PUBLIC HOUSING UTILITY ALLOWANCES{PRIVATE }
FOR THE AUSTIN HOUSING AUTHORITY

By:

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Fisher, Sheehan & Colton, Public Finance and General Economics (FSC) has reviewed the calculation of public housing utility allowances for the Austin Housing Authority (AHA). After an introduction, these comments on the methodology employed will be divided into two major areas: (1) a review of the natural gas component; and (2) a review of the electric component.

1NATURAL GAS ALLOWANCES.

The natural gas consumption included in the AHA utility allowances consists of three specific components:

ËCooking
ËDomestic hot water
ËSpace heating

1.1Cooking

While we know what the *results* are for cooking, we do not know how MTS derived those results. That calculation could be significant. While MTS provided cooking consumption of 35 therms, 38 therms, and 42 therms for 2, 3 and 4 bedroom units respectively in Dade County (FLA), the MTS consumption for AHA was only 25, 28 and 32 therms per year for those sized units. Why? That is completely unexplained.

In contrast, a HUD handbook --though in draft form, it nonetheless presents good information-- recommends consumption of 78, 89 and 97 therms per year for cooking. At the least, AHA should be called upon to explain what appears to be an extraordinarily low gas cooking allowance. A cooking allowance that is only one-third that which has been identified by HUD as reasonable, at the least, calls for explanation.

1.2Domestic Hot Water

The domestic hot water (DHW) allowance proposed for AHA is as follows:

{PRIVATE }Unit Size (# bedrooms)	Therms/Year
1	143
2	167
3	214
4	262

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

Hot water load= $$\frac{\textbf{temp rise x 8.33 lb/gal x gal/year/unit}}{\textbf{system efficiency}}$$

The "temp rise" represents the difference between the water inlet temperature and the temperature of the water in the hot water tank. The "gallons/year/unit" represents the usage per tenant times the number of tenants. The "system efficiency" is the energy efficiency of the hot water heater. The "Btu per fuel unit" and "pounds per gallon" are standard units of measure. Using the data and assumptions set forth by the AHA, the following equation would occur for natural gas hot water heating for a 2 bedroom unit in Chalmers:

$$\frac{\textbf{70 x 8.33 x 9.3/gal/person/day x 365 days}}{\textbf{0.70}}$$

Solving for the equation using the AHA's input[1] would result in annual natural gas consumption of 4,257 kBtu (1 bedroom), 5,938 (2 bedrooms), 9,365 (3 bedrooms), and 12,812 (4 bedrooms) a year respectively for "consumption energy required."[2] In fact, this

[1] This calculation yields an energy load in Btu's. There are 100,000 Btu's in a therm. A therm is the measurement of natural gas sold at retail.

[2] Given the documentation provided, it is not possible to replicate or reconstruct the AHA's calculation of "total energy lost." No opinion is expressed on its adequacy.

was the AHA's result.[3] As is shown below, however, this result is wrong. In making its calculations, the AHA relies upon assumptions that result in lower than reasonable utility allowances.

1.2.1 Water Temperature

In the equation above, the "temperature rise" (also called "Delta T") involves calculating the difference between the water inlet temperature and the temperature at which the hot water is assumed to be delivered. The AHA assumes a hot water temperature of 125E and a water inlet temperature of 55E Fahrenheit. The "temperature rise" is thus calculated to be 70E F by the AHA (125 - 55 = 70).

A hot water temperature of 125E is an unreasonably low assumption. A reasonable assumption is a hot water temperature of 135E. Given a hot water temperature of 135E, the Delta-T is 80E rather than 70E (135 - 55 = 80).

The unreasonableness of the AHA's assumption of a 125E hot water temperature is evident from at least two observations. First, the federal government has prescribed a "uniform methodology for measuring the energy consumption of water heaters."[4] 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."[5] Moreover, in prescribing the "test procedures," the regulations provide that one of the very first steps is to determine whether "the mean tank temperature is within the range of 135 degrees F +/-5 degrees F."[6]

Second, in establishing its uniform methodology, the U.S. Department of Energy (DOE) explained its choice of water temperatures.[7] According to DOE, a 120E hot water temperature is inadequate to perform certain basic household chores. DOE found, for example, that 120E was inadequate to perform clothes washing.[8] Moreover, 120E water in

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[3] Minor differences exist, that are assumed to result from rounding.

[4] 10 ***C.F.R.*** Pt. 430, Subpt. B, App. E (1996).

[5] Appendix E, §2.4.

[6] *Id.*, at §5.1.2.

[7] U.S. Department of Energy, *Energy Conservation Program for Consumer Products: Final Rule Regarding Energy Conservation Standards for Three Types of Consumer Products*, Docket No. CE-RM-88-101, 56 ***Fed. Reg.*** 22250 (May 14, 1991).

