Understanding EPA's ENERGY STAR Energy Performance Scale

Close to 200,000 buildings across the country use EPA's ENERGY STAR energy performance scale to measure, benchmark, and track their buildings' energy performance.[1] As use of the scale grows, so does interest in why and how it functions as it does. This document offers background on the development of the ENERGY STAR energy performance scale, as well as how it relates to energy codes and the concept of net zero buildings.

Why does EPA offer an energy performance scale?

EPA's ENERGY STAR energy performance scale answers the question "how efficient is my building compared to others nationwide (or others in my portfolio, state, region)?" The scale puts a building's measured energy use in perspective, allowing owners, managers, prospective purchasers and tenants, and the public to make more informed decisions about how they manage and use buildings.

An example illustrates the value of the performance scale: Two office buildings that use the same amount of energy per square foot may have very different levels of energy efficiency. One might be open 15 hours a day, while the other is open 10 hours a day and has fewer occupants. Clearly, the building that supports more people for longer hours using the same amount of energy is more efficient. The ENERGY STAR energy performance scale takes into account the unique operating characteristics of each building and assigns a higher score to the more efficient building.

How does EPA develop the scale?

To develop the energy performance scale, EPA follows these steps[2]:

1) Identify the best available survey data that is representative of buildings nationwide and includes information about each building's function, size, energy use, and operation. The US Department of Energy's Commercial Building Energy Consumption Survey (CBECS), conducted every four years, is such a survey and forms the basis for most ENERGY STAR energy performance scales.
2) Assess how certain characteristics of the surveyed buildings relate to their energy use by conducting rigorous statistical analysis of the data. This includes:
    - For each type of building, evaluate dozens of physical and operational characteristics to identify those best correlated with overall building energy use. In addition to the size and location of the building, the characteristics may include hours of operation, number of workers, etc.
    - Develop and evaluate multiple statistical models that combine the key building characteristics.
3) Using the information gleaned from step 2, identify the model that best predicts the energy use of a particular type of building, taking into account the building's location and how it operates. EPA then tests the model with real buildings to make sure it accurately predicts energy use.

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[1] As of January 2011.

[2] For a more detailed technical description, please refer to EPA's Energy Performance Rating – Technical Methodology Document: http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf.

4) For each building in the survey, run the model to calculate predicted energy use and calculate the ratio of actual to predicted energy use (the "energy efficiency ratio").
5) Use the energy efficiency ratios to create a distribution of energy performance for the population of buildings represented by the survey data. This distribution forms the basis of the ENERGY STAR energy performance scale, with each percentage of the population equal to one point on the 1 to 100 scale. In other words, an office building that scores 50 performs at an average level, and one that scores 75 is more efficient than 75% of office buildings nationwide.

To determine the score for a particular building, EPA will then:

1) Use the statistical model to predict the building's energy use, given its size, location, hours of operation, and other relevant characteristics.
2) Calculate the building's energy efficiency ratio and determine where this ratio places the building on the 1 to 100 scale.

EPA updates the ENERGY STAR energy performance scale when new survey data becomes available, typically every four years following release of new CBECS data. As the energy performance of buildings changes over time, the performance scale will reflect these changes. For example, it will become more difficult to achieve a high score on the performance scale if buildings that operate very efficiently become more prevalent in the market.

Why doesn't EPA offer a performance scale for every type of commercial building?

EPA is often asked why some types of buildings can use the energy performance scale while others cannot. As described above, developing a scale that accounts for the operating characteristics of each building requires access to nationally representative, statistically robust survey data. Unfortunately, data that meets this standard is not available for all types of buildings. Anyone seeking to develop a commercial building energy performance scale grounded in real data faces this same limitation.

For those building types not eligible for the ENERGY STAR energy performance scale, EPA provides average energy use per square foot derived from the CBECS data, available at http://www.energystar.gov/ia/business/tools_resources/new_bldg_design/2003_CBECSPerformanceTargetsTable.pdf.

Why is the scale based on how much energy the building uses instead of what equipment it includes or its potential efficiency?

While it is important to understand and assess the equipment installed in a building, the energy performance of a building is not just a function of what equipment it includes, but of how that equipment is operated, commissioned, and maintained, and whether its components work in harmony.

It is not possible to determine a building's energy performance from a catalogue of the building's energy-related equipment.

The concept of a scale that rates a building's *potential* energy efficiency, independent of the way the building is operated, is attractive. The reality, however, is that there is no objective way to measure or benchmark a building's potential.

EPA uses actual energy use because it provides building owners with a complete picture of their buildings' performance and the context to understand if the equipment, integration, and operation are working as intended.

Why is EPA's scale based on the performance of existing buildings instead of theoretical "ideal" buildings, such as zero energy buildings?

The ENERGY STAR energy performance scale is based on existing buildings because this approach supports informed investment decisions that unlock the tremendous energy and carbon emissions reduction potential that exist in the commercial buildings market. A scale based on the estimated energy use of theoretical ideal buildings (e.g., net zero) would categorize most of today's buildings as poor performers, making it hard for investors to distinguish among them. Such a scale would also diminish the value of incremental improvements and establish a goal that many existing buildings can't reasonably achieve. While a handful of specially-designed buildings have achieved net-zero energy, most buildings today cannot – and likely will never be able to -- support enough on-site renewable energy to meet their energy needs, no matter how efficient they are.

