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Updated Miscellaneous Electricity Loads and Appliance Energy Usage Profiles for Use in Home Energy Ratings, the Building America Benchmark Procedures and Related Calculations

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Disclaimer

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Abstract

This report addresses the ever increasing percentage of whole house energy use that is attributable to miscellaneous electricity loads (MELs) and major appliances. It builds on earlier U.S. Department of Energy (DOE) reports on the same subject and incorporates the 2005 Residential Energy Consumption Survey (RECS) public use data set to determine how major appliance use is related to the number of bedrooms in existing homes. These data, coupled with existing and proposed DOE appliance testing and labeling standards, are then used to determine a set of baseline lighting and appliance energy end use values for use in the HERS Reference and Building America Benchmark whole house energy analysis procedures. The report makes recommendations for revising the reference standards that are in current use and provides mechanisms for expanding the number and types of lighting and major appliances that are considered to be rated features of a home.

The report also provides a section on the potential of energy feedback devices and home energy management systems to reduce home energy use.

Executive Summary

The introduction of energy codes and standards following the Arab Oil embargo in 1973 has, over time, dramatically altered the energy use patterns in homes, with considerable relative reductions in heating and cooling energy consumption due to increasing minimum code requirements for these energy end uses. Other major appliances, such as refrigerators and freezers, have also seen major reductions. However, for lighting and appliances, the evidence is that energy use has increased, especially as related to advances in home electronics and entertainment. For example, even moderately sized, high-definition TVs now consume more energy than modern refrigerators. Computer simulation studies on the impact of residential energy codes in Florida show that, for the same sized home, while heating, cooling and hot water energy uses comprised 72% of total new home energy use in 1980, these uses now comprise only 45% of total new home energy use.[1] Accurate estimates of these appliance and lighting energy

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[1] Fairey, P., 2009, "Effectiveness of Florida's Residential Energy Code: 1979 – 2009." FSEC-CR-1806-09, Florida Solar Energy Center, Cocoa, FL. (http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1806.pdf).

uses becomes increasingly important as we move toward lower energy use objectives for residences, culminating in net zero energy homes.

In 2004, the Residential Services Network (RESNET) began developing standards for rating the energy performance of homes that include provisions for all of the energy uses in a home. The result was established by RESNET as their Home Energy Rating System (HERS) standards in 2006.[2] These standards incorporate provisions for estimating the total energy use in homes by adding energy use estimates for lighting and appliances to estimations for heating, cooling and hot water end uses. At the same time, the U.S. Department of Energy (DOE), through their National Renewable Energy Laboratory (NREL) in Golden, Colorado, developed similar methods for estimating lighting and appliance energy estimates for DOE's Building America (BA) program.[3]

Both the RESNET and the BA methodologies for estimating miscellaneous electricity loads (MELs – i.e. lighting and appliances loads) in homes used the International Energy Efficiency Code (IECC) as a basis for comparison. The BA methodology used the 2003 IECC specification for total internal gains in homes (72,000 Btu/day) to calibrate for residual energy uses that were not accounted for by major appliance energy uses derived from appliance EnergyGuide labels and other national studies. RESNET used a similar methodology but developed a total appliance and lighting energy use based on the internal gain equation used in the 2004 supplement to IECC, which was based on the conditioned floor area of the home. Both methods produced similar results as the BA methodology assumed a base home size of 1800 ft^2 and projected the resulting residual "miscellaneous" loads to other homes' sizes.

Following implementation of the BA and HERS methods for estimating residential MELs, practitioners expressed concern that both methods tend to over predict MELs in large homes. For the BA methodology, the proportion of MELs that is attributed to home size has a value equal to 2.47 kWh/yr-ft^2 and for HERS that value is slightly larger at 2.69 kWh/yr-ft^2. However, both of these values originated from values contained in the IECC requiring that specific internal gains be applied to performance-based code compliance calculations. The data supporting these IECC internal gain simulation requirements are scant.

In 2008, a report commissioned by the U.S. Department of Energy (DOE) examined trends in lighting and miscellaneous electricity consumption in U.S. homes in a comprehensive fashion (Roth et al., 2008). These data, coupled with the U.S. Energy Information Administration's (EIA) 2005 Residential Energy Consumption Survey (RECS) public use microdata[4] are used by this report to "re-derive" a set of standard MELs energy use profiles. In particular, measured energy use of specific equipment is used along with saturation data depending on house size to develop explicit relationships based on available data. One important result of the work is that the proportion of MELs that are directly attributable to the size of residences is moderated to 1.76 kWh/yr-ft^2 compared with 2.47 and 2.69 kWh/yr-ft^2 as used by the current BA and HERS

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[2] RESNET, 2006, "Mortgage Industry National Home Energy Rating Standards." Residential Services Network, Oceanside, CA.

[3] Hendron, R., et al., 2004, "Building America Performance Analysis Procedures." Report No. NREL/TP-550-35567, National Renewable Energy Laboratory, Golden, CO.

[4] http://www.eia.doe.gov/emeu/recs/recspubuse05/pubuse05.html

methods, respectively. This result tends to support concerns that present methods overestimate MELs in large homes.

This report also expands on the number of "rated" appliances and lighting attributes in homes that are considered by comparative simulation methods by adding proposed new rating methods for televisions, clothes washers and clothes dryers. Additionally, the report recommends modifying or improving rating methods for lighting, refrigerators, ranges and ovens and ceiling fans.

Finally, in Chapter 10, this report summarizes the potential of smart meters, energy feedback devices and automated controls in reducing MELs and other energy uses in the home. This chapter includes a thumbnail sketch of current but rapidly advancing technologies.

Appendix B of this report presents a set of proposed modifications to the 2006 *Mortgage Industry National Home Energy Rating Standards* that fully incorporates the findings and recommendations of the report.

1 Introduction

As shown in previous research, miscellaneous electricity loads (MELs) in homes is the fastest growing end-use and one that is difficult to appropriately characterize. A recent report completed by TIAX for the U.S. Department of Energy (Roth et al., 2008) provided a comprehensive examination of recent trends in miscellaneous electricity consumption in U.S. homes. However, the information contained in this report (Roth et al., 2008) has not been fully incorporated into analysis procedures with the Building America Benchmark simulation methodology (Hendron, 2008) because the Benchmark is intended to represent houses built in the mid-1990s, when the Building America program was created. Similarly, the same data has not yet been incorporated into the Home Energy Rating (HERS) procedures (RESNET, 2006).

Similarly, the energy use of some major appliances, such as dishwashers and washers, have advanced in recent years with complex influences on electricity consumption that have not been well-captured in HERS procedures.

In this report, we use the TIAX data, as supplemented by the recently available 2005 Residential Energy Consumption Survey (RECS) public use data set to make significant improvements in the prediction methods for estimating energy use of miscellaneous electric loads. Also in considering how best to incorporate the TIAX and RECS data, we further reviewed and assimilated portions of the MELS calculation procedures developed by NREL (Hendron et al., 2004; Hendron and Eastment 2006) and data tables for some small end-uses not covered by TIAX but previously developed by LBNL (Sanchez et al. 1998; Mills et al., 2008). After critical review of available attributes and approaches, we developed methods for incorporating the information into the currently utilized analysis procedures. Our approach was to balance calculation complexity with the need to address elements that make a significant difference in household energy use either for new buildings or retrofit applications. A secondary benefit of the effort is to make the BA Benchmark and HERS procedures more similar in their treatment for the covered energy end-use loads.

The original HERS process, introduced in 1999, only considers heating, cooling and water heating. Energy codes also typically account for only these three large energy uses. In 2006, the HERS process added appliance and lighting to its process, allowing specific ratings for refrigerators, dishwashers, ceiling fans and lighting. Within this report, we attempt to develop methodologies to cover the following ten end-use categories in a consistent fashion using the best available data:

- Indoor lighting
- Outdoor lighting
- Refrigerators
- Clothes dryers
- Clothes washers
- Televisions
- Dishwashers
- Ceiling Fans
- Ranges and ovens
- Residual MELs

Figure 1 shows the average energy use of a typical American home in 2005 according to RECS data. Those data summarized energy use in a typical U.S. household, consisting of 2.57 occupants in a building totaling 1,970 square feet of conditioned floor area.[5] The average U.S. household, reflecting the most typical saturation, has natural gas heat, but uses an electric range and dryer. Such a household uses about 10,918 kWh and 589 therms of natural gas.

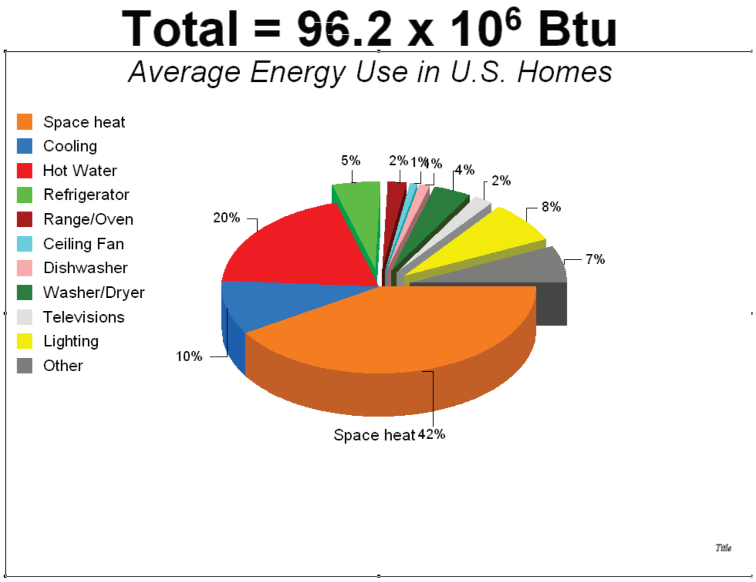

Figure 1. Average energy end uses in the average U.S. household in 2005. Note that the exploded sections of the chart show the 28% of household energy use by the analysis in this report.

As shown in the figure, the analysis in this report addresses or revises the 28% of energy end-uses that comprise lighting and household appliances. It also improves the calculation of 60% of typical residential electric uses.

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[5] The source for the data is given in Appendix 1. Note that the breakout of the minor appliances agree very closely with the RECS estimate for lighting and other appliances in that accounting.

Importance of Correct Assessment of Residual Miscellaneous Energy Use

Properly accounting for miscellaneous electricity use is important, particularly if one is concerned with reducing all energy loads (e.g. Zero Energy Homes). Properly accounting for miscellaneous electricity loads is also critical to accurately predicting influences on heating and cooling. Currently, the HERS ratings system place an emphasis on making certain that simulation software adequately predict the influence of various design variations. However, the suite of tests clearly shows that variations in internal heat loads in buildings has large impacts, not only on energy use of the appliances and lighting involved, but also on the heating and cooling loads experienced by the buildings (Judkoff and Neymark, 1995).

This study finds that miscellaneous electricity use does not vary with house size as aggressively as specified by the current HERS Reference schedule. Thus, designers looking to achieve low energy buildings will best evaluate conditions under more realistic influences as proposed in this document. Here are the implications:

- Smaller (e.g. Habitat size) homes will do best to concentrate on reducing appliance and lighting energy in hot climates to achieve lower energy use since internal gains will dominate cooling loads.

- Larger homes will show that improving the building shell is relatively more important since much of it is relative to the internal gains.

In particular, anyone using a simulation metric that examines all building electrical end-uses,for instance trying to design Zero Energy Homes, should ensure that they use the methods provided below to better estimate the miscellaneous electricity use.

Finally, while acknowledging that differences are certain to remain and as previously described (Fairey et al., 2006), it is desirable that the BA Benchmark and the HERS Energy Rating system standards be as consistent as possible. Thus, the current work is viewed as a possibility to improve the consistency of the analysis methods while advancing the calculation methodology itself for lighting, appliances and miscellaneous electric loads. However, application of these recommendations to the Benchmark must be completed in the context of a comprehensive modernization to 2009 construction practices, appliance standards, consumer products, and occupant behavior, along with a revision to the Building America energy savings targets for consistency with the revised Benchmark.

2 Clothes Washers and Clothes Dryers

DOE test procedures for clothes washers and clothes dryers are described in 10 CFR 430, Appendix J and J-1 of the U.S. Federal Register. These two appliances are intimately linked because the clothes washer’s efficacy defines a large portion of the clothes dryer’s energy use. The linkage is due to the fact that clothes washers not only determine the amount of hot water energy necessary to wash the clothes, but they are also a very large determinant in the amount of water that must be removed by the clothes dryer. The Modified Energy Factor (MEF) is a major determinant of the energy use required for drying the clothes.[6] To separate the energy use for the clothes washing machine itself, hot water for the wash cycle and the later influence on dryer energy use, it is necessary to use the test procedures of Appendix J and J-1 to separate the clothes washer energy use from the test procedures. A similar but dependent procedure must be used to estimate the energy use of clothes dryers alone. Only after this procedure is accomplished can the two devices be "mixed and matched" to determine the energy use associated with combinations of the two appliances under various sets of fuel options (i.e. electricity or natural gas). The proposed calculation procedures are based on a simplification of the procedures originally created by Eastment and Hendron (2006).

2.1 Clothes Washers

Clothes washers are a very common household appliance; 95% of U.S. households have them. As seen in Figure 1, their direct impact on energy use is small—less than half a percent of total household energy consumption. However, clothes washers have large impacts on two other energy using appliances: water heaters and clothes dryers. Thus, relative to energy impacts, clothes washers are also complicated since they have three influences on household energy use.

- They directly use electricity to run the machine, typically for the agitator, drum motor and valves and controls.
- The amount of hot water used to operate clothes washers directly impacts the amount of household hot water that must be supplied by the water heating system.
- The effectiveness of the spin cycle at the end of the washing operation influences how much water must be removed by the clothes dryer, and hence impacts its energy use.

Clothes washers add water, agitate and clean, rinse and then spin dry clothes prior to their being removed for final drying in the clothes dryer.

2.1.1 Variation of Clothes Washer Use

The 2005 RECS data reports on how many clothes washing loads are completed in the typical American household. The data shows that 301average laundry loads are done per year. It should be noted that the RECS data generally shows a considerably lower number of laundry loads done per year with an average of 301loads versus the 392 loads per year that were used in the U.S. DOE washing machine performance labeling procedures.

However, the RECS data does show the laundry loads varying by household size:

```
. regress loadsyr bedrooms

      Source |       SS       df       MS              Number of obs =    3610
-------------+------------------------------           F(  1,  3608) =  170.67
       Model |  6357371.21     1  6357371.21           Prob > F      =  0.0000
```

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[6] The clothes washer MEF intrinsically includes the energy use of the washing machine, its hot water and energy used for drying clothes. Within the DOE Energy Guide label for clothes washers, the labeled kWh, and MEF can be used to derive the specific energy use for the clothes washer machine, hot water use and energy used for clothes drying.

```
    Residual |   134395506  3608  37249.3086           R-squared     =  0.0452
-------------+------------------------------           Adj R-squared =  0.0449
       Total |   140752877  3609    39000.52           Root MSE      =  193.00

------------------------------------------------------------------------------
     loadsyr |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    bedrooms |   45.61842    3.49189    13.06   0.000     38.77215     52.4647
       _cons |    164.423   10.93953    15.03   0.000     142.9748    185.8713
------------------------------------------------------------------------------
```

Standard Loads per Year (SLY) = 164+ 45.6*Nbr
where:
Nbr= Number of bedrooms

Although the R-square is very low, the t-statistic shows an undeniable relationship with the number of bedrooms in the home. Given this formulation, the average three-bedroom household will wash 301 laundry loads per year:

Bedrooms	Loads
1	210
2	256
3	301
4	347
5	393

Different washing machines have different volumetric capacities. To account for this fact, a Nominal Cycles per Year (NCY) is calculated based on the SLY and a standard washing machine capacity of 3.0 ft^3.[7] For this purpose, the capacity of the "typical" clothes washer (2.847 ft^3) used in the DOE engineering analysis for development of the clothes washer test standard is used to create a ratio that can be applied across the variety of clothes washer capacities such that the same quantity of clothes is washed for the household regardless of washer capacity. Thus, the nominal cycles per year for washers become:

NCY = (3.0/2.847) * (164 + Nbr*45.6)

Within our proposed estimation procedure we explicitly assume that a clothes dryer load is done for each clothes washer load. The BA Benchmark currently assumes that 84% of washer loads result in dryer loads (Dryer Utilization Factor, DUF= 84%) based on the DOE test method for clothes washers (10 CFR Part 430, Appendix J1). However, here we assume that all clothes washer loads are dried using the clothes dryer unless otherwise specified.

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[7] The average size of standard sized clothes washers in the EPA Energy Star database is 3.31 cubic feet so the average capacity of clothes washers in use in the U.S. is growing—a fact also agreed upon by the Association of Home Appliance Manufacturers (AHAM) in recently described annual trends. Thus, we assume that the base volume of the clothes washer linked to the number of cycles per year was approximately 3 cubic feet.

2.1.2 Procedure to Estimate Clothes Washer Energy Use

The procedures to account for all the various impacts identified above have already been evaluated by Eastment and Hendron (2006). These procedures use data from the clothes washer energy guide label and the machine Modified Energy Factor (MEF). They also use basic algebra to solve for machine electricity use per cycle, hot water energy use per cycle and residual water remaining in clothes at the end of the cycle. We propose that Building America and RESNET adopt a slightly simplified procedure to show the complex influence of washing machines on household energy use. The full procedure is described below.

$$\mathbf{kWh/yr = ((LER/392)-((LER*(\$/kWh)-AGC)/(21.9825*(\$/kWh) - (\$/therm))/392)*21.9825)*ACY} \qquad \textbf{Eqn. 1}$$

where:

LER = Label Energy Rating (kWh/yr) from Energy Guide Label
$/kWh = Electric Rate from Energy Guide Label
AGC = Annual Gas Cost from Energy Guide Label
$/therm = Gas Rate from Energy Guide Label
ACY = Adjusted Cycles per Year

where ACY = NCY * ((3.0*2.08+1.59)/(CAPw*2.08+1.59))

where

NCY = nominal cycles per year based on RECS data
CAPw = washer capacity in cubic feet from the manufacturer's data or the CEC database[8] or the EPA Energy Star website [9] or use default of 2.874 ft^3

Daily hot water use is calculated as follows:

$$\mathbf{DHWgpd = 120.5* therms/cyc * ACY / 365} \qquad \textbf{Eqn. 2}$$

where:

therms/cyc = (LER * $/kWh - AGC) / (21.9825 * $/kWh - $/therm) / 392

Rating and label Data on clothes washer may be found at the following web sites:

EPA: www.energystar.gov/index.cfm?c=clotheswash.pr_clothes_washers
CEC: www.energy.ca.gov/appliances/database/excel_based_files/Clothes_Washers/

2.1.3 Default Vintage (pre 2008) Clothes Washer

For a functional rating method, we need data for the characteristics of older, unlabeled clothes washers and also unlabeled, new clothes washers manufactured before 2008 when the Modified Energy Factor (MEF) increased to 1.27. Thus, the default unit is for a case where there is no label data and for a unit older than those manufactured in 2008.

The default vintage washer is based on the unit described in the DOE engineering analysis with a 2.847 cubic foot capacity and the following energy related characteristics: [10]

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[8] http://www.energy.ca.gov/appliances/database/excel_based_files/
[9] http://www.energystar.gov/index.cfm?c=clotheswash.pr_clothes_washers

LER = \$704
\$/kWh = \$0.0803/kWh
AGC = \$23
\$/therm = \$0.58
CAPw = 2.847 ft^3
NYC = 320 (for 3 bedroom home)
ACY = 333
Therms/cyc = 0.072

Substituting into equations 1 and 2, the annual electric energy and hot water uses for the default vintage (pre 2008) washer become:

Annual energy use = 69.8 kWh/year
Daily hot water use = 7.94 gpd
Daily hot water savings: 7.94 - 7.94 = 0 gpd (this is the baseline hot water use)

2.1.4 Default Standard Efficiency New Clothes Washer (post 2007)

We also propose a standard new clothes washer without label information. The unit would have been manufactured after 2007. Our proposed standard Efficiency new clothes washer meets the required minimum Modified Energy Factor of 1.27. The standard unit is an actual machine: ad *GE WJSR416D* 3.2 cubic foot top-loader (MEF= 1.27)

LER = \$487
\$/kWh = \$0.0803/kWh
AGC = \$23
\$/therm = \$0.688
CAPw = 3.2 ft^3
NYC = 320 (for 3 bedroom home)
ACY = 304
Therms/cyc = 0.038

Substituting into equations 1 and 2, the annual electric energy and hot water uses become:

Annual energy use = 122.6 kWh/year
Daily hot water use = 3.82 gpd
Daily hot water savings: 7.94 - 3.82 = 4.12 gpd

The technical support document on which this calculation is based is the BA Benchmark: http://www.nrel.gov/docs/fy06osti/39769.pdf

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[10] http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/chapter_4_engineering.pdf

2.1.5 Default Energy Star Clothes Washer

We also propose that a default Energy Star clothes washer be made available for use within the RESNET/HERS procedures. The default minimum Energy Star Clothes Washer is a real model: a *GE WJR 5550H*.* It has an MEF of 1.78 and a Water Factor of 7.9 gallons-- it barely complies with the Energy Star requirement. We suggest that thisunit become the new default Energy Star clothes washer for HERS/RESNET and potentially for BEopt as well.

Weblink for EnergyGuide label for GE unit: http://products.geappliances.com/ApplProducts/Dispatcher?REQUEST=SPECPAGE&SKU=WJRE5550HWW&SITEID=GEA

The following input parameters are used for the default Energy Star clothes washer, although the procedures can be automated so the user does not have to input each parameter:

LER = $281
$/kWh = $0.0860/kWh
AGC = $14
$/therm = $0.910
CAPw = 3.5 ft^3
NYC = 320 (for 3 bedroom home)
ACY = 282
Therms/cyc = 0.026

Substituting into equations 1 and 2, the annual electric energy and hot water uses become:

Annual energy use = 38.2 kWh/year
Daily hot water use = 2.46 gpd
Daily hot water savings: 7.94 – 2.46 = 5.48 gpd

Minimum Energy Star Clothes Washer
(*GE WJR 5550H* 3.5 cubic foot top-loader (MEF= 1.78; Water Factor = 7.9)

Shown above, the reduction in hot water use is a major impact of the more efficient clothes washers.

2.2 Clothes Dryers

Some 93% of U.S. single family households have a clothes dryer in the 2005 RECS data. Of these clothes dryers, about 76% are electric. The remaining dryers are fueled by natural gas or propane.

In most households, electric or natural gas clothes dryers replace the need for clothing lines to dry clothes. However, clothes dryers use an appreciable amount of energy in the average household. Electric clothes dryers typically have a 5,000 Watt heating element and a 0.375 hp tumbler motor and fan blower. Typically, they use about 3 kWh per load of clothes dried.

Natural gas clothes dryers typically use a 22,000 Btu/hr burner which can use a fifth of a therm of natural gas for typical loads of clothes and another 0.5 kWh per load for the electric motor operating the tumbler and blower.

To add them to the BA Benchmark and RESNET standard appliance set, we examined a calculation procedure already developed by NREL and compared that method with the measured dryer energy use from various studies around North America. This calculation is described here relative to the original equations. It is also included as an attached spreadsheet showing the automated procedures.

2.2.1 Electric Clothes Dryers: End Use Studies

Considering a variety of end-use metering projects, electric clothes dryer UEC values consume about 900 kWh/yr. Below we summarize the various studies and measurement.

RECS (2001)
Estimates within the EIA's Residential Energy Consumption Survey (RECS) for 2001 show average electric clothes dryer annual Unit Energy Consumption (UEC) to be 1,079 kWh per year.[11]

Southern California Edison (1991)
In the Southern California Edison, a sample of 92 monitored electric clothes dryers showed an average annual electricity consumption of 1,070 kWh (Smith et. al., 1991).

BPA / ELCAP (1986)
The Bonneville Power Administration sub-metered dry ELCAP data (Pratt et al., 1989) showed: Existing homes (n= 206): 918 kWh/yr. In a sample of 77 new homes the average was 987 kWh/yr

Progress Energy Florida (1999)
Data on 145 homes with monitored electric clothes dryers in 1999 showed an average consumption of 885 kWh (Parker, 2002). As the project also collected 15-minute data, the results produce information on daily load shape and also information on how dryer energy use varied with household size.

Multi-Housing Laundry Association
The *Multi-Housing Laundry Association* (MLA) estimates 3.3 kWh typically per electric clothes dryer load. Assuming 301 standard laundry loads per year, according to the RECS data for a three bedroom household, this estimate equates to about 993 kWh/year, which is comparable with typical monitoring estimates.

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[11] http://www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html

Summary:

The average of all five samples with no particular weighting is 1,005 kWh/yr. Thus, a standard BA Benchmark/RESNET standard electric clothes dryer's typical energy use should be in the range of 900 - 1100 kWh.

