An Evaluation of America's First ENERGY STAR® Buildings: The Class of 1999

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ABSTRACT

The ENERGY STAR® Label for Buildings (Label) was designed to facilitate comparisons of the energy performance of commercial buildings and recognize the most energy efficient and cost effective buildings in the country. The Label attempts to affect both the design and operation of buildings by:

- providing a rating system to measure building energy performance;
- defining a national goal for energy efficiency; and
- creating a certification mark to recognize achievement.

The goal of the Label is to motivate building owners and property managers to improve the energy performance, occupant comfort, and cost effectiveness of commercial buildings while minimizing their deleterious impact on our energy resources and natural environment. By providing a simple metric that evaluates and communicates building energy performance, ENERGY STAR hopes to make understanding building energy performance easier for all parties involved in the design, construction, and operations of commercial buildings. With this knowledge it is further hoped that building designers, owners, operators, appraisers, and lenders will be motivated to identify and pursue mutually beneficial, cost-effective solutions at improving the energy efficiency and indoor performance of commercial buildings.

At the end of its first year, the Label has seen nearly 1,000 users assess the energy performance of over 2,000 buildings through the ENERGY STAR benchmarking tool. Out of those buildings, ninety have earned the ENERGY STAR Label. These first 90 buildings provide a unique opportunity to not only to evaluate the capabilities of the ENERGY STAR benchmarking algorithms at accurately rating the energy performance of buildings, but also identify the differences and similarities of these buildings as compared to their peers. The purpose of this paper, therefore, is to evaluate the range of energy performance, physical, and operational characteristics of the first 90 buildings against existing commercial buildings. Closer examination of these buildings beyond their basic physical and operational characteristics also hopes to identify these buildings as providing full feature, high amenity environments, and identify any operational and technological solutions which may favor superior building energy performance.

Introduction

Numerous methods for measuring energy performance in a building exist. Evaluation methodologies range from complex modeling coupled with short and long term monitoring, to simple billing analysis and benchmarking. However, these existing methodologies lack the ability to readily communicate an energy-based metric comparing individual building performance against the performance of the national building market. The Label is designed to augment these approaches by providing a comparable means to assess building energy performance on an equitable and easily understood 0 to 100 scale. This metric is the basis for demonstrating energy performance in earning national recognition via the ENERGY STAR Label. In addition to being among the top 25% of the market in terms of energy performance, – a 75 or greater on the benchmarking scale, buildings must also demonstrate compliance with industry, namely American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (ASHRAE 1990, 1992) and Illuminating Engineering Society of North America (IESNA) (IESNA 1993), indoor comfort and health.

Central to this rating system is the identification and relative impact of the principal drivers of source energy intensity using regression modeling of data collected through *A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures* (CBECS) (EIA 1998). CBECS is a national sample survey of commercial buildings conducted every 3 to 4 years by the Energy Information Agency (EIA). The survey collects data on building structures, energy consumption, activities, and equipment.

The analysis identified the drivers of energy consumption in office buildings as:

- occupants density;
- weekly operating hours;
- personal computer density;
- building size; and
- cooling degree days.

By removing the impact of these drivers as well as non-office spaces and weather, an office building can be benchmarked against similar office buildings. Thus, an evaluation of the characteristics and performance of the 1999 ENERGY STAR Buildings compared to like sources of data can be made. Through such an evaluation it can be determined whether the first 90 ENERGY STAR Buildings are collectively meeting the programmatic goals of the Label. Perhaps more importantly, this retrospective evaluation offers an opportunity to explore what collection of features and practices are common to buildings nationally recognized as energy efficient.

Approach

In the initial phase of the evaluation, energy, cost, and operating characteristics of the 1999 ENERGY STAR Buildings dataset were compared to CBECS and the Building Owners and Managers Association International (BOMA) *Energy Exchange Report 1997* (EER) (BOMA 1997) datasets. Next, a more detailed evaluation of the physical and operational characteristics of the 1999 ENERGY STAR Buildings dataset and CBECS was performed to assess the presence of building equipment and systems, management practices, and amenities. Since building ownership or management for each of the first 90 ENERGY STAR Buildings chose to apply for the Label, this dataset must be considered a self-selected sample and, as such, is subject to self-selection bias. What follows, then, are the results and conclusions found in simply comparing the first 90 buildings, the 1999 ENERGY STAR Buildings, to other known datasets.