[8] *Id.*, at 22264.

a dishwasher, without a booster heater, provides insufficiently hot water to adequately clean dishes.[9] DOE decided that 135E (+/- 5E) was needed. In "consumer energy information" "fact sheets" published by the Energy Efficiency and Renewable Energy Network (a project of the U.S. Department of Energy), DOE states that while a hot water temperature of 120E is sufficient for most household chores,

> average dishwashers use 8 to 14 gallons of water for a complete wash cycle and require a water temperature of 140 degrees for optimum cleaning. . .If your dishwasher does not have a booster heater, lowering the water-heating temperature is not recommended. Also, many dishwasher detergents are formulated to clean effectively at 140 degrees F and may not perform adequately at lower temperatures.[10]

Unfortunately, based on the limited documentation provided with the electric utility allowances, it is not possible to determine from the face of the utility allowances whether AHA residents use either clothes washers or dishwashers.

Accepting the DOE's finding that water temperature can be expected to vary +/- 5E, it becomes evident that the hot water temperature used by the AHA (125E) can be *expected* to fall to a level that does not provide for safe and sanitary clothes and dish washing. The water temperature adopted by the Department of Energy (135E) should be used as the water temperature appropriate for an energy conservative household.

1.2.2 Water Use by Occupant

In the Chalmers complex, the AHA assumes hot water consumption of less than 10 gallons per occupant per day. Hot water consumption involves all types of hot water use, including showers, cooking, clothes washing, and the like. The 10 gallon per person per day figure is unreasonable.

MTS does not provide any documentation on how it arrived at its hot water use per day. I know from having reviewed the MTS Excel spreadsheet for Dade County (FLA), however, that MTS assumes a base hot water use of 8.0 gallons per day and adds a fixed household use of four (4.0) gallons per day divided by the number of occupants. Thus, the MTS formula results in the following:

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[9] *Id.*, at 22266.

[10] U.S. Department of Energy (Jan. 1995). "Consumer Energy Information: EREC Fact Sheets, Energy Efficient Water Heating."

{PRIVATE }Unit Size (BRs)	Occupants	Base Use	Fixed Use	Per Occupant Use
1	2	8	4/2 = 2	10.0
2	3	8	4/3 = 1.3	9.3
3	5	8	4/5 = 0.8	8.8
4	7	8	4/7 = 0.6	8.6

These per-occupant-per-day consumption figures then appear in the DHW calculation table attached to the utility allowance report provided by AHA.

I will examine the reasonableness of the hot water use from three perspectives:

ËIs the base use per occupant reasonable?

ËIs the fixed use per household reasonable?

ËAssuming the *un*reasonableness of the gallons per occupant number by AHA, what might a reasonable number be?

1.2.2.1Base Water Use per Occupant.

The AHA hot water utility allowance begins with a base daily use per occupant of 8.0 gallons per day. To assist in the evaluation of the reasonableness of this figure, I will briefly consider hot water end uses. According to the Gas Appliance Manufacturers Association (GAMA), a household's hot water consumption looks as follows:\11\

\11\Gas Appliance Manufacturers Association, ***Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment*** (October 1996).

{PRIVATE }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.	

Based on these figures, the AHA per occupant consumption numbers cannot possibly be accurate. On an individual basis, assuming one hand/face washing per day and one shaving per day, an individual would use 6.0 gallons of hot water *before* baths or showers. The GAMA consumption for showers (20 gallons of hot water per day for showers alone), of course, is completely inconsistent with the AHA utility allowance (8 gallons for *total* individual hot water use).

It is possible to take a closer look at the hot water assumptions embedded in the AHA utility allowance. An older showerhead (not a low-flow showerhead) delivers from four to five gallons of water per minute.[12] A typical mixing valve in these older showerheads delivers a hot-to-cold mix of water of 70% hot and 30% cold. The typical showerhead thus delivers from 2.8 to 3.5 gallons of hot water per minute. Rounding this off to 3.0 gallons per minute for ease of calculation, the AHA utility allowance allows for each person to take a shower of about *two and one-half minutes* long each day. If an occupant uses his or her "full" two and one-half minutes in the shower, however, that person will have no hot water left for any other personal use during the day.

[12]National Renewable Energy Laboratory (1995). *Energy Efficient Water Heating*, at 1, U.S. Department of Energy: Washington D.C.

These findings are supported by the literature. Consider, for example, that the average flow rate for existing showerheads is 3.4 gallons per minute.[13] Using the low flow hot water shower flow rate estimated by Lawrence Berkeley Laboratory of 2.5 gallons per minute[14] would allow each person to take a three minute shower each day, with no other hot water use. Again, however, any other use of hot water during the day (*e.g.*, washing hands, cooking, washing dishes) would reduce the time that a person could spend in the shower to below this three minute limit under the AHA assumption of eight gallons of daily per occupant use.

1.2.2.2 Fixed Per Household Consumption to Spread over All Occupants.

An examination of the "fixed" hot water use per household also finds the AHA consumption to be substantially understated. Remember, the AHA assumes a "fixed" per household hot water use of four gallons per day (which is then divided by the number of occupants in the household). According to GAMA, however, hand dishwashing generally takes four gallons of hot water per wash (*not* per day). An average dishwasher uses from eight to 14 gallons of hot water per wash.[15] As can be seen, washing dishes by hand three times a day can range from using somewhat more (12 vs. 8) to almost exactly the same (12 vs 14) hot water as a dishwasher. In either case, however, dishwashing alone uses from two to three times the hot water consumption allowed by the AHA utility allowance.