Although clothes dryers are not an appliance which the U.S. DOE labels, ostensibly because of lack of significant product energy differentiation, technical evaluations suggest that clothes dryer energy use can be reduced (see for instance, Bassily and Colver, 2003). Of these, moisture sensing with enhanced clothes washer spin cycles to remove initial moisture loads are already in progress. Slight changes to current manufacture:

- Improved drum seals to reduce dryer air leakage and shorten drying times
- Increase the outlet flow rate without increasing the inlet flow rate. This has the effect of reducing the impact of drum leakage

Major design changes

- Heat exchanger from air outlet to inlet to allow downsizing of heating element and improved drying efficiency
- Fully condensing clothes dryers
- Heat pump clothes dryers

It should be noted, however, that although clothes dryers do not have labels, their energy efficiency is in fact rated. The tested Energy Factor of the clothes dryers, reported as the lbs of dried clothes per kWh per cycle is available in a database on the California Energy Commission appliances website:

http://www.energy.ca.gov/appliances/database/excel_based_files/Clothes_Dryers/

2.2.2 *Gas Clothes Dryers*

Gas clothes dryers use both natural gas for heat and electricity for the 0.375 hp tumbler motor and the blower and the 400 Watt hot-surface igniter. However, measured data on gas clothes dryer energy use is considerably more limited than for electric dryers.

According to the Multi-Housing Laundry Association (MLA), a typical gas clothes dryer will use 0.17 therms per drying cycle along with 0.5 kWh of tumbler and blower energy.

http://www.mla-online.com/workback.htm

Assuming 301 laundry loads per year on average, this equates to 150 kWh and 51 therms per year for gas clothes dryers. In agreement with this estimate, the *American Gas Association's* 2005 Fact Book shows that a gas clothes dryer will use an average of 51 therms per year. The only monitoring study we could locate was one completed in 1989 by Quantum Consulting (Smith et al., 1991). They found an average of 43 therms used per year in 92 monitored units in

California. Electricity use was not metered. In the KEMA-XENERGY (2004) conditional demand study, gas dryers in California were estimated to use 31 therms and 100 kWh/year. Thus, the available data suggests that gas dryer energy use varies from 31 - 53 therms per year for a typical household and standard efficiency clothes dryer.

Our default clothes dryer in the evaluation procedure uses 35 therms/year and 77 kWh/year to operate the drum, blower and igniter.

2.2.3 Variation of Dryer Energy Use with Occupancy

Realistically, within the HERS/Benchmark procedure, the variation in the use of the clothes dryer is linked with the number of laundry cycles done in the home. This, in turn, is linked to the number of bedrooms and the clothes washer characteristics. We use the same relationship used for clothes washers for the number of annual dryer cycles against bedrooms in the home.

Loads per Year = 164+ 45.6*Nbr

2.2.4 Procedure to Estimate Clothes Dryer Energy Use

As described above, the procedure to estimate clothes dryer energy use is linked to the same procedure that estimates energy use of the clothes washer. An adequate procedure for BA Benchmark and RESNET takes into account the various fuel uses as well as clothes moisture content and impact on dryer energy use. The NREL clothes dryer calculation procedure is based on one used by the U.S. DOE for the evaluation of dryer energy associated with clothes washer operation. The existing BA Benchmark procedure appears fully adequate and within our analysis. Here we check to see that end-uses are being appropriately estimated.

An acceptable method for RESNET should also consider how added loads with greater occupancy and the water contents of those clothes will affect energy use. A “standard” dryer is also needed for the sake of comparison. This comparison is made so that we can estimate how the efficiency of the clothes washer spin cycle affects the energy use of the dryer. Based on the DOE test methods and pre 2008 clothes washers, the baseline dryer energy use is approximately 900-1100 kWh/year.

The calculation procedure here for clothes dryers is taken directly from the evaluation by (Eastment and Hendron, 2006) and is reproduced below. Energy-Guide labeling is not required for clothes dryers; however, a DOE test procedure for clothes dryers does exist for the purpose of determining clothes dryer compliance with federal appliance minimum efficiency regulations. In addition, clothes dryer energy use is dependent on moisture content of the wash load. This method incorporates equations used to determine the Modified Energy Factor (MEF) for clothes washers and equations from the DOE test procedure for clothes dryers in order to model any combination of clothes washer and clothes dryer in a coupled fashion.

The method uses the tested Energy Factor of the clothes dryers, reported as the lbs of dried clothes per kWh per cycle. Data for individual units can be found in this database on the California Energy Commission appliances website:

http://www.energy.ca.gov/appliances/database/excel_based_files/Clothes_Dryers/

From this data, the standard minimum efficiency clothes dryer efficiency factor is 2.67 for natural gas dryers and 3.01 for electricity. For the 516 standard sized electric clothes dryers, the measured EF varied from 2.9 to 3.9. For the 456 gas dryers, the tested EF varied from 2.67 to 3.44. Thus, for our proposed calculation method, we assume that the efficiency of clothes dryers is 3.01 lbs/kWh for electric and 2.67 lbs/kWh for natural gas.

Natural gas dryers also have some electricity use for the operation of the blower and the rotating drum. Within the analysis done by Eastment and Hendron they estimated the electric energy use at 7% of total natural gas dryer energy use. Spot measurements by FSEC on a natural gas dryer verified these numbers as being approximately correct– about 300 Watt hours per cycle for these operations for a standard natural gas dryer.

The procedure also includes an assessment of whether or not the clothes dryer has a moisture sensing termination. Those with this feature – most new models – will see consumption lower by about 12%.

Annual clothes dryer energy use is calculated by equation 3 as follows:

$$\mathbf{kWh/yr = 12.5*(164+46.5*Nbr)*FU/EFdry*(CAPw/MEF - LER/392)/(0.2184*(CAPw*4.08+0.24))} \qquad \textbf{Eqn. 3}$$

where:

Nbr = Number of bedrooms in home
FU = Field Utilization factor =1.18 for timer controls **or** 1.04 for moisture sensing
EFdry = Efficiency Factor of clothes dryer (lbs dry clothes/kWh) from the CEC database [12] or use following defaults: 3.01 for electric or 2.67 for natural gas
CAPw = Capacity of clothes washer (ft^3) from the manufacturer's data or the CEC database or the EPA Energy Star website [13] or use default of 2.874 ft^3
MEF = Modified Energy Factor of clothes washer from Energy Guide Label (default = 0.817)
LER = Labeled Energy Rating of washer (kWh/yr) from Energy Guide Label (default = 704)

We did make small modifications to the Eastment/Hendron procedure. These changes were to assume that the clothes dryer cycles per year is linked with clothes washer size while the weight of clothes washed remains a function of the number of bedrooms and is equal to that of a standard 3 cubic foot washer with a dry clothes weight of 7 lbs for a 3-bedroom home. Thisapproximation was made as there was no reliable data showing how clothes washed varies with clothes washer volume.

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[12] http://www.energy.ca.gov/appliances/database/excel_based_files/
[13] http://www.energystar.gov/index.cfm?c=clotheswash.pr_clothes_washers

2.2.5 Comparison of Calculation to Measured Data

It can be readily shown that the procedures recommended for ratings, including the statistical data and measured end-use, all agree that average electric clothes dryers energy use is about 850-1100 kWh/yr with existing clothes washers. Similarly, annual gas dryer energy use varies from 43 - 53 therms per year for a typical household.

The above calculation procedure is recommended for computing energy use of clothes dryers. In addition, we have identified model characteristics denoting the following classifications which would not need further information:

- Default electric clothes dryer
  - 3.01 lbs/kWh for electric
- Default gas clothes dryer
  - 2.67 lbs/kWh-equiv for natural gas.

Our default electric clothes dryer uses 970 kWh/year in baseline condition (FU=1.18) and 855 kWh/year with moisture controlled cycle termination (FU=1.04). Similarly, the default natural gas clothes dryer uses 35 therms/year and 77 kWh/year; and with moisture controlled termination, it uses 31 therms/year and 67 kWh/year.

3 Dishwashers

Dishwashers have two impacts to household energy use: the energy used by the machine itself and associated impact on household hot water use. The energy use of the machine is not very large – typically 100 - 200 kWh per year depending on frequency of use and vintage. There have been few actual monitoring studies of dishwashers where the units were actually sub-metered. A notable exception was one study performed by the Bonneville Power Administration in 1988 which measured an average consumption of 106 kWh per year in 70 monitored dishwashers (Pratt et al., 1989). However, other studies for the California Energy Commission (Kema-Xenergy et al., 2004), LBNL (Wenzel et al., 1997) and A.D. Little (1998) estimated 84 kWh, 179 kWh and 121 kWh, respectively. Of these, the LBNL study had the strongest basis as it considered measured per cycle energy use rather than reliance on regression methods.

Recently, Hoak and Parker (2008) carefully estimated the machine energy of three widely differing efficiency levels of tested dishwashers and found consumption to vary from 0.9 to 0.35 kWh/cycle with 0.9 kWh/cycle being typical of a standard unit. Assuming that annual cycles per year can easily vary from 100 – 400, this would indicate household energy use for dishwashers varying from 90 – 360 kWh with the average at around 200 kWh strongly depending on the typical number of annual dishwasher cycles. Currently, the LBNL Home Energy Saver software assumes 168 kWh per year from the dishwasher machine itself. However, associated impacts on hot water use can often be greater than the energy directly used by the dishwasher.

3.1 Dishwasher Energy Factor Calculation

The energy-related rating of dishwashers is their Energy Factor. This is defined as 1/ kWh used for doing one load of dishes. Energy factor varies from 0.46 for standard dishwashers all the way up to 1.11 for very efficient models. Energy Star dishwashers have an EF of 0.65 or greater.

Dishwashers have been the focus not only of an analysis of how to derive dishwasher performance from label data (Eastment and Hendron, 2004), but also of an assessment and monitoring of real world dishwasher energy use characteristics (Hoak et al., 2008). Although the Eastment/Hendron analytical method can be used to derive the components of dishwasher energy use, like the evaluation methods for clothes washers, it is complicated and difficult to apply, requiring extensive information both from the dishwasher energy guide label and from the EPA and/or CEC websites. Here, we propose a simpler method for the HERS/Benchmark procedures which utilizes that Energy Guide label or EF value for the dishwasher and the size of the dishwasher (standard vs. compact) to predict impacts on machine energy and associated hot water demand.

The advantage is that the calculation is easily done and only needs the dishwasher EF or the Energy Guide label kWh which are easily available. The source is U.S. DOE's National Impact Assessment for dishwashers and analysis. See Figure 2 for a summary of the source data from the Hoak et al. (2008) analysis.[14]

We suggest this simplification since data we have collected from real dishwashers suggests it will work well and be simpler in application for raters.

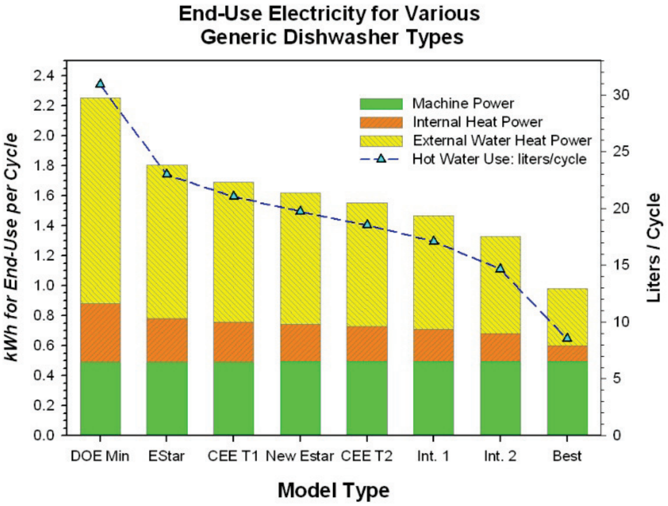

Figure 2. Dishwasher impacts on energy use showing that the largest savings stem from reduced hot water use.

3.1.1 Calculating Dishwasher Machine Energy

The test Energy Factor (EF which is 1/kWh per cycle) and the label for dishwashers can be used to relate to the annual machine-only energy use separate from the external water heating. The assumed cycles per year is 215 in the DOE test procedure.

$$kWh/yr = 86.3 + 0.222 * 215 * 1/EF$$

or :

$$\mathbf{kWh/yr = [(86.3 + 47.73 / EF)/215]*dWcpy} \qquad \textbf{Eqn. 4}$$

where:

dWcpy = dishwasher cycles per year
EF = Labeled dishwasher energy factor

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[14] http://fsec.ucf.edu/en/publications/pdf/FSEC-CR-1772-08.pdf

(Source for this regression showing how internal machine power relates to total power is from the National Impact Assessment by DOE for Dishwashers).

Dishwasher Cycles per year in the 2005 RECS analyzed is:

dWcpy = 88.4 + 34.9*Nbr

```
. reg DWcycyr bedrooms

      Source |       SS       df       MS              Number of obs =    2480
-------------+------------------------------           F(  1,  2478) =  112.48
       Model |  2863098.28     1  2863098.28           Prob > F      =  0.0000
    Residual |  63074734.5  2478   25453.888           R-squared     =  0.0434
-------------+------------------------------           Adj R-squared =  0.0430
       Total |  65937832.7  2479   26598.561           Root MSE      =  159.54

------------------------------------------------------------------------------
       cycyr |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    bedrooms |   34.89742   3.290427    10.61   0.000     28.44515    41.34969
       _cons |   88.44945   10.55624     8.38   0.000     67.74949    109.1494
-----------------------------------------------------------------------------
```

We make a final adjustment to the cycles per year based on the capacity of the dishwasher. This modification is made since most households use dishwashers as soon as they approach being fully-loaded.

dWcpy = (88.4 + 34.9*Nbr) * 12/dWcap
where:
dWcpy= Dishwasher cycles per year
dWcap = Dishwasher place setting capacity; (Range 4 -16); Defaults = 12 settings for standard sized dishwashers and 6 place settings for compact dishwashers

This estimates 193 cycles per year for a three bedroom home with a standard sized dishwasher, and the resulting general equation for the standard dishwasher (12 settings; EF=0.46) as a function of the number of bedrooms is:

dWash kWh/yr = 78 + 31*Nbr

3.1.2 Estimating Dishwasher Hot Water Consumption

Dishwashers, particularly the more efficient models, impact the hot water needed for each cycle as shown in the U.S. DOE data from its National Impact Assessment (NIA) for dishwashers. Thus, they have direct impacts on daily residential hot water consumption.[15] A simple quadratic regression will predict the NIA dishwasher gallons per cycle almost perfectly:

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[15] http://www1.eere.energy.gov/buildings/appliance_standards/

```
. reg gals ef ef2

      Source |       SS       df       MS              Number of obs =       8
-------------+------------------------------           F(  2,     5) =  780.22
       Model |  20.4659717     2  10.2329859           Prob > F      =  0.0000
    Residual |  .065577917     5  .013115583           R-squared     =  0.9968
-------------+------------------------------           Adj R-squared =  0.9955
       Total |  20.5315496     7  2.93307852           Root MSE      =  .11452

------------------------------------------------------------------------------
        gals |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          ef |  -28.49014   1.649299   -17.27   0.000     -32.7298   -24.25048
         ef2 |   12.49906   1.018425    12.27   0.000     9.881116      15.117
       _cons |   18.50763   .6334836    29.22   0.000     16.87921    20.13605
------------------------------------------------------------------------------
```

This relationship estimates gallons of hot water used per cycle for the dishwasher as follows:

Gallons per cycle (gpc) = 18.5 – 28.5*EF + 12.5*EF^2
where EF = labeled Energy Factor of the dishwasher

So, the base dishwasher will use 8.035 gallons per cycle; a minimum Energy Star washer will use 5.3 gallons per cycle, and the best available dishwasher will use 2.3 gallons per cycle. The change to daily hot water use is then calculated as follows:

$$\mathbf{dWdelta\_gpd = [(88.4+34.9*Nbr)*8.035 - (88.4+34.9*Nbr)* 12/dWcap* (18.5- 28.5*EF + 12.5*EF^2)]/365} \qquad \textbf{Eqn. 5}$$

where
dWcap= Dishwasher capacity in number of place settings (default = 12).

Below we list EF and dWdelta_gpd for 3-bedroom homes for a dishwasher with 12 place settings:

EF	deltaGals
0.46	0.00
0.58	0.98
0.62	1.27
0.65	1.47
0.68	1.66
0.72	1.89
0.80	2.29
1.11	3.05

3.2 Comparison of Method with Measured Dishwashers

The default Dishwasher (EF= 0.46; setting =12) in a three bedroom home would show 179 kWh/year for machine energy with 4.3 gallons of hot water used each day to supply the dishwasher.

A minimum efficiency Energy Star dishwasher (EF=0.65; settings =12) would show 152 kWh/year and a reduction in daily hot water use of 1.47 gallons. The various interactions are specified in the HERS/Benchmark spreadsheet.

How does all this compare with real tested dishwashers? For this comparison we have data from the Hoak and Parker assessment (2008).[16] There, the measured electricity use and gallons consumed by the dishwashers was measured.

Standard Kenmore 665-1658220 Dishwasher
EF= 0.49, Measured gallons per cycle = 6.7; Measured electric use: 0.76 kWh/cycle (0.96 with resistance drying).
Model prediction: 7.5 gallons per cycle, Predicted electric use: 0.85 kWh/cycle

EnergyStar Kitchen Aid KUDSO11 Dishwasher
EF= 0.68, Measured gallons per cycle = 5.0; Measured electric use: 0.66 kWh/cycle (0.86 with resistance drying).
Model prediction: 5.3 gallons per cycle, Predicted electric use: 0.73 kWh/cycle

Bosch XHX98M09 Lowest EF Dishwasher
EF= 1.14, Measured gallons per cycle = 2.3; Measured electric use: 0.35 kWh/cycle (1.11 with heavy soiling).[17]
Model prediction: 2.3 gallons per cycle, Predicted electric use: 0.60 kWh/cycle

As seen, the model works well and should be adequate both for HERS and Benchmark purposes.

4 Refrigerators

Virtually all homes in the U.S. have refrigerators with an estimated 183 million units installed that consume one quad of energy in the national economy. Refrigerators are estimated by the RECS survey in 2005 at average electricity consumption in U.S. households of 1,360 kWh. Most modern refrigerators use less than 800 kWh/year, while those manufactured before 1980 often used more than 2,000 kWh per year.Thiscircumstance illustrates two facts regarding this important appliance:

- A significant number of U.S. homes have more than one refrigerator
- Many U.S. homes have older refrigerators

The RECS data itself provides important information about both these facets.[18] Fully 22% of all households have two of more refrigerators and 30% of detached single family homes have a second or even third refrigerator. Refrigerators also last a long time. In some 31% of households the most used refrigerator is older than ten years in age; in 6% of households the main

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[16] http://fsec.ucf.edu/en/publications/pdf/FSEC-CR-1772-08.pdf

[17] This very high efficiency dishwasher does not have an electric resistance drying cycle, but is unusually sensitive to the level of dish soiling.

[18] http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/detailed_tables2005.html

refrigerator is more than 20 years old! The second refrigerator is typically smaller and older; fully 52% of the second refrigerators were older than ten years and 17% were older than twenty years.

The most common refrigerator size and type is still the top freezer with a typical volume around 19 cubic feet, but the larger side-by-side units with through-the-door ice and water are nearly as common. Generally, newer refrigerators– and particularly those in new homes– are of these types.

RESNET standards currently show a standard refrigerator with an energy use of 775 kWh in its reference house. Energy Star refrigerators are at least 20% more efficient than standard types. For instance, a quick evaluation of available Energy Star refrigerators shows many models with an estimated energy use of 618 kWh in the popular side-by-side type of the common 25 cubic foot size. Consumption of refrigerators is highly dependent on size; the estimated maximum annual consumption of a 21.7 cubic foot side by side unit built to the most recent 2005 standards is 671 kWh (U.S. DOE, 2005).[19] However, for this analysis we examined all 5,039 refrigerator-freezers in the California Energy Commission 2009 database.[20] The highest consuming currently manufactured unit, which had a volume of 30 cubic feet, had an estimated annual consumption of 790 kWh. Thus, this finding shows that the choice of the reference refrigerator at 775 kWh a year is a good indicator for typical energy use assuming that the RESNET standard wishes to reward the choice of both more efficient and smaller units. This specification also seems a reasonable choice for the BA Benchmark which wishes to compare consumption to a fictitious home built in the late 1990s.

4.1 Reference Standard Refrigerator

This report recommends that the reference standard for new refrigerators be updated to account for the number of occupants in the home, which according to 2005 RECS data impacts refrigerator size, and to account for the most recent minimum requirements for refrigerator efficiency. To accomplish this task, the 2005 RECS data were regressed to determine the relationship between refrigerator size and the number of bedrooms with the following result:

Frig size No.(y) vs. Number of bedrooms (x)
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.321481
R Square	0.10335
Adjusted R Square	0.103145
Standard Error	0.688125
Observations	4378

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[19] http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrigerator_report_1.pdf

[20] http://www.energy.ca.gov/appliances/database/excel_based_files/Refrigeration/

	Coefficients	*Standard Error*	*t Stat*
Intercept	2.850387	0.02925	97.45024
X Variable 1	0.22248	0.009906	22.45858

However, this regression result is in terms of a “size number,” which contains a range of refrigerator volumes within it (see Figure 3), so some additional analysis is necessary to get to an equation that can be used to define refrigerators in terms of volume (ft^3) and number of bedrooms (Nbr).

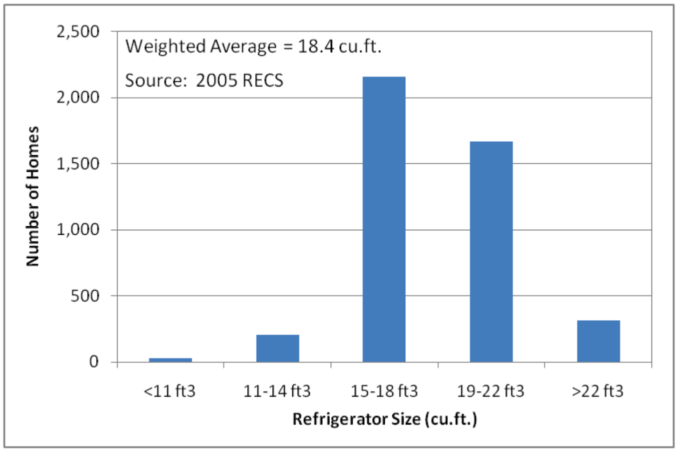

Figure 3. Histogram of refrigerator size categories from 2005 RECS data for existing U.S. homes

To aid in this analysis a histogram of the refrigerator size categories was developed, as shown in Figure 3. These data were then used in conjunction with the regression data to revise the regression equation in terms of refrigerator volume instead of “size number.” First, the original regression equation was solved using the average number of bedrooms in the sample of 2.8. This equation yielded an average refrigerator “size number” of 3.473. The weighted average refrigerator size of 18.4 ft^3 is shown in Figure 3. However, since average new refrigerators are considerably larger than the stock of existing refrigerators in the U.S. (AHAM’s shipment weighted average size was 22.3 cubic feet in 2003), we choose to use that relationship to alter the above equations so as not to bias against newer units which tend to be larger.[21] This volume was divided by this size number (3.473) to determine a conversion factor that could be applied to modify the coefficients of the original regression equation. This modification resulted in the following equation for refrigerator size as a function of the number of bedrooms:

$$\text{frigVol } (ft^3) = 18.3 + 1.43*\text{Nbr}$$

The current 10 CFR 430.32 equation for class 7 refrigerators (side-by-side) with through door ice is as follows:

$$\text{kWh/yr} = 10.1*\text{AV} + 406$$

where:

AV = adjusted volume = (refrigerator compartment volume) + 1.63*(freezer compartment volume), where the refrigerator compartment = 3/5 of the total volume and the freezer compartment = 2/5 of the total volume.

Coupling the above equation for refrigerator volume (frigVol) with the 10 CFR 430.32 equation for annual energy use, one obtains the following standard refrigerator annual energy use as a function of the number of bedrooms in the home:

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[21] Rosenstock, Steve, April 2005. Edison Electric Institute: http://www.peaklma.com/files/public/rosenstockeei.ppt

Nbr	cu.ft	kWh/yr
1	19.7	655
2	21.2	674
3	22.6	692
4	24.0	710
5	25.5	728
6	26.9	746

These data can then be represented using the following general equation for the standard refrigerator annual energy use:

$$\text{frig (kWh/yr)} = 637.4 + 18.1*\text{Nbr}$$

4.2 Rating New Refrigerators

Since the *EnergyGuide* label for refrigerators is both widely available and typically visible, it remains the recommended procedure both for RESNET and for the BA Benchmark procedures to input the energy use of the rated home based on the *EnergyGuide* label for the evaluated or rated home. If the guide is not available, the annual kWh is typically available from the data in the CEC website.

We also conducted an analysis of the minimum *Energy Star* models now available for refrigerators of various size classes based on evaluating the EPA Energy Star Refrigerator website:

Size (Adjusted cubic feet)	Annual kWh
Small (17 - 18 ft3)	433
Medium (21-22 ft3)	443
Large (25-26 ft3)	532
Extra Large (30-31 ft3)	571

Even though this data is made available, it is suggested that the *EnergyGuide* label still be used for estimating the energy use of refrigerators in the evaluated home unless the home's refrigerator has not yet been chosen.