ENERGY STAR Buildings 1999 Database

Through the applicants requisite use of the internet-based benchmarking tool, building characteristics, energy consumption, and expenditure data was collected for 90 commercial office buildings totaling over 40 million square feet of gross floor space representing 17 states and the District of Columbia (Figure 1). To be eligible to apply, buildings are required to:

- have at least 5,000 square feet of gross building area;
- have at least 50% of its gross building area used as office space;
- be in use at least 11 of the previous 12 months; and
- be in operation at least 35 hours per week on average.

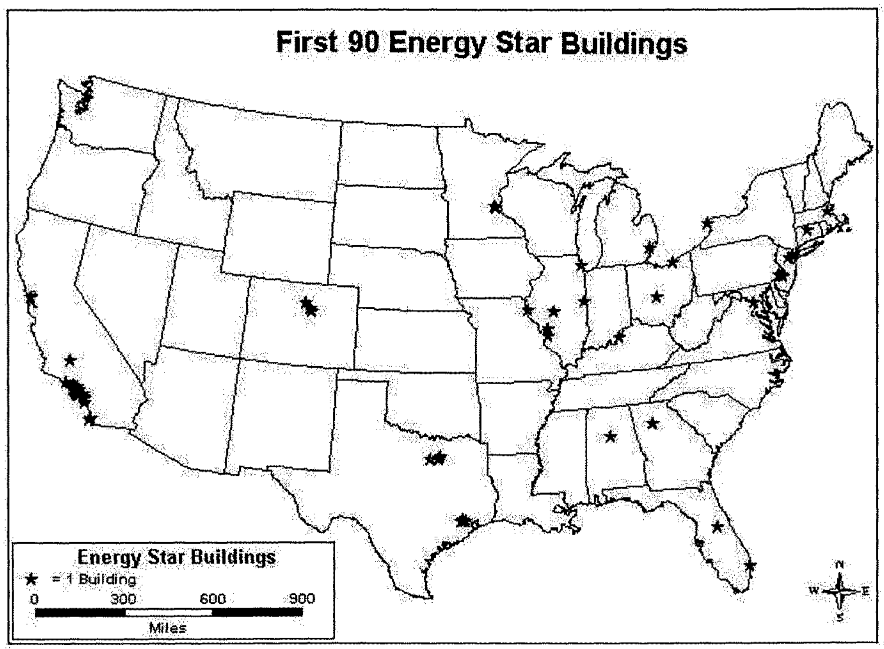

Figure 1. Location of 1999 ENERGY STAR Buildings

Additional data on HVAC and energy management equipment and systems, management, amenities, and architectural characteristics were collected through interviews with the building representatives upon earning the ENERGY STAR designation. Of the 90 office buildings that earned the ENERGY STAR Label in 1999, 74 volunteered to take part in an exit interview typically lasting 15 to 20 minutes. In order to render the Label dataset more physically and operationally comparable to other datasets, four of the 74 building records each having a total gross building area less than 50,000 ft^2 were removed from the dataset.

CBECS Database

The 1995 CBECS contains building characteristics, energy consumption, and energy expenditure data for 5,766 commercial buildings representing all fifty states and the District of Columbia of which 1,228 are U.S. office buildings. The CBECS sample was designed so that survey responses can be used to estimate characteristics of the entire stock of commercial buildings in the United States (EIA 1998; 4). To accomplish this objective, sampling weights were calculated that relate the sampled buildings to the entire stock of commercial buildings. For the analysis contained herein, sampling weights were applied to the CBECS dataset. To produce a more level comparison, the ENERGY STAR eligibility requirements and screening criteria used to develop the ENERGY STAR benchmarking algorithms were applied to the CBECS datasets reducing the total number of office buildings in the working data set to 530 from 1,228 in the raw CBECS data set. The following eligibility requirements were applied:

- Building area $\geq$ 5,000 square feet;
- Weekly Hours $\geq$ 35; and
- Months in use $\geq$ 11.

For the purposes of the leveling the comparison, the following screens were also applied:

- Building area $\geq$ 50,000 square feet;
- Electricity consumption > 0; and
- # of workers > 0.

Additional analysis included evaluations of upper and lower quartile energy performance amongst the 530 CBECS records. Rather than using a simple site or source energy intensity to determine which quartile a record belonged, each of the 530 records was assessed using the same algorithms used in the ENERGY STAR benchmarking tool. This analysis resulted in 144 buildings in the upper quartile, the top 25%, of performance and 125 records in the lower quartile, or bottom 25%.

