THE LAW AND ECONOMICS OF DETERMINING HOT WATER ENERGY USE IN CALCULATING UTILITY ALLOWANCES FOR PUBLIC AND ASSISTED HOUSING

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February 2007

Hot water usage probably doesn't rank high on the list of everyday legal problems facing legal services advocates. But to tenants of public and subsidized housing, the appropriate calculation of hot water consumption could mean the difference of hundreds of dollars a year in utility allowances. Hot water is one of the major sources of energy consumption in a low-income household. According to the U.S. Department of Energy, energy for hot water consumption is generally about 20 percent of a household's total home energy consumption.[1]

Several factors are of particular importance in establishing an appropriate hot water energy allowance for public and assisted housing: (1) hot water temperature; (2) daily hot water consumption per person; and (3) the efficiency of a hot water system. Each of these factors will be discussed separately below.

THE STANDARD EQUATION

An appropriate calculation of the annual energy consumption for hot water relies upon the following formula:

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[1] U.S. Department of Energy, Energy Information Administration (November 1999). "A Look at Residential Energy Consumption in 1997," at 10, Department of Energy: Washington D.C. (hot water consumption 19 mmBtu of 101 mmBtu total consumption).

CALCULATION OF HOT WATER LOAD

$$\text{Hot water load} = \frac{\text{temperature rise x 8.33 lb/gal x gal/year/unit}}{\text{Btu's per fuel unit}}$$

WHERE:

temperature rise =	the temperature difference between the inlet water and the water in the tank. /a/
gallons/year/unit =	the gallons of use per person per day x number of persons per unit x 365 days per year.
8.33 =	weight (lbs) of one gallon of water. /b/
Btu's per fuel unit =	Different fuel types have standard measurements of their Btu's of fuel consumption. /c/ /d/

NOTES:

/a/ The temperature rise is sometimes referred to as the Delta-T.
/b/ The "pounds per gallon" of water is a standard unit of measure.
/c/ A Btu is a British thermal unit. A British thermal unit is the amount of energy needed to raise the temperature of one pound of water one degree.
/d/ For example, one kilowatthour (kWh) has 3,412 Btu's. One therm of natural gas has 100,000 Btu's. One therm of natural gas is also the functional equivalent to one hundred cubic feet (ccf) of natural gas.

This standard equation will derive a hot water consumption in units of energy. Units of energy are converted into dollars through application of the appropriate rate schedule, including taxes, fees, and other appropriate charges.\2\

WATER TEMPERATURE

One of the first key elements in the equation listed above is the temperature of the water to be maintained in the tank. This component is an essential part of calculating the temperature rise (temperature rise = temperature of water in the tank - inlet water temperature). Some times, local housing authorities urge that water temperatures should be maintained at 120 degrees Fahrenheit (120EF) in the tank as an energy conservation tactic. Several lines of analysis, however, lead to the conclusion that a 120E tank temperature is too low.

Ë Since hot water temperatures in the tank are substantially higher than the water temperature delivered at the outlet, a 120E tank temperature cannot

\2\ The exception would be when the utility allowance is provided in terms of energy units for purposes of check-metering.

deliver mixed hot and cold water at the outlet adequate to perform basic household functions.

- Ë An unmixed 120E hot water temperature in the tank cannot perform certain basic household functions such as residential dishwashing and laundry.

- Ë A 120E hot water temperature does not provide for safe and healthy housing, such as allowing for protections against allergens and dust mites.

Each of these observations will be examined in more detail below.

Mixed Water Temperature at the Outlet.

A mixed water temperature at the outlet cannot perform basic household functions when the tank temperature in a hot water heater is only 120E F. The water temperature to be maintained in a hot water heater tank is different from the water temperature delivered at the outlet. An "outlet" is the fixture at the point of use: a faucet, a showerhead, and the like. The water temperature at the outlet is primarily driven by the mixed temperature of hot and cold water. As the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) states in its *Applications* handbook, "Where multiple temperature requirements are met by a single system, the system temperature is determined by the *maximum* temperature needed. Lower temperatures can be obtained by mixing hot and cold water."[3]

A standard equation is used to calculate the mix of hot and cold water to arrive at the delivered temperature at the outlet. That standard equation is:[4]

$$P=\frac{T_m - T_c)}{(T_h - T_c)}$$

WHERE:

P = percentage of hot water in mixed water
T_m = mixed water temperature.
T_h = supply hot water temperature.
T_c = inlet water temperature.

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[3] ASHRAE (1998). ***Applications Handbook***, at 44 - 45, American Society of Heating Refrigeration and Air-conditioning Engineers: Atlanta (GA).

[4] American Society of Plumbing Engineers (1998). ***Domestic Water Heating Design Manual***, at 6, American Society of Plumbing Engineers: Westlake Village (CA).

Ë **<u>Determining the mixed water temperature</u>:** The mixed water temperature is the water temperature actually used for household purposes. The hot water temperatures normally used for common household functions include:[5]

Typical Hot Water Temperatures for Common Household Uses	
Lavatory (sinks)	105E F
Showers and baths	110E F
Residential dishwashing and laundry	140E F

Ë **<u>Determining the inlet water temperature</u>:** The inlet water temperature is a given, with the temperature rise then being the extent to which the water heater will increase that inlet temperature.[6] Actual local inlet water temperatures should not be a serious point of contention. The inlet water temperature for any given locality is generally available from the local office of the U.S. Geological Survey.

Ë **<u>Determining the hot water tank temperature</u>:** The hot water tank temperature is the place where different decisions can affect the energy found to be necessary and appropriate. The temperature of hot water in the tank is discussed in detail below.

<u>Calculating Mixed Water Temperatures at the Outlet</u>: The process of illustrating the percent mix that would be necessary to obtain typical water temperatures for residential sink (lavatory) use and shower use is straightforward using standard equations. The independent variables in this illustration are: (1) the water inlet temperature (assumed throughout this paper to be 55E);[7] (2) the hot water tank temperature (assumed for purposes of illustration to be 120E); and (3) the typical residential hot water temperature for sink use (105E) and shower use (110E). Given these parameters, the percent hot-to-cold water mix would be as follows:

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[5] ***Domestic Water Heating Design Manual***, *supra*, at Table 1.2, page 12.

[6] For ease of analysis, the remainder of this discussion will use a 55° water inlet temperature as a "typical" inlet temperature.

[7] The U.S. Department of Energy (DOE) has reported that an assumed incoming groundwater temperature of 50° F is reasonable. Department of Energy, ***Demand (Tankless) Water Heaters***, at 2, Department of Energy: Washington D.C.

Percent Hot Water Mix with 55E Inlet Temperature and 120E Tank Temperature to Achieve Mixed Water Temperatures for Typical Residential Sink and Shower Use				
	T_m EF	T_c EF	T_h EF	P /a/
Sink	105E	55E	120E	77%
Shower	110E	55E	120E	85%

NOTES:

P is the dependent variable in this Table and the T's are the independent variables.

What this table shows is that given a hot water temperature in the tank of 120E F, a consumer would need to use a mix of hot-to-cold water that has 77% hot water in order to have a mixed water flow in the sink of 105E. The consumer would need to have a mix of hot-to-cold water that has 85% hot water in order to have a mixed water flow in the shower of 110E.

