U.S. DEPARTMENT OF ENERGY

PNNL-22045

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Commercial Building Energy Asset Score

Program Overview and Technical Protocol (Version 1.0)

N Wang
WJ Gorrissen

December 2012

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Richland, Washington 99352

Summary

The U.S. Department of Energy (DOE) is developing a voluntary national energy asset score that includes an energy asset scoring tool to help building owners evaluate their buildings with respect to the score. The goal of the energy asset score is to facilitate cost-effective investment in energy efficiency improvements of commercial buildings. The system will allow building owners and managers to compare their building infrastructure against peers and track building upgrade progress over time. The system can also help other building stakeholders (e.g., building operators, tenants, financiers, and appraisers) understand the relative efficiency of different buildings in a way that is independent from their operations and occupancy.

DOE's long-term goal is to ensure that there is a linked set of compatible metrics and scoring approaches that building stakeholders can seamlessly use to effectively evaluate a building's as-built and in-operation efficiencies. DOE envisions these linked scores describing various aspects of building energy performance, such as the performance of building assets, performance of building operations, and how a building compares to its peers. Given this larger vision, the energy asset score is being designed to work in concert with tools such as ENERGY STAR Portfolio Manager. Where possible, the energy asset score incorporates methods that are consistent with ENERGY STAR Portfolio Manager.

Prior to beginning the energy asset score effort, DOE performed a market study to ensure that the energy asset score will help address market needs and fill identified gaps. In 2012, DOE began initial pilot testing of the energy asset score. As a result of that effort, improvements to the tool, training materials, and other aspects of the program have been made. In 2013, DOE will continue to assess the energy asset score through additional pilot testing as well as evaluations and analyses. Results from these efforts will be published in a separate document. In addition, this report will be updated periodically to reflect changes to the scoring methodology, the scoring tool, and other aspects of the program.

This report outlines the technical protocol used to generate the energy asset score, explains the scoring methodology, and provides additional details regarding the energy asset scoring tool. This report also describes alternative methods that were considered prior to developing the current approach. Finally, this report describes a few features of the program where alternative approaches are still under evaluation.

Energy Asset Score

The energy asset score enables building owners and managers to evaluate the as-built physical characteristics of buildings and overall building energy efficiency, independent of occupancy and operational choices. The physical characteristics evaluated include the building envelope, the mechanical and electrical systems, and other major energy-using equipment, such as commercial refrigeration. The energy asset score is generated by simulating building performance under typical operating and occupancy conditions. By focusing only on buildings' physical characteristics and removing occupancy and operational variations, the system allows "apples-to-apples" comparisons between differently operated buildings (see Table S.1).

Table S.1. Scope of asset score.

Included in Asset Score	Does NOT Affect Asset Score
General	
Building geometry and orientation	Building surroundings (such as shading from trees or other buildings)
Window layout, window-to-wall ratio	
External shading devices (overhangs, vertical fins)	Internal shading devices such as curtains, blinds
Thermal performance of building envelope (walls, windows, roof, and floor)	
Main heating, ventilating, and air-conditioning (HVAC) systems (types and efficiencies)	Back-up systems, efficiency degradation related to age and maintenance, system oversize
Service hot water system (type and efficiency)	
General lighting (types and numbers)	
Percentage of lighting controlled by sensors (occupancy sensors and daylighting controllers)	Settings of sensors and controls
Specific (example only)	
Refrigeration in grocery stores (types, number efficiencies)	Refrigerators in office buildings, schools, etc.
Refrigeration and ventilation in restaurants (types, number, efficiencies)	Kitchen appliances (except commercial refrigeration)
Computer servers in data centers (IT equipment power)	Small server closet in office buildings, schools, etc.
Operating Assumptions	
Typical operating hours for each building type	Actual operating hours
Standard indoor temperature settings	Actual indoor temperature settings
Typical occupancy density for each building type	Actual number of occupants in the building
Typical plug-loads for each building type	Actual plug-loads in

The energy asset score uses modeled source energy use intensity (EUI) as the primary metric to generate the energy asset score, for the following reasons:

- A source energy metric reduces the likelihood that one energy fuel type will be unintentionally penalized or favored over another.
- Source energy more accurately gauges the global impact of energy consumption, taking into account the impact of the energy supply chain rather than only looking at what occurs at the building level.
- Source energy is more closely correlated with energy cost, and so is more likely to drive investment decisions.
- A source energy metric is aligned with the ENERGY STAR Portfolio Manager.

As complementary information, site energy is also calculated and shown as part of the energy asset score report.

The modeled source EUI is used to generate a building's energy asset score. Each building type has an associated 100-point technical scale (not a statistical scale). The calculated EUI is placed on a fixed scale for each building type and no baseline building is needed for the score calculation. The energy asset scoring scale is intended to reflect the current variability within the commercial building stock and allow for improved energy efficiency of both inefficient and high-performance buildings. The scale development and scoring methodology are discussed in detail in this protocol report.

Energy Asset Scoring Tool

The energy asset scoring tool is a web-based modeling tool. The tool is built on a centralized modeling engine to reduce the implementation cost for the users and increase standardization compared with an approach that requires users to build their own energy models. A centralized modeling approach lessens the user's ability to tailor a model to a unique design feature because the levels of the input details are limited to accommodate the common building types and characteristics. With this tool, users can enter building information online to obtain a standard energy asset score report, and to identify energy efficiency opportunities.

The tool integrates a simplified data collection method with full-scale energy modeling through an inference engine, which estimates building parameters not entered by users. Given this approach, the tool reduces the time and expertise required to model a building accurately while supporting variable and complex commercial buildings.

While the tool is a cost-effective way for building owners, managers, and operators to gain insight into the energy efficiency potential of their buildings, it is not intended to replace a more comprehensive energy audit of a building. Rather, it is meant to provide preliminary analysis, directing further effort and investment to where it can be most effectively applied. The protocol documented in this report describes the energy modeling and tool development methodologies.

The energy asset scoring tool provides two levels of use: simple and advanced. The data requirements for each level are outlined in this protocol.

- The *simple* level yields a preliminary score, identifies opportunities for building improvements, and estimates the savings from the combined set of improvements. The preliminary score of building efficiency is based on a minimum set of required building data plus any other applicable details known by the users. For the non-required inputs, users can rely on inferred values generated by the energy asset scoring tool to minimize the data collection requirements.
- The *advanced* score is 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.

Energy Asset Score Report

The energy asset scoring tool produces a standard energy asset score report that includes four sections:

- Energy asset score. The report provides a building's current score and potential score after all recommended upgrades are made.

- Building system evaluations. The system evaluations separately characterize the building's envelope (e.g., windows, walls, roof); lighting system; heating and cooling systems; and service hot water system. This information can help users identify the part of the building most in need of attention. For two buildings with the same energy asset score, the system evaluation helps identify the unique problems and potentials of the two buildings.
- A list of upgrade opportunities. The report identifies upgrade opportunities based on the analysis outlined in section 5.4 of this report.
- Building assets. The report provides a detailed list of building characteristics that contribute to a building's energy asset score.

A sample report is included in this protocol. The contents of each section can also be found in this protocol.

Implementation Phases

The energy asset score is being rolled out in three phases, based on building category:

- Phase I includes buildings in the office, educational, retail, and unrefrigerated warehouse categories. Phase I building types have been implemented in the initial rollout of the energy asset score and tool, which is currently under pilot testing.
- Phase II includes libraries, lodging, multi-family housing, public safety, and religious worship, as well as mixed-use buildings that incorporate Phases I and II use types.
- Phase III buildings are either those with more complex systems or those for which there is currently a limited body of information, such as food sales, food service, data centers, laboratories, refrigerated warehouses, health-care facilities.

This protocol document focuses on the Phase I building types, with limited discussion of the other building types. Some discussions about the scoring and modeling methodologies may not apply to other building types.

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The authors would like to thank to Cody Taylor, Joan Glickman, Subid Wagley, and Benjamin Goldstein at the U.S. Department of Energy for their support and guidance throughout this effort.

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Acronyms and Abbreviations

ANSI	American National Standards Institute
API	application programming interface
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
bEQ	Building Energy Quotient
BPIE	Buildings Performance Institute Europe
CBECS	Commercial Buildings Energy Consumption Survey
COMNET	Commercial Energy Services Network
COP	coefficient of performance
DEC	Display Energy Certificate
DOE	U.S. Department of Energy
EEM	energy efficiency measure
EER	energy efficiency ratio
EPA	U.S. Environmental Protection Agency
EPC	Energy Performance Certificate
EUI	energy use intensity
FEDS	Facility Energy Decision System
FFC	full fuel cycle
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
HVAC	heating, ventilating, and air conditioning
IECC	International Energy Conservation Code
IESNA	Illuminating Engineering Society of North America
kBtu	thousand British thermal units
LCC	life-cycle cost
LEED	Leadership in Energy and Environmental Design
PNNL	Pacific Northwest National Laboratory
SBEM	Simplified Building Energy Model
TDV	time-dependent valuation
TOU	time-of-use
UK	United Kingdom

Glossary

asset score – An assessment of building energy performance based solely on a building's physical characteristics, excluding the effects of building operation characteristics.

asset score report – A short form document showing only key outcomes for a building that has undergone the energy asset scoring process.

baseline energy performance – The amount of energy consumed annually before implementation of energy efficiency measures, based on historical metered data, engineering calculations, submetering of buildings, or energy-consuming systems, building load simulation models, statistical regression analysis, or a combination of these methods.

benchmark – The building profile used as a reference point for comparing energy use and other performance characteristics.

building type – Building classification identifying the principal function of the building.

Display Energy Certificate (DEC) – A certificate that is required to be posted for larger public buildings in the United Kingdom. The DEC reflects the energy usage of a building and should be prominently displayed for the public at all times. The DEC is accompanied by an advisory report that lists cost-effective measures to improve the energy rating of the building.

energy cost – Monetary cost associated with energy consumption at a building site.

energy modeling or simulation – The practice of using computer-based programs to model the energy performance of an entire building or the systems within a building.

Energy Performance Certificate (EPC) – A certificate used in the United Kingdom that provides energy efficiency scores on a scale from A to G along with recommendations for improvement. The scores—similar to those found on consumer products such as refrigerators—are standardized so the energy efficiency of one building can easily be compared with another building of a similar type. EPCs are required on all property sales and leases in the U.K.

ENERGY STAR Portfolio Manager – A web-based, portfolio-wide energy and water tracking system that tracks many metrics of energy use, including total site energy, source energy, weather normalized energy use index, greenhouse gas emissions, indoor and outdoor water usage, and (for some building types) the ENERGY STAR score.

ENERGY STAR energy performance scale – A percentile score (1–100) that indicates how a building performs relative to similar buildings nationwide. The scores are adjusted using standardized methods to account for differences in building attributes, operating characteristics, and weather variables. Buildings performing better than 75% of similar buildings can be certified to ENERGY STAR.

energy efficiency measure (EEM) – Any capital investment that reduces energy costs in an amount sufficient to recover the total cost of purchasing and installing such measure over an appropriate period of time and maintains or reduces non-renewable energy consumption.[1]

energy use intensity (EUI) – A unit of measurement that describes a building's energy use relative to its size. EUI is calculated by dividing the total energy consumed in 1 year (measured in kBtu) by the total floor area of the building (measured in square feet).

interval scale – A scale for which each location along its span relates directly to some metric or measurement.

inference engine – A computer program used in the energy asset scoring tool to estimate building parameters (such as system efficiency) based on the information provided by users (such as system type and age) and provide the inferred values for energy simulation.

metric – A measure of a building's performance.

net onsite energy use – The sum of all energies that are consumed in a building minus any energy that is generated on site.

operational rating – An assessment of building performance that is developed to reflect the energy performance of a building, accounting for its physical assets and its specific operational characteristics.

percentile rank scale – A percentile scale that is defined solely in relation to a sample population; the scale itself contains no information in absence of information regarding the specific sample population. The primary purpose of a percentile rank scale is comparison between peer buildings.

preliminary score – An energy asset score shown on the preliminary energy asset score report, which is automatically generated by the energy asset scoring tool for a simple level user who is not generating a score for official purposes.

site energy use – The amount of energy consumed at a building location or other end-use site, as reflected in the utility bills. Site energy use includes total building energy consumption minus electricity generated by onsite renewable energy systems as well as cogeneration systems.

stakeholder – A building owner, operator, manager, or agency who can supply data on the building physical details and energy consumption or has some authority or influence on decisions made about the building.

source energy use – The total energy used at a site, including upstream losses in distribution, storage, and dispensing of primary fuels, or power generation, transmission, and distribution of electricity.

weather adjustment – The practice of removing the impact of weather variables from building energy simulation results or utility bills to facilitate comparison between different regions or time periods.

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[1] Source: 10 CFR 420.2 [Title 10 – Energy; Chapter II – Department of Energy; Subchapter D – Energy Conservation; Part 420 – State Energy Program; Subpart A – General Provisions for State Energy Program Financial Assistance]

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1.0 Introduction

The U.S. Department of Energy (DOE) is developing a national commercial building energy asset score and an energy asset scoring tool to evaluate the physical characteristics and as-built energy efficiency of commercial buildings and to identify potential energy efficiency improvements. The goal of the energy asset score and tool is to facilitate cost-effective investment in energy efficiency and reduce energy use in the commercial building sector. The energy asset score allows building owners to compare their buildings with those of their peers and track building upgrade progress over time. The energy asset score also enables other building stakeholders (e.g., building operators, tenants, financiers, and appraisers) to understand the relative efficiency of different buildings in a way that is independent from their operations and occupancy.

The energy asset score is intended to complement the U.S. Environmental Protection Agency (EPA) ENERGY STAR Portfolio Manager and other existing building rating and benchmarking tools in the market. The score also supports other DOE initiatives, such as the DOE Better Building Challenge (in which partners commit to an energy savings pledge, assess improvement opportunities across their portfolio, undertake a showcase building retrofit, and share their progress) and DOE's partnership with the Appraisal Foundation (aimed at enabling investors, building owners and operators, and others to accurately assess the value of energy efficiency as part of the overall building appraisal).

In support of DOE's effort to design a voluntary energy asset score that effectively addresses the needs of the commercial building market, Pacific Northwest National Laboratory (PNNL) building scientists undertook a series of tasks. A market research study was conducted from April 2011 through January 2012 to better understand the market demand for energy asset scoring and to find the best way to communicate energy and cost savings to owners, investors, financiers, and others to overcome market barriers and motivate capital investment in building energy efficiency (McCabe and Wang 2012). Webinars, focus groups, a request for information (DOE EERE 2011a), and a stakeholder workshop, among other forums, were used to gain input from outside organizations and others. Existing building energy rating systems, such as the ENERGY STAR Portfolio Manager, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Building Energy Quotient, and the European Energy Performance of Building Directive, were systemically examined to identify the strengths and gaps in the existing tools.

This report documents the protocol followed to develop the energy asset score and the energy asset scoring tool. It also outlines the rationale for the current system. Topics addressed include the following:

- target audiences and buildings for an energy asset scoring tool
- key metrics to evaluate building as-built efficiencies
- data input requirements to obtain an energy asset score
- energy asset scoring methodology
- energy asset scoring tool methodology
- quality assurance techniques
- sample energy asset score report.

This protocol document is organized as follows:

- Section 2 describes the DOE energy asset score in the context of current rating systems and identifies how the system intends to close gaps among those systems.
- Section 3 details the scoring methods (metrics and scales) considered and ultimately selected for the energy asset score.
- Section 4 describes the energy asset scoring tool—the centralized modeling tool developed to facilitate application of the energy asset score.
- Section 5 explains the components of the energy asset score report.
- Appendices A through E provide additional details on building type classifications, the energy asset score tables for Phase I building types, a list of building data input of the energy asset scoring tool, and a sample energy asset score report.

2.0 Energy Asset Score

To date, in the U.S., the dominant way to rate building energy performance has been based on an evaluation of utility bills. Benchmarking tools like ENERGY STAR Portfolio Manager have helped building owners and operators see how their energy usage compares to similar buildings. An energy asset score is a different type of information that building owners, operators, lessees, and buyers can use to further understand the energy performance of a building.

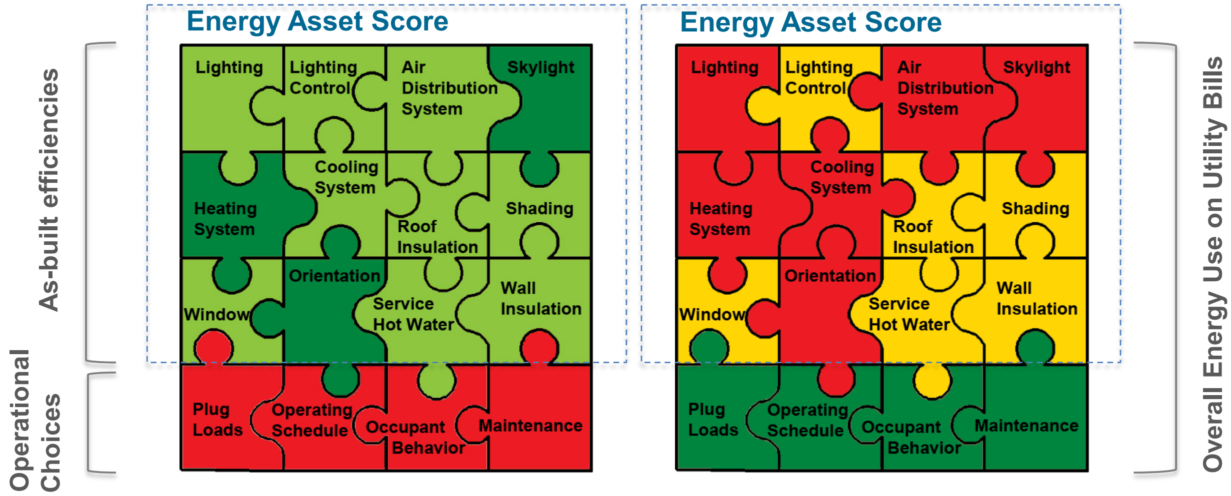
An energy asset score can help commercial building stakeholders decipher the extent to which their usage is being driven by operational choices or by the actual energy systems of a building. By applying consistent operational assumptions, an energy asset score allows evaluation of the physical “as-built” energy systems of a building. As shown in Figure 2.1, two buildings may have the same measured energy consumption but different potential energy consumption based on building design and installed equipment. Energy asset scores of these two buildings can reveal differences in the state of the physical assets (e.g., functioning well or in need of upgrade) that are masked when simply comparing measured energy consumption.

Information provided by the energy asset score can assist building owners and investors in making decisions about efficiency improvements. A primary goal of the score is to encourage improvement of energy-related building characteristics, which include the building envelope; heating, ventilation, and air conditioning (HVAC) systems; lighting systems; and other major building service-related equipment, such as commercial refrigeration. An energy asset score can also inform prospective buyers and tenants who may want to compare among existing, new, and renovated buildings.

Recent regional energy asset rating initiatives, such as California Assembly Bill No. 758[1] and the Massachusetts Commercial Asset Labeling Program (Mass DOER 2010),[2] indicate growing interest in energy asset scoring. More discussion about market drivers and opportunities can be found in the market research report (McCabe and Wang 2012).

[1] “This bill requires the Energy Commission, By March 1, 2010, to establish a regulatory proceeding to develop and implement a comprehensive program to achieve greater energy savings in California’s existing residential and nonresidential building stock.” “The comprehensive program may include, but need not be limited to, a broad range of energy assessments, building benchmarking, energy rating, cost-effective energy efficiency improvements, public and private sector energy efficiency financing options, public outreach and education efforts, and green workforce training” (California Assembly Bill No. 758, Chapter 470).

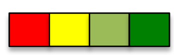
[2] In 2008, the Commonwealth of Massachusetts convened a Zero Net Energy Building Task Force to evaluate how best to achieve net-zero energy construction in both the commercial and residential sectors. Subsequently, Massachusetts was chosen by the National Governors Association Center for Best Practices to participate in its Policy Academy for Building Energy Retrofits. Through these processes, the commonwealth began identifying and addressing the barriers to a commercial building asset labeling program. In December 2010, the Massachusetts Department of Energy Resources (Mass DOER) released *An MPG Rating for Commercial Buildings: Establishing a Building Asset Rating Program in Massachusetts*, outlining a framework and proposed pilot to implement a commercial building asset labeling program as the first step toward a mandatory requirement (Mass DOER 2010).



Building A
High Efficiency Systems
Poor Operation
Poor Maintenance
High plug loads from occupants

Building B
Low Efficiency Systems
Good Operation
Good Maintenance
Normal plug loads from occupants

Low Efficiency
Or More Energy Use



High Efficiency
or Less Energy Use

	Building A	Building B
Lighting	T8 fluorescents	T12 fluorescents
Lighting Control	Occupancy sensors	Timers
Air Distribution System	80% efficient fan	60% efficient fan
Skylight	North-facing sawtooth skylight	No skylight
Heating System	Heat pump system	55% efficient boiler
Cooling System	Rooftop unit energy efficiency ratio (EER) = 9	Rooftop unit EER = 7
Roof Insulation	R20	R15
Shading	Horizontal shading devices for south-facing windows	No shading devices
Window	Double-pane low-e windows	Double-pane windows
Orientation	Facing south/north	Facing east/west
Service Hot Water	80% efficient hot water heater	75% efficient hot water heater
Wall Insulation	R20	R10
Plug Loads	5 W/ft^2	2 W/ft^2
Operating Schedule	70 hours per week	30 hours per week
Occupant Behavior	Occupants override lighting controls.	Occupants turn lights off when not in the room.
Maintenance	No regular maintenance and commissioning	Regular equipment maintenance and commissioning performed

Figure 2.1. Interaction between as-built efficiency and operation choices.

