Home Energy Score Scoring Methodology

February 2017

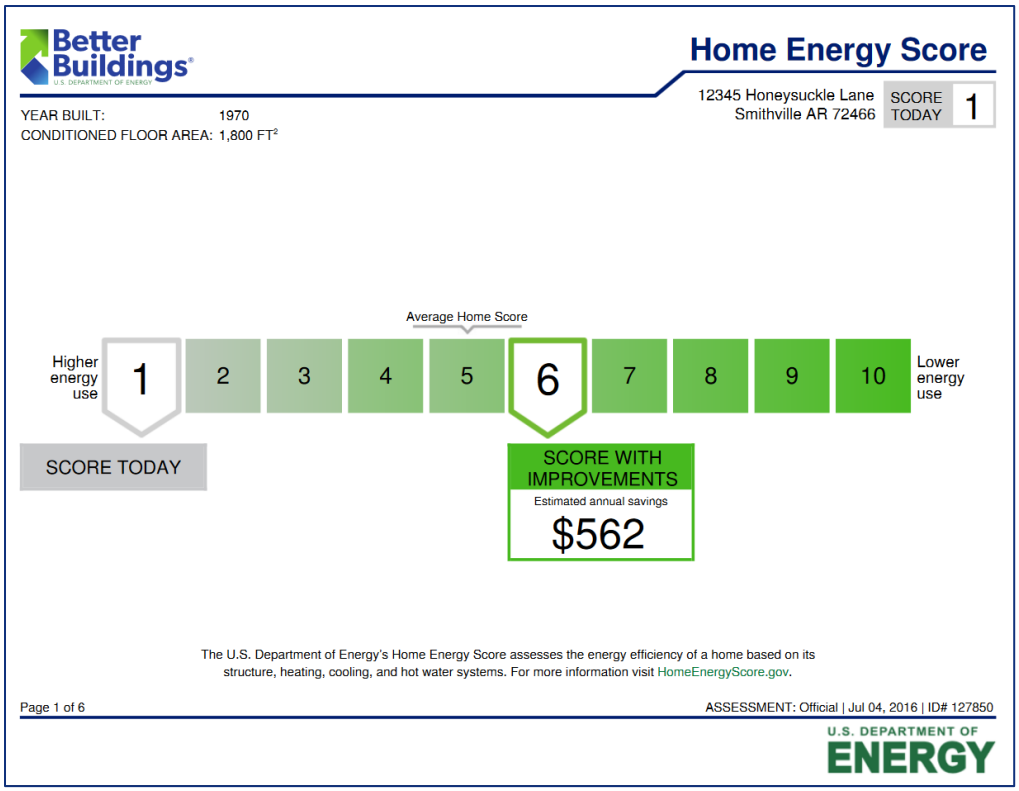
Table of Contents

1. Background

1.1 Purpose, Goal, Audience

Like a miles-per-gallon rating for a car, the Home Energy Score is an easy-to-produce rating designed to help homeowners and homebuyers gain useful information about a home's energy performance. Based on an in-home assessment that can be completed in less than an hour, the Home Energy Score not only lets a homeowner understand how efficient the home is and how it compares to others, but also provides recommendations on how to cost-effectively improve the home's energy efficiency. The Home Energy Score uses a simple 1-to-10 scale where a 10 represents the most energy efficient homes (Figure 1).