It is also important to realize that since refrigerator efficiency has changed so dramatically over time– and many homes with second refrigerators are an older vintage– it is useful to suggest methods to estimate their energy use if no other label data is available.

The 1993 National Appliance Energy Conservation Act (NAECA) standard for minimum refrigerator efficiency provides a ready method to accomplish this estimate (U.S. DOE, 1995). We break the estimated annual kWh into refrigerator type based on NAECA's established minimum levels of performance:

4.3 Estimating Annual Refrigerator kWh for Older Units

Annual energy use may be estimated for existing refrigerators based on 1993 NAECA procedures.

Type	Annual kWh
Top-freezer:	[16.0*AV + 355] * VR
w/TTD	[17.6*AV + 391] * VR
Bottom-freezer:	[16.6*AV + 367] * VR
Side-by-Side:	[11.8*AV + 501] * VR
w/ TTD	[16.3*AV + 527] * VR

where:
AV = Adjusted volume = (refrigerator compartment volume) + 1.63*(freezer compartment volume)
VR= Vintage Ratio
TTD = thru-the-door-ice feature

Increase consumption by 5% for standard models without TDI but with automatic ice maker. Fortunately, available data suggests how the 1993 NAECA standard can be used to estimate energy from older refrigerators of the same types.

Refrigerator Vintage	Vintage Ratio
1972 or before	2.50
1980	1.82
1984	1.64
1988	1.39
1990	1.30
1993+	1.00

Source: E-Source, Residential Appliances, Boulder, CO, 1995, p. 4.4.1- 4.5.2

5 Range and Oven Energy Use

Cooking is generally an energy end use in every American household, albeit one that has been trending downward as cooking at home has receded over the last two decades. Cooking uses two primary fuels: gas and electricity. In single family homes in the U.S., electric range/ovens account for about 62% of the population; the rest use natural gas or propane.[22]

Below, we show the measured range kWh from the *Progress Energy* sub-metered data taken in Central Florida. There were some limitations that should be understood relative to the monitoring. The study only measured a single range. If there was a counter-top island range that was separate or an "other side of the kitchen" oven, the energy use of only one of these appliances was typically recorded. That means that the average numbers are a likely somewhat low, although this circumstance was not that common. Also, the energy use of other kitchen

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[22] Source: http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc9homeappliance/pdf/alltables.pdf

appliances, such as microwave and toaster ovens, was not recorded and is not part of this characterization.

```
. sum rangekwh

    Variable |      Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
    rangekwh |       67    309.8687    218.5101       87.6     1401.6
```

Average range annual electricity was 310 kWh in the 67 homes which were measured. This average is likely somewhat low. Another monitoring study by *Quantum Consulting* of 92 monitored households in California in 1989 found 385 kWh as the average (Smith et al., 1991).

As part of our evaluation, we examined sources for cooking energy use data. Within the ELCAP data (Pratt et. al.), taken in 1984-85 in the Pacific Northwest, a sample of 206 homes they found range/over energy use to average 510 kWh/year. Those same data did not correlate cooking energy use with bedrooms, but they did summarize consumption with occupancy:

Occupants	Annual kWh
1	350 (n=9)
2	453 (n=83)
3	517 (n=31)
4	526 (n=47)
5+	695 (n=26)

It might be noted that in most recent census data, we find that the average number occupants tends to be lower than bedrooms by about 0.5 occupants.

We also examined a monitoring study done by Pacific Gas and Electric in California (Brodsky, 1987) in which 199 range and range/ovens were monitored from 1985-1986. Total cooking energy use averaged 656 kWh/yr. The study noted that many households had both ovens and range tops and range tops with ovens. However, in this study these appliances were metered separately with the following average UECs: Oven and Range/Oven: (334 kWh) and range top (322 kWh).

Examining the RECS data, the EIA shows oven/range energy use averaging 440 kWh/yr. Although this number is derived by the regression procedures within the RECS analysis and thus is less reliable than the other end-use studies, it still aligns well with the ranges observed in the monitoring studies.

http://www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html

We also examined the RECS data to see how frequency of oven use varied with number of bedrooms and found the following:

RECS OvenUses = 140 + 16.5 * Nbr.

Assuming 2.8 bedrooms and 440 kWh/yr as the standard, the equation for range energy use as a function of the number of bedrooms becomes:

Range (kWh/yr) = 331 + 39 * Nbr = 448 kWh/y for 3 bedrooms.

5.1 Gas Ranges

There are few studies that can be located on the energy use of gas ranges. One measurement study by *Quantum Consulting* (EPRI, 1991) of 92 monitored households in California in 1989 found 32 therms per year was the average consumption for gas ranges. The recent *KEMA-XENERGY* evaluation for CEC (2004) estimated 43 therms per year for cooking and the LBNL Energy Source Data Book (1997) estimated 56 therms. However, the later estimates are perhaps less compelling in that they are based on conditional demand estimates.

Another analysis by RMI estimated that a natural gas range would use 30 therms of natural gas per year. However, the oven part of the range also uses a 350 Watt electric resistance hot-surface igniter so that the two average hours of oven use per week will also use 0.7 kWh of electricity. From a heat transfer standpoint, gas ranges are inherently less efficient than electric resistance elements. Tests described by LBNL (1998) in a comprehensive assessment of cooking technologies, showed a 74% efficiency in transferring heat for resistance coils/halogen elements vs. about 40% for natural gas burners. Induction electric ranges have showed approximately a 90% efficiency in the similar tests.

The same detailed analysis conducted by LBNL (1998) suggests that the “glo” ignition in gas ovens consumes an average of about 48 kWh/year for standard operation.[23] Within our analysis, we assume that gas ranges experience the same frequency of use as electric ranges but that their consumption is about 1 kilowatt hour per therm to yield similar values that are consistent with the LBNL work.

5.2 Cooking Trends and Occupancy

Home cooking has been declining (eating out more often) and likely microwave use and toaster oven use has taken away a part of this consumption. Thus, it is not surprising that the older studies identified above show the highest consumption levels.[24]

We further examined the data to see how cooking varied with occupancy using the Central Florida data. However, we didn't suggest much in the way of explanatory variables to explain cooking energy use. Conditioned floor area was not significant. The bedrooms variable was as robust as occupants in the little explanatory power in the examined relationship:

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[23] http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/cookgtsd.pdf; See Table 1.13.

[24] “Cooking Trends: Are We Really Becoming a Fast Food Country in the United States,” DOE/EIA, http://www.eia.doe.gov/emeu/recs/cookingtrends/cooking.html

```
. regress rangekwh bedrooms

      Source |       SS       df       MS              Number of obs =      67
-------------+------------------------------           F(  1,    65) =    3.53
       Model |  162149.489     1  162149.489           Prob > F      =  0.0649
    Residual |  2989131.51    65  45986.6386           R-squared     =  0.0515
-------------+------------------------------           Adj R-squared =  0.0369
       Total |  3151281.00    66  47746.6818           Root MSE      =  214.44

------------------------------------------------------------------------------
    rangekwh |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    bedrooms |   43.24213   23.02847     1.88   0.065    -2.748904    89.23317
       _cons |   202.7314   62.78305     3.23   0.002       77.345    328.1178
------------------------------------------------------------------------------
```

Interestingly, once occupants were accounted for, larger houses had a negative relationship to cooking energy. One interpretation might be that higher income households in big houses eat out more often. Again, it is important to note that these numbers are probably about 30% low (see the RECS data above).

5.3 Calculation Procedure for HERS/Benchmark for Cooking Energy

Based on the above data, our suggested relationship for annual electricity for range/oven cooking is based on the frequency of cooking with household size based on the RECS data:

Electric Range kWh = 331 + 39*Nbr

5.3.1 Natural Gas

Preserving the same ratio of fixed to occupancy related consumption for natural gas cooking based on the *Quantum* study of measured consumption for gas ranges (consider an approximate average target of 30 therms for a three bedroom home) and considering the fundamental efficiency of the heat transfer process (74% for electric standard vs. 40% for gas) suggests the following for annual energy use:

Gas Range therms = 22.6 + 2.7 *Nbr
Gas Range electric kWh = 22.6 + 2.7*Nbr

Note that we also account for electricity use by the natural gas range. Thus, in lieu of more detailed data, we propose the above relationships for cooking energy end uses, both for the BA Benchmark and for the RESNET standard.

5.3.2 More Efficient Cooking Technologies

There is now a more efficient electric cooking technology. Induction ranges, which are now widely available, have measured efficiencies with heat transfer efficiency about 17% better than an electric resistance or hot surface range as seen in the LBNL study.[25]

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[25] See also: http://theinductionsite.com/

However, in application, only about half of this efficiency improvement can be expected since cooking times/ boiling rates are not always regulated precisely and the oven portion of an induction range is not affected by the improvements to the burner efficiency.

Similar, convection ovens have been measured to reduce oven cooking energy by about 25%-30%, although the degree to which this feature is used and the fact that the oven is used for only about half of cooking use, suggests that a convection oven can only be expected to reduce cooking energy use by about 5%.[26] This estimate also aligns with that in the LBNL study (1998). This advantage for convection ovens applies to either natural gas or electric ranges.

There is also at least one manufacturer of gas/propane ranges that uses solid state ignition for the oven and thus avoids the energy use of the electric resistance igniters.

5.4 Recommended Calculation Procedure for Rated homes

5.4.1 Electric Cooking

Electric Range kWh = BEF * OEF * (331 + 39Nbr)

where:

BEF= Burner energy factor = 0.91 for induction ranges and 1.0 otherwise.
OEF = Oven energy factor = 0.95 for convection types and 1.0 otherwise
Nbr = Number of bedrooms

5.4.2 Gas Cooking

Gas Range therms = OEF*(22.6 + 2.7*Nbr)
Gas Range electric kWh = 22.6 + 2.7*Nbr

where:

OEF = Oven energy factor = 0.95 for convection types and 1.0 otherwise

6 Television Energy Use

There are about 275 million TVs currently in use in the U.S., consuming over 50 billion kWh of energy each year — or 4 percent of all households' electricity use. In 2001, there were 2.3 televisions per household, with 20% of those being big screen TVs. By 2005, this number had grown to about 2.5 TVs per household and 2.8 in single family detached homes. Not surprisingly, the number of big screen TVs has also risen -- 38% of single family homes had a big screen TV in 2005. In 2009, the number is certain to be higher and growing rapidly with the saturation of large digital televisions.

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[26] CPUC, "End Use and Technology Specific Data," California Energy Commission, http://docs.cpuc.ca.gov/published/Report/30174.htm. Consumer data on measured saving of convection ovens: http://www.sfgate.com/cgi-bin/article.cgi?file=/c/a/2003/11/19/FDGFQ33E3N1.DTL

6.1 Televisions per Household

The regression of TVs against bedrooms within the RECS 2005 data shows interesting trends. It only explains 17% of the variation, but the t-statistic is hugely significant – meaning the coefficient of a television for every two bedrooms is a powerful influence on the average of televisions found in households in the United States. The essential relationship from the RECS data:

Typical TVs per household = 1.1 + 0.51 (Bedrooms) [n= 4330]

Source regression:

```
. reg tvcolor bedrooms

      Source |       SS       df       MS              Number of obs =    4382
-------------+------------------------------           F(  1,  4380) =  894.44
       Model |  1271.34033     1  1271.34033           Prob > F      =  0.0000
    Residual |  6225.63389  4380   1.4213776           R-squared     =  0.1696
-------------+------------------------------           Adj R-squared =  0.1694
       Total |  7496.97421  4381  1.71124725           Root MSE      =  1.1922

------------------------------------------------------------------------------
     tvcolor |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    bedrooms |   .5128369   .0171476    29.91   0.000     .4792189    .5464548
       _cons |   1.095679   .0506335    21.64   0.000     .9964112    1.194946
------------------------------------------------------------------------------
```

6.2 Issues with Energy Rating for Televisions

While, televisions comprise an estimated 4% of growing household energy use, there are some significant issues associated with rating televisions within HERS ratings. TV energy use is tied to more factors than the number of sets in the residence. First, the fact that a second (or third, etc.) TV exists in a home does not mean that it will be used as often as the primary television. Second, the primary TV set will likely be larger and use more power than second or third TVs. Both of these facts are revealed in recent research on home electronics energy use by Roth and McKenney (2007). The core data for analog TVs from this study is as follows:

TV:	hrs/day	avgSize	activeW	stdbyW
primary	7.1	30	115	4
secondary	4.3	24	93	4
third	3.3	21	79	4
forth	3.2	21	78	4
fifth	2.0	18	67	4
sixth	1.2	18	67	4

These data clearly show that the primary TV is both larger and is used more often than secondary and following TVs, confounding a simplified rating methodology that would use average annual energy consumption for each TV. Fortunately, these data are well characterized by an equation that is based on the logarithm (base 10) of the TV numbers in the home.

Figure 4 presents the results from a regression analysis of these data showing that viewing hours for multiple TVs in homes are well correlated to the logarithm of the TV number. For these purposes TVs are listed from their largest screen size to their smallest screen size and within a given screen size from their largest active wattage to their smallest active wattage. As seen in Figure 4, the correlation coefficient (R Square) for the resulting regression is reasonable. Thus, we recommend that this procedure for ordering multiple TVs in homes and the resulting regression equation be used to determine the number of hours that multiple TVs will be used in homes.

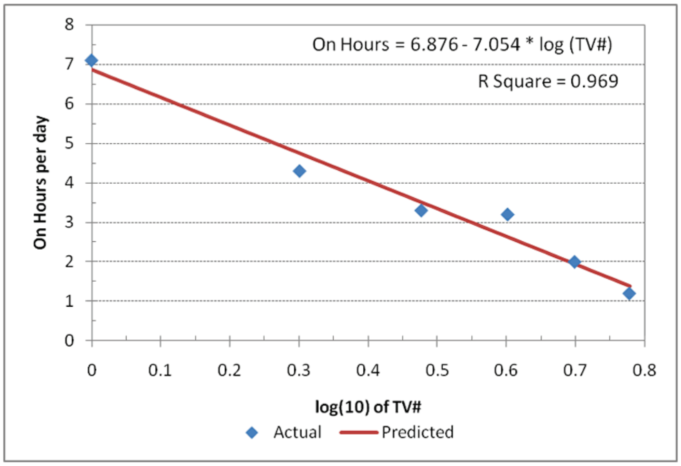

Figure 4. Showing the regression fit of TV viewing hours as a function of the logarithm of primary and secondary TVs in homes.

$$\text{onHours} = 6.876 - 7.054 * \log_{(10)} \text{TV\#}$$
or 0.5 hours, whichever is greater

The source data also show that TV size and active power are related to TV order. The active power data can be correlated to the logarithm of the TV number. However, prior to performing such a regression, it is useful to note that the multiple TV data (Roth and McKenney, 2007) are for analog TVs. The authors are not aware of a corresponding set of data for digital TVs. While digital TVs are not likely to exhibit a significantly different pattern of use with respect to viewing hours, their size and power demand can be significantly larger than for analog TVs. Roth, et al. (2008) report average unit energy consumption (UEC) for analog TVs at 216 kWh/yr per unit with a saturation of 2.05 analog TVs per home. For digital TVs, they report UEC at 392 kWh/yr per unit with a saturation of 0.35 TVs per home. Thus, total average energy consumption for homes becomes 580 kWh per year with a saturation of 2.4 TVs per home, or an average use of 242 kWh/yr per TV set.

This annual average TV energy use value is used along with the viewing hour data to modify the active power demand such that the TV energy use value for a typical 3-bedroom home with $(1.1 + 0.51*Nbr = 2.63)$ TVs equals 636 kWh/year or 242 kWh/yr per TV set. To accomplish this equivalency requires that the active power wattage in the above list be increased by 10% per TV set. This adjustment results in a correlation for the active wattage of standard TVs as follows:

$$\text{actWatts}_{\text{STD}} = 124 - 69.1 * \log_{(10)} \text{TV\#}$$
or 50 watts, whichever is less

The above regression results a correlation coefficient (adjusted R Square) of 0.975. Thus, for the first TV, the active wattage would be 124 watts and the daily viewing time would be 6.88 hours. We propose that the standard TV standby power be maintained as found by Roth and McKenney (2007) at 4 watts. Thus, the standard primary TV would consume (124 watts * 6.88 hours + 4 watts * 17.12 hours =) 922 watt-hours/day or 336 kWh/year.

6.3 Calculation Procedure for Television Energy Use

EPA has largely done the work for ratings and the eventual FTC label that will be seen on all television sets within a year. Within the procedure, the standby (non-active) wattage is measured including the active wattage when in use. These values are tested for each television and will be published on the FTC label. These data are already available within the EPA website for *EnergyStar* compliant televisions. The current spreadsheet can be downloaded here:

http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=TV

It is important to note that the annual energy use values provided in the EPA tables are derived assuming five hours of active viewing and 19 hours of standby wattage. This approximation differs from the procedure described above but the 5 hours is virtually identical to the viewing hour average that one would obtain from the first 3 TV's using the proposed regression equations.

The average television energy use for standard cathode ray tube (CRT) televisions comes from an evaluation done for EPA by the *Cadmus Group* in 2008:[27] This data set is useful in determining the average active wattage of TVs as a function of diagonal screen size. A regression analysis was conducted to make this determination with the following result:

$$\mathrm{actWatts}_{TV} = 9.21 + 1.17*\mathrm{diag} + 0.110*\mathrm{diag}^2$$

This equation may be used to determine the active wattage of TVs that are not otherwise labeled. Additionally, a standby wattage of four watts should be used as the default for TVs that are not labeled. The active and standby wattage is then used in combination with the viewing hours equation to determine annual TV energy use on a unit-by-unit basis, where TVs are ordered by decreasing size and active wattage as described above.

Calculations used to determine annual energy use for either the HERS Reference or BA Benchmark home and the Rated or BA Prototype homes are as follows.

6.3.1 HERS Reference or BA Benchmark Home

The Reference or Benchmark home annual TV energy use is determined based on the following:

$\mathrm{actWatts}_{STD} = 124 - 69.1*\log_{(10)}\mathrm{TV\#}$
or 50 watts, whichever is greater
$\mathrm{offWatts}_{STD} = 4$

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[27] http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/tv_vcr/Dataset.xls

$onHours = 6.876 - 7.054*\log_{(10)}TV\#$
or 0.5 hours, whichever is greater
$offHours = 24 - onHours$

$$\mathbf{TVkWh/yr = \Sigma(actWatts_{STD},i\ *onHours,i\ +\ offWatts_{STD},i\ *offHours,i\ ) + p*(actWatts_{STD},m\ *onHours,m\ +\ offWatts_{STD},m\ *offHours,m)} \quad \textbf{Eqn. 6}$$

where:
$i = 1, n = TV\#$
$n = INT(1.1 + 0.51*Nbr)$
$o = 1.1 + 0.51*Nbr$
$p = o - n$ (a fractional TV)
$m = n +1 = TV\#$ for partial TV

For reference homes with less than 12 bedrooms, the following table may be used to determine the Reference home annual TV energy use:

Nbr	TVkWh/yr	Nbr	TVkWh/yr
1	463	7	858
2	561	8	898
3	636	9	933
4	705	10	966
5	762	11	994
6	814	12	1020

6.3.2 HERS Rated or BA Prototype Home:

For the Rated or Prototype home, TV energy use is determined based on the following protocol.

1) No TV information available – same annual TV energy use as the Reference home
2) EPA Label information[28] or number and size of TVs available
    a. TVs shall be ordered in a list to determine TV# by decreasing screen size and within the same screen size by decreasing active wattage
    b. The number of Rated TVs in the Rated home shall be a minimum of 1.1 + 0.51*Nbr
    c. If number of Rated TVs is less than 1.1 + 0.51*Nbr, then remaining TVs (i.e. 1.1 +0.51*Nbr minus number of Rated TVs), including partial TVs, shall be included in the ordered TV list calculated as standard TVs using the following formula:
    $actWatts_{STD} = 124 - 69.1*\log_{(10)}TV\#$
    or 50 watts, whichever is greater
    d. If number of TVs is greater than 1.1 + 0.51*Nbr, then each TV shall be included in the calculation of Rated home annual TV energy use
    e. If label information is available, active wattage and standby wattage as reported

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[28] http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=TV

on label shall be used for the calculation of annual TV energy use

f. If label information is not available, standby wattage shall be 4 watts and active wattage shall be determined from the diagonal screen size using the following formula:

$$actWatts_{TV} = 9.21 + 1.17*diag + 0.110*diag^2$$

g. Viewing hours shall be determined on a unit-by-unit basis using the following formula:

$$onHours = 6.876 – 7.054*\log_{(10)}TV\#$$
or 0.5 hours, whichever is greater

h. Total annual Rated home TV energy use shall be calculated using the following formula:

$$TVkWh/yr = \Sigma(actWatts_{TV},i *onHours,i \ + \ offWatts_{TV},i *offHours,i) \\ + p*(actWatts_{STD},m *onHours,m \ + \ offWatts_{STD},m *offHours,m)$$

where:

$i = 1, n = TV\#$

$n = INT(1.1 + 0.51*Nbr)$ or total number of Rated TVs, whichever is greater

$o = 1.1 + 0.51*Nbr$ or total number of Rated TVs, whichever is greater

$p = o – n$ (a fractional TV)

$m = n +1 = TV\#$ for partial TV

7 Ceiling Fans

The saturation of ceiling fans in U.S. households has been quickly growing over the last decade. In 2005, there were 111.1 million residential households in the United States; 77.2 million of these households or 69 percent had ceiling fans.[29] This 2005 saturation represents a 27% percent increase over the 61.0 million households with ceiling fans that was reported in the1997 RECS. In houses with ceiling fans, there was an average of 2.9 ceiling fans per household and 2.0 ceiling fans for all U.S. households. Not surprisingly, the saturation of ceiling fans varied strongly by climatic region for the houses they were used. The South (3.2 fans) and Midwest (2.8) census regions had a higher percentage of ceiling fans than the Northeast (2.6) or West (2.4) census regions.

From the various EIA summaries, ceiling fans appear an important end-use energy load in American houses. According to the TIAX study, one of the largest categories of miscellaneous electricity loads (MELs) was ceiling fans. The study also made reasonable assumptions about the average power use of the fans, the fact that ownership is strongly regional and that use varies with the cooling season. Nationwide, the study estimates that each ceiling fan in a home will add about 84 kWh per year. However, the study correctly posits that consumption varies regionally so that the UEC is only 20 kWh/year in New England versus 123 kWh in the South Atlantic region.

However, in this analysis we seek to address several issues associated with ceiling fans in order to improve the calculation methodology within HERS and the BA Benchmark process. In

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[29] http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc9homeappliance/pdf/alltables.pdf

particular, we seek a characterization of how many ceiling fans are typically installed in homes. It is also vital to know how the weather in various locations will influence ceiling fan energy use and thus potential savings around the U.S.

7.1 Power Use of Ceiling Fans

The TIAX study surveyed several studies of ceiling fan speeds and power consumption in both California and Florida. They concluded that the typical speed was medium (ceiling fans typically have low, medium and high speeds). They also concluded that the typical operating wattage was about 35 Watts.

In the past, FSEC has measured ceiling fan power in a number of studies. Low speed tends to be about 10- 20 Watts, medium speed about 25-45 Watts and high speed about 75-95 Watts (Sonne and Parker, 1998). As concluded by TIAX, we agree that medium speed is a good assumption for the calculations. However, there are some differences in fan efficiencies.

A survey of all non-Energy Star ceiling fans, available from *Ecos Consulting,* showed an average medium speed power consumption of 42.6 Watts at a 3,000 cfm flow rate (Fairey, 2005). The power consumption of *Energy Star* models is at least 20% lower than that value but sometimes as much as 40% lower depending on the motor/fan efficiency.

7.2 Hours of Use of Ceiling Fans

In an FSEC study of 400 Florida home in the 1990s, the mean average use of ceiling fans was 13.5 hours on weekdays and 14.2 hours on weekends (James et al., 1996). Occupants in over one-third of these homes reported leaving their fans on 24 hours per day. For homes with fans, the average weekday use was 39.2 fan hours. When averaged over the year, we found 13.7 hours per day for fans that were used but only about ten hours per day for all fans installed.

It is also important to account for the fact that the hours that ceilings are used will obviously vary with the climate and likely seasonally as well. With limited data, we attempt to describe methods to show how ceiling fan use varies with time of year and with weather in a geographic location.

7.3 Load Shape

A larger utility survey (n=371) showed an average of 4.3 ceiling fans in each Florida house with a mean average use of 13.5 hours on weekdays and 14.2 hours on weekends. Over one-third of occupants in these homes reported leaving their fans on 24 hours per day.

Field monitoring was done in two case studies where motor loggers were used to collect data on ceiling fan operation in two very different households. Each home had five fans with data collected over a full year at each home. Average fan use was 12.6 hours/day in one house and 2.7 hours/day in the other where users were very diligent about turning off fans in unoccupied rooms (Sonne and Parker, 1998). Figure 5 and 6 show the two monitored consumption profiles over an entire year.

We found that fans were used most in occupied bedrooms (8.6 hours per day) and to a lesser extent in the living room (2.3 hours per day) and the study of the home (1.2 hours per day). The resulting profiles clearly showed that the bedroom fan was used most at night.