2.1 Scope of the Energy Asset Score

The energy asset score is based on an evaluation of a building's as-built physical characteristics and its overall energy efficiency, independent of occupancy and operational choices. The physical characteristics include the building envelope, the mechanical and electrical systems, and other major energy-using equipment (e.g., commercial refrigeration). Miscellaneous loads (e.g., office equipment and appliances) vary with building occupancy and are therefore standardized by building type in the energy asset score.

The energy asset score also includes installed controls, such as daylighting controls, occupancy sensors, and centralized building energy management systems. However, the specific control schemes/schedules based on building operational choices are modeled. To calculate the associated energy savings from these control systems, assumptions are made based on the average savings. For example, ASHRAE 90.1-2007 Appendix G (Table G3.2) allows by default a 10% reduction in lighting power density for areas that incorporate occupancy sensor control of lighting. Table 2.1 lists the building characteristics that are included in the scope of the energy asset score.

Table 2.1. Scope of asset score.

Included in Asset Score	Does NOT Impact Asset Score
General	
Building geometry and orientation	Building surroundings (such as shading from trees or other buildings)
Window layout, window-to-wall ratio	
External shading devices (overhangs, vertical fins)	Internal shading devices such as curtains, blinds
Thermal performance of building envelope (walls, windows, roof, and floor)	
Main HVAC systems (types and efficiencies)	Back-up systems, efficiency degradation related to age and maintenance, system oversize
Service hot water system (type and efficiency)	
General lighting (types and numbers)	
Percentage of lighting controlled by sensors (occupancy sensors and daylighting controllers)	Settings of sensors and controls
Specific (example only)	
Refrigeration in grocery stores (types, number efficiencies)	Refrigerators in office buildings, schools, etc.
Refrigeration and ventilation in restaurants (types, number, efficiencies)	Kitchen appliances (except commercial refrigeration)
Computer servers in data centers (IT equipment power)	Small server closet in office buildings, schools, etc.
Operating Assumptions	
Typical operating hours for each building type	Actual operating hours
Standard indoor temperature settings	Actual indoor temperature settings
Typical occupancy density for each building type	Actual number of occupants in the building
Typical plug-loads for each building type	Actual plug-loads in

All buildings are scored using the same method. (The scoring method and scale development are discussed in Section 2.) Scoring scales will vary among building types. Weather differences across climate zones are accounted for. Both a current score and an estimated potential score after upgrades are calculated. The energy asset score not only provides an overall building efficiency evaluation, but also gives building stakeholders insight into separate building systems (envelope, electrical and mechanical systems, etc.). Two buildings may have the same utility consumption and energy asset score, but different combinations of system efficiency and therefore different potentials.

As shown in Figure 2.2, Building C has a good HVAC system but a poor lighting system, making it a great candidate for low-cost lighting upgrades. Building D has low-efficiency cooling equipment and poor wall insulation. Because insulation usually costs more to upgrade, Building D's estimated cost-effective potential score may be lower than Building C's. Therefore, building system evaluations provide important information for building owners, manager, tenants, and investors when they buy, lease, or retrofit a building.

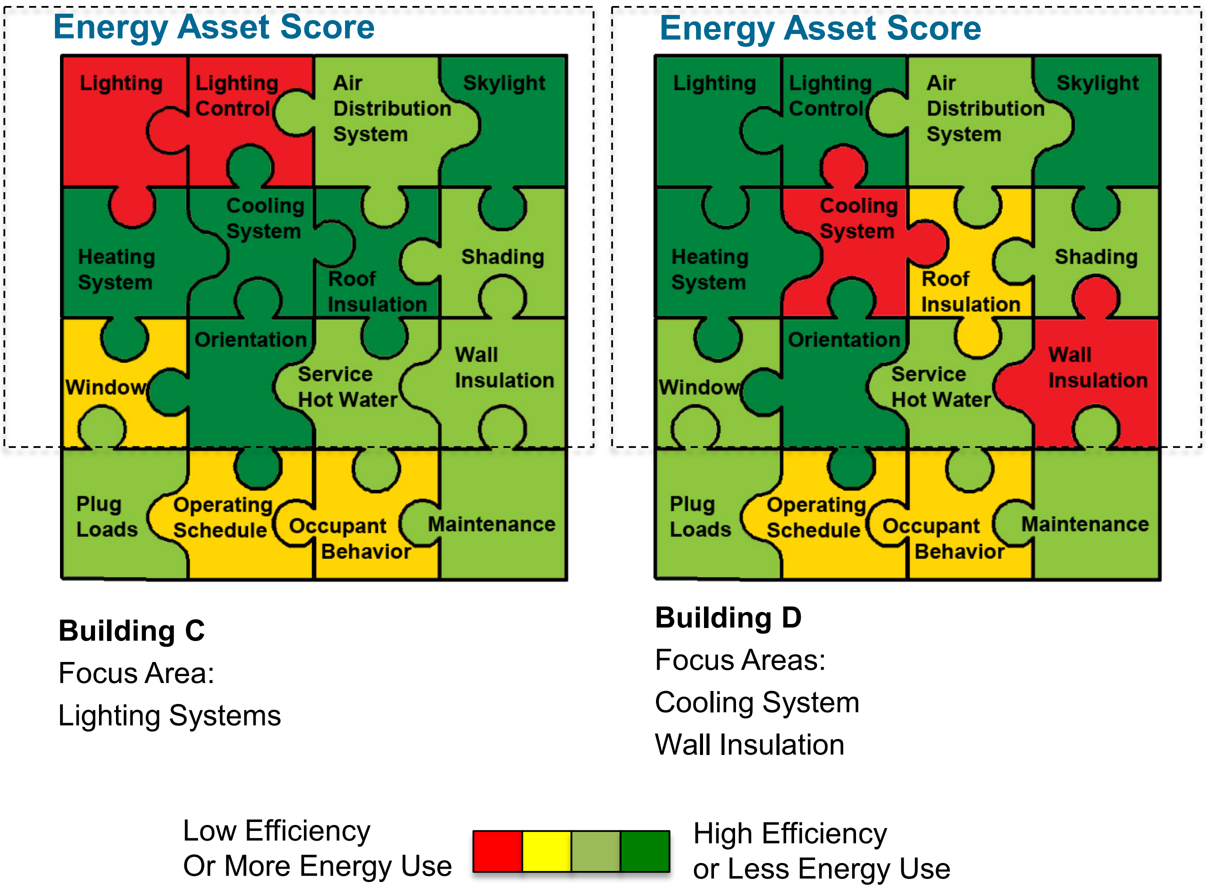


Figure 2.2. System evaluations.

DOE has designed the building energy asset score such that it can be applied broadly to both new and existing commercial buildings and provide affordable and reliable information on building energy efficiency to building stakeholders. DOE intends for the energy asset score to work with and complement the ENERGY STAR Portfolio Manager, once the energy asset score is sufficiently demonstrated. Portfolio Manager compares an existing building to its peers by analyzing the building's energy bills and operational characteristics.

In any given building, several factors influence energy use and the outcomes measured by the energy bill; the energy asset score will help segregate factors related to the building's physical infrastructure. This can enable building stakeholders to better determine whether higher-than-expected energy use is due to inefficient physical infrastructure and specific building systems or to the occupancy, operations, or other factors.

Integrating the energy asset score (which separates out savings related to building infrastructure) with Portfolio Manager (which combines operations and infrastructure energy performance) provides a feedback loop for building owners and operators. This integration would help building owners ensure that buildings are performing as intended and meeting their potential. An integrated building rating system would also help building operators track the results of energy efficiency measures (EEMs) and identify potential operation and maintenance problems.

In the example in Figure 2.1, Building A has good energy assets and its overall performance may be decent, potentially making it a great candidate for low-cost operational improvements. Building B has poor energy assets, although its overall performance may be decent. Building B's obsolete equipment may be more likely to fail, requiring substantial near-term capital investment to replace. Information like this would enable building owners to allocate limited resources more efficiently and, in doing so, improve overall building stock efficacy over time.

Both the DOE energy asset score and the ENERGY STAR Portfolio Manager are expected to evolve, providing opportunities for more integration. The two systems together would comprise a national building score that effectively combines the as-built building efficiency with a gauge of operational success. DOE currently is focused on designing the energy asset score to rate as-built efficiency.

One barrier to energy efficiency investments is the difficulty of obtaining reliable information on building system efficiencies and the related challenge of finding cost-effective ways to improve energy efficiency. Through the energy asset score, DOE is addressing this barrier by developing a common approach for assessing the as-built energy efficiency of commercial buildings and developing an easy-to-use tool to help building owners and stakeholders identify improvement opportunities. Accordingly, the energy asset score has three components:

- The energy asset score, which quantifies building as-built energy efficiency and conveys this information by prescribing operating conditions under which building performance is expected. This gives building owners and operators insight into their building envelope and mechanical and electrical systems.
- The energy asset scoring tool, which includes a web-based application to maintain building data entered by building owners, managers, or operators and to analyze building energy use, accounting for envelope, mechanical and electrical systems, and other major energy-using equipment. This tool predicts the energy performance of a building and enables building owners, managers, and operators to benchmark their building efficiency and identify energy efficiency improvement opportunities.
- The energy asset score report, which is generated by the energy asset scoring tool and provides evaluation results and the potential energy efficiency improvements and their associated savings.

DOE intends to support continuous improvement of energy efficiency by allowing buildings to be re-rated following a retrofit.

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.

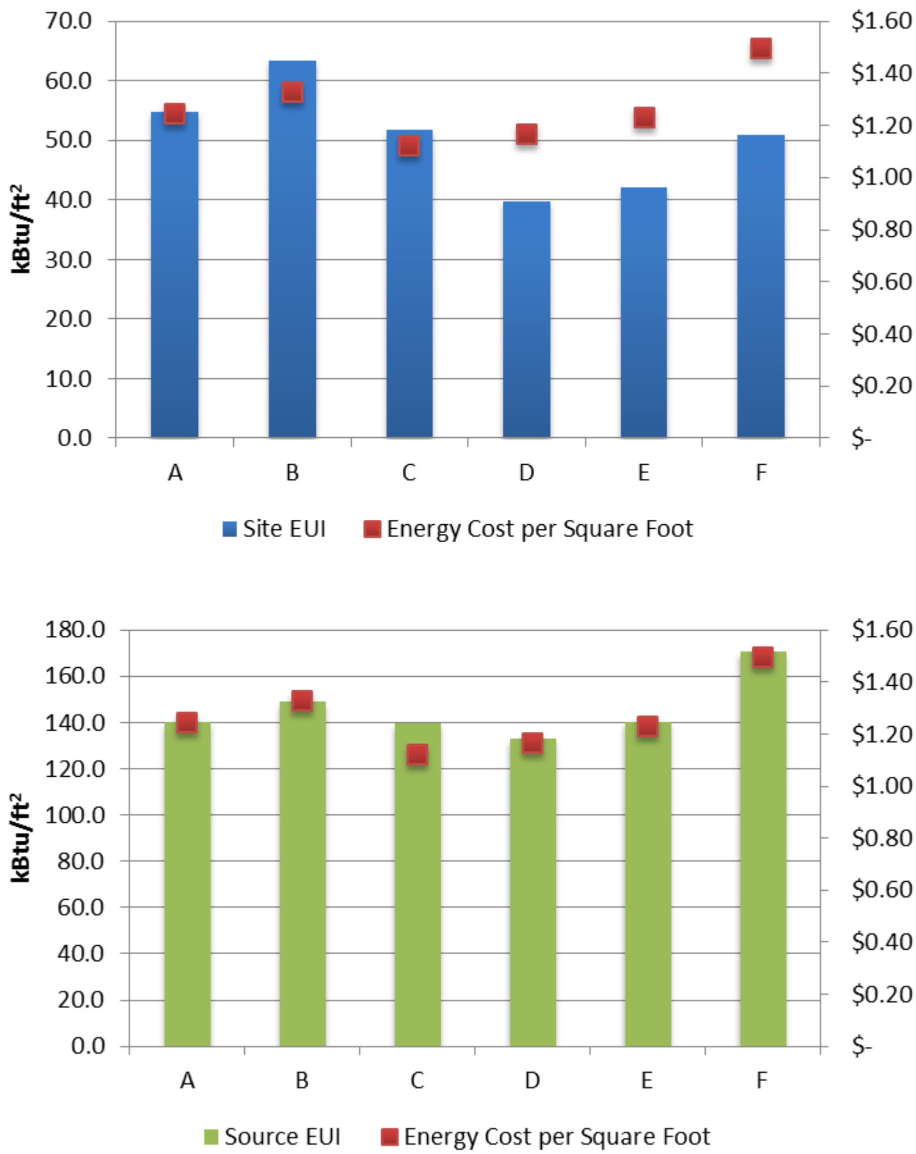


Figure 3.1. Comparison of site EUI and source EUI.

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.

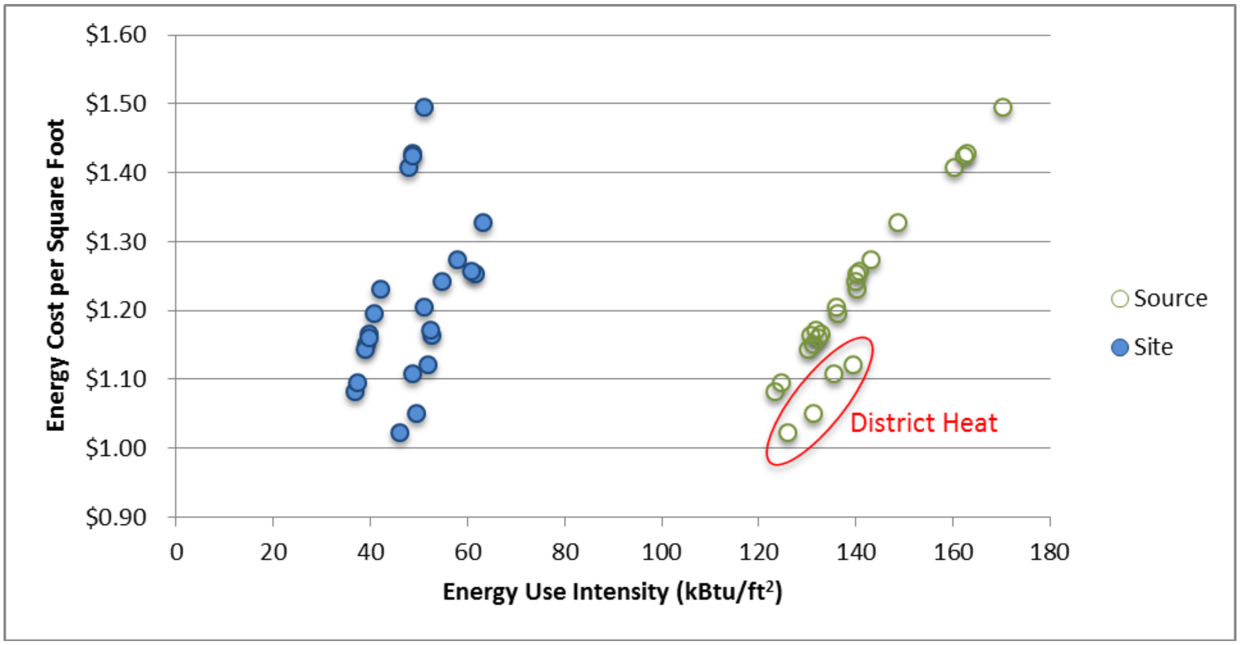


Figure 3.2. Site EUI and source against energy cost.

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.

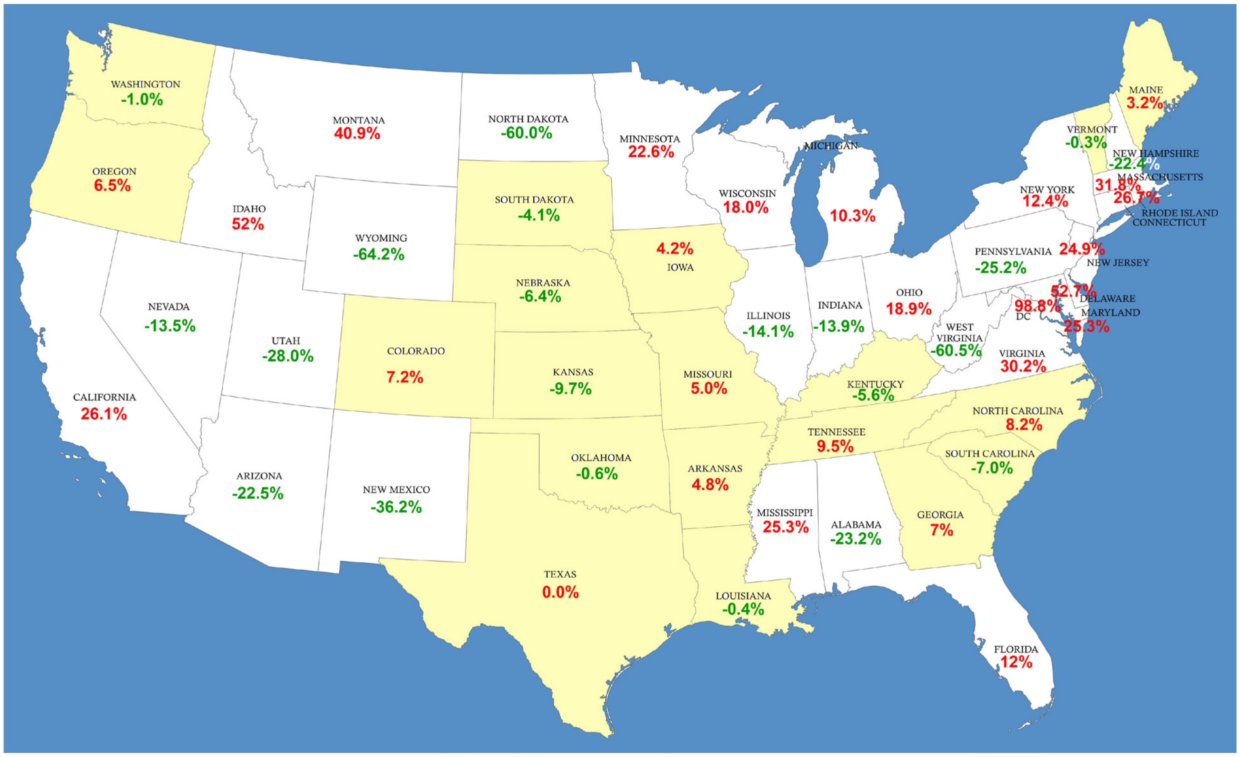


Figure 3.3. State-level energy imports (positive value = import, negative value = export) (EPA 2002, Table B-7; Deru and Torcellini 2007).

- 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.

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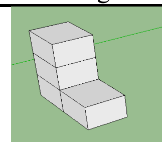
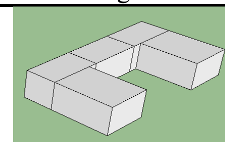
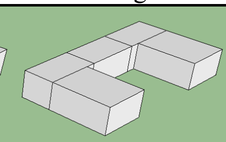
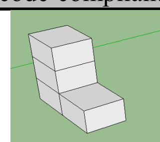
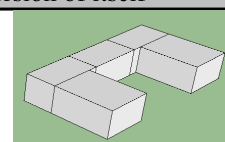
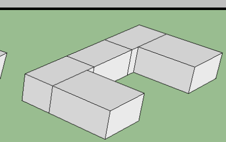
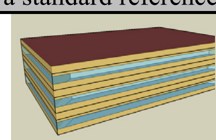
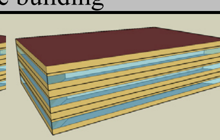
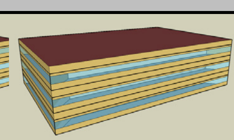
[1] ANSI is American National Standards Institute; IESNA is the Illuminating Engineering Society of North America. For simplicity, ANSI/ASHRAE/IESNA Standard 90.1 is referred to in this document simply as ASHRAE Standard 90.1.

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.