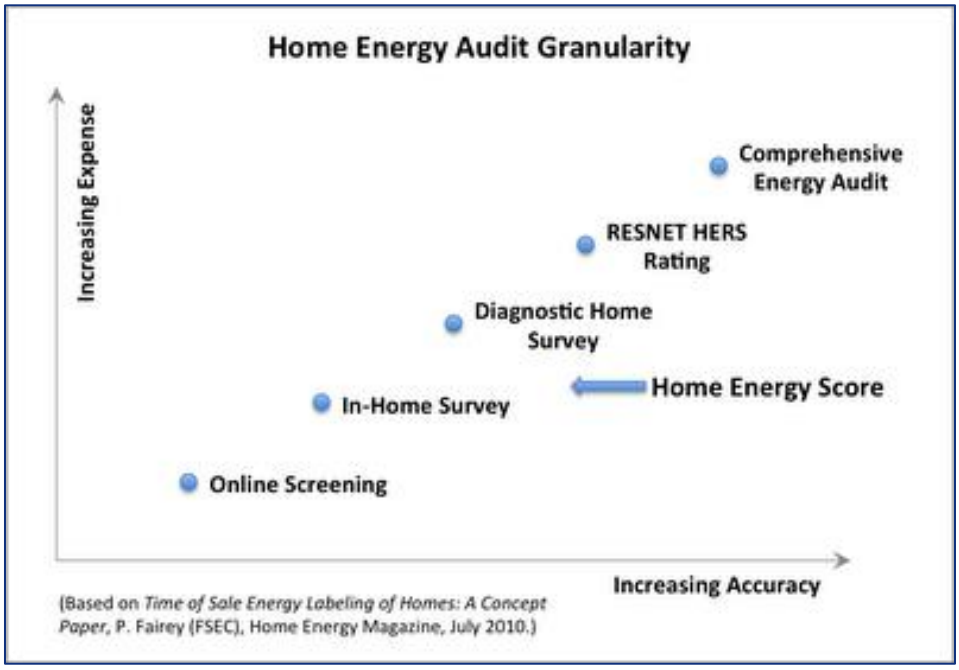
Figure 1. Home Energy Score Label Example



The mission of the Home Energy Score program is to build market value for home energy efficiency among single-family and townhomes. Home Energy Score accomplishes this by valuing, understanding, and allowing for financing of home energy efficiency with nationwide household recognition.

The Scoring Tool is designed to support the existing marketplace for energy analysis tools and services by providing a substantially lower-cost entry-level assessment, which can help the qualified Assessor establish the potential for energy savings, as well as the value of pursuing a more comprehensive assessment and retrofit recommendation report (Figure 2).

Figure 2. Home Energy Audit Granularity



1.2 Historical Context

In 2009 the Vice President and the White House Council on Environmental Quality called upon the Department of Energy (DOE) to create a home energy rating system. The White House's 2009 report, Recovery through Retrofit, identified the lack of straightforward and reliable information about homes' energy use as a key barrier to homeowner investment in home energy upgrades or improvements.

To address this barrier, DOE developed a voluntary program to help homeowners understand their home's energy use and prioritize cost-effective energy improvements. The goal was to allow homeowners to easily and affordably find out how their home's energy performance compares with other homes in the same area, much like the vehicle mile-per-gallon rating. According to guiding principles, the system must be:

a.) Credible, reliable and replicable
b.) Transparent and easy to understand
c.) Affordable
d.) Subject to effective quality control

DOE sought to utilize an online tool (the Home Energy Simulation Training), developed by DOE's Lawrence Berkeley National Laboratory, to train candidate Assessors to collect and input the data into the online Scoring Tool. The result would be a report or label that provides the following information:

- A Home Energy Score on a scale of 1 to 10 (where a "10" is a home that uses less energy than 90% of homes in the U.S.), presented with clear and simple graphics to help homeowners understand their home's energy performance and how it compares to other homes;
- An estimate of how much money could be saved on energy bills by making the recommended energy improvements; and
- An individualized list of recommended energy retrofit improvements that are estimated to payback in ten years or less.

