Emerging Strategies for Effective Energy Efficiency Benchmarking: Normalization, Economic Analysis, and Data Aggregation

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ABSTRACT

The market is being transformed by energy data. Information from the first generation municipal disclosure requirements across the US is widely influencing conversations about commercial real estate. The market is quickly recognizing an important new financial consideration in commercial real-estate transactions: comparative building energy use data. Although this trend represents significant progress toward better management of building sector energy use, the common tools in the market used to normalize, compare, and aggregate building performance tend to be over-simplified, and inadequate as a basis for complicated financial comparisons in leasing and purchase transactions. This presentation explores three aspects of this issue that can support more robust and effective market impacts of comparative benchmarking strategies:

1. How the factors used (or omitted) in data normalization for comparative building performance benchmarking can result in misleading assessments of key real estate value propositions;
2. A new analytical approach that accounts for the comparative economic contribution of commercial building tenants with respect to total building energy consumption as a basis for building performance comparisons, and;
3. New approaches to the design and implementation of data aggregation and analysis for large, heterogeneous sets of commercial buildings, including discussion of fundamental design principles for scalable information infrastructures and emerging approaches to integrating energy efficiency metrics across the lifecycle of commercial buildings.

Taken together, this paper provides a cross-cutting perspective on current and emerging opportunities to improve the viability and effectiveness of commercial sector energy performance benchmarking in driving meaningful market transformation.

Introduction

The market is being transformed by energy data. Information from the first generation municipal disclosure requirements across the US is widely influencing conversations about commercial real estate. The market is quickly recognizing an important new financial consideration in commercial real-estate transactions: comparative building energy use data. Although this trend represents significant progress toward better management of building sector energy use, current comparison metrics tend to be over-simplified, based on limited availability of deeper performance characteristics that would allow more accurate comparisons. For example, a common metric of comparison is Energy Use Intensity (EUI) which is a simple normalization of annual energy use and building square footage. This metric is easy to calculate from readily available utility data and building physical characteristics, and has therefore achieved significant prominence in discussions of comparative building performance. But this metric, and other common tools in the market used to normalize, compare, and aggregate building performance tend to be over-simplified, and inadequate as a basis for complicated financial comparisons in leasing and purchase transactions.

Rationale for Normalization

Normalization is a strategy to increase the comparability and relevance of energy consumption data. It is ubiquitous and often hardly considered in day-to-day practice. However, it also has far-reaching implications for the evaluation and comparison of buildings.

The most basic forms of normalization typically involve time. Absolute energy consumption is normalized to provide time-bounded metrics, such as kilowatts per hour or metric tonnes of CO2 equivalent per year. This is relatively straightforward.

Next, data are typically normalized with respect to the amount of building space served by this energy, such as kBTU per square foot or square meter. In theory, this becomes a measure of efficiency as this metric reflects energy used to meet the needs of a specific unit of space. However, this small step is often complicated by varying definitions of floor area, such as gross square footage, net leasable area, conditioned space, etc. There are many permutations and each has a material impact on energy efficiency calculations. Yet, it is often difficult to confirm the origin of available data or provide field-verified information. Also, a basic limitation of floor area normalization is the inherent assumption that it is the space itself which has energy needs, when in fact floor area is only tangentially related to the factors actually driving building energy use.

More directly impacting comparative building energy use are the weather conditions experienced by the building. Outside temperature is one of the most direct predictors of energy use variation within a building (citation), and the performance of buildings which experience different annual temperature regimens cannot be directly compared on the basis of EUI alone. For this reason climate is one of the key normalization variables used by Energy Star in comparing building performance, and even within individual buildings energy models are not considered predictive of actual performance without direct weather data correlation between modeled and measured conditions (among other variables). Because temperature is such a key predictor of building energy use patterns, even normalizing by average climate conditions (such as TMY3 data) will not lead to consistent comparisons between buildings experiencing different local conditions or year-over-year weather pattern variations.

