Proposed Amendment EXP: 2004-01 – Proposed Incorporating Lighting, Appliances, and On-Site Energy Production to the Rating Score

Proponents: RESNET Lighting and Appliance, and Renewable Energy Subcommittees

Introduction

The purpose of this proposed standards revision is to incorporate the necessary provisions and analysis methodology to allow the evaluation of hard-wired light fixtures, "permanent" appliances and on-site power production within the HERS Technical Guidelines. Since lighting, appliances and on-site power generation would all be scored using a new "expanded HERS score", the separate proposals for a) lighting and appliances and b) on-site power generation have been combined together into this single proposal.

For on-site power generation, the proposed revisions have been purposefully designed to be as general as possible so that they do not address a specific technology but rather so that they allow virtually any technology capable of producing on-site power to be evaluated. The primary component of the proposal that allows for this generality is the establishment of a reference electricity production efficiency with which all on-site power production may be compared. This proposal establishes that efficiency at 40% – an efficiency that is consistent with the best-available, high-efficiency central power plant technology when all associated delivery and distribution losses are included.

This proposal suggests providing an option to the HERS Provider to display on the rating report either:

1) The current "Classic HERS Score" (calculated based on space heating, cooling and domestic hot water using the current normalized modified end use loads method); or
2) Two rating scores: the current "Classic HERS Score" *and* the new "Expanded HERS Score". The latter would include the "expanded denominator" score for space heating, cooling, domestic hot water, lighting, appliances and on-site power generation. Presentation of this score would be optional and determined by the program sponsor, HERS provider or HERS rater (if not specified by the provider or program).

Although a number of individual standards additions and modifications are proposed, they must be considered as a single proposed revision. The approval or disapproval of any individual part of the proposed revision is likely to result in an incomplete or unworkable revision of the Standards.

Chapter 3.A.3. - Revise Definitions and Acronyms, to add the following:

Classic HERS Score – *The rating point score using the normalized modified end use loads for space heating, cooling and hot water.*

Bedroom - A room or space 70 square feet or greater, with egress window and closet, used or intended to be used for sleeping. A "den", "library", "home office" with a closet, egress window, and 70 square feet or greater or other similar rooms shall count as a bedroom, but living rooms and foyers shall not.

Conditioned Floor Area ("CFA") – (INSERT FINAL LANGUAGE FROM AMENDMENT TECH: 2004-04 if adopted).

Equivalent Electric Power – The amount of electricity that would be produced from site fossil fuel uses when converted to electrical power using the Reference Electricity Production Efficiency.

Expanded Score Equipment – Qualifying lighting fixtures, qualifying appliances and on-site power generation equipment that are included in the rating.

Expanded HERS Score - The rating point score including space heating, cooling, domestic hot water and all other rated Expanded Score Equipment.

Light Fixture - A complete lighting unit consisting of a lamp or lamps, and ballasting (when applicable) together with the parts designed to distribute the light, position and protect the lamps, and connect the lamps to the power supply. For built-in valence lighting, strings of low-voltage halogens, and track lights, each individual bulb shall count as a fixture.

Mechanical ventilation system – A fan designed to exchange the air in the house with outside air, sized to provide whole-house service per ASHRAE 62.2, and controlled automatically (i.e. not requiring human intervention to turn on and off).

Non-Rated Light Fixture - All light fixtures except for those in qualifying light fixture locations.

On-site Power Production (OPP) – Electric power produced at the site of a Rated Home. OPP shall be the net electrical power production, such that it equals the gross electrical power production minus any purchased fossil fuel energy, converted to its Equivalent Electric Power, used to produce the on-site power.

Purchased Energy Fraction (PEfrac) – The fraction of the total energy consumption of the Rated Home that is Purchased Energy, wherein all site fossil energy uses are converted to their Equivalent Electric Power using the Reference Electricity Production Efficiency of 40%.

Qualifying Appliances – *For the purposes of rating, includes refrigerator/freezers, dishwashers, and ventilation fans.*

Qualifying Light Fixture Locations – *For the purposes of rating, those qualifying light fixtures located in kitchens, dining rooms, living rooms, family rooms/dens, bathrooms, hallways, stairways, entrances, bedrooms, garage, utility rooms, home offices and all outdoor fixtures mounted on a building or pole. This excludes plug-in lamps, closets, unfinished basements and landscape lighting.*

Qualifying Light Fixture – A light fixture comprised of any of the following components: a) fluorescent hard-wired (i.e. pin-based) lamps with ballast; b) 100% screw-in compact fluorescent bulb(s); or c) light fixture controlled by a photocell and motion sensor.

Reference Electricity Production Efficiency – An electric power production efficiency, including all production and distribution losses, of 40%, approximating the efficiency of a modern, high-efficiency, central power plant. The Reference Electricity Production Efficiency is to be used only to convert site fossil fuel energy uses to an Equivalent Electric Power for the sole purposes of providing home energy rating system credit for On-site Power Production.

Chapter 3.B.1.a. To add a 5th requirement as follows:

(5) If the Rated Home includes On-site Power Production (OPP), then OPP shall be calculated as the gross electric power produced minus the Equivalent Electric Power of any purchased fossil fuels used to produce the electric power. For example, assume 1000 kWh (3413 kBtu or 3.413 MBtu) of gross electrical power is produced using 80 Therms (8 MBtu) of natural gas to operate a high-efficiency fuel cell system. Using these assumptions, OPP = 3.413 MBtu - (8 MBtu * 0.4) = 0.213 MBtu.

Chapter 3.B.1.c. – Amend as follows:

c. All HERS providers shall compare the estimates provided under paragraph B.1.a. of this section to determine the energy efficiency rating of the home and, if applicable, the energy efficiency rating of the home with proposed conservation measures and On-site Power Production installed.