I conclude that when one breaks the AHA hot water allowance into its various component parts, it is clear that the AHA utility allowance is inadequate. Neither the eight gallons per occupant, nor the four gallons per household, hot water consumption is reasonable.

1.2.2.3 What *is* Reasonable?

One can derive a hot water use in one of two ways. On the one hand, it is possible to construct a usage amount from the "bottom up." On the other hand, it is possible simply to take a measured amount ascertained in someone else's study and apply it to one's own situation.

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[13] 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).

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

[15] ***Energy Efficient Water Heating***, *supra*, at 2.

Building a usage from the bottom up would yield the following results:

{PRIVATE }Hot Water Component	Hot Water End Uses
Per occupant	Shower + handwashing
Per household	Dishwashing + (shaving x 2) + food preparation /a/
/a/(Shaving x 2) accounts for 2 adults in each household.	

Using the same methodology used by the AHA consultant, and the GAMA data, would yield a per occupant base use of 24 gallons per day, plus a fixed household use of 21 gallons per day divided by the number of household members. This results in a daily hot water use per occupant as follows:

{PRIVATE }Unit Size (Bedrooms)	Occupants	Daily Per Occupant Use
1	2	34.5 /a/
2	3	31.0 /b/
3	5	28.2 /c/
4	7	27.0 /d/
/a/24 + (21/2) /b/24 + (21/3) /c/24 + (21/5) /d/24 + (21/7)		

These results assume the occupancy rate per bedroom set forth in the AHA utility allowances. If, instead, one assumes two persons per bedroom, the following result arises:

{PRIVATE }Unit Size (Bedrooms)	Occupants	Daily Per Occupant Use
1	2	34.5 /a/
2	4	29.3 /b/
3	6	27.5 /c/
4	8	26.6 /d/
/a/24 + (21/2) /b/24 + (21/4) /c/24 + (21/6) /d/24 + (21/8)		

Whichever way you look at it, however, it is clear that the consumption of less than 10 gallons per occupant is wildly off.

Setting aside this bottom-up approach, it is possible to gain a reasonable estimate of daily per occupant hot water consumption by looking at measured results from other authoritative studies. Sources such as the national laboratories associated with the U.S. Department of Energy, the American Council for an Energy Efficient Economy (ACEEE), and the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) are the types of sources I would routinely turn to in my work.

As is shown below, a 25 gallon per person per day consumption is generally 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.[16] This finding, Berkeley Lab said, was "slightly higher than any of the average values reported in the literature."[17] 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.[18]

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

[17] *Id.*, at 7 (literature reports 27 - 29 gallons per person per day).

[18] 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).

It is appropriate to concede (if "concede" is the right word) that there are differing (and lower) estimates of hot water consumption. Other estimates include:

- A study of residential water use in Tampa (Florida) finding hot water use of 16 gallons per person per day (3 person household).[19]

- The Florida Solar Energy Center metered energy use in two Habitat for Humanity developments near Homestead (Florida), finding an average hot water use of 14 gallons per person per day.[20]

In contrast to this research finding lower consumption, the American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) has recently addressed research and standard-setting attention to hot water consumption issues.[21] ASHRAE research found that specific demographic characteristics correlated to different levels of hot water consumption: high, medium and low. ASHRAE's categorization follows:

[19] Damann Anderson, Wendy Nero and Thomas Konen (1992). "Residential Water Use Characteristics and the Potential for Conservation in Tampa, Florida," at Table 5, American Water Works Association, 1992 Annual Conference Proceedings, at 721 - 729.

[20] Danny Parker, Maria Mazzara and John Sherwin (undated). ***Monitored Energy Use Patterns in Low-Income Housing***, at Table 1, Florida Solar Energy Center: Cocoa, FL.

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

{PRIVATE }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:

{PRIVATE }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.	

In sum, I proposed to replace the 10 gallon per person per day hot water consumption implicit within the AHA utility allowance study with a 25 gallon consumption input figure.[22] This charts a middle road between some of the studies showing a lesser measured consumption, while recognizing the bulk of the literature showing a consumption closer to 30 gallons per occupant per day.

1.2.3 Hot Water System Efficiency

In calculating the amount of energy needed to heat hot water, it is necessary to take into account the fact that natural gas hot water heaters are not 100 percent efficient. If a hot water heater burns 100 Btu's of gas, in other words, it does not produce 100 Btu's of energy. It is, therefore, necessary to determine an appropriate efficiency rating for the hot water

[22] Hot water consumption per person is not linear. There are, as discussed above, certain "fixed" usage amounts. Therefore, it would not be accurate to assume that a six person household uses 150 gallons of hot water (6 x 25 = 150). The non-linear relationship is not discussed here. In the recommendations below, the per person per day hot water consumption has been qualitatively adjusted downward to take into account this non-linear relationship.

heaters used in the AHA public housing units.[23] The assumed system efficiency of 70% is unreasonable.