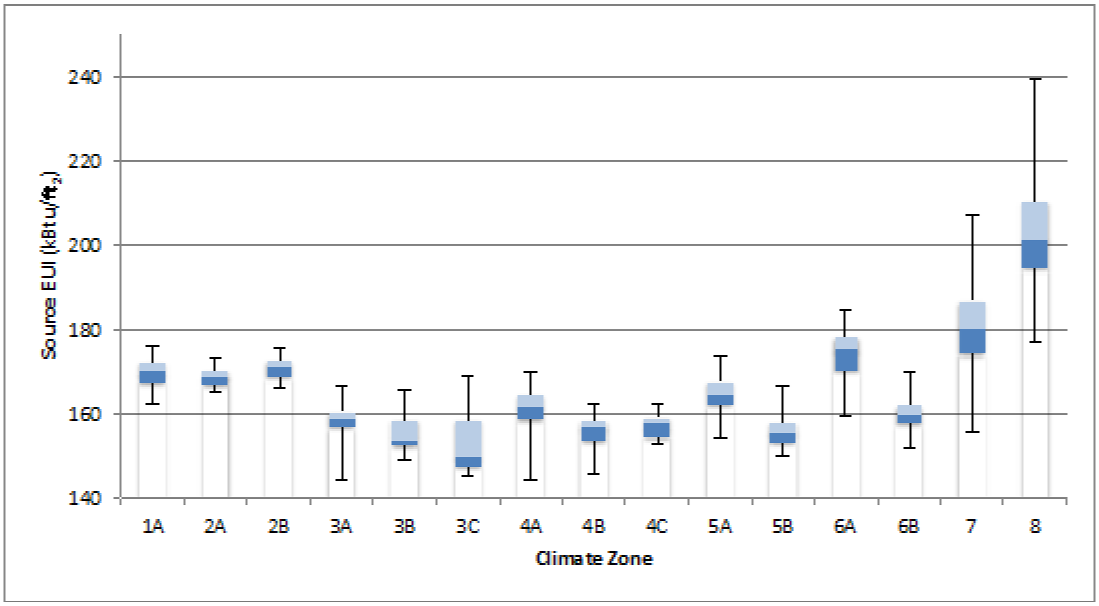


Figure 3.4. Modeled overall building energy use using TMY3 weather files (DOE Commercial Reference Building, Medium Office, New Construction, compliant with ASHRAE Standard 90.1-2004).

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.

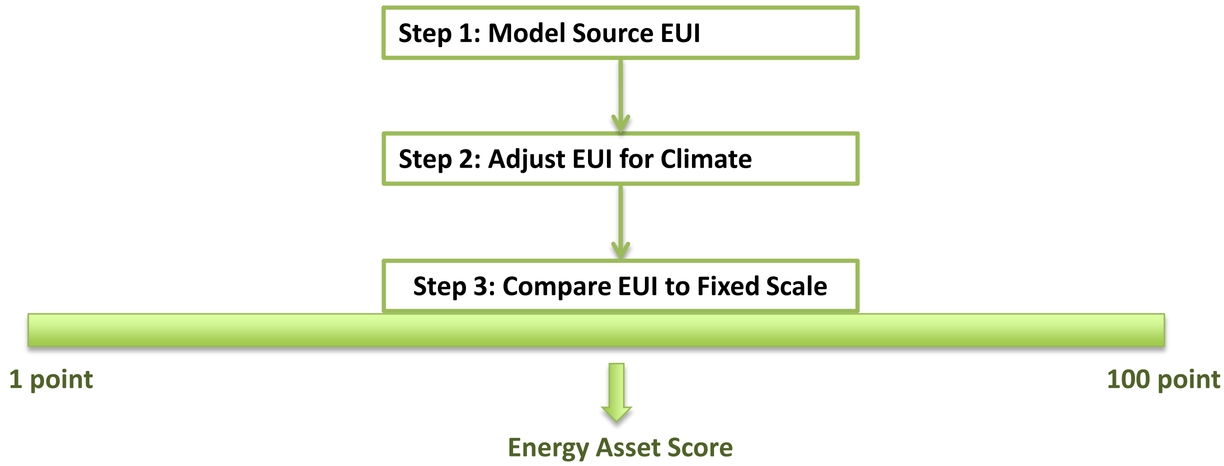


Figure 3.5. Energy asset scoring scale development.

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.

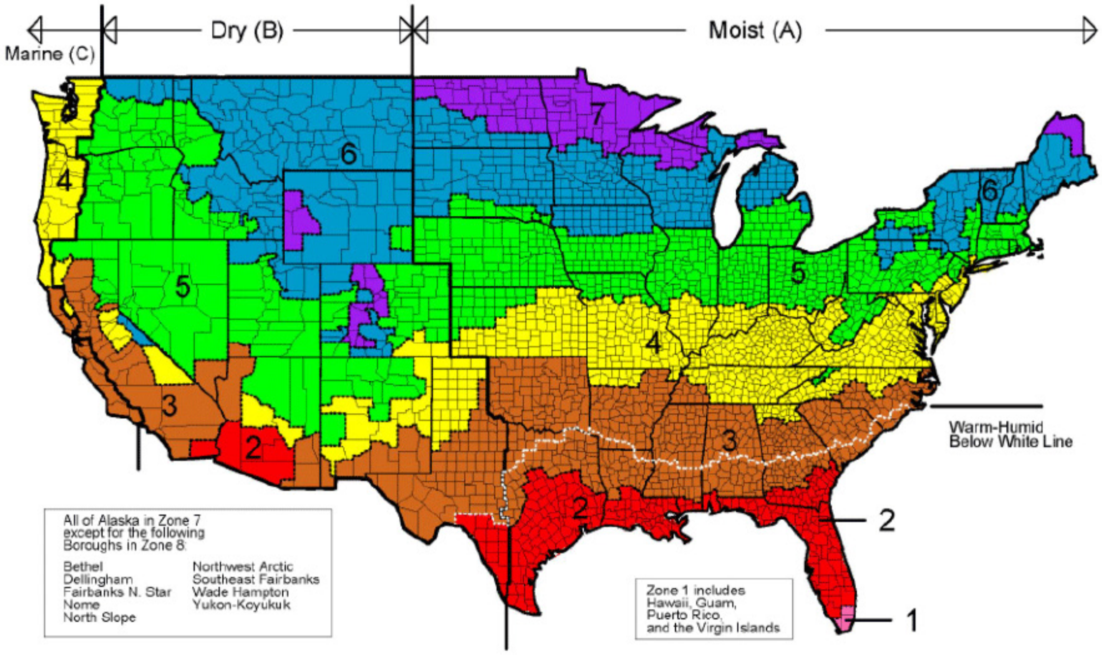


Figure 3.6. Climate zone classification (NREL 2011, p. 7).

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.

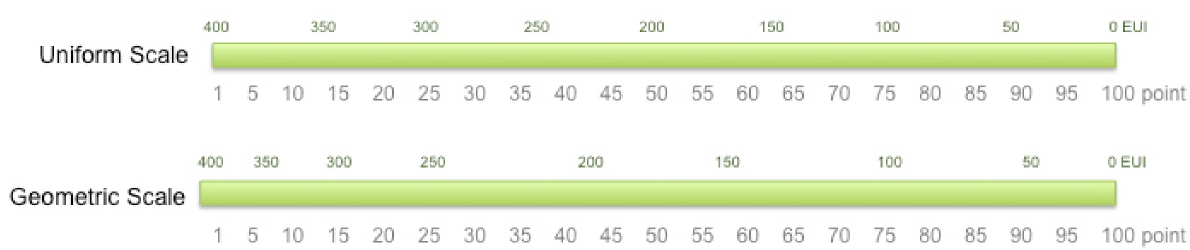


Figure 3.7. Uniform scale and geometric scale.

Data from the 2003 CBECS (EIA 2006) were used as a starting point to understand building stock and to establish the energy asset scoring scale for different building types. The CBECS is a national survey that collects information on the stock of U.S. commercial buildings, their energy-related building characteristics, and their energy consumption and expenditures. The CBECS data provide only measured energy use, which is the outcome of a building's as-built efficiency and its actual operational choices. Under standard operational choices (to calculate energy asset score), the energy use of a building in the CBECS database could be higher or lower than its measured value. Given the large number of buildings in the entire dataset, the distribution of modeled energy use under standard operations was assumed to be similar to that of the measured results.

For the energy asset scoring scale, the CBECS 2003 data were used only once to define the low end of the scale for each building type. Once a scale (for each building type) was developed, it was not updated with a new set of CBECS data. CBECS data are available for all Phase I building types (Table 2.2). For building types without adequate CBECS data, other available databases or energy models will be used to establish the scales. DOE may similarly use CBECS data in the future to help redefine the 100-point value on the scales, given potential movement away equating a score of 100 to net zero energy.

Office buildings are used as an example to describe the method to used develop the energy asset scoring scale. The scoring scales for other Phase I building types are included in Appendix B. The scoring scale development method proceeded as follows:

1. Extract office data. Energy use data by fuel types for office buildings (total 976 buildings), where the principal building activity is "Office," were extracted from CBECS.
2. Calculate source EUI. Source energy use of each office building was calculated using the national site-to-source conversion factors (Table 3.4).
3. Remove data beyond two standard deviations away from the mean. A total of 957 buildings remained in the database; their source energy use is plotted on Figure 3.8. Based on a linear trend line of the remaining data, an EUI between 400 and 450 kBtu/ft^2 could effectively represent the low end of the scale (Scale A). Note that a high EUI value corresponds to a lower energy asset score. A linear trend line was used because a linear scale was chosen for asset score. The purpose of analyzing the CBECS data was not to develop an energy asset scoring scale to represent the database, but to ensure the scale can realistically reflect the energy efficiency levels of the majority of the commercial buildings. On Scale A, the long tail of the CBECS data on the high EUI end was cut off. If the tail were included (Scale B), the energy asset scoring scale would have been skewed to the low-efficiency end.

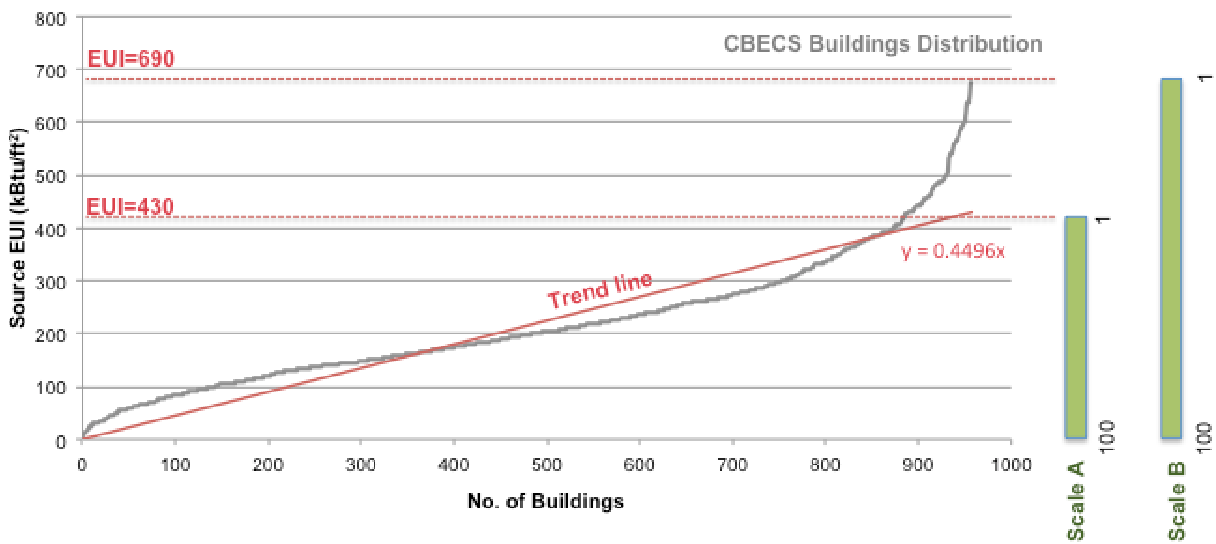
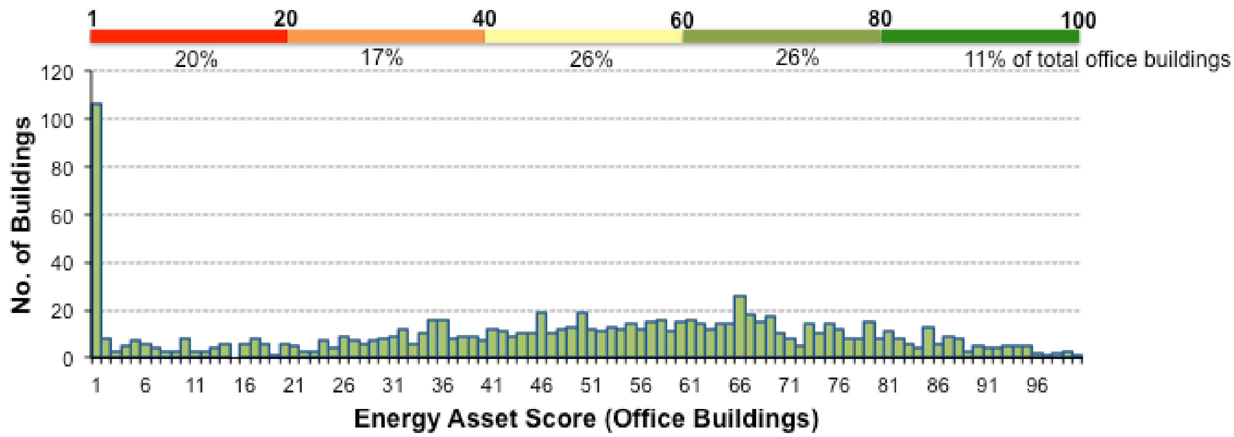
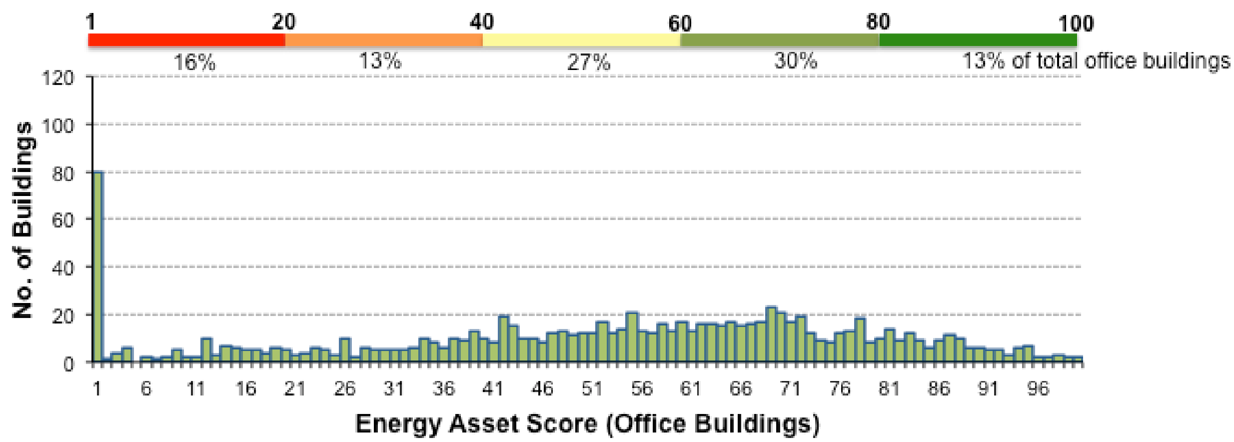


Figure 3.8. Office building scale development based on CBECS 2003 data.

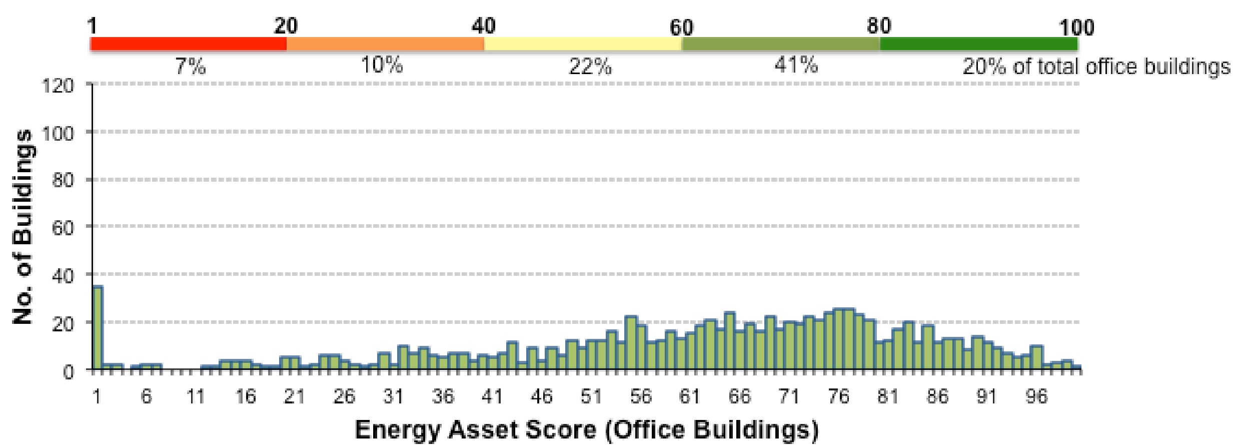
The CBECS office buildings were used to test the developed energy asset scoring scale. Figure 3.9 shows the evolution of the energy asset scores as buildings improve their energy usage over time. A 10% energy reduction for all buildings improves scores slightly. A 30% reduction causes a noticeable change in the population. A 50% energy reduction dramatically increases the overall building rating. Note that the highly efficient buildings still maintain their outstanding position because of the relatively stringent EUI reduction requirement to reach a score above 95.



(a) Original energy use data (976 buildings).

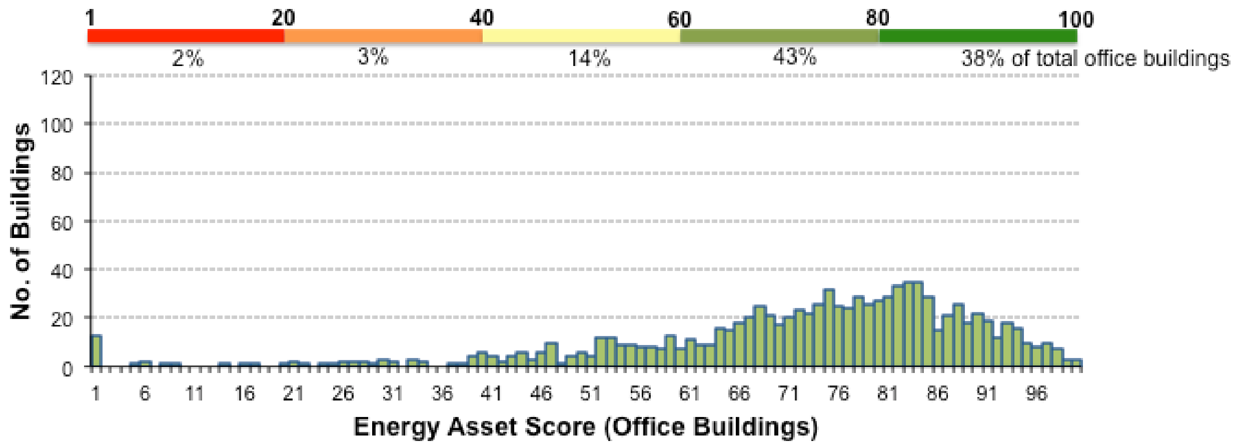


(b) All buildings with 10% energy reduction



(c) All buildings with 30% energy reduction

Figure 3.9. Distributions of CBECS office buildings on energy asset scoring scale.



(d) All buildings with 50% energy reduction

Figure 3.9. (contd)

The energy asset scoring scale was further evaluated using DOE reference buildings. DOE reference buildings provide complete descriptions that allow whole-building energy analysis through EnergyPlus simulation software. Sixteen building models represent approximately 70% of the commercial buildings in the United States (NREL 2011). The reference buildings are intended to characterize the energy performance of typical building types under typical operations (NREL 2011, p. 8).

There are three versions of the reference building models for each building type: new construction, post-1980 construction, and pre-1980 construction. All have the same building form and area and the same operation schedules. The differences are reflected in the insulation values, lighting levels, and HVAC equipment types and efficiencies. The new construction models comply with the minimum requirements of ASHRAE Standard 90.1-2004, the post-1980 models meet the minimum requirements of Standard 90.1-1989, and the pre-1980 models are built to a set of requirements developed from previous standards and other studies of construction practices (NREL 2011, p. 1).

Three of these sixteen models represent small, medium, and large office buildings. Figure 3.10 shows the energy asset scores for nine DOE reference office buildings, built during different periods, based on the average source EUI value of different climate zones. As shown, the post-1980 office buildings are at the middle of the scale, and the new construction reference buildings score close to 60 given the current scale. Also shown in Figure 3.10 is the improvement in building ratings to an approximate score of 70 after a 30% savings relative to ASHRAE Standard 90.1-2004. The energy goal for developing ASHRAE 90.1-2010 is to achieve 30% energy savings relative to 90.1-2004 (Thornton et al. 2011). On average, the new buildings compliant to the most recent energy code are expected to achieve a score above 70 (however, this may vary in building types and locations and needs to be tested further).

It is important to note that DOE plans to reevaluate the scales after pilot testing the scoring tool and system with additional actual buildings. In addition, large numbers of simulations will also be used to make adjustments as needed prior to finalizing the scales for each building type.