Chapter 3.B.1.d. – Amend as follows:

d. To encourage the use of energy efficient lights and appliances, HERS providers may ~~provide~~ collect additional information on ~~estimated~~ light fixtures and appliances ~~energy consumption~~ in the Rated Home to include in the expanded rating point score. ~~This information shall not change the rating score set forth in Section B.2.a. of these Guidelines.~~

Chapter 3.B.2. – Amend as follows:

a. Where programs or providers choose to not report the Expanded Score, only the Classic HERS Score shall be displayed.

Change numbering in this section after adding new "a" above, make old "a" now "b" and old "b" now "c".

Step (2) Determine the ~~point~~ "Classic HERS Score" score using equation 2:

Chapter 3.B.2.a. - Add a new Step (3) as follows:

Step (3) Determine the "Expanded HERS Score" using equation 3:

Point Score = 100 – ((**PEfrac *** $TnML_{EXP}$ / TRL_{EXP}) * 20) (Eq. 3)

Where:

$TnML_{EXP} = nMEUL_{HEAT} + nMEUL_{COOL} + nMEUL_{HW} + EUL_{LA}$

(Total of all normalized Modified End Use Loads as calculated using equation 1 plus Qualifying Light Fixture Locations and Qualifying Appliance loads).

$TRL_{EXP} = REUL_{HEAT} + REUL_{COOL} + REUL_{HW} + REUL_{LA}$

(Total of all Reference Home End Use Loads including Qualifying Light Fixture Locations and Qualifying Appliance loads).

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 B.1.a.(5)

Chapter 3.B.2.b. – Amend as follows:

b. Star rating. The Rated Home will be given a star rating between one and five-plus stars, determined by the numerical score and the corresponding number of stars depicted in Table 2 for each of the Classic and Expanded HERS Scores.

Chapter 3.B.3.a.(1) – Amend as follows:

3. Rating report**.**

a. For each rating conducted under this part, a report shall be prepared containing, at a minimum, the following information:

(1) The numerical rating score(s) for the Classic HERS Score and, when applicable, the Expanded HERS Score determined in Section B.2.a of these Guidelines;

Chapter 3.B.3.e.(3) – Amend as follows:

(3) Rating point score(s) (i.e. Classic HERS Score at all times, and Expanded HERS Score, if applicable) and;

Chapter 3.B.4.a. – Amend as follows:

Add:

(22) Reference home annual lighting use (in kWh) is the product of the house conditioned floor area and the annual lighting intensity for the qualifying fixtures; that is, lighting energy use in kWh/yr = (CFA*0.64) + 364).

(23) Reference home annual refrigerator energy use is 775 kWh/yr.

(24) If a dishwasher is indicated in the design, one will be included in the reference home. When present, reference home annual dishwasher energy use is based on the number of Bedrooms from the following Table 6.

Table 6

Bedrooms	Reference Dishwasher kWh
1	90
2	126
3	145
4	174
5+	203

(25) If a mechanical ventilation system is indicated in the design, one will be included in the reference home. When present, the reference home annual mechanical ventilation system energy use shall be as follows:

Annual vent energy (kWh/year) = 0.03942*CFA + 29.565*(N_{br}+1)

Chapter 3.B.5.- Amend as follows:

a. All HERS providers shall calculate the estimated annual purchased energy consumption for heating, cooling, ~~and~~ water heating (and, if applicable, lighting and appliances) set forth in Section B.1 of these Guidelines using the

energy loss and gain associated with the minimum rated features set forth in Table 7.

Insert new subsections ‘i.’, ‘j.’ and ‘k.’ and re-alphabetize the current ‘i.’ to ‘l.’ :

i. For the purpose of calculating light fixture energy consumption for calculating the rating score, the annual light fixture usage (in kWh) is the product of the annual lighting intensity and the Conditioned Floor Area (CFA), where the annual lighting intensity “ALI” (kWh/yr-ft^2) = (98.38/CFA + 0.1730)*($FL_{\%}$) + (393.5/CFA + 0.6919)*(1-$FL_{\%}$) and where $FL_{\%}$ is the ratio of Qualifying Light Fixtures to all light fixtures in Qualifying Light Fixture Locations. The rated home shall never have $FL_{\%}$ less than 10%.

For the purpose of calculating the light fixture energy consumption to report annual purchased energy, the annual lighting consumption is equal to ALI 0.8 *CFA (kWh/yr).

j. For the purposes of calculating dishwasher energy consumption and hot water energy consumption, when a dishwasher is present, space is provided or if specified, the energy consumption shall be calculated based on the following formula with inputs from the following Cycles/Year by number of Bedroom (N_{br}) as specified in Table *[insert appropriate table number].*

Dishwasher annual energy use (kWh/yr) = (0.27) * (cycles/yr) / (dishwasher rated Energy Factor)

And the reduction in hot water use (gallons/day) shall be based on the following formula, to be used in adjusting Equation 7 under 3.B.6.b.5.:

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

[Table #]

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

k. If the Rated Home includes On-site Power Production, the Purchased Energy Fraction for the Rated Home shall be used to determine the impact of the On-site Power Production on the HERS point score.

Chapter 3.B.5. Table 7 – Amend as follows:

Break Table 7 into two tables: 7A and 7B
Create new Table 7B as follows:

Table 7B. Additional Minimum Rated Features for Expanded HERS Score

1. Light fixtures	Number of qualifying and non-qualifying light fixtures in qualifying locations (i.e. kitchens, dining rooms, living rooms, family rooms/dens, bathrooms, hallways, stairways, entrances, bedrooms, garage, utility rooms, home offices and all outdoor fixtures mounted on a building or pole (excluding landscape lighting)).
2. Refrigerator(s)	Total annual energy consumption (kWh) for all units from: California Energy Commission: Appliance Database at http://www.energy.ca.gov/appliances/appliance/index.html or Association of Home Appliance Manufacturers (AHAM) directories
3. Dishwasher(s)	Total annual energy consumption (kWh) for all units from: http://www.ftc.gov/bcp/conline/edcams/eande/index.html
4. Mechanical Ventilation System(s)	Equipment type, daily run hours, and wattage (may be listed in the Certified Home Ventilating Products Directory available from the Heating and Ventilation Institute (HVI), www.hvi.org).
5. Photovoltaics	Total annual kWh generation from

	installer/manufacturer.