The problem with these mixed water flow results, however, is that the *typical* residential water mix in a home involves a much lower ratio of hot-to-cold water. Under these circumstances, a hot water temperature in the tank of 120E will result in water temperatures *below* those normally used for typical household chores. Indeed, calculating T_m given a hot water supply temperature of 120E F and a hot-to-cold mix ranging from 50%/50% to 70%/30% would yield the following:

Water Outlet Temperature Given 120E Hot Water Tank Temperature and 55E Water Inlet Temperature at Various Levels of Hot-to-Cold Water Mixes (P)

T_h (EF)	T_c (EF)	P	T_m (EF) /a/
120E	55E	50%	88E
120E	55E	60%	94E
120E	55E	70%	100E

NOTES:

/a/ In this table, P, T_h and T_c are the independent variables, with T_m the dependent variable.

As can be seen, even at a 70%/30% hot-to-cold water mix (P=.70), the warmest the temperature will become (100E) is less than the typical hot water temperature used for handwashing in a bathroom sink (105E). The water temperature does not even approach that normally used in showers (110E). One can conclude that at normal household mixing rates, a hot water tank temperature of 120EF will not result in mixed water temperatures at the outlet sufficiently hot to perform basic household chores. Indeed, hot water with temperatures below 90E F, according to ASPE, is "unusable."[8]

Taking Distribution Temperature Drops into Account: Even setting aside the loss of temperature due to mixing, one aspect of assessing the difference in hot water temperature in the tank and at the outlet involves accounting for the energy loss of hot water as the water travels through the water pipes.[9] As the hot water loses energy, by definition, it is dropping in temperature. According to Procter and Gamble, given 140E hot water in the tank, the average hot water temperature at the tap is 132.5E, a drop of three percent (7.5E).[10]

Given this temperature drop in the distribution system, with no mixing of cold water, a tank temperature of 120E will deliver a tap temperature of 116E (120 - (0.03 x 120) = 116). Using this actual hot water temperature delivered at the tap as the temperature at which cold water is mixed yields the following water temperature delivered to the customer assuming different mix levels:

T_H	T_C	P	T_M
116E	55E	50%	86E
116E	55E	60%	92E
116E	55E	70%	98E

The hot water delivered to the consumer at these temperatures is not sufficient for basic household purposes as provided by either ASHRAE or ASPE. Remember, again, also, that "hot" water delivered at less than 90° F is unusable according to ASPE.

Impact of Hot Water Tank Temperature on Gallons of Use Per Person: Using the same water inlet temperature as above (55E), it is possible to consider the reasonableness of hot water tank temperatures starting with consumption amounts as the point of departure for our inquiry. Consider a typical shower in a residential home. Alternatively assume a low-flow

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[8] ***Domestic Water Heating Design Manual***, *supra*, at 16.

[9] According to the American Society of Plumbing Engineers: "[Consider] the minimum acceptable hot water temperatures at various plumbing fixtures and pieces of equipment. Since there will be heat losses in transporting the hot water from the heater to the point of use, these losses should be considered in determining the optimum temperature for water leaving the heater." Cyril Harris (1998). ***Practical Plumbing Engineering***, at 14.15, American Society of Plumbing Engineers: Westlake (CA).

[10] U.S. Department of Energy, Office of Conservation and Renewable Energy, "Energy Conservation Program for Consumer Products: Final Rule Regarding Energy Conservation Standards for Three Types of Consumer Products," 56 ***Fed. Reg.*** 22250, 22266 (May 14, 1991).

showerhead with a total flow rate of roughly 2.5 gallons a minute[11] and a normal showerhead with a flow rate of roughly 3.4 gallons per minute.[12] Assume, further, a typical seven minute shower for a person. The total mixed water consumed is thus 17.5 gallons (2.5 gallons/minute x 7 minutes) and 23.8 gallons (3.4 gallons/minute x 7 minutes) for the low-flow and normal showerheads respectively.

With a mixed water temperature of 110E F for showers, and a P term of 85% for a 120E/ 55E hot-to-cold water combination (*i.e.*, 85% of the mixed water would need to be hot water to have a mixed temperature of 110E), the necessary hot water use for a seven minute shower using a low-flow or normal showerhead would be 14.9 gallons (17.5 total gallons x 85% = 14.9 gallons of hot water) and 20.2 gallons (23.8 total gallons x 85% = 20.2 gallons of hot water) respectively. Reducing the length of the shower to just five minutes reduces the hot water consumption for a daily shower to 10.6 (12.5 gallons x 0.85) gallons and 14.4 gallons (17.0 gallons x 0.85) respectively.

Hot Water Use for Five and Seven Minute Shower
Using a Low-Flow or Normal Showerhead
(assuming 120E tank temperature and 55E inlet temperature)

Shower length	Low-Flow Total Water Use (gallons) /a/		Normal Total Water Use (gallons) /b/		P Term /c/	Hot Water Use (gallons) /d/	
	Flow/minute	Total	Flow/minute	Total		Low-Flow	Normal
5 minutes	2.5	12.5	3.4	17.0	.85	10.6	14.5
7 minutes	2.5	17.5	3.4	23.8	.85	14.9	20.2

NOTES:

/a/ Flow (in gallons/minute) x minutes.
/b/ Flow (in gallons/minute) x minutes
/c/ The percent of hot water needed in mix of water at 120E F tank temperature to achieve 110E F outlet temperature.
/d/ Total gallons of consumption x P.

Given these parameters, if the hot water consumption provided to a public housing tenant does not equal at least 14.9 gallons and 20.2 gallons for a seven minute shower using low-flow and normal showerheads respectively, it is *impossible* for the mixed water temperature

[11] E. Vine *et al.*, ***Domestic Hot Water Consumption in Four Low-Income Apartment Buildings***, at 12, Lawrence Berkeley Laboratory: 1986.

[12] J.Koomey *et al.*, "The Effect of Efficiency Standards on Water Use and Water Heating Energy Use in the U.S.: A Detailed End-Use Treatment," at 7-103, 7-104, ACEEE 1994 Summer Study on Energy Efficiency in Buildings (1994).

to reach 110E as is reported by ASPE to be normal for residential showers. Given hot water consumption of less than these figures, in other words, use of a 120E hot water tank temperature is unreasonable.[13]

According to the U.S. Department of Housing and Urban Development (HUD), typical water inlet temperatures by region are as follows:[14]

Typical Water Inlet Temperatures by Region			
North	North Central	South Central	South
40°	50E	60°	70°

In multiple regions of the country, groundwater temperatures are roughly consistent with the temperatures assumed in this analysis. Only in the South, and South Central regions of the country, however, do groundwater temperatures, which represent the cold water inlet temperature, exceed those used in this discussion. In the North, ground water temperatures are substantially lower than that temperature assumed in this analysis.

Assessing Tank Temperatures Impact on Availability of Hot Water: Since the temperature of hot water in the tank affects the amount of hot water that will be needed to achieve any particular mixed water temperature (*i.e.*, the lower the tank temperature, the more gallons of hot water needed to achieve a particular mixed water temperature), it is possible to measure the reasonableness of utility allowance assumptions by calculating the impact of those assumptions on the sustained availability over time of hot water. The way to assess the reasonableness of a hot water tank temperature in this regard is to allow the hot water use (gallons and tank temperature) to be the independent variables and to calculate a shower length as the dependent variable. The shower temperature is a constant and the hot-to-cold water mix is mathematically derived from the tank temperature, the inlet temperature, and the mixed water temperature.

Rearranging the data established above, we know as follows for a 120E tank temperature:

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[13] Moreover, one should note that as the water *inlet* temperature goes down, the use of hot water from the tank goes up since more hot water from the tank is needed to reach the same mixed water temperature at the outlet. If the water inlet temperature is 50° F rather than 55°, for example, the amount of hot water needed to reach any given mixed water temperature is greater.

