are even more significant.

On another note, it should be pointed out that the Energy Star assumption of 20 year life for gas tankless water heaters is unrealistically high. That value is more representative of regularly maintained central boilers, not residential potable-water-heating-only tankless water heaters with their many water-quality, corrosion, and controls failures issues. While we have not seen any studies on life of such units, anecdotal evidence suggests that they will not last any longer than tank-type units, and that they will require more maintenance because of their more complicated controls.

Tankless Electric Water Heaters

We agree with many of the Energy Star concerns regarding whole-house electric tankless water heaters. However, it should be recognized that smaller electric tankless water heaters can serve an important energy-savings niche that will grow over time, and hence Energy Star should consider them for inclusion in the Energy Star program.

As information about hot water distribution system energy losses (3, 4, 5, 6, 7, 8, 9) becomes more widely known, it will become more apparent to practitioners that small under-sink electric tank and tankless water heaters can significantly reduce energy losses due to distribution system water and energy waste. This is achieved by eliminating the hot water piping to some fixtures. Potential benefits of using multiple water heaters are discussed in the Service Water Heating Chapter of the 2007 ASHRAE Applications Handbook (10). When multiple water heaters, including small electric water heaters, are applied correctly, they can save both site and source energy compared to other central system gas and electric alternatives.

We recommend that electric tankless water heaters with input ratings of less than 6 kW (such that they are not large enough to serve whole-house applications, thus assuring that their use displaces hot water piping) be included in the Energy Star program, as long as they carry a written caution that they are not for whole-house applications.

Warranties

We understand why Energy Star would like to brand only reliable products. However, requiring certain minimum warranties will not achieve that result. Reliability can only be achieved by manufacturer commitment to excellence, and by establishing the infrastructure to support the product – activities beyond Energy Star control. Hence we feel that no minimum warranty requirements should be required.

First Hour Rating Or Other Heating Rate Related Requirements

We note that in several areas of the Energy Star water heating proposal, minimum required first hour ratings are specified. While we understand that the desire is to ensure Energy Star rated products will satisfy customers, requiring minimum first hour ratings will not achieve that goal and could be detrimental to use of Energy Star rated products in appropriate applications. A battle has been raging for years between different manufacturers and product types over the first hour rating issue, in order to achieve a market advantage. In reality, first hour rating is for grouping for product comparison purposes, and is not intended for use in system sizing, although many entities attempt (inappropriately) to use it for that purpose. Numerous studies have shown that required hot water system sizing is a trade off between heating rate and storage capacity, relative to the load to be served. This is demonstrated in the Service Water Heating Chapter of the 2007 ASHRAE Applications Handbook (10). There are multiple combinations of heating rate and storage capacity than can serve a given hot water use profile. The maximum hot water a unit can produce in one hour has little direct bearing on how well that unit can serve a given load – the one hour time point is arbitrarily chosen. In fact, studies have shown (11, 12, 13, 14) that in residential applications, required water heater sizing is usually dictated over time frames considerably less than one hour – usually around 15-30 minutes.

We suggest that all references to first hour rating or other measures of heating rate be eliminated, since inclusion of such requirements will not ensure proper application, and in fact could result in equipment being inappropriately applied (e.g. oversized) just to purchase an Energy Star rated product..

Piping and Distribution System Effects

While the Energy Star program does not currently intend to address water and energy waste caused by hot water distribution systems, it is important to recognize that such losses represent a large fraction of total water heating system energy use, and hence that products than can reduce such losses should be encouraged. Tests and analysis (3, 4, 5, 6, 7, 8, 9) have shown that heat loss from hot water distribution system piping, and additional energy losses resulting from wasting luke-warm water to drain while waiting for hot-enough-to-use water to arrive at fixtures, typically represent a minimum of 10-15 % of total water heating system energy use even in well designed and implemented central hot water distribution systems, and have been measured at over 90% in some applications (5, 6). As efforts to expand awareness of these losses continue, it can be expected that an increasing number of installations will use more than one water heater in order to eliminate distribution-system associated energy losses. Each of those multiple water heaters can be smaller than one sized to serve whole building loads through a central system.

Care should be exercised when setting Energy Star requirements to ensure that as use of multiple water heaters becomes more commonplace, inappropriate size and heating rate limitations are not set that would result in use of wrong-sized (oversized) equipment just to get an "Energy Star" rated product that may have worse energy use characteristics in the application than a "right sized" product.

To avoid this, in general we recommend that references to minimum required maximum heating rate capability (whether stated as gpm, first hour rating, kWh input, or Btu/hr input rate), storage volume, etc. be deleted. Exceptions would be the 6 kW maximum heating rate limitation for tankless electric, and the 0.25 gpm minimum activation flow rate for gas tankless units.

Conclusion

Thank you for considering our comments

Sincerely,

Dr. Carl C. Hiller, P.E.
President

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