Chapter 3.B.6.b. – Amend as follows:

b. All HERS providers shall estimate the annual purchased energy consumption for heating, cooling , ~~and~~ water heating and, if applicable, the annual purchased energy consumption for light fixtures and appliances for both the Rated Home and the Reference Home using the following assumptions–

(3) Internal heat gains ("IGain" in Btu/day per dwelling unit) from lights, people and equipment of 17,900 + 23.8 * CFA + 4,140 * N_{br}

as adjusted for lower internal gains assuming 90% of the change in the lighting energy with respect to the Reference home light fixtures and assuming 100% of the change in appliance energy with respect to the Reference home for lights and appliances in the Rated home that are more efficient than those of the Reference home.

Chapter 3.B.7. Table 10 - Amend as follows:

Add as introductory language between the table name "TABLE 10.-Annual Energy Use for Non-Rated Features" and the table itself:

The values in Table 10 shall be used for the Classic HERS Score. If the Expanded HERS Score is to be displayed, actual energy use shall be used for those end-uses included in the Expanded HERS Score.

Insert in alphabetical order in Table 10:

End use	Units/year	Energy estimate	Applicability
Dishwasher	kWh	- As specified in 3.B.4.a.(25).	If present, if specified, or if space is dedicated for ~~Dw~~dishwasher.
Freezer	kWh	641	Each one present.
Lights	kWh	- (0.64*CFA + 364)/0.8	All homes.

Mechanical Ventilation System	kWh	- As specified in 3.B.4.a.(26).	Each one present.
Refrigerator	kWh	- As specified in 3.B.4.a.(23).	Each one present.
Photovoltaics	kWh	None	Each one present

Justification:

Lighting and Appliances

There appears to be a consensus in the HERS industry around an approach for including light fixtures and appliances in the HERS rating. The process of moving towards this consensus has included discussions at the 2001, 2002 and 2003 RESNET Conferences, work done by the states and HERS providers, working meetings at the 2002 EEBA Conference and subsequent teleconferences. The current proposal is to allow HERS providers or raters (at the direction of HERS-related programs, like ENERGY STAR, state and utility programs) to display on the rating report either:

1) the "Classic HERS Score" (i.e. the current score); or
2) the Classic HERS Score *and* the new "Expanded HERS Score" (which includes consideration of certain light fixtures, appliances and on-site power generation equipment—see below).

From the beginning of HERS, there has been an interest in giving credit in the rating score for efficient lighting and appliances. However, there have also been many vocal opponents, as well. Early arguments against incorporating lighting and appliances have included:

- We need to focus on the major end-use loads in the house;
- We need to not burden the rating process with additional complexity;
- There aren't big differences in the energy use of different appliances;
- Building codes don't address these end-uses, so we shouldn't; and
- There is no way to distinguish between efficient appliances and inefficient ones.

At this time, there is growing support for expanding what HERS covers. There is a white paper[1] and a study[2] on the subject that each examines the issues and solutions.

[1] "Incorporating Lighting, Refrigerators and Photovoltaic Power Generation into the HERS Rating Method", Philip Fairey, Danny S. Parker and Robin K. Vieira, Florida Solar Energy Center (FSEC), January 2002.
[2] "Incorporating Lighting and Appliance Energy Consumption into the Home Energy Rating Score – A Pilot Study", David Roberts, Architectural Energy Corporation (AEC) for the Massachusetts Joint Management Committee, December 2001.

As a result, there are some sound reasons to address lighting and appliances in HERS, including;

- As homes become more efficient, lighting and appliances have become a greater piece of the total energy consumption (e.g. energy use associated with lighting and appliances represents 47% of the total annual energy cost for a home)[3];
- Collecting lighting and appliance data as part of the rating can be made optional so that only those programs that want to give credit for these new end-uses can include them in the rating;
- With today's technology, there can be pretty significant differences in the energy consumption of certain light fixtures (up to 70% savings), refrigerators (up to 80% savings) and dishwashers (up to 30% savings);
- Just because codes don't address certain end uses, does not mean that HERS should not.; and
- With appliance directories (i.e. GAMA, AHAM, etc.) and ENERGY STAR labeling, there is currently the information available to distinguish efficient appliances from standard or inefficient ones.

Benefits

The proposed "Expanded HERS Score" approach offers the following benefits:

- Incorporating light fixtures and appliances in HERS reports is optional, as is collecting lighting and appliance data in the field;
- Gives credit for lighting and appliances without having to change current rating point thresholds;
- Gives credit for building elements not currently considered in the rating score;
- Provides tangible credit to give lighting and appliances manufacturers motivation to support market transformation and HERS;
- Uses same methodology as the current system ("pure");
- The ability to opt-in or opt-out provides flexibility for programs, providers and raters;
- Recognizes and encourages the purchase and use of energy efficient lighting and appliances in new and existing construction;
- Recognizes that lighting and appliances are a significant part of the total energy use of homes;
- Utility programs using HERS can benefit from greater comprehensiveness;
- A phased approach allows the market to react and adjust in

[3] Residential Energy Consumption Study, Energy Information Administration/US Department of Energy, 1997, http://www.eia.doe.gov/emeu/recs/recs97/rx97toc.html

preparation for full adoption of lighting and appliances in the rating score at some point in the future; and
- Reflects market transformation successes.

On-Site Power Generation

A number of technologies that promise on-site electric power production potential are beginning to emerge in the marketplace, including photovoltaic (PV) systems, home-sized fuel cells and micro turbines, and combined heat a power (CHP) systems. Each of these system types can impact the quantity of Purchased Energy used by a Rated Home. To maintain meaning in the marketplace, Home Energy Rating Systems must be kept as up-to-date as possible with respect to contemporary and emerging technology.

