2.2 Target Audience and Guiding Principles

The energy asset score is intended to enable building stakeholders—including owners, managers, operators, investors (who buy a stake in exchange for a return on investment), and financiers (banks or lenders for loans) to directly compare expected as-built energy performance among similar buildings and to analyze the potential for capital improvements to cost-effectively improve energy efficiency. The system is intended to give building stakeholders insight into a property's long-term energy cost. It is intended to illustrate for stakeholders the impact of potential capital improvements. Research (McCabe and Wang 2012; McKinsey 2009) shows a need to communicate energy and cost savings to owners, investors, financiers, and others to overcome market barriers and motivate capital investment in building energy efficiency.

In addition, the energy asset score is aimed at tenants, appraisers, and designers. It may also inform local governments, utilities, and green-building rating systems. The energy asset scoring tool provides technical information and identifies opportunities for improvement to building professionals who would be implementing the recommendations.

Finally, the energy asset score can raise public awareness of building efficiency among those who have limited knowledge of building energy use. The rating system provides an easy-to-understand score that can convey building energy efficiency information.

DOE's intention is to provide an affordable system that gives a useful score with minimal data collection. The program's primary goal is to encourage commercial building energy improvements in new construction and/or retrofits. Therefore, the score's guiding principles (listed below) are based on market needs:

- Information must be credible, reliable, and replicable.
- Information must be transparent and easy to understand.
- Costs of collecting information and generating a score must be affordable.
- Opportunities identified must be relevant and practical.
- The energy asset score must include effective quality assurance.
- The energy asset score must recognize building energy performance across the full range of building efficiency.

2.3 Building Types

Buildings have been categorized in different ways. Examples include the Commercial Buildings Energy Consumption Survey (CBECS), ENERGY STAR benchmarking, and Commercial Energy Services Network (COMNET) energy modeling (Appendix A). To ensure a fair score and comparison, buildings need to be categorized by use type, primarily because the assumed standard operating conditions differ among building types. For example, operating schedules and miscellaneous plug loads in schools differ substantially from those in retail establishments. In the energy asset score, the building type classifications determine the standard operating conditions, including occupant density, receptacle power, and operating schedule.

The energy asset score is being rolled out in three phases, based on building type (Table 2.2):

- Phase I, which is being included in the initial rollout, includes buildings in the office, education, retail, and nonrefrigerated warehouse categories. These building types are included in Phase I because there is adequate literature on them to provide reliable references. There is also sufficient building performance data (e.g., CBECS), which is another primary consideration for selecting building types by phase because the existing building stock is an important reference to establish scoring scales that truly reflect the energy use of each building type.
- Phase II includes library, lodging, multi-family housing, courthouse, and religious worship buildings, as well as mixed-use buildings that incorporate Phase I and II use types. These buildings are included in Phase II because less information is available on them compared with the Phase I building types, and therefore additional energy modeling and analysis is required to fill in the information gap. Development of the Phase I building types will help provide references and experience for the Phase II building types.
- Phase III includes buildings with highly variable use characteristics, complex systems, or those for which limited information is available, such as food sales, food service, data centers, laboratories, refrigerated warehouse, health-care facilities.

The energy asset score building types are based on CBECS building classifications. Some building types in Phases II and III, such as public assembly and service buildings, have diverse subtypes and will need further investigation before being classified for energy asset score.

Table 2.2. Building types.

			Availability of Reference Resources			
Phase	Energy Asset Score Building Type	Building Use Type Examples	CBECS	Portfolio Manager	DOE Reference Building and 90.1 Prototype Building	COMNET
I	Office	Administrative/professional Bank/other financial Government Medical non-diagnostic	x	x	x	x
	Education	College/university[(a)] Elementary/middle school High school Preschool/daycare	x	x	x	x
	Retail	Strip shopping mall Enclosed mall Retail other than mall (vehicle dealership/showroom, retail store)	x	x	x	x
	Warehouse (Non-refrigerated)	Distribution and shipping center Self-storage Non-refrigerated warehouse	x	x	x	x
II	Public Assembly (Library)	Library (including college/university library)	x			x
	Lodging	Dormitory/fraternity/sorority Hotel Motel or inn	x	x	x	x

Phase	Energy Asset Score Building Type	Building Use Type Examples	Availability of Reference Resources: CBECS	Portfolio Manager	DOE Reference Building and 90.1 Prototype Building	COMNET
	Multi-family Housing	Apartment/multi-family housing			x	x
	Public Order and Safety (Courthouse)	Courthouse	x	x		x
	Religious Worship		x	x		x
III	Food Sales	Convenience store Convenience store with gas station Grocery store/food market	x	x	x	
	Food Service	Fast food Restaurant/cafeteria Bakery	x	x	x	x
	Inpatient Health Care	Hospital/inpatient health	x	x	x	x
	Nursing	Nursing home/assisted living				
	Outpatient Health Care	Medical office (diagnostic) Clinic Veterinarian	x	x	x	x
	Data Center			x		
	Laboratory		x			
	Warehouse (Refrigerated)	Refrigerated warehouse	x	x	x	x
	Public Assembly	Entertainment/culture Recreation Social/meeting Funeral home Exercise center/pool				
	Service	Post office/postal center Repair shop Vehicle service/repair shop Vehicle storage/maintenance Industrial shop Dry-cleaning/laundry				
	Public Order and Safety	Fire station/policy station Jailhouse Penitentiary				
	Truck Terminal					
	Parking Garage					

(a) Depending on the actual functions, not all college/university buildings are in the Education category. For example, university libraries should be considered in the Library category; buildings for administration only should be considered in the Office category; buildings with laboratories may be considered as Laboratory or Mixed-use type.

The energy asset score is equally applicable to both new and existing buildings:

- For new construction, the energy asset score can be used for preconstruction evaluation. A design team could enter the design parameters into the energy asset scoring tool and examine how different design options can affect the energy use and score. DOE anticipates creating an application programming interface (API) in the future to allow design software to easily integrate with the energy asset score.

- For existing buildings, the process is equivalent, except that the installed systems should be used instead of the designed systems.

In addition to overall building energy use evaluation, the energy asset score can be used to obtain system evaluation and measures to improve performance.

2.4 User Levels

The energy asset score is designed for two user levels—simple and advanced.

- The *simple* application requires minimal data from the users. The simple application yields a preliminary score based on building efficiency, identifies opportunities for improvements, and estimates energy impact of those improvements. The simple score is based on a minimum set of building data plus any other known applicable building characteristics. It can give users quick feedback on building efficiency and improvement opportunities.
- The *advanced* application provides an advanced score based on a more comprehensive set of required data plus any additional pertinent building characteristics known to the user. Real estate transactions would likely require this level of score.

The energy asset scoring tool is not intended to replace engineering analysis needed for building retrofits, but instead to provide building owners and operators with a quick, low-cost, standardized way to rate building energy assets through a national program. DOE expects that all scores—whether simple or advanced—would be considered preliminary until validated by a qualified professional. Requirements for validation have not yet been developed.

3.0 Energy Asset Scoring Methods

This section discusses scoring metrics as well as methods for creating a scoring scale. The energy asset score is intended to work as part of a broader set of commercial building energy performance tools, including ENERGY STAR Portfolio Manager. Therefore, as described below, where possible, the energy asset score incorporates methods that are consistent with ENERGY STAR Portfolio Manager.

Section 3.1 details the scoring metrics considered in developing the energy asset score, including source energy use intensity (EUI), site EUI, energy cost, and greenhouse gas emissions. Source EUI was ultimately selected for the energy asset score, for reasons discussed below.

The selection of scoring scales is discussed in Section 3.2. After examining numeric scale reflecting physical units (e.g., kBtu/ft^2), categorical scale (e.g., A−E ratings), interval scale (e.g., 10-point scale), and continuous scale (e.g., 100-point scale), DOE selected a non-statistical 100-point scale. A rating scale is being developed for each building type. The score calculation methodology and the intended durability of the developed score are also discussed in Section 3.2.

3.1 Energy Asset Scoring Metrics

There are several ways to describe a building's expected energy performance, including energy use, energy cost, and greenhouse gas emissions associated with building energy use. Various factors may be relevant to evaluating the effect of a building's source energy use, such as fuels used in the building, varying fuel mix for electric generation, onsite renewable generation, and combined heat and power.

While no single metric can tell the whole story about building energy use, DOE selected source EUI as the primary metric for generating the energy asset score. Other metrics, including site energy use, cost savings, simple payback, and relative system-level indicators, are provided as reference metrics. These additional metrics may help building owners, managers, and operators more fully understand and communicate the reasons behind their results. The following sections discuss the pros and cons of using the source energy metric and the additional energy metrics.

3.1.1 Primary Metric: Source Energy Use Intensity

An energy metric is the most transparent and portable way to represent building energy performance. All functioning buildings consume energy. DOE considered four building energy metrics for the energy asset score:

- site energy use
- net onsite energy use (considering onsite renewable generation)
- source energy use (considering transmission, delivery, and production losses)
- full-fuel-cycle (FFC) energy use (considering extracting, processing, and transport of primary fuels in addition to source energy use).

DOE selected source EUI as the primary metric, for the reasons discussed below.

3.1.1.1 Site Energy vs. Source Energy

Site energy measures a building's use of electricity, natural gas, propane, and/or fuel oil at the site. Site energy use can be directly calculated using the sum of electricity, natural gas, and any other fuel consumption. If renewable energy is generated onsite, net onsite energy use also can be calculated by subtracting the expected energy generation from total site consumption. Site energy use appears to be simple, transparent, and easy to collect using utility bills. However, site energy considers primary energy (such as natural gas directly burned onsite) and secondary energy (such as electricity generated off site) equivalent. In reality, a unit of raw fuel and a unit of converted fuel do not have the same global impact. Therefore, to provide a fair comparison, all externalities of delivered energy should be accounted for.

Source energy incorporates all transmission, delivery, and production losses, thereby enabling a complete assessment of energy efficiency in a building. A source energy metric requires a conversion factor to convert site electricity use to a source equivalent, which allows consumers to more equitably consider all fuel types and the environmental consequences of electricity generation. Although site energy is most closely related to the values that customers see on their energy bills for each fuel type, source energy more closely reflects the cost to the end users of different fuels and in doing so the reveals the long-term cost implications of different energy choices. The conversion of site energy to source energy is discussed in Section 3.1.2.

3.1.1.2 Comparison of Site EUI and Source EUI

To better understand the differences between site and source EUI, consider an example in which six identical buildings need the same amount of energy for heating, cooling, lighting, and other functions; the heating system is the only variable resulting in different electricity and gas use. These buildings are shown for illustrative purposes only. The same examples of six heating systems are used by ENERGY STAR to show the value of using source energy (EPA 2011). The energy use and cost values in the examples are modified for the purpose of this energy asset score analysis. Table 3.1 calculates the site EUI, source EUI, and energy cost per square foot for the six example buildings. (To simplify the calculation, the demand charge is ignored in this example.) Based on site energy use, Building D, which has a geothermal heating system, is the most efficient. Building F, which has an electric heating system, appears to be more efficient than Building A, which has an 80% efficient boiler. However, if source EUI is used as the basic metric, Building F becomes the least efficient building. The geothermal system in Building D is still highest performance system.

Table 3.1. Illustrative comparison of the site and source EUI of six identical buildings with different heating systems.

	Building A	Building B	Building C	Building D	Building E	Building F
Heating system	Boiler	Boiler	District steam	Ground source heat pump	Air source heat pump	Electric resistance heat
Heating fuel	Natural gas	Natural gas	District steam	Electric	Electric	Electric
System efficiency	80%	55%	95%[(a)]	COP[(b)] = 4.0	COP = 2.5	COP = 1.0
Baseline Case						
Electricity (kBtu/ft^2)	36.0	36.0	36.0	39.8	42.0	51.0
Gas or district steam (kBtu/ft^2)	18.8	27.3	15.8	0.0	0.0	0.0
Site EUI (kBtu/ft^2)	54.8	63.3	51.8	39.8	42.0	51.0
Source EUI (kBtu/ft^2)	139.9	148.8	139.4	132.8	140.3	170.3
Energy cost ($/ft^2)	$1.24	$1.33	$1.12	$1.17	$1.23	$1.49

Assumptions:
1. Energy use breakout: 34% heating, 22% cooling, 22% lighting, 11% ventilation, 11% other (in mild climate zone).
2. Site-to-source conversion factors: electricity 3.340, natural gas 1.047, district steam 1.210[1] (source: EPA 2011).
3. Energy cost: $0.10/kWh[2]; $1.00/therm[3]; $5.00/klb steam.[4]
(a) Minor losses occur onsite due to steam distribution, resulting in an onsite system efficiency of 95%.
(b) COP is coefficient of performance.
(c) Only the heating system is changed. The COP of heating systems does not extend to the cooling system in this example.

Figure 3.1 displays the source and site energy use from Table 3.1 as it relates to energy cost for the six buildings. As shown in Figure 3.1, source EUI is a relatively good proxy for cost. In contrast, ranking the buildings shown in Table 3.1 in terms of site energy is not at all consistent with a ranking by cost. Accounting based solely on site energy could lead to illogical decisions like replacing gas water heaters with electric when this would not be cost effective.

[1] The national source-site ratio for district steam is the weighted average of two source-site factors: 1.35 for conventional steam factor and 1.01 for CHP (combined heat and power) steam factor.
[2] The average retail price of electricity to commercial buildings in the past five years (2007 to 2011). Source: EIA 2012a.
[3] The average retail price of natural gas to commercial buildings in the past five years (2007 to 2011). Source: EIA 2012b.
[4] The cost of steam generation depends on fuel type, unit fuel cost, boiler efficiency, feedwater temperature, and steam pressure (DOE EERE 2012a). Various sources (e.g., http://www.hged.com/html/district_steam.html) show that steam costs from $3 to $7 per 1000 lb. An average of $5 per 1000 lb is used in the example.