Indeed, the unreasonableness of the assumed system efficiency is even greater considering the age of the hot water heaters. While I do not know the *precise* age of the water heaters, I can deduce that they are not only not new, but that they are not of recent vintage at all. It is clear that the water heaters are not new. The "DHW calculations" attached to the utility allowances show a "pilot consumption rate" of 400 Btu/hour and a total pilot consumption of 3504 kBtu. That means the pilot operated all 8,760 hours in the year (400 x 8760 / 100 = 3504). Gas water heaters sold in recent years, however, have electronic ignitions. These ignitions mean that there is *not* a continuous pilot. The existence of a continuous pilot indicates that the water heaters are of at least a certain age.

Moreover, the "DHW calculation" reports that the "R-value" of the water heater shell is 3 F-sf-hr/Btu. New natural gas water heaters tend to have shell R-values of 12 to 15. In addition, a generation of water heaters sold in the interim tend to have shell R-values in excess of 6 to 8. We can conclude, therefore, that the AHA water heaters are more than a few years old. Given this age, we can consider the reasonableness of the assumed efficiency of 70 percent.

The AHA's efficiency assumption of 70% for hot water heaters is too high and should be replaced with a reasonable figure. A hot water energy efficiency level of 70 percent is associated only with top of the line *new* hot water systems today. In contrast, the efficiency of gas water heaters is *typically* in the range of 50 to 55 percent. The U.S. Department of Energy, Lawrence Berkeley Laboratory reported the average efficiency of natural gas hot water heaters by the year in which the water heater was purchased.[24]

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[23] If a system is less efficient, it needs more fuel to deliver the same amount of energy. More fuel purchased, of course, means a higher bill.

[24] Roland Hwang *et al.*, Lawrence Berkeley Laboratory, ***Residential Appliance Data, Assumptions and Methodology for End-Use Forecasting with EPRI-REEPS 2.1***, at 59 (May 1994).

{PRIVATE }Gas-fired Storage Water Heater Stock Data		
Year of Purchase	Average Efficiency	Share of 1990 Stock
pre-1973	47.4%	14.7%
1973, 1974	47.6%	5.1%
1975, 1976	47.9%	6.0%
1977, 1978	48.1%	7.1%
1979, 1980	48.5%	7.5%
1981, 1982	48.9%	8.5%
1983, 1984	49.3%	10.6%
1985, 1986	50.8%	12.5%
1987, 1988	52.7%	13.9%
1989, 1990	54.5%	14.1%

In addition to this work by Lawrence Berkeley Laboratory, the U.S. Department of Energy publishes annual figures on energy efficiencies.[25] DOE's *Annual Energy Outlook 1995*, for example, reported the following for natural gas water heaters:

{PRIVATE }Energy Efficiency Factors: Natural Gas Water Heaters: 1993		
Stock Average	New Purchases	Best Available Technology
52%	54%	72%
SOURCE:Department of Energy, Energy Information Administration, *Energy Outlook 1995*, at Table 5.		

To assume an *average* water heater efficiency of 70% as was done by AHA cannot be justified. For purposes of these allowances, an assumed system efficiency of 55% is used, particularly for older water heaters.

[25] DOE publishes this data in its *Annual Energy Outlook: 199x* (Energy Information Administration).

1.2.4Results of the changes

Making the recommended corrections to the utility allowance above results in increased natural gas consumption to be included in the AHA utility allowances. A comparison of the AHA hot water consumption to the corrected hot water consumption is presented below:

{PRIVATE }AHA DHW Consumption vs. Corrected DHW Consumption (therms) (Chalmers)			
Number of bedrooms	AHA	Corrected	
		AHA Occ/BR	2 Occ/BR
1	143	231	342
2	167	452	563
3	214	629	731
4	262	780	873

1.3Space Heating

The third component of the natural gas consumption is a space heating component. The AHA utility allowance provides the following gas heating allowances:

{PRIVATE }Unit Size (Bedrooms)	Gas Allowance (therms)
1	149
2	153
3	168
4	196

The derivation of these figures is set forth in the "heating load tables" attached to the utility allowances. Two observations should be made about the heating allowances.

1.3.1 Wall and Ceiling Insulation.

The data in the heat load calculations set forth in the heat load tables includes a "U value" for the roof of 0.030. This implies an "R value" for the roof of 33. While this is a good energy efficient roof for 1999, it is unlikely that a building constructed many years ago[26] in Austin (TX) had insulation sufficient to result in a roof with an R value of 33. Unless the AHA has insulated its public housing in recent years, this is unlikely to be the case.

The data in the heat load calculations also includes a "U value" for walls of 0.070. This implies an "R value" for the walls of 14. Again, while this is a good energy efficient wall for 1999, it is unlikely that a building constructed many years ago in Austin (Texas)[27] had wall insulation sufficient to result in a wall with an R value of 14. Unless the AHA has insulated its public housing in recent years, this is unlikely to be the case.

