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Energy use assessment of educational buildings: Toward a campus-wide sustainable energy policy

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ABSTRACT

The purpose of this article is to assess the viability of blanket sustainability policies, such as Building Rating Systems in achieving energy efficiency in university campus buildings. We analyzed the energy consumption trends of 10 LEED-certified buildings and 14 non-LEED certified buildings at a major university in the US. Energy Use Intensity (EUI) of the LEED buildings was significantly higher (EUI_{LEED} = 331.20 kBtu/sf/yr) than non-LEED buildings ($EUI_{non\text{-}LEED}$ = 222.70 kBtu/sf/yr); however, the median EUI values were comparable (EUI_{LEED} = 172.64 and $EUI_{non\text{-}LEED}$ = 178.16). Because the distributions of EUI values were non-symmetrical in this dataset, both measures can be used for energy comparisons—this was also evident when EUI computations exclude outliers, EUI_{LEED} = 171.82 and $EUI_{non\text{-}LEED}$ = 195.41. Additional analyses were conducted to further explore the impact of LEED certification on university campus buildings energy performance. No statistically significant differences were observed between certified and non-certified buildings through a range of robust comparison criteria. These findings were then leveraged to devise strategies to achieve sustainable energy policies for university campus buildings and to identify potential issues with portfolio level building energy performance comparisons.

1. Introduction

Widespread reduction in building energy use will be a critical part of lowering green house gas emissions, and ultimately slowing global warming trends (IPCC, 2014). In the U.S., building industry accounts for over 40% of the annual energy demand and 40% of CO_2 emissions (USDOE, 2012). This paper presents an analysis of energy use of a large portfolio of buildings co-located at a major American university. The findings suggest that campus-wide sustainable building energy policies may benefit from de-emphasizing the role of ‘blanket’ classification schemes. Among others, incorporating expert measurement procedures to quantify outcomes of energy use (e.g., CO_2 emissions) can provide a more effective approach in reducing the overall energy use, and ultimately achieving effective sustainability policies.

1.1. Building design and energy efficiency

Several building energy improvement programs exist to promote energy efficiency. For example, the United States (US) Environmental Protection Agency (EPA) Energy Star program is a voluntary program developed to identify and promote a performance-based approach for new and existing buildings (https://www.energystar.gov/). The EPA’s Target Finder is a web-based tool that uses the 2003 U.S. Energy Information Agency’s Commercial Building Energy Consumption Survey (CBECS) data (EIA, 2003) to estimate projected Energy Use Intensities (EUI) based on the building occupancy type, area, fuel source and use derived from energy simulations. Examples of energy codes include California’s Title 24 (California Energy Commission, 2013) and the International Energy Conservation Code (IECC), which has been adopted by several states in the U.S. (ICC, 2012).

Regardless of these efforts, what brought the topic of energy efficiency into the attention of masses has been adoption of Building Rating Systems (BRS) with their promise on improved energy efficiency. In the US, the two major BRS are the Leadership in Energy and Environmental Design (LEED) guidelines of the US Green Building Council (USGBC) and Green Globes of the Green Building Initiative—the former with the significant market share.

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Building energy performance that primarily focuses on operational energy use is a major component in BRS. For example, 27% and 39% of the total points in the latest LEED and Green Globes rating systems are assigned to energy performance credits respectively (Srinivasan, 2013; USGBC, 2014).

Building energy use—and efficiency thereof—is a complicated phenomena affected by numerous *operational and design* characteristics. Architectural building design and, in a lesser extent, construction principles can significantly affect the overall energy use and efficiency (Ihm & Krarti, 2012; Sozer, 2010). Interestingly, the university policies reviewed for this study did not classify any design characteristics to be followed for increased energy efficiency. The closest adopted policy to a fundamental design-driven energy savings is the adoption of LEED building standards as the defining guidelines for new construction and major renovation activities. LEED and the other BRS are not necessarily design criteria, but benchmarks for building design and operation characteristics compared to different baselines for performance. Regardless, in most cases, LEED rating systems and others have been accepted to be the *de facto* design guidelines for energy efficiency and ultimately overall sustainability of the certified buildings. LEED rating system is the most widely accepted and adopted BRS in the U.S. with a total of over 44,000 registered and certified buildings since 2001. Note that this sum does not differentiate between the two—registration is a pre-requisite to certification but not necessarily guarantees it.