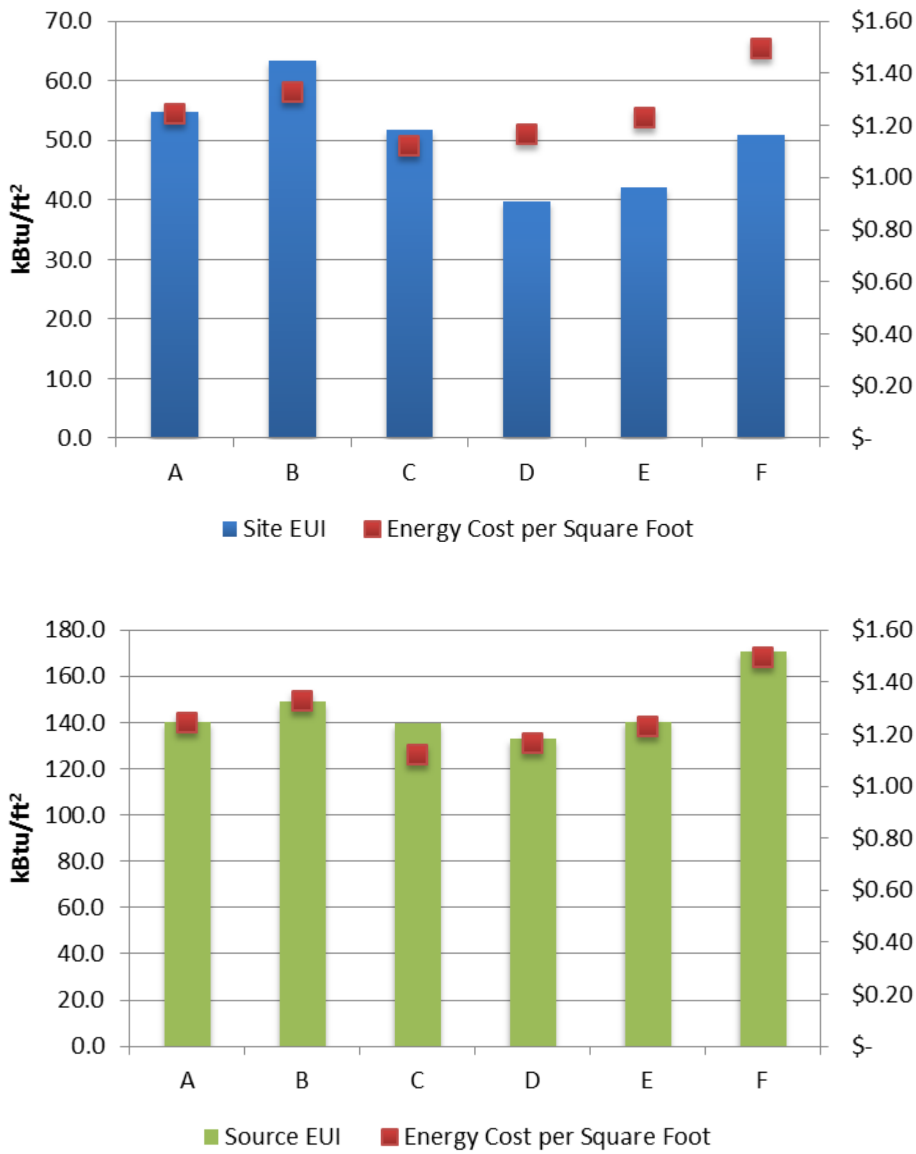


Figure 3.1. Comparison of site EUI and source EUI.

Can source energy effectively reflect energy efficiency improvements? Using the same example of the six buildings, three upgrade scenarios are considered: 20% energy use reduction in lighting, heating, and cooling, respectively. Table 3.2 shows the site, source energy uses, and energy cost per square foot. If site EUIs are compared, Building D (with a geothermal heating system) is the most efficient, followed by Building E, which is heated by an air source heat pump. Building F (with electric heating) and Building D (heated by district steam) appear to be equally efficient. Buildings A and B (with boilers) are the least efficient. Source EUIs tell a different story. Building F becomes the least efficient because of its electricity use, followed by Building B with its low-efficiency boiler. The overall efficiencies of Buildings A, C, and E are very similar.

Table 3.2. Energy uses of six buildings after efficiency upgrades.

	Building A	Building B	Building C	Building D	Building E	Building F
Energy Saving Scenario 1: 20% reduction in lighting energy use						
Electricity (kBtu/ft^2)	33.0	33.0	33.0	36.9	39.3	48.8
Gas or district steam (kBtu/ft^2)	19.7	28.6	13.1	0.0	0.0	0.0
Site EUI (kBtu/ft^2)	52.7	61.6	46.1	36.9	39.3	48.8
Source EUI (kBtu/ft^2)	130.8	140.2	126.1	123.4	131.3	162.8
Energy cost ($/ft^2)	$1.16	$1.25	$1.02	$1.08	$1.15	$1.43
Energy Saving Scenario 2: 20% reduction in heating energy use						
Electricity (kBtu/ft^2)	36.0	36.0	36.0	39.0	40.8	48.0
Gas or district steam (kBtu/ft^2)	15.0	21.8	12.6	0.0	0.0	0.0
Site EUI (kBtu/ft^2)	51.0	57.8	48.6	39.0	40.8	48.0
Source EUI (kBtu/ft^2)	135.9	143.1	135.5	130.3	136.3	160.3
Energy cost ($/ft^2)	$1.21	$1.27	$1.11	$1.14	$1.20	$1.41
Energy Saving Scenario 3: 20% reduction in cooling energy use						
Electricity (kBtu/ft^2)	33.6	33.6	33.6	37.4	39.6	48.6
Gas or district steam (kBtu/ft^2)	18.8	27.3	15.8	0.0	0.0	0.0
Site EUI (kBtu/ft^2)	52.4	60.9	49.4	37.4	39.6	48.6
Source EUI (kBtu/ft^2)	131.9	140.8	131.3	124.7	132.3	162.3
Energy cost ($/ft^2)	$1.17	$1.26	$1.05	$1.09	$1.16	$1.42

Figure 3.2 depicts the site EUIs and source EUIs from Table 3.1 and Table 3.2 against the cost data from these tables. As the figure clearly shows, when both site EUIs and source EUIs (of the baseline case and the three upgrade scenarios) are plotted against energy cost, energy cost has a much higher correlation with source EUI than with site EUI. Therefore, using source energy is less likely to unintentionally favor or penalize the use of one energy fuel type over another.

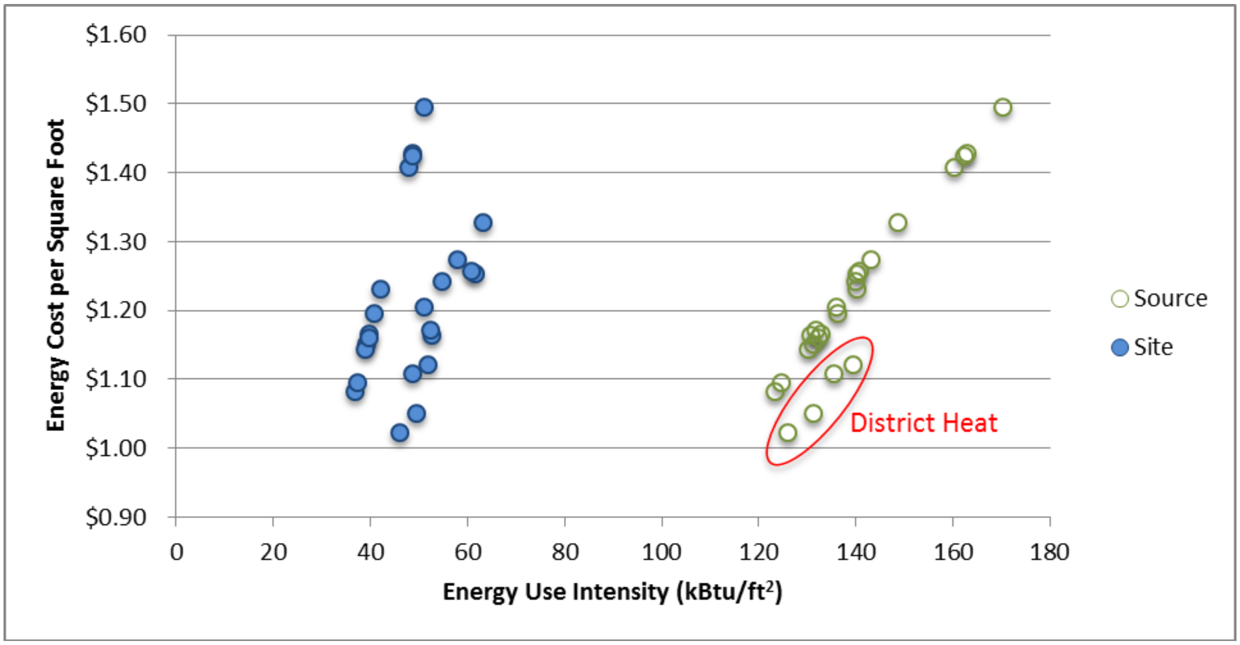


Figure 3.2. Site EUI and source against energy cost.

Given this analysis as well as a goal of reducing overall energy use, the energy asset score uses source energy as the basic metric because source energy can most accurately represent total energy use of a building and the related environmental impacts. Using source energy also aligns the energy asset score with ENERGY STAR Portfolio Manager, which uses source energy as its basic metric. Source energy use is familiar to building owners and operators who have been using Portfolio Manager or other building scoring methods that rely on Portfolio Manager. Source energy use (or primary energy use, extended site energy use) has been used by DOE for assessing the impact of energy use on the economy, security, and environmental quality (National Research Council 2009).

3.1.1.3 Source Energy Use vs. Full Fuel Cycle

A concept similar to source energy is full-fuel-cycle (FFC) measure. In addition to site energy use, the FFC measure takes into account the energy consumed in extraction, processing, and transport of primary fuels such as coal, oil, and natural gas; energy losses in the thermal combustion in power-generation plants; and energy losses in transmission and distribution to buildings (National Research Council 2009).

EPA's source energy analysis does not account for the energy that is consumed before power-generation plan. According to EPA, "[t]his type of analysis (energy used in mining, transporting, and refining crude products) may provide an instructive look at the lifecycle costs of energy use, it is beyond the scope of a building-level assessment" (EPA 2011, p. 7).

DOE has proposed the use of FFC measures to estimate the impact of energy conservation standards for consumer products and certain commercial and industrial equipment (DOE EERE 2011a). The proposed FFC measures would be based on the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model, which is used to compare the total energy use and greenhouse gas emissions of vehicle technologies and different fuels. However, site-to-FFC conversion factors that can be used to accurately estimate FFC energy consumption for buildings have not yet been developed. Therefore, DOE chose EPA's source-site ratios (see Table 3.4 in Section 3.1.2) to calculate energy asset score.

DOE may consider a transition to use FFC in the future when site-to-FFC conversion factors are available. The effect of such a transition on the building energy asset score is expected to be minimal. The significant energy losses in generation and transmission of electricity are captured in source energy (for example, 100% electricity use on the building site consumes 334% primary energy). Converting from primary energy to FFC energy would only add 2.1 to 14.7% to the source energy use (Table 3.3). Adjusting the conversion factors for all buildings may even have little influence on an individual building's relative position on the energy asset scoring scale. See Section 3.2 for the score calculation method.

Table 3.3. Conversion factors from primary energy to FFC energy (GREET preliminary estimates).

	Natural Gas	Fuel Oil	Coal	Biomass	Uranium
2010	1.071	1.134	1.021	1.032	1.065
2030	1.071	1.147	1.021	1.032	1.038

3.1.2 National Average Site-Source Conversion Factors

To convert each unit of energy (in kBtu) used on site into the total energy use of equivalent source energy consumed, a conversion factor (or source-site ratio) for each fuel type is needed. Depending on how the secondary energy is generated, the conversion factors can be different for the same fuel type.

DOE considered three types of site-to-source conversion factors for the energy asset score:

- state average
- regional average
- national average.

After evaluating these options, DOE chose a national average conversion factor. National average site-to-source conversion factors allow national-level comparisons and ensure that a building does not receive a high or low rating for the relative efficiency of its regional power grid. DOE intends to employ the national conversion factors used by Portfolio Manager.

Source-site ratios shown in Table 3.4 are used by Portfolio Manager to convert each kBtu of energy used on site into the total kBtu of equivalent source energy consumed. The current grid-purchased electricity and natural gas conversion factors are based on the averages over 5 years, from 2001 through 2005. The most current revision of all source-site ratios occurred in 2007; these ratios are expected to change as the national infrastructure and fuel mix evolve. EPA reviews the ratios every 3 to 5 years, and updates accordingly (EPA 2011). DOE will review the updated ratios in the future and evaluate their effect on the energy asset score. Buildings that have received an energy asset score will receive notice and an updated score if any changes are made to the source-site ratios.

Table 3.4. Source-site ratios (EPA 2011).

Source	Ratio
Electricity (grid purchase)	3.34
Electricity (onsite solar or wind installation)	1.0
Natural gas	1.047
Fuel oil (1, 2, 4, 5, 6, diesel, kerosene)	1.01
Propane and liquid propane	1.01
Steam[(a)]	1.21
Hot water	1.28
Chilled water[(b)]	1.05
Wood	1.0
Coal/coke	1.0
Other (e.g., waste biomass)	1.0

(a) The weighted average of two source-site factors: 1.35 for conventional steam factor and 1.01 for CHP (combined heat and power) steam factor (EPA 2011).
(b) The weighted average of two source-site factors: 1.14 for electric chiller and 1.04 is for natural gas-fired chiller (EPA 2011).