I have adjusted the ceiling R-values to R-11 and wall insulation to R-4. I have then recalculated the total apartment heat loss rate using the MTS spreadsheet. Making only these two adjustments yields a heating load of the following:

{PRIVATE }Unit Size (BRs)	Space Heating Consumption (ccf)	Fan Consumption (kWh)
1	185	209
2	207	161
3	225	179
4	337	289

1.3.2 Heat Loss through Air Infiltration/Air Exchanges

Aside from the heat infiltration that normally occurs through a home's walls and ceiling, one of the major areas of heat loss is through air exchanges with the outdoors through "leaks" in the home. The heat loss attributable to air infiltration for the AHA units is attributable only to the cracks around doors, windows, and the perimeter footage. In fact, the heat loss at these

[26] The date of construction is not known. Given, however, the lack of funding for the construction of new public housing units in recent years, it is assumed that these units are not of recent vintage. Given further the age of the water heaters, it is assumed that the buildings do not post-date the water heaters.

[27] *See* note **Error! Bookmark not defined.**, *supra*.

points is a relatively small contributor to overall heat loss. The biggest infiltration occurs from other penetrations (everything from electric service, to wiring and cable t.v. in the attic, to the plumbing stack/vent stack). One major source of heat loss in multi-family units involves gaps between the party walls between units. If a leak to the outside lets air *in* during a blower door audit, that leak will let heat *out* during the heating season. During a blower door test, a trained. The overall heat loss through infiltration is likely to be much higher and, therefore, the heating consumption much higher.

Even homes that are newly constructed or rehabilitated may have significant air leakage. Tiny cracks around chimneys, floors and windows may, in the aggregate, result in the substantial loss of heating energy. Air can enter a structure through framing cavities, voids in the building envelope and through smaller cracks around doors, windows, trim, moldings, penetrations, and the like. The heating system type, also, can increase building leakage through combustion venting and air distribution systems.

Every cubic foot of air which has been heated or cooled, and which leaks out of a building, must be replaced by an equal volume of air that requires heating or cooling. As you can imagine, that process of heating or cooling air, having it escape to the outdoors, and then needing to heat or cool new air wastes energy and costs the consumer money. It is the reason that you do not leave a window open in the middle of winter. To give you an idea of the significance of air sealing, if you add up all of the small leaks that can be identified through a blower door test, it would be the equivalent of leaving a typical first flow window open 24 hour a day 365 days a year with the resulting heating and cooling loss.

The amount of air that is escaping or entering a home is generally referred to as the air infiltration rate, air exchange rate, or air changes per hour. Air leakage can occur between the inside of a home directly to the outside. Similarly, there can be air leakage between the home and the home's attic.

Energy efficiency auditors speak in terms of leakage through "penetrations." Let's think of what those penetrations might be. In a typical home, the entry point for wires is a common point for air leakage. Wires enter the home to deliver electricity, for example, as well as to deliver such things as cable television and telephone service.

Where might there be penetrations that breach the inside building envelope without going directly outside? One such point of air leakage involves electric wall sockets. A wall socket may easily allow air to come in, and go out, into and through wall cavities. Particularly in instances where multi-family dwellings have common walls that are hollow, substantial air leakage can occur.

Penetrations from the inside building envelope into the attic can result in substantial air leakage and thus substantial heating (and dollar) loss. Attic penetrations can involve electric, telephone and cable tv wires as previously noted. Another common penetration involves recessed lighting, the canisters for which can have small cracks which, when added up, can represent a sizable hole from the heated living space into the unheated attic space and out. Another common penetration point involves the space surrounding a home chimney. Unless carefully sealed at the attic level, if there is any infiltration at all via cracks or otherwise, that space provides an unobstructed passage for hot air to move up into the attic and out of the home.

The question presented at this point is how much of an adjustment to make to the heating allowance to account for these leaks even though no specific tests have been made on the homes.

There is, in fact, considerable literature on the *savings* that would be generated from air sealing a home. The American Council for an Energy Efficient Economy (ACEEE) sponsors a biannual forum on energy efficiency in buildings. The ACEEE forum presents the latest research on energy efficiency. In recent years, ACEEE has devoted considerable attention to residential air sealing. In a modern well-insulated home, air infiltration can account for as much as half of the total heat loss.[28] Duct leakage alone can result in energy losses of 12 - 20 percent. I make the assumption, therefore, that in the absence of air sealing, usage will be higher by an equivalent amount.

Given the age and type of housing found in the Chalmers development, it would be reasonable to expect heat losses due to air infiltration at the higher end of the potential range. However, without some measurement of infiltration, no particular number could be supportable as a rule of thumb. To come down in the middle part of the range, and to provide an indication of the scope of the adjustment that would be necessary to account for air infiltration, I have made a heating adjustment to reflect a 30% heating loss attributable to air infiltration (*i.e.*, leaks). That adjustment yields a final heating consumption as follows:

[28] Larry Palmiter, Ian Brown and Tami Bond, "Infiltration and Ventilation in New Electrically Heated Homes in the Pacific Northwest," in *Residential Data, Design and Technologies--Proceedings from the ACEEE 1990 Summer Study on Energy Efficiency in Buildings*, at 9.241, American Council for an Energy Efficient Economy: Washington D.C.