[14] U.S. Department of Housing and Urban Development (May 30, 1995), *A Handbook for the Preparation of Lifecycle Cost Analysis for Utility Combinations to be Used in Connection with the Development of Public Housing and Indian Housing Projects*, Handbook 7418.1, at pp. 2-5 – 2-11.

Time Period During which Hot Water is Available for Residential Shower Assuming: (1) an Eight Gallon Per Day Hot Water Allotment; (2) a 120° Tank Temperature; and (3) a 55° Inlet Temperature					
Showerhead	Flow (gal/min)	P	DHW gal/min /a/	Allowed DHW Use /b/	DHW Available (mins) /c/
Low-flow	2.5	0.85	2.1	8.0	3.8
Normal	3.4	0.85	2.9	8.0	2.8

NOTES:

/a/ Flow x P = hot water flow (gallons/minute)
2.5 x .85 = 2.1
3.4 x .85 = 2.9
/b/ Hypothetical
/c/ Total allowed DHW (domestic hot water) use / Use per minute = total minutes of available hot water

As this table shows, just as the water heater tank temperature places limits on the gallons of consumption to be expected, the gallons of water consumption place limits on the hot water temperature to be assumed in the tank. In the illustrations above, it is impossible to mix eight gallons of hot water at 120E in the tank (assuming an inlet temperature of 55E) and achieve reasonable water temperatures for showers of reasonable lengths. Given the hot water at a tank temperature of 120E needed to be mixed with cold water (at 55° F inlet temperature) in order to deliver a 110E shower temperature, eight gallons would last only 2.8 minutes at a normal shower flow. A low flow showerhead would consume eight gallons of hot water in only 3.8 minutes.

Why Use 135E as the Tank Temperature

Setting aside mixed hot water temperatures at outlets such as showers and faucets, even unmixed hot water temperatures cannot perform basic household functions given a hot water tank temperature of 120E F. If a public housing authority's residents use hot water for either laundry or dishwashing, the water temperature in the housing units hot water tank must be at least 135E to adequately perform those functions.\15\ Hot water temperatures of less than 135E cannot be relied upon to adequately operate dishwashers and washing machines.

Washing Machines and Hot Water Temperatures

It has been established that 120E water is not adequate for the proper operation of consumer washing machines. In promulgating its "energy conservation program for consumer

\15\ The common design hot water temperature for "residential dishwashing and laundry" is 140°. ***Domestic Water Heating Design Manual***, *supra*, at 12.

products," the U.S. Department of Energy decided that the reasonably expected hot water temperature for washing machines was 130E F. The U.S. Department of Energy discussed hot water energy efficiency for residential clothes washers:

> In the proposed rule, the Department calculated energy savings for this design option based on the assumption that *the valves would control the hot water wash temperature to 120 degrees F*. In testimony at the public hearing, Whirlpool and Speed Queen contended that 120 degrees F is too low a wash temperature for washing clothes stained with grease and oil. (Schornhorst, Testimony at 6-8; Coates, Testimony at 4-5). These views were supported in comments offered by P&G and AHAM. (P&G, No. 27 at 3; AHAM No. 29 at 19-20).[16] *These companies believe that clothes washers' performance would decrease at the lower temperature of 120 degrees F.* On the other hand, ACEEE stated that only a small segment of the population requires a hot wash temperature for clothes washing; for them, ACEEE argued that manufacturers could provide washing machines that would use 130 degrees water for their hot water washes, while achieving the necessary energy savings elsewhere. *P&G, however, contended that virtually all purchasers of washing machines would have need of an occasional 130 degrees F hot water wash.* Therefore, P&G strongly supported a 130 degrees F or better inlet water temperature be considered for all clothes washers in order to remove greasy soils. *Given P&G's extensive work in researching the solubility and the effectiveness of different laundering agents, the Department puts great credibility in its comments.* As a result, for the Final Rule, the Department calculated energy savings for the thermostatically controlled mixing valves based on the assumption that the valves would control the hot water wash temperature to 130 degrees F. This reduced the estimated energy saving potential of that design option from that proposed.[17]

There are three significant observations to be made of this DOE discussion:

1. DOE's temperature discussion is considering hot water at the outlet, not in the tank. In either of the alternatives considered (*i.e.*, 120E or 130E wash), DOE was beginning with a hotter tank temperature and considering a "thermostatically controlled *mixing valve*" --remember, the mixed water temperature discussion above--[18] designed to control temperatures to either

[16] AHAM is the Association of Home Appliance Manufacturers. P&G is Procter and Gamble.
[17] 56 ***Fed. Reg.*** 22250, 22264 (1991). (emphasis added).
[18] An assumption of a 130° tank temperature would mean that the "mixing valve" didn't mix anything. Hypothetically, the only way for a 130° tank temperature to result in a 130° outlet temperature is for the mixing valve to allow a 100%

120E or 130E. (emphasis added). Note that DOE explicitly states that "*valves* would control the hot water temperature to 120° F." (emphasis added).

2. When Procter and Gamble testified that "virtually all purchasers of washing machines would have need of an occasional 130 degrees F hot water wash," DOE responded, saying "the Department puts great credibility in (P&G's) comments" and explicitly tied its decision to the P&G testimony ("as a result. . .the Department calculated. . .").

3. The Department's decision inherently rejects the use of a 120E tank temperature. Mixing water will result in *lower* outlet temperatures compared to the tank, not a higher temperature. In approving a mixing valve to control hot water temperatures to 130E, therefore, DOE necessarily assumed a tank temperature of at least 130E and probably more.

Residential Dishwashers

In addition to clothes washing, DOE found that dishwashers using a hot water tank temperature of 120E will adequately clean dishes only if fit with a supplemental "booster heater." In defining an energy conservation dishwasher, DOE found that a 120E "water heater set point" could be used *if* the dishwasher had a booster heater "providing for the use of higher wash water temperature when necessary." The DOE discussion said:

> P&G stated that its studies show that 130 degrees F water is needed for satisfactory fatty and greasy soil removal in dishwashers. (P&G, No. 27 at 3). P&G states that the wash temperature may not reach 130 degrees F until the third water fill. P&G's data indicate that the average tap temperature is 132.5 degrees F. P&G said that the water heater temperature should stay at 140 degrees F and that the dishwasher inlet temperature should be left unchanged. In addition, AHAM referenced a P&G report that shows "the need for 130-140 degrees F water in dishwashers." (AHAM, No. 29 at 17). Also, GEA stated that reduced inlet water temperature can be accomplished only through use of water heating dishwashers. (GEA, No. 21 at 4).[19]

DOE continued:

(..continued)
hot/0% cold water mix. Even a tank temperature of 130°, however, will not deliver an outlet temperature of 130° considering the fact that hot water loses temperature in the distribution lines. Accordingly, to have 130° hot water at the outlet, it is necessary to have a tank temperature of more than 130°.

[19] ***DOE Conservation Standards***, at 22266 - 22267 (emphasis added).