When renewable energy is produced at a building through solar photovoltaic panels or wind turbines, DOE is currently undecided whether the electrical calculation will be based on an annual net basis or an instantaneous basis. An annual net-basis approach calculates the net site electricity use (total annual electricity use minus total onsite generation) and converts it to source energy. An instantaneous-basis approach calculates the net energy use per time unit (for example, hourly electricity use minus hourly onsite generation), converts it to source energy, and then calculates the annual energy use. The latter approach more accurately reflects the actual amount of electricity purchased from the grid or generated on site; however, it requires more complicated energy simulation.

Table 3.5 shows an example of how the two calculation methods can affect the source energy use of a building. An instantaneous-basis calculation yields higher source energy use because the source-site ratio for onsite generation is lower than that for grid purchase. Further analysis will be conducted to evaluate the effects of these two methods on energy asset score. More discussion on renewable energy calculation can be found in Section 3.2.2.3.

Table 3.5. Comparison of annual-basis and instantaneous-basis calculations.

Time Unit	Electricity Use (kBtu)	Electricity Generation (kBtu)	Net Site Electricity Use	Source-Site Ratio	Source Energy Use
1	1,000	2,000	-1,000	1	-1,000
2	2,000	2,000	0	1	0
3	3,000	2,000	1,000	3.34	3,340
4	4,000	3,000	1,000	3.34	3,340
5	8,000	3,000	5,000	3.34	16,700
6	5,000	3,000	2,000	3.34	6,680
7	3,000	3,000	0	1	0
8	2,000	3,000	-1,000	1	-1,000
9	1,000	2,000	-1,000	1	-1,000
10	500	2,000	-1,500	1	-1,500
Total using instantaneous-basis calculation					25,560
Total using annual-basis calculation			4,500	3.34	15,030

As stated above, DOE also considered state and regional average conversions factors, but decided against these for the following reasons:

- State average site-to-source conversion factors are not effective indicators because there is significant energy transfer between some states and it is hard to account for the source of the imported energy. As shown in Figure 3.3, 19 states have less than 10% energy transferred from or to other states (highlighted in yellow); while the remaining states have 10% to 99% energy exchange.

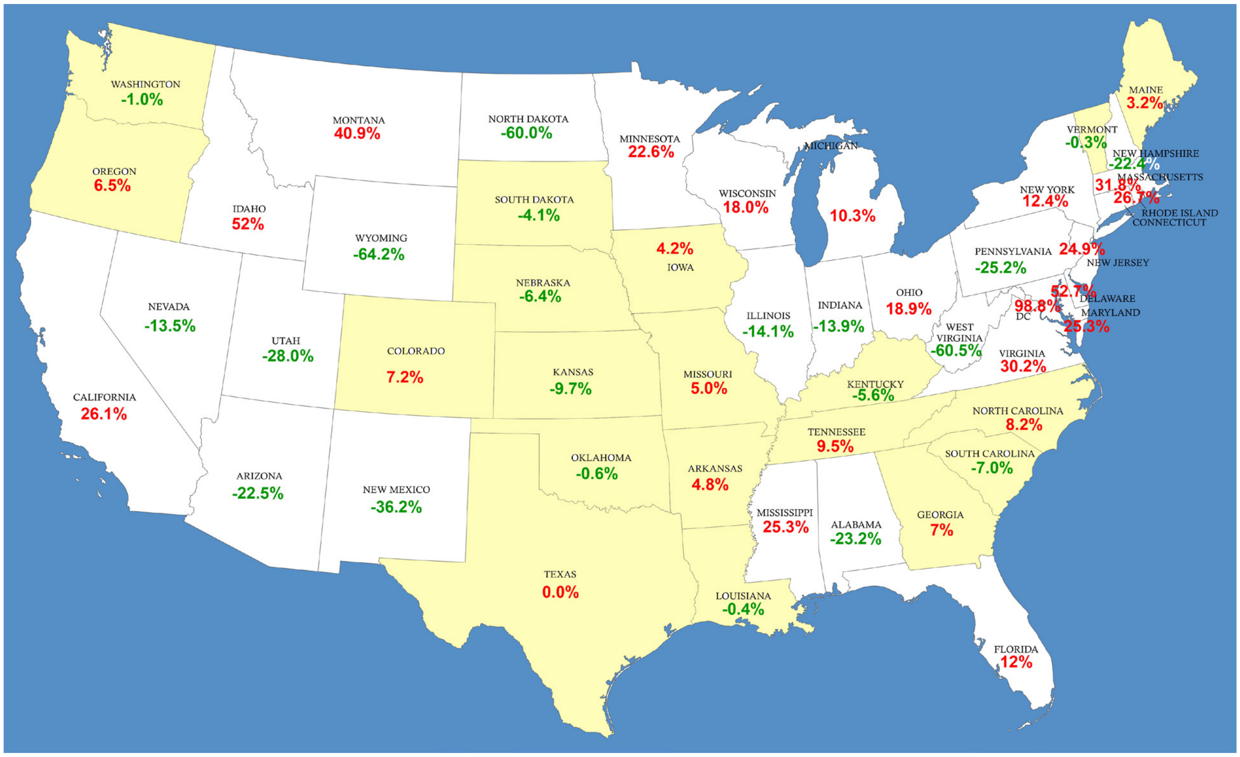


Figure 3.3. State-level energy imports (positive value = import, negative value = export) (EPA 2002, Table B-7; Deru and Torcellini 2007).

- Regional or subregional average site-to-source conversion factors more accurately represent the actual electricity and fuel supply infrastructure used by the buildings in a specific region. For example, some regions have a higher percentage of hydroelectric power and other regions use a great quantity of coal. However, consumers generally do not control the offsite generation mix. The analysis for the energy asset score is focused on the building, not on the utility. Two buildings with the same level of efficiency should receive the same score regardless of their utility companies. In addition, the energy asset score is a national program. For the above considerations, which are consistent with Portfolio Manager's approach, DOE did not select the regional conversion factors for the energy asset score.

3.1.3 Additional Metrics

The energy asset score provides additional metrics as references to give building owners, managers, and operators a full picture of building energy use and efficiency. These metrics include:

- site energy use by fuel type and system type
- energy cost savings
- system-level performance indicators.

DOE is also considering the best way to include other metrics (such as greenhouse gas emissions) that are of interest of building owners and their stakeholders as optional indicators.

3.1.3.1 Site Energy Use

The energy asset scoring tool generates a report that gives the modeled site energy use under common operating conditions, separated out by fuel type and building system. Building owners, managers, and operators can use this information to estimate the cost savings based on their own financial models. Site energy use breakout by fuel type and system type can inform building operators about building energy use distribution and help identify the areas where the most savings can be realized. Local governments, utilities, and other interested parties can also develop the local source energy use indicator based on the regional site-to-source factors.

3.1.3.2 Energy Cost Savings

Consumers are generally more familiar with cost metrics. However, energy costs for commercial buildings vary considerably in different parts of the country and change over time, including over the course of the day. Without much more specific information about a building's operations and its time-dependent per-unit energy prices, energy cost is not a durable, comparable metric on which to base a score. Another downside of using energy cost is that the cost includes a demand component, which relates to the utility infrastructure and greatly varies by region. Therefore, a cost metric alone cannot be used directly to judge building energy performance. For these reasons, DOE did not choose cost information as the primary metric for the energy asset score.

The energy asset score uses cost information as a metric to assess opportunities to improve building energy efficiency and describe the likely cost savings associated with those improvements. The energy asset scoring tool performs life cycle-cost analysis and provides an EEM package and associated energy cost savings. This information is not intended to be used by building owners and managers to purchase equipment or materials, but to help them learn their buildings' potential and identify opportunities. It is expected that building owners and managers will seek professional assistance in the identified opportunity areas when they make building retrofit decisions.

Time-dependent valuation (TDV) has been used in the cost-effectiveness calculation for the Title 24 Energy Standards since 2005. Compared to energy cost savings based on annual average price of electricity or natural gas, TDV accounts for variations in cost related to time of day, seasons, geography, and fuel type by summing the hourly savings over the analysis year. This method requires developing an hourly TDV factor for each climate location (for example, 16 sets of TDV factors for 16 climate zones in California). Under a similar concept, COMENT also developed time-of-use rate schedules for electricity, gas, steam, and chiller water. The energy asset score considers the cost savings related to high cost times of the day and year. The methodology is discussed Section 5.4.

3.1.3.3 System-Level Performance Indicators

The energy asset scoring tool generates a report that evaluates building systems. Although whole building EUI indicates the overall building efficiency as an integrated system, it is inadequate in fully explaining the influence of individual characteristics. A building with a well-insulated envelope and low-efficiency HVAC equipment could, theoretically, use the same amount of energy as a building with a poorly insulated envelope and high-efficiency HVAC equipment. System evaluations are provided for the building envelope (roof, walls, windows), lighting, HVAC, and service hot water systems. This information can help identify the specific components of the building most in need of attention. For two buildings with the same energy asset score, the system-level evaluations can give users insight into existing problems and point to potential improvements for the two buildings.

3.1.3.4 Greenhouse Gas Emissions

Energy use significantly contributes to greenhouse gas emissions, and the energy asset score can provide an opportunity to educate consumers and help them reduce emissions. Using greenhouse gas as the primary program metric would most closely link the energy asset score to environmental impact; however, the primary focus of the energy asset score is cost-effective energy efficiency improvements. As noted by the Northeast Energy Efficiency Partnerships, a greenhouse gas metric can “confuse the existence of non-carbon power sources—including large hydropower and nuclear power—with actual energy savings” (Dunsky et al. 2009, p. 94). Therefore, DOE did not choose greenhouse gas emissions as the primary metric for the program. However, DOE is exploring ways to support greenhouse gas information as an optional element of the program based on a partner’s interest.

3.2 Energy Asset Scoring Scale

3.2.1 Scale Selection: 1- to 100-Point Interval Scale

There are several ways to deliver building energy performance information to consumers. Various types of scales have been used in the existing building rating systems, including the following:

- **Scale reflecting physical units:** This type of scale is based on a certain type of physical unit. For example, the EnergyGuide label found on household appliances uses a physical scale (supplemented with cost information), such as kilowatt-hours per year in the case of refrigerators, supplemented with the expected annual cost of the particular refrigerator. Although physical units can communicate technical information to consumers, consumers may be unable to judge if they are unfamiliar with the units. Energy units such as kBtu/ft^2 do not mean enough to most consumers without engineering or energy knowledge. The energy asset score aims to promote market transformation and educate consumers, and the public may have difficulty interpreting an absolute energy scale. In addition, an unprocessed numeric scale does not offer a comparison among similar buildings, which is desirable because consumers are often motivated by how their buildings compare with others.

- **Scale converting physical units into other categories:** Physical units can be converted into a category system, which can be presented in letters, stars, or other symbols. Compared with continuous numeric scales, categorical scales have been shown to improve comprehension because they are easy to use and quickly deciphered (Thorne and Egan 2002a). Viewers can more easily gauge a building’s performance relative to other buildings or a reference point. Letter grades have been used in multiple building rating systems such as the ASHRAE Building Energy Quotient and the UK Display Energy Certificate. While stars and grades simplify things for consumers, a binned system also has drawbacks. Using a binned system can appear qualitative. The number of bins is also important. Too many bins may complicate the system, while too few bins can make it hard for a building to improve from one bin to the next and may not appropriately reflect the investments made and the savings being achieved.

- **Scale converting physical units into a numeric score:** Another rating method converts physical units into a score or index that consumers may understand more easily than a numeric scale reflecting simply physical units. ENERGY STAR Portfolio Manager, for example, converts energy use in commercial buildings into a score on a 100-point scale. Scores can be calculated using either a percentile rank method or an interval method. ENERGY STAR Portfolio Manager uses a 100-point percentile rank scale based on supporting databases that provide statistical representation of a given building type. A percentile approach was not selected for the energy asset score because of insufficient data regarding energy use of existing buildings under common operating conditions.

After considering the alternatives, DOE selected a 1- to 100-point scale for the commercial building energy asset score. Each additional point on the scale corresponds to an equivalent amount of reduction in source EUI. In other words, to move from a score of 25 to a score of 26 requires the same reduction in EUI as moving from a 62 to 63, or any other consecutive points along the 100-point scale. An advantage of this scale is that the rating system can recognize building efficiency and building efficiency improvements similarly at all efficiency levels.

A 10-point interval scale, used by the Home Energy Score (DOE EERE 2012b), is simpler than a 100-point scale, but it does not imply the same degree of precision. The energy asset scoring scale needs to provide enough granular data for buildings to show improvements over time as upgrades are made. For example, if a 10-point interval scale is used to represent an EUI range of 200 kBtu/ft^2, a building must reduce energy use by 20 kBtu/ft^2 on average to earn an additional point. This amount of energy reduction may require many system upgrades. On a 100-point scale that covers the same 200 kBtu/ft^2 range, the building would only need to reduce energy use by 2 kBtu/ft^2 to earn an additional point. This is more achievable, and the scores can reflect different levels of effort effectively.

The energy asset scoring scale should also be easily understood, interpreted, and familiar to people. Unlike other numerical scores, which can be interpreted in different ways, a 100-point interval scale is easily understood by the public. Compared with a letter scale, the 100-point scale will likely cause less prejudgment. For example, a B-rated building may carry a negative meaning, while a mid-range scoring building can still be considered good, depending on the market average.

Both the energy asset score and ENERGY STAR Portfolio Manager use a 100-point scale; however, the energy asset score evaluates as-built systems, not operation of the building. Therefore, the energy asset score cannot be compared directly to the ENERGY STAR score. In some cases, a building's energy asset score and ENERGY STAR Portfolio Manager score may align, but in many cases they will not. DOE and EPA plan to develop a systematic approach to help communicate the meaning of each score to users. As market research shows (McCabe and Wang 2012), the comparison of energy asset score and ENERGY STAR can provide very valuable information to building owners and operators.

3.2.2 Scoring Scheme Development

To convert energy use (measured or modeled) into a score, a baseline building is often used by setting the scoring metric to be the ratio of the scored building's energy use to that of a baseline building. The baseline building can be the same building designed to meet energy efficiency code requirements or a typical building like DOE reference buildings.

