US Commercial Building Energy Performance Sector-Wide, 1996–2016

Michael MacDonald
Energy Performance Measurement Institute (EPMI)
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Interest in rating the real-world energy performance of commercial buildings has led to a wide array of applicable energy performance measurement systems, and such systems continue to be developed today (for US examples, see http://energystar.gov and https://www.ashrae.org/technical-resources/building-eq). But moving beyond individual buildings toward city-, state-, or country-wide performance, complexities can increase (see *Cox et al* for some discussion, http://iopscience.iop.org/article/10.1088/1748-9326/8/3/035018/pdf).

EPMI has examined means of measuring country-wide energy performance, and this technical note examines US commercial building energy performance from 1996 to 2016 in five-year intervals for the entire country.

Simplified Performance Measurement

A simple and straightforward way of quantifying and comparing building energy performance is accomplished by using annual total energy to determine energy intensity values. Annual total energy is the sum of the energy content of all fuel used by a building in one year. Energy intensity is the total energy used divided by the total floor area. It is also possible to examine annual energy and energy intensities for individual fuels. The strength of energy intensities as a performance measure lies in ease of use and widespread familiarity. However, with this simplified approach, knowledge is lacking regarding causes of variation that have been observed and the relative impacts of factors such as schedules, functional uses, and density of use on the energy performance. The more complicated energy performance measurement systems for buildings have been developed to help account for impacts of other factors such as these.

As *Cox et al* present, there is no national performance measurement system readily recognized, although EPMI has presented simplified energy performance for the entire United States and all individual states, covering all end-use sectors (http://epminst.us/states/Backing%20into%20State-led%20Energy%20Performance%20Focus.pdf). EPMI has presented state-level commercial energy performance grades also for all 50 states and the District of Columbia for the year 2014 (http://epminst.us/states/Grading%20the%202014%20Commercial%20Sector%20Energy%20Performance%20by%20State.pdf).

Many cities have begun performance measurement efforts focused on aggregating results from many individual buildings (e.g., see http://buildingrating.org), but true overall performance of all commercial buildings in a city is not known using such approaches, although extrapolation methods can be used to estimate overall performance.

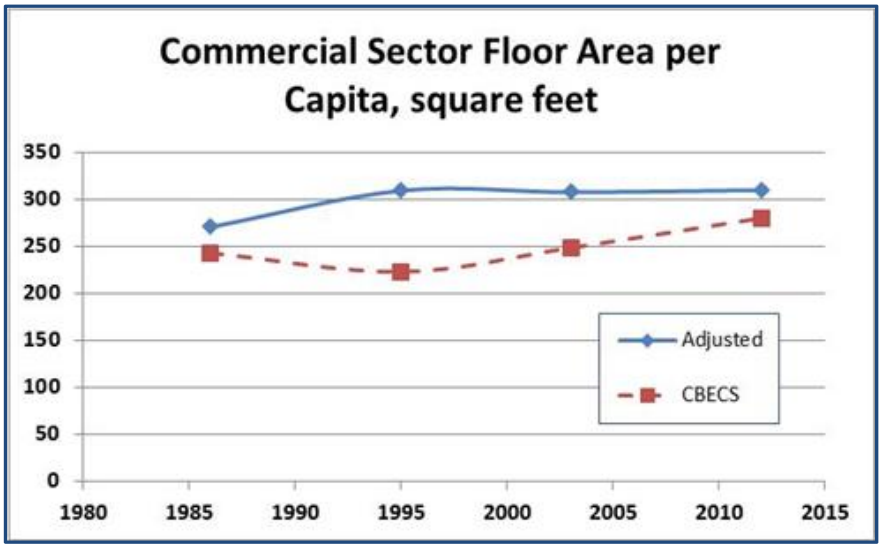
Knowledge developed previously in reporting on commercial sector energy use will be used here to present simplified measured energy performance results for commercial buildings country-wide.

Energy Use Indexes (EUIs)

The annual energy intensity mentioned above is one form of energy use index (EUI) based on dividing total annual energy use by total floor area of a building. EPMI has also indicated that measurement of commercial energy performance on scales wider than just an individual building or campus can be more effective if based on using population as the normalizing factor (energy use indexed to number of people).