> On the other hand, ACEEE and NRDC both commented that the Department had not presented evidence that loads containing animal fats would be insufficiently cleaned by lower water temperatures. (ACEEE, No. 10 at 6; and NRDC, No. 16 at 34). DOE reviewed the P&G study and found that P&G studied four kinds of fat at three temperatures (90 degrees F, 120 degrees F, and 140 degrees F). 120 degrees F water appeared to remove most of the fats after one use and wash. However, on a seventh use and wash, the removal of one of the fats (pork) was inadequate. The Department notes that there was no discussion of what took place between the first and seventh uses and washes to cause the problem. Additionally, there was no discussion of the use of alternative detergents. Furthermore, the comments do not address dishwashers with booster heaters such as water heating dishwashers. NRDC, Portland General Electric (PGE), and ACEEE commented that booster heaters should be considered as a design option, not as a separate class. (NRDC, No. 16 at 34-35; PGE, No. 23 at 2; and ACEEE, No. 18 at 4).[20]

DOE concluded:

> After reviewing the comments, the Department has concluded that a water heating dishwasher, which is essentially the same as a standard dishwasher with a booster heater, does not offer a distinct utility to the consumer. Accordingly, the Department dropped from consideration water heating dishwashers, both 115 and 220 volts, as separate classes, and added, as a design option for standard dishwashers, booster heaters, which allow a 120 degrees F water heater set point while providing for the use of higher wash water temperature when necessary.[21]

As can be seen, DOE agreed with comments that a 120E temperature will not consistently clean dishes. There will be times when a higher temperature is necessary. A 120E water heater set point is thus appropriate *only* if the dish washer has a booster heater to provide that hotter water when necessary.

The context of the DOE rulemaking is instructive as to the significance of its factual discussion. DOE is under a statutory obligation to promulgate minimum energy efficiency standards for appliances.[22] Pursuant to the statute, however, one factor for DOE to consider in its deliberations about any particular proposed level of efficiency is whether the proposed

[20] ***DOE Conservation Standards***, at 22266 - 22267 (emphasis added).
[21] ***DOE Conservation Standards***, at 22266 - 22267 (emphasis added).
[22] 42 U.S.C. §6295 (1994 and 2001 supp.).

efficiency standard would result in a reduced utility of the appliance.[23] If a proposed standard resulted in reduced utility, DOE is not allowed to adopt it.

With dishwashers, manufacturers argued that an efficiency standard setting maximum water temperatures at 120E[24] at the outlet would result in a reduced utility since those water temperatures would not adequately clean dishes. DOE agreed, permitting a water outlet temperature of 120E only if the dishwasher had a booster heater to increase the hot water temperature when necessary. As can be seen, for a housing authority to set a maximum water heater tank temperature at 120E, therefore, if dishwashers do not have booster heaters, would subject public housing tenants to precisely the lack of dish cleaning ability that DOE considered and rejected.

Other Hot Water Temperature Standards

Two other national standard setting bodies agree with DOE's assessment. Both ASHRAE[25] and ASPE[26] report a 140E hot water temperature for residential dishwashing and laundry uses. Indeed, according to a 1988 ASPE report:

> All available literature on design of service hot water systems use 140F as the design temperature. All technical and design information furnished by manufacturers of water heaters, heat exchangers and other equipment use the 140F criterion. Tables and charts in the ASHRAE Guide and ASPE Data Book use the 140F criterion. Guarantees and warranties are still based on the 140F criterion.[27]

Finally, DOE test procedures for hot water energy consumption rely on a hot water tank temperature of 135E. The federal government has prescribed a "uniform methodology for measuring the energy consumption of water heaters."[28] In defining the "storage tank temperature" to be used in this methodology, those federal regulations state that "the average temperature of the water within the storage tank shall be set to 135 +/- 5 degrees F."[29] Moreover, in prescribing the "test procedures," the regulations provide that one of the very

[23] One of seven factors for DOE to consider is whether a proposed standard results in "any lessening of the utility or the performance of the covered products likely to result from the imposition of the standard." 42 U.S.C. §6295(o)(2)(B)(i)(iv).
[24] In this situation, the outlet is the dishwasher..
[25] ASHRAE has, for example, indicated that only dishwashers with booster heaters can be used with water temperatures of less than 140°. ***Applications Handbook***, *supra*, at 44 - 45.
[26] ***Domestic Water Heating Design Manual***, *supra*, at Table 1.2, page 12.
[27] ***ASPE Temperature Limits***, *supra*, at 7.
[28] 10 ***C.F.R.*** Pt. 430, Subpt. B, App. E (1996).
[29] Appendix E, §2.4.

first steps is to determine whether "the mean tank temperature is within the range of 135 degrees F +/-5 degrees F."\30\

Hot Water, Asthma and Allergens

A hot water tank temperature of 120E does not deliver water that is hot enough to provide a safe and healthy living environment. In particular, hot water washing has been identified as a necessary activity to help control the asthma epidemic that is now facing the United States.

Asthma is one of the most prevalent chronic diseases facing Americans as the United States heads into the 21st Century. And it is getting worse. "In 1995 alone, asthma caused 1.8 million emergency room visits and 10 million missed school days, making it the number one reason of school absenteeism."\31\ In the year 2000, more than 14 million people in the United States suffered from asthma.\32\ Asthma caused 10.4 million office visits in 1995.\33\ In 1998, about 19.5 people died every day from asthma.\34\ The Pew Environmental Health Commission found that:

> By the end of (2010), if no action is taken to reverse this trend, and it continues at its current pace, the Commission calculates that 22 million Americans will suffer from asthma --eight million more than at present. That's one in 14 Americans and one in five families forced to live with the disease.\35\

Asthma rates are higher in low income and minority communities.\36\ Social factors, including nutrition and poverty, are factors that cause asthma development\37\ and exacerbation.\38\ There is little question but that asthma disproportionately affects low-income persons. The Pew Environmental Health Commission reports:

> Our analysis shows that the burden of asthma falls most heavily on those below the Poverty line. Our research and the research of others indicates that the prevalence rates of asthma among people living below the Poverty Level

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\30\ *Id.*, at §5.1.2.
\31\ Lowell Weicker, Jr. (2000). ***Attacking Asthma: Why America Needs a Public Health Defense System to Battle Environmental Threats***, at 4, Pew Environmental Health Commission: Philadelphia (PA).
\32\ *Id.*, at 8.
\33\ *Id.*
\34\ *Id.*, at 10.
\35\ *Id.*, at 4.
\36\ *Id.*, at 6.
\37\ *Id.*, at 9. Asthma development is initiation of asthma in persons without the disease. *Id.*
\38\ *Id.*, at 9. Asthma exacerbation is the triggering of an asthma attack or worsening of an attack in a person with asthma. *Id.*, at 9.

> are significantly higher than the rates of Americans who are not poor. Our analysis shows that about 15% of asthma among the poor is attributed to poverty.[39]

Pew continues:

> There are also important integrations between social and environmental factors. The Institute of Medicine report on environmental justice found inequities in health risk based on low income and minority status. These inequities could result in more exposure to substances that cause asthma symptoms. Today, there is a substantial disparity in the impact of asthma that could have a significant social component; many studies have reported especially high rates of asthma hospitalizations and emergency room visits in low income, inner city and minority communities. Our research shows that there is a strong relationship between asthma and poverty.[40]

Exposure in early life to allergens is one of the primary "inducers of asthma."[41]

Asthma and Hot Water

The significance of this discussion of asthma for purposes of discussing hot water needs for public housing lies in the factors that cause either the development of asthma or the exacerbation of asthma (as these terms are defined above).[42] Controlling environmental conditions is an important aspect to controlling asthma. "It is expected that improving environmental conditions that asthmatics face will cut down on the number and severity of their attacks and may diminish the number of people sensitized to environmental agents."[43]

The 1999 Institute of Medicine report *Clearing the Air* found a direct causal relationship[44] between dust mites and both the development and exacerbation of asthma.[45] Dust mites, in

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[39] *Id.*, at 10.