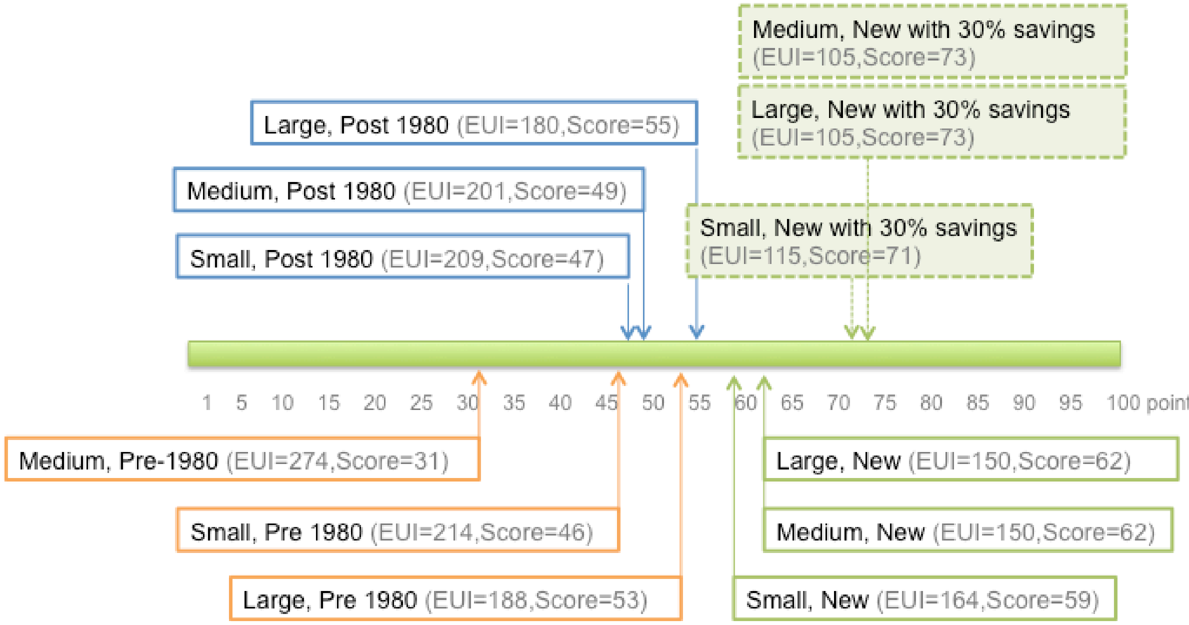


Figure 3.10. Energy asset scores for DOE reference buildings.

3.2.3 Scoring for Mixed-Use Types of Buildings

Mixed-use types of buildings that incorporate Phase I and Phase II use types will be included in Pilot #2, to begin in spring 2013. Those with more complex systems or those for which there is currently limited information (such as food sales, food service, data centers, laboratories, refrigerated warehouses, and health-care facilities) will be included in the Phase III rollout.

A weighted rating is used to evaluate mixed-use types: rate the different uses separately and then compute the weighted rating based on the square footage of each use type as an overall rating.

Table 3.7 provides an example of two office/retail mixed-use buildings. Both buildings have the same floor area (70% of office and 30% retail) and total energy use. Building A has a more efficient office portion, while Building B has a more efficient retail portion. The office and retail portions are assessed separately using the corresponding scale. Then, the weighted ratings for the mixed-used commercial properties are calculated based on the floor area of each use type.

Another weighting approach could be in proportion to the total energy use instead of the total floor area. However, a weighted overall rating by energy use cannot consistently represent the energy efficiency of a mixed-use building and its use-type portions. In the example of Building A in Table 3.7, the overall scores based on percentage of energy use tend to favor retail—a use type with high energy intensity. The original score is close to the score of the retail portion, although it accounts for only 30% of the total floor area. A 20% energy reduction in the office portion does not affect the overall score. A 20% energy reduction in the retail portion will affect the overall score more. This would lead building owners to ignore the energy efficiency of the office portion. In the example of Building B in Table 3.7, after a 20% energy reduction in the retail portion, the overall score unexpectedly decreases.

Using floor area as a weighting factor does not favor or penalize a building for its use types. It can also fairly reflect the energy reduction of each portion of the building. As shown in Table 3.7, the overall score improvement is proportional to the overall energy savings. Therefore, it is expected that a mixed-use building's score will be prorated based on the percentage of floor area of each use type.

Table 3.7. An example of prorated scores for mixed-use buildings.

	Building A		Building B		Building A with 20% energy reduction in office portion		Building B with 20% energy reduction in office portion		Building A with 20% energy reduction in retail portion		Building B with 20% energy reduction in retail portion	
Total Floor Area (ft^2)	100,000		100,000		100,000		100,000		100,000		100,000	
Use Type	Office	Retail	Office	Retail	Office	Retail	Office	Retail	Office	Retail	Office	Retail
Floor Area (ft^2)	70,000	30,000	70,000	30,000	70,000	30,000	70,000	30,000	70,000	30,000	70,000	30,000
Source Energy Use (MMBtu)[(a)]	7000	9000	13000	3000	5600	9000	10400	3000	7000	7200	13000	2400
Total Energy Saving (MMBtu)	N/A		N/A		1400		2600		1800		600	
Source EUI (kBtu/ft^2)	100	300	186	100	80	300	149	100	100	240	186	80
Energy Asset Score by Use Type	82	55	54	89	87	55	67	89	82	67	54	91
% of Floor Area	70%	30%	70%	30%	70%	30%	70%	30%	70%	30%	70%	30%
Overall Score by Floor Area	74		65		77		74		78		65	
Additional Points After Savings	N/A		N/A		4		9		4		0	
% of Energy Use	44%	56%	81%	19%	38%	62%	78%	22%	49%	51%	84%	16%
Overall Score by Energy Use	67		61		67		72		74		60	
Additional Points After Savings	N/A		N/A		0		11		8		-1	

(a) MMBtu is million British thermal units.

3.2.4 Durability of Energy Asset Scoring Scales

The durability of energy asset scoring scales (i.e., the period for which a scoring scale is valid) depends on three factors:

- changes in building stock
- equipment degradation
- updates to underlying simulation software.

Given DOE's consideration of these factors as discussed below, DOE expects that a building's score will remain current for at least 10 years, as long as the building does not undergo significant infrastructure changes including replacement of asset-related energy systems. After establishing 100-point scales for all relevant building types, DOE expects that the scales can remain static for at least 10 years.

3.2.4.1 Changes in Building Stock

Table 3.8 shows that average commercial primary energy consumption intensities of existing buildings are projected to vary within 8 kBtu/ft^2 over the next two decades. On the current energy asset scoring scale (Appendix B), buildings need to reduce energy use by 2 to 8 kBtu/ft^2 (depending on the building types) to earn an additional point. An 8-kBtu/ft^2 variation in 20 years equates to a score change of 1 to 4 points on average. The scale can still effectively reflect the building stock in 20 years if the projected energy consumption is realized.

The DOE energy reduction goals are to develop strategies to construct new buildings that achieve improvements of 50% by 2016 (relative to ASHRAE Standard 90.1-2004) and for net-zero energy buildings to be a cost-effective alternative to traditional construction by 2025 (DOE EERE 2010). The rate of change in commercial building stock is expected to begin to accelerate rapidly if these goals are achieved. Taking office buildings as an example, if an across-the-board energy savings of 50% is achieved, more than 50% of the existing buildings would have energy asset scores between 80 and 100 (Figure 3.11). At that time, the low end of the scoring scale (a score of 1) would need to be adjusted to ensure the full range of the scale was related to the building stock. DOE will periodically review latest energy consumption data to determine whether updates to the scale are needed.

Table 3.8. Commercial energy consumption intensities prediction (DOE EERE 2011b).

3.1.3 Commercial Delivered and Primary Energy Consumption Intensities, by Year

			Percent	*Delivered Energy Consumption*		Primary Energy Consumption	
		Floorspace (million SF)	Post-2000 Floorspace (1)	Total (10^15 Btu)	Consumption per SF (thousand Btu/SF)	Total (10^15 Btu)	Consumption per SF (thousand Btu/SF)
1980		50.9	N.A.	6.02	118.3	10.62	208.7
1990		64.3	N.A.	6.76	105.2	13.39	208.3
2000	(2)	68.5	N.A.	8.22	120.0	17.22	251.4
2008	**(2)**	**78.8**	**18%**	**8.62**	**109.5**	**18.47**	**234.4**
2010	(2)	81.2	26%	8.54	105.1	18.35	226.0
2015	(2)	85.5	35%	9.02	105.5	18.94	221.7
2020	(2)	91.5	45%	9.51	104.0	20.22	221.0
2025	(2)	97.4	54%	9.96	102.3	21.43	220.1
2030	(2)	103.5	62%	10.51	101.5	22.75	219.7
2035	(2)	109.8	70%	11.07	100.8	24.02	218.8

Note(s): 1) Percent built after Dec. 31, 2000. 2) Excludes parking garages and commercial buildings on multi-building manufacturing facilities.

Source(s): EIA, State Energy Data 2008: Consumption, June 2010, Tables 8-12, p. 24-28 for 1980-2000; DOE for 1980 floorspace; EIA, Annual Energy Outlook 1994, Jan. 1994, Table A5, p. 62 for 1990 floorspace; EIA, AEO 2003, Jan. 2003, Table A5, p. 127 for 2000 floorspace; and EIA, Annual Energy Outlook 2011 Early Release, Dec. 2010, Summary Reference Case Tables, Table A2, p. 3-5, Table A5, p. 11-12, and Table A17, p. 34-35 for 2008-2035.

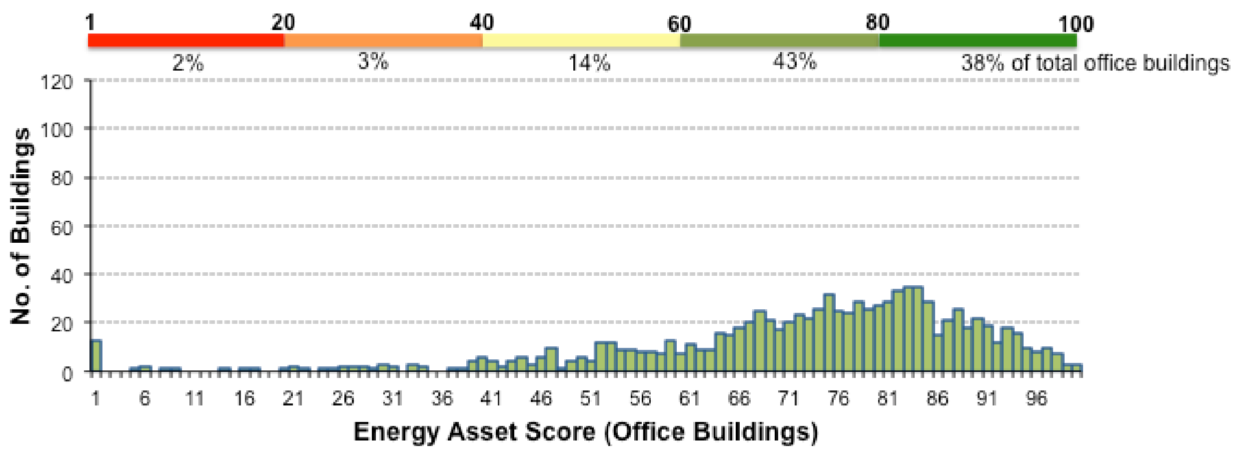


Figure 3.11. Improvement of energy performance 50% over the CBECS 2003 baselines (office buildings).

3.2.4.2 Degradation of HVAC Equipment

Degradation of HVAC equipment is another consideration when determining energy asset scoring scale durability. It is difficult to measure equipment degradation relative to initial conditions because many factors affect HVAC system performance and it can be impossible to separate equipment degradation from maintenance problems. For example, common problems such as leaves blown against the HVAC condenser coil and blocking airflow, a ductwork leak causing additional fan energy use, or an economizer being disabled would not be captured in an equipment test procedure, which evaluates system efficiency, but could be addressed in an operations and maintenance program. Some equipment degradation issues, such as refrigerant charge, compressor wear, expansion valve wear or failure, bending of condensers fins, filter clogging, or dirty condenser coils, can also be addressed with proper maintenance.

Drawing the line between equipment degradation with age and system maintenance/commissioning is complicated, and testing actual equipment efficiency is expensive. In addition, the literature review did not reveal any significant research on how aging influences HVAC system performance. A test on water heaters showed no clear correlation between age and the magnitude of performance degradation (Goetzler et al. 2011). Therefore, equipment degradation should not affect the durability of the energy asset scoring scale. In other words, if a building does not undergo significant infrastructure changes, its energy asset score will remain the same until the scoring scale is updated.

3.2.4.3 Major Updates to Underlying System Software

The energy asset scoring tool is built on EnergyPlus and the Facility Energy Decision System (FEDS). The tool development methodology is discussed in Section 4. EnergyPlus generates the EUI, which is used to calculate a building's energy asset score. FEDS provides default or inferred values when a certain variable is not entered by users. FEDS also runs life-cycle cost (LCC) analysis to identify building upgrade opportunities. An update to EnergyPlus has been released about every 6 months since 2001[1]; the FEDS database has been updated annually. Most often, the new features of the updated software extend modeling capability and increase simulation speed. New versions of software and their effect on energy asset scores will be examined annually.

The scoring tool will be updated periodically to incorporate new versions of the energy models. Many of these updates are unlikely to affect the modeled results. However, if updates do change modeled results, tool users who have received an energy asset score will be notified and receive an updated score.

The EEMs database will be updated regularly to reflect the new technologies and cost information. These updates will not affect a building's score but may affect the identified upgrade opportunities. For example, the lower cost of LED lights in the future may make this EEM applicable for more buildings. The building owners who have received an energy asset score will be notified about the database updates. The building owners can choose to resubmit their buildings without modifying the building information. Neither of the above changes will require tool users to modify the data entered for their buildings. A building would need to be re-rated only if an energy efficiency upgrade were implemented.

As noted above, DOE expects that a building's score is unlikely to change for at least 10 years if no significant changes are made to building equipment. To the greatest extent possible, the scales and scoring tool are being designed to create enduring scores.

[1] EnergyPlus Release Schedule can be found at http://apps1.eere.energy.gov/buildings/energyplus/energyplus_schedule.cfm.

4.0 Energy Asset Scoring Tool

This section describes the energy asset scoring tool—the centralized modeling tool developed to facilitate application of the energy asset scoring system.

The basic criteria for establishing a national building energy score include the consistency, repeatability, and accuracy of the modeled results. Another consideration is the time and resources required to obtain a score. With energy expenditures in U.S. commercial buildings averaging \$2.44/ft^2 (\$26.26/m^2) (DOE EERE 2011c), a 20% improvement in efficiency could yield savings of \$0.49/ft^2 (\$5.25/m^2). However, a comprehensive energy audit and modeling analysis can cost up to \$0.50/ft^2 (\$5.38/m^2) (CEC 2000; Carver 2011). The cost of audits depends on the location, level of detail, size, and complexity of the facility. For example, one consulting firm charges base fees of \$200 plus \$0.25/ft^2 for a Level 1 audit (walkthrough analysis) and \$200 plus 0.35/ft^2 for a Level 2 audit (energy survey and analysis) (Bluegill 2012). An environmental consulting and design firm that has assisted on LEED projects estimated energy modeling costs of \$15,000 to \$30,000 per project (Northbridge Environmental Management Consultants 2003). Therefore, detailed audits and modeling can often be cost-prohibitive for all but the largest buildings and commercial building owners. Any cost burden related to data collection and modeling is a barrier to the implementation of the energy asset score.

The usability of the energy asset score is another critical criterion. Unlike large institutional investors who are actively benchmarking their portfolios to improve the market value of their properties, many smaller-building owners/investors and owner-occupied building owners may lack motivation to obtain an energy asset score, especially when their real estate exposure is in less desirable markets. For this group of building owners, easy, ready access to suggestions for energy efficiency improvement is likely to be more valuable than a score.

Based on these considerations, DOE developed the energy asset scoring tool as part of the energy asset score to facilitate application, reduce cost, and increase standardization, allowing for consistent and reliable comparisons. In addition to generating a building energy asset score, the tool provides users with a tailored list of potential EEMs.

The energy asset scoring tool is not intended to replace a full energy audit of a building, but rather to produce a preliminary assessment that can then direct more detailed energy analysis and investment. The tool has three objectives:

1. give property owners a way to gauge the efficiency of their properties compared both to a potential efficiency and to similar properties
2. provide guidance on key actions to motivate owners to make reasoned and value-conscious investments
3. enable the targeting of limited capital resources toward those areas that will produce the greatest return.

4.1 Experience from Established Rating Tools and Auditing Protocols

The building characteristics or inputs considered by energy asset rating tools affect the accuracy and usability of their scores. In December 2010, the Buildings Performance Institute Europe (BPIE) published a review of European Union experience under the Energy Performance Building Directive. The BPIE review discusses measures that increase the effectiveness of implementation and public acceptance of the rating systems. The research (BPIE 2010) suggests that model reproducibility is improved by simplifying the data acquisition and relying on a larger number of default values required for the calculation—the overall inaccuracy of modeled results is reduced from 20% to 15%. With simplified data inputs, the deviation from calculated performance to actual building performance is also reduced from 30% to 10%. Simplified data acquisition also requires less expertise, time, and effort from the assessors, and therefore reduces costs.

Existing auditing procedures (ASHRAE 2004) specify a walkthrough analysis for a Level 1 assessment. A Level 2 analysis requires measurement of key operating parameters and comparing them to design, as well as a breakdown of the total annual energy use into end-use components. The deliverable from such an analysis includes both a discussion of the existing situation and reasons for excess energy use and an outline of the recommended mitigation measures. Such auditing guidelines set out generalized procedures to guide the analyst and require that each analyst exercise a substantial amount of judgment. An energy audit may take half a day to several days, depending on the size and complexity of the facility. The rule of thumb is 1 hour per 1,000 ft^2, on average (Bluegill 2012; Energy Audit Masters 2012). The energy asset score data requirement is expected to require less time and effort to collect than an ASHRAE Level 2 audit. Based on information collected during initial pilot testing of the score, the estimated data collection time is 6 to 8 hours. Additional pilot testing may further refine this estimate.

Different approaches have been taken to standardize energy modeling.

- ISO 13790:2008, widely applied in Europe to calculate building energy performance, defines the calculation recipe according to a set of normative statements about functional building category, assumed usage scenario, system efficiency, and so on. Three types of methods are covered in the ISO standard: (1) monthly quasi-steady-state calculation method, (2) simple hourly dynamic calculation method, and (3) calculation procedures for detailed dynamic simulation.
- The fully prescribed monthly quasi-steady-state method was adopted by UK Department of Communities and Local Government and developed into a simplified asset-based calculation procedure, Simplified Building Energy Model (SBEM) (BRE 2010). The SBEM is also used by Ireland to calculate energy use of simple, nonresidential buildings for energy performance certificate (energy asset rating).
- Dynamic simulation software is used for complex nonresidential buildings, for example in Ireland and Portugal (Lee et al. 2011). The monthly calculation method gives more accurate results on an annual basis, but large relative errors occur in the months close to the beginning and the end of the heating and cooling season (ISO 13790:2008, Section 5.3). However, the accuracy of the calculated energy use becomes less relevant because a standardized expression of performance does not need to predict the actual energy consumption but rather needs to guarantee the results of energy asset rating,

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.

used). The drawback of the detailed modeling approach is that if users need to provide all inputs required to build a detailed model, the tool will be limited to the most experienced user group.

To overcome the inherent issues in each of the approaches examined, the energy asset scoring tool has been built on a combination of an analytic tool and a sub-hourly energy-modeling tool. The energy asset scoring tool includes a simplified user interface, an analytic engine, and a detailed energy modeling engine. The user interface enables the creation of a simplified building geometry and the collection of a reduced set of model inputs. EnergyPlus,[1] a widely accepted building energy modeling tool, is used to generate a whole-building energy model. One reason to use a detailed energy model is to enable users to store their building information in a standardized model that can be user-downloaded and used for other purposes. For example, a third party may develop a building retrofit tool that modifies the standardized model generated by the energy asset scoring tool. Although such a sub-hourly simulation may provide more information than needed for an energy asset score at this stage, the approach provides opportunities for future expansion. This method is in essence similar to the wizard levels (schematic and design development) of eQUEST.[2] In the wizards, all inputs have defaults based on the California Title 24 building energy code, and users need little energy analysis experience. To use eQUEST's detailed interface, users must have knowledge of building technology and experience with energy analysis simulation tools.

To link a simplified user interface with a detailed energy model input for the energy asset scoring tool, it was necessary to use an analytic engine to infer additional building variables not entered by users. This was accomplished by building on the aforementioned existing analytic tool—FEDS (PNNL 2008). FEDS maps out one-to-many relationships between the different building characteristics, which are derived from a number of sources, including

- multiple years of CEBCS and the Residential Energy Consumption Survey[3]
- building energy audit/survey activities
- building energy end use monitoring data
- building energy codes
- building equipment standards
- ASHRAE handbooks of many years
- equipment deployment trends
- other inferred/entered values for related systems
- energy model internal heat balance and system sizing algorithms.