Previous Results to Use for EUIs

Study of commercial sector energy use by EPMI, based on combining results from two sets of commercial sector data from the US Energy Information Administration (EIA), indicated that from 1995–2012, total US commercial sector buildings gross floor area remained constant at close to 310 square feet per capita, as shown by the curve labeled 'Adjusted' in the figure here. These results were significantly different than results based on EIA's Commercial Building Energy Consumption Survey (CBECS, https://www.eia.gov/consumption/commercial/), as shown by the red curve labeled 'CBECS' in this chart.[1]



The CBECS is conducted at multi-year intervals and focuses on obtaining fairly detailed data on buildings in the commercial sector (first data set). With the large diversity of commercial buildings, this detail has been important for developing a better understanding of energy use in this sector. Although the detail is valuable, there are limitations to the CBECS results (see report in footnote 1, pp 12–13), such as the issue that CBECS does not really capture the entire commercial sector (which also leads to the red curve in the figure above being lower than the blue curve). The CBECS limitations are why EPMI has also extensively studied EIA's SEDS data (the second data set). The State Energy Data System (SEDS) is the EIA's comprehensive repository of US state-level energy statistics (http://www.eia.gov/state/seds/). SEDS provides a historical time series of data for the whole country and by state that are defined as consistently as possible over time and across sectors for analysis and forecasting purposes. SEDS focuses on covering energy use in total, which is challenging given the wide array of energy sources and means of distribution.

In order to truly measure total US commercial building energy performance, the most straightforward approach is to cover the entire commercial sector, which means the SEDS data must be used. Analysis at the level of entire countries must typically be based first on easily understandable simple indexes or performance metrics. EUIs are simple metrics that are well known. US sector-wide commercial building EUIs will be covered next. National

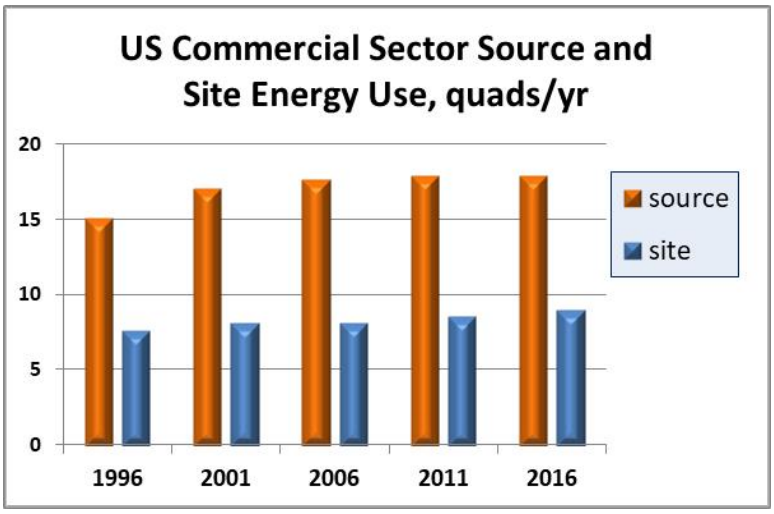
[1] *Understanding Commercial and Service Sector Energy Use*, EPMI, pp 44–46, November 2016. http://epminst.us/commercial/Understanding%20commercial%20and%20service%20sector%20energy%20use.pdf

EUIs can tell us exactly what energy performance improvements or declines have occurred for the entire sector of commercial buildings in the United States.

US National EUIs from 1996–2016

Using the simple relationship of 310 square feet of commercial building floor area per capita for the entire country, total floor area of the entire commercial sector can be calculated for specific years as a function of population. Based on previous study, this calculation should be expected to be accurate within less than 1% potential error (less than 3 out of 300 expected error).

The US commercial sector national source and site energy values are taken directly from SEDS data parameters (TECCB and TNCCB), where source energy has electricity losses included and 'site' energy does not. While there may be quibbles about exactly what energy is included or excluded in source and site energy, the results are mainly interesting for the relative changes observed. The relative changes should remain close to what is presented here, regardless of what finessing is done to the energy quantities involved.