Given the commonly increased use of ceiling fans in nighttime hours, it is logical to assume that the largest use will occur at night but that, on average, there also will be significant daytime use in living and family rooms. The proposed schedule is based on this premise with 60% of maximum available fan energy use occurring at night and 25% occurring during the day. The resulting data are given in Table 1, where the sum of the total daily use fractions equals 10.5 full-load fan hours per day per fan. This estimate is in close agreement with the TIAX evaluation (Roth et al., 2008) of various sources and the weighted assessment by FSEC (James et al., 1996) which showed approximately ten hours per day in households with ceiling fans when total hours are divided by the number of installed fans. The proposed profile of the on-time distribution data are plotted in Figure 7.

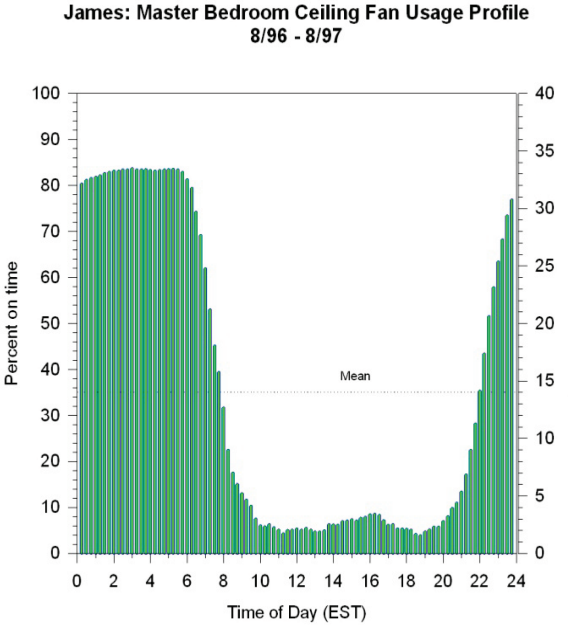

Figure 5. James home ceiling fan load profile

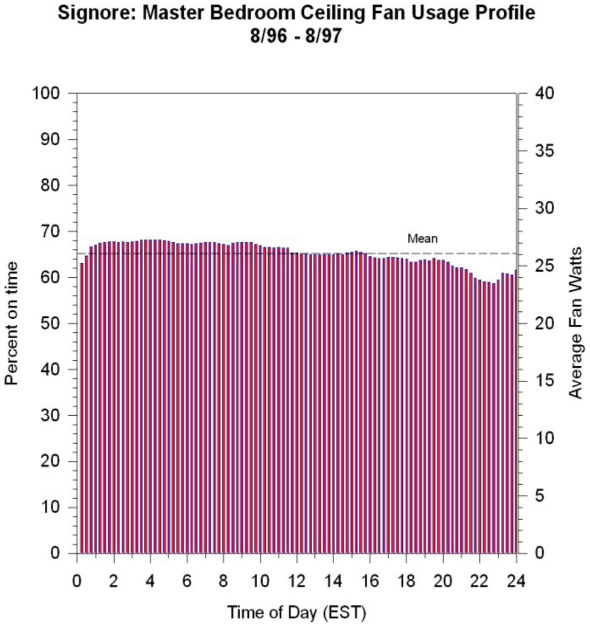

Figure 6. Signore home ceiling fan load profile

In the TIAX report, a proxy for ceiling fan days was determined to be days in which the average air temperature was 70 F or greater. Given that Cooling Degree Days are computed at a 65 F base, this reading seems high. However, based on observation of ceiling fan use in Florida, there is a ceiling fan "season" where behavior does not vary substantially from day to day but rather from month to month as the longer term temperatures continue to cool. One simplification we propose might be to only assume ceiling fans run in months in which the average temperature is greater than 63 F but that they are then available on all days in that month. This assumption would automatically capture variations both in climate and seasonality.

Table 1. Ceiling Fan Schedule

Hour	Use Fraction	Hour	Use Fraction
1	0.60	13	0.25
2	0.60	14	0.25
3	0.60	15	0.25
4	0.60	16	0.25
5	0.60	17	0.25
6	0.60	18	0.25
7	0.60	19	0.60
8	0.25	20	0.60
9	0.25	21	0.60
10	0.25	22	0.60
11	0.25	23	0.60
12	0.25	14	0.60

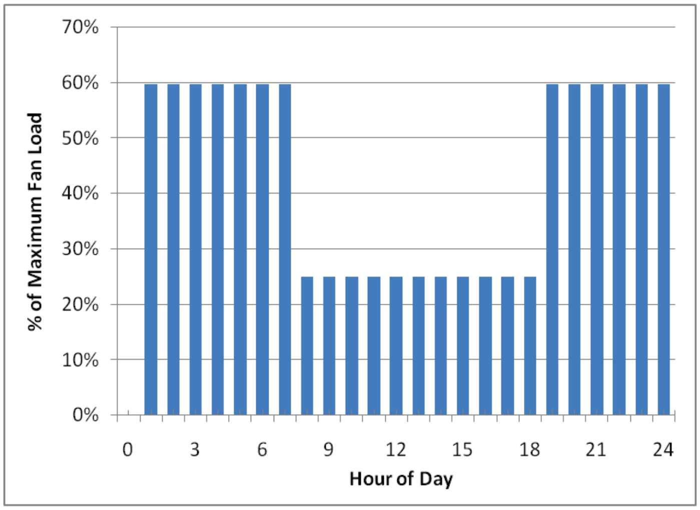

Figure 7. Proposed schedule for ceiling fan operation.

For instance, in Tampa, FL, ceiling fans would be assumed to operate from March - November inclusive (275 days with a total of 3,712 fan hours per fan, leading to an annual consumption of 130 kWh/fan. However, in Denver, CO, the fan season would be June - August, 93 days and 1255 fan hours and 44 kWh/fan. At the extremes, Miami, FL would have a year-round ceiling fan season (365 days and 172 kWh/fan), while International Falls, MN would only have a ceiling fan season for July and August (62 days and 30 kWh). In general, the range of estimates using this procedure are in close agreement with the assumptions also made in the TIAX study.

7.4 Influence of Ceiling Fan Use on Thermostat Setting

Homeowner-reported summer thermostat settings were approximately the same for homes with and without ceiling fans. The smaller sample of measured interior temperatures for July again showed no correlation between temperatures and ceiling fan availability or use. One large study of 400 homes in Florida (James et al., 1996) showed the poor relation found between ceiling fan use and reported and measured interior temperatures. Comparing households that meet the Florida Energy Code requirement with one ceiling fan in each bedroom did show a slight (0.5 ^{o}F) increase in thermostat set point.

Thus, for homes which have a ceiling fan located in each bedroom, the available evidence would suggest a 0.5 F increase in the implemented cooling thermostat set point. However, as noted in the same paper, this level of thermostat increase often will not offset the energy use of the ceiling fans themselves along with their internal heat generation.

7.5 Methods to Reduce Ceiling Fan Energy Use

More energy-efficient *Energy Star* ceiling fans are now on the market. These fans use at least 20% less electricity to provide the same airflow of standard fans. Based on analysis of currently available models as made available by the U.S. EPA, we can estimate example ceiling performance to be as follows:

Non-Energy Star

High	5,000 cfm, 80 W, 62.5 cfm/W
Medium	3,000 cfm, 45 W, 67 cfm/W
Low	1,700 cfm, 20 W, 85 cfm/W

Energy Star (20% better than min. values prescribed by EPA)*

High	5,000 cfm, 55 W, 90 cfm/W
Medium	3,000 cfm, 25 W, 120 cfm/W
Low	1,700 cfm, 9 W, 185 cfm/W

Of course, some ceiling fans have even better performance characteristics than the minimum Energy Star ratings. Thus, their specific performance should be accounted for within proposed procedures if published performance data are available.

* Minimum CFM/W for Energy Star is 155 for low, 100 for medium and 75 cfm/W for high.
http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/ceil_fans/final.pdf

7.6 How do Ceiling Fans Vary within Households?

Assuming that ceiling fans are used in homes, how many are typically installed?
In Florida, a ceiling fan survey for Progress Energy (Parker, 2001) gave a mean of 4.3 ceiling fans in each house, and occupants claimed to use an average of 2.5 fans at one time. We used the large Progress Energy Study audit results (Parker, 2001) to examine how ceiling fan ownership varies. While we found the large expected variation, we also found that ceiling fans scaled somewhat with number of bedrooms (defined to include dens and studies in the auditing procedure) and that number of bedrooms was the best estimator of fan ownership for houses with ceiling fans.

The parsimonious result and the recommended result for BA and HERS is to use the number of ceiling fans as:

No. Ceiling Fans = 1 + Nbr

We used a regression model to estimate how ceiling fan ownership varies with number of bedrooms. While the explanatory power of the relationship was poor (R-square was only 0.12), the t-statistic of the number of bedrooms variable indicated an undeniable influence on the typical number of ceiling fans installed in homes.

```
      Source |       SS       df       MS              Number of obs =     203
-------------+------------------------------           F(  1,   201) =   28.90
       Model |   87.692266     1   87.692266           Prob > F      =  0.0000
    Residual |  609.815123   201  3.03390609           R-squared     =  0.1257
-------------+------------------------------           Adj R-squared =  0.1214
       Total |  697.507389   202  3.45300688           Root MSE      =  1.7418
```

```
------------------------------------------------------------------------------
 ceilingfans |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    bedrooms |   .8264022   .1537135     5.38   0.000     .5233044      1.1295
       _cons |   1.757692   .4690237     3.75   0.000      .832854     2.68253
-----------------------------------------------------------------------------
```

The t-statistic (5.38) for number of bedrooms is highly significant meaning that the number of bedrooms is an important driver for the number of ceiling fans in homes.

The averages by the number of bedrooms

```
______________________________________________________________________________
-> bedrooms = 2
    Variable |     Obs        Mean   Std. Dev.       Min        Max
-------------+--------------------------------------------------------
 ceilingfans |      56       3.625    1.66856          0         10


_______________________________________________________________________________
-> bedrooms = 3
    Variable |     Obs        Mean   Std. Dev.       Min        Max
-------------+--------------------------------------------------------
 ceilingfans |     110    4.145455   1.723216          0          8


_______________________________________________________________________________
-> bedrooms = 4
    Variable |     Obs        Mean   Std. Dev.       Min        Max
-------------+--------------------------------------------------------
 ceilingfans |      32     4.90625   1.802496          0          7


_______________________________________________________________________________
-> bedrooms = 5
    Variable |     Obs        Mean   Std. Dev.       Min        Max
-------------+--------------------------------------------------------
 ceilingfans |       4        5.75   2.217356          3          8


______________________________________________________________________________
```

7.7 Summary of Recommendations for Ceiling Fans

We present summary recommendations for how to treat ceiling fans in either Benchmark or in HERS simulations

1) Ceiling fan electricity consumption = 42.6 Watts when on; 34 Watts for default Energy Star ceiling fan models. Otherwise with labeled CFM/W values at medium speed, the consumption is computed as: W = 3,000 cfm/ CFM/Watt(Medium Speed)

2) Ceiling fan on-time = 10.5 hours/day, preferably distributed according the fractional-on time schedule given in Table 1 and shown in Figure 7.

3) Assumptions on the number of ceiling fans installed for the credit:
   Cfan, number = 1 + Nbr

4) Internal Heat Gain: 100% of the fan power consumption is assumed released indoors.

8 Lighting Energy Use

Lighting energy consumption in U.S. homes accounts for about 7% of total site energy use but approximately 20% of total average electricity energy use. Thus, when energy is evaluated on a source energy basis, lighting is a major energy end-use in U.S. homes.

Estimates of interior household lighting energy in the United State vary from a low of approximately 1,000 kWh per year (EIA, 1996) to approximately 1,820 kWh/year based on monitoring individual light fixtures in 161 homes in the Pacific Northwest (Tribwell and Lermann, 1996). These homes had a floor area of approximately 1,800 square feet. Another study in 53 homes with a sample of fixtures monitored suggested an annual energy use of lighting of 2,390 kWh/year (Carlson, 1994). The EIA estimate has high uncertainty as it was based on a conditional demand analysis– a fact revealed in its own analysis (see EIA, 1996; Appendix C).

It is also worth noting that FSEC did two case studies in Florida homes where the energy use of each light fixture was measured over an entire year. Although only case studies, these two houses showed much higher lighting levels– averaging 2.5 kWh/square foot of floor area. The energy use of outdoor nighttime lighting was very high in one of the houses. (Parker and Schrum, 1996) where the overall consumption was estimated at 4,050 kWh/year (3.02 kWh/sqft) with 34% of the measured lighting energy outside the home.[30] The other home that had each fixture measured showed 2.05 kWh/sqft. While these remain case studies only, they point out the likely high variability of home lighting and also the importance of accounting for outdoor lighting.

In monitoring of 171 homes in Central Florida, FSEC estimated lighting energy use and its demand profile in the *Progress Energy* households (Parker, 2001). The lighting fixtures were audited as well with the finding of 29 average lamps in the households and a connected potential lighting load of 1.5 kW. Average fixture power was 60 Watts.

To estimate household lighting use in that study, we used the “other” residual electrical demand profile over a daily cycle and subtracted the base load from the profile. This method results in a lighting load profile which is zero at 4 AM. Although this is strictly not the case due to nighttime lighting, previous analysis of this technique shows that it can fairly well estimate the lighting demand profile (Parker and Schrum, 1996). Since the resulting profile obviously includes television, stereo and other end uses, we then bound a likely estimate of the lighting demand profile by three values: one 60% of the resulting loads as the lower bound, 75% as the most likely and another 90% as the upper bound for lighting energy use. This methodology results in the lighting demand profile seen in Figure 8.

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[30] Some 23% of the household lighting energy use was in the kitchen area– in agreement with standard engineering estimates which show lighting energy use in this room to dominate home lighting energy use. See Table 2: http://www.fsec.ucf.edu/en/publications/html/FSEC-CR-914-96/

Since the estimate was obtained by differencing metered end-use loads from total, there was some uncertainty. Our estimates ranged from a low of 940 kWh to a high of 1,500 kWh. Average house size was 1580 sq ft, so the median average consumption would be about 0.8 kWh/sqft. There is also an implicit assumption within the way we estimated lighting – that lighting energy goes to zero when "other" was at its minimum at 3 AM (see Figure 8 illustrating the analysis). Of course, this is not likely true (some lights on in the average house at 3 AM), so the most likely value is probably between 1,220 and 1,950 kWh/year (0.9 kWh/sqft). Thus, we arrived at the conclusion that an estimate of 0.9 kWh/sqft is probably reasonably accurate. This estimate fits very closely with the previously cited data sources, but does not include outdoor lighting.

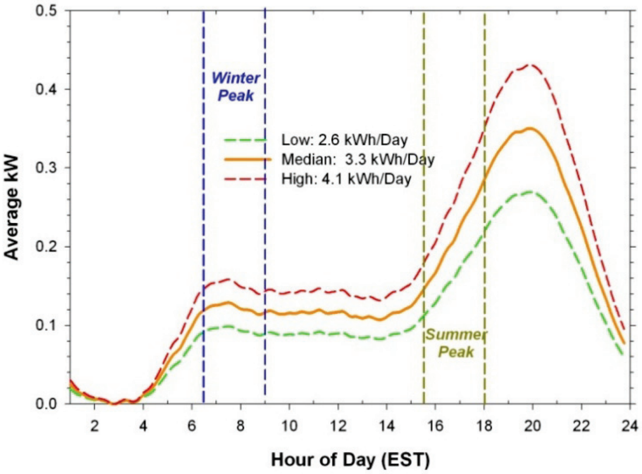

Figure 8. Estimated lighting demand profile and energy use for 171 home sample of Progress Energy homes in 1999.

The number of lamps in households has been audited and varies from 26 - 45 lamps per household depending on the utility study (See Jennings et al, 1995, Navigant 2002 and SCE, 1993). It is also worth considering that while the average home has about 35 lighting fixtures, those fixtures are in no way equivalent in terms of energy use. One study estimated that 25% of the lighting fixtures use 80% of household lighting (Jennings et. al., 1995). Available studies conclude that each lamp is on an average of 2.1 to 2.8 hours per day with an average 60 Watts per lamp typically installed.

8.1 Previous Calculations

The total annual lighting use for the Building America Benchmark is used as the basis for our estimates. These equations were derived from data for both single-family and multi-family housing and were documented in a lighting study conducted by Navigant for DOE (Navigant 2002).

Interior Lighting = (455 + 0.8*CFA) kWh/yr
Exterior Lighting = 250 kWh/yr
Garage Lighting = 100 kWh/yr
where:
CFA= conditioned floor area

Annual indoor lighting kWh was expressed as a linear function of finished house area relative to a constant base value, while garage and exterior lighting are constants. Interestingly, the TIAX study (2008) estimated outdoor lighting to average about 243 kWh per household in the U.S. but did not estimate overall interior lighting levels.

In our proposed formulation, we only split out interior and exterior lighting. The reasons for this simplification to the Benchmark and change to the HERS procedure are as follows:

- The data quality do not support a more detailed assessment relative to garage/outdoor. However, all things equal, larger houses are likely to have larger outdoor and non-interior zones to be illuminated (eg. Large perimeter; larger garages, utility rooms etc.)
- It is useful to explicitly separate interior from exterior lighting since there is a very large difference in impact on space conditioning loads.[31]

We propose the following Reference Home lighting energy use:

Interior lighting = 455 + 0.80*CFA (kWh/yr)
Exterior lighting = 50 + 0.05*CFA (kWh/yr)
Garage lighting = 100 kWh/yr (if and only if the home has enclosed garage)

8.2 Procedure for Calculating Rated Home Impacts:

For an equivalent light output, compact fluorescent lamps (CFLs) require about 25% of the electrical input for an equivalent lumen output. There are many examples.[32] For instance, realizing that the 60 Watt bulb illumination is the most common type in U.S. households, they are typically replaced by a 13-15 Watt CFL. Newly available LED light sources tend to have similar efficacies to the CFLs:

The HERS procedures specify that 10% of the interior lighting in the HERS Reference Home is assumed to be fluorescent. In order to calculate improvements in Rated Home lighting energy use, it is necessary to adjust the standard interior lighting equation to account for this assumption and to provide a variable for the interior lighting fluorescent fraction:

Interior lighting kWh/yr = ((4 – 3*FF_I)/3.7)*(455 + 0.80*CFA) **Eqn. 7**

where:
FF_I = Fraction of interior fixtures that are fluorescent or LED lighting types
CFA = Conditioned floor area

However, the HERS rules also assume that 20% of interior lighting may not be rated for greater efficiency because it consists of plug-in lamps and other rarely used lighting (e.g. hall closets, etc.). As a result, only 80% of lighting fixtures are considered to be in "qualifying locations" for HERS rating purposes. To account for this assumption, the equation must be modified as follows:

kWh/yr = 80%*((4-3*qFF_I)/3.7)*(445 + 0.8*CFA) + 20%*(455 + 0.8*CFA) **Eqn. 8**

where:
qFF_I = Fraction of interior fixtures in qualifying locations which are fluorescent or LED lighting types

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[31] Even if a simplistic fixture count is used to estimate the impact of efficient lighting, having an explicit count of those fixtures interior and exterior that are efficient will lead to better estimates of relative impact.

[32] http://www.gelighting.com/na/home_lighting/ask_us/faq_compact.htm#which_bulb

CFA = Conditioned floor area

Note that if $qFF_I = 0.1$(10%), then equation 8 reduces to the reference standard interior lighting equation (i.e. interior lighting kWh/yr = 455 + 0.8*CFA).

For exterior and garage lighting, the procedure is more straightforward, as follows:

Exterior lighting: kWh/yr = $(50 + 0.05*CFA)*(1-FF_E) + 0.25*(50 + 0.05*CFA)*FF_E$
Garage lighting: kWh/yr = $100*(1-FF_G) + 25*FF_G$

where:
FF_E = Fraction of exterior fixtures that are fluorescent, LED or IR-motion/light level controlled lighting types
FF_G= Fraction of garage fixtures that are fluorescent or LED lighting types.
CFA = Conditioned floor area

Note that internal gains from interior lighting energy are released to the interior at 100% while no heat from exterior or garage lighting is added to the building internal heat gains.

9 Determination of Residual Miscellaneous Energy Use

Along with the 2005 RECS data, the TIAX report has been (Roth, et al., 2008) relied on to generate data for this report. This report describes the miscellaneous electric energy uses in average U.S. homes by appliance end use. A few of these appliances are included explicitly in the above procedures for estimating miscellaneous energy consumption. For example, national average ceiling fan, TV and outdoor lighting energy uses are included in the TIAX data. These uses are explicitly dealt with in the above sections of this report.

Other major appliances that are subject to standardized testing, rating and labeling procedures promulgated by DOE (10 CFR 430) are not included in the TIAX report. For all practical purposes, these items are broadly classified as “major” appliances. These major appliances are also explicitly dealt with in the above sections of the report. This leaves the minor appliances for which we do not have explicit methods of estimating that must be lumped into a category that we will call “residual” miscellaneous energy use. These residual energy uses also must be included in energy estimations for homes; otherwise, we will underestimate whole building energy use in engineering models that are designed to project typical home energy use.

The data for these appliances, as derived from the TIAX report, are given in Table 2.

Table 2. Residual Miscellaneous Electric Loads - MELs (principally from TIAX report)

End Use	UEC	Saturation	kWh/year	Source	Notes
Desk top Computer	235	0.64	150	TIAX	Table 6-20
Well Pump	862	0.17	147	TIAX	Saturation = RECS 2001
Microwave	131	0.96	126	TIAX	Table 4-26
Rechargeable Electronics	69	1.00	69	TIAX	Table 4-71
Spa	2040	0.03	61	TIAX	Tabel 5-15
Set-top Box Cable	133	0.45	60	TIAX	Section 4.14
Computer Monitor	85	0.64	54	TIAX	Section 4.8
Component Stereo	122	0.40	49	TIAX	Table 4-3
Clothes Iron	53	0.92	49	TIAX	Table 5-7
Vacuum Cleaner	42	0.98	41	TIAX	Table 5-25
Printers/MFD	57	0.68	39	TIAX	p. 4-50.
Coffee Maker	61	0.61	37	TIAX	Table 4-16
VCR Player	47	0.79	37	TIAX	Table 4-98
Hair Dryer	42	0.86	36	TIAX	Table 5-5
Toasters & Toaster Oven	39	0.90	35	TIAX	Table 5-21
Water Bed	1096	0.03	33	TIAX	p. 5-35
Component Audio	81	0.40	32	TIAX	Table 4-3
Set-top Box Satellite	129	0.25	32	TIAX	Section 4.14
Aquarium	210	0.13	27	TIAX	Table 5-1
DVD Player	36	0.74	27	TIAX	Table 4-98
Cable/DSL Modem	53	0.40	21	TIAX	Table 4-33
Notebook Computer	72	0.25	18	TIAX	Table 6-20
Home Theater in a Box	89	0.17	15	TIAX	Table 4-3
Security System	61	0.24	15	TIAX	Table 4-74
Clock Radio	15	0.90	14	TIAX	Table 4-3
Portable Audio	17	0.30	5	TIAX	Table 4-3
Other Miscellaneous	329	1.00	329	LBNL	See Sheet #2
Residual Miscellaneous Electric Loads (+10%)			**1,714**		

Since these TIAX data are not tied to any specific average home size, we assume an average home size of 1900 ft^2 (from RECS data) and an average number of occupants (number of bedrooms) of 2.8 (from Census data). This information is necessary because the remainder of typical miscellaneous energy use, as described in the preceding sections, is tied to home size, number of bedrooms or both. Residual MELs are increased by 10% to account for the increases in peripheral home electronics and entertainment devices that have likely occurred since the data contained in Table 2 were collated (~2005). With these assumptions, we are able to calculate the total miscellaneous energy loads (MELs) for a home of this size and number of bedrooms. The data for these lighting and major appliances energy uses are provided in Table 3.

Table 3. Explicit & Total Miscellaneous Energy Uses for national average home (1900 ft^2, 2.8 bedrooms).

End Use	**kWh/year**
Interior lighting	1,975
Clothes dryers	941
Refrigerators	687
TVs	621
Ovens/Ranges	440
Ceiling fans (TIAX national average)	332
Exterior lighting	195
Dishwashers	165
Clothes washers	69
Subtotal Explicit MELs	5,426
Subtotal Residual MELs (from Table 2)	1,714
Total (1900 ft^2 home with 2.8 bedrooms)	**6,984**

It is important to note that the data provided in Table 3 are specific to the characteristics of the home specified in the table. For homes of different square footage and number of bedrooms, the values would change as a function of these variables in accordance with the provisions outlined in the previous sections of this report.