[40] *Id.*, at A1-6 and A1-12. *See generally*, Institute of Medicine, Committee on Environmental Justice (1999). ***Toward Environmental Justice: Research, Education and Health Policy Issues***, National Academy Press: Washington D.C.; Eggleston, P.A., et al. (1999). The Environment and Asthma in U.S. Inner Cities. Environmental Health Perspective 1999; 107 Suppl. 3:439-450; Sarpong, S.B., et al. (1996). Socioeconomic status and race as risk factors for cockroach allergen exposure and sensitization in children with asthma, J. Allergy Clinical Immunology. 97: 1393-401; Claudio, L., et al. (1999). Socioeconomic factors and asthma hospitalization rates in New York City. J. Asthma 36:343-50.

[41] *Id.*, at 13.

[42] *See*, notes 37- 38, *supra*, and accompanying text.

[43] *Id.*, at 14.

[44] Other categories of relationship included sufficient evidence of association; limited/suggestive evidence of association; and inadequate evidence of association.

particular, are an "indoor allergen"[46] that is subject to control (or mitigation) through appropriate household actions.

The availability of hot water is critical to the control of dust mites as a causal source of both the development and exacerbation of asthma. In addition to the seminal Institute of Medicine study linking dust mites to asthma, institutions ranging from the National Institute of Health (NIH)[47] to the American Lung Association[48] have reached the same conclusion. The only way to effectively control dust mites is through hot water clothes washing. According to the American Lung Association, families with persons experiencing asthma should wash bedding and pillows in hot water of at least 130E F to 140E F on a weekly basis. The American Lung Association says:

> Dust mites are tiny, microscopic spiders usually found in house dust. Several thousand mites can be found in a pinch of dust. Mites are one of the major triggers for people with allergies and asthma. They need the most work to remove.. . .Following these rules can also help get rid of dust mites:. . .Wash all bedding every week in water that is at least 130 degrees F. . .[49]

The American Lung Association recommendation is echoed by much distinguished medical opinion. Blue Cross/Blue Shield, for example, states that "families with members who have asthma can do the following to improve the home environment. . .wash sheets and blankets weekly in hot water (= or > 130EF)."[50] The Nemours Foundation, sponsors of the national Kids Health campaign, recommends that: "A family needs to take the environmental control measures that reduce exposure to a child's allergy triggers. . .The following are suggested environmental control measures for different allergens and irritants:. . .Wash sheets and blankets a child sleeps on once a week in very hot water (130 degrees F or higher) to kill dust mites."[51] Finally, the University of Illinois Extension notes that dust mites may be *the*

(..continued)

[45] ***Attacking Asthma***, *supra* note 31, at A1-8, *citing* Institute of Health (1999). ***Clearing the Air: Asthma and Indoor Air Exposures***, National Academy Press: Washington D.C.

[46] *See* text accompanying note 49 for a description of dust mites.

[47] National Institute of Health and National Heart, Lung and Blood Institute (July 1997). ***Guidelines for the Diagnosis and Management of Asthma, Clinical Practice Guidelines, Expert Panel Report No. 2***, at 46, National Institute of Health: Washington D.C.

[48] American Lung Association (2000). ***Home Control of Allergies and Asthma***, at 3, American Lung Association: Washington D.C.

[49] *Id.*, at 3.

[50] Blue Cross/Blue Shield of Texas (2000). ***Staying Healthy: Chronic Diseases: Asthma***, at 7 - 8, Blue Cross/Blue Shield of Texas: Austin (TX).

[51] Nemours Foundation (2000). ***Kids Health: Asthma: Environmental Control Measures***, at 1, Nemours Foundation: New York.

major "indoor trigger of asthma attacks."[52] That extension service tells households: "since the bedroom is a hot spot for dust mites, wash bedding every week in hot water (above 130 degrees). Heat from the washer and dryer should kill the mites. . .Soft toys can also contain dust mites, and should be washed frequently as well."[53]

In sum, mixing water can only *reduce* the temperature of hot water at the outlet. If the water in the tank is 120° without a booster heater on the washing machine, the temperature of the water in which clothes are washed will be less than 120°. Unless, therefore, Housing Authorities provide clothes washers which heat water to the necessary temperatures, rather than mixing hot water from the tank to achieve the water temperatures in the wash cycles, the provision of 120E temperatures in the hot water tank is at odds with existing medical recommendations on how to control the critical childhood disease of asthma.

Analyzing the Proffered Justifications for a 120E Tank Temperature

A hot water tank temperature of 120E F can be justified on two basic grounds, according to proponents of the lower temperature. First, a lower tank temperature is argued to be a public safety mechanism. Second, a lower tank temperature is argued to be an energy conservation mechanism. Neither argument has a sound basis.

Reduced Tank Temperatures as a Public Safety Device.

There will be times when a local housing authority will argue that a 120E F tank temperature is needed for safety reasons. According to these arguments, consumers will be placed in danger of serious scalding should hot water temperatures be permitted to reach greater than 120E F. Given the acknowledged consumer need of temperatures, other than for laundry and dishwashing, of less than 120E F, this argument has some intuitive appeal. On closer examination, however, the argument fails.

The danger arising from hot water can be assessed in terms of first degree burns. A first degree burn is the least serious type of burn and causes no irreversible damage. According to research at the Harvard Medical School,[54] relied upon by the American Society of Plumbing Engineers (ASPE):

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[52] Bartman, Debra (1999). ***Controlling Dust Mites in the Home can Help Alleviate Allergy Symptoms***, at 1, University of Illinois Extension Service: Champaign (IL).
[53] *Id.*
[54] Moritz, A.R. and Henriques, F.C., Jr. (1947). "The Relative Importance of Time and Surface Temperature in the Causation of Cutaneous Burns," ***American Journal of Pathology***, 23:695-720.

> it takes a 3-second exposure to 140EF (60EC) water to produce a first-degree burn. At 130EF (54EC), it takes approximately 20 seconds, and at 120EF (40EC), it takes 8 minutes to produce a first degree burn.[55]

The normal threshold for pain, however, is approximately 118EF.[56] A person exposed to 120EF water would "immediately experience discomfort," ASPE notes.[57] Nonetheless, a person would need to expose themselves to 130E water for nearly 20 seconds to experience a first degree burn.

In 1988, ASPE released its two year study of "temperatures limits in service hot water systems."[58] In recommending a hot water tank temperature of either 135E or 140E, the ASPE study observed that the potential for scalding, while not an insignificant concern, should not govern hot water tank temperatures. It should be noted, ASPE said, "that virtually all severe burns and scalding deaths occur as the result of immersion in hot water in a bathtub rather than as a result of being sprayed by hot water in a shower."[59] Moreover, ASPE noted, the greater vulnerability to such injuries involves the elderly, young children, and "especially patients in health care facilities."[60] According to ASPE, the danger of scalding from a 135E water tank temperature "can be minimized and practically eliminated by the selection of thermostatic or pressure balancing mixing valves at bath/shower facilities. It is also important that a maximum temperature limit stop be incorporated in these mixing valves."[61]

Controlling temperature at the outlet is the safety mechanism recommended by Housing Authority Insurance Company, an insurance company serving local housing authorities nationwide. Housing Authority Insurance released its recommendations on controlling the risk of "tap water scald injuries" in 1996. According to this insurance carrier:

> Research shows that children left unsupervised tend to be at higher risk of scald injuries. The children are also more likely to live in multi-family residential buildings where the boiler is set at a high temperature to meet the larger demand for hot water. The water in the lower level units is often extremely hot because of the close proximity to the boiler.

[55] ***Domestic Water Heating Design Manual***, *supra*, at 14.
[56] *Id.*
[57] *Id.*
[58] Alfred Steele (1988). ***Temperature Limits in Service Hot Water Systems***, American Society of Plumbing Engineers Research Foundation: Westlake (CA).
[59] ***ASPE Temperature Limits***, *supra*, at 5.
[60] *Id.*
[61] ***ASPE Temperature Limits***, *supra*, at 7.