After a year of industry research, analysis and development, DOE launched a pilot program to test the Home Energy Score. Building on the results of the pilots and other research, including industry factors and homeowner motivations,

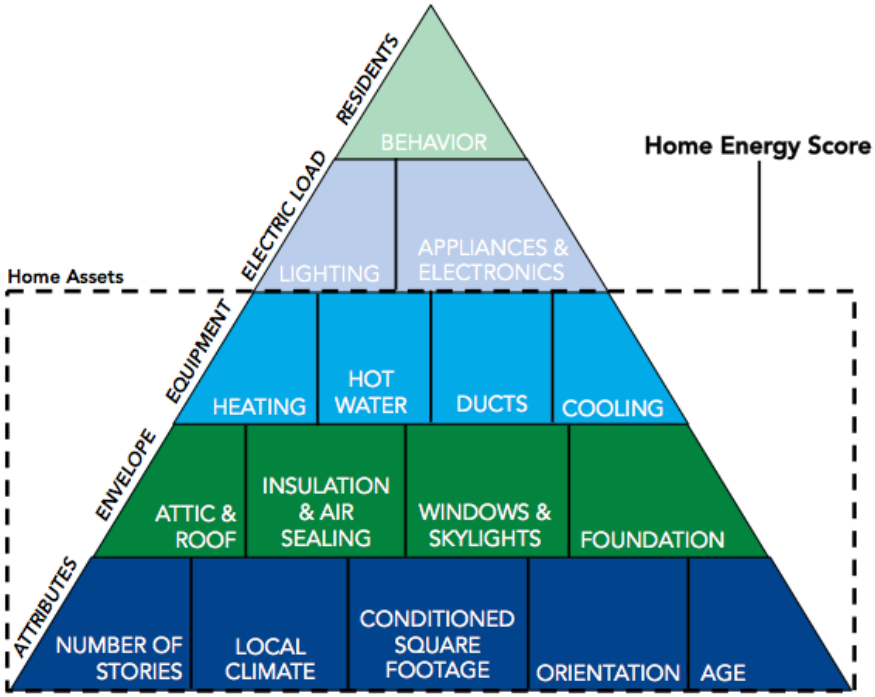
DOE officially launched the Home Energy Score nationwide in 2012. It became the first national asset rating method that allows all US regions to opt into a simplified and standardized energy assessment process that complements existing advanced home energy audit methods.

1.3 Asset vs. Operational Ratings

1.3.1 What is an asset rating?

The Home Energy Score is an asset rating. An asset rating seeks to quantify the energy efficiency of a building based solely upon the inherent components of the house. The Scoring Tool captures data on insulation levels and the heating equipment efficiencies, but does not take into account thermostat settings, appliances, or plug loads because the energy used to operate these components can vary widely depending on occupant behavior. The way the Scoring Tool defines "home assets" for Home Energy Score is displayed in Figure 3.

Figure 3. Home Energy Use Pyramid



An asset score allows homes to be compared an "apples to apples" basis because it compares houses to one another based on their assets and not how occupants operate the houses. The Home Energy Scoring Tool assesses the effect of changes in a home's assets, while the occupant-dependent factors and behaviors are assumed to be somewhat constant.

1.3.2 What is an operational rating?

An operational rating normalizes the measured energy use of a building (e.g. energy bills) so that it can be compared to the measured energy use of a similar building type, such as a single-family home, school or office. Differences within building type, such as size, number of occupants, climate or hours of operation, may be used to normalize the measured energy use to facilitate an equitable comparison. Operational ratings can be used to prioritize a group of buildings for efficiency improvement based on the poorest measured energy performance. Home Energy Score is not an operational rating, but can be paired with operational assessments to further refine recommendations for each home.

2. Scoring Methodology

2.1 How are homes scored?

A qualified Assessor inspects each home on-site and enters 50 data points into the online Home Energy Scoring Tool. The data collection sheet with the list of data elements and possible values can be found here. After entering all necessary data, the Scoring Tool will provide a summary of inputs for review and prompts the assessor to create the label (Figure 1). After creating the label, data inputs are locked and cannot be changed. The Home Energy Score label can be immediately printed or emailed to the customer. DOE approved, third-party software allows Assessors to submit appropriate fields through an application-programming interface (API) and receive the Score and calculated results.