These relationships, previously developed by PNNL to provide inference capabilities for FEDS (PNNL 2008), allow the energy asset scoring tool to produce the required detailed inputs from a small subset of user inputs. The smallest allowable set of user inputs is described as the simple-level input set. This input level is required by all tool users, and so was developed to be relatively simple to collect accurately. This set of simplified inputs is then used to predict the remaining building characteristics to

[1] http://apps1.eere.energy.gov/buildings/energyplus/.
[2] http://doe2.com/.
[3] http://www.eia.gov/consumption/residential/.

make the tool useful to many disparate user groups. Inference values are arrived at by a number of means. All are based in some way on user inputs, such as building location and age (Table 4.1). These inputs are used in conjunction with data derived from a wide range of sources, listed above. As users include more detailed inputs on the way to the advanced-level set, the energy model results reflect the added detail by becoming more tailored to the user's specific building.

Table 4.1. Model inference methodology.

Minimum User Inputs	Inferred Values for Energy Model	Inferences Based on
Roof type	Roof assembly U-value, insulation thickness/R-value	Roof type, building location, year of construction, wall type, use type
Wall type	Wall assembly U-value, Insulation thickness/R-value	Wall type, building location, year of construction, use type
Window framing type and glass type	Window U-value, Solar heat gain coefficient	Window framing type and glass type
Lighting type and % of floor served	No. of fixtures	Standard illuminance levels for the building space type
Cooling equipment type	Cooling COP	Equipment type and year of manufacture (assuming typical replacement rates based on the type of equipment)
Heating equipment type and fuel	Heating efficiency	Equipment type and year of manufacture (assuming typical replacement rates based on the type of equipment)
	Thermal zone layout and perimeter zone depth	Building footprint dimension
Service hot water type and fuel	Hot water system efficiency	Equipment type and year of manufacture (assumed to be year of construction if not entered by users)

As stated above, DOE considered other modeling approaches, including the pre-simulation method, time series data analysis, and normative calculation method, but decided against these for the following reasons:

- The pre-simulation method runs a large number of models by changing the building characteristics and stores the results in a database. When a candidate building queries the database, the database provides the result from a similar building or an interpolated result based on a pre-developed regression curve. Pre-simulation could provide a robust modeling approach and allow for relatively simple tool development but would not provide adequate flexibility. The energy asset scoring tool needs to accurately represent the diversity of buildings that could be addressed using the tool. Adding more variables in the pre-simulation models increases the size of the database exponentially.
- Time series data analysis predicts a building's energy use pattern or structure by examining an ordered sequence of metered data. It was discounted as an option for developing the energy asset scoring tool because it is linked so closely to the operation and maintenance characteristics of a specific building. It thus would not have allowed the comparisons between buildings for which the tool is designed.
- The normative calculation method uses a set of algebraic equations and observable or empirical parameters. One disadvantage of this method is that special energy-saving technologies may not be

properly considered because normative calculations assume the building performance as a series of steady states and ignore the dynamics between the steady states. Therefore, some countries, such as Ireland, allow use of approved dynamic simulation software. This dual approach complicates the rating system and decreases the standardization.

The combination of the simplified user interface, an analytic engine, and a modeling engine makes the final tool user-friendly to encourage broad adoption and provides the accuracy, detail, and extensibility needed for applicability across the wide range of variation that exists within the built environment. Two key elements of this approach are data collection design and parameter categorization into different levels of input sets. The energy asset score data inputs are outlined in the following sections.

4.3 Energy Asset Score Data Input Requirements

Building performance is determined by multiple factors, including building function and design, occupant behavior, equipment degradation and failure, and climate aging of building materials. To account for this, the energy modeling methodology for the energy asset score defines a consistent set of inputs for energy asset characteristics and standard assumptions for characteristics of non-energy assets. When the set of required user-collected inputs is defined, the focus is on factors that drive the most significant changes in energy efficiency. Interviews and feedback received during the development of the energy asset scoring tool reflected responses from a mix of stakeholders; although there is a concern over additional burden of time and expense, some stakeholders also desired more detailed energy modeling to build confidence in simulation results. The following sections describe the inputs required for the energy asset scoring tool, with consideration given to such stakeholder feedback.

4.3.1 General Input Classification

To determine the required inputs that energy asset scoring tool users would be expected to provide, the input variables had to be classified. The first step was to collect a comprehensive list of building characteristics that influence building energy consumption. This list of candidate inputs was derived from several sources, including

- building energy modeling inputs from EnergyPlus and FEDS
- literature on analyzing actual building energy use data (e.g., the CEBCS data)
- literature on analyzing modeled building energy use data (e.g., the Advanced Energy Design Guide and ASHRAE 90.1 Appendix G)
- building energy auditing guidelines (e.g., ASHRAE's *Procedures for Commercial Building Energy Audit*).

These sources provided a comprehensive list of all potential user inputs that were considered. (See Appendix C, column E for a complete list of model parameters.) Variables related to operational choices were removed from the list, then the potential asset-rating variables were assessed based on three characteristics:

- ease of collection by target user

- impact on energy consumption
- expected variability between buildings.

Each variable was rated as low, medium, or high for each of the three characteristics.

4.3.1.1 Ease of Collection

Ease of collection was first ascertained through questionnaires distributed to experienced building energy professionals at PNNL. The following questions were asked:

- In your experience, what are the most difficult building characteristics to determine when auditing a building?
- Which difficult-to-obtain variables are due to the time/tedium required (example: counting lights)?
- Which difficult-to-obtain variables are due to the expertise required (example: ascertaining HVAC efficiency?)
- Which variables are difficult to obtain through nondestructive examination (example: wall cavity insulation thickness)?

Questionnaire responses drove the initial categorization of potential inputs by ease of collection, which is considered a proxy for cost to obtain for this assessment. Interviewees were not asked to provide great detail but rather a general assessment based on experience.

The ASHRAE energy auditing guideline was also used to examine the different levels of data collection. Building data that can be collected through a Level I audit (walk through analysis) was considered easy and low-cost. Building data that can be collected through Level II (energy survey and analysis) and Level III (detailed analysis of capital-intensive modifications) audits was considered more difficult and expensive to collect. Examples of simple-to-collect building characteristics include geographic location, floor area, and the year built; more difficult variables include HVAC system details and envelope thermal characteristics.

The effort required for each aspect of data collection and input will be further examined through additional pilot testing of the energy asset score. Pilot participants will be asked to rate the difficulty level of data collection for each energy asset score variable based on their field experience.

4.3.1.2 Impact on Energy Consumption

In addition to ease of collection, variables were categorized based on their likely impact on the energy use of a building. Two main sources were used to assess the potential impact of a specific variable: domain experts and literature on building energy modeling inputs.

The first source was interviews with domain experts, consisting of experienced building energy analysts at PNNL who were not working on the energy asset scoring tool development. The interviewees were asked to assess the variables selected in terms of the likelihood that a small change would lead to a large overall change in total energy consumption. These variables included building characteristics such as air infiltration, HVAC equipment efficiency, and wall and ceiling R-values.

The second source was literature on building energy modeling inputs, which was examined to supplement the feedback provided by the domain experts. Much of the literature pointed more to the inconsistencies among the impacts of variables across building use type, configuration, and location (ASHRAE 2006). For example, a sensitivity analysis performed by the California Energy Commission to develop California building energy asset rating systems shows that wall insulation, roof insulation, glazing U-value, heating efficiency, and ventilation airflow have low impact (less than 2%) on electricity and gas use of office buildings and higher impact (3% to 23%) on retail buildings. The variation among the four tested climate zones (California building climate zones 9, 10, 12, 15) is up to 8%. However, based on empirical data, there is no doubt that in a cold climate zone, envelope insulation and heating efficiency have a large influence on building energy use. Therefore, to maintain broad applicability of the tool, when a variable's impact could not be agreed upon, the variable was generally considered important because it could have a large influence on energy use in some situations. A sensitivity analysis will be performed (in 2013) to further examine the influence of the variables that are difficult to collect. The results of the sensitivity analysis will be published in a separate document.

4.3.1.3 Expected Variability Between Buildings

The third metric used to categorize the selected potential energy asset score inputs was the expected variability between buildings. The expected variability of an input from one building to another was determined by consulting both building energy auditors and building energy modeling experts at PNNL. They were asked to rank, based on their experience, the expected variability of the potential inputs as low, medium, or high. Often, inputs that were deemed highly variable, such as occupancy patterns and outdoor air levels, were those that will be held constant as a result of the specific requirements of energy asset scoring, and so in this specific case these can be considered no-variability inputs.

4.3.1.4 Classification of Input Variables

The input variables were then classified by the different combinations of ease of collection, impact, and variability. Seven input types were selected based on the combination of characteristics and the corresponding suitability for making the input required, based on the competing drivers of ease of use and accuracy of results. Table 4.2 provides a matrix of these seven variable types.

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).

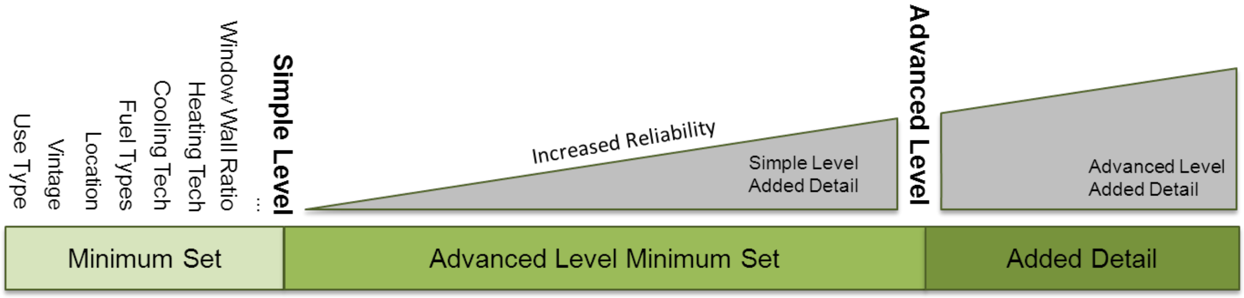


Figure 4.1. Different levels of data collection.

- 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.

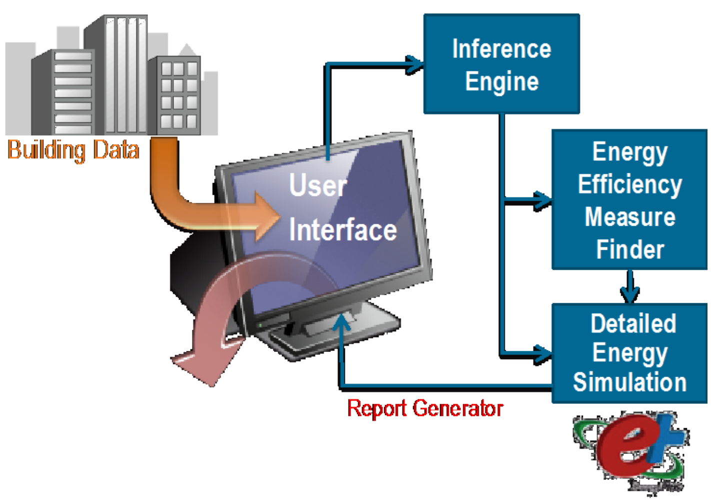


Figure 4.2. Energy asset scoring tool components.

4.4.1 User Interface

The user interface allows the user to create any number of buildings, each of which can contain multiple blocks (Figure 4.3). Each block will be one of six different shapes (rectangle, courtyard, L, H, U, or T), and the user can specify values for the following seven categories:

- building information, including location, year of construction, use type, number of floors, floor-to-ceiling height, and orientation
- block geometry dimensions
- opaque envelope characteristics, including wall, roof, and floor construction types, insulation thickness, and R-value
- glazing specifications, including window and skylight layout and size, framing types, solar heat gain coefficient, and U-value
- lighting characteristics, including luminaire type, number, and lighting control systems
- HVAC system characteristics, including zone layout, HVAC types, efficiencies, and capacities
- water heater type, capacity, and efficiency.

Block properties can be copied from existing blocks to save time when users create a complex building. As the users work, they see a live 3D representation of the building, which can be manipulated to accurately represent the shape of the building being modeled.

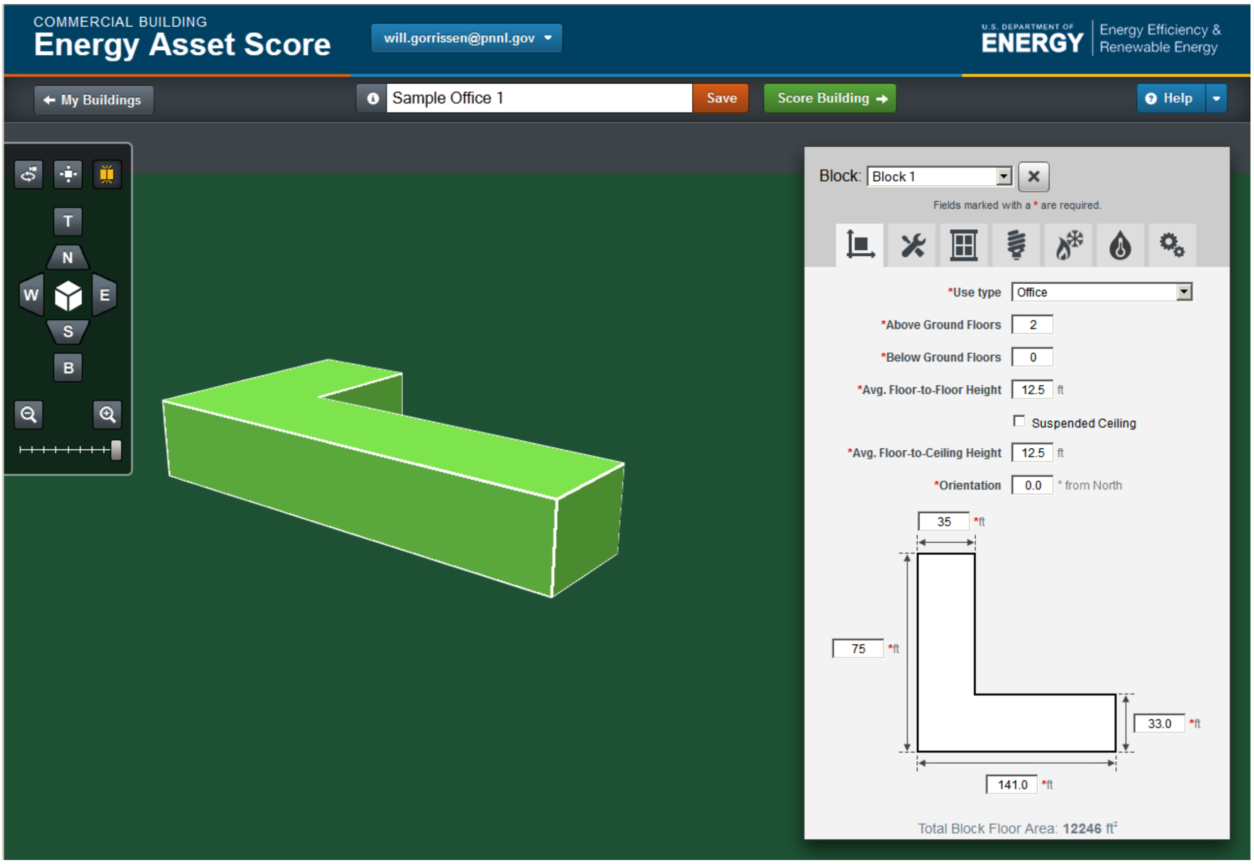


Figure 4.3. Energy asset scoring tool user interface.

4.4.2 Analytic Engine

To minimize effort for the user, a mechanism was needed to predict a building's difficult-to-find characteristics. Most existing modeling tools either use the chosen energy codes to provide defaults or rely on a regional database that applies only to a certain climate condition. FEDS—developed previously by PNNL to facilitate performing large numbers of building energy audits over a short period of time (PNNL 2008)—has been identified to meet the requirements of energy asset scoring tool development. The similarity between the existing FEDS tool and the energy asset scoring tool, as well as the established nature of the FEDS system and the in-house access to the FEDS developers, led DOE to adopt both the FEDS inference approach and the FEDS retrofit optimization techniques for use in the energy asset scoring tool. The constraints of that task closely mirror those of a low-cost energy asset scoring tool.

The FEDS tool inferences are derived from multiple sources and techniques, including the following:

- dummy variable ordinary least squares regression of CBECS data based on age, use type, size, and climate
- equipment efficiency standards
- building energy codes and adoption rates
- ASHRAE handbooks (*Fundamentals* and *HVAC Systems and Applications*)

- 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/.

All user-entered data and the final energy asset score and report are also written to a database in parallel with the above steps.

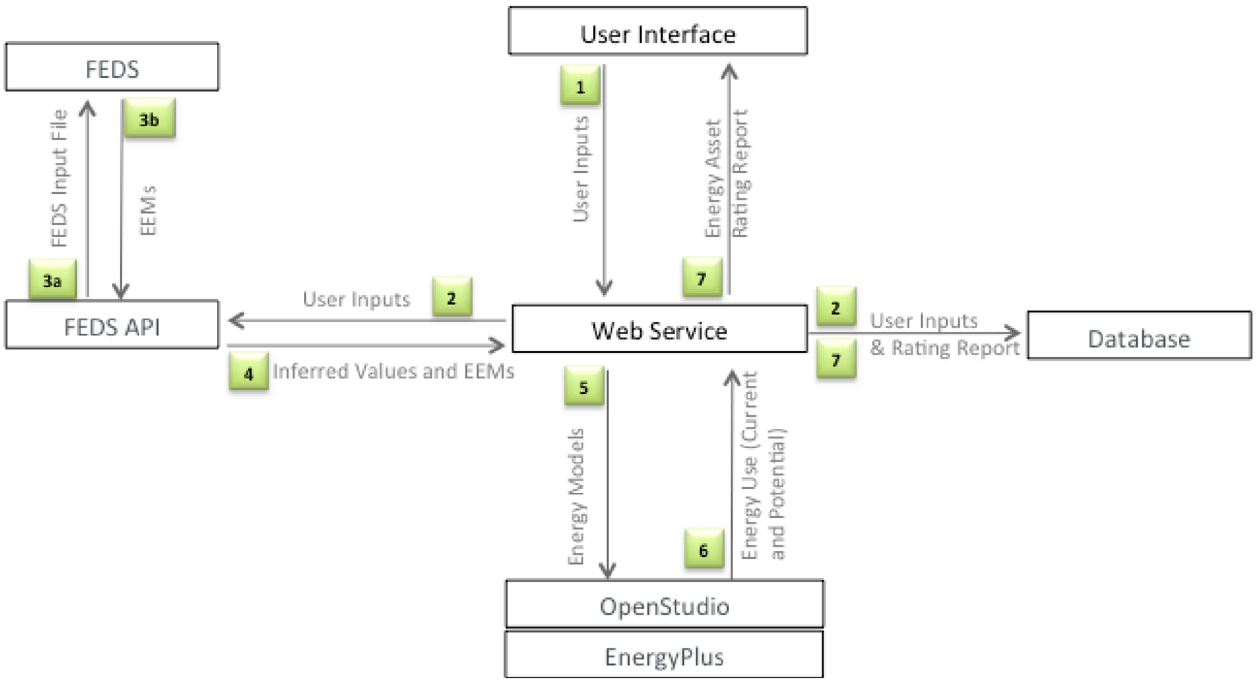


Figure 4.4. Energy asset scoring tool architecture.

4.5 Building Use-Dependent Operational Settings

The energy asset score disaggregates building energy use information by simulating building performance under standard operating and occupancy conditions. Focusing only on buildings' physical characteristics and removing occupancy and operational variations allows "apples-to-apples" comparisons between differently operated buildings. To evaluate building energy use under typical operations, maintenance, and occupancy conditions, inputs related to building operation and maintenance are standardized. Operating assumptions include thermostat settings, number of occupants, and receptacle, process, and hot water loads. Schedules of operation for HVAC, lighting, and other systems also are included. Assuming all buildings of a similar type have identical hours of operation and occupancy patterns allows the energy asset scoring tool to focus on the as-built efficiency of a building.

Table 4.5 shows the standard operating inputs currently used in the energy asset scoring tool. The data are derived from COMNET Appendix B Modeling Data (Architectural Energy Corporation 2010). COMNET modeling data are consistent with the Performance Rating Method in Appendix G of ASHRAE Standard 90.1-2007. COMNET also establishes baselines for receptacle power density and refrigeration power density, which do not exist in ASHRAE Standard 90.1. The building operation schedules are derived from COMNET Appendix C Schedules, which is also consistent with ASHRAE 90.1-2007. The model assumptions that are not specified in COMNET and ASHRAE Standard 90.1 follow the inputs as specified in the DOE commercial reference buildings models or use EnergyPlus defaults (NREL 2011).

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/ft²)	Occupant Density (ft²/person)	Heat Gain per Occupant		Minimum Ventilation (cfm/ft²)	Water Heating Load (G/day-occ)	Interior Gas Appliance Power Density (Btu/h-ft²)	Refrigeration Power Density (W/ft²)
			Sensible (Btu/occ)	Latent (Btu/occ)				
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.