1997 BOMA Experience Exchange Report Database

The 1997 EER contains tables of operating income and expense data for 3,364 buildings located in 92 cities in the United States covering over 600 million square feet of office space. Access to the data was derived from the published tables; no direct access to microdata was made public. The EER contains National Cross-Tabulation tables that provide select analyses sorted by building location, age, and size. EER tabulated data is organized by city rather than census region and is therefore not directly amenable to location comparisons.

Results

As shown in Table 1, the site energy intensity of the 1999 ENERGY STAR Buildings was, on average, 44% lower than that of the average building stock as represented by CBECS. Similarly, the energy cost intensity of this group was $0.50/ft^2, or 30% – less than the average building stock as represented by CBECS and $0.56/ft^2, or 33% – less than the average building stock as represented in the EER The reported vacancy rate among the 1999 ENERGY STAR Buildings was nearly half of that reported in the EER. Site energy, source energy, and energy cost intensities of the upper quartile of CBECS buildings suggest that this group is outperforming the 1999 ENERGY STAR Buildings on average which is itself a subset of the upper quartile ostensibly.

Table 1. Comparison of Energy Use Intensity, Energy Cost Intensity, and Vacancy

	Site Energy Intensity ($kBtu/ft^2$-year)	Source Energy Intensity ($kBtu/ft^2$-year)	Energy Cost Intensity ($\$/ft^2$)	Vacancy (%)
ENERGY STAR	56.4	150.9	1.12	5.6
CBECS Average	101.1	261.8	1.62	--
CBECS Top 25%	48.2	113.9	0.81	--
CBECS Bottom 25%	217.0	511.0	2.80	--
BOMA EER	--	--	1.68	10.2

Table 2 provides results of select average building operating characteristics including gross floor area, weekly operating hours, occupant density, personal computer density, and percentage of buildings operating as all-electric in each population. Perhaps the most striking difference between the 1999 ENERGY STAR Buildings and the other datasets is found in the average building size where the ENERGY STAR Buildings were over twice the average size of the both the CBECS and EER datasets on average. While the reported weekly hours of ENERGY STAR Buildings were less than that of the CBECS average and CBECS upper quartile, the reported occupant density of the ENERGY STAR Buildings were significantly greater.

Table 2. Comparison of Select Building Characteristics

	Size (ft^2)	Weekly Hours (hrs/week)	Occupant Density (Occ./ksf)	PC Density (PCs/ksf)	% All Electric
ENERGY STAR	467,893	70.6	3.32	3.33	30%
CBECS Average	129,677	74.7	2.65	3.31	24%
CBECS Top 25%	123,051	78.6	2.72	3.54	30%
CBECS Bottom 25%	119,482	79.4	2.43	2.73	16%
BOMA EER	209,262	--	3.31	--	39%

Personal computer density, often used as a proxy for equipment load density, was relatively uniform across each dataset. Although source energy intensity, not site energy intensity, is used as the determinant for ENERGY STAR, the percentage of all-electric buildings—30%—earning ENERGY STAR in 1999 were consistent with the CBECS average and upper quartile populations of 24% and 30% respectively.

Closer examination of the all-electric ENERGY STAR Buildings in Figure 2 shows that the distribution of all-electric versus multi-fuel buildings were consistent across all score ranges. All totaled 22 of the 74 ENERGY STAR Buildings interviewed were all-electric with the remaining 52 being multi-fuel buildings. Fifty percent of the both the all-electric buildings and the multi-fuel buildings scored between 75 to 79. Distribution across other score ranges were consistent as well.

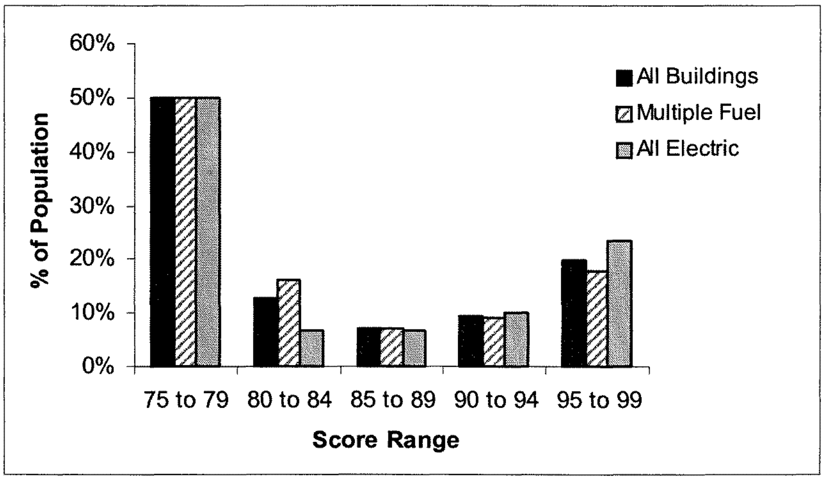

Figure 2. Distribution of Multiple-Fuel and All-Electric ENERGY STAR Buildings by Score