2. Energy efficiency comparisons of LEED and non-LEED buildings

Due to its widespread adoption and emphasis on promised energy savings, portfolio level energy performance assessment of LEED buildings have been the most prolific line of literature for performance-based energy consumption research. Turner and Frankel (2008) compared the operational efficiencies of recently constructed LEED certified buildings to non-certified buildings in the CBECS database (EIA, 2003), finding that the median EUI values of LEED certified buildings were 24% less than the national average. They extended their analysis to account for climate, building size, certification level, and building type and concluded that for all the analyses conducted, LEED buildings were found to be more energy efficient than non-LEED buildings.

Since then, several studies have re-analyzed the data to address the lack of completeness (∼25% of the data were reported originally) and to add statistical rigor. Newsham, Mancini, and Birt (2009) stratified the data by building description and expected energy demand. *T*-tests results showed that LEED buildings were 18-39% more efficient than their non-LEED counterparts; however, one-third of LEED buildings required more energy. No significant relationship between building energy, consumption trends, and LEED certification levels and energy credits were found in this study (Newsham et al., 2009). Subsequently, Scofield (2009) rejected the conclusion that LEED certified buildings were more energy efficient, comparing site (energy used by the building) and source (incorporates the off-site losses associated with distribution and generation) energy consumption data. Scofield further argued that building size should also be used in the comparisons—because of the relative significance of renewable energy production as a fraction of overall energy use—and showed that they can alter the results when area-based weighting is used in computations.

Results from an evaluation of electricity and water consumption of U.S. Navy LEED buildings, showed that nine of the eleven buildings evaluated did not meet the 30% energy savings goal set by the administration, whereas only two of the nine buildings have not met the water saving goals when compared to similar buildings under Naval Command (Menassa, Mangasarian, El Asmar, & Kirar, 2012). The authors also stated that the majority of the Naval LEED buildings were consuming more electricity than the comparable buildings from CBECS data. Lastly, Scofield (2013) compared energy efficiency of 21 office LEED buildings to a large dataset of 953 non-LEED buildings and concluded that LEED buildings did not show any energy improvements when compared to non-LEED buildings. The author, however, identified differences in energy performance among different certification levels, for example, gold certified buildings were found to save source energy whereas silver certified and basic certified buildings were not.

In the following sections, we discuss the energy efficiency of a large LEED educational portfolio, i.e., buildings situated in a university campus setting, and discuss the implications of adopting LEED building rating system as a blanket policy on overall energy performance and how well the design component of energy efficiency is met by this policy.

3. Energy efficiency in higher education buildings

Higher education institutions have been early and comprehensive adopters of building energy efficiency and sustainability policies. For example, more than 680 universities have signed the American College and University Presidents' Climate Commitment (AUPCC) agreement, which requires participating institutions to reduce greenhouse gas emissions. University campuses are an excellent study set to assess the design and enforcement of sustainability and energy efficiency policies. The building stock is usually highly uniform and maintained by the same entity under a standard set of policies and best practices in energy use. The variations are generally confined to the construction time and details of building functionality combinations (e.g., teaching, research, laboratory, administration). This is a sharp contrast to majority of commercial construction (the most common projects that seek BRS certification), as there are multiple parties involved throughout project life cycle with different levels of engagements and priorities. Another benefit of study campuses is the extensibility of results. A brief review of the Association for the Advancement of Sustainability in Higher Education (AASHE) website—which outlines university energy policies—revealed that the generally accepted best operational practices in energy efficiency (e.g., temperature set points for HVAC systems, multiple/individual zones for controls, assigning individual responsibilities for saving energy, etc.) are, for the most part, consistent across universities. Interestingly, LEED certification appears to be the most prominent design related guideline; although, as discussed earlier, the certification guidelines are not necessarily devised to serve this purpose.

Although the LEED energy efficiency topic has been analyzed in great detail in earlier literature, no clear conclusions were drawn about energy performance of LEED buildings; thus, their capacities as a de facto design consideration criteria. We provide detailed analyses of energy consumption of 10 LEED-certified and 14 non-LEED educational buildings, all of which are located on main campus of the University of Florida (UF), in Gainesville, Florida. Monthly consumption data for chilled water, steam, and electricity for 2013 were used to analyze energy consumption trends to assess the viability of BRS-based blanket sustainable energy policies for university campuses.

3.1. Building descriptions

UF has one of the largest LEED educational building portfolios with 29 LEED-certified buildings (Dougherty, 2010). Because multiple comparable non-certified buildings to LEED-certified buildings exist on campus with available data, a realistic comparative