{PRIVATE }Unit Size (BRs)	Space Heating Consumption (ccf)	Adjusted for Leaks
1	185	264
2	207	296
3	225	321
4	337	481

I have not calculated the corresponding impact on the heating fan consumption though there would be such an impact.

1.4Natural Gas Summary

In sum, I reach the following conclusions with respect to the Austin Housing Authority's natural gas consumption for utility allowances:

1.While it is impossible to determine the basis for the AHA cooking allowance, it appears to be unreasonably low.

2.The natural gas domestic hot water allowance is unreasonably low in at least the following ways:

a.The per occupant hot water consumption is too low.

b.The tank temperature (and thus the Delta-T) is too low.

c.The assumed energy efficiency is too high.

3.The natural gas space heating allowance is unreasonably low in at least the following ways:

a.The assumed wall and ceiling R-values are unreasonably high.

b.The assumed absence of air infiltration other than through cracks around doors and windows is unreasonable.

Correcting each of these natural gas errors results in the following natural gas consumption allowances in Austin:

{PRIVATE }Unit Size (BRs)	Cooking	DHW	Space Heating	Total
1	69 /a/	342	185	596
2	78	563	207	848
3	89	731	225	1,045
4	97	873	337	1,307
/a/Need to confirm from HUD handbook.				

2ELECTRICITY

The calculation of AHA electric utility allowances raises issues in each of the components. The proposed electric consumption allowances in Austin are as follows for the Chalmers development:

{PRIVATE }	Lights	Refrigerator	Fans/Heat	Misc.	Total
1	635	1183	153	534	2,505
2	777	1314	108	703	2,902
3	920	1445	123	1002	3,490
4	1007	1557	150	1323	4,037

2.1Fans/Heating

The electric consumption for fans/heating is for the purpose of operating the furnace fan on the forced air heating system. This fan consumption is dependent on the heating needs calculated above in these comments. The electric fan requirements associated with the increased heating needs are:

{PRIVATE }1	209
2	161
3	179
4	289

2.2Refrigerators

The primary change to the electric utility allowance comes in the refrigerator component. The refrigerator allowance provided by the AHA consultant is uniform throughout the country. MTS, for example, has used the identical refrigerator allowances in the calculation of electric consumption in Rock Island (IL), Dade County (FL), and Austin (TX).

The use of a national figure is inappropriate for setting refrigerator electricity consumption for a Texas housing authority. We know that when you have two spaces next to each other, one of which is colder and the other which is warmer or hotter, there will be a heat exchange between the two spaces. The amount of energy it takes to keep a space cold is directly related to what's called the Delta-T, the temperature difference between the cold space and the warm space. This has significance for us here because what it means is that it takes more energy to keep a refrigerator cold in Texas than it does in other parts of the country (and certainly more so than any national average).

This conclusion is not mere conjecture. The *Residential Energy Consumption Survey*,[\29\] Table 5.27, presents refrigerator consumption figures for the country as a whole, as well as for the five most populous states. As the RECS states, the average refrigerator consumption for the total U.S. is 1,386 kWh per year. The Texas annual refrigerator energy consumption, however, is 1,860 kWh a year. If the AHA utility allowance is going to be based on published sources (rather than on some type of engineering calculation), it is unreasonable to use a national average when Florida-specific consumption data is available.

The impact of ambient room temperatures on the kWh of use by refrigerators is recognized both by engineering estimates and by measured consumption. As with heating consumption, the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) publishes guidelines on how to calculate refrigeration consumption. According to ASHRAE, a refrigerator's electric use can be estimated using the following equation:[\30\]

[\29\]U.S. Department of Energy's Energy Information Administration, Washington D.C. (1993).

[\30\]***1998 ASHRAE Handbook: Refrigeration***, at Chapter 12, Refrigeration Load (SI Edition), American Society of Heating, Refrigerating and Air Conditioning Engineers: Atlanta, GA.

EQ-2 $$q = uA \Delta t$$

Where
q = heat gain, W
A = outside area of section, m^2
Δ t = difference between outside air temp and air temp of refrigerated space

The significance of this equation for our purposes here is not in the ultimate outcome of the calculation. Instead, the significance lies with the various factors in the equation. The relevant factor showing the sensitivity of refrigerator consumption to ambient room temperature is the Delta-T factor. As this factor increases, the heat gain (q) will increase as well, with a resulting increased energy consumption for the refrigerator.