This proposed revision to the Guidelines provides a methodology designed to accommodate virtually any on-site power production technology within a uniform and equitable evaluation system. In addition, the U.S. Department of Energy has recently created a Zero Energy Home (ZEH) program that is aimed directly at the utilization of such on-site power production systems in combination with exemplary energy efficiency. The program is designed to encourage the production of homes that use very little purchased energy by virtue of the fact that they are both highly energy efficient and incorporate on-site power production. It is potentially very advantageous to the HERS industry for its home energy rating system to be able to accurately account for the powerful combination of these two impacts on the purchased energy use in homes.

Given this comparison and evaluation capability, the U.S. DOE may choose to utilize home energy rating systems to “determine” the point at which a home has reached ZEH status. This represents a situation that is not unlike the situation that existed when EPA first considered implementation of their ENERGY STAR new homes program – a home energy rating system was available, so it became the standard by default. Thus, the mere existence of such national programs is strong and powerful justification for the HERS industry to adopt guidelines and procedures that are capable of evaluating the overall efficiency of such homes.

Supporting Documents

Incorporating Lighting, Refrigerators and Photovoltaic Power Generation into the HERS Rating Method

Philip Fairey Danny S. Parker Robin K. Vieira

Florida Solar Energy Center
January 23, 2002 (Revised 7/19/03)

Introduction

Since the inception of the HERS rating method, it has been the desire of many stakeholders to incorporate lighting and appliance energy use in the rating of homes. This paper is intended to shed some light and provoke some thought on the issues associated with this.

First, by means of a small analysis, the potential impact of adding lighting and refrigerator energy use to the HERS rating method is analytically examined. To produce the data for the analysis, the energy end uses of typical homes in Chicago, IL (a cold climate), Miami, FL (a hot, humid climate), Baltimore, MD (a mixed climate) and San Diego, CA (a benign climate) are simulated using EnergyGauge USA. A 2000 ft^2, 3 bedroom, frame home on a slab or crawlspace – depending on the climate – that is configured as the HERS Reference home is used for the simulations. The energy use values resulting for lighting and refrigerators are derived from the procedures proposed here. Table A below presents the results of EnergyGauge USA simulations using this home.[4]

Table A. Comparison of Energy End Uses Across Climate Types

Climate:	**Chicago**		**Miami**		**Baltimore**		**San Diego**	
End Use:	MBtu*	% Tot	MBtu*	% Tot	MBtu*	% Tot	MBtu*	% Tot
Heating	29.8		0.1		21.8		3.4	
Cooling	4.2		28.5		8.0		1.2	
Hot Water	9.8		9.6		10.6		6.2	
HERS Base	**43.8**	**67%**	**38.1**	**63%**	**40.4**	**65%**	**10.7**	**33%**
Lighting	6.1	9%	6.1	10%	6.1	10%	6.1	19%
Sub Tot	**49.9**	**76%**	**44.3**	**74%**	**46.5**	**75%**	**16.8**	**51%**
Refrigerator	3.2	5%	3.2	5%	3.2	5%	3.2	10%
Sub Tot	**53.2**	**81%**	**47.5**	**79%**	**49.8**	**80%**	**20.1**	**61%**

[4] Analysis accomplished using EnergyGauge USA (v.1.26) energy rating software. (See also http://energygauge.com/usares/ on the Internet.) Annual simulation results are produced by selecting the "View HERS Reference Home" option under the "View" menu and then selecting the "Annual Simulation" option under the "Calculate" menu.

Dryer	3.0		3.0		3.0		3.0	
Range	1.5		1.5		1.5		1.5	
Other	8.1		8.1		8.1		8.1	
Total	**65.8**	**100%**	**60.2**	**100%**	**62.4**	**100%**	**32.7**	**100%**

* Site energy use for fossil fuel-fired end uses are adjusted to their modern electric equivalent (for full explanation, see section entitled **"Accounting for On-Site PV Power Production in HERS Scores**" that follows later in this paper). Homes located in Chicago and Baltimore assume natural gas heating and hot water and homes located in Miami and San Diego assume all electric equipment.

The current HERS rating method considers only heating, cooling and hot water energy uses (the sum of which is shown in Table A as the row labeled 'HERS Base'). Table A shows a large range (between 33% and 67%) for the percentage of the total energy use represented by these "rated" end uses. However, most interesting to note is that, unless the climate is benign (as in San Diego), there is a relatively small range for this percentage (i.e. from a low of 63% in Miami to a high of 67% in Chicago). As can be seen in the Table, the inclusion of lighting in the base will increase "rated" energy use by about 9-10% in most climates but by about double that amount (19%) in benign climates. The same trend holds for refrigerators, which show about twice the contribution to total home energy use in benign climates as in the other climates.

The analysis clearly indicates that accounting for lights and refrigerators in Ratings will substantially increase the base energy use that is considered by the HERS method in all climates, bringing it from about 65% to about 80% of the total in most climates but almost doubling it from 33% to 61% in benign climates. Therefore, incorporating these additional features into the rated features of a home will have some impact on the HERS scores of homes. There are both advantages and disadvantages.

Lighting and appliance end uses were originally (circa 1994) not included in the rated features of homes primarily because they are not included in code compliance requirements and there was a fervent hope on the part of many stakeholders that a strong linkage between codes and rating systems would develop. This remains a principal disadvantage in the minds of many who are opposed to incorporating these additional features into the HERS rating method. Probably a greater perceived disadvantage, however, is that HERS scores would no longer have their original value ("old" scores would be lower on the "new" scale because the "base" energy use is increased). The concept of a HERS score that does not changes over time is one of the original HERS Council tenants (again, circa 1994) that is often touted as reason enough that the rating method should not be changed.