9.1 Proposed Standards for BA Benchmark and HERS Reference Homes

For the purposes of defining the miscellaneous electric loads (MELs) and the internal gains (iGain) in the BA Benchmark and the HERS Reference Homes, we define all end uses and component loads except TVs using the following general equation:

$$Y = a + b*CFA + c*Nbr$$

where:
Y = the appropriate MEL or internal gain as appropriate
a, b & c = the specified offset and coefficients for the calculation of ‘Y’
CFA = the conditioned floor area of the home
Nbr = the number of bedrooms in the home

Table 4a presents two sets of these coefficients for all electric homes. The first, for MELs, determines the total electric use for each end-use component in the home and the second, for total internal gains (iGains), defines the percentage of these MELs that end up as internal gains in the conditioned space. The total internal gains are calculated on a component by component basis as a percentage of each individual end use expected to result in an internal gain in the home. The relevant percentage used in the calculation is shown for each end-use component.

Table 4a. Reference Home miscellaneous electric loads and their associated internal gains*

End Use Components	MELs (total energy use):			Internal (iGain as % of MELs):			
	a	b	c	% MELs	a	b	c
Residual MELs		0.91		90%		0.82	
Interior lighting	455	0.80		100%	455	0.80	
Exterior lighting	100	0.05					
Refrigerator	637		18	100%	637		18
TVs	See Table 4c			100%	See Table 4c		
Range/Oven (elec)	331		39	80%	265		31
Clothes Dryer (elec)	524		149	15%	79		22
Dish Washer	78		31	60%	47		19
Clothes Washer	38		11	30%	11		3
Gen water use					203		68
Occupants				100%			764

* All values given in kWh per year. To convert to Btu/day multiply by (3,412/365) = 9.35

For homes with natural gas cooking or clothes drying, it is necessary to replace the values used in Table 4a for these end-use components with values representing standard natural gas use. Table 4b provides these data.

Table 4b. Reference Home natural gas appliance loads and associated internal gains

End Use Components	MELs (total energy use):			Internal (iGain as % of MELs):			
	a	b	c	% MELs	a	b	c
Range/Oven (therms)	22.6		2.7	80%	18.1		2.2
Range/Oven (kWh)	22.6		2.7	80%	18.1		2.2
Clothes Dryer (therms)	18.8		5.3	15%	2.8		0.8
Clothes Dryer (kWh)	41.0		11.8	15%	6.2		1.8

* Values given in kWh per year or therms per year. To convert to Btu/day multiply kWh/yr by (3,412/365) = 9.35 or therms/yr by (100,000/365) = 274

Table 4c. Reference Home TV electric loads and internal gains

Nbr	TVkWh/yr	TV iGain	Nbr	TV kWh/yr	TV iGain
1	463	463	7	858	858
2	561	561	8	898	898
3	636	636	9	933	933
4	705	705	10	966	966
5	762	762	11	994	994
6	814	814	12	1020	1020

* All values given in kWh per year. To convert to Btu/day multiply by (3,412/365) = 9.35

Note that for the Residual miscellaneous electric loads given in Table 4a there is only a ‘b’ coefficient. This coefficient is simply derived by dividing the total Residual miscellaneous electric load given in Table 2 by the square footage of the national average home (1900 ft^2). Although there is little information on how the residual miscellaneous loads vary with floor area, since they are primarily influenced by plugs and minor appliances which are distributed throughout the building, the likelihood is that these loads at least primarily follow the floor area itself. The derivations for the other miscellaneous electric loads are provided in the previous sections of this report.

General water use, which shows up only for internal gains, is also provided. This item is provided as an estimate of internal energy gains to the space from hot water used in the conditioned space for uses ranging from water use in sinks and showers to kitchen end-uses. It is based on an evaporated water use that does not go down the drain in the average home of three gallons per week, with a commensurate water temperature of 90 °F. It is apportioned to an offset and a coefficient for the number of bedrooms in the home in the same fashion that the standard daily hot water energy consumption is determined (where gallons per day (gpd) = 30 +10*Nbr). The proportion of the two gallons per week attributed as an offset is derived from the offset of 30 and the proportion attributable to the number of bedrooms is derived from the coefficient of ten, such that the value scales with number of bedroom in the home in the same fashion that hot water is assumed to scale. The impact becomes much more clear in Table 5 where internal gains are apportioned into their latent and sensible components.

Occupant internal gains are estimated based on the assumption of one occupant per bedroom. Occupants are assumed to be sedentary, to generate 350 Btu/hr in total gains and to be present within the home for 85% of the day. Of these occupant gains, 44% are assumed to be latent and 56% sensible.

In addition, ceiling fans are not included in Table 4 because they represent a special case that cannot be generally defined for all climates. All the evidence indicates that the use of ceiling fans is strongly dependent on climate with significantly more use in warm southern climates than in northern cold climates. As a result, many homes in northern climates are not equipped with ceiling fans. Therefore, we recommend that ceiling fans be handled in much the same way they are currently dealt with by the RESNET Standards (RESNET, 2006).

Ceiling fans would be included in the BA Benchmark or HERS Reference Home only if they are installed in the BA Prototype or HERS Rated Homes. The annual energy use for ceiling fans would be determined as previously recommended, as a function of the subject climate, where ceiling fan use is expected to occur only in months having an average monthly temperature exceeding 63 °F. During these months, the requisite number of ceiling fans would be operated for 10.5 full-load hours per day in both the Rated/Prototype and Reference/Benchmark Homes with 100% of the energy consumed added to both the home energy use and to the internal gains of the home. Ceiling fans would make no contribution to latent internal gains.

9.2 Internal Gain Percentages

Not all miscellaneous electric loads result in internal gains to the conditioned space of a home. Outdoor lighting is one clear example. Here we provide a recapitulation of the internal gain percentage values contained in Table 4 above along with some of the logic for each value.

Residual – 90% of residual loads are assumed to accrue to internal gains. While there is no reported data to confirm this value, it is considered reasonable as these loads include some fraction of electrical use for electrical tools and equipment that is used outside the conditioned space.

Interior Lighting – 100% of internal lighting loads are assumed to accrue to internal gains for self-evident reasons.

Outdoor Lighting – 0% of outdoor lighting is assumed to accrue to internal gains for self-evident reasons.

Refrigerators – 100% of refrigerator loads are assumed to accrue to internal gains as refrigerators are normally wholly contained within the conditioned space. In the event that second refrigerators or freezers are located outside the conditioned space, such as in an unconditioned garage, they should not result in additional internal gains to the space.

TVs – 100% of television loads are assumed to accrue to internal gains as no televisions are assumed to be located in separate, unconditioned spaces or outdoors.

Range/Ovens – 80% of cooking loads are assumed to accrue to internal gains. The remaining 20% are assumed to be vented to the outdoors by kitchen ventilation hoods.

Clothes washers – 30% of clothes washer loads are assumed to accrue to internal gains. This value assumes that 60% of clothes washer loads result in heat gain through the cabinet but that roughly 50% of clothes washers are located in separate, unconditioned laundry rooms or garages and would, therefore not contribute to internal gains. Clothes washers are sometimes located outside the conditioned space. In these cases, no internal gains would accrue from this appliance.

Clothes Dryers – 15% of clothes dryer loads are assumed to accrue to internal gains. This value assumes that 30% of the clothes dryer load results in heat gain through the cabinet but that roughly 50% of clothes dryers are located in separate, unconditioned laundry rooms or garages and would, therefore, not contributing to internal gains. Like clothes washers, clothes dryers may be located in unconditioned space. In these cases, no internal gains would accrue from this appliance.

Dishwashers – 60% of dishwasher loads are assumed to accrue to internal gains. The remaining 40% is assumed to go down the drain as hot water.

Table 5 presents a breakdown of the total internal gains (iGains) into their latent and sensible load components. Again, the latent component is calculated as a percentage of the individual total internal gain, and the sensible portion is then calculated as the difference between this latent portion and the total.

Table 5a. Latent and sensible partitioning of internal gains*
for all electric Reference Homes

End Use Components	**Latent Gain (as % of iGain)**				**Sensible Gain (iGain-latent)**		
	% iGain	**a**	**b**	**c**	**a**	**b**	**c**
Residual MELs	5%		0.04			0.78	
Interior lighting					455	0.80	
Refrigerator					637		18
TVs					See Table 4c		
Range/Oven	10%	26		3	238		28
Clothes Washer	10%	1		0	10		3
Clothes Dryer	10%	8		2	71		20
Dish Washer	50%	23		9	23		9
Gen water use		133		44	2		1
Occupants	44%			367			462
* All values given in kWh per year. To convert to Btu/day multiply by (3,412/365) = 9.35							

Again, note in Table 5a that general water use is attributed overwhelmingly to latent gains. This is due to the latent heat of condensation and the fact that all of these two gallons per week of water use is assumed to evaporate into the living space. The very small portion that remains as a sensible gain results from the fact that an average water temperature of 90 ^{o}F is assumed for this general water use category.

For homes with natural gas cooking and clothes drying, the values in Table 5a must be replaced by the values in Table 5b.

Table 5b. Latent and sensible partitioning of internal gains*
for Reference Homes with natural gas appliances

End Use Components	**Latent Gain (as % of iGain)**				**Sensible Gain (iGain-latent)**		
	% iGain	**a**	**b**	**c**	**a**	**b**	**c**
Range/Oven (therms)	20.6%	3.7		0.4	14.4		1.7
Range/Oven (kWh)	10.0%	1.8		0.2	16.3		1.9
Clothes Dryer (therms)	11.1%	0.3		0.1	2.5		0.7
Clothes Dryer (kWh)	10.0%	0.6		0.2	5.5		1.6
* Values given in kWh per year or therms per year, as appropriate. To convert to Btu/day multiply kWh/yr by (3,412/365) = 9.35 or therms/yr by (100,000/365) = 274							

The latent internal gains in Table 5a and 5b are based on assumed percentages of the total gains that are latent (moisture) rather than sensible. The latent percentages for natural gas in Table 5b have been increased over their electric counterparts in Table 5a due to the fact that combustion of natural gas produces water vapor at the rate of approximately 10,600 Btu per therm (or approximately 10.6% of the thermal energy). For natural gas energy use, the increased 10.6% is added to the latent percentage given in Table 5a to arrive at the latent percentages given in Table 5b, but the electric energy use latent percentage is left unchanged from Table 5a. The percentages used are the authors' best logical estimates. These estimates are not derived from reported data, and the authors are not aware of empirical data that lend themselves to such a derivation. However, generally accepted engineering practice has long held that latent internal gains should be on the order to 20% of total internal gains. Table 6 provides a set of calculations based on Table 5a values for both total (iGains) and latent internal gains for various all electric home sizes and number of bedrooms as a means of determining the reasonableness of these proposed latent internal gain percentages.

Table 6. Internal Gains (including occupants)

Configuration	iGain*	Latent*	% latent
1000-2br	49.1	10.02	20.4%
1000-3br	57.7	13.78	23.9%
1500-2br	56.6	10.21	18.0%
1500-3br	65.3	13.97	21.4%
2000-3br	72.8	14.16	19.4%
2000-4br	81.5	17.92	22.0%
2500-3br	80.4	14.35	17.8%
2500-4br	89.0	18.11	20.3%
3000-3br	88.0	14.54	16.5%
3000-4br	96.6	18.30	18.9%
5000-4br	126.9	19.07	15.0%
5000-5br	135.5	22.83	16.8%
		Average =	19.2%

* Internal gains given in units of kBtu/day

Based on Table 6, the authors believe that the proposed latent percentages are reasonable and within the bounds of generally accepted engineering practice. The overall average latent percentage for the entire set of all electric home configurations is 19.2%, which is very close to the generally accepted "norm" of 20%. In addition, the 1500 ft^2, 3-br home and the 2000 ft^2, 3-br home bound the 20% norm value, lending some credence to the recommended end use percentages.

The majority of software analysis tools incorporate internal gains in hourly or daily rather than annual increments. Additionally, internal gains are normally expressed in terms of Btu rather than kWh. Therefore, Tables 7a and 7b convert the equation coefficients in Tables 5a and 5b from kWh/yr and therms/yr to Btu/day for ease of use in software analysis.

Table 7a. Internal gains for all electric Reference Homes

End Use Components	**Sensible Gains (Btu/day)**			**Latent Gains (Btu/day)**		
	a	**b**	**c**	**a**	**b**	**c**
Residual MELs		7.27			0.38	
Interior lighting	4,253	7.48				
Refrigerator	5,955		168			
TVs	See Table 7c					
Range/Oven (elec)	2,228		262	248		29
Clothes Washer	96		28	11		3
Clothes Dryer (elec)	661		188	73		21
Dish Washer	219		87	219		87

End Use Components	Sensible Gains (Btu/day)			Latent Gains (Btu/day)		
	a	b	c	a	b	c
Gen water use	27		9	1,868		623

Table 7b. Internal gains for natural gas appliances in Reference Homes.

End Use Components	Sensible Gains (Btu/day)			Latent Gains (Btu/day)		
	a	b	c	a	b	c
Range/Oven (gas)	4,086		488	1,037		124
Clothes Dryer (gas)	739		209	91		26

Table 7c. Sensible internal gains for Reference Home TVs

Nbr	Btu/day	Nbr	Btu/day
1	4,324	7	8,018
2	5,243	8	8,399
3	5,942	9	8,726
4	6,593	10	9,028
5	7,119	11	9,293
6	7,608	12	9,538

For certain applications like performance-based code compliance, which consider only heating, cooling and hot water energy use and for which appliance fuel types are generally not known, it is appropriate to have a single set of internal gains. This can be accomplished by weighting the internal gains for natural gas and electric Range/Ovens and Clothes Dryers according to their market penetrations. According to the 2005 RECS data set, these market penetrations are 38% and 24% for natural gas Range/Ovens and Clothes Dryers, respectively. Table 7d presents these data along with a weighted total, which can be used as the basis for a weighted set of single equations for sensible and latent internal gains for these purposes. Note also that it is necessary to make a number of bedroom assumption to televisions to arrive at weighted totals for these internal gains.

Table 7d. Weighted average electric/gas internal gains for Reference homes

End Use Components	Sensible Gains (Btu/day)			Latent Gains (Btu/day)		
	a	b	c	a	b	c
Residual MELs		7.27			0.38	
Interior lighting	4,253	7.48				
Refrigerator	5,955		168			
TVs (assumes 3-br)	5,942			5,942		
Range/Oven (wgt'd)	2,934		348	547		65
Clothes Dryer (wgt'd)	680		193	78		22
Dish Washer	219		87	219		87
Clothes Washer	96		28	11		3
Gen water use	18		6	1,245		415
Weighted Total	**20,096**	**14.75**	**830**	**8,042**	**0.38**	**592**

9.3 Comparison with Current HERS Standards

Summing the ‘a’, ‘b’ and ‘c’ coefficient values given for MELs by Table 4 results in the following overall equation for MELs (not counting televisions) for all electric homes:

$$\text{MELs (kWh/yr)} = 2{,}163 + 1.76*\text{CFA} + 248*\text{Nbr}$$

Likewise, for the HERS Reference home, RESNET standards provide the following overall equation for MELs (including TVs):

$$\text{MELs (kWh/yr)} = 2{,}016 + 2.69*\text{CFA} + 0*\text{Nbr}$$

where:

CFA = Conditioned Floor Area (ft^2)

Nbr = Number of bedrooms

The offsets for these two equations are very similar – both are very near 2,000 kWh/year. However, the ‘b’ and ‘c’ coefficients for conditioned area and number of bedrooms, respectively, are quite different. On examining these differences, it becomes clear that the coefficient for conditioned area has significantly more impact on the final MELs result than either the offset or the coefficient for number of bedrooms. Even for home sizes of 1,000 ft^2 the conditioned area coefficient yields annual kWh values similar to the offset value and greater than the number of bedrooms value for four bedrooms. Since one of the formulations includes televisions and the other does not, the equations are not directly comparable. However, the two standards can be compared across a range of home sizes and number of bedrooms to observe the differences between the present and proposed standards for MELs evaluation.

Figure 9 presents results of such a comparison showing both the MELs and the total internal gains (not counting the gains from the occupants) for both the current HERS Reference Home and this proposed standard for various home sizes and number of bedrooms. While MELs and internal gains are reasonably similar for the two standards in small homes, it is clear that the proposed standard provides for significantly reduced MELs and internal gains in larger homes. The change in MELs represented by the proposed standard ranges from +13% for the 1000 ft^2, 3-bedroom home configuration to -18% for the 5000 ft^2, 4-bedroom home configuration. The change in internal gains represented by the proposed standard ranges from -0.6% to -24% for the same two home configurations.

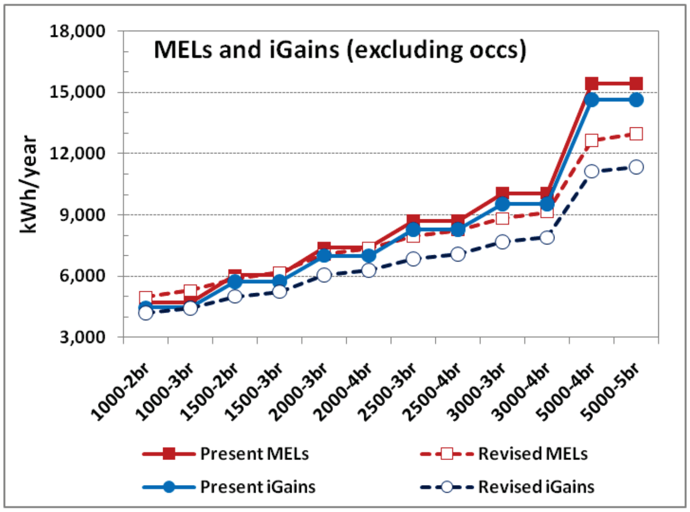

Figure 9. MELs and total internal gains, excluding occupants, in representative home configurations for current and proposed standards.

There have been significant anecdotal reports on this subject, all of which tend to support the perspective that the current standard over predicts MELs and internal gains in large homes. This is consistent with results from this study. It is also a reasonable result since the current RESNET standard for MELs was developed based on the 2003 IECC equation for internal gains in homes, which, in turn, was based on only very limited data and analysis. Thus, it is not surprising that a more detailed study of these lighting, appliance and miscellaneous loads would yield different results.

10 Potential of Energy Feedback, Automated Controls and Smart Meters in Homes

Until recently, most new and existing homes in North America have had no means to judge household energy use other than their monthly utility bill. Unfortunately, this fact does not readily provide insight as to how or where the energy is being used. Available studies show that providing direct instantaneous feedback on household electrical demand can reduce energy consumption by 5 - 15%.[33] Recently, such feedback devices are commercially available and widely being installed in utility smart metering programs around the U.S.

Not only are these feedback-related reductions potentially large as they comprise *all* end-uses, they may provide unique opportunities to realize goals for high-efficiency buildings. Reducing and shifting electrical demand is particularly important in Zero Energy Homes (ZEH), where it would be desirable to match solar electric PV output with household loads. There are parallels with hybrid automobiles, where accumulating evidence suggests that feedback from dash-mounted displays allows drivers of Toyota's *Prius* and other similar hybrids to improve their mileage as they learn from experience. As the physical efficiency attributes of buildings improves, there are decreasing returns to further investment in efficiency upgrades. Behavioral changes may hold the best hope for further cost-effective reductions.

10.1 Feedback Studies

Past studies show that providing household energy feedback promises to reduce consumption, (Katzev and Johnson, 1986; Farhar and Fitzpatrick, 1989). For instance, an early study in Twin Rivers, NJ in the 1970's showed the promise of real-time energy displays to reduce energy use by 10-15% (Seligman and Darley, 1977; 1978). Other early studies showed similar savings (Palmer et al., 1977, McClelland and Cook, 1979). Potential savings also extend to non-electric fuels; Van Houwelingen and Van Raaij (1989) showed a 12% drop in natural gas consumption in Dutch homes provided with daily feedback. A few studies could not reliably observe savings from energy-use feedback. For instance, in experiments in Canada and California, Hutton et al. (1986) showed uneven results with electricity savings of 5% in 92 Quebec homes compared with a control group but less than 3% in a California sample.

There are fewer larger scale studies of the impacts of real time energy-feedback. In one study conducted by *Ontario Hydro* in Canada, Dobson and Griffin (1992) found that displays in 25

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[33] B. Neenan and J. Robinson, Residential Energy Use Feedback: A Research Synthesis and Economic Framework, EPRI-1016844, Electric Power Research Institute, Palo Alto, CA, December 2008.

Canadian homes produced overall electricity savings of 13%, which largely persisted after the devices were removed.

Another intriguing study of instantaneous electric demand feedback was conducted in Japan. This evaluation showed 12% measured average total energy reduction from feedback in ten highly instrumented test homes (Ueno et al., 2005). The savings in electricity were even greater at 18% against those for natural gas (9%). Perhaps most compelling was that measured reductions in "other appliance" electricity use averaged 31%. In Florida, Parker et al., 2007, conducted a study which showed a 7% measured electricity reduction in 20 homes that were tracked over a two year period before and after receiving real-time feedback. A compilation of available data on real-time feedback studies (Darby, 2000) suggests an average 10-15% reduction in overall energy.

Since Darby's compilation, a large sample study of 500 sites compared with a similarly-sized control group has been conducted in Canada using the *PowerCost Monitor*. This project showed a 6.5% savings from having instantaneous feedback to consumers (Mountain, 2006). A further sub-sample showed a 7-10% savings if having the device is coupled with educational tips for what can be done to drop loads. Several large sample studies will soon be available. For instance, a 100 home pilot study of the impact of an enhanced real-time feedback system is being conducted in Cape Cod and Martha's Vineyard (Cole and Calligan, 2009) with results expected in mid 2010. One rather obvious weakness of all the feedback systems thus far is that none of them address natural gas or fuel oil use which is exceedingly common for heating and water heating around the U.S.

10.2 Potential of Comparative Feedback

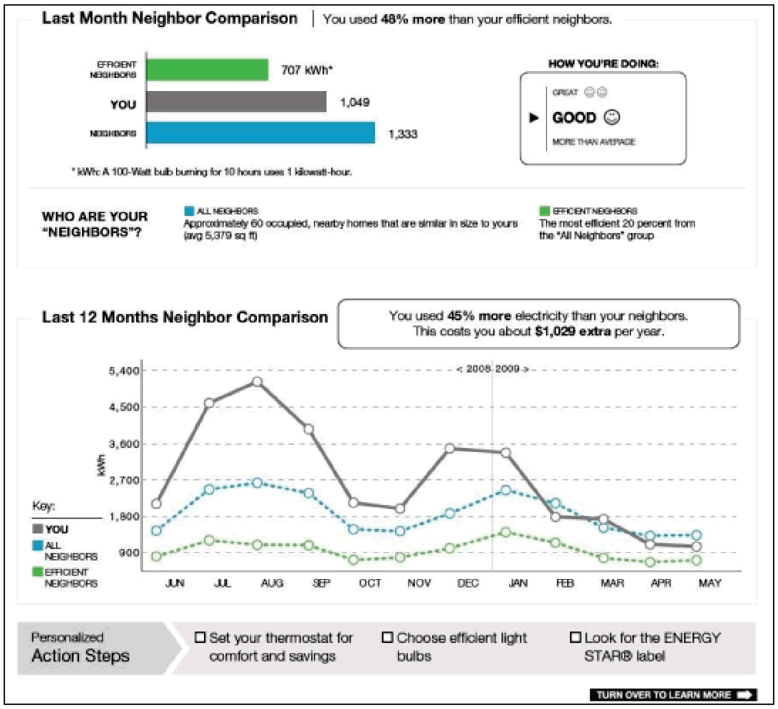
A number of evaluations are finding that energy reducing user behavior can be enhanced by appealing to competitive human nature or providing information. For instance, Ceniceros (2009) found a 2% measured energy reduction in Sacramento, California by simply providing utility bills that showed energy use in comparative homes with a similar demographic. Another study of 175 homes in Madison, Wisconsin found a 7% energy reduction from providing an energy audit along with information on how to reduce home energy loads (Kindig, 2009). Finally in Juneau, Alaska in April, 2008 an avalanche downed power lines, drastically reducing available electric power. When both expert advice, conservation information and a high price signal was provided, the city was able to drop its electricity consumption by over 30% in a matter of days (Chen, 2008). Such studies (IEA, 2005) likely test the maximum potential that behavioral-related technologies have to offer, and such levels are not likely sustainable over the long term without enabling technologies.

Opower is a company focused on home energy efficiency through an innovative program that helps homeowners to see where their energy consumption fits relative to their neighbors. It collects and analyzes utility customers' bills and provides customized reports and recommendations on how to shave consumption. One of the key features is giving people access to a portal where they can see how their energy usage compares to neighbors. Microsoft has a similar system, but the *Opower* system currently appears further developed.[34]

Thus far, *Opower* has partnered with over twenty utilities to provide owner-vs- neighbor comparisons into gas and electric bills. Based on the success of pilot programs in Sacramento and the Puget Sound area in Washington, *Opower* has recently added *National Grid* of Waltham, Mass., and *Seattle City Light*. Currently, one million households currently receive customized reports, which show them how much energy they are using vs. similar households in their neighborhood. (To establish "comparable neighbors," *Opower* looks at the conditioned floor area of the home, heating system type and whether there are large amenities such as a swimming pool.