The ratio method using standard reference buildings has two potential challenges: selecting the proper reference building and the accuracy of using a representative climate city. Different scoring systems rely on different reference buildings. For example, the 2009 version of the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) for New Construction and Major Renovations (USGBC 2009) requires that the baseline building performance rating be calculated according to the building performance rating method in Appendix G of ANSI/ASHRAE/IESNA[1] Standard 90.1-2007. In contrast, the ASHRAE Building Energy Quotient uses modified DOE reference buildings modeled to a chosen ANSI/ASHRAE/IESNA standard.

Table 3.6 illustrates how selection of reference buildings can affect a building's rating or score. Using the code-compliant approach (Method 1 in Table 3.6), three buildings with varying site and source energy uses all receive the same rating since they all are code compliant. When DOE reference buildings are chosen as the baseline buildings (Method 2 in Table 3.6), the same three buildings score very differently.

The example in Table 3.6 shows that comparison to a code-compliant baseline building (Method 1) is not effective for the energy asset score because the influence of building geometry is not addressed when the baseline building uses the floor plan of the rated building. Gas and electric heating systems, if both meet the code requirements, are considered equally efficient because the baseline building and the rated building are modeled with the same type of HVAC system. In other words, a boiler is compared with a code-compliant boiler; a furnace with electric reheat is compared with a code-compliant furnace with electric reheat. The difference between types of HVAC systems is not considered. In this case, using site or source EUI to generate the ratio of the rated building and the baseline building yields the same result.

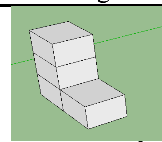
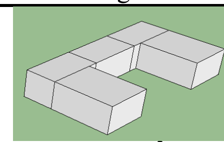
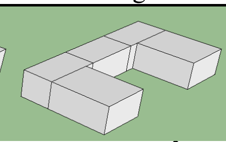
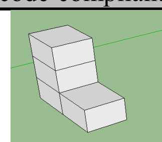
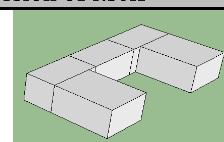
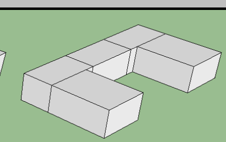
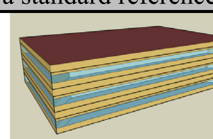
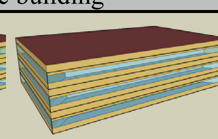
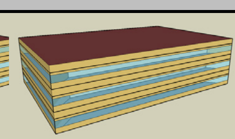
DOE considered the possibility of using commercial reference buildings: the large office type is 498,588 ft^2, medium office is 53,628 ft^2, and small office is 5,500 ft^2 (DOE EERE 2012c). The modeled site energy uses of post-1980 construction (compliant with ASHRAE Standard 90.1-1989) for these three reference buildings in climate zone 5A (Chicago) are 63 $kBtu/ft^2$, 66 $kBtu/ft^2$, and 72 $kBtu/ft^2$, respectively. There are no distinct cutoff points to define small, medium, and large office buildings. In addition, only 16 building types have been developed to represent approximately 70% (NREL 2011) of the commercial buildings in the United States. The remaining 30% might be difficult to represent by the typical reference building approach, so the application of energy asset scoring to all commercial buildings would be limited.

The second challenge is the accuracy of using a representative city for each climate zone. Sixteen cities are often used to represent sixteen climate zones. However, Figure 3.4 shows that, within each climate zone, the difference between the highest and lowest modeled source energy use varies from 10 to 60 $kBtu/ft^2$ when the weather location changes. To evaluate the building characteristics fairly, specific weather locations should be used. These two challenges—building size and location—complicate the selection of a baseline for comparison.

For these reasons, DOE has selected a scoring system that does not rely on reference buildings and instead simply converts modeled source EUI into a score.

[1] ANSI is American National Standards Institute; IESNA is the Illuminating Engineering Society of North America. For simplicity, ANSI/ASHRAE/IESNA Standard 90.1 is referred to in this document simply as ASHRAE Standard 90.1.

Table 3.6. An example of ratio calculations.

	Building A[a]	Building B[a]	Building C[a]
Rated building			
Total floor area	100,000 ft^2	100,000 ft^2	100,000 ft^2
Heating fuel	Gas	Gas	Electricity
Heating equipment	Boiler (80% efficiency)	Boiler (80% efficiency)	Electric resistance heat (100% efficiency)
Modeled site energy use	32.9 kBtu/ft^2	36.5 kBtu/ft^2	34.0 kBtu/ft^2
Modeled source energy use	83.9 kBtu/ft^2	93.2 kBtu/ft^2	113.6 kBtu/ft^2
Method 1: Compare to a code-compliant version of itself			
Baseline building			
Total floor area	100,000 ft^2	100,000 ft^2	100,000 ft^2
Heating fuel	Gas	Gas	Electricity
Heating equipment	Boiler (80% efficiency)	Boiler (80% efficiency)	Electric resistance heat (100% efficiency)
Modeled site energy use	32.9 kBtu/ft^2	36.5 kBtu/ft^2	34.0 kBtu/ft^2
Modeled source energy use	83.9 kBtu/ft^2	93.2 kBtu/ft^2	113.6 kBtu/ft^2
Ratio of rated building and baseline building based on site EUI	1	1	1
Ratio of rated building and baseline building based on source EUI	1	1	1
Method 2: Compare to a standard reference building[b]			
Baseline building			
Total floor area	(53,628 ft^2)	(53,628 ft^2)	(53,628 ft^2)
Heating fuel	gas	gas	gas
Heating equipment	Furnace (78% efficiency)	Furnace (78% efficiency)	Furnace (78% efficiency)
Modeled site energy use	50.4 kBtu/ft^2	50.4 kBtu/ft^2	50.4 kBtu/ft^2
Modeled source energy use	174.6 kBtu/ft^2	174.6 kBtu/ft^2	174.6 kBtu/ft^2
Ratio of rated building and baseline building based on site EUI	0.65	0.72	0.67
Ratio of rated building and baseline building based on source EUI	0.48	0.53	0.65

(a) Assuming buildings A, B, and C are office buildings built to ASHRAE Standard 90.1-2007 in Baltimore.
(b) DOE reference building: medium office, new construction, compliant with ASHRAE Standard 90.1-2004 in Baltimore. Source: DOE EERE 2012c.

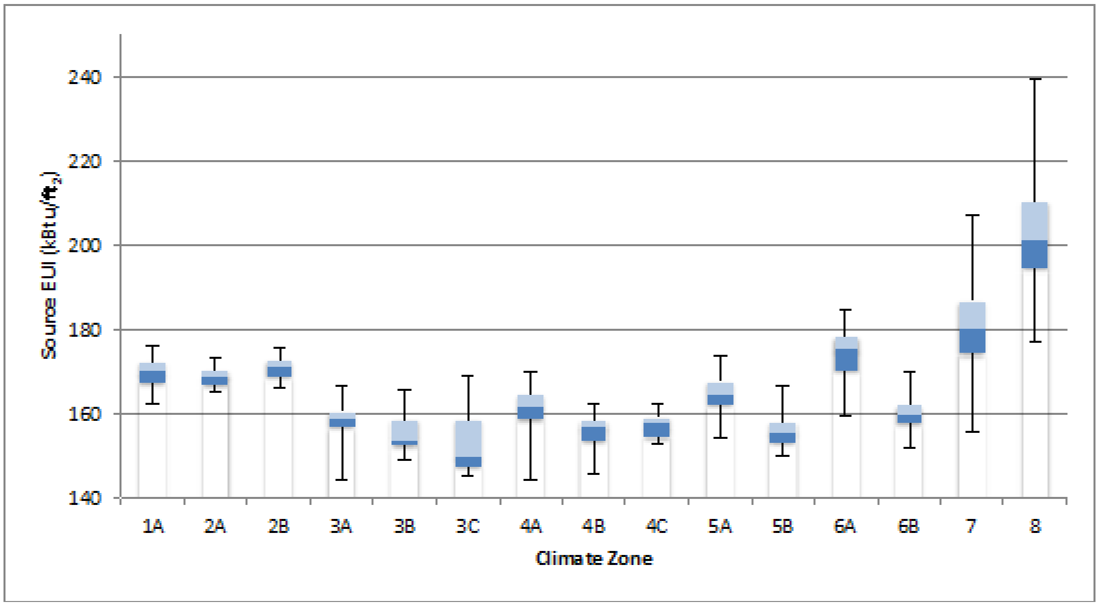


Figure 3.4. Modeled overall building energy use using TMY3 weather files (DOE Commercial Reference Building, Medium Office, New Construction, compliant with ASHRAE Standard 90.1-2004).

To develop a simple and standardized score, DOE is using a predefined scale for each building type. A source energy use value corresponds to a fixed point on the 100-point scale. In other words, a score is calculated directly based on the modeled energy use without the need to create a reference building. The overall methodology for determining a building's energy asset score includes three steps, as shown in Figure 3.5:

- **Step 1:** Source EUI is obtained by performing the whole-building energy simulation using the energy asset scoring tool. The tool chooses the closest weather station based on the user-entered zip code.
- **Step 2:** The modeled source EUI is adjusted to account for local climate.
- **Step 3:** An energy asset score is calculated using the adjusted EUI and the predefined equation, which is explained in Section 3.2.2.3.

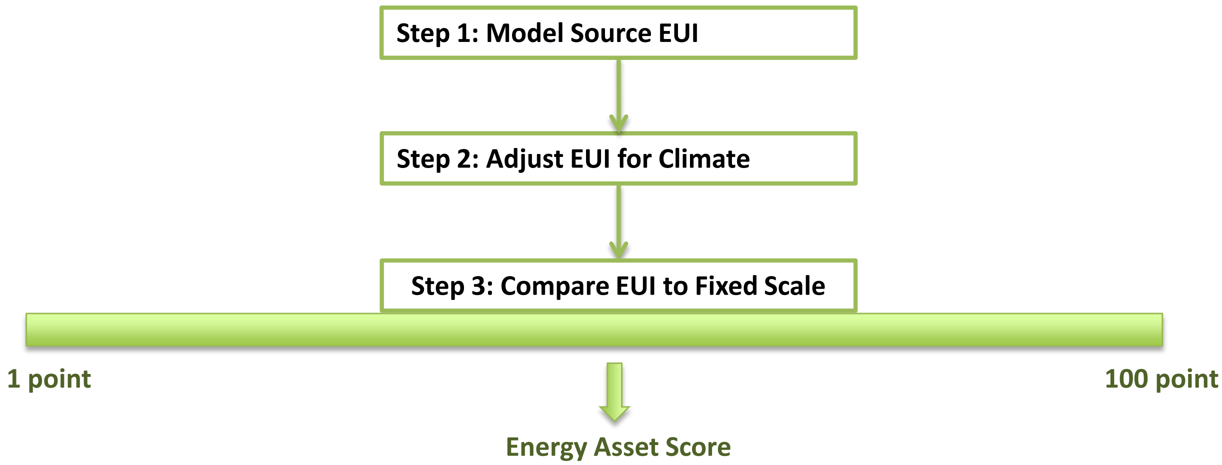


Figure 3.5. Energy asset scoring scale development.

3.2.2.1 Whole-Building Energy Simulation

The whole-building energy simulation is performed via the energy asset scoring tool—a web-based application. The tool consists of a simple user interface, the EnergyPlus simulation engine to calculate the building energy use, and an EEMs database to provide upgrade recommendations. An inference engine is also built into the tool to allow all key variables for a full-scale EnergyPlus model to be inferred from a reduced set of variables. Users submit the required data and receive an energy asset score report through the online tool. The development of such a tool reduces modeling time and expertise requirements while supporting the variability and complexity of commercial buildings. The tool development methodology is discussed in Section 4.

3.2.2.2 Weather Adjustment

The DOE commercial reference buildings were used to investigate how the weather affects modeled energy use across 16 climate zones (Figure 3.6). These reference buildings provided a consistent baseline for comparison and were used to develop coefficients for weather adjustment. A reference building representing a typical building type, size, and age was modeled using all available weather station data files (TMY3 data sets), which represent multiple locations within each climate zone in the United States. Using an identical building model (with envelope characteristics adapted to ASHRAE Standard 90.1 for each climate zone) in all locations allowed the effect of weather to be isolated. It was assumed that all buildings of similar use type, size, and age respond to weather similarly.

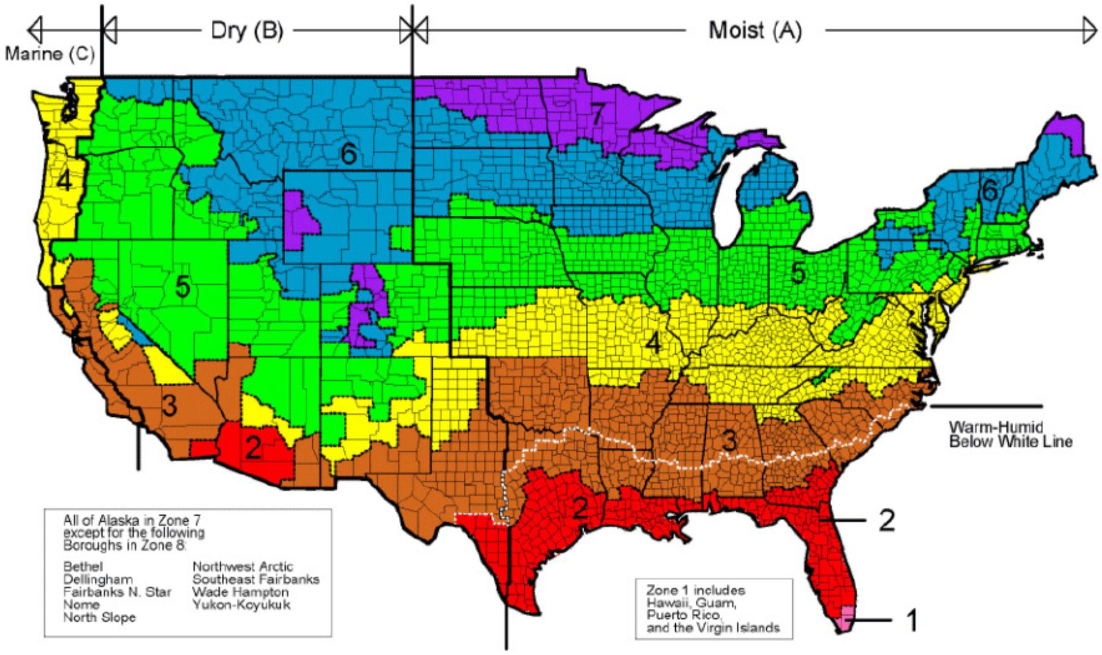


Figure 3.6. Climate zone classification (NREL 2011, p. 7).