The next logical step in normalization is the inclusion of information about building use patterns, but this is where the accuracy and consistency of information breaks down considerably in the marketplace. Of course it is widely recognized that different use types need to be compared separately, such as office, retail, residential, or medical uses all of which have very different energy use patterns and intensity. But what about when a building includes multiple use types? This can be very difficult to track or account for in most comparisons. And add in a small data center and all bets are off for meaningful comparison among buildings.

But even within use types, occupancy patterns can vary widely. In office buildings, the occupants themselves are major contributors to building energy use, and their share of the total increases as building envelope and systems become more efficient. An office building may include an occupant density of 500 sf/person, or twice that, or half. And the equipment load associated with each occupant can vary considerably, from shared efficient workstations to multiple computers and monitors for each workstation in software, financial, and high-tech firms. Additional uncertainties are introduced based on work schedules and lease rates, neither of which are easy to track or account for in currently available normalizations comparing building energy use.

Energy Star uses a proxy of number of workstations as a placeholder for occupancy, which levels the comparisons generated by that system to some degree. In fact, the ENERGY STAR system incorporates normalization proxies for a number of these variables, as represented by the formula:

f(EUI/sf/year, SU, HDD, CDD) where:

- SU is a combination of proxies, such as number of computers and hours of operation to represent occupant use patterns
- HDD represent heating degree days (or hours) and CDD represent cooling degree days (or hours) for a presumably nearby weather station.

The resulting value is essentially dimension-less or, at least, its dimensions are challenging to communicate. Each of these normalization steps injects complexity while, nominally, controlling for perceived exogenous factors.

Normalization in Green Building Rating Systems

Normalization strategies are also pervasive in green building rating systems. These tools attempt to provide mechanisms for performance assessment and recognition. Rating systems vary widely with respect to their use of normalization. For example:

- Certification under the *Living Building Challenge* requires that a candidate building achieve net zero energy operations for one year. This standard does not establish a specific EUI target for basic building performance, rather it requires a balance of on-site generation and energy use. Effectively LBC's normalization is:

  (Annual On-Site Supply – Annual On-Site Demand)/Year >= 0

- Certification under Energy Star makes much more extensive use of normalization to recognize commercial buildings in the Top 25% of US assets. This calculation requires comparing a candidate building's energy use intensity to others of similar type while normalizing for space utilization and climate. The denominator in this equation is a statistical regression representing the average US building stock for this space type controlling for utilization and climate. This might be represented as:

  CANDIDATE f(TYPE, EUI/sf/year, SU, HDD, CDD) ≤ 0.75 * CBECS f(TYPE, avg EUI/sf/year, avg SU, avg HDD, avg CDD)

- Certification under the USGBC's Leadership in Energy and Environmental Design for New Construction (LEED-NC®) uses a different normalization strategy. In its most widely used form, LEED-NC references ASHRAE 90.1 (Appendix G) to establish a baseline for whole building energy performance. Projects receive points based on the degree to which their proposed design reduces operational energy costs relative to the code baseline. This might be represented as:

DESIGN (annual operational energy cost) / BASELINE (annual operational energy cost) $\leq$ X

Where DESIGN and BASELINE are calculated based on rules in ASHRAE 90.1 Appendix G and X is a matrix relating the level of cost reduction to reward in LEED points. X varies for ground up new construction and major renovations. This approach requires holding a core set of energy model parameters constant (e.g., conditioned floor space, climate, etc.), while allowing for change in others (e.g., HVAC components, glazing, etc.). Because the evaluation includes a range of unregulated loads, such as plug loads, which are held constant in relation to the project baseline, but are not held constant relative to other projects, this analysis does not provide reasonable project to project comparison.