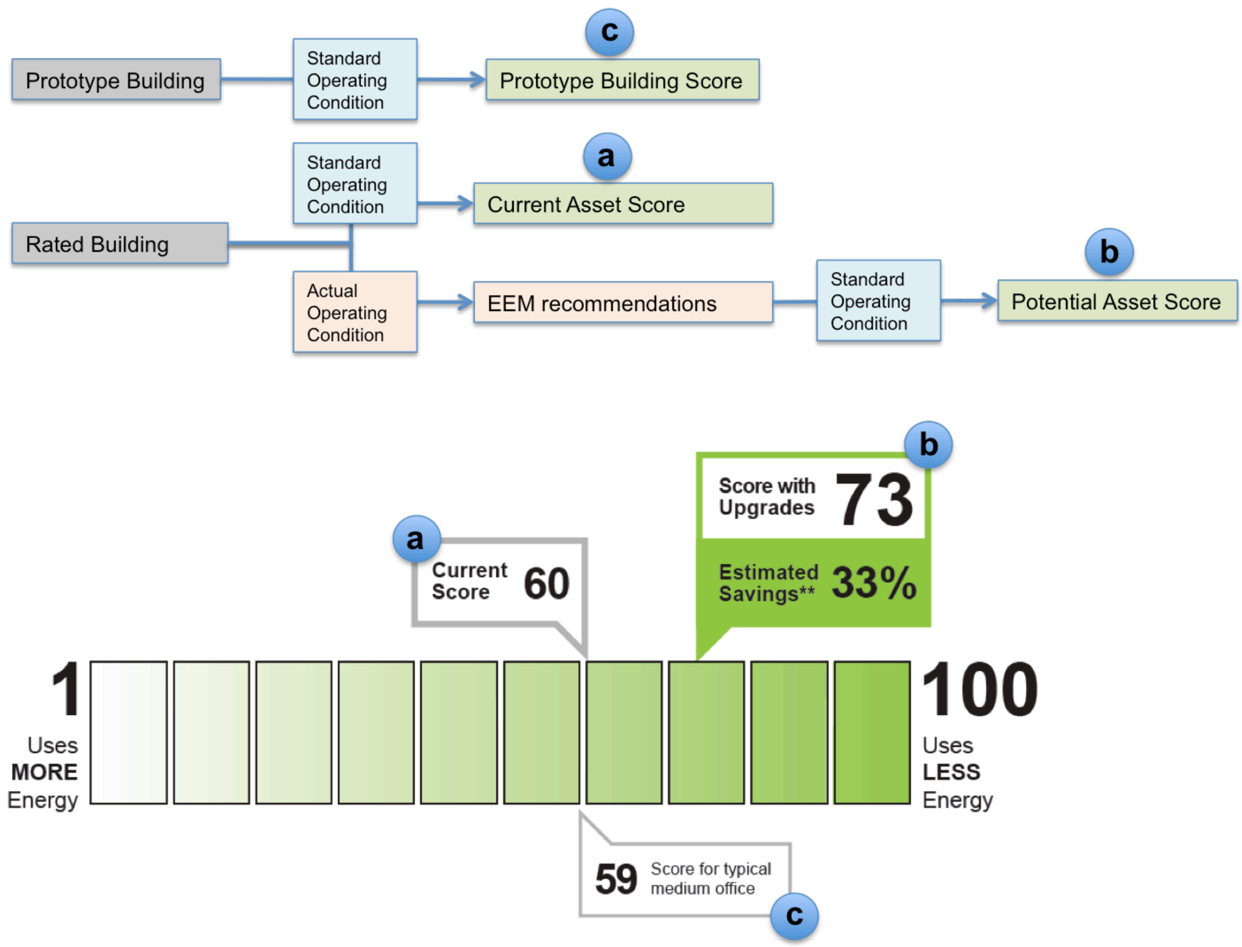


Figure 5.1. Current, potential, and reference scores.

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
		2004	2007	2010	2004	2007	2010	2004	2007	2010	Low	High	Method
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.

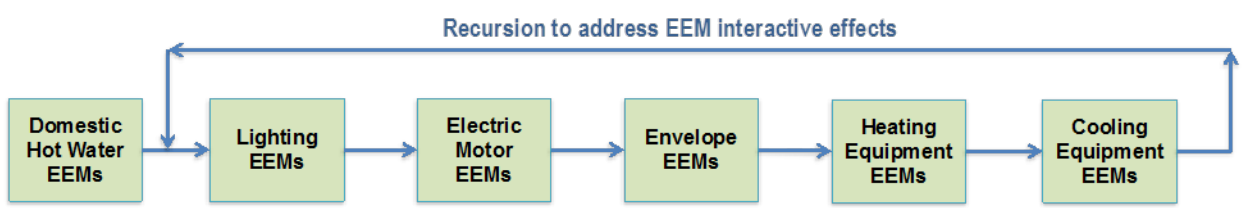


Figure 5.2. Energy efficiency measure ranks.

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

Appendix B

Energy Asset Score Tables

B.1 Building Type: Office

Table B.1. Energy asset score table for office buildings.

Score	EUI	Score	EUI	Score	EUI
100	0	65	140	30	280
99	4	64	144	29	284
98	8	63	148	28	288
97	12	62	152	27	292
96	16	61	156	26	296
95	20	60	160	25	300
94	24	59	164	24	304
93	28	58	168	23	308
92	32	57	172	22	312
91	36	56	176	21	316
90	40	55	180	20	320
89	44	54	184	19	324
88	48	53	188	18	328
87	52	52	192	17	332
86	56	51	196	16	336
85	60	50	200	15	340
84	64	49	204	14	344
83	68	48	208	13	348
82	72	47	212	12	352
81	76	46	216	11	356
80	80	45	220	10	360
79	84	44	224	9	364
78	88	43	228	8	368
77	92	42	232	7	372
76	96	41	236	6	376
75	100	40	240	5	380
74	104	39	244	4	384
73	108	38	248	3	388
72	112	37	252	2	392
71	116	36	256	1	396
70	120	35	260		
69	124	34	264		
68	128	33	268		
67	132	32	272		
66	136	31	276		

B.2 Building Type: School

Table B.2. Energy asset score table for school buildings.

Score	EUI	Score	EUI	Score	EUI
100	0	65	105	30	210
99	3	64	108	29	213
98	6	63	111	28	216
97	9	62	114	27	219
96	12	61	117	26	222
95	15	60	120	25	225
94	18	59	123	24	228
93	21	58	126	23	231
92	24	57	129	22	234
91	27	56	132	21	237
90	30	55	135	20	240
89	33	54	138	19	243
88	36	53	141	18	246
87	39	52	144	17	249
86	42	51	147	16	252
85	45	50	150	15	255
84	48	49	153	14	258
83	51	48	156	13	261
82	54	47	159	12	264
81	57	46	162	11	267
80	60	45	165	10	270
79	63	44	168	9	273
78	66	43	171	8	276
77	69	42	174	7	279
76	72	41	177	6	282
75	75	40	180	5	285
74	78	39	183	4	288
73	81	38	186	3	291
72	84	37	189	2	294
71	87	36	192	1	297
70	90	35	195		
69	93	34	198		
68	96	33	201		
67	99	32	204		
66	102	31	207		

B.3 Building Type: Retail

Table B.3. Energy asset score table for retail buildings.

Score	EUI	Score	EUI	Score	EUI
100	0	65	280	30	560
99	8	64	288	29	568
98	16	63	296	28	576
97	24	62	304	27	584
96	32	61	312	26	592
95	40	60	320	25	600
94	48	59	328	24	608
93	56	58	336	23	616
92	64	57	344	22	624
91	72	56	352	21	632
90	80	55	360	20	640
89	88	54	368	19	648
88	96	53	376	18	656
87	104	52	384	17	664
86	112	51	392	16	672
85	120	50	400	15	680
84	128	49	408	14	688
83	136	48	416	13	696
82	144	47	424	12	704
81	152	46	432	11	712
80	160	45	440	10	720
79	168	44	448	9	728
78	176	43	456	8	736
77	184	42	464	7	744
76	192	41	472	6	752
75	200	40	480	5	760
74	208	39	488	4	768
73	216	38	496	3	776
72	224	37	504	2	784
71	232	36	512	1	792
70	240	35	520		
69	248	34	528		
68	256	33	536		
67	264	32	544		
66	272	31	552		

B.4 Building Type: Warehouse (non-refrigerated)

Table B.4. Energy asset score table for non-refrigerated warehouse.

Score	EUI	Score	EUI	Score	EUI
100	0	65	70	30	140
99	2	64	72	29	142
98	4	63	74	28	144
97	6	62	76	27	146
96	8	61	78	26	148
95	10	60	80	25	150
94	12	59	82	24	152
93	14	58	84	23	154
92	16	57	86	22	156
91	18	56	88	21	158
90	20	55	90	20	160
89	22	54	92	19	162
88	24	53	94	18	164
87	26	52	96	17	166
86	28	51	98	16	168
85	30	50	100	15	170
84	32	49	102	14	172
83	34	48	104	13	174
82	36	47	106	12	176
81	38	46	108	11	178
80	40	45	110	10	180
79	42	44	112	9	182
78	44	43	114	8	184
77	46	42	116	7	186
76	48	41	118	6	188
75	50	40	120	5	190
74	52	39	122	4	192
73	54	38	124	3	194
72	56	37	126	2	196
71	58	36	128	1	198
70	60	35	130		
69	62	34	132		
68	64	33	134		
67	66	32	136		
66	68	31	138		

Appendix C

Energy Asset Score Data List

Appendix C

Energy Asset Score Data List

Input Data Element	Data Collection Method	Input Rank-Simple	Input Rank-Verified	Description of Component	Purpose for AS and E+
General Building Information					
Building Name / ID	user provides	required	required	Identification name for building being scored.	
Building Location	user provides	optional	optional	State, City	
Zip Code	user provides	required	required	Zip code of building being scored.	For climate zone and weather file look up.
Building vintage / year of construction	user provides	required	required	Year of construction or major renovation of the the building being scored.	infer values (envelope properties and System Efficiencies) not provided by user.
Building classification / type	user selection	required	required	Space Use Classification-Office/Retail/Education	Generate standard operational assumptions and infer other values
Total Conditioned floor area	Visual Inspection/GIS/ Architectural Dwgs	required	required		To calculate building EUI, asign load densities for lighting, plug loads.
Area of each block (In case of multiple blocks)	Visual Inspection/GIS/ Architectural Dwgs	required	required	Area of each major use type for mixed use buildings.	Account for atriums for internal loads.
Geometry					
Geometry configuration	Visual Inspection/GIS/ Architectural Dwgs	required	required	Shape of building. Selected from available options.	Create 3D model
Geometry Dimensions	Visual Inspection/GIS/ Architectural Dwgs	required	required	length and width of exterior surfaces	Calculate building area
Aspect Ratio	NA	NA	NA	Calculated from 3D Model	
Number of floors above grade	Visual Inspection/ Architectural Dwgs	required	required		Assign construction for above grade, below grade and on grade surfaces.
Number of floors below grade	Visual Inspection/ Architectural Dwgs	required	required		
Floor to ceiling height	Visual Inspection/ Architectural Dwgs	required	required		Calculate building volume
Floor to floor height	Visual Inspection/ Architectural Dwgs	required	required		Define plenum zones, if any.
Envelope Details					
Envelope- Roof					
Roof Type	Visual Inspection/ Architectural Dwgs	required	required	Metal Surfacing/Shingles/ Built-up with Metal-Concrete-Wood Deck	Assign appropriate construction assembly.
Roof Thermal Properties	Building Specifications	required	required	U Value/R Value/ Insulation Thickness	Calculate heat transfer through roof assembly
> Roof U Value	Building Specifications	optional	> required	Roof Assembly U value	
> Roof R Value	Building Specifications	optional	> required	Roof Insulation R Value	
> Roof Insulation Thickness	Building Specifications	optional	> required	Roof Insulation Thickness	
> I don't know	NA	optional	NA		Value is inferred based on year of construction and roof type.
Roof Solar Reflectance	NA	NA	NA	To analyze Cool Roof Properties	Not Present in AS
Roof Thermal Emittance	NA	NA	NA	To analyze Cool Roof Properties	
Presence of Suspended Ceiling	NA	NA	NA		Not Present in AS
Envelope- Exterior Walls					

Input Data Element	Data Collection Method	Input Rank- Simple	Input Rank- Verified	Description of Component	Purpose for AS and E+
Exterior Wall Type	Visual Inspection/ Architectural Dwgs	required	required	Wood Framed/ Steel Framed/ Mass	Assign appropriate construction assembly.
Wall Thermal Properties	Building Specifications	required	required	U Value/R Value/ Insulation Thickness	Calculate heat transfer through roof assembly.
> Wall U Value	Building Specifications	optional	> required	Wall Assembly U value	
> Wall R Value	Building Specifications	optional	> required	Wall Insulation R Value	
> Wall Insulation Thickness	Building Specifications	optional	> required	Wall Insulation Thickness	
> I don't know	NA	optional	NA	NA	Value is inferred based on wall type and year of construction
Envelope- Floor					
Floor Type	Visual Inspection/ Architectural Dwgs	required	required	Basement/Slab on Grade/Carpet	
Has Carpet	Visual Inspection	optional	required		
Floor Insulation	Building Specifications	optional	required	R Value/ Insulation Thickness	Calculate heat transfer through floor assembly
> Floor R Value	Building Specifications	optional	> required	Floor Insulation R Value	
> Floor Insulation Thickness	Building Specifications	optional	> required	Floor Insulation Thickness	
> I don't know	NA	optional	NA	NA	Value is inferred based on floor type and year of construction
Envelope- Skylights					
Skylight Layout	Visual Inspection/ Architectural Dwgs	required	required	Core Only/All Zones	To distribute skylights in relevant zones based on user input.
% of Roof Area	Building Specifications	required	required	Skylight to Roof area percentage	Calculate heat transfer throughskylights. If user input not provided, these parameters are inferred based on year of construction.
U Value	Building Specifications	optional	required	Skylight Glazing U Value	
SHGC	Building Specifications	optional	required	Skylight glazing SHGC	
VT	Building Specifications	optional	optional	Skylight glazing Visible transmittance	
Envelope- Windows					
Windows Framing Type	Visual Inspection/ Architectural Dwgs	required	optional	Metal/ Metal with Thermal Breaks/ Wood-Vinyl Fiberglass	Accurate acess window performance
Windows Glass Type	Building Specifications	required	optional	Single Pane/Double Pane/ Double Pane w Low e/Triple Pane/ Triple Pane with Low E	Accurate acess window performance
Windows Gas Fill Type	Building Specifications	required	optional	None/ Air / Other	Accurate acess window performance
Windows- Fixed/Operable	Visual Inspection	required	optional	Fixed/ Operable	Accurate acess window performance
Window Layout	Visual Inspection/ Architectural Dwgs	required	required	Various/ Discrete / Continuous	Distribute WWR along facades more accurately.
WWR	Visual Inspection/ Architectural Dwgs	required	required		
U Value	Building Specifications	optional	required	Window Glazing U Value	
SHGC	Building Specifications	optional	required	Window glazing SHGC	
VT	Building Specifications	optional	optional	Window glazing Visible transmittance	
Doors	Visual Inspection/ Architectural Dwgs	NA	NA	Excluded cause of Low Impact	
Envelope- Shading					
Exterior Shading Type	Visual Inspection	required	required		

Input Data Element	Data Collection Method	Input Rank-Simple	Input Rank-Verified	Description of Component	Purpose for AS and E+
> External Overhangs - Height Above Window	Visual Inspection/ Architectural Dwgs	optional	required	Overhang details	Accurately model external overhang.
> External Overhangs- Projection	Visual Inspection/ Architectural Dwgs	optional	required		
> Vertical Fins- Fin Depth	Visual Inspection/ Architectural Dwgs	optional	required	Vertical fins details	Accurately model Vertical Fins.
> Vertical Fins- Edge Fins Only	Visual Inspection/ Architectural Dwgs	optional	required		
> Vertical Fins- Distance Between Fins	Visual Inspection/ Architectural Dwgs	optional	required		
> Light Shelves- Distance From Top	Visual Inspection/ Architectural Dwgs	optional	required	light shelves Details	
> Light Shelves- Exterior Protusion	Visual Inspection/ Architectural Dwgs	optional	required		
> Light Shelves- Interior Protusion	Visual Inspection/ Architectural Dwgs	optional	required		
Envelope- Infiltration					
Envelope Leakage	NA	NA	NA	Infiltration rate through exterior envelope components.	Based on Standard Assumptions
Door Infiltration	NA	NA	NA	Infiltration due to opening and closing of doors.	Based on Standard Assumptions
Internal Loads					
Lighting					
Interior Lighting					
Lighting Power Density				LPD (W/sq.ft) is required to calculate lighting energy use based on lighting use schedules	
Mounting Type	lighting survey	required	required	Recessed/ Surface/ Pendant	
Lighting Type	lighting survey	required	required		
Input Method		required	required	Percentage Served/ Number of Lamps	
> Percentage Served	lighting survey	> required	> required		
> Number of Lamps	lighting survey	> required	> required		
> Number of Lamps >> Lamp Wattage	lighting survey	> required	> required	Wattage of Each Lamp	Calculate Total wattage for each lamp type.
Percent Heat to Space	NR	NR	NR	Based on standard assumptions	
Interior Lighting Controls					
> Occupancy Sensors	visual inspection	required	required		
> Daylight Controls	visual inspection	required	required		
Electrical plug intensity (W/m²)	Based on Standard Assumptions for Building Use Type				
Gas appliance intensity (W/m²)	Based on Standard Assumptions for Building Use Type				
People density (People/100m²)	Based on Standard Assumptions for Building Use Type				
Exterior Lighting					
> Exterior Lighting Power	lighting survey	optional	> required		
> Exterior Lighting Power Controls	lighting survey	optional	> required		
Schedules of Operation					

Input Data Element	Data Collection Method	Input Rank-Simple	Input Rank-Verified	Description of Component	Purpose for AS and E+
Occupancy Schedule	NR	NR	NR	Based on Standard Assumptions for Building Use Type	
Lighting Schedule	NR	NR	NR	Based on Standard Assumptions for Building Use Type	
Equipment SChedule	NR	NR	NR	Based on Standard Assumptions for Building Use Type	
Heating/ Cooling Setpoint Schedule	NR	NR	NR	Based on Standard Assumptions for Building Use Type	
Fan Availability Schedule	NR	NR	NR	Based on Standard Assumptions for Building Use Type	
HVAC Systems					
Thermal Zone Layout	visual inspection	required	required	Single Zone/ Permeter/ Perimeter and Core	
Perimeter Zone Depth	visual inspection	required	required		
HVAC System Configuration	visual inspection	required	required		
Cooling					
System Type	System Specifications	required	required	No Cooling/ Terminal DX/ Central DX Single Zone/ Central DX Multi-Zone/ Chiller/ District	Assign System type and corresponding distribution system
Year of Manufacture	System Specifications	required	required		
Number of Pieces of Equipment	visual inspection	required	required		
System COP	System Specifications	optional	required	COP/EER/SEER	Calculate system performance
System Part Load Efficiency	NR	NR	NR	inferred based on system curves	Simulate part load performance accurately
System Capacity	System Specifications	optional	optional	Nominal cooling capacity of the equipment	Provide recommendations based on equipment size calculated through AS.
Sensible Cooling Capacity	NR	NR	NR	Based on standard assumptions	
Cooling Supply Air Temperature	NR	NR	NR	Based on standard assumptions	
Chiller Plant					
Chiller > CHW Loop Design	NR	NR	NR	Standard Assumption- Modeled as variable primary.	
Chiller > CHW Pump Control Type	NR	NR	NR	Standard Assumption - Modeled as Primary only, variable speed pump.	
Chiller > CHW Pump Motor Efficiency	NR	NR	NR	Based on standard assumptions	
Chiller > CHW Pump Head	NR	NR	NR	Based on standard assumptions	
Chiller > Distribution Type	System Specifications	required	required	Fan Coil/ Single Zone AHU/ Multi Zone AHU	Assign appropriate terminal Units
Chiller > Compressor Type	System Specifications	required	required	Scroll-Screw/ Reciprocating/ Centrifugal	Correspondingly assign chiller curves for part load performance etc.
Chiller > Condenser Type	System Specifications	required	required	Air Cooled Condenser/ Water Cooled (Cooling Tower)/ Evaporative Condenser	Add capability to simulate evaporative condenser.
Chiller > Condenser Type >> Cooling Tower >>> Type	NR	NR	NR	Based on standard assumptions	
Chiller > Condenser Type >> Cooling Tower >>> Drive Type	NR	NR	NR	Based on standard assumptions	
Chiller > Condenser Type >> Cooling Tower >>> Capacity	NR	NR	NR	Based on standard assumptions	
Chiller > Condenser Type >> Cooling Tower >>> Fan Power	NR	NR	NR	Based on standard assumptions	
Chiller > Condenser Type >> Evaporative Condenser >>> Effectiveness	NR	NR	NR	Based on standard assumptions	
Chiller > Condenser Type >> Evaporative Condenser >>> Operation Range	NR	NR	NR	Based on standard assumptions	
Chiller > Condenser Type >> Evaporative Condenser >>> Condenser Power	NR	NR	NR	Based on standard assumptions	

