The Home Energy Scoring Tool: A Simplified Asset Rating for Single Family Homes

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ABSTRACT

In 2010, the U.S. Department of Energy (DOE) and Lawrence Berkeley National Laboratory (LBNL) initiated development of a new web-based computer tool and method for providing an energy asset rating of single-family homes. The resulting Home Energy Scoring Tool (http://homeenergyscore.lbl.gov) is a key component of the DOE's Home Energy Score Program (http://www.homeenergyscore.gov) for residential building energy labeling, a voluntary national asset rating method that uses a simplified and standardized energy assessment process. The Scoring Tool component of the program has been designed to support the existing energy analysis marketplace by providing a substantially lower-cost entry-level assessment method.

This paper presents technical details of the Home Energy Scoring Tool itself, including the Scoring Tool's relationship to the Home Energy Saver building simulation engine, the Home Energy Score calculation methodology, and the web services feature that allows any qualified third-party software developer to integrate the Home Energy Score method into their own web-based applications and market delivery strategy.

Introduction

Globally, energy used in the buildings sector is responsible for 11 billion metric tons per year of greenhouse-gas emissions, or about a third of all emissions from human activity (IPCC 2007). The proportion is similar in the U.S., and corresponded to an energy bill of $392 billion in 2006, of which homes were responsible for $226 billion (USDOE 2009a).

Recognizing the magnitude of residential energy use – and the potential for savings through enhanced energy efficiency – in 2010 the U.S. Department of Energy (DOE) tasked the Lawrence Berkeley National Laboratory (LBNL) to develop a new tool within the Home Energy Saver suite (Mills 2007) to provide an "asset-based" analysis of residential home energy performance. The primary goal is to provide standardized energy assessment information for homeowners, buyers and sellers of detached single-family and townhomes in the United States. The resulting Home Energy Scoring Tool (Scoring Tool) is available at http://homeenergyscore.lbl.gov.

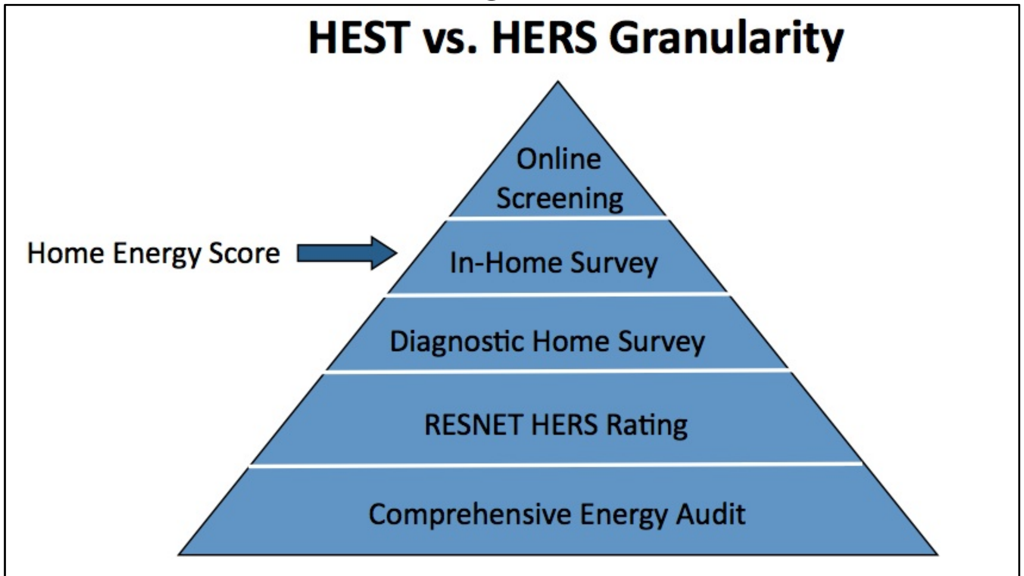
The Scoring Tool is a key component of the DOE's residential labeling initiative within the Recovery Through Retrofit plan of the American Recovery and Reinvestment Act of 2009. The Home Energy Score Program (http://www.homeenergyscore.gov) will provide the first national asset rating method that allows all individual USA regions to opt into a simplified and standardized energy assessment process that complements the existing industry of advanced home energy audit methods.