These engineering estimates have been confirmed by measured energy use in empirical studies. According to research published by the American Council for an Energy Efficient Economy, "a number of researchers have reported on the strong dependence of refrigerator performance on outside air temperature,[31] which is presumed (in the absence of monitoring kitchen temperature) to be highly correlated with the temperature in the immediate environment of the refrigerator."[32] Detailed long-term monitoring of residential refrigerator consumption "showed substantial increases in consumption with kitchen temperature."[33] A December 1997 study of energy efficiency in Florida households reported that "experience indicated that refrigerator energy use in Florida homes is often 10-20% greater than the label values due to higher interior temperatures."[34]

Based on both the conceptual and empirical data relating refrigerator consumption to room temperatures, I conclude that the use of a national average refrigerator consumption for

[31] J. Proctor and G. Dutt (1994). "Pacific Gas & Electric Company Refrigerator Rebate Evaluation Monitoring Report," Proctor Engineering Group, Corte Madera, California; A. Meier and A. Megowan (1993). "The New York State Refrigerator Monitoring Project," Lawrence Berkeley Laboratory, LBL-33708, Berkeley, CA.

[32] Laurence Kinney and Michael Stiles (1994). "Refrigerator Monitoring System Development and Field Testing Results," ACEEE 1994 Summer Study on Energy Efficiency in Buildings, at 2-209, American Council for an Energy Efficient Economy: Washington D.C.

[33] D. Parker and T. Stedman (1992). "Measured Electricity Savings of Refrigerator Replacement: Case Study and Analysis," in *Commercial Performance: Analysis and Measurement--Proceedings from the ACEEE 1992 Summer Study on Energy Efficiency in Buildings*, at 3.199-3.211, American Council for an Energy Efficient Economy: Washington D.C.

[34] Danny Parker et al. (December 1997). ***Measured Energy Savings of a Comprehensive Retrofit in an Existing Florida Residence***, Florida Solar Energy Center: Cocoa, FL.

purposes of determining AHA utility allowances is inappropriate and unreasonable. In the absence of adequate engineering estimates, I recommend the use of the U.S. Department of Energy's Texas refrigerator consumption adjusted for unit sizes in the same proportion as presented by AHA:

{PRIVATE }Unit Size (BRs)	Consumption
1	1,860 /a/
2	2,066 /a/
3	2,272 /a/
4	2,448 /a/
/a/Increased use per unit size in same proportion as presented in MTS utility allowance study for AHA.	

2.3Miscellaneous Appliances

The AHA electric consumption provided for miscellaneous small appliances is inadequate to account for the usage of such appliances. Unfortunately, it is impossible to ascertain the "miscellaneous" appliances which AHA provides for in the four corners of the utility allowance "study." All the utility allowance study reports is a set of final numbers as follows:

{PRIVATE }1	534
2	703
3	1002
4	1323

No indication is given of what appliances underlie these numbers. We know from the MTS Dade County study that MTS includes at least the following in the calculation of miscellaneous electric usage:

{PRIVATE }Unit Size	TV	Radio	Wash'g Machine	Total
1				0
2	228	69	38	335
3	319	84	64	467
4	411	107	89	607

The difference between Dade County and Austin is inexplicable without further inquiry. Miscellaneous appliances include things such as clocks, toasters, microwave ovens, blenders, coffee makers, irons, vacuum cleaners, and other small appliances. The AHA utility allowance study does not include any such small appliances. This failure to include other miscellaneous appliances is unreasonable and contrary to HUD regulations. When the proposed utility allowance for "small appliances" is considered in light of reasonable small appliance consumption (e.g., toasters, vacuum cleaners, microwave ovens), it becomes evident that the proposed electric allowance for "small appliances" is unreasonable low. The basis for this recommendation lies in the list of small appliances in a typical home, and their associated annual electric usage, presented in the table below.

I would propose that the "small appliance" consumption for a 1 bedroom unit be increased to 825 kWh per year with increases for other unit sizes in the same proportion as proposed in the AHA study. That results in the following utility allowance:

{PRIVATE }Unit Size (BRs)	Misc. Appliances
1	825
2	1,086
3	1,548
4	2,044

{PRIVATE }Annual Kilowatt Hour (kWh) Usage By Small Appliance	
Hand iron	50
Blender	33
Coffee maker	80
Dishwasher	170
Mixer	3
Microwave	200
Toaster	50
Garbage disposal	10
Hair dryer	50
Stereo	70
VCR	40
Clock	17
Sewing machine	12
Vacuum cleaner	40
Total	825

2.4Lights

The lighting consumption provided by AHA is unreasonably low. The AHA utility allowances presents the following consumption allowances for lighting:

{PRIVATE }1	635
2	777
3	920
4	1007

Lighting consumption is calculated by taking the number of lighting fixtures x the number and size of bulbs in each fixture x the hours of operation. AHA seems to low-ball each of these numbers: (a) the number of fixtures is too few; (b) the use of a single 60 watt bulb per light seems unreasonable; and (c) the number of hours of operation seems to be too few.

The AHA lighting allowance would appear to follow this methodology. AHA presents a "lighting table" as the basis for its lighting calculation. This table, however, is misleading in at least the following respects: (1) the "watts per fixture" is a generic number included in the MTS computer spreadsheet rather than a measured observation at Chalmers; and (2) the "hours per day" operation for each light fixture is a generic number included in the MTS computer spreadsheet rather than a measured observation at Chalmers.