These examples illustrate the challenge of comparing buildings based on carefully considered, but divergent, measures of energy efficiency. Moreover, these examples represent only a fraction of the variation see in green building rating systems around the world. Additional complexity is created by considering transitions in normalization strategies over the lifecycle of assets. For example:

- **Building design and construction:** LEED-NC recognizes whole building energy efficiency as the percentage reduction in modeled energy efficiency between the proposed design and a code-compliant baseline.
- **Interior fit out:** LEED for Commercial Interiors recognizes a number of energy efficiency metrics, including lighting power density (watts per unit floor area) and the fraction of appliances ENERGY STAR (number ENERGY STAR / total number of appliances).
- **Existing buildings:** LEED for Existing Building Operation and Maintenance recognizes energy efficiency based on a facility's ENERGY STAR score. Effectively this measures the building relatively to others of the same types as represented in the Department of Energy's Commercial Building Energy Consumption Survey.
- **Energy Star:** This metric compares measured building energy use to a CBECS data sample, normalized for occupancy, use type, and weather, but not for building age, construction type, or other factors.

These are entirely self-consistent, valid measures of energy efficiency for different phases in the lifecycle of an asset. However, each has a fundamentally different basis for establishing performance, normalizing by certain factors, and ranking an asset in comparison to others. Consequently, performance on one measure has limited predictive power for scores on another.

Normalization across Organizational Scales

We have illustrated some of the complexity of energy efficiency normalization at the building scale. It is increasingly necessary to understand building scale efficiencies in the context of whole portfolios. In some cases, organizations are looking to create portfolio-scale efficiencies by reducing absolute space use and increasing the intensity of space at individual facilities. These organizations may report their performance in aggregate, such as the Carbon Disclosure Project. The CDP asks organizations to report whole enterprise energy use and green house gas emissions, and head count. This information is used to calculate carbon emissions intensity, typically metric tonnes CO2 equivalent per full time equivalent. This emissions intensity metric is used to compare organizations. This metric can be reduced by lowering the average energy use of individual buildings, reducing the ratio of floor space to employees, or potentially divesting of energy intensive facilities. However, changes in floor space or space usage are explicitly held constant for many single building energy efficiency measures, such as LEED-NC or ENERGY STAR. This illustrates how normalization factors at one scale become variables at another. This is useful feature of these complementary tools; however, it can also be a source of confusion when comparing outcomes and designing programs.

Normalization for Various Sector Use

Within individual building types and industries, there are additional normalizations which focus on specific characteristics. Residential buildings may count number of beds, bedrooms, or residents as a basis for comparison among facilities. In health care the metrics may include utilization rates or length of stay. Restaurants may count meals served, while retail often evaluates sales volume per square foot. And data centers have a whole language around computation efficiency to comparatively evaluate facilities.

These factors represent the complexity of comparison needed to realistically compare facility energy use, while suggesting the difficulty in tracking enough information to inspire confidence in the comparisons.

Normalization with Economic Factors

Recent studies have created the first links between building scale energy use (Source Energy) and the economic contribution of commercial buildings, merging the world's largest building energy benchmarking database with the world's largest commercial tenant database (Baumgartner, 2013) This information demonstrated the relationship between energy consumed by buildings and the buildings' economic contribution, weighted by tenant types.

By comparing this data, early trends can be revealed between commercial buildings' energy use and the economic contribution that the buildings' tenants bring to the economy. The Building Economic Energy Coefficient (BEEC) is a new metric that defines building efficiency as a ratio of the economic contribution of a building's tenants to the source energy that they consume. The following describes this metric and its implications further.