The Home Energy Score has been designed to support the existing marketplace of home energy analysis tools and services by providing a low-cost opportunity assessment of a home's fixed energy systems (also known as an "asset rating") and provide the home owner or authorized stakeholders with general feedback on the building systems that likely need detailed attention from certified home performance diagnostics and weatherization professionals.

In the existing home energy audit market, the Residential Energy Services Network, (RESNET, www.resnet.us) and the Building Performance Institute (BPI, www.bpi.org) currently certify home audit professionals. While both organizations provide the same fundamental building science training, RESNET principally uses the Home Energy Rating System (HERS) standard (RESNET, 2012) and has historically focused on newer homes built after 2004. In March of 2012, RESNET amended its standards in order to better address existing homes. BPI on the other hand has always directly provided a suite of professional certifications that target the energy performance improvement of both older and recently built homes.

Figure 1 provides a concise depiction of how the Home Energy Score is targeted with respect to RESNET's characterization of home rating assessment methods currently in the marketplace. The intention is to help service providers establish the potential energy savings in a home and demonstrate to the homeowner the value of pursuing a more comprehensive audit that produces a formal retrofit work scope proposal. In the DOE's 2011 Pilot Test of the Home Energy Score program, auditor surveys reported that in a typical home, an experienced assessor could complete a Scoring Tool analysis in under an hour. Comprehensive audits, which produce an upgrade work scope and that require detailed diagnostic testing, can take several times that long.

Figure 1



Time of Sale Energy Labeling of Homes: A Concept Paper, Philip Fairey (FSEC), Home Energy Magazine, July 2010 Issue.

Within an ethic of supporting the existing retrofit market, Application Programming Interface (API) web services[1] were developed within the Scoring Tool to enable approved third-

[1] For documentation, see https://developers.buildingsapi.lbl.gov/

party energy software developers to embed the nationally standardized Home Energy Score methodology into their products and business processes.

Asset Rating

An asset rating seeks to evaluate a home to allow it to be compared to others based on differences in its fixed characteristics, while holding occupant-determined factors and behaviors constant. An asset rating also excludes the performance of energy features that are not considered fixed components of the building. Thus, the efficiency of a furnace would be regarded as an asset attribute while the operation of the thermostat controlling that furnace would be deemed a behavioral (non-asset) attribute. There is some subjectivity in determining which energy-using components of a home are "assets". For the purposes of the Scoring Tool, space conditioning and water-heating systems (and the associated building envelope components) are considered asset components, while non-hardwired appliances, lighting, and other equipment are not.

Moreover, a process of standardizing non-asset features is required for the stipulation of many factors about the home within the Scoring Tool. These include appliance saturations and utilization, lighting power and utilization, and the exclusion of non-standard features such as pools, workshops, and many miscellaneous loads.

To ensure that users proactively define asset characteristics, no input values are defaulted, and all questions must be answered. For those systems not considered fixed assets (e.g., type of lighting and hours of use), values are not adjustable by the user and are set to be consistent with the defaults used by the Home Energy Saver site.

The Scoring Tool provides an "asset" calculation and has limited application toward informing home occupants on how to optimally operate their home, or for identifying retrofit opportunities on non-asset components. Asset ratings thus should not be expected to match individual utility bills. For these needs, Scoring Tool session data must be exported into operational assessment tools such as the Home Energy Saver (hes.lbl.gov, hespro.lbl.gov). These tools allow the homeowner or contracted energy professional to consider the operational/behavioral aspects of the home as well as add the characteristics of the other energy-using devices that are exclude in the Scoring Tool.

Fixed Assumptions and Default Values

For an asset rating to have meaning in the marketplace, one home must be comparable to another, without the variations introduced by differences in occupancy and equipment utilization. For home characteristics that are not considered fixed assets and not individually recorded and entered into the Scoring Tool, key standardized default assumptions largely match those of the Home Energy Saver Consumer and Pro tools, which are based on the best-available data and methodologies for modeling the energy use, costs, and greenhouse-gas emissions of homes under US conditions (e.g. USDOE 2009b, Sherman and Matson 1997, Sanchez et al., 1998, Lutz et al., 1996).[2] The key operational assumptions include:

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[2] For the latest engineering methods and a full list of reference sources, see https://sites.google.com/a/lbl.gov/hes-public/