Table 3 provides more detailed building characteristics comparison results of the 1999 ENERGY STAR Buildings to those found in the CBECS average, upper quartile, and lower quartile. Selected characteristics are categorized by type: construction; HVAC; energy efficiency; management; and amenities. Two trends of note are present within the construction category. First, thirty percent of the 1999 ENERGY STAR Buildings reported as having glass as the primary wall construction material. Review of CBECS indicates buildings having glass as the primary wall construction material are generally more energy intensive; a fact that appears to be bore out by the lower incidence of glass in the CBECS average and upper quartile. Second, the median age of the 1999 ENERGY STAR Buildings, 1982, was four years older than the CBECS average and upper quartile median age of 1978 indicating that sets of data are of a similar vintage and likely subject to similar buildings codes and standards.

Looking at HVAC equipment revealed that the 1999 ENERGY STAR Buildings were much more likely to use a chiller for cooling and a variable air volume (VAV) system for comfort air distribution, while buildings in the CBECS average and upper quartile tended to use packaged units. Like the 1999 ENERGY STAR Buildings, buildings in the CBECS lower quartile – the worst performing buildings – tended to use a chiller for cooling and VAV system for distribution.

The 1999 ENERGY STAR Buildings, on average, showed a greater use of energy management systems (EMS), economizers, variable speed drives (VSDs), and motion sensors than buildings found in the CBECS average and upper quartile. Similar to results found with the HVAC equipment, the presence of energy efficiency equipment and systems amongst the ENERGY STAR Buildings generally tracked most closely with the buildings in the CBECS lower quartile. This suggests that while the 1999 ENERGY STAR Buildings typically contain efficient equipment, the mere presence of efficient technologies alone may not be indicative of an energy efficient building.

Table 3. Building, Equipment, and Management Characteristics of 1999 ENERGY STAR Buildings and CBECS Average, Upper Quartile, and Lower Quartile

	1999 ENERGY STAR Buildings	CBECS Average	CBECS Upper Quartile	CBECS Lower Quartile
# of Records	70	530	144	125
Construction				
Concrete	21%	16%	10%	22%
Glass	30%	15%	12%	20%
Masonry	44%	63%	71%	56%
Year (Median)	1982	1978	1978	1974
HVAC				
Boiler	35%	46%	32%	49%
Chiller	69%	43%	26%	65%
Packaged	25%	59%	70%	47%
VAV	76%	50%	36%	67%
Energy Efficiency				
EMS	93%	43%	23%	56%
Economizer	79%	55%	29%	73%
VSDs	73%	33%	19%	45%
Motion Sensors	61%	16%	8%	21%
Management				
Energy Audit	79%	24%	23%	36%
Regular O&M	99%	96%	92%	98%
Renovation	65%	--	--	--
Equip. Upgrade	87%	--	--	--
Amenities				
Class A	75%	--	--	--
Elevators	94%	--	--	--
Escalators	18%	--	--	--
Atriums	35%			
Balconies	27%	--	--	--

The 1999 ENERGY STAR Buildings were three times more likely to have had an energy audit conducted within the past three years than the CBECS average and upper quartile buildings, but just over twice as likely as the CBECS lower quartile. Reported operation and maintenance (O&M) was found to exceed 90% throughout each of the datasets. Although not collected by CBECS, 87% of 1999 ENERGY STAR Buildings reported having an energy upgrade for a major energy consuming component within the last three years, and nearly two-thirds reported having had a major renovation over the same time period.

While data on building amenities was not collected in CBECS nor the EER, a limited amount of such data was collected for the 1999 ENERGY STAR Buildings. As reported by the building owners and their building management, 75% of 1999 ENERGY STAR Buildings were considered Class A buildings defined by the BOMA building classification system as the most prestigious buildings competing for premier office users with rents above average for the area. Given the reported quality of the 1999 ENERGY STAR Buildings, not surprisingly 94% of the buildings used elevators, 35% contained an atrium, 27% contained a balcony, and 18% used escalators.