A total of 983 weather coefficients were developed for each of the Phase I building types. The office buildings are taken as an example in this section to describe the methodology. At every weather station, source EUIs of office building type were calculated for nine different buildings. The nine buildings represent all permutations of new, post-1980, and pre-1980 building construction dates, combined with large, medium, and small building sizes. The analysis made no distinction between construction date and building size but treated each of the nine observations as unique observations at the given weather station.

First, nine candidate buildings were modeled at each of the weather stations, and source EUIs were computed for each building. To assess the effect of the local climate conditions on EUI, an EUI ratio for a building at each weather station site was computed by dividing the modeled EUI of the building at that site by the average of all EUIs obtained by modeling that building at all TMY3 weather station sites.

$$EUI\ Ratio_{Building\ Type\ 1, Size\ 1, Vintage\ 1, Weather\ Site\ 1} = \frac{EUI_{Building\ Type\ 1, Size\ 1, Vintage\ 1, Weather\ Site\ 1}}{Average\ EUI_{Building\ Type\ 1, Size\ 1, Vintage\ 1, All\ Weather\ Sites}}$$

Second, the average EUI ratio for each weather location was calculated and a weather coefficient was defined as the inverse of the average EUI ratio.

$$Weather\ Coefficient_{Building\ Type\ 1, Weather\ Site\ 1} = \frac{1}{Average\ EUI\ Ratio_{Building\ Type\ 1, All\ Size, All\ Vintaege, Weather\ Site\ 1}}$$

EnergyPlus contains 1,012 weather files. A total of 983 weather coefficients for office buildings were developed because some weather files did not work for two reasons. First, some weather files (.IDD) were incomplete. These weather files did not work for any building type because the weather file itself was corrupted. Most data points were deleted for this reason. The second reason was an error generated by HVAC systems. The HVAC systems of the reference buildings are generic—not designed specifically for a particular weather station in a climate zone. Therefore, the HVAC systems did not correctly function in the energy simulation. In this case, the weather files worked for some models (new construction) but generated errors for others (pre-1980 construction). To correct this type of error would require modification of the HVAC systems. However, such a modification would change the building characteristics and create inconsistent comparisons of the same building across different weather stations. Therefore, these data points were removed.

Only 29 weather stations were removed—that is, less than 3% of the total number of weather files. Exclusion of these data points did not affect the development of the weather adjustment coefficients, given the sufficient observations to generate significant results.

The developed weather adjustment coefficients were stored in the database of the energy asset scoring tool. After the simulation engine generates a building's EUI, a corresponding coefficient is applied to the modeled EUI to account for differences in climate. For example, given the modeled EUI of a candidate building A located near weather station site 1, the adjusted EUI is calculated as follows:

$$\begin{aligned} Adjusted\ EUI_{Building\ A, Type\ 1, Weather\ Site\ 1} \\ &= Weather\ Coefficent_{Type\ 1, Weather\ Site\ 1} \\ &\times\ Modeled\ EUI_{Building\ A, Type\ 1, Weather\ Site\ 1} \end{aligned}$$

The adjusted EUI is used only to calculate the energy asset score, not to represent the building energy use. The building energy use data presented on the energy asset score report (for example, energy use by system or by fuel type) is the modeled EUI before adjustment. Tool users do not see the adjusted EUI. The weather adjustment coefficients will be published on the energy asset scoring tool website for transparency.

3.2.2.3 Scale Development

Developing the energy asset scoring scale begins with defining the EUI for the two end points, 1 and 100. The high end of the scale represents high-efficiency buildings, and a score of 100 should be set at a point that represents a stretch goal.

For the purposes of Pilot #1, a score of 100 was equated to zero energy use. A benefit of setting 100 at net zero energy is that the high end of the scale would never need to change. However, the net zero setting has drawbacks as well. First, the current scoring tool does not capture renewables, making it impossible for any building at this time to score 100. Second, even after renewables are incorporated into the tool, very few net-zero energy buildings exist today. Existing buildings are unlikely to ever achieve net zero, and very few new buildings will achieve net zero, at least in the foreseeable future. Given these realities, DOE is reconsidering how to set the EUI for the 100-point rating on the scales for different building types. For the near term, during pilot testing, DOE will likely equate a score of 100 to net zero energy, recognizing that this likely will change.

The energy asset score is designed to emphasize energy efficiency prior to renewable energy, so only onsite renewable generation will affect the score as currently defined. In the initial rollout, the energy asset scoring tool will not be able to account for renewable generation. DOE expects that for the purposes of determining a building's asset score, a building's net site energy use would be converted to source energy use to calculate the energy asset score. In other words, if a building's net site energy use is zero, it will receive a 100-point rating.

Various supply-side renewable energy technologies (waste streams, biomass, utility-based wind, etc.) are also available for achieving the zero energy building goal. However, these are not considered to be part of the asset of the building. Furthermore, buildings are more likely to reduce their loads if investing in onsite renewable generation than if simply purchasing offsite renewable energy. Proper calculation of onsite generation and potential consideration of offsite supply options will be further evaluated and added to the tool later as appropriate.

The low end of the scale represents inefficient buildings. However, DOE has chosen not to use the least efficient building in today's commercial building stock to define the score of 1 because this would skew the scale toward the low-efficiency end. Furthermore, it should be noted that a score of 50 does not necessarily correspond to the mean or median of any database because the energy asset scoring scale is not a statistical scale, but an interval scale tied to source EUI.

To be effective, the energy asset scoring scale needs to reflect the variability within the building stock and recognize the energy efficiency improvements of both low- and high-efficiency buildings. A uniform scale was compared with a geometric scale to develop the most applicable scale type for energy asset scoring:

- On a *uniform* scale, the decremental EUI, the required energy reduction to earn an additional point, is constant.
- On a *geometric* scale, buildings with different EUIs need to reduce various amounts of energy use to earn an additional point.

Figure 3.7 shows an example of a uniform scale alongside a geometric scale. A uniform scale is simple and transparent. A geometric scale can better reflect the effort required to improve energy efficiency because it is usually more expensive to further reduce energy use in a high-performance building where all of the low-cost measures have been implemented. However, lack of simple correlation between upgrade costs and decremental EUI makes it difficult to build a geometric scale that is truly related to upgrade cost. Therefore, a uniform, linear scale was chosen for asset score.

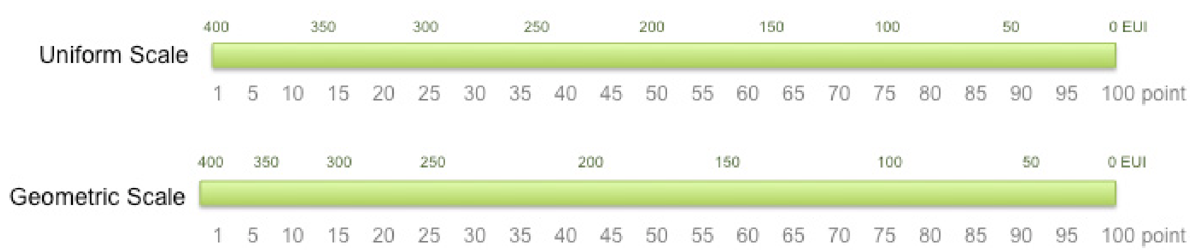


Figure 3.7. Uniform scale and geometric scale.

which in the case of the European energy asset rating system is the energy performance coefficient of the rated building and the baseline building (Lee et al. 2011).

- In the United States, guidance for certifying energy and power cost savings in energy-efficient commercial buildings (Deru 2007) specifies that the energy modeling must be completed in accordance with the performance rating method presented in ASHRAE Standard 90.1-2004, Appendix G (ASHRAE 2004). COMNET's *Commercial Buildings Energy Modeling Guidelines and Procedures* also provides a standard modeling approach for building energy modeling professionals (COMNET 2010). The ASHRAE Building Energy Quotient (bEQ) program[1] is developing a modeling specification similar to Standard 90.1, Appendix G, to guide individual professionals to create energy models for bEQ asset rating. All of these modeling guidelines provide useful references for developing the DOE energy asset score.

The above systems are examples of auditing protocols and approaches, which vary in terms of the time and expertise required of the user. The direct audiences of the above guidelines are not building owners and operators, who often need assistance from professional auditors and/or modelers to implement the data collection and energy model. Participation of professionals provides a certain level of quality assurance but also increases the implementation cost. Achieving a balance between ease of use and accuracy of results is essential for developing a reliable and useful score.

4.2 Modeling Approach: Dynamic Energy Simulation

All buildings are different, and conventional building energy modeling requires each modeler to use a substantial amount of judgment. This judgment leaves room for different interpretations of standards and different approaches to modeling a specific situation. While this flexibility can be a boon to modelers, it can create challenges when trying to compare models created by different individuals.

To avoid potential modeler bias and reduce the implementation cost, the energy asset scoring tool is designed to reduce reliance on specialized energy modeling expertise. The tool sets out generalized procedures by using a uniform method of estimating building performance while following the applicable modeling requirements specified in Appendix G of ASHRAE Standard 90.1-2007 and COMNET.

After evaluating several options, DOE selected dynamic energy simulation as the modeling approach for the energy asset scoring tool. DOE considered two different real-time dynamic building energy modeling options as a means to calculate building energy use:

- Energy modeling based an existing analysis tool, such as FEDS (PNNL 2008). This type of analysis tool usually uses a number of approximations and simplifications to develop a simplified energy model and provides a quick energy simulation and model analysis. This approach was abandoned due to a desire to have the modeling flexibility afforded by some of the more advanced sub-hourly simulation engines available on the market.
- A highly detailed, sub-hourly whole-building energy model. This approach can provide the level of detail required to model the most complex buildings being built today and produce results in which the end users would presumably have greater confidence (assuming that an established tool were

[1] http://buildingenergyquotient.org.

Table 4.2. Classification of input variables.

Ease of Collection	Variability	Impact on Energy Use	Variable Type	Examples	Inferable for Simple	Inferable for Advanced	Inferable for Beyond Advanced
Easy	Low	Low	A1	Floor plate type		X	X
Easy	Low	Medium	A1			X	X
Easy	Low	High	A1			X	X
Easy	Medium	Low	A1			X	X
Easy	Medium	Medium	S1	Floor area	X		
Easy	Medium	High	S1	Building vintage	X	X	X
Easy	High	Low	S1	Wall type	X	X	X
Easy	High	Medium	S1	Lighting type	X	X	X
Easy	High	High	S1		X	X	X
Moderate	Low	Medium	A2	Insulation thickness			
Moderate	Low	High	A2	Window solar heat		X	X
Moderate	Medium	Medium	A2	gain coefficient		X	X
Moderate	Medium	High	S2	Shading dimension	X		
Moderate	High	Medium	S2	HVAC efficiency	X	X	X
Moderate	High	High	S2		X	X	X
Moderate	Low	Low	A3	Wall insulation			
Moderate	Medium	Low	A3	thickness		X	X
Moderate	High	Low	A3	Service hot water		X	X
				efficiency			
Difficult	Low	Low	BA1	Fan blade			
Difficult	Low	Medium	BA1	efficiencies			X
Difficult	Low	High	BA1				X
Difficult	Medium	Low	BA1				X
Difficult	High	Low	BA1				X
Difficult	Medium	Medium	BA2	Air infiltration rates			
Difficult	Medium	High	BA2	Wall insulation R-			X
Difficult	High	Medium	BA2	value			X
Difficult	High	High	BA2				X

(a) S = simple level (minimum required set of user inputs).
(b) A = advanced level (minimum required set of user inputs for an advanced score).
(c) BA = beyond advanced level (additional user inputs for more accurate results).

4.3.2 Levels of Input Sets

After the inputs had been separated into the seven categories, the energy asset score data collection list was separated into three levels (shown in Table 4.2) based on the designation of each required variable. The levels were defined as follows:

- Simple-level variables (variable types S1 and S2). These variables are easy or moderately difficult to collect. They significantly influence energy use, and the values vary from one building to another.
- Advanced-level variables (variable types S and A). Compared with the simple level, these required variables—types A1, A2, and A3—are easy or moderately difficult to collect, and their influence on energy use may be high, even though their variability may not be high. These variables are required to obtain accurate simulation results.
- Beyond advanced-level variables (variable types S, A, and BA). These required variables—types BA1 and BA2—are difficult to collect.

The grouped variables correspond to the input thresholds for two use-cases, each having a unique purpose and target users and thus having different levels of requirements for data reliability (Figure 4.1).