On the other hand, incorporating these additional end-use features into the HERS rating method has significant advantages. It provides for increased energy and cost savings opportunities through voluntary programs like Energy Star, which require that homes to go beyond minimum code requirements. Also, as it is more comprehensive (i.e. 80%,

as opposed to 65%, of total energy use is evaluated) , the resulting HERS score is a significantly better reflection of overall household energy use and cost. And every home, even the smallest and most modest, has lighting and refrigeration. Most important, the cost-effectiveness of these efficiency options are often superior to many of the alternative options. For example CFLs have a very rapid payback and often choosing the most efficient refrigerator is a very low cost option.

Additionally, many code jurisdictions have now adopted the 1998 or 2000 IECC. These requirements are different from and exceed the 1993 MEC requirements upon which the HERS Reference home and score were based. As a result, HERS scores are not directly "translatable" into code compliance in these jurisdictions, making code "linkage" very difficult, if not impossible.

Adding Rated End-Use Features

If additional rated features are to be added to the HERS rating method, there are two central questions that weigh heavily on the issues:

- What is the basis of the Reference home standard for the feature?
- Can the energy use of the feature be "effectively measured" in the Rated Home?

For heating, cooling and hot water, the Reference home standards find their basis in the 1993 CABO Model Energy Code and the NAECA minimum standards for heating, cooling and hot water equipment. Argument over these Reference home standards has been minimized by the fact that their adoption by code officials pre-dated their adoption in the HERS Technical Guidelines. The "effective measurement" of these energy use features is provided by the HERS industry requirement that Accredited Rating software be subjected to the BESTEST procedures in accordance with the HERS Accreditation Procedures and Technical Guidelines.

While a convincing case may be made that NAECA covers refrigerators and can be used as the basis for a HERS Reference home refrigerator, there is no prevailing standard for lighting energy use in homes.

Lighting

Lighting energy use can be most easily and effectively "measured" in the Rated home by simply determining the portion of the lighting that is supplied by fluorescent lighting. However, there is currently no prevailing consensus standard that can serve as the basis for establishing a Reference home lighting energy use. The following describes a simple procedure that can be used to calculate the value of high-efficiency lighting in the case where a Reference home lighting energy use has been or can be established.

The discussion also proposes a method to incorporate these relatively simple procedures into the HERS rating method.

First, it is necessary to establish a "standard" for the annual lighting energy use intensity (normalized by conditioned floor area) for the Reference home.[2] This proposal adopts the proposed lighting standard of the DOE *Building America* program's "Benchmark" home at an annual lighting intensity equal to 455 + 0.80*CFA kWh/yr, where CFA equals conditioned floor area.

Now make the following additional assumptions:

- For the Reference home, 90% of annual lighting energy use is from incandescent lighting and 10% is from fluorescent lighting. (Consistent with finding of Report #DOE/EIA-555(96)/2, 1996 – see footnote 2.)
- Lighting luminosity is equal everywhere (i.e. all rooms have the same lumens/ft^2).
- The luminous efficacies of the incandescent and fluorescent lighting are: 15 lumens/watt and 60 lumens/watt, respectively.
- For both the Reference and Rated home, 10% of lighting is by outdoor lights and 90% is indoor lighting use (consistent with the referenced data – see footnote 2).
- The % of the total conditioned floor area that is lit by fluorescent lighting ($FL_{\%}$) is the "measure" of lighting efficiency.

One can now construct an equation that will calculate lighting energy use as a function of conditioned floor area and the percent of that floor area that is lit by fluorescent lighting. From the assumptions, fluorescent lighting requires only ¼ the energy of incandescent lighting (i.e. "y = 0.25 * x", where "x" represents incandescent watts). Also from the assumptions, annual use for the Reference home is 10% fluorescent and 90% incandescent. Thus, we can write the following simultaneous equations:

$$\text{kWh/yr-ft}^2 = 0.1 * y + 0.9 * x$$
$$y = 0.25 * x$$

which can be solved to yield 'x' and 'y' in terms of the normalized annual lighting energy use for the Reference home, such that:

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[2] There are 3 sources of data known to the authors: 1) Proprietary monitoring data collected by FSEC between 1999-2000 on 196 typical central Florida homes that shows an average annual lighting energy use intensity of 0.9 kW/yr-ft^2; 2) Monitored data collected in 161 homes in the pacific northwest as part of the Bonneville Power Administration's "Baseline Residential Lighting Energy Use Study" (published in Proceedings of 1996 ACEEE Summer Study on Energy Efficiency in Buildings) that shows an average per household lighting energy use of 1818 kWh/yr. Personal communication with one of the authors of this study (David Lerman) revealed that the average conditioned floor area is 1800 ft^2, producing a normalized lighting use of 1.0 kWh/yr-ft^2; and 3) An econometric study conducted using 1993 survey data and published in 1996 by the Energy Information Administration under the title "Residential Lighting: Use and Potential Savings" (Report #DOE/EIA–555(96)/2), which estimates average household lighting energy use at 940 kWh/yr. This appears to be the source of the value used in Table 10 of the HERS Technical Guidelines. The average reported home size in the study is 1667 ft^2, yielding a normalized use of only 0.56 kWh/yr-ft^2, significantly smaller than the reported measured lighting energy uses.

$$x = kWh/yr\text{-}ft^2 / (0.1 * 0.25 + 0.9)$$
$$y = 0.25 * kWh/yr\text{-}ft^2 / (0.1 * 0.25 + 0.9)$$

and for kWh/yr = 455 + 0.80*CFA,
and @80% qualifying lighting, kWh/yr = 364 + 0.64*CFA,
therefore, $kWh/yr\text{-}ft^2 = 364/CFA + 0.64$,

and

$$x = 393.5/CFA + 0.6919$$
$$y = 98.38/CFA + 0.1730$$

Now by expressing the lighting percentages in the above equation (i.e. 0.1 and 0.9) in general terms (i.e. $FL_{\%}$ and $1\text{-}FL_{\%}$), we can write a general equation to calculate the normalized annual lighting intensity (ALI) per square foot of conditioned floor area for any combination of incandescent and fluorescent lighting, as follows:

$$ALI\ (kWh/yr\text{-}ft2) = (98.38/CFA + 0.1730)*(FL_{\%}) + (393.5/CFA + 0.6919)*(1\text{-}FL_{\%})$$