- Occupancy is scaled per the number of bedrooms as defined in the *Building America House Simulation Protocols* (Hendron & Engebrecht, Oct. 2010)
    - Up to 3 bedrooms the occupant/bedroom ratio equals 1, then gradually scales downward for 4 bedrooms and higher homes
- Stove, oven, and clothes-drying fuels are set as electric
- The building length and width are fixed at a 5:3 aspect ratio (discussed more in Required Inputs section)
- Long term typical TMY weather data are used to estimate HVAC energy use
- The thermostat set point is scheduled all year as:
    - 08:00-17:00 Heating 64ºF, Cooling 81ºF
    - 17:00-08:00 Heating 68ºF, Cooling 78ºF

In keeping with a standardized asset-based scope, the predicted energy cost savings assume state-average energy prices and include improvements to home envelope and major equipment, but does not include upgrades of non-asset lighting and appliances or usage changes. As a result, predicted energy costs may be different from actual utility bills. The extent of these variations will depend on additional factors such as local economic conditions, how the occupant maintains their home, appliance ownership and amount of use, actual number of occupants, and year-to-year weather variations. Parker et al. (2012) discuss differences in predictive power between asset and operational energy modeling approaches.

Figure 2. Input page example.

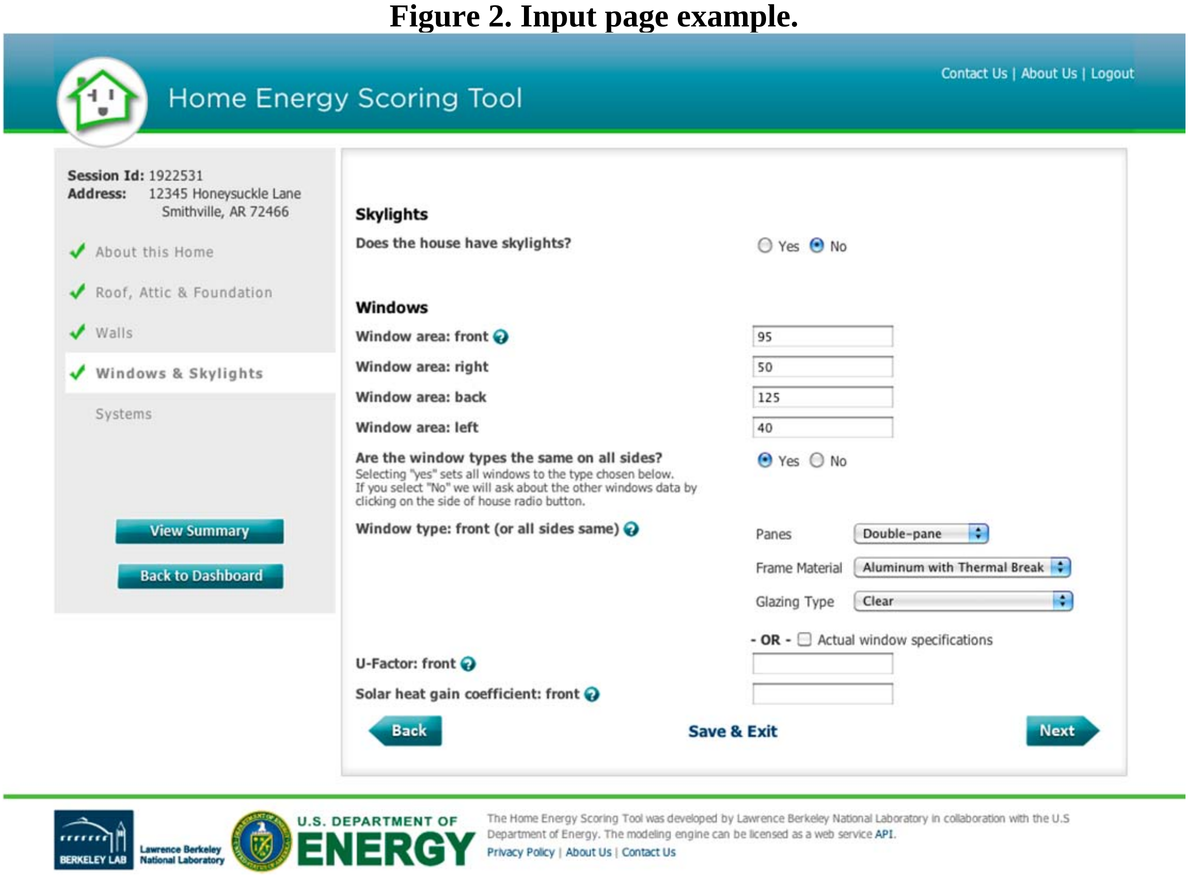


Table 1. List of Required Inputs

About this Home	Assessment date, Physical address, Year built, Conditioned floor area, Number bedrooms, Number Floors, Ceiling height, Orientation, Air leakage rate, Auditor comments