2.1.1 Scale

When developing the scoring system, DOE considered many factors and data sources to fairly compare the energy performance of existing homes. DOE sought to develop a simple system that allows consumers to understand how a home compares to other homes regardless of location and weather patterns. The current methodology is applicable to single-family homes and townhomes or duplexes in the continental U.S. and Alaska. The Scoring Tool scores a home on a 10-point scale, where a 10 corresponds to greatest efficiency (lowest energy use) and a 1 corresponds to the least efficient (highest energy use). Each point on the scale corresponds to a small range of energy use estimates within the full 10-point range.

2.1.2 How does the Scoring Tool compensate for differences in home size, location, and other factors?

2.1.2.1 *Home Size* – A home's energy use depends on a variety of factors, one of which is its size. Larger homes have more surface area, which translates into greater energy requirements for heating and cooling. A home's Score is based on estimated annual energy use, not energy per square foot; so, given all other things equal, a larger home will score lower than a smaller home.

2.1.2.2 *Climate of Location* – Home Energy Score uses TMY3 climate data. It maps the zip code for the house address to the nearest weather station. Each weather station has its own definition of Score ranges based on local weather.

2.1.3 The Home Energy Score Scale: Bin Definitions

The Home Energy Score's scale is based on RECS 2009 data, which is a survey of residential energy consumption by the Energy Information Administration (EIA). The scale was designed to reflect existing housing stock and also allow for mobility on the scale to encourage home energy retrofits. Seventy-five percent of U.S. score between 2 and 9 on the scale, and a home that uses an average amount of energy – in the 50th percentile range of energy use – scores a 5. An example of the MBtu cutoffs between Score bin values is included below, although actual values vary by geographic region and local weather patterns.

- The source energy scoring bins are sized to produce consistent scores based on performance level, as both low efficiency and high efficiency homes have large differences in source energy use based on weather severity.
- The maximum and minimum energy cut-offs corresponding to 1 and 10 on the scale also reflect the different types of housing stock found in various parts of the country.

Example Scoring Bin Format

Weather Station #	Weather Station Name	**1** greater than	**2** up to	**3** up to	**4** up to	**5** up to	**6** up to	**7** up to	**8** up to	**9** up to	**10** less than
#	Name	148	147	132	118	103	90	80	70	60	50
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
#	1000+ locations	x MBtus	x MBtus	x MBtus	x MBtus	x MBtus	x MBtus	x MBtus	x MBtus	x MBtus	x MBtus

2.1.4 Site to Source Conversion Factors

Home Energy Score is based on the asset source energy used by the home, which accounts for the inefficiencies related to processing and transporting energy. For example, there are significant losses associated with generating and providing electricity that do not exist with on-site energy generation. The conversion from the site energy value (as calculated by the energy model) and the source energy value is based on national averages conversion factors. These factors reflect updated technical guidance from DOE's Office of Energy Efficiency and Renewable Energy as of October 2016.

Fuel	Conversion Factor
Electricity	2.76
Natural Gas	1.05
LPG	1.01
Fuel Oil	1.01
Wood	1.01

2.1.5 Accounting for Residential Solar Installations

Given that solar PV is one of many energy-related home assets, a home's PV system is credited to the home's Score as of February 14, 2017. With the release of v. 2017, the Home Energy Scoring Tool accounts for solar PV in three metrics provided in the Home Energy Score Report: the Score, estimated electricity usage, and estimated energy costs.

The Score. Home Energy Score Assessors collect solar PV data consistent with NREL's PV Watts tool to estimate the system's annual energy production. To generate a Home Energy Score, the Scoring Tool will subtract the estimated solar PV annual production value (in MBtu) from the estimated amount of energy required to meet the home's heating, cooling, and hot water needs (i.e., asset loads). This new MBtu value will then be used to determine the home's Score – one that reflects all of the home's major energy-related assets, including PV.