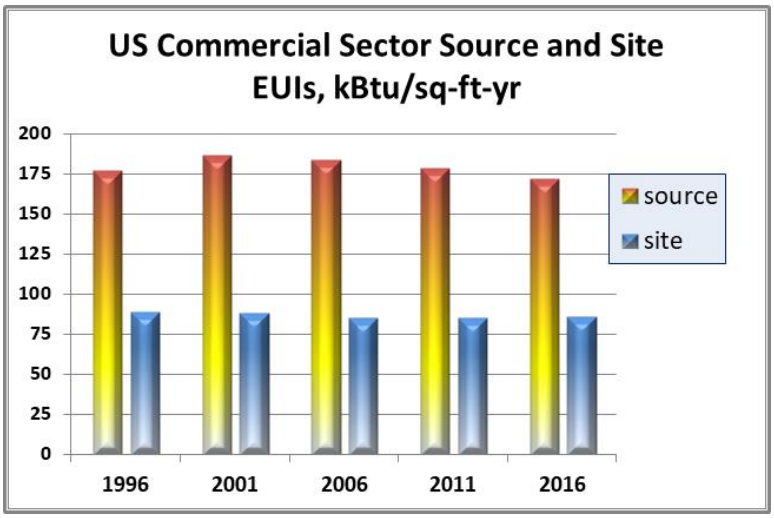


The first figure here presents these US commercial sector source and site energy values (direct SEDS data values) for the years 1996, 2001, 2006, 2011, and 2016.

Population data are taken from US Census intercensal estimates (July 1 of each year) for the same years to calculate total US commercial sector floor area as shown in the table below.

The source and site EUI values are then calculated as total commercial sector energy use divided by total floor area, as shown in the next figure.

US Commercial Buildings Total Area		
Year	Population (millions)	Floor area (billions sq-ft)
1996	265.2	85.6
2001	285.0	91.9
2006	298.4	96.3
2011	311.6	100.5
2016	323.4	104.3



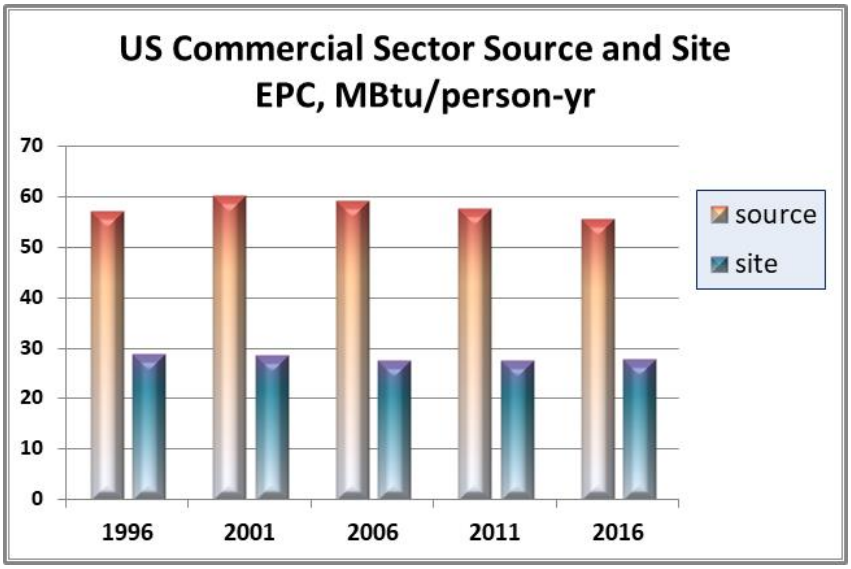
The site EUIs have remained almost constant for this 20-yr period, dropping from 89 kBtu per ft^2 in 1996 to 85 in 2006, but nudging back up to about 86 in 2011 and 2016.

The source EUI went up from 1996 to 2001, but has been on a downward trend since then, from 186 in 2001 down to 172 in 2016 (even lower than the EUI of 177 in 1996).

Since floor area is based directly on population, energy per capita changes will exactly mirror EUI changes, and a per-capita metric will provide the same results as a floor area metric. Per-capita values are shown next.