Roof, Attic & Foundation	Roof construction, Roof surface solar absorption, Attic or ceiling type, Attic floor insulation, Foundation type, Foundation insulation level, raised floor insulation level
Walls	Walls the same on all sides indicator, Wall construction(s) layers
Windows & Skylights	Skylights present, Skylight type, Skylight total area, Windows the same on all sides indicator, Window type(s) or custom input of U-Factor/Solar Heat Gain Coefficient
Systems	Heating system type & efficiency, Cooling system type & efficiency, Duct location, Duct insulation, Duct sealing status, Domestic hot water system type & efficiency, Combined space and water heating type

Required Inputs

The Scoring Tool has five screens of required user inputs used to describe the home construction and equipment (Figure 2). The total number of required inputs is typically less than 50 if the home has the same window and wall types on each building side. Unlike the Home Energy Saver website, the Scoring Tool does not pre-populate inputs with regional average values and all inputs must be provided by the user. A concise list of the inputs is provided in Table 1.

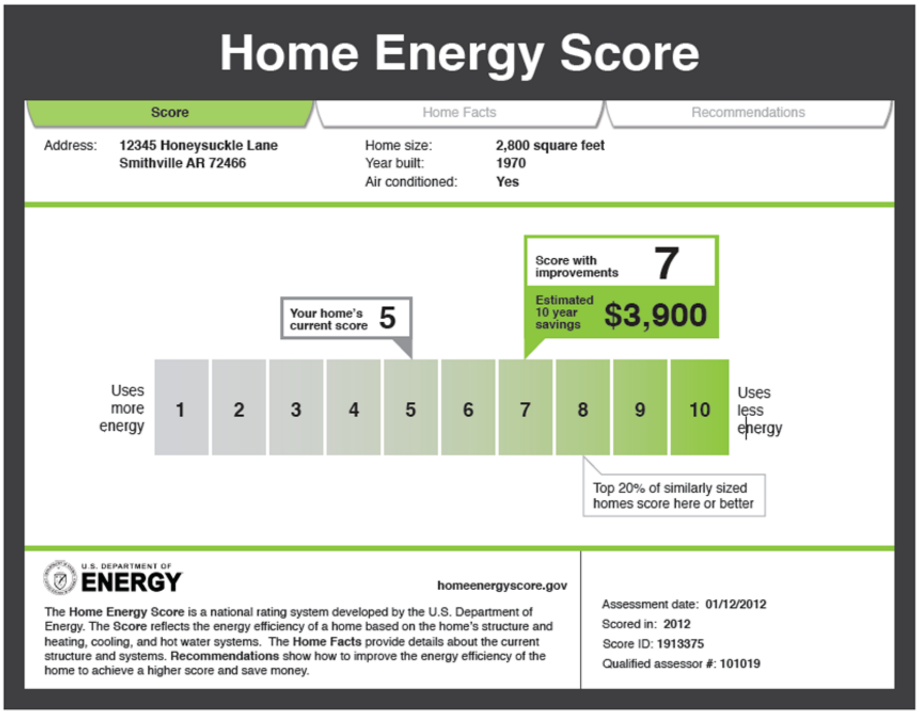
Extensive model input sensitivity analyses, balanced with considerations of audit time implications, were conducted with the goal of determining which inputs to require (ICF, 2010). The study conducted an analysis of 88 measures and determined that air leakage, duct leakage, ceiling height, and building shape (in order of results sensitivity) were important to include in the final Scoring Tool. The first three have been implemented in the national release version, while building shape has been delayed for consideration in future versions, in the interest of maintaining a simplified user interface in the initial Scoring Tool release.

