What Metrics Make the Most Sense?

Benchmarking Building Energy Use

BY DAVID N. SCHURK, MEMBER ASHRAE

When considering how to improve a building's energy footprint, it is critical to understand how the building is performing. Benchmarking can help to compare the building's energy performance to something similar, such as the like performance of the building at the same time last year, or the like performance compared to similar facilities (peer buildings) elsewhere. Several simple benchmarking approaches used today will provide insight to help identify energy consumption.

Energy Use Intensity

One recognized method of building benchmarking is to enter the utility bill information into the Energy Star Portfolio Manager. This provides insight into the building's energy use intensity, or EUI. The EUI is defined as the total amount of energy used by a building (electricity, natural gas and other fuels) per square foot of floor area (annually), and is used to establish the facility's baseline energy use. ANSI/ASHRAE Standard 105-2014, *Standard Methods of Determining, Expressing, and Comparing Building Energy Performance and Greenhouse Gas Emissions* defines this square footage as "gross floor area," and further states that it includes the sum of the floor area of all the spaces within the building with no deductions for floor penetrations other than atria. Once established, the building's EUI can then be tracked over time and compared to that of others (of like type). The lower the EUI (and higher the Energy Star label) the better the energy performance.

Source EUI is the total amount of raw fuel that is consumed in the operation of a building. It takes into account all transmission, delivery and production losses. Also, it can provide a more comprehensive assessment of the environmental (or resource) effects of a building.

Site EUI is the amount of energy consumed by a building as reflected in the utility bill(s). Site EUI may be more important to a building owner because it represents the actual energy purchased and provides a baseline in determining how much this energy use may change over time. The EPA relies on source EUI as the basis for the Energy Star labeling system, but Portfolio Manager makes both metrics available to the user.

Site EUI is a relatively straightforward calculation that requires identification of the energy used in the facility

David N. Schurk is director of health care accounts for Heat Transfer Solutions in Houston.

by adding up all the units of energy (in this case Btus) purchased. The yearly consumption of gas and electricity may be found by aggregating the values for each, listed on monthly utility bills.

Natural gas can be converted to Btus by multiplying the number of therms purchased × 100,000 Btu/therm. Likewise, kWh of electricity is converted to Btus by multiplying kWh purchased × 3,412 Btu/kWh.

To calculate site EUI, simply find the total square footage of gross floor space and divide the total Btus used per year by the square footage of space. For example, a hospital with 500,000 ft^2 (46 452 m^2) of conditioned space uses 470,000 therms (50 000 GJ) of gas and 14.2 million kWh of electricity in one year.

What is the hospital's site EUI?

- Gas: 470,000 therms × 100,000 Btu/therm = 47 billion Btu/yr (50 000 GJ/yr).
- Electricity: 14.2 million kWh × 3,412 Btu/kWh = 48.5 billion Btu/yr (51 000 GJ/yr).
- Total Btu/ft^2·yr: 95.5 billion Btu ÷ 500,000 ft^2 = 190,920 Btu/ft^2·yr (2169 MJ/m^2·yr).

Note: While electricity and natural gas are referenced, there may be other fuels involved as well.

This may be broken down further into a more common measurement used in commercial building benchmarks, thousand Btus per square foot (kBtu/ft^2), by dividing the number derived above by 1,000: kBtu/ft^2·yr = 190,920 Btu/ft^2 ÷ 1,000 = 191 kBtu/ft^2·yr (2169 MJ/m^2·yr).

Table 1 shows some typical source and site EUIs for various building types as listed in the Commercial Building Energy Consumption Survey (CBECS) and reported by the U.S. Energy Information Administration (EIA). These represent national building median energy use in kBtu/ft^2·yr.

With information like this, a building's site EUI can be considered similar to a car's miles per gallon rating used to label the efficiency or economy of an automobile when compared to another. It allows one to relate total yearly gas and electricity consumption to industry standards, which can help in recognizing if the facility is on or off the energy mark when compared to others.

One of the challenges with using EUI for benchmarking energy is in fuel selection. Different fuels have a different cost impact on the site, regardless of how efficiently the process or systems use that energy. For example, two buildings may have similar EUIs (kBtu/ft^2), but if one is heated using natural gas and the other with electricity, the associated costs to heat these buildings would be different.

TABLE 1 2003 Commercial Buildings Energy Consumption Survey.

BUILDING USE	SOURCE EUI (KBTU/FT^2·YR)	SITE EUI (KBTU/FT^2·YR)
College University	244	104
Convenience Store	657	228
K-12 School	141	58
Fast Food	1170	418
Office & Bank	148	67
Strip Mall	247	94
Outpatient Health Clinic	194	67

Recent national average fuel costs (Jan. 2015) as made available by the EIA[1] would allow calculation of the following cost per million Btus purchased:

- Site cost/MMBtu of electricity: at $0.1062/kWh = $31.44 (at 99% efficiency).
- Site cost/MMBtu of natural gas: at $8.16/1,000 ft^3 = $10.20 (at 80% efficiency).