Input Data Element	Data Collection Method	Input Rank-Simple	Input Rank-Verified	Description of Component	Purpose for AS and E+
Chiller > Condenser Type >> Evaporative Condenser >>> Water Side Economizer Type	NR	NR	NR	Based on standard assumptions (Strainer Cycle/ Heat Exchanger / Refrigerant Migration)	
Chiller > Condenser Type >> Evaporative Condenser >>> Water Side Economizer Heat Exchanges Effectiveness	NR	NR	NR	Based on standard assumptions	
Chiller > Condenser Type >> Evaporative Condenser >>> Water Side Economizer Heat Exchanges Effectiveness	NR	NR	NR	Based on standard assumptions	
Heating					
System Type	System Specifications	required	required	No Heating/ Single Zone Central Furnace/ Multi-Zone Central Furnace/ Heat Pump/ Boiler/ Radiator/ Space Heater/ District Heat	Assign System type and corresponding distribution system
Year of Manufacture	System Specifications	required	required		Required to Infer User Inputs not provided
Number of Pieces of Equipment	visual inspection	required	required		
System Efficiency	System Specifications	optional	required	AFUE/ Thermal Efficiency/ Combustion Efficiency	Accurately simulate system performance
System Part Load Efficiency	NR	NR	NR	inferred based on system curves	Simulate part load performance accurately
System Capacity	System Specifications	optional	optional	Nominal heating capacity of the equipment	Provide recommendations based on equipment size calculated through AS.
Fuel Type	Visual Inspection	required	required	gas/ electricity / Oil	
Heating Supply Air Temperature	NR	NR	NR	The constant air temperature of the air used for heating the zone	Based on standard assumptions
Supplemental Heating	Visual Inspection	required	required	Gas/ Electric/ None	
Supplemental Heating > Coil Efficiency	System Specifications	optional	required	AFUE/ Thermal Efficiency/ Combustion Efficiency	Accurately simulate system performance
Supplemental Heating > Coil Capacity	System Specifications	optional	optional	System size	Autosized in E+.
Pre-Heat Coil	Visual Inspection	required	required	Gas/ Electric/ None	
Pre-Heat Coil > Coil Efficiency	System Specifications	optional	required	AFUE/ Thermal Efficiency/ Combustion Efficiency	Accurately simulate system performance
Pre-Heat Coil > Coil Capacity	System Specifications	optional	optional	System size	Autosized in E+.
Boiler Plant					
Boiler > Distribution Type	System Specifications	required	required	Fan Coil/ Single Zone AHU/ Multi Zone AHU/ Radiators	
Boiler > Draft Type	System Specifications	required	required	Mechanical/ Other Draft	
Heat Pump					
Heat Pump > Sink/Source Type	System Specifications	required	required	Air/ Ground	To simulate an Air Source heat pump or Ground Source Heat Pump
Heat Pump > Supplemental Heating Coil Type	NR	NR	NR	Electric/ Gas	Based on standard assumptions
Heat Pump > Supplemental Heating Control Temperature	NR	NR	NR	Maximum SAT from the supplemental heating coil.	Based on standard assumptions
Heat Pump > Crankcase Heater Capacity	NR	NR	NR	Prevents freezing of the coil when OAT is low.	Based on standard assumptions

Input Data Element	Data Collection Method	Input Rank-Simple	Input Rank-Verified	Description of Component	Purpose for AS and E+
Heat Pump > Crankcase Heater Shut Off Temperature	NR	NR	NR	Maximum OAT above which the compressor's crankcase heater is disabled	Based on standard assumptions
HVAC System Controls					
Optimum Start Controls	NR	NR	NR	Based on standard assumptions	
Min VAV stop	NR	NR	NR	Based on standard assumptions	
Night Cycling HVAC Control	NR	NR	NR	Based on standard assumptions	
Cooling/ Heating SAT Reset based on OAT	NR	NR	NR	Based on standard assumptions	
Night Purge Availability/ Control	NA	NA	NA		Not Present in AS
Fan Position	NR	NR	NR	Based on standard assumptions	
Motor Position	NR	NR	NR	Based on standard assumptions	
Ventilation					
Outdoor Air					
> Ventilation Rate	NR	NR	NR	OA Intake based on 62.1 2004 Requirements.	
> OA Damper Control	NR	NR	NR	Based on standard assumptions	
> Minimum Damper Position	NR	NR	NR	Based on standard assumptions	
Fans					
> Fan Control	NR	NR	NR	Constant Volume/ Variable Volume	Modeled based on system type.
> Fan Efficiency	System Specifications	optional	required		
> Fan Static Pressure	System Specifications	NR	NR	Calculated based on User Input and Standard Assumptions	
> Fan Capacity	System Specifications	NR	NR	Autosized in E+	
> Fan Motor Efficiency	System Specifications	optional	required		
Heat Recovery Ventilators (HRV)					
> HRV Present	visual inspection	required	required	Required to add heat recovery ventilators for exhaust air	Will be Added this FY
> HRV Effectiveness	System Specifications	optional	optional		Will be Added this FY
Economizers					
> Economizer Controls	System Specifications	NR	NR	Fixed Dry Bulb/ Differential Dry Bulb/ Fixed Enthalpy/ Differential Enthalpy	Based on Standard Assumptions
> Economizer Present	visual inspection	required	required	Maximum- Minimum DBT Limit/ Maximum-Minimum Enthalpy Limit	Based on Standard Assumptions
Miscellaneous Inputs					
Condenser Heat Recovery	NA	NA	NA		Not Present in AS
Building Automation System	NA	NA	NA		Not Present in AS
Humidifier	NA	NA	NA		Not Present in AS
Desiccant System	NA	NA	NA		Not Present in AS
Service Water Heating					
Fuel Type	Visual Inspection	required	required	Gas/ Electricity/ Oil	
Heat Pump Used	Visual Inspection	required	required	Yes/ No	
Year Installed	System Specifications	required	required		Will be added this FY- For SHW Inference
Distribution Type	System Specifications	required	required	distributed/looped	

Input Data Element	Data Collection Method	Input Rank-Simple	Input Rank-Verified	Description of Component	Purpose for AS and E+
Thermal Efficiency	System Specifications/ Visual Inspection	optional	required		
Tank Volume	System Specifications/ Visual Inspection	required	required		
Tank Insulation Thickness	System Specifications/ Visual Inspection	optional	required		
Tank Insulation R Value	System Specifications/ Visual Inspection	optional	required		
HW Use Details (Number of Faucets/ Shower Heads etc)	NR	NR	NR	Based on standard assumptions	

Appendix D

Energy Asset Score Report

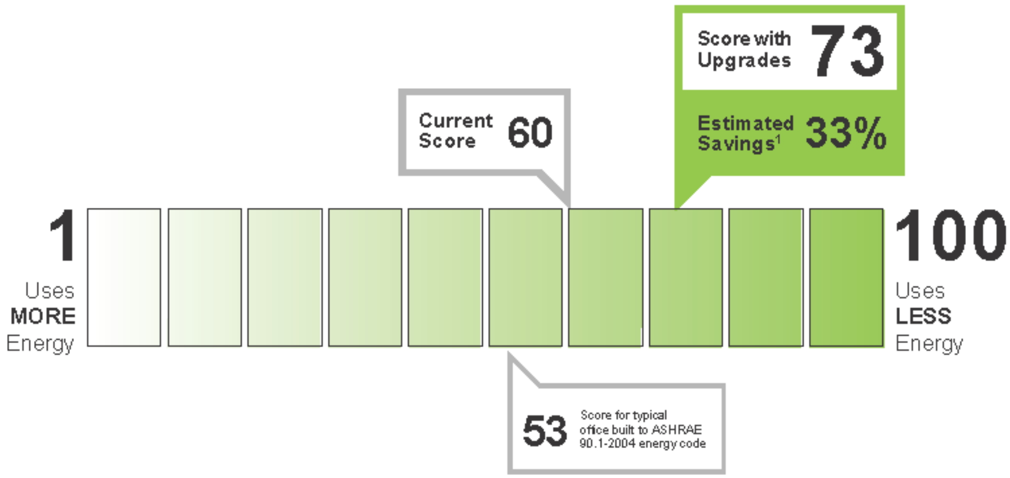
COMMERCIAL BUILDING
ENERGY ASSET SCORE

Score | Structure and Systems | Opportunities | Building Assets

Example Building
1 Main Road
Chicago, IL 60601

Building Type: **Office**
Gross Floor Area: **100,000 ft²**
Year Built: **2005**

Report #: **IL-1234567**
Score Date: **07/2011**



Model Assumptions for this Building Type

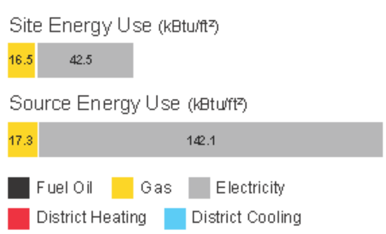
Number of Occupants	**500**
Hours of Operation	**96 hrs/wk**
Cooling Set Point	**70°F**
Heating Set Point	**73°F**
Misc. Energy Loads	**2.54 W/ft²**

Estimated Source Energy Use Under Model Assumptions[2] (kBtu/ft²)

Current Building	**159**
Upgraded Building	**107**
Typical Office	**187**

- 3 Story, 54,000 ft²
- Modeled under the same climatic conditions

Energy Use Intensity by Fuel Type



The **Commercial Building Energy Asset Score** is a national rating system developed by the U.S. Department of Energy. The **Score** reflects the energy efficiency of a commercial building based on the building's structure, heating, cooling, ventilation, and hot water systems. The **Structure and Systems** are the details on the current structure and systems for the building. The **Opportunities** show how to improve the energy efficiency of the building to achieve a higher score and save energy and money.

U.S. DEPARTMENT OF ENERGY

http://www1.eere.energy.gov/buildings/commercial/assetscore.html

[1] The savings are based on standard operating conditions as defined in the Model Assumptions above and reflect source energy savings. The upgrade opportunities are identified on the Opportunities page.

[2] Modeled energy use assumes typical operating and normal weather conditions as defined in the Model Assumptions for this Building Type.

COMMERCIAL BUILDING

ENERGY ASSET SCORE

Score | **Structure and Systems** | Opportunities | Building Assets

Example Building
1 Main Road
Chicago, IL 60601

Building Type: **Office**
Gross Floor Area: **100,000 ft²**
Year Built: **2005**

Report #: **IL-1234567**
Score Date: **07/2011**

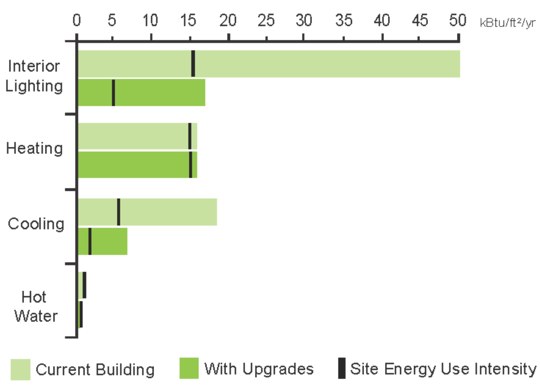
ABOUT THE BUILDING ENVELOPE

	Current Building	With Upgrades	Reference Value[1]	Ranking[2]	EEM Identified[3]
Roof U-Value (Btu/ft² h °F)	0.056	0.033	0.027 - 0.065	Good	✔
Floor U-Value (Btu/ft² h °F)	0.052	—	0.033 - 0.087	Good	
Walls U-Value (Btu/ft² h °F)	0.077*	—	0.064 - 0.123	Good	
Windows U-Value (Btu/ft² h °F)	0.68	0.30	0.35 - 0.67	Fair	✔
Walls + Windows U-Value (Btu/ft² h °F)	0.38	0.19	0.13 - 0.29	Fair	
Window Solar Heat Gain Coefficient	0.60	—	0.40 - 0.49	Fair	

ABOUT THE BUILDING SYSTEMS

	Current Building	With Upgrades	Reference Value	Ranking	EEM Identified
Interior Lighting[4] (kBtu/ft²)	50.40	30.00	21.99 - 38.74	Fair	✔
Heating[5]	0.32	—	0.11 - 0.18	Superior	
Cooling[5]	0.50*	1.10	0.46 - 1.32	Good	✔
Overall HVAC Systems[5]	0.46	0.80	0.31 - 0.97	Good	
Hot Water[5]	0.65	0.71	0.70 - 0.76	Fair	✔

SOURCE ENERGY USE INTENSITY BY END USE



	Current Building (kBtu/ft²/yr)		With Upgrades (kBtu/ft²/yr)	
	Source	Site	Source	Site
Interior Lighting	50.4	15.1	16.7	5.0
Heating	15.7	15.0	15.7	15.0
Cooling	18.7	5.6	6.7	2.0
Hot Water	1.6	1.5	1.0	1.0

[1] Range defined by ASHRAE 90.1 prototype building compliant with ANSI/ASHRAE/IESNA Standard 90.1, where 90.1-2004 and 90.1-2010 define Fair and Superior performance thresholds, respectively.

[2] Fair: less efficient than the reference value range.
Good: within the reference value range.
Superior: more efficient than the reference value range.

[3] Energy Efficiency Measure (EEM) identified on the **Opportunities** page.

[4] Source energy use.

[5] Ratio showing the level of service (heating, cooling, etc.) supplied by 1 unit of source energy. A higher ratio indicates a more efficient system.

*Value not directly entered by user. Value estimated from building properties entered by the user.

COMMERCIAL BUILDING
ENERGY ASSET SCORE

Score	Structure and Systems	Opportunities	Building Assets

Example Building
1 Main Road
Chicago, IL 60601

Building Type: **Office**
Gross Floor Area: **100,000 ft²**
Year Built: **2005**

Report #: **IL-1234567**
Score Date: **07/2011**

COST EFFECTIVE UPGRADE OPPORTUNITIES[1]

	Energy Savings[2]	Payback
Building Envelope		
• Add Roof Insulation in "Example Building"	5 - 10%	15 - 25 yrs
• Upgrade Windows in "Example Building" with High Performance Double Pane Windows	5 - 10%	10 - 15 yrs
Interior Lighting		
• Upgrade T8 Fluorescent Lighting in "Example Building" to High Efficacy T8 Fluorescent Lighting	10 - 15%	1.5 - 5 yrs
HVAC Systems		
• Upgrade Cooling System in "Example Building" with High Efficiency Terminal Electric DX	10 -15%	5 - 10 yrs
Hot Water Systems		
• Upgrade Service Hot Water System in "Example Building" with Improved System Efficiency	0 - 5%	< 1.5 yrs

[1] Text in quotes has been entered by user.

[2] The percent savings range reflects the expected incremental savings associated with the specific EEM assuming all other recommended EEMs have already been implemented. This assumption is made to avoid double counting of savings. The estimated savings reflect site energy savings and are based on the actual building operating conditions that the user entered.

COMMERCIAL BUILDING
ENERGY ASSET SCORE

Example Building
1 Main Road
Chicago, IL 60601

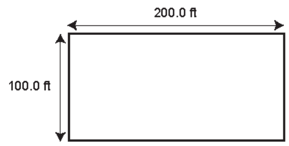
Building Type: **Office**
Gross Floor Area: **100,000 ft²**
Year Built: **2005**

Report #: **IL-1234567**
Score Date: **07/2011**

BUILDING SYSTEM CHARACTERISTICS SUMMARY

Geometry

Above Ground:	5 floor
Below Ground:	0 floor
Floor-to-Floor Height:	12.0 ft
Drop Ceiling Installed:	No
Floor-to-Ceiling Height:	9.0 ft
Orientation:	0.0° from North



	Current Building	Energy Code Requirements (ASHRAE 90.1-2004)
Roof		
Roof Type:	Built-up/EPDM w/metal deck	
Roof U-Value:	U-0.056	U-0.063
Wall		
Exterior Wall Type:	Brick/Stone on steel frame	
Wall U-Value:	U-0.077*	U-0.08
Floor		
Ground Coupling:	Slab	
Carpet Installed:	No	

	Current Building	Energy Code Requirements (ASHRAE 90.1-2004)
Windows		
Window Frame Type:	Metal	
Glass Type:	Single pane	
Gas Fill Type:	None	
Operable Windows:	No	
Window Layout:	Discrete	
Window to Wall Ratio:	0.4	
Window U-Value:	U-0.68	U-0.46
Window SHGC:	0.8	
Window VT:	0.7*	
Shading		
Exterior Shading Type:	External overhang	
Height Above Window:	0 ft	
Projection:	2 ft	
Skylight		
Skylights Installed:	No	
Indoor Lighting		
Lighting Type:	Fluorescent T8	
Mounting Type:	Recessed	
Percent of Total Floor Area Served:	100%	
Occupancy Controls:	Yes	
Daylighting Controls:	No	
EMCS/Timer:	No	
Lighting Power Density:	1.1 W/ft²*	1.0 W/ft²

*Value not directly entered by user. Value estimated from building properties entered by the user.

COMMERCIAL BUILDING
ENERGY ASSET SCORE

Score | Structure and Systems | Opportunities | **Building Assets**

Example Building
1 Main Road
Chicago, IL 60601

Building Type: **Office**
Gross Floor Area: **100,000 ft²**
Year Built: **2005**

Report #: **IL-1234567**
Score Date: **07/2011**

BUILDING SYSTEM CHARACTERISTICS SUMMARY

	Current Building	Energy Code Requirements (ASHRAE 90.1-2004)
Cooling		
Cooling Type:	Terminal DX	
Year of Manufacture:	2005	
Efficiency (COP):	2.54*	3.23
Heating		
Heating Type:	Single Zone Central Furnace	
Year of Manufacture:	2005	
# Pieces of Equipment:	1	
Efficiency:	82%	80%
Fuel Type:	Gas	
Ventilation		
Fan Efficiency:	80%	
Service Hot Water		
Fuel Type:	Gas	
Heat Pump Installed:	No	
Distribution Type:	Distributed	
Water Heater Efficiency:	80%	80%
Tank Volume:	80 Gallon*	
Tank Insulation Thickness:	2 in.*	

Facility Operation

The information in this section does not affect the current energy asset score. It is only used to identify upgrade opportunities. If the fields are left blank, standard schedules and operating conditions are used to identify upgrade opportunities.

Miscellaneous Electric Load:	4W/ft²
Miscellaneous Gas Load:	0 kBtu/ft²
Number of Days Open per Week:	5
Opening Time - Closing Time:	8AM – 7PM
Total Occupants:	450
Setpoint, Heating:	76°F
Setpoint, Cooling:	72°F

*Value not directly entered by user. Value estimated from building properties entered by the user.