Conclusions

Since the 1999 ENERGY STAR Buildings must be considered a self-selected sample and the Label is still early in its development, definitive conclusions regarding the effectiveness of the Label, the benchmarking tool, and their characteristics must be made with caution. However, based on the data and analysis of the buildings that earned the Label in 1999, the programmatic goals of the ENERGY STAR Label for Buildings appear on track. Supporting this claim is found in the fact that the energy performance of the 1999 ENERGY STAR Buildings is demonstrably better than the average stock of buildings; specifically that the average site energy intensity of the 1999 ENERGY STAR Buildings was 44% lower than the market average. As designed, the performance of buildings corresponding to the ENERGY STAR threshold – the 75th percentile – should be roughly 27% more efficient than the market average. A value of 44% lower than the market average suggests that the average energy performance of the 1999 ENERGY STAR Buildings well exceeds ENERGY STAR threshold. Additionally, the average energy cost intensity of the 1999 ENERGY STAR Buildings was 30% to 33% lower than the market average meeting the stated program design objective of 30% to 35%. It follows then, for the 90 buildings earning the Label in 1999, the rating system of ENERGY STAR Buildings has indeed identified buildings whose energy performance and cost is superior to market averages.

In addition to meeting the energy and cost intensity objectives, the 1999 ENERGY STAR Buildings appear to be of high quality, both in objective and subjective terms. In order to apply for ENERGY STAR, buildings must be verified by a professional engineer to meet current standards for indoor environment: ASHRAE 62 - 1989 for ventilation and control of indoor air pollutants; ASHRAE 55 - 1992 for adequate temperature and humidity levels; and IESNA Lighting Handbook - 1993 for proper illumination levels. This coupled with the fact the 75% of the 1999 ENERGY STAR Buildings were reported to be Class A space suggest that among the buildings to have earned the Label in 1999 the goal for recognizing high quality buildings has been met.

The other program goal – to fairly assess individual building energy performance independent of fuel choice – also appears to be on track as evidenced by the percentage of all-electric buildings represented in each dataset. The 1999 ENERGY STAR Buildings are found to follow the national average in their fuel consumption mixes with all-electric and mixed-fuel buildings being equally distributed throughout qualifying ranges of ENERGY STAR scores (i.e. percentiles). In addition, the 1999 ENERGY STAR Buildings are found in both expensive and inexpensive energy markets. These results indicate that while market conditions undoubtedly factor into the owners and operators decisions to pursue efficiency, these considerations are not exclusively evident in the pursuit of efficient buildings. Confirming, at least for the 1999 ENERGY STAR Buildings, the equitable treatment that fuel use has received in the ENERGY STAR benchmarking tool.

Beyond the commonality of superior energy performance, the 1999 ENERGY STAR Buildings exhibit a diversity of characteristics. This diversity suggests that there is no definable path to achieving energy efficiency and that energy performance may be achieved with various technical approaches and operating practices. While one could argue that based on comparisons of the 1999 ENERGY STAR Buildings to the CBECS average and upper quartile buildings that the presence of certain features such as chillers, VAVs, an EMS, economizers, VSDs, and motion sensors will likely yield an energy efficient building, a like comparison to the CBECS lower quartile conflicts with this simple conclusion. A further exploration of the characteristics reveals that ENERGY STAR Buildings have a very high incidence rate of energy audits (79%), efficiency upgrades (87%), and major renovations (65%) suggesting a building or corporate level commitment to investing in energy efficiency. This commitment is also current, with those indicating major renovations and audits as completed in 1996 and 1998 respectively.

Evaluating the 1999 ENERGY STAR Buildings, the Label, thus far, has met the intended technical objectives: equitably assessing building energy performance independent of fuel use and recognizing high quality, energy efficient office buildings. While no one path leading to energy efficiency can be positively discerned, a strong case for good practice technologies coupled with motivated building management appears to exist.

References

American National Standards Institute (ANSI) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 1992. *ANSI/ASHRAE Standard 55-1992, Thermal Environmental Standards for Human Occupancy*. ISSN 1041-2336. Atlanta, GA.

ANSI/ASHRAE. 1990. *ANSI/ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality*. ISSN 1041-2336. Atlanta, GA.

Energy Information Administration (EIA). 1998. *A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption and Expenditures*. DOE/EIA-0625(95). Washington, DC.

Building Owners and Managers Association International (BOMA). 1997. *BOMA Energy Exchange Report*. ISSN 0738-2170. Washington, DC.

Illuminating Engineering Society of North America (IESNA). 1993. *Lighting Handbook, 8th Edition*. ISBN 0-87995-102-8. New York, NY.