The Reference home is assumed to have 10% fluorescent lighting coverage yielding the reference annual lighting intensity of 0.9 $kW/yr\text{-}ft^2$. For the Rated home, the equation determines the lighting use based on the % fluorescent coverage ($FL_{\%}$). For example, if 50% of lighting is fluorescent, then it will use 0.6081 $kW/yr\text{-}ft^2$ and if 100% is fluorescent then the Rated home will use only 0.2432 $kW/yr\text{-}ft^2$.

Altering the lighting energy use for the Rated home should also alter its internal gains. Assuming 10% of the lighting energy use is outdoors, = 3.07 Btu (3.413 * 0.9) of heat energy should be subtracted from the Rated home's sensible internal gains for each watt of lighting energy reduction below that of the Reference home (i.e. 900 $watts/yr\text{-}ft^2$). Lighting efficiency changes will then be properly reflected in the heating and air conditioning energy end uses for the Rated home.

To incorporate lighting into the HERS rating method, simply add a lighting end use to both the Reference and the Rated home so that four energy end uses are considered instead of the original three. Equation 1 for the lighting energy end use then becomes:[5]

$$nMEUL_{LGT} = REUL_{LGT} * (nEC_x,_{LGT} / EC_r,_{LGT})$$

where

$REUL_{LGT} = EC_r,_{LTG} * 3.413$ (lighting energy consumption in the Reference home) *[needed to convert lighting energy to lighting load]*

$nEC_x,_{LGT} = EC_x,_{LGT}$ (lighting energy consumption in the Rated home)

and the terms of Equation 2 become:

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[5] Section B.2, *National Home Energy Rating Technical Guidelines*, National Association of State Energy Officials, September, 1999.

$$TnML = nMEUL_{HEAT} + nMEUL_{COOL} + nMEUL_{HW} + nMEUL_{LGT}$$

and

$$TRL = REUL_{HEAT} + REUL_{COOL} + REUL_{HW} + REUL_{LGT}$$

Refrigerators

A relatively simple method of incorporating refrigerators into the HERS rating method is proposed. Select a 'standard' refrigerator volume [recommend 25 ft^3] and model type [recommend side-by-side with through-the-door ice maker (TDI)] to calculate the Reference home annual refrigerator energy use.

The recommendation of volume and model type is based on examination of the available sizes (25 ft^3 is near the largest) and models (side-by-side TDI is the most popular) and careful consideration of the balance that is required between allowing too little or too much "room for improvement" as compared to the Reference. In other words, the trick is to provide a large enough reference energy use to make efficiency improvements worthwhile but not so large as to provide unrealistically large predicted energy savings from these improved refrigerators.

If we choose to use a 25 ft^3, automatic defrost, side-by-side, thru-the-door ice (TDI) model, the equation (defined as product class 7 in 10CFR430.32.pdf file) for the minimum standard efficiency (maximum energy use) is:

$$kWh/yr = 10.10*AV + 460.0$$

where: AV = 1.0 * refrigerator volume + 1.63 * freezer volume

If one assumes the freezer is 1/3rd the total volume (probably somewhat conservative), then this equation evaluates as follows:

$$kWh/yr = 10.10*(2/3*25 + 1/3*25*1.63) + 460 = 765\ kWh/yr$$

If we assume the freezer volume is 2/5ths of the total volume (a little less conservative), then this equation evaluates as 776 kWh/yr.

As a simple check, if we take 660 kWh/yr as a reasonable value for a 25 ft^3 Energy Star refrigerator and we "assume" for the sake of the calculation that this Energy Star refrigerator is 20% more efficient than the minimum standard, we will get the following value:

$$kWh/yr = 660/(1-20\%) = 825\ kWh/yr$$

If we assume the Energy Star refrigerator is only 15% more efficient than the minimum standard model we will get 776 kWh/yr, which is identical to the value we calculate

directly from the minimum standard equation assuming the freezer is 2/5ths of the total volume.

Based on the above analysis, it is recommended that 775 kWh/yr is a reasonable and defensible value for the reference standard refrigerator.

The Rated home's refrigerator energy use (which may be calculated by vintage for existing homes or taken directly from the manufacturers "Energy Guide" for new homes) can then be compared with this Reference home refrigerator's energy use in the HERS rating method.

Incorporating refrigerator energy use into the HERS rating method is exactly the same as lighting. Annual refrigerator energy use is simply added to the annual lighting energy use in both the Rated and Reference homes and the above "lighting" procedures are followed, changing only the nomenclature for this end use from "lighting" to "lighting and appliances." In addition, much like for lighting, any energy savings resulting from the use of improved refrigerators should be subtracted from internal gains in the Rated home at 100% – watt for watt – so that they are properly reflected in the heating and air conditioning energy end uses for the Rated home.

The final consideration regarding refrigerators is how to treat new homes where the refrigerator is not specified as part of the home, but rather is left to the home purchaser as an "after the fact" decision and purchase. Clearly the same "default" refrigerator energy use must be used for both the Reference and the Rated homes under this circumstance. For simplicity, this default refrigerator should be set equal the Reference home refrigerator (or 951 kWh/yr).