> Since that type of problem cannot be eliminated, it had been hoped that turning down the hot water service to 120E F would be an attractive and simple method of achieving anti-scald protection. However, a study of families showed that 80% abandoned the trial because they either ran out of hot water or the water was not hot enough to meet all of their needs.[62]

Stating that "prevention techniques are necessary" to respond to potential scald injuries, Housing Authority Insurance then considered a variety of mechanisms to control the exposure of local housing authority tenants to tap water scald injuries. The insurance company ultimately recommended:

> A thermostatic mixing valve is a device that reduces or shuts off the supply of hot water if the temperature of the hot and cold mix exceeds a certain level. The temperature limit is set by a qualified installer and usually the adjustment can be locked to avoid tampering. Thermostatic mixing valves are either situated close to the hot water heater, near the individual outlets, or integrated into the mixer tap. Temperature Actuated Flow Reduction Valves (TAFRs) are simple to install devices. TAFRs can be installed by staff maintenance personnel as a retro-fit accessory. They fit into individual plumbing fixtures, such as shower heads, bath and utility faucets, and sink and lavatory faucets. They are temperature-sensitive, not pressure sensitive. TAFRs do not mix or adjust the water temperature, but reduce water flow to a trickle of less than 1/4 gallon per minute when the water temperature exceeds 120E F at the point of discharge. These devices can be activated by too much hot water being used or the cold water pressure dropping. They resume full flow when the temperature reaches a safe level of approximately 98E F.[63]

In sum, several important pieces of information have been added by the recommendations made by Housing Authority Insurance Company:

Ë The risk of scalding due to high temperature water is primarily associated with multi-level, multi-family buildings, where hot water temperatures are kept higher in order to serve the higher hot water demand in the upper floors.

Ë A test of reducing water temperatures in housing authority tanks to 120E resulted in 80% of the households dropping out of the test because they either ran out of hot water or the water was not hot enough to meet all of their needs.

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[62] Housing Authority Insurance Company, "Tap Water Scald Injuries," ***Risk News***, at 1 (Spring 1996).
[63] ***Tap Water Scald Injuries***, *supra*, at 2.

Ë Temperature-controlled "thermostatic mixing devices" can be installed to protect against scald injuries. They are easy to install, can be "locked" to prevent tampering, and are effective at controlling dangerous exposure to hot water temperatures.

Reduced Water Temperature as Energy Conservation.

One argument that might be advanced by a local housing authority is that a lower water temperature in the tank will result in energy savings. As a result, the argument goes, use of a lower water temperature is appropriate under the statutory and regulatory "energy conservative household" standard for setting public utility allowances.\64\ Intuitively, the argument makes sense. Intuitively, if you need to heat water to a lower temperature, you use less energy in doing so.

In fact, however, the intuitive answer is wrong. Total hot water energy consumption is not simply a function of the temperature in the tank. It is instead a function of *two* factors: (1) the temperature to which the water is heated; *and* (2) the amount of hot water that is used. As is evident from the discussion above, these two factors do not stand alone; they are inversely related to each other. Given the fact that water delivered to the tap is at a lower temperature than the temperature in the tank, it mathematically follows that:

- as the hot water temperature in the tank goes up, the amount of hot water (in gallons) needed to obtain a specified mixed water temperature at the outlet goes down; and

- conversely, as the hot water temperature in the tank goes down, the amount of water (in gallons) needed to obtain a specified mixed water temperature goes up.

If the water consumption is thus appropriately set, the total energy consumed at different water temperatures in the tank should be identical.\65\ Total energy consumption is driven not by the hot water temperature in the tank, but rather by the hot water temperature at the outlet. If, in other words, a person uses a 110E temperature for showers, it does not matter from an energy perspective whether the 110E is obtained by a 70%/30% hot-to-cold water mix (with the tank water temperature set at 135E) or by a 85%/15% hot-to-cold water mix

\64\ HUD regulations provide: “The objective of a PHA in designing methods of establishing utility allowances for each dwelling unit category and unit size shall be to approximate a reasonable consumption of utilities by an energy- conservative household of modest circumstances consistent with the requirements of a safe, sanitary, and healthful living environment. 24 C.F.R. §965.505(a) (2001).

\65\ Energy losses are addressed below.

(with the tank temperature set at 120E). The factor driving the energy use is the temperature of the shower, not the temperature in the tank.

This conclusion can be shown mathematically. The energy consumption needed to deliver hot water is a two-step process.

Step #1: **<u>Determine how much hot water it is necessary to deliver</u>:** As was shown above, the percent of mixed water that needs to be hot, given the water outlet temperature and the water tank temperature, is calculated by the following equation:[66]

$$P = \frac{T_m - T_c)}{(T_h - T_c)}$$

WHERE:

P = percentage of hot water in mixed water
T_m = mixed water temperature.
T_h = supply hot water temperature.
T_c = inlet water temperature.

Taking showers as an example (110E F mixed water temperature), and assuming a 55E inlet temperature, the result of this calculation is:

120E tank temperature: $\frac{110E - 55E}{120E - 55E} = \frac{55}{65} = 0.85 = P$

135E tank temperature: $\frac{110E - 55E}{135E - 55E} = \frac{55}{80} = 0.69 = P$

What this shows is that for a 20 gallon shower (7 minutes x 3 gallons/minute = 21 gallons), the following amount of *hot* water is needed:

120E tank temperature: 20 gallons x .85 = 17.0 gallons

135E tank temperature: 20 gallons x .69 = 13.8 gallons

Step #2: **<u>Determine energy needed to heat water to desired temperature</u>:** Having established the amount of hot water used, it is possible to

[66] *See*, note 4, *supra*, and accompanying text.

calculate the energy needed to heat the required amount of water to the tank temperature. The following equation is that which is used to calculate the energy consumption:

$$Energy_{TH} = \frac{\text{Temperature Rise} \times 8.33 \times Use_{TH}}{\text{Energy efficiency}}$$

WHERE:

$Energy_{TH}$ = energy to heat water to specified temperature
Temperature rise = $T_h - T_c$
8.33 = lbs per one gallon of water
Use_{TH} = hot water use at specified tank temperature and outlet temperature

With use having previously been calculated, the equation becomes:[67]

$$Energy_{120} = (120 - 55) \times 8.3 \times 17.0$$

$$Energy_{135} = (135 - 55) \times 8.3 \times 13.8$$

Solving for our seven minute shower from a tank temperature of 120E results in an energy consumption of 9130 Btu's.[68] Moreover, the energy for our seven minute shower from a tank temperature of 135E is an identical 9130 Btu's.[69]

The fact that the Btu consumption will be identical is not only *not* surprising, it is a mathematical certainty. What has really happened is that the process has heated the total amount of water used in the shower to 110E. Whether that is done by heating some amount of water to 135E and mixing that with a certain amount of cold water to get a mixed water temperature of 110E, or by heating some amount of water to 120E and mixing that with a somewhat different amount of cold water to get to 110E, the energy consumption result will be the same as a matter of mathematics.

In sum, the energy consumption associated with hot water use is driven by the water temperature at the water outlet (*e.g.*, the faucet, the showerhead, etc.), *not* by the water temperature in the hot water tank. Given otherwise identical hot water uses in a home, the energy consumption associated with 135E tank temperatures and 120E tank temperatures will be identical.

[67] Since the energy efficiency is a constant between our two examples, it has been dropped out of the equation.
[68] It is important to note that the 17 is really 16.92308.
[69] It is important to note that the 13.8 is really 13.75000.