Scoring Methodology

The heart of the Home Energy Score is the scoring methodology. The DOE and LBNL took into account many different factors and available data sources in an effort to develop a scoring system that could fairly compare the energy performance of existing homes. The DOE objective is to provide a simple system that helps consumers understand how homes compare in energy performance throughout the country, self adjusting as much as possible for the regional construction differences, dominant energy supplies and differing climate. The resulting methodology is applicable to single-family homes and townhome residential dwellings.

The Scoring Tool scores a home on a 10-point scale, where a 10 corresponds to best efficiency (lowest energy use) on the scale (Figure 3). Each point on the scale corresponds to a range of source energy use. National average source energy factors (Deru & Torcellini, 2007) were selected instead of site energy, since a key DOE requirement of the program is to adequately characterize the wider energy system impacts and different mixes of energy types. Given that heating and cooling loads vary considerably across the U.S., the DOE and LBNL opted for a system that uses a suite of customized source energy scoring bins covering distinct regions of the country.

Figure 3. Home Energy Score Label – Front Page



Pilot Test Version

A pilot version of the scoring method and tool was tested in nine regions across the country during the spring/summer of 2011. Through these diverse pilot programs, the DOE and the pilot test partners were able to examine a wide range of issues associated with the Home Energy Score, Scoring Tool, the scoring bins and climatic adjustments in the scoring method.

For the development of a test version of the Scoring Tool, the team used the Home Energy Saver website which extensively uses Residential Energy Consumption Survey micro data for model input defaults (USDOE 2009b & 2012). Within the Home Energy Saver websites, the RECS micro data are categorized into 19 regions (RECS Zones),[3] originally developed by LBNL for several research projects (Ritchard et al. 1992; Huang et al. 1999; Apte 2004).

Drawing from the RECS data, different source energy ranges for each RECS Zone were established. For example, the energy range for the 10-point scale in Minneapolis is greater than the range in San Diego – given that San Diego is a much milder climate. By calibrating the range of potential energy results in each zone, the 10-point score can be applied in a consistent manner nationally.

Within each of the 19 data sets, the top and bottom 2 percentiles of high-energy and low-energy outlier points were cut off and the remaining data were sorted by energy use. The RECS

[3] https://sites.google.com/a/lbl.gov/hes-public/calculation-methodology/default-energy-consumption-and-house-configuration/average-energy-bills-for-existing-houses

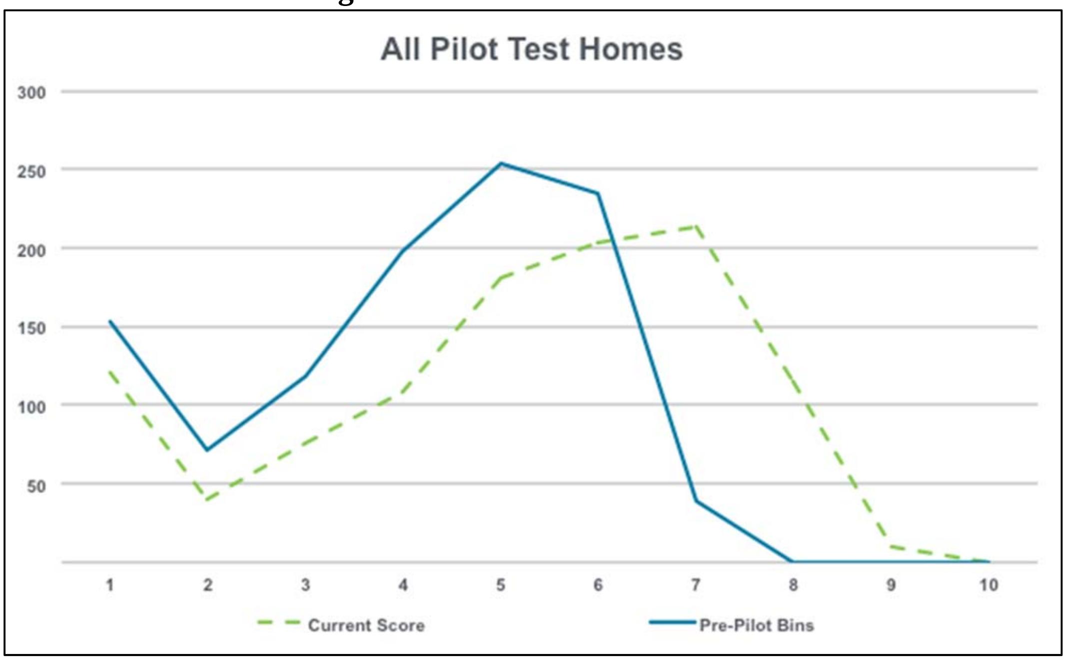
energy consumption data was not normalized by home size or weather location and the absolute energy consumption values were maintained throughout. Each data set was then divided into 10 equally sized energy bins and the energy value at the top of each bin was extracted, producing a set of 10 scoring thresholds from low to high energy use.