Per-Capita Energy Metric (EPC)

Total US commercial sector energy use per capita (EPC) will also be presented for source and site energy, in million Btu (MBtu) per person-yr. The EPC values are a direct calculation of energy performance based on population, and the EUI values here are derivative, but many years of experience by practitioners with EUI values allows existing knowledge and expertise to be compared to these results.



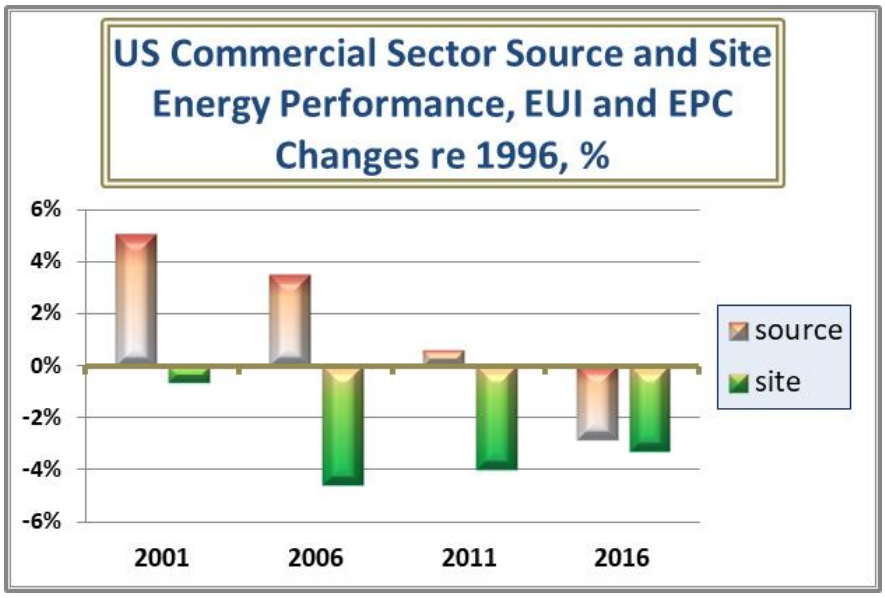
The figure here shows the source and site EPC values for US commercial buildings sector-wide for the same years.

The site EPC decreased from 28.7 MBtu per capita in 1996 to 27.4 in 2006, and increasing slightly to 27.6 and 27.8 in 2011 and 2016 respectively.

The source EPC decreased from 60.1 in 2001 to 55.6 in 2016.

Energy Performance as Change in Index Value from 1996 to 2016

The figure here displays the percent change in sector-wide EUI and EPC relative to 1996 as a base year. This percent change can be considered an energy performance value for all commercial buildings in the entire country for a given year relative to 1996. Negative changes represent energy use reductions and positive changes show energy use increases. Changes in EUI and EPC are identical with the approach used here.



Since energy air emissions track most closely with source energy, the source energy performance indicates air emissions reductions for the commercial sector relative to 1996 indexes. The first figure in this presentation shows that total source energy use has been held stable (and was a slight reduction) relative to 2011.

Reductions in EUI and EPC are an important accomplishment for the country, indicating energy efficiency improvements overall are progressing for commercial buildings. The sector-wide energy performance is impacted by the mix of commercial buildings, but from a worldwide perspective, the energy performance of entire countries (and entire sectors in countries) is of interest.

Conclusion

The energy performance of all commercial buildings in the United States (sector-wide performance) has been quantified using EUI and EPC for five-year intervals from 1996 to 2016. The energy performance results indicate the commercial sector site EUIs reduced from 1996 to 2006, but began to increase slowly from 2006 to 2016. Of more import relative to air emissions from energy use, source EUIs have been decreasing from 2001 to 2016, and in 2016 are less than in 1996.

The truly sector-wide EUIs developed here are based on data results developed to represent the commercial sector as a whole, and not on attempted extrapolation of data for individual buildings to claim representation for the entire sector.

The energy performance results seen in 2016 for source energy are encouraging re efforts to reduce air emissions from energy use in the commercial sector.

The next CBECS is planned to cover information for reference year 2018, and results may be available by 2021 or so. With a new CBECS, evaluation of the building population influences on EUIs from 2012 onward should be able to be determined. Until that time SEDS (and related) data will have to suffice.