Results have shown that customers in the program have reduced annual energy usage by an average of 2.8%, or the equivalent of 280 kilowatt-hours per year. In its pilot evaluation with the *Sacramento Municipal Utility District*, the savings have been greatest in households that with the largest energy use pre-*Opower*: Such households have reduced consumption by an average of more than 6%.[35]

10.3 Technology Summary



Last Month Neighbor Comparison | You used **48% more** than your efficient neighbors.

* kWh: A 100-Watt bulb burning for 10 hours uses 1 kilowatt-hour.

WHO ARE YOUR "NEIGHBORS"?

🟦 ALL NEIGHBORS
Approximately 60 occupied, nearby homes that are similar in size to yours (avg 5,379 sq ft)

🟩 EFFICIENT NEIGHBORS
The most efficient 20 percent from the "All Neighbors" group

Last 12 Months Neighbor Comparison

You used **45% more** electricity than your neighbors.
This costs you about **$1,029 extra** per year.

Personalized Action Steps

☐ Set your thermostat for comfort and savings
☐ Choose efficient light bulbs
☐ Look for the ENERGY STAR® label

TURN OVER TO LEARN MORE

Figure 10. Customized *OPower* homeowner monthly energy bill showing motivational comparison with neighborhood.

Due to advances in microelectronics and computing, energy feedback devices and smart meters for home use are now commercially available and low in price. Models typically provide a small wall or desk mounted display that communicates the second-by-second electric power demand of the household. Most accumulate data to show expected monthly utility costs or time related energy cost data. Some devices are now available for as little as $200. For instance, more detailed and expensive systems can report on disaggregated end uses. The *Whirlpool Corporation* has developed an advanced "Energy Monitor" system which provides information on household total

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[34] Not surprisingly, Microsoft has also ventured into the smart grid arena with a home energy management business system called *Hohm*, a Web application. This service is similar to *Opower*, but is it instead emphasizes home innovation and retrofit. So far, Microsoft has signed deals with a couple of utilities so consumers can have bill information fed into the application. Hohm provides advice on how to lower home energy through a detailed survey.

[35] http://www.forbes.com/feeds/businesswire/2009/10/01/businesswire129684303.html

electricity demand and data from 14 separate circuits. In one pilot project with monitoring, no impact was seen although the device was not fully functional. However, the project did show over a five month period from April- August 2005, lighting and plug loads comprised 1300 kWh or 35% of total household use.

This example calls into question whether the additional information is a benefit or liability ("valuable insight" vs. "too much information"). Commercially available models vary in terms of capability. Two popular devices currently are the *PowerCost Monitor* (Masters, 2006) and *The Energy Detective,* TED. Both systems simplify installation by avoiding costly hard-wiring. The TED sends the energy demand signal over household wiring, whereas the *PowerCost Monitor* uses a radio signal from an optical pickup on the meter itself.

Of significance is that the most recent TED device, the *TED 5000* not only allows in-home display of power use but also displays that data on an in-home computer for logging and sharing of the data via an Internet gateway.[36] These data can be made available on TED's own dashboard and with various displays as shown in Figure 11 - 13.

December 11 2009 4:35 PM
Days Left In Billing Cycle: 21
Current Rate In Effect: $0.12000
Plan Type: Flat Rate

MTU 1: 0.402 kW
MTU 2: -0.005 kW
0.402 kW

Peak kW Today: 2.604 kW @ 9:19 AM
Peak $ Spent Today: $0.32 @ 11:40 AM
Low Voltage Today: 116.6 V @ 1:21 AM
High Voltage Today: 122.5 V @ 11:40 AM

Peak KW MTD: 4.852 kW on Dec 2
Peak $ Spent MTD: $0.59 on Dec 2
Low Voltage MTD: 116.6 V on Dec 11
High Voltage MTD: 125.7 V on Dec 8

7.1 kWh
170.9 kWh
511.7 kWh

Figure 11. *TED 5000* energy use dashboard showing current power use of 0.402 kWh and 7.1 net kWh used since midnight.

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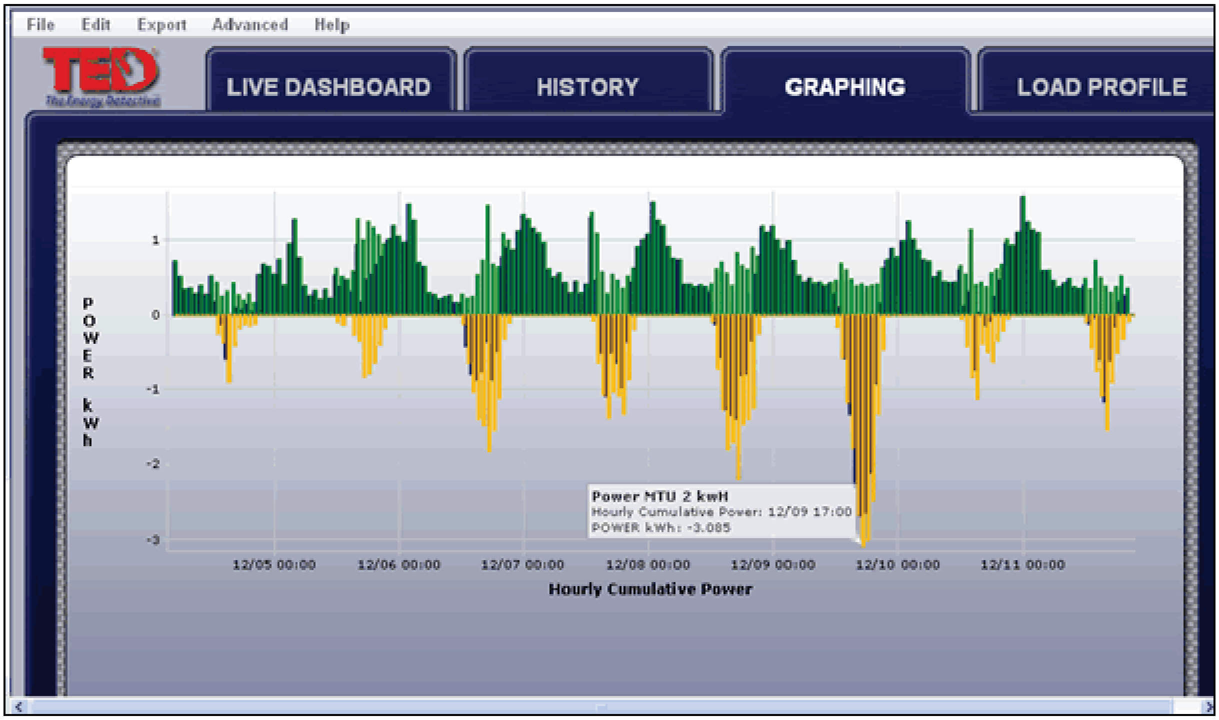
[36] http://www.theenergydetective.com/what/features.html)

Figure 12. TED 5000 desktop display showing the house
with an electrical demand of 3.940 kW



Power MTU 2 kwH
Hourly Cumulative Power: 12/09 17:00
POWER kWh: -3.085

Figure 13. *TED* hourly data display showing house power (green) and
PV output (yellow) over last seven days.

10.3.1 Feedback with Automated Controls

While national studies have shown 5 - 15% whole-house energy savings from feedback, this strategy alone, automated controls with feedback, may potentially produce better performance or at least obtain the upper end of this range more dependably.

Smart thermostat control systems such as *Ecobee* or *Dreamwatts* allow control of household thermostats and data access to temperatures over a broadband connection. Automated controls for shedding loads (www.greenswitch.tv) in homes such as *Greenswitch* are also available.

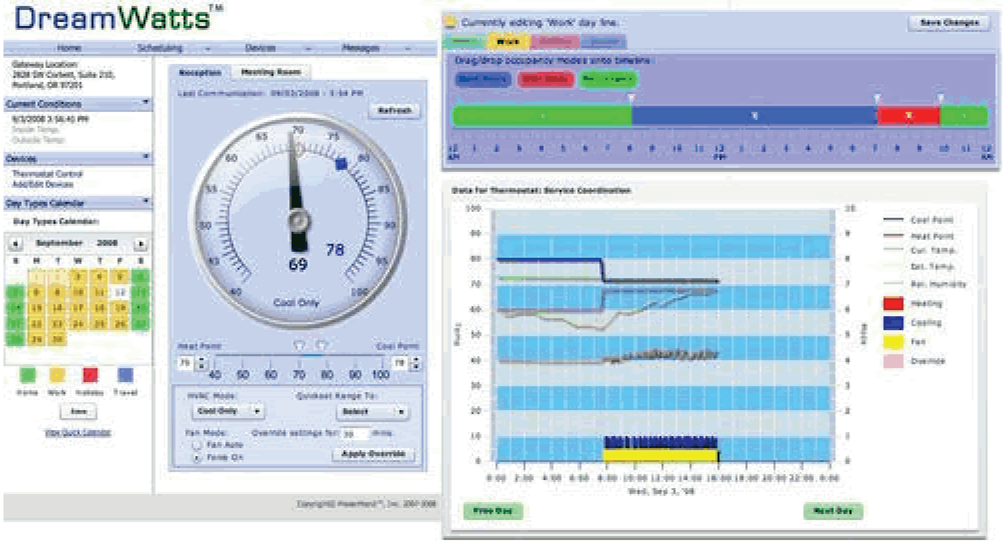


Figure 14. *Dreamwatts:* web displayed and controlled wireless thermostat.

Greenswitch provides a wireless switch that sets back the HVAC thermostat and deactivates up to six wall and plug switches after a master switch is turned off to signal an unoccupied home. Such systems have reduced consumption by up to 20% in the hotel industry, but there is no reliable data on the savings that can be readily achieved in homes. One system with both feedback and controls is the *Energy Hub* system.[37] *EnergyHub* provides information on overall household power and the power used by devices plugged into the various deployed plug modules. The device also allows control of the devices plugged into various switches and plugs around the house with simple touch-pad activation. Capabilities include:

- Real time energy feedback on whole house energy use for effective feedback.
- Automated control ability to set up or set back the household thermostat when asleep or away from home.
- Radio controlled load shed of plug loads around the home.

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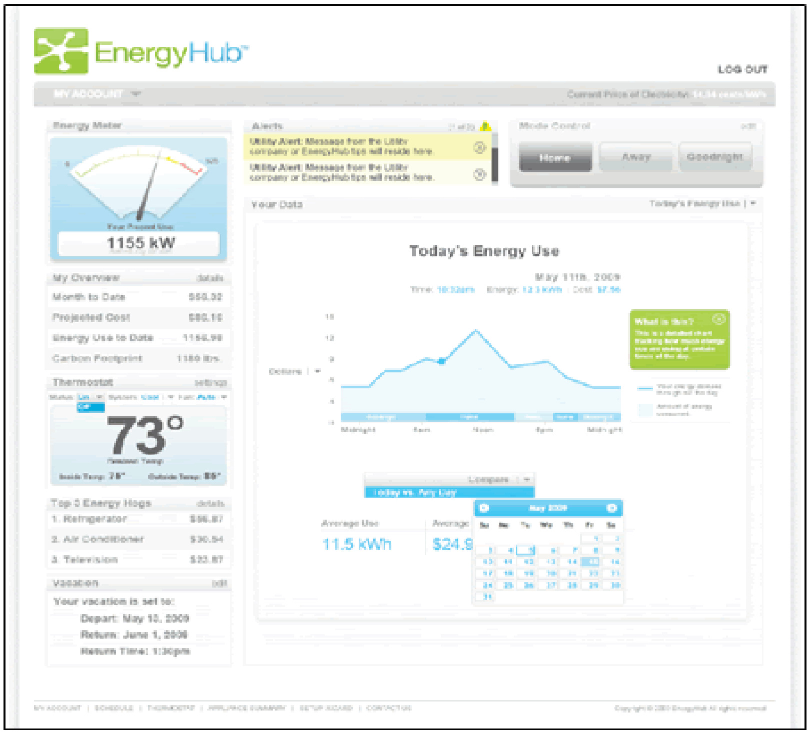
[37] http://www.energyhub.net/

Figure 15. *Energy Hub* display and outlet control modules.



Utility Alert: Message from the Utility company or EnergyHub tips will reside here.

Utility Alert: Message from the Utility company or EnergyHub tips will reside here.

May 11th, 2009

My Overview	
Month to Date	$50.32
Projected Cost	$80.16
Energy Use to Date	1156.98
Carbon Footprint	1180 lbs.

Top 3 Energy Hogs	
1. Refrigerator	$56.87
2. Air Conditioner	$30.54
3. Television	$23.87

Average Use 11.5 kWh

Your vacation is set to:
Depart: May 13, 2009
Return: June 1, 2009
Return Time: 1:30pm

Figure 16. Example of feedback information from the Energy Hub display.

Energy Hub plans to not only provide information on household power but also to provide data on generation from PV, wind or co-generation as well. In addition, data developed within the *Building America* program has shown that homes with solar electric power generation are more motivated by displays that provide information on the balance of power being used in the building vs. what is being generated (Parker et al., 2006). Within this framework, many participating homeowners become involved in a game or sport with the display where the idea is to get the net power to zero or below when the sun is up. Evidence suggests engagement may boost active participation with displays and overall effectiveness of projects that include generation. Similar data has been developed in parallel in the United Kingdom.[38] For instance the *TED 5000* equipment allows visualization of the output of the solar system, and the household electric power consumption as shown in Figure 17.

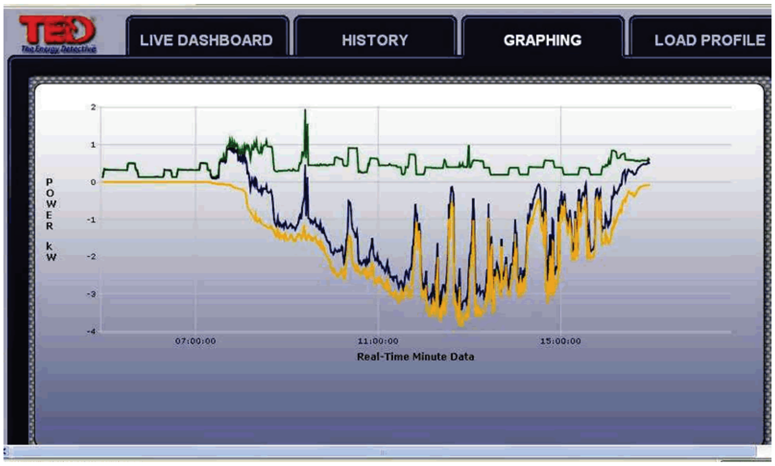


Figure 17. Daily display of PV system performance (yellow) vs. house demand (green) and net demand (dark blue)

10.3.2 Recent Developments in Smart Meters

Recently, there have been many new feedback displays and controls that have become available with the large interest in smart meters. These are meters that record electrical use in more detail than standard meters, often recording when power was used. They also allow for feedback to consumers regarding the potential for control and the remote reading of energy use by utilities. There are many more of these than can be easily described here since many are startup companies and the field is very rapidly changing. However, we describe some representative types of displays, technologies and commonly employed approaches, freely making use of information from vendors and trade journals.

Smart grid systems will likely become more prevalent in the future, as efforts at establishing a national smart grid accelerate and electricity providers begin providing more data – and possibly in a standardized format to customers, as advocated by *Google*. Many illustrations of the success of such an approach are emerging where consumers reduce energy use using data from smart meters to compete with neighbors or even the larger family of smart meters users.[39]

However, entrenched divisions across utilities remain, with considerable doubt whether they will agree on one method for communicating data through smart meters. There is also debate regarding the preferred wireless standard to use, with *ZigBee* popular in the United States while

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[38] Keirstead, J (2007) "Behavioural responses to photovoltaic systems in the UK domestic sector", *Energy Policy*. 35(8): p. 4128.
[39] Shogren, Elizabeth. "Smart Meter Saves Big Bucks for Pennsylvania Family." National Public Radio, 28 April 2009.

Zwave dominates in Europe. For now, however, there are many competing standards for how these programs and devices operate, and utility companies appear reluctant to make their data accessible to third-party developers.

Control4, Inc.

Figure 18. Control4 main home display

Control4 is an innovative home technology management system that is being currently tested by utilities for smart metering applications. *Control4's* EMS-100 includes a wireless thermostat that connects to a wireless in-home display. As initially configured, it has energy management and demand response capabilities, plus various "lifestyle" applications including weather and photo viewing. Control can be exercised too, over the internet via computer or *iPhone*. For instance, *Control4*'s Mobile Navigator License is one of the few *iPhone* applications that allow remote control of devices in homes – from lights to thermostat controls. Other energy management functions are planned.[40] With a compatible home entertainment system, the in-home display also becomes a universal remote control. *Control4* expects the later function to become a major motivator for users choosing that system. While *Control4* appears to have a strong position relative to technological capabilities, the system displays do not appear to be as compelling as some of the other reviewed systems.

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[40] *Our Home Spaces*, has developed an iPhone application to control any home device that's WiFi-connected, including high kW draw items such as water heaters and dryers. http://www.ourhomespaces.com/index.html

Greenbox Technology, Inc. (Silver Spring Networks)

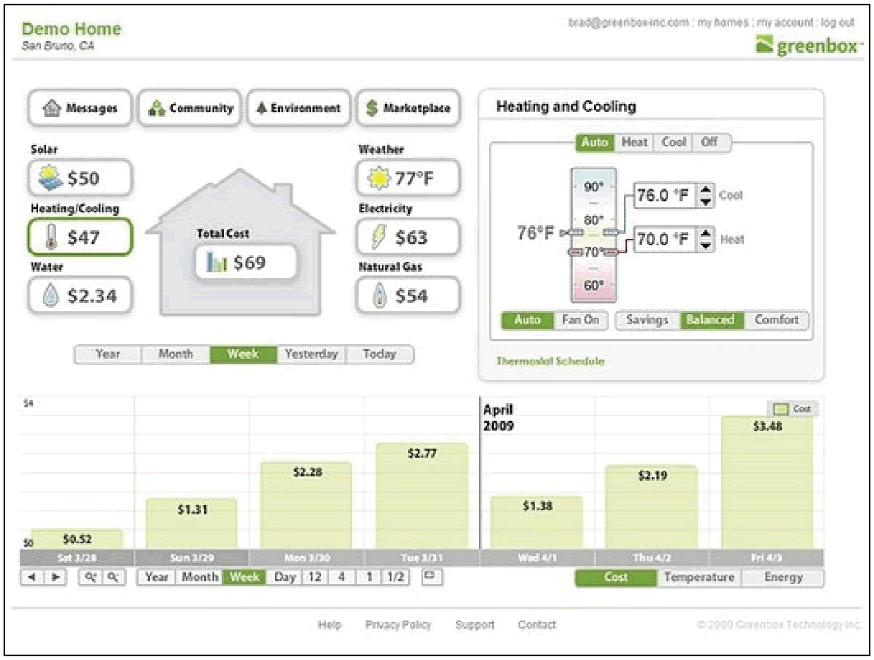

Figure 19. Greenbox computer home graphic display.

Greenbox Technology, recently acquired by Silver Spring Networks, features a system which lets a residential customer view, interpret, and act on their utility consumption over the Internet. *Greenbox* also allows examination and control of distributed generation resources such as solar photovoltaic energy production and remote control of some devices over the web.

A strength of the *Greenbox* approach is helping users to interactively diagnose and understand home equipment and appliance load profiles, identifying home base load phantom loads and other energy waste. However, one weakness of the *Greenbox* system is that the information is not available over a dedicated in-home display and must be accessed over the computer. In many homes, that computer or computers are often involved in other tasks and thus energy information must compete with other computer end-uses. Still, one pilot of the *Greenbox* system in 24 homes showed that most users were able to use the system to cut their electricity use by 15-20%– higher than typically achieved.[41]

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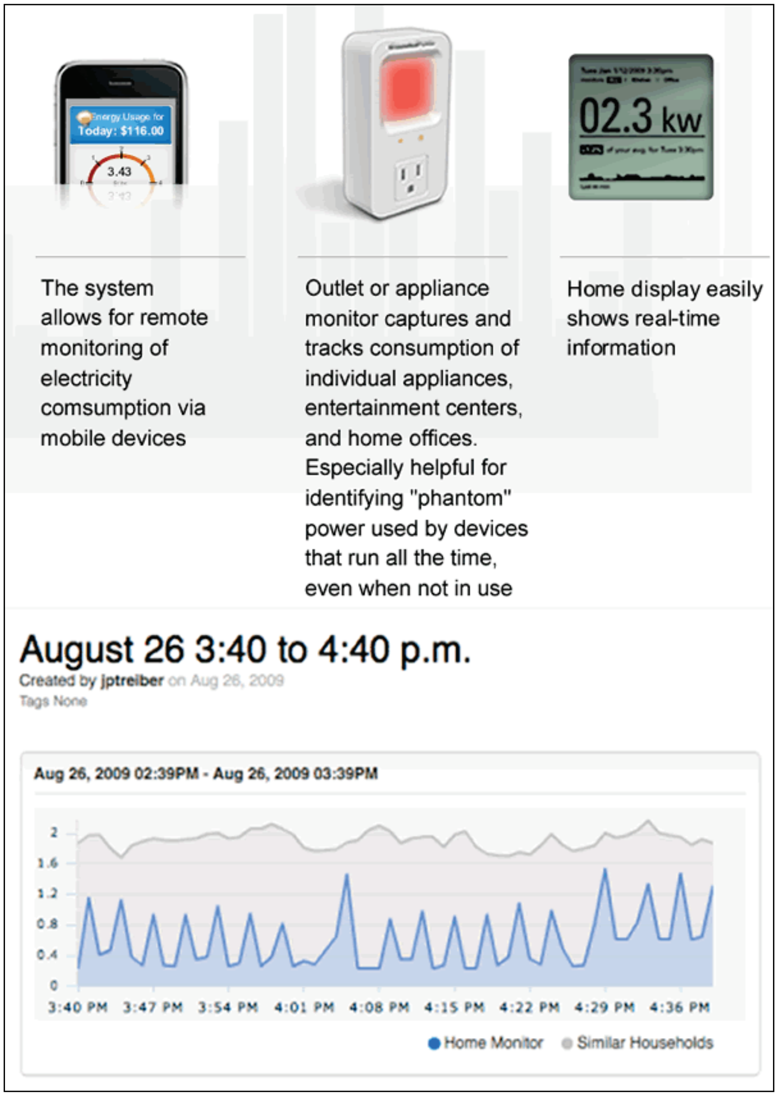
[41] "Smart Meters Open Markets for Smart Apps," by Erik Olsen, New York Times, 7 October 2008.

Grounded Power, Inc.

Grounded Power is a Massachusetts smart grid start up using innovative displays and social psychology to motivate energy consumers to save. Users can see how their energy usage compares to others in their region and they can set individual goals using system software. The system also attempts to engage users via comparison and even competition. Data is made available on a dedicated display and on the computer via Internet. Dedicated plug monitors allow evaluation of energy use of specific devices to isolate phantom loads and use of various appliances.



The system allows for remote monitoring of electricity comsumption via mobile devices

Outlet or appliance monitor captures and tracks consumption of individual appliances, entertainment centers, and home offices. Especially helpful for identifying "phantom" power used by devices that run all the time, even when not in use

Home display easily shows real-time information

August 26 3:40 to 4:40 p.m.

Created by jptreiber on Aug 26, 2009

Tags None

Aug 26, 2009 02:39PM - Aug 26, 2009 03:39PM

Figure 20. Grounded Power in home display and computer comparison comparing current usage with that of neighboring houses.

Grounded Power is testing their system with a few utilities in Massachusetts where utility employees can communicate with customers on how to reduce energy based on their data. *Grounded Power* has a large scale pilot evaluation (300 homes) underway in the Cope Cod area. This study consists of an experimental group and two control groups, one a true control group and another one which wished to have the feedback devices installed, but did not receive installation and were instead recruited to create a mirror control group to eliminate self-selection bias.

Tendril

Tendril is another start-up smart metering system that can communicate with a wireless gateway to provide energy use data. *Tendril* consists of several components (TREE: Tendril Residential Energy Ecosystem) with similar functionality to *Energy Hub's*: *Tendril Insight* is the primary display providing feedback on realtime energy use. *Tendril Thermostat* is a wireless thermostat that interfaces with the main control system to provide user controlled operation of the household thermostat. The *Tendril Volt* is a *Zigbee*-enabled plug that allows people to monitor energy use and control appliances plugged into it.

KILOWATTS P/HR: 350 kWh

MO/YR EST. COST: $120.99 / $1451.88

CARBON FOOTPRINT: 579 tonnes

Figure 21. Tendril home energy use display.

Data from the system can also be viewed via Web portal. Currently, *Tendril's* products are only available through utilities using energy-management systems during smart grid trials pilot programs. However, like *Energy Hub*, *Tendril* is a full featured product with the capabilities of feedback display, access of information over the internet and control of specific devices and the heating and cooling system.

Comverge

Comverge is smart grid company that is providing feedback and load reduction services to utilities and their customers using advanced metering and wireless Zigbee communication. The system emphasizes systems that will help consumers and home energy systems respond to time-of-day electric pricing. A wireless display (*PowerPortal*) provides information on real-time household electric consumption. However, the device is unique in that colored LEDs (green, amber and red) advise the homeowner as to whether they are in low cost vs. high cost utility supply periods or even periods of Critical Peak Pricing (CPP).