As an adjustment method for the operational energy use component that is implicitly embedded in RECS, Home Energy Saver models with asset operational assumptions were run in each zone. The results were used to adjust the scoring bin range and bin sizes with care taken to assure an acceptable range of score mobility within each bin set. Key observations included the ability of energy efficiency improvements to affect score improvements and maintaining acceptable capacity at the high-energy efficiency range to accommodate an improving building stock over time.

National Release Version

Over 1000 homes were scored during the pilot test project and in most cases, the scores reflected acceptably normal distributions (Figure 4), however the results showed a need to reconsider bin values in some climates, especially in more energy intensive heating climates. Immediately, at the beginning of the pilot test the pre-pilot bins required adjustments for energy intensive regions. In parallel with the pilot testing an in-depth analysis and update of the Home Energy Saver modeling defaults was conducted. The findings of the modeling defaults exercise complimented the pilot test findings and the Scoring Tool was revised in preparation for a version 1.0 national launch. A significant number of model defaults were adjusted and the changes are documented on the public Home Energy Saver website.[4]

Figure 4. Pilot Test Home Scores



[4] Release History section at https://sites.google.com/a/lbl.gov/hes-public/home-energy-scoring-tool/release-history

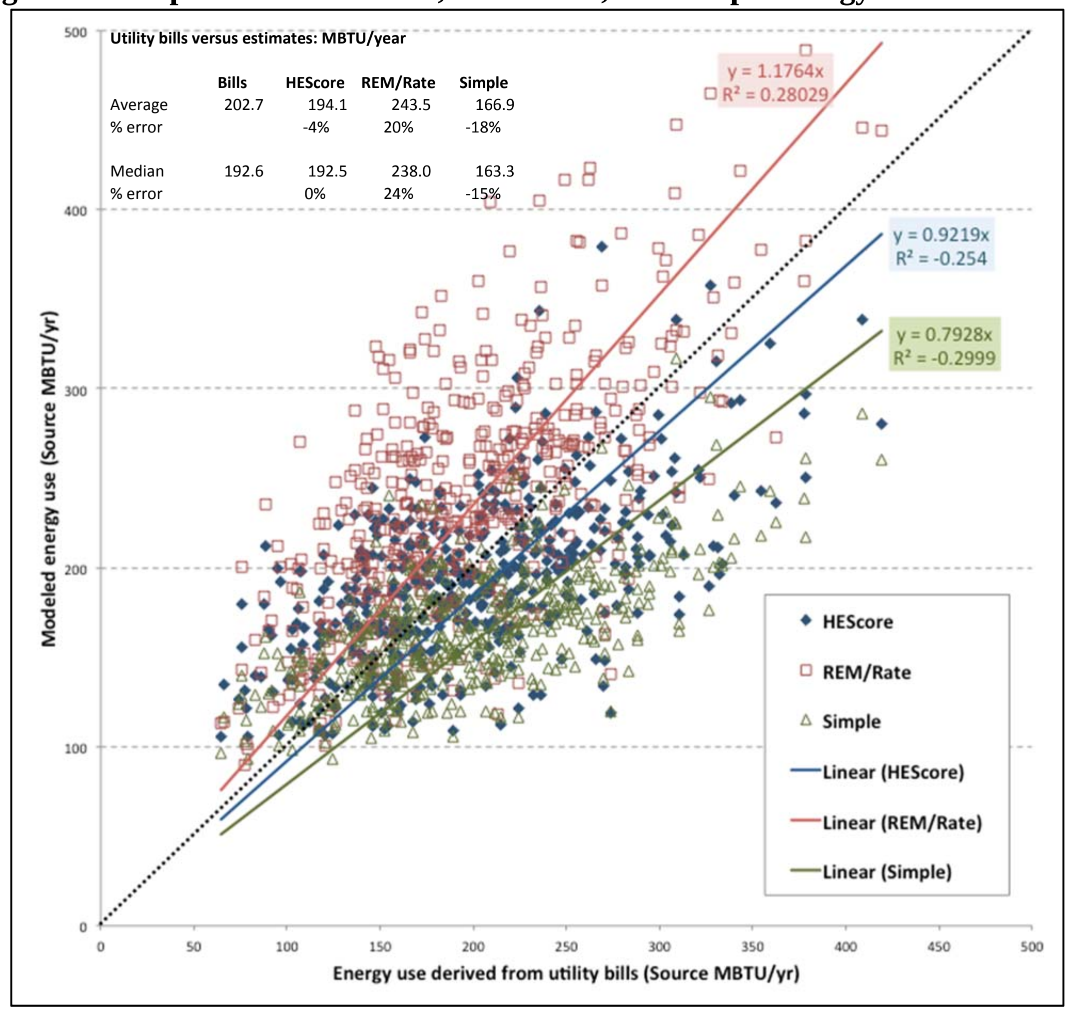
In response to scoring bin adjustments that were identified during the pilot projects and from general public stakeholder input, we converted to a more climate-responsive scoring method by creating individual scoring bins sets for each of the Typical Meteorological Weather Year (TMY2) data files that the Scoring Tool references for the source energy use calculation (Table 2). This enables the tool to issue a Home Energy Score on a much finer climate resolution than the 19 RECS Zone set used in the pilot test version.