Energy Cost Intensity

EUI does not take energy cost into consideration, so another important and useful benchmark is the building's energy cost intensity (ECI). This is the dollar cost of energy used annually per square foot of conditioned space. To compute a facility's ECI, all the energy used in the facility needs to be identified, and the associated costs can be aggregated. Determine the gross square footage of conditioned space and divide the total dollars of energy used per year by the square footage.

For example, a hospital with 500,000 ft^2 (46 452 m^2) of conditioned space pays $470,000 per year for natural gas and $1.42 million per year for electricity.

What is the hospital's site ECI?

- Gas: $470,000/yr ÷ 500,000 ft^2 = $0.94/$ft^2$·yr ($10.10/m^2·yr).
- Electricity: $1.42 million/yr ÷ 500,000 ft^2 = $2.84/$ft^2$·yr ($30.57/m^2·yr).
- Total $/$ft^2$·yr: $470,000 (gas) + $1.42 million (electricity) ÷ 500,000 ft^2 = $3.78/$ft^2$·yr ($40.69/m^2·yr).

Note: The ECI is often preferred by financial decision makers, who find dollars easier to relate to than Btus.

The next step is to determine specifically where the energy is being consumed, so savings can be targeted in those areas that show the greatest use. Unless energy meters are installed on each piece of equipment, this determination may be made using an industry benchmark average for the building type under consideration. Be sure to consider local influences as it will reflect a more accurate estimate of the real consumption and savings potential.

Figures 1 and *2* were created from data that appears in the ASHRAE *HVAC Design Manual for Hospitals and Clinics*, reflecting hospital site energy use profiles for several large hospitals in Houston.

This provides insight into where and how much energy may be used throughout health-care facilities located in this region. Information like this can be used to help determine a reasonable approximation of a building's energy use per consumption category listed. Without definitive energy meter readings, this benchmarking method may prove to be a reasonable choice in arriving at an energy breakout.

Assuming the facility in question is well represented by any benchmark values, it's now easy to determine the major energy consumers. A simple spreadsheet can be made (*Tables 2* and *3*), which breaks down all processes by end use and calculates their dollar cost impact while ranking the results in order of magnitude.

Without first determining how much (and from where) energy is being used, there is no way to determine which efficiency measures should be studied, making it extremely difficult to define savings opportunities and partner with management for the project's financial support.

For this large Houston hospital, fan energy and reheating are the largest consumers and probably hold the biggest potential for utility bill savings. Applying resources accordingly will help produce the biggest return on any financial investments made to save energy.

Reducing fan and airside pressure drop, tuning boilers, calibrating temperature sensors, verifying scheduling (turning things off when they can be turned off) and making sure everything possible is being done to eliminate the need for reheat are all great places to start in reducing this building's energy cost footprint.

FIGURE 1 Typical large hospital electrical use for Houston.

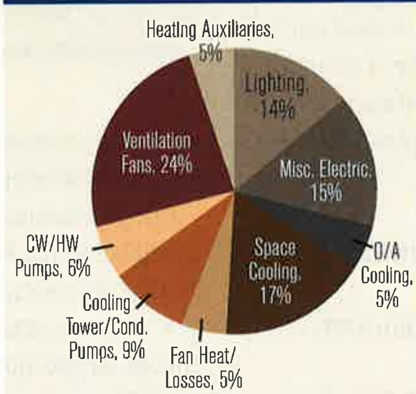
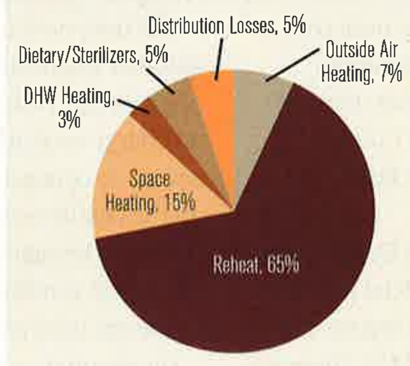


FIGURE 2 Typical large hospital gas use for Houston.



Regardless of whether EUI or ECI is used, a metric has been established from which a facility's energy consumption can be compared to itself over time or to others within the same industry. Both measurements indicate how much energy is being used (one in Btus and the other in dollars). However, these measurements alone may not provide insight into the true efficiency of a building, particularly if comparisons are made within an industry of poor energy performers.

Resource Cost Intensity?

One major issue in using the present methodologies for calculating EUI and ECI is that neither reflects the entire picture of a building's true operational cost footprint. Neither of these benchmarks takes water consumption (and water treatment costs) into consideration. Water is a utility and is billed in the same way as both gas and electricity.