Figure 22. Comverge power portal display.

A separate thermostat control module (*SuperStat*) using information from the utility to provide proportional demand reduction from the HVAC system in response to utility and consumer preferences. The smart thermostat monitors HVAC operation and control cycles using percentage-based commands.

Figure 23. Comverge radio controlled Superstat.

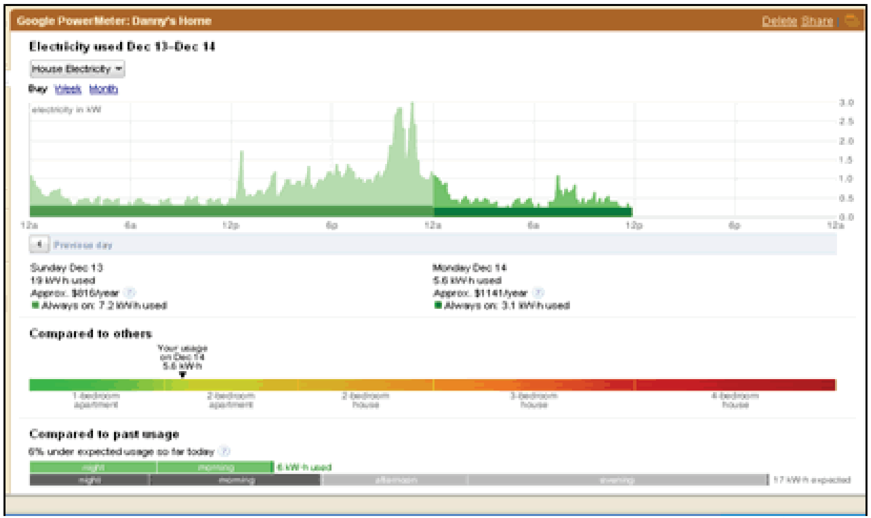
This strategy helps to eliminate "freeriders" and provides greater control of oversized systems and more equitable load reduction across customers. The system also monitors the room temperature rise during a cycling control event and reduces the cycling depth once the room temperature reaches the setback value. This feature helps to reduce customer discomfort during long control periods or in poorly insulated homes.

Comverge smart meters and associated controls are in a large smart grid pilot program in Oklahoma Gas and Electric Company territory. The program is using time-of-day pricing, feedback and smart thermostats to achieve changes to load shape and peak load reduction.

Google Power Meter

Data from some smart meters can also be displayed with the *Google Power Meter* website which allows the information to be made available anywhere in the world in a consistent format on their *iGoogle* home page.[42] *Google*'s recent entrance to the open utility market has generated a great deal of interest. Third-party access to residential utility consumption data has a very large perceived value, and it seems obvious that Google sees opportunity in selling services around that information.

Currently, *Google Power Meter* is working with smart meters within the following utilities: *TXU Energy, JEA, WPS, SDG&E* and *White River Valley Electric Cooperative*. Google is also providing the same service for owners of the TED 5000 system. In such a fashion, the data are easily shared and saved as desired, which is shown in Figure 24.



Sunday Dec 13
19 kWh used
Approx. $816/year
Always on: 7.2 kWh used

Monday Dec 14
5.6 kWh used
Approx. $1141/year
Always on: 3.1 kWh used

6% under expected usage so far today

Figure 24: Google power meter display for December 13-14th.

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[42] http://www.google.org/powermeter/

10.4 Consideration for Implementation into Rating Systems

As described earlier, there is generally wide consensus from data from a multitude of projects around the world that the savings from providing realtime feedback to homeowners varies from 5-15%. *One possible recommendation is that the lower end of this range be applied to applicable projects as a credit for reduced electrical consumption: a 5% reduction.* How would this be applied? All electrical end uses that have behavioral influences– perhaps all other than refrigeration would be eligible for this credit if an operable system is provided with real-time feedback capability.

The potential of feedback coupled with smart control of devices such as *Energy Hub* is certain to be larger, but are not yet known within available research. *A straw man recommendation might be a 10% reduction to electrical energy end uses, if both feedback, and controls for thermostats and/or plugs are made available and operational.* This credit would apply to all electrical end-uses other than refrigerators.

11 Summary

Through detailed incorporation of both the TIAX report on miscellaneous electric loads and the detailed work done by NREL on better calculation of appliance end-use energy, we suggest a series of recommended procedures to better estimate lighting, appliance and residual electric loads in simulation analyses. The following nine residential end uses are addressed:

- Lighting
- Refrigerators
- Clothes dryers
- Clothes washers
- Televisions
- Dishwashers
- Ceiling Fans
- Cooking
- Residual electric use

Television energy use – 4% of national residential energy use – is addressed for the first time. A number of end-uses have received more complete evaluation. Some end uses, such as clothes washers and dishwashers, include a refined calculation procedure which much better reflects their influences and interactions with multiple end uses.

Finally, the impact of household energy feedback and home automation schemes using smart meters are examined. Based on available empirical data, preliminary recommendations made for implementation into rating and calculation procedures.

These procedures provide a consistent and helpful framework for analyzing differences in residential energy systems that influence the ability of future residential buildings to reach advanced energy-efficiency targets. The analysis pursued a balanced approach where increasing calculation complexity was weighed against those items that potentially make a difference in future energy efficiency designs or with analyses of existing homes for retrofit and improvement.

The documentation and description of the mathematical procedures are contained in this report in a complete form. However, for convenience, an EXCEL spreadsheet including the data sources, analysis and methods for the specific calculations are available for download. [43]

12 Future Work

We anticipate the following work in further refinements of the BA Benchmark and residential rating procedures.

1) A more comprehensive assessment of lighting and lighting influences. We know that all lighting fixtures are not equal. For instance, kitchen lighting appears at least twice as important as lighting in other areas. There are also seasonal effects given changes in sunrise/sunset times. However, methods need to be developed that allow better assessment and reasonable approaches for raters. NREL is actively working on this task.

2) Consider large UEC equipment and appliances such as pool pumps, well pumps, spas and water beds for inclusion in rating systems

3) Incorporation of digitized shading patterns (e.g. Solmetric sun-eye technology) into PV performance prediction (a 30% effect on PV output in shaded environments may not be uncommon).

4) Influence of fireplaces on default leakage rates. Fireplaces often show up in energy surveys and statistical analyses as factors increasing energy use. It would be useful to know how specific leakage areas typically vary with the presence of fireplaces and the degree to which they are sealed.

5) Specific adjustments of rating procedures for existing homes where equipment or envelopes are at significant variance with those in new homes. This includes refrigerators, since vintage is such a large influence, poorly charged old air conditioners, uninsulated frame walls and many other items.

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[43] The spreadsheet download showing the calculations is available at the following BA website sponsored by FSEC: http://www.fsec.ucf.edu/download/MELs/

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Appendix A: RECS 2005 Average U.S. Consumption Data

Table US14. Average Consumption by Energy End Uses, 2005
Million British Thermal Units (BTU) per Household

	U.S. Households (millions)	Energy End Uses (million Btu of consumption per household)					
		All End Uses	Space Heating (Major Fuels)[4]	Air-Conditioning[5]	Water Heating[6]	Refrigerators	Other Appliances and Lighting
Total	111.1	94.9	40.5	9.6	19.2	4.6	24.7
Census Region and Division							
Northeast	20.6	122.2	71.8	4.5	21.9	4.3	23.0
New England	5.5	129.3	85.6	2.5	21.5	4.1	20.1
Middle Atlantic	15.1	119.7	66.9	5.1	22.0	4.4	24.0
Midwest	25.6	113.5	58.4	6.2	20.6	4.9	25.9
East North Central	17.7	117.7	63.3	5.7	20.9	4.9	26.2
West North Central	7.9	104.1	47.8	7.3	19.7	5.0	25.4
South	40.7	79.8	21.0	14.5	15.8	4.8	25.0
South Atlantic	21.7	76.1	21.3	13.3	13.9	4.8	24.2
East South Central	6.9	87.3	27.6	12.7	16.2	5.3	26.8
West South Central	12.1	82.4	16.7	17.7	19.1	4.6	25.5
West	24.2	77.4	26.3	7.6	21.3	4.3	24.1
Mountain	7.6	89.8	34.3	14.1	20.5	4.5	24.0
Pacific	16.6	71.8	22.4	4.2	21.7	4.2	24.2
Four Most Populated States							
New York	7.1	118.2	71.5	4.1	22.4	4.0	21.1
Florida	7.0	60.0	3.4	20.3	10.4	4.4	22.2
Texas	8.0	81.5	13.2	19.4	19.8	4.7	25.7
California	12.1	67.1	15.7	4.7	23.3	3.7	23.8
All Other States	76.9	101.8	47.1	8.3	19.0	4.9	25.2
Urban/Rural Location (as Self-Reported)							
City	47.1	85.3	36.7	9.5	18.3	4.0	21.2
Town	19.0	102.3	48.1	8.5	19.4	4.7	24.3
Suburbs	22.7	108.6	42.6	11.0	23.4	5.1	28.9
Rural	22.3	95.1	39.5	9.5	16.8	5.4	28.0
Climate Zone[1]							
Less than 2,000 CDD and--							
Greater than 7,000 HDD	10.9	117.9	68.1	3.1	20.6	4.9	24.9
5,500 to 7,000 HDD	26.1	115.0	63.8	4.8	20.3	4.6	24.4
4,000 to 5,499 HDD	27.3	101.7	47.6	7.4	19.6	4.8	24.6
Fewer than 4,000 HDD	24.0	76.4	21.4	9.1	20.3	4.4	25.1
2000 CDD or More and--							
Less than 4,000 HDD	22.8	72.4	10.0	19.4	15.7	4.6	24.5
Type of Housing Unit							

	U.S. Households (millions)	**Energy End Uses** (million Btu of consumption per household)					
		All End Uses	**Space Heating (Major Fuels)**[4]	**Air-Conditioning**[5]	**Water Heating**[6]	**Refrigerators**	**Other Appliances and Lighting**
Single-Family Detached	72.1	108.4	44.2	11.0	21.7	5.2	29.3
Single-Family Attached	7.6	89.3	41.7	6.7	19.0	4.0	20.9
Apartments in 2-4 Unit Buildings	7.8	85.0	48.5	6.3	15.6	3.5	16.3
Apartments in 5 or More Unit Buildings	16.7	54.4	25.0	6.6	12.2	3.0	11.8
Mobile Homes	6.9	70.4	26.1	9.2	13.3	4.2	21.4
Ownership of Housing Unit							
Owned	78.1	104.4	43.1	10.4	20.8	5.1	28.0
Single-Family Detached	64.1	109.8	44.7	11.0	21.9	5.4	29.8
Single-Family Attached	4.2	94.9	44.0	6.3	20.2	4.1	21.9
Apartments in 2-4 Unit Buildings	1.8	110.5	65.8	4.8	18.4	4.1	19.5
Apartments in 5 or More Unit Buildings	2.3	50.9	20.4	7.3	10.8	2.9	13.1
Mobile Homes	5.7	70.5	25.5	9.4	12.8	4.2	21.8
Rented	33.0	72.4	33.8	7.7	15.4	3.5	16.7
Single-Family Detached	8.0	96.5	39.8	10.8	20.1	4.2	25.3
Single-Family Attached	3.4	82.6	38.8	7.2	17.6	3.9	19.7
Apartments in 2-4 Unit Buildings	5.9	77.1	42.8	6.8	14.8	3.3	15.3
Apartments in 5 or More Unit Buildings	14.4	55.0	25.7	6.5	12.5	3.1	11.6
Mobile Homes	1.2	70.0	29.2	8.4	15.9	4.0	19.6
Year of Construction							
Before 1940	14.7	120.4	71.6	5.7	20.2	4.5	23.1
1940 to 1949	7.4	104.0	51.6	7.9	21.8	4.2	23.8
1950 to 1959	12.5	98.3	47.3	7.9	19.1	4.3	22.5
1960 to 1969	12.5	94.9	42.9	8.6	19.2	4.7	24.3
1970 to 1979	18.9	83.4	33.8	9.5	16.8	4.6	22.9
1980 to 1989	18.6	81.4	26.7	10.7	18.0	4.6	24.2
1990 to 1999	17.3	94.4	31.0	11.8	20.1	5.4	28.6
2000 to 2005	9.2	94.4	28.7	13.4	21.3	4.5	28.5
Total Floorspace (Square Feet)							
Fewer than 500	3.2	56.5	30.3	4.9	12.2	3.2	11.2
500 to 999	23.8	62.0	28.4	6.8	13.3	3.3	14.5
1,000 to 1,499	20.8	82.0	33.5	9.2	17.2	4.0	21.4
1,500 to 1,999	15.4	93.8	36.5	10.9	19.2	4.9	26.0
2,000 to 2,499	12.2	102.3	41.2	10.2	21.0	4.8	27.6
2,500 to 2,999	10.3	112.2	48.2	9.8	22.4	5.2	29.6
3,000 to 3,499	6.7	115.6	53.2	9.8	21.1	5.4	28.9
3,500 to 3,999	5.2	129.2	60.9	10.7	23.2	5.8	31.6
4,000 or More	13.3	140.4	56.8	13.1	27.7	6.5	38.2
Household Size							
1 Person	30.0	70.7	37.4	6.1	11.7	3.9	14.4
2 Persons	34.8	96.4	41.9	10.1	18.5	4.9	24.4
3 Persons	18.4	104.1	41.4	10.7	21.7	5.0	28.8
4 Persons	15.9	108.4	41.0	11.4	24.2	4.8	31.4
5 Persons	7.9	117.1	41.9	13.1	27.2	4.9	34.5

	U.S. Households (millions)	**Energy End Uses** (million Btu of consumption per household)					
		All End Uses	**Space Heating (Major Fuels)**[4]	**Air-Conditioning**[5]	**Water Heating**[6]	**Refrigerators**	**Other Appliances and Lighting**
6 or More Persons	4.1	123.8	41.7	12.8	33.3	4.9	38.4
2005 Household Income Category							
Less than $10,000	9.9	73.7	38.6	7.0	14.1	3.7	15.2
$10,000 to $14,999	8.5	76.2	37.9	6.7	14.1	4.0	17.0
$15,000 to $19,999	8.4	78.8	37.5	7.6	15.3	4.0	18.2
$20,000 to $29,999	15.1	84.9	39.5	8.2	16.2	4.1	20.6
$30,000 to $39,999	13.6	86.2	36.4	10.0	17.3	4.5	22.3
$40,000 to $49,999	11.0	95.0	39.9	9.9	18.5	4.6	25.0
$50,000 to $74,999	19.8	99.2	38.7	10.5	20.8	4.9	27.2
$75,000 to $99,999	10.6	112.4	47.5	10.6	22.1	5.1	30.3
$100,000 or More	14.2	130.5	47.3	12.9	29.2	6.1	38.2
Income Relative to Poverty Line							
Below 100 Percent	16.6	79.8	39.0	7.7	16.3	3.8	18.4
100 to 150 Percent	12.9	80.7	35.3	8.6	16.0	4.1	20.6
Above 150 Percent	81.5	100.3	41.5	10.2	20.3	4.9	26.6
Eligible for Federal Assistance[2]							
Yes	38.6	83.1	39.5	7.9	16.6	4.0	19.7
No	72.5	101.2	41.0	10.5	20.6	5.0	27.3
Payment Method for Utilities							
All Paid by Household	97.5	97.3	40.2	10.1	19.7	4.8	25.9
Some Paid, Some in Rent	7.6	77.2	44.4	5.0	15.2	3.5	15.1
All Included in Rent	4.7	74.9	40.3	7.4	15.1	3.6	14.1
Other Method	1.3	95.0	42.1	9.6	18.0	5.3	26.0
Ethnic Origin of Householder							
Hispanic Descent	14.8	80.3	32.6	10.3	19.6	3.8	21.2
Non-Hispanic Descent	96.3	97.2	41.6	9.6	19.2	4.8	25.2
Race of Householder[3]							
White	79.1	98.2	42.2	9.6	19.2	4.9	25.6
Hispanic	5.0	73.5	26.4	10.9	18.8	3.9	20.6
Non-Hispanic	74.1	99.9	43.1	9.5	19.3	4.9	25.9
Black	13.4	92.5	39.5	9.9	18.7	4.1	22.5
Hispanic	0.3	99.6	53.0	7.1	18.0	4.2	19.3
Non-Hispanic	13.1	92.3	39.1	9.9	18.7	4.0	22.6
Asian	3.3	75.2	28.4	9.1	20.0	3.9	21.2
Multi-Racial	1.3	87.0	31.7	10.5	18.5	4.6	26.5
Other	7.1	85.9	33.8	9.8	19.7	4.4	23.2
Undetermined (Race Reported as Hispanic)	6.9	82.4	36.2	9.6	19.1	3.8	21.1

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[1] One of five climatically distinct areas, determined according to the 30-year average (1971-2000) of the annual heating and cooling degree-days. A household is assigned to a

	U.S. Households (millions)	Energy End Uses (million Btu of consumption per household)					
		All End Uses	Space Heating (Major Fuels)[4]	Air-Conditioning[5]	Water Heating[6]	Refrigerators	Other Appliances and Lighting

climate zone according to the 30-year average annual degree-days for an appropriate nearby weather station.

[2] Below 150 percent of poverty line or 60 percent of median state income.

[3] Respondents were permitted to select more than one racial category to describe themselves. The "Other" category includes Native Americans, Native Alaskans, and Pacific Islanders.

[4] Housing units where the main or secondary space-heating fuel is electricity, natural gas, fuel oil, kerosene, or LPG.

[5] The number of housing units where the end use is electric air-conditioning, does not include households that did not use their equipment (1.9 million). It does include the small number of housing units where the fuel for central air-conditioning equipment was something other than electricity; those households were treated as if the fuel was electricity.

[6] Housing Units where the main or secondary water-heating fuel is electricity, natural gas, fuel oil, kerosene, or LPG.

Q = Data withheld either because the Relative Standard Error (RSE) was greater than 50 percent or fewer than 10 households were sampled.

N = No cases in the reporting sample.

(*) Number less than 0.5, 0.05, or 0.005 depending on the number of significant digits in the column, rounded to zero.

Notes: ● Because of rounding, data may not sum to totals. ● See "Glossary" for definition of terms used in this report.

Source: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-457 A-G of the 2005 Residential Energy Consumption Survey.

Appendix B: Proposed Changes to RESNET Standards

Proposed Changes to the RESNET Standards for Updating Lighting, Appliances and Miscellaneous Electric Loads

Add the following definition to Section 302, Definitions and Acronyms:

MBtu – One million British thermal units (Btu).

Modify Section 303.2.1 as follows:

Step (2) Determine the HERS Index using equation 2:

HERS Index = PEfrac * (TnML / TRL) * 100 **(Eq. 2)**

where:

TnML = $nMEUL_{HEAT} + nMEUL_{COOL} + nMEUL_{HW} + EUL_{LA}$ (Total of all normalized modified end use loads for heating, cooling and hot water as calculated using equation 1 plus EUL_{LA} ~~= [(18,842 + 25.1*CFA) * 365] / (1*10^6) MBtu/year~~, modified by allowable reductions for qualifying lighting and appliances as specified by Section 303.4.1.7.2 of this Standard in MBtu/yr).

TRL = $REUL_{HEAT} + REUL_{COOL} + REUL_{HW} + REUL_{LA}$ (Total of all Reference Home end use loads for heating, cooling and hot water plus $REUL_{LA}$ ~~= [(18,842 + 25.1*CFA) * 365] / (1*10^6) MBtu/year~~ in MBtu/yr).

and where:

EUL_{LA} = Rated Home end use loads for lighting and appliances as defined by Section 303.4.1.7.2, converted to MBtu/yr, where MBtu/yr = (kWh/yr)/293 or (therms/yr)/10 as appropriate.

$REUL_{LA}$ = Reference Home end use loads for lighting and appliances as defined by Section 303.4.1.7.1, converted to MBtu/yr, where MBtu/yr = (kWh/yr)/293 or (therms/yr)/10 as appropriate.

and where:

PEfrac = (TEU - OPP) / TEU

TEU = Total energy use of the Rated Home including all rated and non-rated energy features where all fossil fuel site energy uses are converted to Equivalent Electric Power by multiplying them by the Reference Electricity Production Efficiency of 40%

OPP = On-site Power Production as defined by Section 303.1.1.5

Modify Table 303.4.1(1) as follows:

Internal gains:	As specified by Tables 303.4.1(3) and 303.4.1(4) ~~IGain = 17,900 + 23.8*CFA + 4104*N_{br} (Btu/day per dwelling unit)~~	Same as HERS Reference Home, except as provided by Section 303.4.1.7.2

Table 303.4.1(3). Internal Gains for HERS Reference Homes (a)

End Use / Component	Sensible Gains (Btu/day)			Latent Gains (Btu/day)		
	a	b	c	a	b	c
Residual MELs		7.27			0.38	
Interior lighting	4,253	7.48				
Refrigerator	5,955		168			
TVs	see Table 303.4.1(4)					
Range/Oven (elec) (b)	2,228		262	248		29
Range/Oven (gas) (b)	4,086		488	1,037		124
Clothes Dryer (elec) (b)	661		188	73		21
Clothes Dryer (gas) (b)	739		209	91		26
Dish Washer	219		87	219		87
Clothes Washer	96		28	11		3
Gen water use	18		6	1,245		415
Occupants (c)			3978			3,162

Notes for Table 303.4.1(3)

(a) Table values are coefficients for the following general equation: Gains = a + b*CFA + c*Nbr where CFA = Conditioned Floor Area and Nbr = Number of bedrooms.

(b) For Rated Homes with electric appliance use (elec) values and for Rated homes with natural gas-fired appliance use (gas) values

(c) Software tools shall use either the occupant gains provided above or similar temperature dependant values generated by the software where number of occupants equals the number of bedrooms and occupants are present in home 85% of the time.

Table 303.4.1(4) Sensible Internal Gains for HERS Reference Home Televisions

Nbr	TV Btu/day	Nbr	TV Btu/day
1	4,324	7	8,018
2	5,243	8	8,399
3	5,942	9	8,726
4	6,593	10	9,028
5	7,119	11	9,293
6	7,608	12	9,538

Renumbering all following tables accordingly.