Accounting for On-Site PV Power Production in HERS Scores

HERS Guidelines and Procedures provide no guidance for consideration of on-site photovoltaic (PV) power production from sunlight. To be strictly accurate regarding the actual impacts of PV on "rated" energy uses, it would be necessary to apportion the PV production in accordance with the electric proportion of these building energy uses at the time the PV is being produced. However, such a procedure would tend to raise more questions and cause more problems than it would solve. For example, what happens during periods when the PV production is greater than energy use demands of these "rated" energy uses in the home? Since PV produces only electricity, how will homes with fossil fuel-fired heating and water heating systems be treated? For PV systems that are tied to the electric grid, how is the electricity that is "sold back" to the utility to be treated? And does PV production during periods of peak utility demand have the same "value" as "off-peak" PV production?

Clearly, technical details and local circumstances are so numerous and complex that simplifying assumptions are required. Thus, the following assumptions are proposed:

- All PV power production, whether used on site by the Rated home or sent back into the utility grid for use elsewhere, shall be "credited" to the Rated home's energy use.
- In "crediting" PV power, all on-site fossil fuel use by the Rated home shall be converted to its electric equivalent using a power plant efficiency that is representative of highly-efficient, modern plants.[6] (An overall plant efficiency of 40% – including all transmission and distribution losses – is proposed.)
- "Net metering" (running the electric meter backward if power is going from the Rated home to the utility) shall be assumed for all cases. (Note that this does not preclude the use of time-of-day pricing.)

Even given these simplifying assumptions, there remain two alternative methods of incorporating on-site PV power production into HERS scores:

[6] This is necessary in order to provide an equitable PV credit to homes that use natural gas to provide space heating and hot water. Without this adjustment, the total site energy use of homes with fossil fuel-fired equipment increases substantially, making the apparent contribution of the PV production significantly smaller than if that same fossil fuel were used to produce electricity at modern power plant efficiencies. The proposed plant efficiency of 40% is based on a modern, combined-cycle natural gas power plant which the PV production is offsetting.

Method 1. Apply the PV power production "credit" to total home energy use, including all so-called "non-rated" energy consuming devices.

Method 2. Apply the PV power production "credit" to only that part of the home energy use that is "rated" (currently heating, cooling and hot water or 35% - 65% of total home energy use).

The second method would provide for significantly larger HERS score increases than the first, but it would also mislead consumers in that it implies that a much greater portion of total home energy use is being displaced by PV than is the actual case. This can be a critical consideration for at least two very important reasons, as follows:

- The U.S. Department of Energy's new Zero Energy Buildings program (http://www.eren.doe.gov/solarbuildings/zero_energy_blds.html) bases its definition of "zero energy" on total purchased energy use, not just an arbitrary segment of the energy uses that are designated as "rated" features. The early monitored energy use data from demonstrations homes (see http://infomonitors.com/zeh/) clearly show that homes can be designed and constructed that do, in fact, have zero net energy use. Based on this fact, the first method of accounting for PV production appears preferable to the second. Otherwise, the HERS rating method is perceived to contradict DOE's newest and most potentially vibrant PV program.

- It seems clear that new features will continue to be added to the list of "rated" features over time as the industry's ability to establish a basis for references and to effectively measure those end uses in Rated homes is improved. This being the case, the first method would again be preferable. *Otherwise, each time a new feature is added to the list of "rated" features, the value of PV power production would appear to be diminished in the HERS score.* This fact would tend to impede the continued development of an ever more inclusive and comprehensive rating system, one that provides the maximum possible information to the consumer.

For the above reasons, the authors propose the use of the first method, where total home energy use (the sum of both the rated and the non-rated energy uses) is the basis against which PV power production is applied. A simple procedure to incorporate the PV power production into the HERS rating method is proposed.[7]

Three steps are required, as follows:

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[7] EnergyGauge USA uses PVFORM to compute hourly PV power production based on long-term local climate data and complete PV systems configuration and performance data. RE: Menicucci, David F., "PVFORM Version 3.0 – A Photovoltaic Systems Simulation Program for Stand-alone and Grid-interactive Applications." September, 1985.

a Calculate the total energy use for the home in accordance with Section B.7 of the Technical Guidelines,[8] multiplying all fossil fuel energy uses by 40% (the efficiency of modern gas-fired power plants) before summing the energy end uses.

b Calculate the percent purchased energy use (PPE) as (Total-PV)/(Total), where 'Total' is the annual energy use calculated in Step 1 and 'PV' is the total annual power production of the PV system, both is the same energy units.

c Use PPE as an adjustment coefficient for TnML in Equation 2 to calculate the HERS score for the Rated home.

The above steps can be easily incorporated into the rating method through a simple modification of Equation 2 of the Technical Guidelines:[7]

Point score = 100 _ ((PPE * TnML/ TRL) * 20) **(new Eq. 2)**

where:

PPE = Percent Purchased Energy use

TnML = $nMEUL_{HEAT}$ + $nMEUL_{COOL}$ + $nMEUL_{HW}$ (Total of all normalized Modified End Use Loads as calculated using equation 1).

TRL = $REUL_{HEAT}$ + $REUL_{COOL}$ + $REUL_{HW}$ (Total of all Reference Home End Use Loads).

This procedure apportions the PV power production as an equal percentage to all end uses, including "non-rated" features. Both electric and fossil-fuel energy uses are counted equitably. Since PV produces only electricity, fossil fuels are converted to their electric equivalent at a modern plant efficiency of 40% (i.e. a heat rate of 8,532 Btu/kWh), including all transmission and distribution loses. In this way the on-site PV electric production can be directly compared with the purchased site energy as though all the home energy uses are electric.

For instance, if we take the simulation analysis results given in Table A and assume that 3,500 kWh/yr of PV power is produced at the homes, we can quickly determine the resulting HERS Score. Recalling that the data in Table A are for HERS Reference homes so that their HERS scores are 80.0 by definition, we can calculate the HERS score for these homes with the added PV as

$$\text{HERS Score w/ PV} = 80 + (1-\text{PPE}) / 0.05$$

or, expressed in words, the score with PV equals 80 plus the PV contribution (as a %) divided by 5% per HERS point. This analysis can be quickly performed for both of the two scoring methods discussed above. For Method 1, the PV power production (MBtu/yr) is divided by the 'total' energy use given in Table A to obtain

[8] *National Home Energy Rating Technical Guidelines*, National Association of State Energy Officials, September, 1999.

the % PV contribution and for Method 2, the PV power is divided by the "HERS base" value given in Table A. Performing these simple calculations results in the data shown below in Table B.