Tank Temperatures and Stand-By Energy Losses

A second argument frequently advanced in support of lower hot water set points is that lower set points will result in conserving energy because it results in lower stand-by energy losses. No question exists but that lower tank temperatures will reduce stand-by losses. These reductions, however, tend to be inconsequential under normal circumstances.

Stand-by losses occur when the heat in hot water migrates through the shell of the water heater tank into the room. Whenever there is a difference between the temperature of the room and the temperature of the hot water, this heat transfer will occur. Given tank temperatures of 120 degrees and more, this heat loss will certainly happen. As the difference between the ambient air temperature and the hot water increases, the heat loss will increase as well. Given a constant room temperature, a tank with 135 degree hot water will have a higher heat loss than a tank with 120 degree hot water. As heat moves from the hot water into the room, the water needs to be reheated to maintain a constant temperature in the tank, thus increasing the use of energy.

The issue to be addressed in any consideration of hot water temperature set points, from the perspective of stand-by energy losses, however, is not whether this heat loss occurs, *or* whether a reduction in tank temperature would reduce the loss (and thus lower energy use). The issue instead is whether a reduction in tank temperature would generate a significant or consequential energy savings, particularly in light of the known adverse medical consequences, as well as the reduced consumer utility, resulting from such an action.

Making a determination of the magnitude of the stand-by loss does not settle the issue of how much energy is to be saved through a reduction in the tank temperature. A reduced hot water tank temperature would not save the entire stand-by loss. The savings would instead only be the *difference* between the stand-by loss at the higher tank temperature and the stand-by loss at the lower temperature. It can be shown that the reduced loss would be some relatively small portion of the total stand-by loss.

The results can be demonstrated mathematically. Stand-by heat losses are calculated using the following equation:

$$Loss_{BTU} = A \times HDD \times U \times (Temp_{DHW} - Temp_{Ambient})$$

WHERE

A= area in square meters
H = heating degree days
U = 1 / R-Value of tank shell
$Temp_{DHW}$ = Hot water tank temperature
$Temp_{Ambient}$ = Ambient air temperature

Exercising this equation for tank temperatures of 120E and 135E respectively, holding all else equal, thus shows the annual energy savings generated by the lower tank temperature. The savings below are converted from BTUs to therms of natural gas to place the savings in a more common day-to-day context.

Stand-by Energy Loss Savings in Typical Residential Hot Water Heater
Generated by Reducing Tank Temperature from 135 Degrees F to 120 Degrees F

	135 degrees F	120 degrees F	Loss Savings
Area	17.5	17.5	
Annual hours of use	8,760	8,760	
Ambient air temperature	72 degrees	72 degrees	
Hot water temperature	135 degrees	120 degrees	
U value (R value = 3.5) /a/	0.29	0.29	
Shell heat loss (Btus) /b/	2,759,400	2,102,400	
Shell heat loss (Therms) /c/	28 therms	21 therms	7 therms

NOTES:

/a/ U value = 1 / R-value
/b/ Shell heat loss = Area x (hot water temperature - ambient air temperature) x (hours of use x U-value).
/c/ Therms = Heat loss in BTUs / 100,000

The table above assumes a relatively inefficient hot water heater (R-value of shell = 3.5), and no tank insulation, in order to maximize the amount of energy loss avoided by reducing the tank temperature. The calculations further assume a standard sized residential hot water heater and a typical ambient room temperature of 72 degrees F.

The table shows that a reduction in hot water tank temperature from 135 degrees to 120 degrees generates an insubstantial energy savings from reduced stand-by energy losses. Stand-by energy losses decrease from 28 therms per year (at 135 degrees) to 21 therms per year (at 120E).[70] A savings of seven (7) therms per year, given a price of $0.70 per therm, would result in an annual cost savings of less than $5.00 per year for the user, or about $0.40 per month. With an average gas consumption of 1,100 therms per year, the reduced hot water set point yields a consumption savings of 7/1100ths, or six tenths of one percent (0.6%).

The calculations above use an uninsulated hot water heater in order to maximize stand-by energy losses (and thus maximize the energy loss savings from a reduced tank temperature). If a heater with an R-value of more than 3.5 (e.g., a hot water heater with insulation wrap or a more recent hot water heater with a shell R-value of 13) is used instead, the stand-by energy losses would be as follows:

Stand-by Energy Loss Savings in Typical Residential Hot Water Heater
Generated by Reducing Tank Temperature from 135 Degrees F to 120 Degrees F
Assuming an Energy Efficient Hot Water Heater Tank Shell (R-13)

	135 degrees F	120 degrees F	Loss Savings
Area	17.5	17.5	
Annual hours of use	8,760	8,760	
Ambient air temperature	72 degrees	72 degrees	
Hot water temperature	135 degrees	120 degrees	
U value (R value = 13) /a/	0.08	0.08	
Shell heat loss (Btus) /b/	772,632	588,672	
Shell heat loss (Therms) /c/	7.7 therms	5.9 therms	1.8 therms

NOTES:

/a/ U value = 1 / R-value
/b/ Shell heat loss = Area x (hot water temperature – ambient air temperature) x (hours of use x U-value).
/c/ Therms = Heat loss in BTUs / 100,000

As this table shows, a reduced hot water tank temperature on a tank with an energy efficient shell (or a hot water insulation wrap) would yield reductions in stand-by energy losses that are virtually non-existent.

In sum, arguments that reduced hot water tank temperatures are needed as an energy conservation measure due to reduced stand-by heat losses are not well-founded. Given

[70] Applying the rule that stand-by losses are roughly 10 percent of total hot water energy use, reducing the tank temperature reduces hot water energy use from 280 therms to 273 therms.

maximum levels of stand-by energy losses, reducing tank temperatures from 135 degrees F to 120 degrees F would yield savings of only seven (7) therms per year (or less than $5.00 per year). If hot water tanks are newer (and thus have more efficient shells), or if they have been insulated with hot water tank wraps, the savings attributable to reduced hot water tank temperatures are virtually non-existent.

DAILY PER PERSON USE OF HOT WATER CONSUMPTION

One of the major determinations of hot water usage to be used in calculating hot water energy consumption is the amount of hot water used by a household each day. As discussed above, the energy consumption associated with hot water use is determined using the following equation:

CALCULATION OF HOT WATER LOAD

$$\text{Hot water load} = \frac{\text{temperature rise} \times 8.33 \text{ lb/gal} \times \text{gal/year/unit}}{\text{Btu's per fuel unit}}$$

WHERE:

Temperature rise =	the temperature difference between the inlet water and the water in the tank. /a/
Gallons/year/unit =	the gallons of use per person per day x number of persons per unit x 365 days per year.
8.33 =	weight (lbs) of one gallon of water. /b/
Btu's per fuel unit =	Different fuel types have standard measurements of their Btu's of fuel consumption. /c/ /d/

NOTES:

/a/ The temperature rise is sometimes referred to as the Delta-T.
/b/ The "pounds per gallon" of water is a standard unit of measure.
/c/ A Btu is a British thermal unit. A British thermal unit is the amount of energy needed to raise the temperature of one pound of water one degree.
/d/ For example, one kilowatthour (kWh) has 3,412 Btu's. One therm of natural gas has 100,000 Btu's. One therm of natural gas is also the functional equivalent to one hundred cubic feet (ccf) of natural gas.

As noted, in this equation, the figure of gallons per year per unit is calculated by multiplying the gallons of use per person per day times the number of persons per unit and then times 365 days in a year. It thus becomes clear that the variable which sets forth an individual's gallons of hot water use per day is a critical variable.