Using custom Scoring Tool batch API scripts, thousands of prototypical home models were run through 245 USA weather climate locations. Once again, as was done for the pilot test version, care was taken to design bin sets that assure a fair range of scoring mobility in each weather region.

Table 2. Weather station based scoring bin format example

	1	2	3	4	5	6	7	8	9	10
Weather station	**Greater than**	**Up to**	**Up to**	**Up to**	**Up to**	**Up to**	**Up to**	**Up to**	**Up to**	**Up to**
station name	425	425	394	363	332	301	270	239	208	177
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
245 locations	*x* Mbtu	*x* Mbtu	*x* Mbtu	*x* Mbtu	*x* Mbtu	*x* Mbtu	*x* Mbtu	*x* Mbtu	*x* Mbtu	*x* Mbtu

Figure 5. Comparison of HEScore, REM/Rate, and Simple energy estimates



Accuracy Considerations

The accuracy of operational energy use estimates by the system underlying Home Energy Score has been established (Parker et al., 2012). Defining the expectations for accuracy of an asset-based modeling protocol is more nuanced, given that behavioral factors are normatively held constant and standardized defaults are applied to many appliances, and some loads that may be present in a real home (well pumps, workshops, pools, etc.) are assumed not to be present. Thus, significant differences can be expected between measured and predicted energy use for a *given* home, especially if that home is in any way non-average. These caveats notwithstanding, an asset-based tool would ideally produce estimates near the *average* bill for a large, diversified set of actual homes. This is indeed the case for Home Energy Score (Figure 5), which achieved excellent agreement with actual consumption among accuracy testing of three asset analysis tools. The analysis is based on the audit and billing data of 885 occupied homes in Oregon, Wisconsin, Minnesota, North Carolina and Texas.

In the case of asset tools that map estimated energy use to a discrete score, it is important that assignments of such scores are largely in agreement with assignment of scores using model estimates. Given a 10-bin scoring scale (described below), assessor-error (data entry, engineering assumptions, etc.) the analysis suggests that the Home Energy Score process will assign the correct score (i.e., within +/- 1 bin) 90% of the time. However, when all conceivable modeling uncertainties (assuming accurate assessor inputs) are included this decreases to +/- 1 bin 67% of the time. Though not relevant for determining the accuracy of the asset score, the study reassuringly notes that after including even the considerable uncertainties introduced by occupancy behavior effects, the estimated score will be correct in not less than 50% of the cases. In this analysis, field data were translated into HES inputs from REM/Rate inputs in NREL’s Field Data Repository (Roberts, et al. 2012 – see Appendix C), and furnished to the paper authors by NREL.