Modify Section 303.4.1.7 as follows:

303.4.1.7 Lighting, ~~and~~ Appliances and Miscellaneous Electric Loads (MELs)

~~**303.4.1.7.1 Lighting.** Reference home annual lighting use in kWh/yr/(dwelling unit) shall be calculated as (455 + 0.80 * CFA) with an internal gain factor equal to 90% of lighting energy use (10% of lighting energy use is assumed to occur outside of the conditioned floor area of the home).~~

~~For the purpose of adjusting the annual light fixture energy consumption for calculating the rating, EUL_{LA} shall be adjusted by adding lighting ΔEUL_{LA}, where ΔEUL_{LA} (MBtu/yr/(dwelling unit)) = [29.5 – 0.5189*CFA*$FL_{\%}$ – 295.12*$FL_{\%}$ + 0.0519*CFA] * 0.003413, and where $FL_{\%}$ is the ratio of Qualifying Light Fixtures to all light fixtures in Qualifying Light Fixture Locations, and CFA is the Conditioned Floor Area. For calculation purposes, the rated home shall never have $FL_{\%}$ less than 10%.~~

~~For lighting, internal gains in the Rated home shall be reduced by 90% of the lighting ΔEUL_{LA} calculated in Btu/day using the following equation: $\Delta Igain = 0.90 * \Delta EUL_{LA} * 10^6 / 365$..~~

~~**303.4.1.7.2 Refrigerators.** Reference home annual refrigerator energy use shall be 775 kWh/yr per dwelling unit.~~

~~For the purposes of adjusting the annual refrigerator energy consumption for calculating the rating, the EUL_{LA} shall be adjusted by adding ΔEUL_{LA}, where refrigerator ΔEUL_{LA}(kWh/yr/(dwelling unit)) = Total Annual Energy Consumption of Refrigerators in Rated Home – 775.~~

~~For refrigerators, internal gains in the Rated home shall be reduced by 100% of the refrigerator ΔEUL_{LA} calculated in Btu/day using the following equation: $\Delta Igain = \Delta EUL_{LA} * 10^6 / 365$.~~

~~**303.4.1.7.3 Mechanical Ventilation System Fans.** If ventilation fans are present, the EUL_{LA} shall be adjusted by adding ΔEUL_{LA}, where ΔEUL_{LA} (kWh/year/(dwelling unit)) = Total Annual Energy Consumption of the Ventilation System in the Rated Home – [0.03942*CFA + 29.565*(N_{br}+1)]~~

~~**303.4.1.7.4 Dishwashers.** A dishwasher, with annual energy use as specified by Table 303.4.1.8 with an internal gain factor equal to 60% of dishwasher energy use, shall be assumed in the Reference home. If no labeled dishwasher energy factor is specified for the Rated home, the Rated home shall have the same dishwasher annual energy use and internal gain factor as the Reference home.~~

~~**Table 303.4.1.8**~~

~~**Bedrooms per Dwelling Unit**~~	~~**Reference Dishwasher kWh**~~
~~1~~	~~90~~
~~2~~	~~126~~
~~3~~	~~145~~
~~4~~	~~174~~
~~5+~~	~~203~~

~~For the purposes of calculating dishwasher energy savings and hot water energy savings for calculating the rating, the energy savings shall be calculated based on the following formula using Cycles/Year by number of Bedroom (N_{br}) as specified in Table 303.4.1.9~~

~~Dishwasher annual energy use for each dwelling unit in the rated home (kWh/yr) = (0.27) * (cycles/yr/(dwelling unit)) / (dishwasher rated Energy Factor)~~

~~Table 303.4.1.9~~

~~N_{br} per Dwelling Unit~~	~~Cycles/Yr per Dwelling Unit~~
~~1~~	~~154~~
~~2~~	~~214~~
~~3~~	~~247~~
~~4~~	~~296~~
~~5+~~	~~345~~

~~EUL$_{LA}$ shall be adjusted by adding dishwasher ΔEUL$_{LA}$, where ΔEUL$_{LA}$ (MBtu/yr/(dwelling unit)) = (cycles/yr)*[0.27/(dishwasher rated Energy Factor) – 0.587]*0.003413.~~

~~Internal gains in the Rated Home shall be reduced by 60% of the dishwasher ΔEUL$_{LA}$ calculated in Btu/day using the following equation: ΔIgain = 0.60 * ΔEUL$_{LA}$ * 10^6 / 365.~~

~~The reduction in hot water use (gallons/day) shall be based on the following formula, to be used in adjusting the hot water Use Equation given by Table 303.4.1(1):~~

~~Reduction in hot water use (gallons/day/(dwelling unit)) = [(7.4 gal/cycle) – (0.73)/(dishwasher rated Energy Factor in cycles/kWh)/(90 °F)/(0.0024 kWh/gal/F)] * [(cycles/yr/(dwelling unit))/(365 days/year)]~~

303.4.1.7.1 HERS Reference Home. Lighting, appliance and miscellaneous electric loads in the HERS Reference Home shall be determined in accordance with the values provided in Table 303.4.1.7.1(1) and Table 303.4.1.7.1(2) or Table 303.4.1.7.1(3), as appropriate, and the following general equation (except for televisions):

kWh (or therms) per year = a + b*CFA + c*Nbr

where:

‘a’, ‘b’, and ‘c’ are values provided in Table 303.4.1.7.1(1) or Table 303.4.1.7.1(2)
CFA = conditioned floor area
Nbr = number of bedrooms

Television energy use in the HERS Reference Home shall be determined in accordance with Table 303.4.1.7.1(2) or the following equation:

$$TVkWh/yr = \Sigma(actWatts_{STD},i * onHours,i \ + \ offWatts_{STD},i * offHours,i) \\ + p*(actWatts_{STD},m * onHours,m \ + \ offWatts_{STD},m * offHours,m)$$

where:

$i = 1, n = TV\#$
$n = INT(1.1 + 0.51*Nbr)$
$o = 1.1 + 0.51*Nbr$
$p = o – n$ (a fractional TV)
$m = n +1 = TV\#$ for partial TV

and where:

$actWatts_{STD} = 124 – 69.1*\log_{(10)}TV\#$ (or 50 watts, whichever is greater)
$offWatts_{STD} = 4$
$onHours = 6.876 – 7.054*\log_{(10)}TV\#$ (or 0.5 hours, whichever is greater)
$offHours = 24 – onHours$

303.4.1.7.1.1 All Electric Reference Homes. Where the Rated Home has all electric appliances, the HERS Reference Home lighting, appliance and miscellaneous loads shall be determined in accordance with the values given below in Tables 303.4.1.7.1(1) and 303.4.1.7.1(2).

Table 303.4.1.7.1(1). Lighting, Appliance and Miscellaneous Electric Loads in all electric HERS Reference Homes

End Use Component[(a)]	Equation Coefficients		
	a	b	c
Residual MELs		0.91	
Interior lighting	455	0.80	
Exterior lighting	100	0.05	
Refrigerator	637		18
Televisions	See Table 303.4.1.7.1(2)		
Range/Oven	331		39
Clothes Dryer	524		149
Dish Washer	78		31
Clothes Washer	38		11

Table 303.4.1.7.1(1) Notes:

(a) For homes with garages, an additional 100 kWh per year shall be added to the HERS Reference home for garage lighting.

Table 303.4.1.7.1(2). Annual Television Energy Use for HERS Reference Home [(a)]

Nbr	TVkWh/yr	Nbr	TVkWh/yr
1	463	7	858
2	561	8	898
3	636	9	933
4	705	10	966

Nbr	TVkWh/yr	Nbr	TVkWh/yr
5	762	11	994
6	814	12	1020

Table 303.4.1.7.1(2) Notes:

(a) For homes with more than 12 bedrooms, the equation provided in Section 303.4.1.7.1 may be used

303.4.1.7.1.2 Reference Homes with Natural Gas Appliances. Where the Rated Home is equipped with natural gas cooking or clothes drying appliances, the Reference Home cooking and clothes drying loads defined above in Table 303.4.1.7(1) shall be replaced by the natural gas and electric appliance loads provided below in Table 303.4.1.7(3), as applicable.

Table 303.4.1.7(3). Natural Gas Appliance Loads for HERS Reference Homes with gas appliances

End Use Component$^{(a)}$	Equation Coefficients		
	a	b	c
Range/Oven (therms)	26		3.1
Range/Oven (kWh)	26		3.1
Clothes Dryer (therms)	18.8		5.3
Clothes Dryer (kWh)	41		11.8

Table 303.4.1.7(3) Notes:

(a) Both the natural gas and the electric components shall be included in determining the HERS Reference Home annual energy use for the above appliances.

303.4.1.7.1.3 Garage Lighting. Where the Rated Home includes an enclosed garage, 100 kWh/yr shall be added to the energy use of the Reference Home to account for garage lighting.

303.4.1.7.1.4 Mechanical Ventilation. Where mechanical ventilation is provided in the Rated home, $REUL_{LA}$ shall be modified for the Reference Home by adding [0.03942*CFA + 29.565*(N_{br}+1)] kWh/yr for ventilation fan operation, converted to MBtu/yr, where MBtu/yr = (kWh/yr)/293.

303.4.1.7.1.5 Ceiling Fans. Where ceiling fans are included in the Rated Home they shall also be included in the Reference Home in accordance with the provisions of Section 303.4.1.7.2.11 of this Standard.

303.4.1.7.2 Rated Homes. For Rated homes, the following procedures shall be used to determine lighting, appliance and residual miscellaneous electric load energy consumption.

303.4.1.7.2.1 Residual MELs. Residual miscellaneous electric loads in the Rated Home shall be the same as in the HERS Reference Home and shall be calculated as 0.91*CFA, where CFA is the conditioned floor area.

303.4.1.7.2.2 Interior Lighting. Interior lighting in the Rated home assumes that 10% of the value determined for interior lighting by the values provided in Table 303.4.1.7.1(1) accrue from fluorescent lighting fixtures. These procedures also assume that only 80% of lighting fixtures are located in qualifying locations. As a result, the standard interior lighting equation is modified for Rated Home assessment to account for these provisions and to provide a variable that accounts for additional high-efficiency lighting, when present, in qualifying locations. This is accomplished using the following equation:

$$\mathbf{kWh/yr = 0.8*[(4 - 3*qFF_{IL})/3.7]*(445 + 0.8*CFA) + 0.2*(455 + 0.8*CFA)}$$

where:

CFA = Conditioned floor area

qFF_{IL} = Fraction of interior fixtures in qualifying locations that are fluorescent or LED lighting types, where qFF_{IL} is the ratio of the Qualifying Light Fixtures to all light fixtures in Qualifying Light Fixture Locations.

For rating purposes, the Rated Home shall not have qFF_{IL} less than 0.10 (10%).

(Informative Note: When $qFF_{IL} = 0.10$ (10%), the above equation reduces to the standard interior lighting equation of: kWh/yr = 455 + 0.8*CFA.)

For the purpose of adjusting the annual interior lighting energy consumption for calculating the rating, EUL_{LA} shall be adjusted by ΔEUL_{IL}, which shall be calculated as the annual interior lighting energy use derived by the procedures in this section minus the annual interior lighting energy use derived for the HERS Reference Home in Section 303.4.1.7.1, converted to MBtu/yr, where MBtu/yr = (kWh/yr)/293.

For Interior lighting, internal gains in the Rated home shall be modified by 100% of the interior lighting ΔEUL_{IL} converted to Btu/day as follows: $\Delta EUL_{IL} * 10^6 / 365$.

303.4.1.7.2.3 Exterior Lighting. Exterior lighting in the Rated home shall be determined by the following equation:

$$kWh/yr = (100 + 0.05*CFA)*(1-FF_{EL}) + 0.25*(100 + 0\ .05*CFA)*FF_{EL}$$

where

CFA = Conditioned floor area

FF_{EL} = Fraction of exterior fixtures that are fluorescent, LED or IR-motion/light level controlled lighting types

For the purpose of adjusting the annual exterior lighting energy consumption for calculating the rating, EUL_{LA} shall be adjusted by ΔEUL_{EL}, which shall be calculated as the annual exterior lighting energy use derived by the procedures in this section minus the annual exterior lighting energy use derived for the HERS Reference Home in Section 303.4.1.7.1, converted to MBtu/yr, where MBtu/yr = (kWh/yr)/293.

Internal gains in the Rated Home shall not be modified as a result of reductions in exterior lighting energy use.

303.4.1.7.2.4 Garage Lighting. For Rated homes with garages, garage lighting in the Rated home shall be determined by the following equation:

$$kWh = 100*(1-FF_{GL}) + 25*FF_{GL}$$

where:

FF_{GL} = Fraction of garage fixtures that are fluorescent or LED lighting types

For the purpose of adjusting the annual garage lighting energy consumption for calculating the rating, EUL_{LA} shall be adjusted by ΔEUL_{GL}, which shall be calculated as the annual garage lighting energy use derived by the procedures in this section minus the annual garage lighting energy use derived for the HERS Reference Home in Section 303.4.1.7.1 (i.e. 100 kWh/yr), converted to MBtu/yr, where MBtu/yr = (kWh/yr)/293.

Internal gains in the Rated Home shall not be modified as a result of reductions in garage lighting energy use.

303.4.1.7.2.5 Refrigerators. Refrigerator energy use for the Rated Home shall be determined from either Refrigerator Energy Guide Labels or from age-based defaults provided in Table 303.4.1.7.2.5(1).

Table 303.4.1.7.2.5(1) Age-based Refrigerator Defaults

Refrigerator Type	Annual kWh Equation
Top freezer	(16.0*AV + 355)*VR
with TDI	(17.6*AV + 391)*VR
Side-by-side	(11.8*AV + 501)*VR
with TDI	(16.3*AV + 527)*VR
Bottom freezer	(16.6*AV + 367)*VR
where: AV = Adjusted Volume = (refrigerator compartment volume) + 1.63*(freezer compartment volume) TDI = Through the door ice VR = Vintage Ratio from Table 303.4.1.7.2.5(2)	

Table 303.4.1.7.2.5(2) Age-based Vintage Ratios

Refrigerator Vintage	Vintage Ratio
1972 or before	2.50
1980	1.82
1984	1.64
1988	1.39
1990	1.30
1993 forward	1.00

For the purpose of adjusting the annual refrigerator energy consumption for calculating the rating, EUL_{LA} shall be adjusted by ΔEUL_{FRIG}, which shall be calculated as the annual refrigerator energy use derived by the procedures in this section minus the annual refrigerator energy use derived for the HERS Reference Home in Section 303.4.1.7.1, converted to MBtu/yr, where MBtu/yr = (kWh/yr)/293.

For refrigerator energy use, internal gains in the Rated home shall be modified by 100% of the refrigerator ΔEUL_{FRIG} converted to Btu/day as follows: $\Delta EUL_{FRIG} * 10^6 / 365$. Internal gains shall not be modified for refrigerators located in unconditioned spaces (e.g. unconditioned garages, etc.)

303.4.1.7.2.6 Televisions. Television energy use in the Rated Home shall be determined using the following protocol:

1) No TV information available – same annual TV energy use as the Reference home in accordance with Section 303.4.1.7.1 of this standard
2) EPA Label information[44] **or** number and size of TVs available
    a. TVs shall be ordered in a list to determine TV# by decreasing screen size and within the same screen size by decreasing active wattage
    b. The number of Rated TVs in the Rated home shall be a minimum of 1.1 + 0.51*Nbr
    c. If number of Rated TVs is less than 1.1 + 0.51*Nbr, then remaining TVs (i.e. 1.1 +0.51*Nbr minus number of Rated TVs), including partial TVs, shall be included in the ordered TV list calculated as standard TVs using the following formula:

$$actWatts_{STD} = 124 - 69.1*\log_{(10)}TV\#$$

or 50 watts, whichever is greater

    d. If number of TVs is greater than 1.1 + 0.51*Nbr, then each TV shall be included in the calculation of Rated home annual TV energy use
    e. If label information is available, active wattage and standby wattage as reported on label shall be used for the calculation of annual TV energy use
    f. If label information is not available, standby wattage shall be 4 watts and active wattage shall be determined from the diagonal screen size using the following formula:

$$actWatts_{TV} = 9.21 + 1.17*diag + 0.110*diag^2$$

    i. Viewing hours shall be determined on a unit by unit basis using the following formula:

$$onHours = 6.876 - 7.054*\log_{(10)}TV\#$$

or 0.5 hours, whichever is greater

    j. Total annual Rated home TV energy use shall be calculated using the following formula:

$$TVkWh/yr = \Sigma(actWatts_{TV},i *onHours,i + offWatts_{TV},i *offHours,i) + p*(actWatts_{STD},m *onHours,m + offWatts_{STD},m *offHours,m)$$

where:

i = 1, n = TV#
n = INT(1.1 + 0.51*Nbr) **or** total number of Rated TVs, whichever is greater

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[44] http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=TV

o = 1.1 + 0.51*Nbr **or** total number of Rated TVs, whichever is greater
p = o – n (a fractional TV)
m = n +1 = TV# for partial TV

For the purpose of adjusting the annual television energy consumption for calculating the rating, EUL_{LA} shall be adjusted by ΔEUL_{TV}, which shall be calculated as the annual television energy use derived by the procedures in this section minus the annual television energy use derived for the HERS Reference Home in Section 303.4.1.7.1, converted to MBtu/yr, where MBtu/yr = (kWh/yr)/293.

For television energy use, internal gains in the Rated Home shall be modified by 100% of the television ΔEUL_{TV} converted to Btu/day as follows: $\Delta EUL_{TV} * 10^6 / 365$. Internal gains shall not be modified for televisions located in unconditioned spaces (e.g. unconditioned garages, porches, etc.)

303.4.1.7.2.7 Range/Oven. Range/Oven (cooking) energy use for the Rated Home shall be determined as follows:

1) For electric cooking:
kWh/yr = BEF * OEF * (331 + 39*Nbr)
2) For natural gas cooking:
Therms/yr = OEF*(22.6 + 2.7*Nbr)
plus:
kWh/yr = 22.6 + 2.7*Nbr
where:
BEF= Burner Energy Factor = 0.91 for induction ranges and 1.0 otherwise.
OEF = Oven Energy Factor = 0.95 for convection types and 1.0 otherwise
Nbr = Number of bedrooms

For the purpose of adjusting the annual Range/Oven energy consumption for calculating the rating, EUL_{LA} shall be adjusted by ΔEUL_{RO}, which shall be calculated as the annual Range/Oven energy use derived by the procedures in this section minus the annual Range/Oven energy use derived for the HERS Reference Home in Section 303.4.1.7.1, converted to MBtu/yr, where MBtu/yr = (kWh/yr) / 293 or (therms/yr) / 10, whichever is applicable.

For Range/Oven energy use, internal gains in the Rated Home shall be modified by 80% of the Range/Oven ΔEUL_{RO} converted to Btu/day as follows: $\Delta EUL_{RO} * 10^6 / 365$. Of this total amount, internal gains shall be apportioned as follows, depending on fuel type:

a) For electric Range/Ovens, 90% sensible internal gains and 10% latent internal gains
b) For gas Range/Ovens, 80% sensible internal gains and 20% latent internal gains.

303.4.1.7.2.8 Clothes Dryers. Clothes Dryer energy use for the Rated Home shall be determined by the following equation.

kWh/yr = 12.5*(164+46.5*Nbr)*FU/EFdry*(CAPw/MEF

- LER/392)/(0.2184*(CAPw*4.08+0.24))

where:

Nbr = Number of bedrooms in home
FU = Field Utilization factor =1.18 for timer controls **or** 1.04 for moisture sensing
EFdry = Efficiency Factor of clothes dryer (lbs dry clothes/kWh) from the CEC database [45] or use following defaults: 3.01 for electric **or** 2.67 for natural gas
CAPw = Capacity of clothes washer (ft^3) from the manufacturer's data or the CEC database **or** the EPA Energy Star website [46] **or** use default of 2.874 ft^3
MEF[47] = Modified Energy Factor of clothes washer from Energy Guide Label **or** use default of 0.817
LER[37] = Labeled Energy Rating of washer (kWh/yr) from Energy Guide Label **or** use default of 704

For the purpose of adjusting the annual Clothes Dryer energy consumption for calculating the rating, EUL_{LA} shall be adjusted by ΔEUL_{CD}, which shall be calculated as the annual Clothes Dryer energy use derived by the procedures in this section minus the annual Clothes Dryer energy use derived for the HERS Reference Home in Section 303.4.1.7.1, converted to MBtu/yr, where MBtu/yr = (kWh/yr) / 293 or (therms/yr) / 10, whichever is applicable.

For Clothes Dryer energy use, total internal gains in the Rated Home shall be modified by 15% of the Range/Oven ΔEUL_{RO} converted to Btu/day as follows: $\Delta EUL_{TV} * 10^6 / 365$. Of this total amount, 90% shall be apportioned to sensible internal gains and 10% to latent internal gains. Internal gains shall not be modified for Clothes Dryers located in unconditioned spaces (e.g. unconditioned garages, etc.)

303.4.1.7.2.9 Dishwashers. Dishwasher energy use for the Rated Home shall be determined using the following equation.

kWh/yr = [(86.3 + 47.73 /EF)/215]*dWcpy

where:

EF = Labeled dishwasher energy factor
dWcpy = (88.4 + 34.9*Nbr)*12/dWcap

where:

dWcap = Dishwasher place setting capacity; Default = 12 settings for standard sized dishwashers and 6 place settings for compact dishwashers

And the change (Δ) in daily hot water use (GPD – gallons per day) for dishwashers shall be calculated as follows:

ΔGPD_{DW} = [(88.4+34.9*Nbr)*8.035 - (88.4+34.9*Nbr)

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[45] http://www.energy.ca.gov/appliances/database/excel_based_files/

[46] http://www.energystar.gov/index.cfm?c=clotheswash.pr_clothes_washers

[47] This value must be determined from the energy rating for clothes washer as it determines the amount of moisture remaining in the clothes after the washer cycle is completed.

$$*12/dWcap* (18.5- 28.5*EF + 12.5*EF^2)]/365$$

For the purpose of adjusting the annual Dishwasher energy consumption for calculating the rating, EUL_{LA} shall be adjusted by ΔEUL_{DW}, which shall be calculated as the annual Dishwasher energy use derived by the procedures in this section minus the annual Clothes Dishwasher energy use derived for the HERS Reference Home in Section 303.4.1.7.1, converted to MBtu/yr, where MBtu/yr = (kWh/yr) / 293 or (therms/yr) / 10, whichever is applicable.

For the purpose of adjusting the daily hot water use for calculating the rating, the daily hot water use change shall be 'ΔGPD_{DW}' as calculated above.

For Dishwasher energy use, total internal gains in the Rated Home shall be modified by 60% of the Dishwasher ΔEUL_{DW} converted to Btu/day as follows: $\Delta EUL_{DW} * 10^6 / 365$. Of this total amount, 50% shall be apportioned to sensible internal gains and 50% to latent internal gains.

303.4.1.7.2.10 Clothes Washers. Clothes Washer annual energy use and daily hot water use for the Rated Home shall be determined as follows.

Annual energy use shall be calculated using the following equation:

$$kWh/yr = ((LER/392)-((LER*(\$/kWh)-AGC)/(21.9825*(\$/kWh) - (\$/therm))/392)*21.9825)*ACY$$

where:

LER = Label Energy Rating (kWh/yr) from Energy Guide Label
\$/kWh = Electric Rate from Energy Guide Label
AGC = Annual Gas Cost from Energy Guide Label
\$/therm = Gas Rate from Energy Guide Label
ACY = Adjusted Cycles per Year

and where:

ACY = NCY * ((3.0*2.08+1.59)/(CAPw*2.08+1.59))

where:

NCY = (3.0/2.847) * (164 + Nbr*45.6)
CAPw = washer capacity in cubic feet from the manufacturer's data or the CEC database[48] **or** the EPA Energy Star website [49] **or** use default of 2.874 ft^3

And daily hot water use shall be calculated as follows:

$$DHWgpd = 120.5* therms/cyc * ACY / 365$$

where:

therms/cyc = (LER * \$/kWh - AGC) / (21.9825 * \$/kWh - \$/therm) / 392

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[48] http://www.energy.ca.gov/appliances/database/excel_based_files/
[49] http://www.energystar.gov/index.cfm?c=clotheswash.pr_clothes_washers

For the purpose of adjusting the annual Clothes Washer energy consumption for calculating the rating, EUL_{LA} shall be adjusted by ΔEUL_{CW}, which shall be calculated as the annual Clothes Washer energy use derived by the procedures in this section minus the annual Clothes Washer energy use derived for the HERS Reference Home in Section 303.4.1.7.1, converted to MBtu/yr, where MBtu/yr = (kWh/yr) / 293 **or** (therms/yr) / 10, whichever is applicable.

For the purpose of adjusting the daily hot water use for calculating the rating, the daily hot water use change shall be calculated as the daily hot water use derived by the procedures in this section minus 7.94 gallons per day for the reference standard clothes washer.

For Clothes Washer energy use, total internal gains in the Rated Home shall be modified by 30% of the Clothes Washer ΔEUL_{CW} converted to Btu/day as follows: $\Delta EUL_{CW} * 10^6 / 365$. Of this total amount, 90% shall be apportioned to sensible internal gains and 10% to latent internal gains. Internal gains shall not be modified for Clothes Washers located in unconditioned spaces (e.g. unconditioned garages, etc.)

Rating and label data on clothes washer may be found at the following web sites:

EPA: www.energystar.gov/index.cfm?c=clotheswash.pr_clothes_washers
CEC: www.energy.ca.gov/appliances/database/excel_based_files/Clothes_Washers/

~~303.4.1.7.5~~303.4.1.7.2.11 Ceiling Fans. If ceiling fans are included in the Rated home, they shall also be included in the Reference home. ~~Three (3)~~The number of bedrooms plus one (Nbr+1) ceiling fans shall be assumed in both the Reference Home and the Rated Home. A daily ceiling fan operating schedule equal to ~~14~~ 10.5 full-load hours shall be assumed in both the Reference Home and the Rated Home during periods when ceiling fans are operational. Ceiling fans shall be assumed to operate only during the cooling season, which may be estimated to be all months with an average temperature greater than 63 °F. The cooling thermostat (but not the heating thermostat) shall be set up by 0.5 °F in both the Reference and Rated Home during periods when ceiling fans are assumed to operate.

The Reference Home shall use number of bedrooms plus one (Nbr+1)~~three (3)~~ Standard Ceiling Fans of 42.6 watts each ~~for total full-load fan wattage of 128 watts (42.6 * 3 = 128)~~. The Rated Home shall use the Labeled Ceiling Fan Standardized Watts (LCFSW), also multiplied by number of bedrooms plus one (Nbr+1)~~three (3)~~ fans to obtain total ceiling fan wattage for the Rated Home. The Rated Home LCFSW shall be calculated as follows:

LCFSW = (3000cfm) / (cfm/watt as labeled at medium speed)

Where installed ceiling fans in the Rated Home have different values of LCFSW, the average LCFSW shall be used for calculating ceiling fan energy use in the Rated Home.

During periods of fan operation, the fan wattage, at 100% internal gain fraction, shall be added to internal gains for both the Reference and Rated Homes. In addition, annual ceiling fan energy use, in MBtu/y~~ear~~ [(kWh/y~~ear~~)/293]~~ * 3.413x10^{-3})~~, for both the Rated and Reference homes shall be added to the lighting and appliance end use loads (EUL_{LA} and $REUL_{LA}$, as appropriate) ~~given in~~as specified by Equation 2, Section 303.2.1 of this Chapter.

303.4.1.7.2.12 Mechanical Ventilation System Fans. If ventilation fans are present in the Rated Home, EUL_{LA} shall be adjusted by adding total annual kWh energy consumption of the ventilation system in the Rated Home, converted to MBtu/yr, where MBtu/yr = (kWh/yr) / 293.

303.4.1.8 If the Rated Home includes On-site Power Production, the Purchased Energy Fraction for the Rated Home (see Section 303.2.2) shall be used to determine the impact of the On-site Power Production on the HERS Index.