Estimated Electricity Use. The Home Energy Score Report includes a number of additional metrics and values that reflect how much energy is used by and generated at the home. These metrics and values do not include transmission, distribution, and heat losses. The user can distinguish site from source numbers because all MBtu numbers are source, all energy specific units are site energy. For example, the kWh value shown on the Home Energy Score Report is the estimated amount of electricity required to meet all of the home's electricity needs, including plug load. Shown in kWh, it is a site energy number, not one converted to source energy. If a home has PV, the total kWh generated by the system is subtracted from the total kWh required to meet the home's electricity needs.

2.1.6 Cost savings: What utility rates are assumed?

The Scoring Tool uses the most recent state average utility rates as provided by the DOE's Energy Information Agency to determine the estimated energy savings displayed on the first and last pages. The total energy cost for a home with PV will reflect the offset provided by all of the electricity generated by the PV.

2.1.7 Carbon Savings: Carbon Conversion Factors

To calculate the home's carbon footprint (measured in CO_2), the Scoring Tool multiples the annual energy for each fuel type by the emissions factor for the respective fuel (see Carbon Emissions Factors Table 33 and 34). Natural gas and fuel emission factors are derived from DOE (1994), while the LPG emission factor is from DOE (1996). U.S. EPA's Emissions & Generation Resource Integrated Database (eGRID) provides electricity grid emission factors. eGRID contains emissions and resource mix data for virtually every power plant and company that generates electricity in the United States (US EPA, 2009).

2.2 How are recommendations generated by the Home Energy Score?

In keeping with the asset-based methodology, a consistent set of upgrade recommendations are considered for each home's assets, given the home's location. Variations occur as a function of home characteristics, cost-effectiveness, etc. Upgrades considered in the Scoring Tool include improvements to the house envelope and major equipment (the "assets"), but not to upgrades of lighting, appliances or behavioral changes (e.g. change thermostat settings). Unlike other rating tools, the Scoring Tool applies a fixed, standardized retrofit cost (from the NREL National Residential Efficiency Measures Database) and generates recommendations that provide the highest performance level with a payback time of 10 years or less. Recommendations considered during the improvements analysis are as follows:

Category	Measure
Basement wall insulation	R11
	R19
Central air conditioner	Energy Star (SEER 15)
Attic insulation	R19
	R30
	R38
	R49
	R60
Cool roof	High Slope - 15% reflectivity
Foundation wall insulation	R11
	R19
Duct insulation	R6
Duct sealing	Reduce leakage to 3% of total airflow
Floor insulation	R11
	R19
	R25
	R38
Gas boiler	Energy Star (85% AFUE)
Gas Furnace	Energy Star (90% AFUE – South, 95% AFUE - North)
Heat pump	Energy Star (SEER 15, HSPF 8.5)
Envelope/Air sealing	75% of existing leakage (25% reduction)
Oil boiler	Energy Star (85% AFUE)
Oil furnace	Energy Star (85% AFUE)
Propane furnace	Energy Star (90% AFUE)
Propane Boiler	Energy Star (85% AFUE)
Room air conditioner	Energy Star v 3.0 (EER 11.3)
Roof EPS insulation	Add R5 exterior foam sheathing
Skylights	Energy Star (Double-pane solar-control low-E argon gas wood frame)
Wall insulation	R13
	Add R5 exterior foam sheathing (only available for wood frame construction w/ wood, aluminum or vinyl siding)
Water heater, electric	Energy Star (heat pump, EF 2.76)
Water heater, natural gas storage	Energy Star (0.67 energy factor)
	Premium Efficiency (energy factor 0.81, 88% recovery efficiency)
Water heater, propane storage	Energy Star (0.67 energy factor)
Windows	Energy Star (Double-pane solar-control low-E argon gas wood frame)

These recommendations are provided in two categories:

Type 1 improvements can help the homeowner save energy immediately. These include:

- Attic insulation
- Basement wall insulation
- Basement/crawlspace floor insulation
- Crawlspace wall insulation

- Air tightness
- Exterior walls
- Duct sealing
- Duct insulation

The Type 1 energy savings are achieved by moving between the baseline home and the upgrade recommendation. The cost used for the cost-benefit analysis is the full cost of installation.