Appendix E

Energy Costs Used in the Energy Asset Scoring Tool

Appendix E

Energy Costs Used in the Energy Asset Scoring Tool

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
1A	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	12-21	$2.85	$0.239
				Mid-Peak	9-11, 22-24	$0.91	$0.076
				Off-Peak	1-8	$0.85	$0.071
			Weekends/Holidays	Off-Peak	1-24	$0.85	$0.071
		Fall (September-November)	Weekdays	Peak	12-21	$1.13	$0.095
				Mid-Peak	8-11, 22-24	$0.81	$0.068
				Off-Peak	1-7	$0.77	$0.065
			Weekends/Holidays	Off-Peak	1-24	$0.77	$0.065
		Winter (December-February)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	8-23	$0.78	$0.065
				Off-Peak	24-7	$0.71	$0.059
			Weekends/Holidays	Off-Peak	1-24	$0.71	$0.059
		Spring (March-May)	Weekdays	Peak	13-21	$0.96	$0.080
				Mid-Peak	9-12, 22-23	$0.84	$0.070
				Off-Peak	24-8	$0.77	$0.065
			Weekends/Holidays	Off-Peak	1-24	$0.77	$0.065
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.080
				Mid-Peak	8-11,22-23		$0.068
				Off-Peak	24-7		$0.063
			Weekends/Holidays	Off-Peak	1-24		$0.063
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$9.33	$0.782
		High Demand Season (November-March)	All	All	1-24	$11.42	$0.957
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$133.74	$11.207
		High Demand Season (November-March)	All	All	1-24	$163.80	$13.726
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.15	$0.096
		High Demand Season (November-March)	All	All	1-24	$1.41	$0.118
2A	Electricity ($/kWh)	Summer (June-September)	Weekdays	Peak	14-21	$2.51	$0.210
				Mid-Peak	22-1, 11-13	$0.85	$0.071

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
				Off-Peak	2-10	$0.81	$0.068
			Weekends/Holidays	Off-Peak	1-24	$0.81	$0.068
		Fall (October-November)	Weekdays	Peak	13-23	$0.99	$0.083
				Mid-Peak	9-12	$0.78	$0.065
				Off-Peak	24-8	$0.75	$0.063
			Weekends/Holidays	Off-Peak	1-24	$0.75	$0.063
		Weekdays	Peak	NA	NA	NA	NA
				Mid-Peak	8-22	$0.85	$0.071
				Off-Peak	23-7	$0.77	$0.065
			Weekends/Holidays	Off-Peak	1-24	$0.77	$0.065
		Spring (March-May)	Weekdays	Peak	13-22	$1.06	$0.089
				Mid-Peak	10-12, 23-24	$0.87	$0.073
				Off-Peak	1-9	$0.82	$0.069
			Weekends/Holidays	Off-Peak	1-24	$0.82	$0.069
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.080
				Mid-Peak	8-11,22-23		$0.072
				Off-Peak	24-7		$0.066
			Weekends/Holidays	Off-Peak	1-24		$0.065
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.60	$0.721
		High Demand Season (November-March)	All	All	1-24	$11.85	$0.993
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$123.31	$10.333
		High Demand Season (November-March)	All	All	1-24	$169.94	$14.241
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.06	$0.089
		High Demand Season (November-March)	All	All	1-24	$1.46	$0.122
2B	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	9-21	$2.47	$0.207
				Mid-Peak	NA	NA	NA
				Off-Peak	22-8	$0.74	$0.062
			Weekends/Holidays	Off-Peak	1-24	$0.74	$0.062
		Fall (September-November)	Weekdays	Peak	13-21	$0.94	$0.079
				Mid-Peak	11-12	$0.86	$0.072
				Off-Peak	22-10	$0.79	$0.066
			Weekends/Holidays	Off-Peak	1-24	$0.79	$0.066
		Winter (December-February)	Weekdays	Peak	7-9, 18-22	0.92	$0.077
				Mid-Peak	10-13	$0.88	$0.074
				Off-Peak	23-6, 14-17	$0.82	$0.069

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
			Weekends/Holidays	Off-Peak	1-24	$0.82	$0.069
		Spring (March-May)	Weekdays	Peak	13-21	$0.89	$0.075
				Mid-Peak	10-12, 22-23	$0.80	$0.067
				Off-Peak	24-9	$0.74	$0.062
			Weekends/Holidays	Off-Peak	1-24	$0.74	$0.062
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.075
				Mid-Peak	8-11,22-23		$0.069
				Off-Peak	24-7		$0.066
			Weekends/Holidays	Off-Peak	1-24		$0.066
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.37	$0.701
		High Demand Season (November-March)	All	All	1-24	$11.78	$0.987
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$120.05	$10.060
		High Demand Season (November-March)	All	All	1-24	$168.88	$14.152
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.03	$0.086
		High Demand Season (November-March)	All	All	1-24	$1.45	$0.122
3A	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	12-19	$3.48	$0.292
				Mid-Peak	8-11, 20-23	$0.89	$0.075
				Off-Peak	24-7	$0.82	$0.069
			Weekends/Holidays	Off-Peak	1-24	$0.82	$0.069
		Fall (September-October)	Weekdays	Peak	12-20	$0.91	$0.076
				Mid-Peak	7-11, 21-22	$0.79	$0.066
				Off-Peak	23-6	$0.76	$0.064
			Weekends/Holidays	Off-Peak	1-24	$0.76	$0.064
		Winter (November-February)	Weekdays	Peak	6-11, 18-21	0.84	$0.070
				Mid-Peak	12-17	$0.79	$0.066
				Off-Peak	22-5	$0.75	$0.063
			Weekends/Holidays	Off-Peak	1-24	$0.75	$0.063
		Spring (March-May)	Weekdays	Peak	12-21	$0.97	$0.081
				Mid-Peak	7-11	$0.88	$0.074
				Off-Peak	22-6	$0.77	$0.065
			Weekends/Holidays	Off-Peak	1-24	$0.77	$0.065
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.075
				Mid-Peak	8-11,22-23		$0.068
				Off-Peak	24-7		$0.065
			Weekends/Holidays	Off-Peak	1-24		$0.064

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.90	$0.746
		High Demand Season (November-March)	All	All	1-24	$11.95	$1.001
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$127.61	$10.694
		High Demand Season (November-March)	All	All	1-24	$171.38	$14.362
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.10	$0.092
		High Demand Season (November-March)	All	All	1-24	$1.47	$0.123
3B (LA)	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	13-19	$3.59	$0.301
				Mid-Peak	9-12, 20-23	$0.94	$0.079
				Off-Peak	24-8	$0.59	$0.049
			Weekends/Holidays	Off-Peak	1-24	$0.59	$0.049
		Weekdays	Peak	NA	NA	NA	NA
				Mid-Peak	9-22	$1.40	$0.117
				Off-Peak	23-8	$0.71	$0.059
			Weekends/Holidays	Off-Peak	1-24	$0.71	$0.059
			Weekdays	Peak	11-15, 18-22	1.04	$0.087
					8-10, 16-17	$0.96	$0.080
					23-7	$0.72	$0.060
				Off-Peak	1-24	$0.72	$0.060
			Weekdays	Peak	12-18	$1.08	$0.091
					8-11, 19-23	$0.97	$0.081
					24-7	$0.65	$0.054
				Off-Peak	1-24	$0.65	$0.054
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.097
				Mid-Peak	8-11,22-23		$0.086
				Off-Peak	24-7		$0.058
			Weekends/Holidays	Off-Peak	1-24		$0.058
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.77	$0.735
		High Demand Season (November-March)	All	All	1-24	$11.22	$0.940
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$125.72	$10.535
		High Demand Season (November-March)	All	All	1-24	$160.95	$13.488
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.08	$0.091
		High Demand Season (November-March)	All	All	1-24	$1.38	$0.116

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
3B	Electricity ($/kWh)	Summer (June-September)	Weekdays	Peak	14-20	$3.60	$0.302
				Mid-Peak	9-13, 21-22	$0.83	$0.070
				Off-Peak	23-8	$0.71	$0.059
			Weekends/Holidays	Off-Peak	1-24	$0.71	$0.059
		Fall (October-November)	Weekdays	Peak	17-21	$1.00	$0.084
				Mid-Peak	7-16	$0.95	$0.080
				Off-Peak	22-6	$0.83	$0.070
			Weekends/Holidays	Off-Peak	1-24	$0.83	$0.070
		Winter (December-February)	Weekdays	Peak	17-21	0.91	$0.076
				Mid-Peak	7-16	$0.79	$0.066
				Off-Peak	22-6	$0.75	$0.063
			Weekends/Holidays	Off-Peak	1-24	$0.75	$0.063
		Spring (March-May)	Weekdays	Peak	12-21	$0.87	$0.073
				Mid-Peak	7-11	$0.81	$0.068
				Off-Peak	22-6	$0.73	$0.061
			Weekends/Holidays	Off-Peak	1-24	$0.73	$0.061
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.075
				Mid-Peak	8-11,22-23		$0.069
				Off-Peak	24-7		$0.065
			Weekends/Holidays	Off-Peak	1-24		$0.065
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.90	$0.746
		High Demand Season (November-March)	All	All	1-24	$11.83	$0.991
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$127.68	$10.700
		High Demand Season (November-March)	All	All	1-24	$169.57	$14.210
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.10	$0.092
		High Demand Season (November-March)	All	All	1-24	$1.46	$0.122
3C	Electricity ($/kWh)	Summer (July-September)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	8-11, 17-18	$1.53	$0.128
				Off-Peak	19-7, 12-16	$1.11	$0.093
			Weekends/Holidays	Off-Peak	1-24	$1.11	$0.093
		Fall (October-November)	Weekdays	Peak	9-20	$0.95	$0.080
				Mid-Peak	6-8, 21-23	$0.79	$0.066
				Off-Peak	24-5	$0.74	$0.062
			Weekends/Holidays	Off-Peak	1-24	$0.74	$0.062
		Winter (December-April)	Weekdays	Peak	NA	NA	NA

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
				Mid-Peak	8-22	$1.29	$0.108
				Off-Peak	23-7	$0.77	$0.065
			Weekends/Holidays	Off-Peak	1-24	$0.77	$0.065
		Spring (May-June)	Weekdays	Peak	9-18	$1.01	$0.085
				Mid-Peak	7-8, 19-23	$0.75	$0.063
				Off-Peak	24-6	$0.66	$0.055
			Weekends/Holidays	Off-Peak	1-24	$0.66	$0.055
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.088
				Mid-Peak	8-11,22-23		$0.082
				Off-Peak	24-7		$0.061
			Weekends/Holidays	Off-Peak	1-24		$0.061
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$9.36	$0.784
		High Demand Season (November-March)	All	All	1-24	$11.18	$0.937
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$134.26	$11.251
		High Demand Season (November-March)	All	All	1-24	$160.36	$13.438
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.15	$0.096
		High Demand Season (November-March)	All	All	1-24	$1.38	$0.116
4A	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	12-20	$3.41	$0.286
				Mid-Peak	8-11, 21-23	$1.02	$0.085
				Off-Peak	24-7	$0.83	$0.070
			Weekends/Holidays	Off-Peak	1-24	$0.83	$0.070
		Fall (September-November)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	7-24	$0.88	$0.074
				Off-Peak	1-6	$0.72	$0.060
			Weekends/Holidays	Off-Peak	1-24	$0.72	$0.060
		Winter (December-February)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	7-20	$0.96	$0.080
				Off-Peak	21-6	$0.83	$0.070
			Weekends/Holidays	Off-Peak	1-24	$0.83	$0.070
		Spring (March-May)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	8-22	$0.95	$0.080
				Off-Peak	23-7	$0.77	$0.065
			Weekends/Holidays	Off-Peak	1-24	$0.77	$0.065
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.078
				Mid-Peak	8-11,22-23		$0.076

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
				Off-Peak	24-7		$0.066
			Weekends/Holidays	Off-Peak	1-24		$0.065
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$9.07	$0.760
		High Demand Season (November-March)	All	All	1-24	$11.99	$1.005
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$130.05	$10.898
		High Demand Season (November-March)	All	All	1-24	$171.95	$14.409
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.12	$0.094
		High Demand Season (November-March)	All	All	1-24	$1.48	$0.124
4B	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	11-20	$3.04	$0.255
				Mid-Peak	8-10, 21-22	$0.86	$0.072
				Off-Peak	23-7	$0.85	$0.071
			Weekends/Holidays	Off-Peak	1-24	$0.85	$0.071
		Fall (September-October)	Weekdays	Peak	12-20	$0.91	$0.076
				Mid-Peak	7-11, 21-22	$0.80	$0.067
				Off-Peak	23-6	$0.76	$0.064
			Weekends/Holidays	Off-Peak	1-24	$0.76	$0.064
		Winter (November-February)	Weekdays	Peak	18-22	0.84	$0.070
				Mid-Peak	7-17	$0.81	$0.068
				Off-Peak	23-6	$0.75	$0.063
			Weekends/Holidays	Off-Peak	1-24	$0.75	$0.063
		Spring (March-May)	Weekdays	Peak	11-16, 19-21	$0.96	$0.080
				Mid-Peak	7-10, 17-18	$0.91	$0.076
				Off-Peak	22-6	$0.77	$0.065
			Weekends/Holidays	Off-Peak	1-24	$0.77	$0.065
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.075
				Mid-Peak	8-11,22-23		$0.069
				Off-Peak	24-7		$0.065
			Weekends/Holidays	Off-Peak	1-24		$0.064
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.33	$0.698
		High Demand Season (November-March)	All	All	1-24	$11.15	$0.934
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$119.46	$10.011
		High Demand Season (November-March)	All	All	1-24	$159.81	$13.392
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.03	$0.086

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
		High Demand Season (November-March)	All	All	1-24	$1.37	$0.115
4C	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	10-18	$2.25	$0.189
				Mid-Peak	7-9, 19-23	$0.96	$0.080
				Off-Peak	24-6	$0.64	$0.054
			Weekends/Holidays	Off-Peak	1-24	$0.64	$0.054
		Fall (September-October)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	8-23	$0.91	$0.076
				Off-Peak	24-7	$0.76	$0.064
			Weekends/Holidays	Off-Peak	1-24	$0.76	$0.064
		Winter (November-March)	Weekdays	Peak	8-12, 17-21	1.52	$0.127
				Mid-Peak	13-16, 22-23	$0.95	$0.080
				Off-Peak	24-7	$0.76	$0.064
			Weekends/Holidays	Off-Peak	1-24	$0.76	$0.064
		Spring (April-May)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	8-23	$0.76	$0.064
				Off-Peak	24-7	$0.60	$0.050
			Weekends/Holidays	Off-Peak	1-24	$0.60	$0.050
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.083
				Mid-Peak	8-11,22-23		$0.084
				Off-Peak	24-7		$0.059
			Weekends/Holidays	Off-Peak	1-24		$0.059
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$9.01	$0.755
		High Demand Season (November-March)	All	All	1-24	$11.10	$0.930
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$129.13	$10.821
		High Demand Season (November-March)	All	All	1-24	$159.20	$13.341
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.11	$0.093
		High Demand Season (November-March)	All	All	1-24	$1.37	$0.115
5A	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	13-21	$3.08	$0.258
				Mid-Peak	10-12, 22-24	$1.05	$0.088
				Off-Peak	1-9	$0.76	$0.064
			Weekends/Holidays	Off-Peak	1-24	$0.76	$0.064
		Fall (September-October)	Weekdays	Peak	13-22	$1.07	$0.090
				Mid-Peak	9-12	$0.91	$0.076
				Off-Peak	23-8	$0.72	$0.060

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
			Weekends/Holidays	Off-Peak	1-24	$0.72	$0.060
		Winter (November-March)	Weekdays	Peak	18-22	1.21	$0.101
				Mid-Peak	8-17, 23-24	$0.99	$0.083
				Off-Peak	1-7	$0.80	$0.067
			Weekends/Holidays	Off-Peak	1-24	$0.80	$0.067
		Spring (April-May)	Weekdays	Peak	12-20	$1.20	$0.101
				Mid-Peak	9-11, 21-24	$1.01	$0.085
				Off-Peak	1-8	$0.78	$0.065
			Weekends/Holidays	Off-Peak	1-24	$0.78	$0.065
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.093
				Mid-Peak	8-11,22-23		$0.080
				Off-Peak	24-7		$0.066
			Weekends/Holidays	Off-Peak	1-24		$0.064
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.97	$0.752
		High Demand Season (November-March)	All	All	1-24	$11.78	$0.987
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$128.57	$10.774
		High Demand Season (November-March)	All	All	1-24	$168.85	$14.150
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.10	$0.092
		High Demand Season (November-March)	All	All	1-24	$1.45	$0.122
5B	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	11-20	$2.69	$0.225
				Mid-Peak	8-10, 21-22	$0.81	$0.068
				Off-Peak	23-7	$0.76	$0.064
			Weekends/Holidays	Off-Peak	1-24	$0.76	$0.064
		Fall (September-October)	Weekdays	Peak	13-20	$0.71	$0.059
				Mid-Peak	6-12, 21-22	$0.61	$0.051
				Off-Peak	23-5	$0.54	$0.045
			Weekends/Holidays	Off-Peak	1-24	$0.54	$0.045
		Winter (November-March)	Weekdays	Peak	9-17	1.1	$0.092
				Mid-Peak	7-8, 18-23	$1.07	$0.090
				Off-Peak	24-6	$0.93	$0.078
			Weekends/Holidays	Off-Peak	1-24	$0.93	$0.078
		Spring (April-May)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	7-22	$0.96	$0.080
				Off-Peak	23-6	$0.80	$0.067
			Weekends/Holidays	Off-Peak	1-24	$0.80	$0.067

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.076
				Mid-Peak	8-11,22-23		$0.073
				Off-Peak	24-7		$0.065
			Weekends/Holidays	Off-Peak	1-24		$0.063
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.28	$0.694
		High Demand Season (November-March)	All	All	1-24	$10.71	$0.897
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$118.69	$9.946
		High Demand Season (November-March)	All	All	1-24	$153.51	$12.864
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.02	$0.085
		High Demand Season (November-March)	All	All	1-24	$1.32	$0.111
6A	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	12-20	$3.32	$0.278
				Mid-Peak	9-11, 21-24	$0.97	$0.081
				Off-Peak	1-8	$0.78	$0.065
			Weekends/Holidays	Off-Peak	1-24	$0.78	$0.065
		Fall (September-October)	Weekdays	Peak	12-21	$1.11	$0.093
				Mid-Peak	8-11, 22-23	$0.84	$0.070
				Off-Peak	24-7	$0.80	$0.067
			Weekends/Holidays	Off-Peak	1-24	$0.80	$0.067
		Winter (November-March)	Weekdays	Peak	9-13, 18-22	1.16	$0.097
				Mid-Peak	14-17	$1.00	$0.084
				Off-Peak	23-8	$0.83	$0.070
			Weekends/Holidays	Off-Peak	1-24	$0.83	$0.070
		Spring (April-May)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	8-23	$0.89	$0.075
				Off-Peak	24-7	$0.71	$0.059
			Weekends/Holidays	Off-Peak	1-24	$0.71	$0.059
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.086
				Mid-Peak	8-11,22-23		$0.078
				Off-Peak	24-7		$0.065
			Weekends/Holidays	Off-Peak	1-24		$0.065
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.86	$0.742
		High Demand Season (November-March)	All	All	1-24	$11.53	$0.966
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$127.02	$10.644
		High Demand Season (November-	All	All	1-24	$165.38	$13.859

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
		March)					
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.09	$0.091
		High Demand Season (November-March)	All	All	1-24	$1.42	$0.119
6B	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	12-21	$2.27	$0.190
				Mid-Peak	8-11, 22-23	$0.79	$0.066
				Off-Peak	24-7	$0.76	$0.064
			Weekends/Holidays	Off-Peak	1-24	$0.76	$0.064
		Fall (September-October)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	8-18	$0.84	$0.070
				Off-Peak	19-7	$0.81	$0.068
			Weekends/Holidays	Off-Peak	1-24	$0.81	$0.068
		Winter (November-March)	Weekdays	Peak	8-11, 18-21	1.44	$0.121
				Mid-Peak	12-17	$0.87	$0.073
				Off-Peak	22-7	$0.79	$0.066
			Weekends/Holidays	Off-Peak	1-24	$0.79	$0.066
		Spring (April-May)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	7-23	$0.86	$0.072
				Off-Peak	24-6	$0.80	$0.067
			Weekends/Holidays	Off-Peak	1-24	$0.80	$0.067
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.078
				Mid-Peak	8-11,22-23		$0.081
				Off-Peak	24-7		$0.067
			Weekends/Holidays	Off-Peak	1-24		$0.067
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.32	$0.697
		High Demand Season (November-March)	All	All	1-24	$10.63	$0.891
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$119.26	$9.994
		High Demand Season (November-March)	All	All	1-24	$152.40	$12.771
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.02	$0.085
		High Demand Season (November-March)	All	All	1-24	$1.31	$0.110
7	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	10-21	$2.48	$0.208
				Mid-Peak	7-9, 22-23	$0.77	$0.065
				Off-Peak	24-6	$0.62	$0.052
			Weekends/Holidays	Off-Peak	1-24	$0.62	$0.052
		Fall (September-September)	Weekdays	Peak	NA	NA	NA

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
				Mid-Peak	8-21	$0.90	$0.075
				Off-Peak	22-7	$0.58	$0.049
			Weekends/Holidays	Off-Peak	1-24	$0.58	$0.049
		Winter (October-March)	Weekdays	Peak	8-13, 17-22	1.28	$0.107
				Mid-Peak	14-16	$1.00	$0.084
				Off-Peak	23-7	$0.86	$0.072
			Weekends/Holidays	Off-Peak	1-24	$0.86	$0.072
		Spring (April-May)	Weekdays	Peak	NA	NA	NA
				Mid-Peak	7-21	$1.13	$0.095
				Off-Peak	22-6	$0.82	$0.069
			Weekends/Holidays	Off-Peak	1-24	$0.82	$0.069
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.090
				Mid-Peak	8-11,22-23		$0.085
				Off-Peak	24-7		$0.064
			Weekends/Holidays	Off-Peak	1-24		$0.063
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.95	$0.750
		High Demand Season (November-March)	All	All	1-24	$11.41	$0.956
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$128.26	$10.748
		High Demand Season (November-March)	All	All	1-24	$163.63	$13.712
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.10	$0.092
		High Demand Season (November-March)	All	All	1-24	$1.40	$0.117
8	Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	9-23	$0.78	$0.065
				Mid-Peak	NA	NA	NA
				Off-Peak	24-8	$0.65	$0.054
			Weekends/Holidays	Off-Peak	1-24	$0.65	$0.054
		Fall (September-September)	Weekdays	Peak	8-23	$0.79	$0.066
				Mid-Peak	NA	NA	NA
				Off-Peak	24-7	$0.68	$0.057
			Weekends/Holidays	Off-Peak	1-24	$0.68	$0.057
		Winter (October-April)	Weekdays	Peak	8-23	1.61	$0.135
				Mid-Peak	NA	NA	NA
				Off-Peak	24-7	$0.81	$0.068
			Weekends/Holidays	Off-Peak	1-24	$0.81	$0.068
		Spring (May-May)	Weekdays	Peak	9-23	$0.77	$0.065
				Mid-Peak	NA	NA	NA

cz	Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost	Actual Energy Cost ($/unit)
				Off-Peak	24-8	$0.64	$0.054
			Weekends/Holidays	Off-Peak	1-24	$0.64	$0.054
		FED Winter (March-May)	Weekdays	Peak	12-21		$0.089
				Mid-Peak	8-11,22-23		$0.088
				Off-Peak	24-7		$0.059
			Weekends/Holidays	Off-Peak	1-24		$0.059
	Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$9.20	$0.771
		High Demand Season (November-March)	All	All	1-24	$11.56	$0.969
	Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$131.93	$11.056
		High Demand Season (November-March)	All	All	1-24	$165.76	$13.891
	Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.13	$0.095
		High Demand Season (November-March)	All	All	1-24	$1.42	$0.119

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