Upgrade Recommendation Opportunities

Also in keeping with the asset-based methodology, a consistent set of upgrade recommendation opportunities are analyzed for each scored home (variations of which are recommended is a function of home characteristics, cost-effectiveness, etc.). Upgrades calculated in the Scoring Tool include improvements to the building envelope and major equipment (the "assets"), but not to lighting and appliances or any occupant usage changes. The Scoring Tool applies a fixed, national average standardized retrofit cost derived from the NREL National Residential Efficiency Measures Database.[5]. The upgrade recommendations are categorized as either “Repair Now” items such as envelope and duct improvements, or “Replace Later” items for upgrades that make economic sense only at the time of other work such as replacement or repair.

All of the Repair Now recommendations are listed with their estimated annual energy savings in dollars per year and the list is limited to items achieving a simple payback of less than 10 years. Since simple payback is calculated using a national average cost, these recommendations are only intended to provide a list of opportunities to assist the homeowner in

[5] http://www.nrel.gov/ap/retrofits

identifying areas that can benefit from a more comprehensive audit and retrofit recommendation report from a local home energy audit professional.

All of the Replace Later recommendations are again listed with their estimated annual energy savings in dollars per year, with items included up to a 25-year simple payback threshold. The payback threshold was increased for Replace Later items, to create a more inclusive recommendations list with the understanding that homeowners often consider these upgrade technologies with more factors than cost alone.

The recommendations assessed by the Scoring Tool are:

Repair Now - These upgrades can help you save energy right away

- Attic floor insulation
- Basement wall or foundation slab edge insulation
- Floor insulation above a basement or crawlspace
- Crawlspace wall insulation
- Building air-sealing
- Exterior wall insulation
- Duct sealing
- Duct insulation

Replace Later - Recommendations for when you replace the affected equipment at a later time when needed or desired.

- Central air conditioner – ENERGY STAR unit
- Boiler or Furnace or Heat pump – ENERGY STAR unit
- Room air conditioner – ENERGY STAR unit
- Roof – increased reflectance
- Roof – insulated sheathing
- Skylights – ENERGY STAR units
- Siding – insulated exterior sheathing
- Water heater – ENERGY STAR unit
- Windows – ENERGY STAR units

It is important to note that the sum of the savings from the individual measures in the recommendations report may not equal the total savings for the package of selected upgrades (the number shown on the front page label). The difference is due to interactive effects of individual energy improvements. When improvements reduce energy consumption within the same end-use (e.g., a window upgrade plus an air conditioner upgrade), the resulting dollar savings is less than the sum of the savings shown for the individual improvements.

Building Registry and Qualified Assessor Databases

Qualified Assessors

In order to use the Scoring Tool and the Home Energy Score program, the user must become a DOE Qualified Assessor (QA) by meeting the following requirements:

- Must be working directly with a Home Energy Score Local Partner [6]
- Be certified by the Building Performance Institute (BPI) or by a Residential Energy Services Network (RESNET) Provider, and
- Complete and receive a passing grade on the DOE's Home Energy Score online training module and test.

This approach was deemed important as a means to help distribute the front-line administrative functions to partners that are well established in specific localities and market segments. The Partners are then also able to play a constructive role in managing providers and ensuring quality of the services delivered.

Building Registry

As mentioned in the Introduction, the Home Energy Scoring Tool backend server calculations are implemented as an API web service (Mills et al., 2012 – separate paper in this proceedings). This means that the DOE's official Scoring Tool web site described in this paper is using the same home energy calculation engine that is available to any Home Energy Score licensed third-party software developer. As a result, the online API web service merges all Home Energy Score assessment data into a public Building Registry. Eventually, as the program grows and delivers home scores in a majority of U.S. regions, the valuable Building Registry data can be combined with existing and future RECS data to help improve the energy benchmarking capabilities of the Scoring Tool. Additionally, the Building Registry will provide valuable data that can help the building science community better understand the relative energy efficiency of the existing residential building stock and thereby help target effective energy efficiency programs and market support strategies.

Next steps

The Scoring Tool will not remain static in years to come. An annual update of the Scoring Tool energy calculation methods, reference data and the included building components will be done as new assessment methods are vetted within the building science community. The necessary Scoring Tool system infrastructure has been put in place to facilitate a recalculation of prior scores when needed.

For 2012 and in ongoing years, the DOE will continue to increase the number of partners throughout the country, welcoming all local governments, utilities, and non-profit organizations that have existing energy efficiency programs.

[6] Local Partner details located at www.homeenergyscore.gov

Acknowledgments

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