Type 2 improvements are recommendation that should be implemented when it is time to replace specific equipment or building materials. These include:

- Central air conditioner
- Boiler, furnace or heat pump
- Room air conditioner
- Roof - reflectance
- Roof - insulated sheathing
- Skylights
- Siding - insulated sheathing
- Water heater
- Windows

Type 2 improvements are recommended at the time of product replacement. The incremental cost between equipment that meets the standard and the cost of the installed equipment is used in cost-benefit analysis.

Home Energy Scoring Tool v. 2017 does not include solar PV as an automatic recommendation for homes to improve their Scores. If an Assessor believes a home is a good candidate to improve their Score through solar PV, they can utilize the Tool's "Alternative EEM" feature to showcase the home's Score with Improvements with solar PV included.

It is important to note that the sum of the savings from each measure recommended does not equal the total savings for the package of selected upgrades (the number shown on the label). This difference is due to interactive effects of some energy improvements. For example, insulation will reduce heat and cooling energy use. This will reduce the potential savings available to the heating/cooling system upgrade. This difference will be reflected in the total savings number on the Home Energy Score label.

3. Building Simulation Model

3.1 What models are used in the Home Energy Scoring Tool?

3.1.1 Heating and Cooling – DOE2 is a widely used and accepted freeware building energy analysis program that can predict the energy use and cost for all types of buildings. DOE-2 uses a description of the building layout, constructions, operating schedules, conditioning systems (lighting, HVAC, etc.) and utility rates, along with weather data, to perform an hourly simulation of the building and to estimate utility bills. The DOE 2.1E documentation can be found here.

3.1.2 Water Heater Model – Total hot water used is the sum of clothes washer, dishwasher and fixture related usage. These are determined based on the estimated number or occupants in the house. The modeled water use is based on Danny Parker's and James Lutz's, "Estimating Daily Domestic Hot Water Use in North American Homes". The numbers are then used in the equations provided here to calculate the domestic hot water use.

3.1.3 Infiltration Model – The Home Energy Scoring Tool uses the Residential Diagnostics Database developed by

Lawrence Berkley National Lab to model the house infiltration rates. Information on that model can be found here. The implementation of the model into Home Energy Score can be found here.

3.1.4 Weather – Home Energy Score uses TMY3 data to account for the local weather. The house zip code is mapped to the closest TMY3 weather station to calculate energy use.

3.1.5 Model Defaults – Home Energy Score is an asset rating; therefore, the influence of the occupants must be standardized so houses can be compared on an apples-to-apples basis. To do this, Home Energy Score assumes the following default characteristics for each house.

3.1.5.1 Occupancy is determined based on the number of bedrooms using this equation (0.59 * number of bedrooms + 0.87) from the Building America Simulation Protocols (Hendron & Engebrecht, 2010). Using this method, the number of bedrooms directly affects the household's amount of estimated domestic hot water consumption. Further, occupancy is used to determine miscellaneous electric loads such as television.

3.1.5.2 Stove, oven and clothes drying are assumed to be electric.

3.1.5.3 Electric load calculations are based on Updated Miscellaneous Electricity Loads and Appliance Energy Usage Profiles for Use in Home Energy Ratings, the Building America Benchmark Procedures and Related Calculations (Parker, Fairey & Hendron, 2010). Testing of refinements in this model showed much better predications for total home energy than with fixed occupancy and no dependence on floor area.

Electricity Consumption Type	Equation
Miscellaneous Electric Load (kWh)	= (0.91)*(conditioned floor area)
Interior Lighting (kWh)	= 455 + (0.8)*(conditioned floor area)
Exterior Lighting (kWh)	= 50 + (0.05)*(conditioned floor area)
TV Energy Use (kWh)	= (-3)*(# of bedrooms)^2 + (89)*(# of bedrooms) + 390

3.1.5.4 The building length and width are fixed to a 5:3 aspect ratio.

3.1.5.5 The thermostat schedule is defined in the table below and is based on the information in Determining Appropriate Heating and Cooling Thermostat Set Points for Building Energy Simulations for Residential Buildings in North America (Parker, 2013).