A U.S. Department of Energy study, published in the ASHRAE Journal, found that "[i]n most cases, an older building cannot be a ZEB [zero energy building][3]." Furthermore, even for new buildings, with "today's technologies and practices, the technical potential is that 22% of the buildings could be ZEBs. With projected 2025 technologies, the technical potential is that 64% of the buildings could be ZEBs."[4] In other words, less than two-thirds of all new buildings in 2025 could theoretically produce as much energy as they use, assuming new technologies are developed, deployed, and used as anticipated. A scale based on the potential to achieve such buildings could discourage investment needed today in available, market-tested efficiency solutions.

Finally, a scale based on the existing population of buildings has the flexibility to change over time. If buildings that operate with very low energy become more prevalent in the market, higher energy using buildings will find it more difficult to score well on the ENERGY STAR energy performance scale. In the meantime, it is the lower performing/higher carbon existing buildings that have the greatest potential for energy and carbon reductions.

[3] Paul A. Torcellini and Drury B. Crawley, "Understanding Zero-Energy Buildings," ASHRAE Journal, September 2006.
[4] B. Griffith, P. Torcellini, et. al., "Assessment of the Technical Potential for Achieving Zero-Energy Commercial Buildings," NREL Conference Paper, NREL/CP-550-39830, June 2006.

How does the energy performance scale relate to energy codes?

The ENERGY STAR energy performance scale is related indirectly to energy codes, since most of the buildings on which it is based were subject to an energy code at construction. Unlike codes, however, the energy performance scale evaluates the actual, total energy use of these buildings, not the estimated energy use of their "regulated loads" (the portion of a building's energy use covered by the code).

Energy codes, which are typically updated every few years, set minimum standards for new buildings, such as the required level of insulation and efficiency of lighting and heating systems. Over time, the building stock theoretically becomes more efficient as newer codes penetrate the market. As the efficiency of existing buildings changes over time, the energy performance scale will reflect the changes, as demonstrated through updated survey data that form the basis of the scale.
In reality, the average energy use of existing buildings has not improved in recent years even as codes have changed substantially. After a decline from 1979 to 1986, the average energy intensity of commercial buildings remained roughly the same through 2003, the most current CBECS survey year.[5]

In terms of individual buildings, a recent analysis of LEED (Leadership in Energy and Environmental Design) buildings provides further evidence that buildings subject to newer codes (in fact, buildings designed to beat the code) are not always performing as expected; in many cases, these buildings perform worse than the CBECS average.[6]

Energy codes are critical to establishing minimum acceptable building practices, but do not provide insight into how buildings perform once those practices are implemented; the energy performance scale reveals how efficiently buildings are operating in the market.

How does the energy performance scale relate to "better-than-code" approaches for new construction, such as in LEED NC and ASHRAE 189.1?

The "better-than-code" approach entails comparing a new building's modeled energy use to the modeled energy use of the building if it just met the minimum requirements of the building energy code. EPA's ENERGY STAR energy performance scale is based on the measured performance of buildings in the market, rather than code specifications or modeled energy use.

Energy codes are critical to establishing minimum acceptable building practices, and energy modeling is an invaluable tool to inform design and technology decisions; however, the practice of modeling a proposed building relative to its modeled minimum code-compliant baseline for the purposes of specifying performance and recognizing efficiency needs to be re-evaluated.

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[5] U.S. Energy Information Administration, Overview of Commercial Buildings, 2003: http://www.eia.doe.gov/emeu/cbecs/cbecs2003/overview2.html
[6] New Buildings Institute, *Energy Performance of LEED for New Construction Buildings*, March 4, 2008.

Some advocates of a "better-than-code" approach to energy performance claim that energy codes, unlike the ENERGY STAR energy performance scale, cover all types of commercial buildings. While it is true that local officials apply energy codes to all types of commercial buildings, the codes themselves cover only a portion of the energy load of any particular building (the 'regulated load'). For some types of energy intensive buildings, such as hospitals and supermarkets, the regulated load may be less than half of the total energy use of the building.

Recent studies illustrate the concerns. The New Buildings Institute report entitled *Energy Performance of LEED NC Buildings* discovered that in addition to one-quarter of the study buildings grossly underperforming in energy efficiency (energy performance worse than the average building), there was a huge range of variability in actual building performance relative to modeled performance, ASHRAE 90.1 code baseline, LEED peers, national building stock, and ENERGY STAR ratings.[7] Follow up evaluations of this dataset by John Scofield [8] further explore why the "better-than-code" approach falls short of establishing and achieving aggressive performance targets in individual buildings, and improving commercial building stock efficiency as a whole.

While sub-par construction, lack of commissioning, and poor O&M practices no doubt contribute to the underperformance of LEED certified buildings, the more fundamental driver may be the inherent inability of a better-than-code approach to set consumption targets that are realistic, aggressive relative to the peer market, and clearly communicated throughout the design, construction, and operation of the building.

[7] http://www.newbuildings.org/downloads/Energy_Performance_of_LEED-NC_Buildings-Final_3-4-08b.pdf
[8] http://www.oberlin.edu/physics/Scofield/pdf_files/Scofield%20IEPEC%20paper.pdf