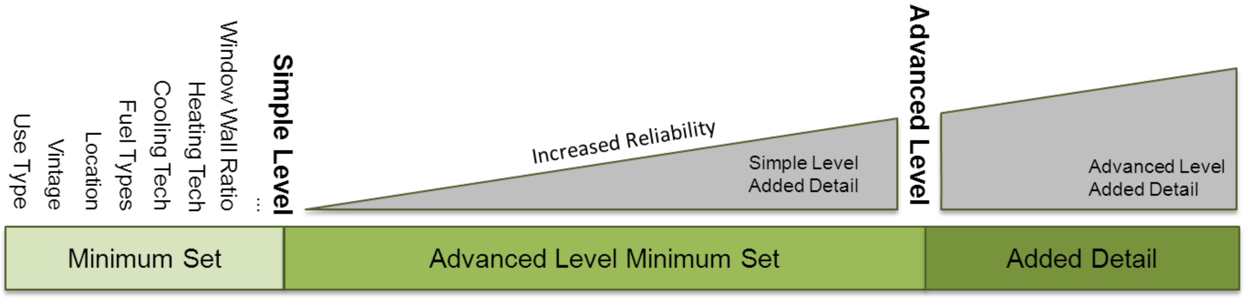


Figure 4.1. Different levels of data collection.

- Simple-level use only requires a minimum set of data from the user. Its use is not recommended for official purposes, such as real estate transaction, appraisal, or public display.
- Advanced-level use requires more data from the user. If a stakeholder wants to use a score for official purposes, it is likely that the advanced level would be required as well as some type of validation of the score and data inputs.

The inferability of different variable types, as described in Section 4.2, is outlined by variable type in Table 4.3. Appendix C provides a complete data input list (column G) for the energy asset scoring tool and the inferability of each variable (column K).

Table 4.3. Inferability of variable types.

Variable Type	Inferable for Simple Level	Inferable for Advanced Level
S1, S2	No	No
A1, A2, A3	Yes	No
BA1, BA2	Yes	Yes

4.3.2.1 Simple Level

The first application corresponds to the simple-level variables. The application for this set of inputs represents a preliminary analysis of building performance and guidance in finding potential areas for building performance upgrades. These variables are generally quick to collect and do not require a high level of building energy domain expertise to accurately ascertain. If a variable deemed slightly more time consuming to collect is placed into this category, it is because it is considered to be highly important in accurately assessing a building's total energy consumption.

Examples of simple-level data are shown in Table 4.2. The full list is included is Appendix C, column L. This minimum dataset will be further evaluated through pilot testing when the data collection process is tested with real buildings. Any of the other variable types (A1, A2, A3, BA1, BA2) can be entered to refine the result of the simple-level application, up to the complete set of simple and advanced levels of variables, at which point there is sufficient detail to meet the needs of an advanced-level application.

4.3.2.2 Advanced Level

The advanced-level application requires that the user enter all inputs in categories S and A (advanced-level variables). These inputs have been selected to produce more robust predictions of building energy use and likely areas for cost-effective asset upgrades. Table 4.2 gives examples of the current advanced-level inputs.

The advanced-level users of this tool can refine their results by adding any of the remaining tool inputs—that is, those that fall into categories BA1 and BA2 and thus make up the inputs beyond the minimum requirements for the advanced level. Examples of these additional inputs include air infiltration rates and fan blade efficiencies. Further, these inputs are difficult to capture and are not required, but could potentially provide the expert user with added detail and thus more insight into the performance of the building being examined. The full data input list is included in Appendix C, column G. There is no distinction between advanced- and beyond-advanced levels of inputs. This dataset will be evaluated through a sensitivity analysis (testing the impact of each variable) and a pilot project (testing the data collection process). After that, the minimum dataset for the advanced level will be finalized.

4.3.2.3 User Requirements

Commercial property owners, managers, and operators are expected to be the primary users of the energy asset scoring tool. Secondary users of the energy asset score may include lenders and investors, appraisers, and designers/engineers. Owners of larger properties or portfolio owners may use the tool as a first pass, essentially a preliminary energy report to assess their buildings and prioritize which buildings should be investigated further using a more detailed energy audit. Smaller property owners can use the tool as a low- or no-cost way to evaluate energy efficiency and identify opportunities for improving building performance. At a minimum, the individual collecting the building information needs some familiarity with building systems and the process of extracting building characteristics from drawings and equipment cut sheets, or have ready access to people with such experience. There is no qualification requirement for users interested in generating a score for informal purposes. User requirements to ensure quality of the data will likely be needed to generate a validated score.

4.3.3 Data Collection Time

In addition to the input variable classification described in the previous sections, the process of data collection was classified based on likely information source and the time estimated to collect it. Some information will likely be immediately known to the facility manager (e.g., number of floors, HVAC system type), whereas collecting other inputs may require referring to the architectural or mechanical construction drawings or equipment cut sheets (e.g., window-to-wall ratios, fan airflows), or performing onsite measurement (e.g., air infiltration). These inputs were further classified as immediate, short, and long, based on the time required to collect the information as described in Table 4.4. The estimated average time for collecting data of the immediate, short, and long variable types is less than 2 minutes, 5 to 10 minutes, and 10 to 30 minutes, respectively, given appropriate level of expertise and access to building systems or data. The total required time is estimated to be less than 6 hours for the simple level and less than 20 hours for the advanced level. These estimations are based on the interviews with the experienced energy auditors at PNNL. They are used only to guide the tool development. The field assessment during the pilot project will further examine the time required for each level of data collection.

4.3.4 Automated Error-Checking

The energy asset scoring tool gives users a warning message when automated checks suggest that data entered may be incorrect or incomplete. Users cannot submit their building information if any required data are missing. Users may leave non-required fields in the application set at their respective defaults, allowing the system to infer values based on reported characteristics of the building. If users enter an invalid value, they will be informed of the proper range of the input.

Table 4.4. Estimation of data collection time.

Data Collection Time	Data Description
Immediate (easy)	Information immediately known to a person experienced with the building; e.g., number of floors, HVAC system type.
Short (moderate)	Information that may be obtained immediately after referring to the building drawings; e.g., wall construction, thermal zoning.
Long (difficult)	Information that may be obtained after studying the building drawings or equipment specifications and performing further analysis, or through an onsite measurement; e.g., air infiltration, cooling tower fan power.

4.4 Software Development

The energy asset scoring tool has three components (Figure 4.2):

- user interface
- analytic engine (infers model parameters not entered by users; identifies upgrade opportunities; assigns a whole building score as well as qualitative assessments of individual building systems)
- modeling engine.

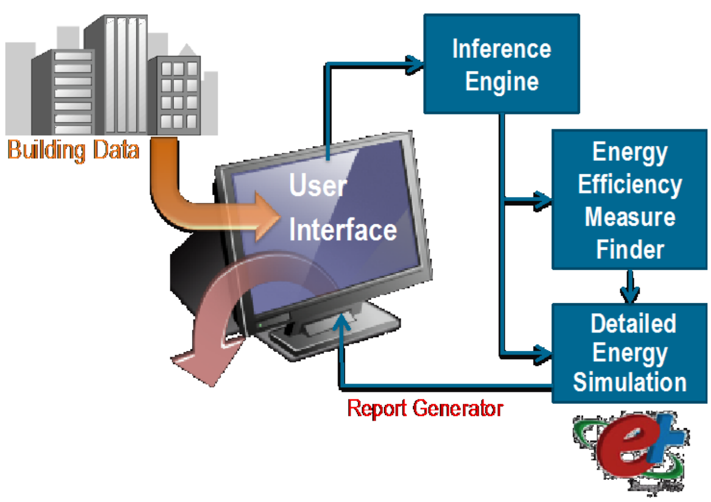


Figure 4.2. Energy asset scoring tool components.

- energy model internal system sizing algorithms
- previous research, including the Bonneville Power Administration End-Use Load and Consumer Assessment Program (ELCAP; Pratt et al. 1991).

4.4.3 Energy Models

In addition to data-driven inferences, FEDS uses an internal energy modeling system to predict the necessary system capacities for a specific building. This system is based on the cooling load temperature difference/cooling load factor method outlined in the 1989 *ASHRAE Handbook−Fundamentals* (ASHRAE 1989). This widely-used load prediction method allows for the rapid determination of a building's heating and cooling load. This load is then used in conjunction with the system parameters specified by the user to estimate the required equipment capacity for a building. These system capacities, along with system age and type, are then used to infer expected system efficiencies. The internal load prediction model is also used to select a package of LCC-optimized EEMs as described in Section 5.4.

When the necessary building characteristics have been inferred, such that a complete building data description is available, it is then necessary to predict the energy consumption of the building based on those characteristics. EnergyPlus was selected as the tool to perform this estimation. Built on OpenStudio[1] (a cross-platform collection of software tools to support whole-building energy modeling using EnergyPlus), a web service translates the user inputs and inferred variables into the complete set required for an EnergyPlus simulation.

4.4.4 Data Processing and Report Generation

Figure 4.4 illustrates how the energy asset scoring tool processes data and generates an energy asset score report. The steps are as follows:

1. The user interface collects all pertinent data available from the user.
2. The web service (an API) passes data through to FEDS.
3. FEDS fills in default building information and missing user data to produce a complete building data file. This data file is also used within FEDS to generate EEM opportunities—the method is explained in Section 5.4.
4. The original building configuration data and the EEM-implemented building configuration data are sent back to the web service.
5. The web service builds two energy model files—current building and upgrade building—and passes them to EnergyPlus to perform the detailed energy simulation. OpenStudio, a cross-platform collection of software tools to support whole-building energy modeling using EnergyPlus, runs the energy simulation. This will allow the energy asset scoring tool to expand its functionality when more features are added to OpenStudio.
6. The results of the EnergyPlus simulation are combined with the identified EEMs and passed back to a report processor in the web service.
7. An energy asset score report is sent to the user.

[1] http://openstudio.nrel.gov/.

It is important to note that DOE is currently evaluating other options for some of these inputs (e.g., office plug load) given indications that the some of the values are not in line with typical usage patterns. DOE will consider actual building data and review various other sources before finalizing the inputs to be used for scoring buildings.

Table 4.5. Standard operating inputs.

	Receptacle Power Density (W/ft^2)	Occupant Density (ft^2/person)	Heat Gain per Occupant Sensible (Btu/occ)	Heat Gain per Occupant Latent (Btu/occ)	Minimum Ventilation (cfm/ft^2)	Water Heating Load (G/day-occ)	Interior Gas Appliance Power Density (Btu/h-ft^2)	Refrigeration Power Density (W/ft^2)
Education	1.02	25	246	171	0.32	0.61	0.04	0.03
Office	2.47	150	250	206	0.15	1.00	0.04	0.06
Retail	0.86	100	250	250	N/A	0.61	0.03	0.14
Warehouse	0.45	333	375	625	0.15	0.61	0	0.28

5.0 Energy Asset Score Report

5.1 Report Structure Overview

The energy asset score report includes four sections: score, system evaluation, identified opportunities, and building assets.

- The *score* page includes basic building information (e.g., address, floor area, year built, use type), standard operating assumptions, site and source EUIs by fuel type, current energy asset score, and potential score that could be achieved with identified upgrade opportunities. A reference point is also provided to show the energy asset score of a prototype building[1] (compliant with ASHRAE 90.1-2004) of the same use type, similar size, in the same climate zone. This reference point does not affect a building's score but is included to help users understand the scoring scale.
- The *structure and systems* page includes site and source EUIs by system, as well as evaluations of building envelope and lighting, HVAC, and hot water systems.
- The *opportunity* page provides identified opportunities, including their energy savings and payback periods.
- The *building assets* page provides a list of building characteristics used in the energy asset model.

A sample report can be found in Appendix D.

DOE is also considering working with interested partners to include local benchmark information on the energy asset score report for comparison. For example, a state might wish to include information pertaining to average energy asset scores for a specific building type within the state. Additional information that is not currently in the report may be provided in the future, such as a reference point to help users understand how their building score compares to a specific energy code, indication of whether the building has systems to provide a certain amount of energy from onsite renewables, and greenhouse gas emissions.

5.2 Scores

The primary modeling output of the energy asset scoring tool is the EUI, which is used to generate the energy asset score. No baseline or comparable buildings are needed because the calculated EUI is placed on a fixed scale. The scale development and score calculation are discussed in Section 3.2.2. Three sets of scores and associated modeled EUIs are presented on the same energy asset scoring scale: (1) current score, (2) potential score, and (3) prototype building score (Figure 5.1).

The energy asset scoring tool generates identified upgrade opportunities based on LCC analyses of applicable EEMs. Users can enter the actual operating conditions to receive recommendations tailored to their buildings. In other words, a building may receive different packages of EEM recommendations if different actual operating conditions are entered into the tool because the EEM package is based on LCC analyses. An EEM recommended for a building operated 60 hours per week may not be cost-effective for the same building operated 30 hours per week. The standard operating conditions are applied to the

[1] https://www.energycodes.gov/development/commercial/90.1_models.

upgraded building models to generate the potential score. Although the actual operating conditions are not used to calculate the energy asset score, they may influence the potential score to some degree by affecting the LCC analysis of the upgrade package.