Type	Weekday	Temp. °F
Heating	11:00 pm - 6:00 am	65
	6:00 am - 5:00 pm	67
	5:00 pm - 11:00 pm	68
Cooling	11:00 pm - 6:00 am	74
	6:00 am - 5:00 pm	77
	5:00 pm - 11:00 pm	76
Weekend		
Heating	11:00 pm - 6:00 am	65
	6:00 am - 5:00 pm	68
	5:00 pm - 11:00 pm	68
Cooling	11:00 pm - 6:00 am	74
	6:00 am - 5:00 pm	76
	5:00 pm - 11:00 pm	76

3.1.5.6 To calculate estimated energy savings in dollars, the Tool uses state average utility rates as provided by DOE's Energy Information Administration.

3.2 User Inputs

3.2.1 About This House

1. Assessment date
2. Year built
3. Number of bedrooms
4. Stories above ground
5. Interior floor-to-ceiling height
6. Conditioned floor area
7. Direction faced by front of house
8. Measured or estimated air leakage rate
9. Whether Home was professional air-sealed

3.2.2 Roof, Attic, Foundation

10. Attic Area
11. Roof construction
12. Roof color
13. Attic or ceiling type
14. Foundation Area
15. Insulation level of the attic floor
16. Foundation type
17. Foundation insulation level
18. Insulation level of the floor above the basement or crawlspace

3.2.3 Walls

19. Building type; townhouse or otherwise
20. Building position; required if type is townhouse
21. Walls construction same on all sides (yes/no)
22. Front; Back; Right; Left (if type is townhouse adjoining wall(s) set by system)
23. Materials
24. Insulation levels

3.2.4 Windows and Skylights

25. Does house have skylights? (yes/no)
26. Skylight size
27. Skylight type
28. Glazing, frames, fill
29. U-Factor
30. Solar heat gain coefficient
31. Window areas
32. Window types are same on all sides
33. Front; Back; Right; Left
34. Glazing, frames, fill
35. U-Factor
36. Solar heat gain coefficient

3.2.5 Heating, Cooling, Hot Water, and Solar

37. Percentage of conditioned floor area served by system
38. Type of heating system
39. Heating system efficiency
40. Year heating system installed
41. Type of cooling system
42. Cooling system efficiency
43. Year cooling system installed
44. Duct location; up to three
45. Percentage of total ducts in each location
46. Duct insulation
47. Duct sealing

48. Water heater type
49. Year water heater installed
50. Water heater Energy Factor
51. Solar PV installation year
52. Solar PV orientation
53. Solar PV number of panels or rated DC kW output (choose one)

3.3 Access to the Scoring Tool through an application-programming interface (API)

A software provider interested in including the Home Energy Score as part of the report output provided by their software may use the API provided by PNNL. Full documentation can be found here.

3.3.1.1 The software provider must supply information to DOE about how the Home Energy Score will be used and by whom (e.g. Is the software being used for a single client or multiple clients?). DOE needs to be able to keep track of who is using what software to maintain/verify continued data compliance.

3.3.1.2 DOE will provide the API evaluation keys, API documentation and implementation support. DOE will provide data manipulation rules and test scenarios.

3.3.1.3 The software provider will build the API functionality within their tool and include any logic necessary to implement the data manipulation rules. If using the HPXML file format to submit the house characteristics, these rules are already built into the "translator" and thus the software provider does not need to build this logic.

3.3.1.4 When that has been completed, the software provider will enter the test scenarios into their tool and provide those runs to the Home Energy Scoring Tool through the API. They will also provide proof of entry and example output for these runs to DOE.

3.3.1.5 DOE will confirm the data was properly manipulated and transferred.

3.3.1.6 When this is confirmed, the software provider will receive the production API and qualified assessors may begin using that tool.