The per person hot water consumption generally reported in the literature is 25 gallons per day for a unit that uses low-flow faucets and aerators. Units that are *not* equipped with these water-saving devices will have hot water requirements that are even higher. FSC assumes the presence of water savings devices and uses the 25 gallons per person per day.

A 25 gallon per person per day consumption is overwhelmingly supported by existing research. The U.S. DOE's Lawrence Berkeley Laboratory found an estimated daily personal use of 31 gallons of hot water per person per day.[71] This finding, Berkeley Lab said, was "slightly higher than any of the average values reported in the literature."[72] More recently, a paper presented at the American Council for an Energy Efficient Economy biannual "Summer Studies" program found that average residential hot water consumption was 30 gallons per person per day.[73]

Obviously, daily hot water usage includes more than simply showering. According to the Gas Appliance Manufacturers Association (GAMA), average gallons of hot water per usage include:[74]

Use	Gallons of Hot Water Per Use
Shower	20
Shaving	2
Hands and Face Washing	4
Hand Dishwashing	4 /a/
Food Preparation	5
NOTES: /a/ This does not set forth average daily use. Thus, for example, while an average of four gallons of hot water is used for each hand dishwashing, hand dishwashing generally occurs three times a day.	

In addition to this research, the American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) has recently addressed research and standard-setting

\71\ E. Vine *et al.*, ***Domestic Hot Water Consumption in Four Low-Income Apartment Buildings***, at 12, Lawrence Berkeley Laboratory: 1986.
\72\ *Id.*, at 7 (literature reports 27 - 29 gallons per person per day).
\73\ F.Goldner and D.Price, "Domestic Hot Water Loads, System Sizing and Selection for Multifamily Buildings," at 2-105, ACEEE 1994 Summer Study on Energy Efficiency in Buildings (1994).
\74\ Gas Appliance Manufacturers Association, ***Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment*** (October 1996).

attention to hot water consumption issues.[75] ASHRAE research found that specific demographic characteristics correlated to different levels of hot water consumption: high, medium and low. ASHRAE's categorization follows:

Demographic Characteristics Correlation to DHW Consumption (ASHRAE 1996)	
No occupants work	High
Public assistance and low income (mix)	
Family and single-parent households (mix)	
High percentage of children	
Low income	
Families	Medium
Public assistance	
Singles	
Single-parent households	
Couples	Low
Higher population density	
Middle income	
Seniors	
One person works, one stays homes	
All occupants work	
NOTES: Demographics listed in order from highest consumption to lowest consumption.	

According to the ASHRAE research, a low-income housing project will generally fall somewhere between the "low income" and "no occupants work" categories of high-volume water consumption. ASHRAE then set national standards for sizing hot water equipment for multi-family buildings. According to ASHRAE, the average daily per person usage to be assumed for purposes of sizing a hot water heater would be as follows:

[75] The American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) is a national standard-setting body.

National DHW Sizing Guidelines (Low-Medium-High) (ASHRAE 1996)	
	Average Per Person Per Day
Low	14 gallons
Medium	30 gallons
High	54 gallons
NOTES: These data are for centrally fired units. Consumption for individually metered are likely to be somewhat lower.	

A variety of demographic factors have been found to affect hot water usage. "The presence of children less than six years old increased the average total daily use by approximately 20%."[/76/] So, too, the presence of people at home on weekdays has been found to be an "influencing factor" which shows a significant effect on hot water usage.[/77/] Indeed, the number of people at home during the day is one of the four most explanatory variables of annual average consumption of hot water (in gallons per day).[/78/] NYSERDA found that of all the dependent variables, the number of people home during the day on weekdays explained the most variance in hot water consumption. The number of peoples home during the day included both the number of elderly tenants and the number of children.[79]

A hot water use per person per day of between 30 and 54 gallons is justified. A hot water use per person per day substantially less than 30 gallons is not justified.

Hot Water Line Loss

One use of hot water in a residential situation involves the hot water introduced into a home's circulation system but never used while hot. Consider, for example, that hot water is not produced instantaneously at the showerhead when a person takes a shower. Instead, the hot water is turned on in the bathroom, placing a demand on the hot water heater, which introduces hot water into the circulation system of the home. Within a reasonable period of time, the hot water will have flowed through the piping to the bathroom where it will flow out of the showerhead. When the showerhead is turned off, however, residual hot water will

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[76] M.Perlman and B.E. Mills, "Development of Residential Hot Water Use Patterns," 91 ***ASHRAE Transactions***, part 2, at 657, 663.
[77] *Id.*, at 665.
[78] Walter Coss, et al., "Domestic Hot Water Consumption and Efficiency: Researching Consumption and Demand in New York City Multifamily Apartment Buildings," at I-37 – I-38, New York State Energy Research and Development Authority: Albany (NY).
[79] *Id.*, at I-38 – I-39.

remain in the piping. If not immediately used, that hot water will cool to room temperature by the simple process of heat transfer through the piping to the ambient air.

The amount of hot water used in this manner can be quantified through a consideration of the time that elapses from the time a water outlet is turned on until the outlet begins to deliver hot water. With copper piping and a 25 foot piping length from the water heater to the outlet, a 15 second delivery time is reasonable for a four gallon per minute (4 gpm) outlet, and 24 seconds for a 2.5 gpm outlet.[80] The hot water used in this fashion can thus be determined by calculating the flow rate (per minute) x delivery time (minutes). A 25 foot copper piping would thus yield:

Flow Rate/Minute	Delivery Time (seconds)	Delivery Time (minutes) /a/	Cooled Hot Water in Pipe /b/
2.5 gpm	24	0.40	1.00
4.0 gpm	15	0.25	1.00
NOTES: /a/ Delivery time (seconds) / 60 seconds per minute. /b/ Flow rate per minute x delivery time (in minutes)			

As can be seen from this table, in a typical residential setting, a hot shower will generally consume one gallon of hot water per shower simply by stranding such hot water in the home's water circulation system.

Hot Water Leaks

In addition, high hot water consumption is often driven by leaks, particularly in older homes. According to the American Housing Survey, performed by the Census Bureau and the U.S. Department of Housing and Urban Development (HUD), the presence of water leaks is related to the income of a householder. According to the American Housing Survey, performed by the Census Bureau and the U.S. Department of Housing and Urban Development (HUD), while only 13.9 of all occupied units in the country were occupied by households living below the Poverty Level, nearly 20 percent of all households with leaking pipes were in low-income homes.[81]

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[80] American Society of Plumbing Engineers (1998). ***Domestic Water Heating Design Manual***, at 200, American Society of Plumbing Engineers: Westlake Village (CA).

[81] U.S. Department of Housing and Urban Development (January 2000), ***American Housing Survey of the United States, 1999***, at Table 2-7 (Additional Indicators of Housing Quality), U.S. Department of Housing and Urban Development: Washington D.C.

In addition, the AHS reports, nearly one-fifth of all leaks that were "unreported" but discovered upon inspection of the housing being surveyed were in homes occupied by households living below the Poverty Level.[82]

The AHS reports that 27% of the occupied households experiencing "severe" physical problems with their plumbing were low-income households, while in addition, 33% of the occupied households experiencing "moderate" physical problems with their plumbing were low-income households.[83]

SUMMARY AND CONCLUSIONS

The hot water component of a public housing authority's utility allowance provided to tenants of public and subsidized housing is a major determinant of the overall reasonableness of the utility allowance. A variety of empirical inquiries must be used to support the hot water utility allowance. A failure to calculate a reasonable hot water component will result in a utility allowance that does not serve the reasonable needs of a low-income household.

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[82] *Id.*

[83] *Id.*