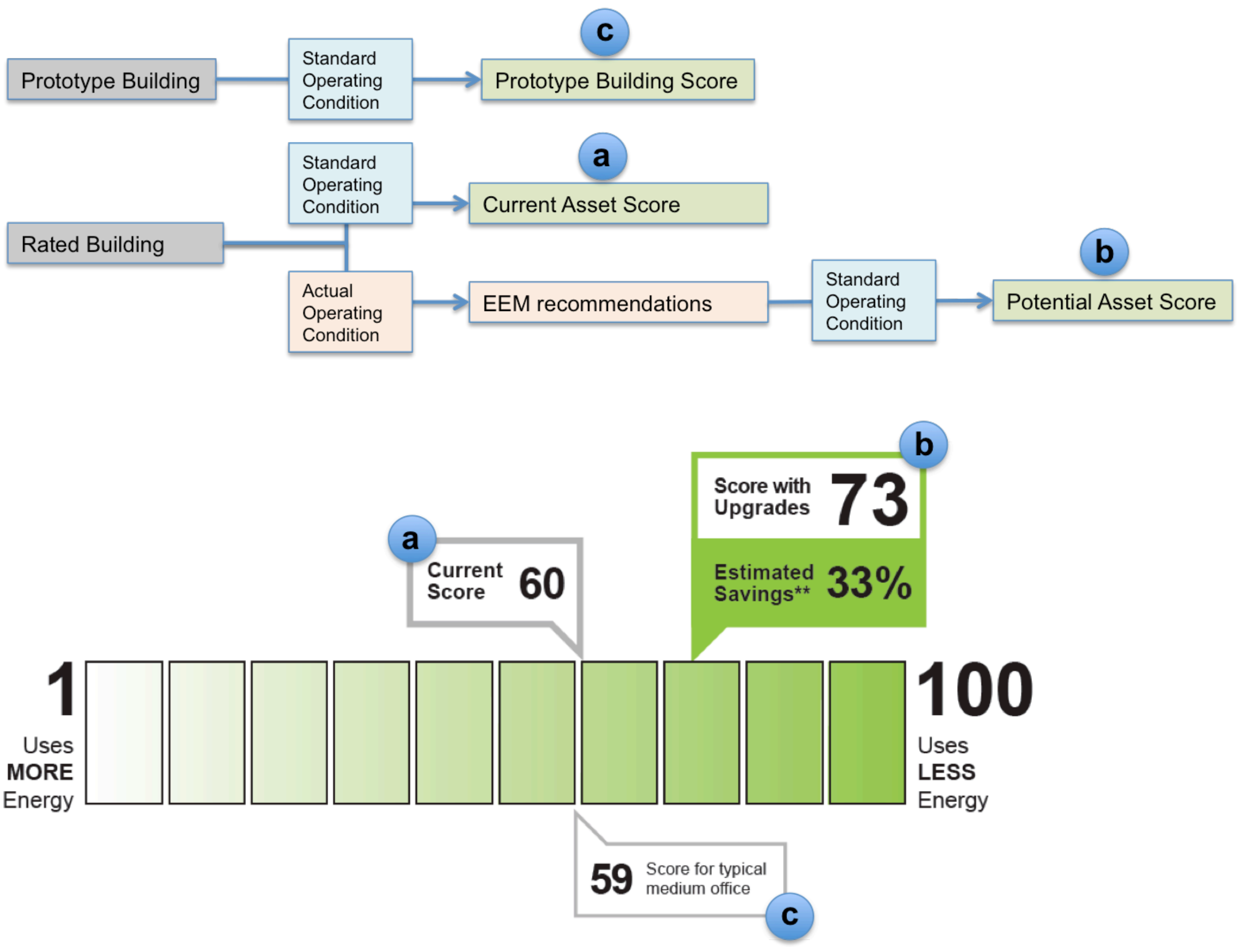


Figure 5.1. Current, potential, and reference scores.

The score of a prototype building of the same use type and similar size is also presented on the scale as a reference to help users compare their building to a code-compliant building. However, the score of a rated building is independent from the chosen reference point. Ideally, the reference points will reflect either the national or local average, but there is currently no database for energy asset scoring. Therefore, DOE prototype buildings are used to create the reference points. The climate-appropriate prototype building was modeled in the same manner as was used to find the weather adjustment factor (one representative city for each International Energy Conservation Code (IECC) climate zone and state combination). For example, Texas has regions that are classified as 2A, 2B, 3A, and 3B; therefore, four different reference values will be found by modeling the IECC climate zone and use type appropriate prototype in four representative cites: Houston, Laredo, Dallas, and El Paso; this approach gives a total number of 119 simulations for each prototype building. These modeled results are then mapped to the 100-point scale in the same way as the user's building (weather adjusted source energy).

5.3 Structure and Systems

Although the whole building EUI indicates the overall building efficiency as an integrated system, it is inadequate to fully understand the effect of individual characteristics. A building with a well-insulated envelope and low-efficiency HVAC equipment could, theoretically, use the same amount of energy as a building with a poorly insulated envelope and high-efficiency HVAC equipment. System evaluations are provided for the building envelope (roof, walls, windows, floor), lighting, HVAC, and service hot water systems. This information can help identify the specific components of the building most in need of attention. For two buildings with the same energy asset score, the system-level evaluations can give users insight into the existing problems and point to potential improvements for the two buildings.

Both prescriptive and performance approaches have been used in energy standards to design and evaluate building systems.

The prescriptive approach specifies some minimum acceptable construction or system standards, such as minimum R-value (or maximum U-value) for building envelopes or required equipment efficiencies for mechanical systems. A prescriptive approach is easy to use, especially for building or system design. However, for existing system evaluations, a prescriptive approach can be restrictive, for several reasons:

- A prescriptive approach is generally limited to single variable input comparisons. More complex systems with multiple input characteristics and/or different configurations need to be modeled to understand how the different characteristics operate in concert. For example, a chiller is defined both by its design condition coefficient of performance and characteristic part-load performance curves of its compressor.
- It is difficult to compare different HVAC systems using a prescriptive approach. For example, in ASHRAE Standard 90.1-2007, Tables 6.8.1A through D specify the minimum efficiency ratings for 54 cooling equipment types. For some equipment types, multiple ratings are given based on the equipment size. The efficiency ratings are presented in different units—including EER (energy efficiency ratio), SEER (seasonal energy efficiency ratio), kW/ton, COP (coefficient of performance), IPLV (integrated part load value), and HSPF (heating seasonal performance factor)—depending on the test procedures. There is no industry standard against which to rank different mechanical systems because they have their advantages in various applications. For instance, the minimum efficiency for an air-cooled air conditioner with a capacity of 240 to 760 kBtu/h is 10.0 EER, while the minimum efficiency is 11.0 EER when the equipment capacity is lower (ASHRAE 90.1-2007, Table 6.8.1A). To make a proper system evaluation, the HVAC equipment size needs to be examined first. Developing such a standard goes beyond the scope of the energy asset score; therefore, a prescriptive approach was not chosen.
- A prescriptive approach isolates a system from the evaluated building. For example, a building with a low thermal mass due to it envelope characteristics may force its HVAC system to handle more extreme operating conditions and use more energy than another building with the same HVAC system but more thermal mass.

Due to the multivariate nature of most systems examined by the energy asset scoring tool and considering the appropriate level of data that can be collected by users, DOE selected a model-based performance approach as the primary system evaluation method for envelope, lighting, HVAC, and service hot water systems. A performance approach compares the energy use of a building or system with that of a baseline or reference design. It allows a high level flexibility and considers a building as a single system. The following metrics are used as indicators of system performance (Table 5.1).

Table 5.1. Performance indicators for building systems

Building Systems	Performance Indicators	Calculation Methods	Evaluations
Window	$kBtu/ft^2$	Heating and cooling load through windows / total window area	Higher value indicates more heat transfer through windows, and therefore represents poor thermal performance
Wall	$kBtu/ft^2$	Heating and cooling load through walls / total wall area	Higher value indicates more heat transfer through walls, and therefore represents poor thermal performance
Window + Wall (account for window-wall ratio)	$kBtu/ft^2$	Heating and cooling load through walls and windows / total wall plus window area	Higher value indicates more heat transfer through walls and windows, and therefore represents poor thermal performance
Roof	$kBtu/ft^2$	Heating and cooling load through roof / total roof area	Higher value indicates more heat transfer through roof, and therefore represents poor thermal performance
Floor	$kBtu/ft^2$	Heating and cooling load through floor / total floor area	Higher value indicates more heat transfer through floor, and therefore represents poor thermal performance
Lighting System	$kBtu/ft^2$	Lighting energy use / total floor area	Higher value indicates more lighting EUI, and therefore represents low-efficiency lighting system
Heating System	Annual heating system efficiency (no unit)	Annual heating load / annual heating energy use	Lower value indicates more heating energy use to meet the load, and therefore represents low-efficiency heating system
Cooling System	Annual cooling system efficiency (no unit)	Annual cooling load / annual cooling energy use	Lower value indicates more cooling energy use to meet the load, and therefore represents low-efficiency cooling system
Overall HVAC System	Annual HVAC system efficiency (no unit)	Heating and cooling load / heating and cooling energy use	Lower value indicates more heating and cooling energy use to meet the load, and therefore represents low-efficiency HVAC system
Service Hot Water System	Annual hot water system efficiency (no unit)	Hot water energy load / hot water use	Lower value indicates more hot water energy use to meet the load, and therefore represents low-efficiency hot water system

Note: Source energy is used in the above calculations.

5.3.1 Building Envelope

For the envelope assessment, the heating and cooling loads due to envelope gains are extracted from the energy model. The loads are divided by the exterior surface area of the particular envelope component being examined to calculate the net heat gain or heat loss per unit area of the component (measured in $kBtu/ft^2$). A higher value indicates more heat transfer across the envelope and therefore reflects poor thermal performance. This method goes beyond typical prescriptive standards, which simply use assembly U-values, because it reflects the overall effect of the envelope on the heating and cooling loads, considering such factors as orientation, layout, and non-conductive heat transfer properties. The same evaluation method is applied to windows, walls, combination of windows and walls, roof, and floor to separately evaluate their performances. The combination of windows and walls accounts for window-wall ratio. Because thermal resistance is usually much lower for windows than it is for walls, a building envelope with well-insulated walls and windows may not have good overall performance if the window-wall ratio is high. Table 5.2 shows a few examples of envelope evaluation scenarios.

Table 5.2. Examples of envelope evaluation.

	Walls	Windows	Window-Wall Ratio	Walls and Windows Combination
Building A	Good	Good	High	Fair
Building B	Good	Good	Low	Good
Building C	Poor	Poor	High or Low	Poor
Building D	Good	Poor	High	Fair
Building E	Good	Poor	Low	Good
Building F	Poor	Good	High or Low	Poor

A technical barrier at this moment is that EnergyPlus output files do not specify the heat transfer through an envelope component (windows, walls, roof, floor). However, EnergyPlus is expected to provide such output function in the near future. Until then, the interim approach used to evaluate building envelope is a prescriptive method. The U-values (of windows, walls, roof, or floor) are directly compared to the minimum required U-value specified in ASHRAE Standard 90.1-2004.

5.3.2 Lighting System

For the lighting system assessment, the lighting EUI is used. A higher value indicates more lighting energy use based on the standard assumptions of operating schedules. Therefore, it represents less efficient lighting systems. Compared to lighting power density (W/ft^2), which only considers installed lighting load, lighting EUI ($kBtu/ft^2$) includes the effects of lighting controls and daylighting in the building, considering each component of the system together, rather than just looking at a single aspect. Source energy is used to account for the production and transmission loss of electricity.

5.3.3 HVAC Systems

For the HVAC systems, annual system efficiency is used. Annual system efficiency is defined as a ratio of the total heating and cooling energy load and the total energy consumed by the HVAC system. Source energy is used to account for the production and transmission loss of different fuel types. The concept of annual system efficiency is similar to COP. The rated COP is obtained from the typical tests performed at fixed standard conditions, accounting for part load performance as loads fluctuate throughout the year and the distribution system efficiency. Annual system efficiency is calculated from a building's energy asset score model. Annual cooling system efficiency, annual heating system efficiency, and annual HVAC system efficiency are separately calculated to provide a comprehensive evaluation of heating, cooling, and the integrated HVAC systems. A higher value indicates less heating and cooling energy use, and therefore represents a more efficient HVAC system. Fan energy used to provide outdoor air ventilation is assigned to either cooling or heating energy use based on the mode of operation of the system while the ventilation air is delivered.

5.3.4 Service Hot Water System

Service hot water systems are evaluated using the ratio of the energy delivered in the form of hot water to energy input. Source energy is used to account for the production and transmission loss of different fuel types. A higher value indicates that less energy is used to deliver a unit of hot water, and therefore represents a more efficient hot water system.

5.3.5 Baseline Development Methodology

Reference values are provided to communicate the meaning of the system performance indicators. If a system's performance is within the reference range, its performance is considered "Good." A value that is below or above the range indicates systems are "Fair" or "Superior," respectively. A fourth ranking below "Fair" (e.g., "Poor") may be created to indicate the least efficient systems.

Three sets of prototype buildings (compliant with ASHRAE Standard 90.1-2004, 2007, and 2010) are used to calculate the reference ranges. The prototype buildings represent 80% (Thornton et al. 2011) of the commercial building floor area in the United States for new construction, including both commercial buildings and mid- to high-rise residential buildings. These prototype buildings—derived from DOE's Commercial Reference Building Models—cover all the reference building types except supermarkets.[1] They were selected to provide consistency and transparency and to provide an industry accepted baseline for the performance indicator comparison. The characteristics of the prototype buildings are well documented and the models are readily available online.

Table 5.3 shows an example of system performance levels for office buildings. The ranges are developed based on the best and the worst results obtained by modeling all prototype buildings available for a particular building use type. Typically the 90.1-2004 model corresponds to the minimum efficiency level considered "Good," and the 90.1-2010 model corresponds to the minimum efficiency level considered "Superior." Under the current method, any system with efficiency less than the minimum level allowed for "Good" would be characterized as "Fair." As stated above, a fourth level below "Fair" may be developed.

[1] https://www.energycodes.gov/development/commercial/90.1_models.

Table 5.3. Example of baseline system development for climate zone 5A.