The U.S. Environmental Protection Agency (EPA) reports that water use in the United States is increasing every year, with many areas feeling the pressure. In the last five years, nearly every region of the U.S. has experienced water shortages. At least 36 states are either anticipating or experiencing local, regional, or statewide water shortages, even under non-drought conditions. According to a recent report in *USA Today*,[2] users pay 75% more for water today than in 2000. The report predicted water rates will increase by a whopping 5% to 15% per year, outpaced only by heating oil.

Buildings that include water-cooled air conditioning, swimming pools, locker room showers, restaurants, etc., can consume large amounts of water. With this comes a direct cost that should be reflected in the operational budget. Water bills may include both a basic and volume charge as well as a sewer charge, as shown for the City of Houston commercial water rate structure for 2012 in *Table 4*.

TABLE 2 Electrical energy (cost) by process.

PROCESS	CONSUMPTION (%)	DOLLARS	RANK
Lighting	14	$198,800	4
Misc. Electrical	15	$213,000	3
Outdoor Air Cooling	5	$71,000	7
Space Cooling	17	$241,400	2
Fan Heat/Losses	5	$71,000	7
Cooling Tower & Pumps	9	$127,800	5
CW & HW Pumps	6	$85,200	6
Ventilation Fans	24	$340,800	1
Heating Auxiliaries	5	$71,000	7

500,000 ft^2 × \$2.84/ft^2 · yr electric = \$1.42 million/yr utility cost

TABLE 3 Gas energy (cost) by process.

PROCESS	CONSUMPTION (%)	DOLLARS	RANK
Outdoor Air Heating	7	$32,900	3
Reheat	65	$305,500	1
Space Heating	15	$70,500	2
DHW Heating	3	$14,100	5
Dietary/Sterilizers	5	$23,500	4
Distribution Losses	5	$23,500	4

500,000 ft^2 × \$0.94/ft^2 · yr gas = \$470,000/yr utility cost

TABLE 4 2012 City of Houston commercial water and sewer rates.

RATE	VOLUME CHARGE (WATER)	VOLUME CHARGE (SEWER)
Per 1,000 gallons	$3.74	$5.30

TABLE 5 400 ton cooling tower water consumption.

GPM CONSUMED	LOAD (%)	RUNTIME (%)	HR/YR	GAL/YR
18	100	1	87.6	94,608
18	75	42	3,679.2	2,980,152
18	50	45	3,942.0	2,128,680
18	25	12	1,051.2	283,824
		Total	8,760.0	5,487,264

An example of the impact water and chemical treatment can have on building operational cost will be examined. A small 400 ton cooling tower (used with water-cooled chillers) can use over 5 million gallons of makeup water each year (*Table 5*). This water is supplied to replace that which is consumed through evaporation, drift and blowdown, each an integral part of the tower's operational process. If this water is metered, only the basic water charge will be applicable, but if unmetered, sewer charges would be included in the bill.

Using the City of Houston volume water charge of \$3.74/1,000 gallons (\$0.99/1,000 L) (meter charges not included) results in a yearly water bill of over \$20,000. Add to this any necessary chemical treatment costs (estimated at \$3.00/1,000 gallons [\$0.79/1,000 L]), and the total dollar impact would be over \$37,000/year (not including sewer charges, tower fan and pump energy, maintenance, etc.). Large hospitals can have thousands of tons of chiller capacity, so the water and chemical costs for cooling towers alone could be substantial.[3]

Otherwise identical buildings might have slightly different EUIs due to the cooling equipment type installed, one using water-cooled chillers and towers and the other air-cooled (no towers required). If the impact of water is not accounted for, it might appear they are running at comparable efficiencies and assumed to cost about the same to operate, when in fact a metric that included the cost of water would tell a different story altogether. Perhaps a metric reflecting "resource cost intensity" in addition to ECI should be considered.

It's easy to see that gas and electricity make up only a part of the total equation when it comes to forming an approach aimed at both understanding and then reducing operational costs of a building. One may also conclude that water consumption can vary drastically from one building to another, even within the same category type. Water use can play a big factor in how much is spent each year on operations.

Moving forward, it may be prudent to consider water use in a similar manner to the more traditional energy consumers, with benchmarking taking the impact of water (its consumption and cost) into account.

It's also important to realize that comparing one building to another using only EUI can lead to a false impression of a facility's financial acuity unless fuel types and costs are included and compared. While recognizing source energy is important in guarding natural resources, at the end of the day it's what the building costs to operate that has the biggest impact on the owner's bottom line. Be sure to benchmark your building using measurements that produce metrics that make the most sense.

References

1. EIA. 2015. "Today in Energy." U.S. Energy Information Administration. www.eia.gov/todayinenergy/.

2. McCoy, K. 2012. "Water Costs Gushing Higher." *USA Today*. Sept. 29. http://tinyurl.com/q38e4pp.

3. Schurk, D. 2014. "Air-cooled chillers in health care applications." *Heating/Piping/Air-Conditioning Engineering* (5):24 –29. ■