Table B. Comparison of HERS Scores for 3500 kWh/yr PV System

Energy	Chicago	Miami	Baltimore	San Diego
HERS base	43.8	38.1	40.4	10.7
Total	65.8	60.2	62.4	32.7
PV	11.9	11.9	11.9	11.9
Score:	83.6	84.0	83.8	87.3
Method 2	85.5	86.3	85.9	102.3

The above data show about a 4 HERS-point increase in typical climates and a 7 HERS-point increase in San Diego if Method 1 is used to derive HERS scores. For Method 2, the HERS-point increase in typical climates is near 6. However, for the benign climate it is 22, pushing the HERS score above 100 points in a home where only about one-third of the energy use has been offset by PV power production. Thus, in addition to the above logical arguments that appear to favor Method 1, these data indicate that it is also the more practical of the rating methods and provides a better reflection of the real influences in homes.

Conclusions and Recommendations

From the available information, the following may be concluded:

- Lighting and refrigeration comprise a substantial part (~15%) of total home energy use.
- Including lighting and refrigerators in the Rating Method will, on the whole, decrease HERS scores slightly.
- The integration of highly efficient buildings with photovoltaic technology seems likely the only practical means of producing "zero energy" homes.

The authors have also made detailed recommendations related to these conclusions within the body of this document. These recommendations can be briefly summarized as follows:

- Include lighting and refrigerators in the HERS Rating Method, incorporating their energy uses into both the Reference and Rated homes' loads in Equation 1 of the Technical Guidelines
- Establish a Reference home lighting energy use intensity of 455 + 0.80*CFA kWh/yr
- Establish a Reference home refrigerator energy use of 775 kWh/yr (2001, 25 ft^3, side-by-side w/TDI)

- Include PV power production in the HERS Rating Method using total home energy, both “rated” and “non-rated,” as the basis against which the PV is applied, incorporating the “credit” through a “purchased power” coefficient applied in Equation 2 of the Technical Guidelines

Determining Mechanical Ventilation Requirements for the HERS Reference Home

P. Fairey
January 19, 2003

From the most recent version of BSR/ASHRAE Standard 62.2P, the following section is quoted:

4.1 Ventilation Rate

A mechanical exhaust system, supply system, or combination thereof shall be installed for each dwelling unit to provide whole-building ventilation with outdoor air each hour at no less than the rate specified in Table 4.1a and Table 4.1b, or equivalently, Equations 1a and 1b based on the floor area of the conditioned space and number of bedrooms.

$$\mathbf{Q_{fan} = 0.01A_{floor} + 7.5(N_{br}+1)} \qquad \text{[Eq. 4.1a]}$$

where:

Q_{fan} = fan flow rate in cubic feet per minute (cfm).
A_{floor} = floor area in square feet (ft^2).
N_{br} = number of bedrooms; not to be less than 1.

Starting with the above Standard requirements and assuming ventilation fan efficiency of 0.45 watt/cfm, substitute into Eq. 4.1a, above as follows:

$$W_{fan} = 0.45 * 0.01 * A_{floor} + 0.45 * 7.5 * (N_{br}+1)$$

Which reduces to:

$$W_{fan} = 0.0045 * A_{floor} + 3.75 * (N_{br}+1)$$

The above equation represents is the fan wattage required to achieve the Standard mechanical ventilation rate at a vent fan efficiency of 0.45 watt/cfm. The Standard also requires that this ventilation rate be provided each hour. Thus, the annual energy requirement will be 365*24 = 8760 times the above fan power, or

$$\textbf{Annual vent energy (kWh/year)} = \mathbf{0.03942 * A_{floor} + 29.565 * (N_{br}+1)}$$

An example is provided – assume a 2000 ft^2, 3-bedroom home:

$$\begin{aligned} \text{Annual vent energy} &= 0.03942 * 2000 + 29.565 * 4 \\ &= 78.84 + 118.26 \\ &= 197.1 \text{ kWh/year} \end{aligned}$$

This would become the HERS Reference Home ventilation energy standard and Rated home systems that are more efficient would result in an increase in HERS score while less efficient Rated home ventilation systems would result in a decrease in HERS score.

Determining Freezer kWh Consumption for the HERS Reference Home

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5/20/2003

Methodology

There does not appear to be any reasonable way of identifying typical freezer consumption for the HERS reference home without making a series of simplifying assumptions. The following assumptions have been made for this analysis:

- Use of 1992 chest freezer and upright freezer consumption ratings are sufficient for the purpose. The California Energy Commission has published the Directory of Certified Refrigerators, Freezers, and Refrigerator Freezers for 1979 – 1992 models. This information is publicly available at no cost. The source database from AHAM with more current data is available at a cost of $5,000.

- Readily available sales data for freezers is sufficient to develop a weighted consumption average between chest and upright freezers. AHAM sales data for the two different residential model freezers is publicly available for the year 2000 so this ratio may be used to project typical freezer consumption for a HERS reference home.

Analysis

Based on these data sources, the following table may be developed:

Freezer Model	**1992 AHAM kWh Rating**	**2000 Sales Data**
Chest Freezer	559	1,285,100
Upright Freezer	755	930,100
Weighted Average	**641**	N/A

Conversion of 641 kWh to the MMBtu common denominator necessary for use in calculating a HERS score is accomplished as follows:

1. 641 kWh x 3413 Btu/kWh = 2,187,733 Btu
2. 2,187,733 Btu / 1,000,000 = 2.188 MMBtu

Recommendation

The HERS reference home use 2.188 MMBtu as the consumption rate for freezers.