		Prototype Buildings									Baseline Values		Candidate Building
		Small Office			Medium Office			Large Office			Range		Evaluation Method
		2004	2007	2010	2004	2007	2010	2004	2007	2010	Low	High	
Window U (Btu/ft^2 h °F)	Non-metal	0.67[a]	0.35	0.35	0.67[a]	0.35	0.35	0.67[a]	0.35	0.35	**0.35**	**0.67**	
	Metal		0.45	0.45		0.45	0.45		0.45	0.45			
Window Solar Heat Gain Coefficient		0.49[a]	0.40	0.40	0.49[a]	0.40	0.40	0.49[a]	0.40	0.40	**0.40**	**0.49**	
Wall U (Btu/ft^2 h°F)	Mass	0.123	0.090	0.090	0.123	0.090	0.090	0.123	0.090	0.090	**0.064**	**0.123**	
	Metal	0.113	0.113	0.069	0.113	0.113	0.069	0.113	0.113	0.069			
	Steel-farmed	0.084	0.064	0.064	0.084	0.064	0.064	0.084	0.064	0.064			
	Wood-framed	0.089	0.064	0.064	0.089	0.064	0.064	0.089	0.064	0.064			
Window + Wall (Btu/ft^2 h °F) [b]		0.17	0.13	0.13	0.20	0.16	0.16	0.29	0.24	0.24	**0.13**	**0.29**	More efficient than range: Superior Within range: Good Less efficient than range: Fair
Roof (Btu/ft^2 h °F)	Insulation above deck	0.063	0.048	0.048	0.063	0.048	0.048	0.063	0.048	0.048	**0.027**	**0.065**	
	Metal building	0.065	0.065	0.055	0.065	0.065	0.055	0.065	0.065	0.055			
	Attic and other	0.034	0.027	0.027	0.034	0.027	0.027	0.034	0.027	0.027			
Floor (Exposed to Unconditioned Air) (Btu/ft^2 h °F)	Mass	0.087	0.074	0.074	0.087	0.074	0.074	0.087	0.074	0.074	**0.033**	**0.087**	
	Steel-joist	0.052	0.038	0.038	0.052	0.038	0.038	0.052	0.038	0.038			
	Wood-framed and other	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033			
Floor (Slab on Grade) (Btu/ft h °F)	Unheated	0.730	0.730	0.730	0.730	0.730	0.730	0.730	0.730	0.730	**0.730**	**0.730**	
Lighting System (kBtu/ft^2)[c]		38.74	38.74	29.82	30.96	30.96	21.29	30.96	30.96	23.04	**21.99**	**38.74**	
Service Hot Water System[c]		0.70	0.70	0.70	0.75	0.75	0.75	0.76	0.76	0.76	**0.70**	**0.76**	
Heating System[c]		0.18	0.14	0.15	0.14	0.13	0.16	0.13	0.12	0.11	**0.11**	**0.18**	
Cooling System[c]		0.46	0.55	0.53	0.95	1.01	1.08	0.96	0.98	1.32	**0.46**	**1.32**	
Overall HAVC System[c]		0.31	0.33	0.33	0.43	0.50	0.56	0.70	0.75	0.97	**0.31**	**0.97**	

(a) The highest u-value for all window-wall ratios.
(b) Based on the window-wall ratio and construction type of prototype buildings.
(c) Based on source energy use.

5.4 Opportunities

The energy asset scoring tool is intended to provide easy and low-cost assistance, giving preliminary guidance on whether it is worthwhile to retrofit a building and how to prioritize the activities. Based on the building information entered, the tool identifies potential opportunities in areas of HVAC equipment, envelope, glazing, service hot water, and lighting. The recommendations provided by the tool are based on a building's specific characteristics; they are not intended to replace detailed engineering evaluation or to guide decisions to purchase specific equipment or materials. Rather, the energy asset scoring tool can help users recognize the types of projects that may enhance building energy performance.

The energy asset scoring tool follows a two-step process to generate a list of recommended retrofits. First, the tool performs an LCC assessment of retrofit measures, using a modified version of the life-cycle methodology[1] required for federal buildings, as specified in 10 CFR part 436. The LCC relies on existing algorithms and capital and operating costs defined in the FEDS software. This approach accounts for the effects of the recommendations on operations and maintenance costs and on changes in the energy consumption to determine the cost effectiveness of potential retrofit measures.

The economic assumptions used in the LCC analysis were selected to produce a diverse, comprehensive list of EEMs, not in an attempt to match a user's unique set of economic expectations. Building owners and operators should bear this in mind when deciding whether to pursue specific recommendations. The primary LCC assumptions are follows.

- **Discount Rate**: A discount rate of 0% was selected to ensure that users would receive a comprehensive list of deep energy retrofit options. That is, this approach results in a list of all recommendations where savings over the life of the equipment (not discounted) are greater than the upfront cost of the improvement. Commercial property owners typically will apply a higher discount rate; however, an LCC analysis based on a higher rate may exclude valid EEMs from the list of identified opportunities. Furthermore, since different property owners apply different discount rates to their investment decisions, there is no way to pick a rate that will satisfy all users. Based on the information provided in the energy asset score report, building owners can develop their own financial models outside of the energy asset scoring tool or seek professional assistance to evaluate the potential project economics.
- **Life-Cycle Period:** For evaluating and ranking alternative recommendations for existing buildings, the study period is set to the expected life of the retrofit or 25 years from the beginning of beneficial use, whichever is shorter.
- **Non-fuel Costs:** The relevant non-fuel costs include investment cost, replacement cost, and operating and maintenance costs. Material and labor costs are adjusted for state-level differences and consist of stage averages (PNNL 2008). Data sources vary and include industry construction cost manuals and information from vendors, suppliers, and contractors. Typically, the FEDS database undergoes a major update every 3 to 5 years; more targeted updates of specific technologies (e.g., lighting technologies) may occur more frequently.

[1] This methodology provides "a systemic analysis of relevant costs, excluding sunk costs, over a study period, relating initial costs to future costs by the technique of discounting future costs to present value" (10 CFR part 436, p. 421).

- **Energy Costs**: Energy costs are derived from COMNET default time-of-use (TOU) prices. COMNET TOU prices estimate the present value of energy costs at different time periods (on-peak, mid-peak, off-peak, weekdays, weekends) in 15 climate zones by calculating the marginal electricity cost based on the sum of energy value components (including generation energy, losses, ancillary series, system capacity, transmission and distribution capacity, and environment). Considering that the cost structures vary greatly between service providers and overtime, COMNET TOU prices provide more accurate estimates of long-term energy cost savings than using a national or state average. The COMNET present values of energy cost savings were converted into the current costs of energy. Appendix E shows the energy costs used in the energy asset scoring tool. DOE may allow users to provide their own utility cost information, particularly for a non-validated score.

This initial LCC assessment is performed for EEMs that depend on multiple user inputs, where multiple recommendation options exist for a single system or component and for highly interactive building systems. Systems addressed in this initial assessment include the following:

- opaque envelope elements
- fenestration
- cooling equipment
- heating equipment
- lighting
- hot water.

Building LCC analysis algorithms provided by the National Institute of Standards and Technology are used to rank recommendations (Figure 5.2). When the minimum LCC configuration of generation and end-use technologies is determined, all interactive effects between energy systems are explicitly modeled. For example, when a lighting retrofit is under consideration, the FEDS energy model evaluates the change in energy consumption in all building energy systems, such as heating and cooling. This provides more accurate savings estimates and thus more useful recommendations.

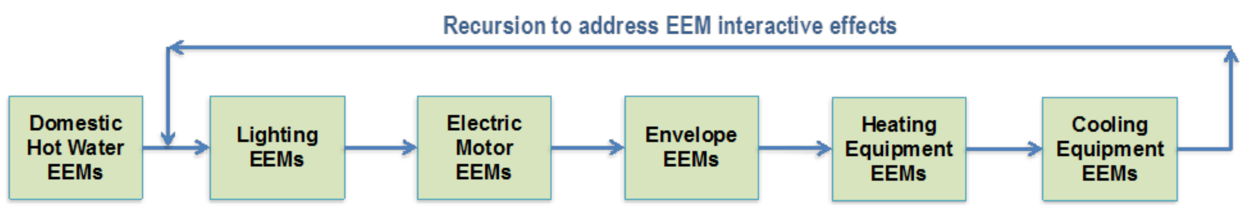


Figure 5.2. Energy efficiency measure ranks.

After the initial LCC analysis, a second group of EEMs is generated using a separate method. These are EEMs with limited interactive effects and simple yes/no user inputs. Examples or retrofits that will be addressed using this secondary methodology are:

- variable frequency drives
- economizers
- heat recovery

- individual high efficiency HVAC components.

Based on a user's indication as to whether their building has a particular piece of equipment, and based on a building's specific systems, a group of appropriate measures is selected for application to the model. This set of measures is combined with those identified in the initial LCC and then applied to the current building model to create a potential building model. The potential building model includes all identified EEMs applied and is run though EnergyPlus. The predicted EUIs of the current and potential buildings are then compared to give the user an estimate of the energy that would be saved if all of the EEMs were implemented in their building.

The user receives a general description of all the recommended measures along with the total potential energy savings of the entire package. At this point, the estimated energy savings and any economic parameters (payback period, savings-to-investment ratio, etc.) for each potential EEM will not be available to the user. Due to the number of economic variables and the likelihood of the ones used by the tool not lining up with those of the user, it will be left to the user to perform the final assessment, either by following the "Next Steps Guidance" provided in the retrofit description or by engaging a third party specialist.

5.5 Building Assets

The energy asset score report provides a summary of building characteristics used in the energy asset model to generate the energy asset score and system evaluations. If a value has been inferred, the inferred input will be shown. This energy asset summary page can help users quickly check their input values and document their building information for future use. In the instance of a validated score, this summary can provide a detailed list of important building characteristics for building evaluators, financiers, and tenants.

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Appendix A

Building Type Classifications

Appendix A

Building Type Classifications

CBECS Building Types[a]	CBECS Subcategories from 2003 CBECS Questionnaire[b]	DOE Commercial Reference Buildings and Prototype Buildings [c]	Portfolio Manager[d]	COMNET
Education	Elementary or middle school	Primary School	K–12 School	K-12 School
	High school	Secondary School		
	College or university			College/ University
	Preschool or daycare			
	Adult education			
	Career or vocational training			
	Religious education			
Food Sales	Grocery store or food market	Supermarket	Supermarket	
	Gas station with a convenience store			
	Convenience store			
Food Service	Fast food	Quick Service Restaurant		Dining, Bar/Cocktail Lounge
	Restaurant or cafeteria	Full Service Restaurant		Dining, Cafeteria/Fast Food
				Dining, Family
Health Care (Inpatient)	Hospital	Hospital	Hospital (General Medical and Surgical)	Hospital
	Inpatient rehabilitation			
Health Care (Outpatient)	Medical office (with diagnostic medical equipment)	Outpatient Health Care	Medical Office	
	Clinic or other outpatient health care			Health Care Clinic
	Outpatient rehabilitation			
	Veterinarian			

CBECS Building Types[a]	CBECS Subcategories from 2003 CBECS Questionnaire[b]	DOE Commercial Reference Buildings and Prototype Buildings [c]	Portfolio Manager[d]	COMNET
Lodging	Motel or inn	Small Hotel	Hotel	Motel
	Hotel	Large Hotel		Hotel
	Dormitory, fraternity, or sorority			Dormitory
	Retirement home			
	Nursing home, assisted living, or other residential care			
	Convent or monastery			
	Shelter, orphanage, or children's home			
	Halfway house			
Mercantile (Retail Other Than Mall)	Retail store	Stand-alone Retail	Retail Store	Retail
	Beer, wine, or liquor store			
	Rental center			
	Dealership or showroom for vehicles or boats			
	Studio/gallery			
Mercantile (Enclosed and Strip Malls)	Enclosed mall	Strip Mall		
	Strip shopping center			
Office	Administrative or professional office	Large Office	Office	Office
	Government office	Medium Office		
	Mixed-use office	Small Office		
	Bank or other financial institution		Bank/Financial Institution	
	Medical office (no diagnostic medical equipment)			
	sales office			
	Contractor's office (e.g., construction, plumbing, HVAC)			
	Non-profit or social services			
	Research and development			
	City hall or city center		Town Hall	
	Religious office			
	Call center			

CBECS Building Types[a]	CBECS Subcategories from 2003 CBECS Questionnaire[b]	DOE Commercial Reference Buildings and Prototype Buildings [c]	Portfolio Manager[d]	COMNET
Public Assembly	Social or meeting (e.g., community center, lodge, meeting hall, convention center, senior center)			
	Recreation (e.g., gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports)			Gymnasium
	Entertainment or culture (e.g., museum, theater, cinema, sports arena, casino, night club)			Museum- General
				Performing Arts Theater
				Motion Picture Theater
	Library			Library
	Funeral home			Sports Arena
	Student activities center			Exercise Center
	Armory			
	Exhibition hall			
	Broadcasting studio			
	Transportation terminal			Transportation
Public Order and Safety	Police station			Police/Fire Station
	Fire station			
	Jail, reformatory, or penitentiary			Penitentiary
	Courthouse or probation office		Courthouse	Court House
Religious Worship	No subcategories collected.		House of Worship	Religious Building
Service	Vehicle service or vehicle repair shop			Auto Repair
	Vehicle storage/ maintenance (car barn)			
	Repair shop			Workshop
	Dry cleaner or laundromat			
	Post office or postal center			Post Office
	Car wash			
	Gas station			
	Photo processing shop			
	beauty parlor or barber shop			
	Tanning salon			
	Copy center or printing shop			
	Kennel			

CBECS Building Types[a]	CBECS Subcategories from 2003 CBECS Questionnaire[b]	DOE Commercial Reference Buildings and Prototype Buildings [c]	Portfolio Manager[d]	COMNET
Warehouse and Storage	Refrigerated warehouse	Warehouse	Warehouse (refrigerated and non-refrigerated)	Warehouse
	Non-refrigerated warehouse			
	Distribution or shipping center			
Other	Airplane hangar			
	Crematorium			
	Laboratory			
	Telephone switching			
	Agricultural with some retail space			
	Manufacturing or industrial with some retail space			Manufacturing Facility
	Data center or server farm		Data Center	
			Municipal Wastewater Treatment Plant	
		Midrise Apartment, High-rise Apartment	Residence Hall/Dormitory	Multi-Family
			Senior Care Facility	
				Parking Garage

(a) http://www.eia.gov/emeu/cbecs/building_types.html
(b) http://www.eia.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set1/2003pdf/a1.pdf
(c) http://www1.eere.energy.gov/buildings/commercial/ref_buildings.html. http://www.energycodes.gov/development/commercial/90.1_models
(d) http://www.energystar.gov/index.cfm?c=eligibility.bus_portfoliomanager_eligibility

Appendix B

Energy Asset Score Tables