Aside from the objection that lighting utility allowances should be based on some type of actual local data, the generic number included in the MTS spreadsheet is substantively unreasonable. Research should be undertaken to determine whether single fixtures with two 60 watt light bulbs in rooms such as living rooms and bedrooms are substantively reasonable from the perspective of providing illumination for normal activities of daily living.

In the absence of any data upon which to base a review of the AHA lighting allowance, I have included HUD's "monthly electric consumption requirements for lighting, typical ranges." According to the HUD *Utility Allowance Guidebook*, "energy consumption requirements for lighting in public housing typically fall into the ranges" presented here.

{PRIVATE }Annual Lighting Consumption Allowances (kWh) Chalmers					
2 Bedrooms		3 Bedrooms		4 Bedrooms	
Low	High	Low	High	Low	High
1,080	1,620	1,260	2,220	1,440	2,820

Picking the low-point of this range of typical lighting consumption yields the following recommended lighting consumption for AHA:[35]

{PRIVATE }Annual Lighting Consumption Allowances (kWh) Chalmers		
2 Bedrooms	3 Bedrooms	4 Bedrooms
1,080	1,260	1,440

2.5Electric Leaks

One aspect of miscellaneous appliance usage that is increasingly being recognized today involves electric "leaks." As with hot water heaters, which have "stand-by energy losses," many *electric* appliances use power even when they are "off." According to recent research by Lawrence Berkeley Laboratory, TVs and VCRs are the two appliances with the largest aggregate standby losses. Some of the most common sources of leaks are cable television boxes, compact video equipment, and computer peripherals. Altogether, according to LBNL, leaking electricity represents about five percent of total residential electric use, or about 50 watts per home.[36] The Florida Solar Energy Center found a "phantom load" from appliances "that are constantly on but not in use" of 43 W (375 kWh/yr) or four percent of total consumption.[37]

[35] By selecting the low point of the reasonable range, I do not endorse the conclusion that AHA residents should be lower than typical. It is merely to introduce a note of conservatism into the recommendation in the absence of an administrative record.

[36] Alan Meier, Wolfgang Huber and Karen Rosen, "Reducing Leaking Electricity to 1 Watt," Lawrence Berkeley Laboratory Report 42108 (August 1998); Leo Rainer, Steve Greenberg and Alan Meier (1996). "You Won't Find These Leaks with a Blower door: The Latest in `Leaking Electricity' in Homes," American Council for an Energy Efficient Economy Suummer Study in Energy Efficiency in Buildings. LBNL devotes an entire Web page to "leaking electricity." See, http://www.eetd.lbl.gov/Leaking.

[37] ***Measured Energy Savings in an Existing Florida Residence***, *supra*, at text accompanying note 10.

A home with 50 watts of leaking electricity will consumer 438 kWh per year in standby electricity. This standby consumption should be added to the AHA electric utility allowance.

2.6Cooling

You have seen my analysis of cooling allowances in my Dade County report. I do not repeat it here. You should note that empirical research has been found showing that, in Florida, typical users report having 2.5 fans on at any one time with the average fan operated 13.4 hours per day. This research reports that the average power draw for a fan to be 40 W.[\38\] A "sister study" found an average fan use of five fans, operating 12.6 hours per day, with an estimated annual energy consumption of 920 kWh.[\39\]

2.7SUMMARY

Any estimate of an alternative electric utility allowance for AHA is somewhat shaky given the lack of AHA data on what comprised its "miscellaneous" small appliance usage. However, assuming the presence of dishwashers but not washing machines --no allowance was made for washington machines in the hot water calculations-- it is possible to present a reasonable generic electric consumption allowance:

{PRIVATE }Unit Size	Lights	Misc	Stand-By	Refrigerator	Heating Fans	Total
1	840	825	438	1860	209	4,172
2	1080	1086	438	2066	161	4,831
3	1260	1548	438	2272	179	5,697
4	1440	2044	438	2448	289	6,659

3SUMMARY AND CONCLUSIONS

Based on all of the above, I conclude that the utility allowances proposed for the Austin Housing Authority are substantively and significantly inadequate. Neither the natural gas

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\38\ ***Measured Energy Savings in an Existing Florida Residence***, *supra*, at Table 5 and accompanying text.

\39\ ***Measured Energy Savings in an Existing Florida Residence***, *supra*, at note 9.

nor the electric consumption utility allowances reflect reasonable consumption for an energy conservative household.

This letter opinion does not address any "procedural" deficiency in the utility allowances. Nor does it seek to present the substantive analysis within a legal context. Many of the shortcomings identified above, for example, can be traced to a failure to comply with the nine mandatory utility allowance factors set forth in HUD regulations.

Finally, this evaluation is limited to information found on the face of the documents (as supplemented by my general knowledge of the spreadsheet models used by the particular consultant retained by AHA). Any final or complete review, as well as any final opinion, would depend on a review of appropriate discovery and supplemental materials provided by AHA.