In 2012, NYC released energy benchmarking data for 2,065 commercial properties. A major milestone for the Mayor's PlaNYC initiative, this represents the first time that New York City – or any US municipality – has disclosed private sector building energy data from a mandatory benchmarking policy (Local Law 84 or LL84). Several key trends emerged from the LL84 data analysis, including a wide range of Energy Use Intensity (EUI) for commercial buildings and a counterintuitive tendency for older buildings to generally have both lower EUI and better EnergyStar ratings than their newer counterparts. With these metrics now publically available, developers and operators are increasingly concerned with above-average energy consumption and are seeking justification for increased consumption based on similarly above-average, high-intensity operations. These owners and developers are suggesting that their newer, efficient-yet-energy-intensive buildings add increased economic value to the city, and therefore justify their higher energy spends per square foot than their older, outclassed predecessors.

In addition to the information made available through LL84, the authors have collected the largest database of tenants and tenant types in New York City and assigned each one an economic metric, based on economic contribution and indexed, normalized, and weighted by zip code. The authors then combined this dataset with the benchmarking data to develop a ratio of a building's economic contribution to its site energy intensity providing a better understanding of the relationships between energy consumption and economic output.

The BEII is a metric that quantifies a building's relative contribution to the economy based on the mix of tenants it houses. The higher the BEII, the more favorable (i.e. the more economic contribution a building's tenants generate for the economy). The BEEC is the ratio of BEII to Weather-normalized Source Energy Use Intensity (EUI). This metric quantifies the relative economic contribution of a building per one unit of source energy. The higher the numerical value, the more favorable (i.e. the more economic productivity a building's tenants contribute to the economy per source energy that building consumes).

The authors of the study have developed a methodology and have begun organizing this large dataset by several factors, including building age, tenant groups, LEED certification levels, and submarkets (e.g., Financial District, Midtown East).. The implications of the metrics presented in the larger study and briefly discussed here may have relevance for city officials, policymakers, and stakeholders within the real estate industry and, as preliminary data trends will show, begin to create a dialogue around the benefits of 'tall buildings' and densification.

The development of the BEII and BEEC metrics is a step toward elevating the conversations around triple bottom line sustainability, in particular drawing connections between environmental and economic impacts. Graphs and conclusions from this study were presented at Greenbuild (November 2013) and ASHRAE Winter Conference (January 2014) with discussion and debate. Highlights from this study will be presented at the ACEEE Summer Study.

Figure 1 shows the relationship between BEII and Weather-normalized Source EUI. For the dataset studied, a loose correlation exists between the energy consumed in a building and the economic contribution of that building's tenants. This suggests that as buildings use more energy per square foot, they are increasing their economic contribution. In short, the energy being consumed is leveraged towards more economic benefit.

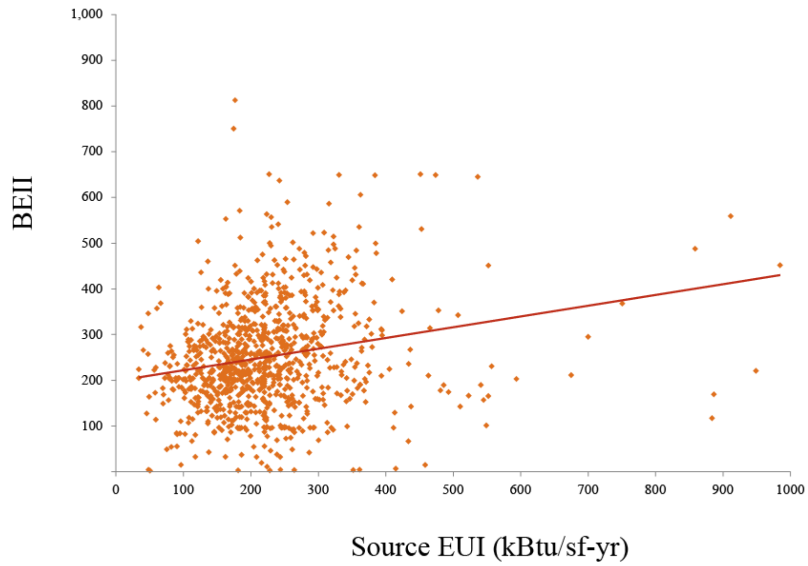
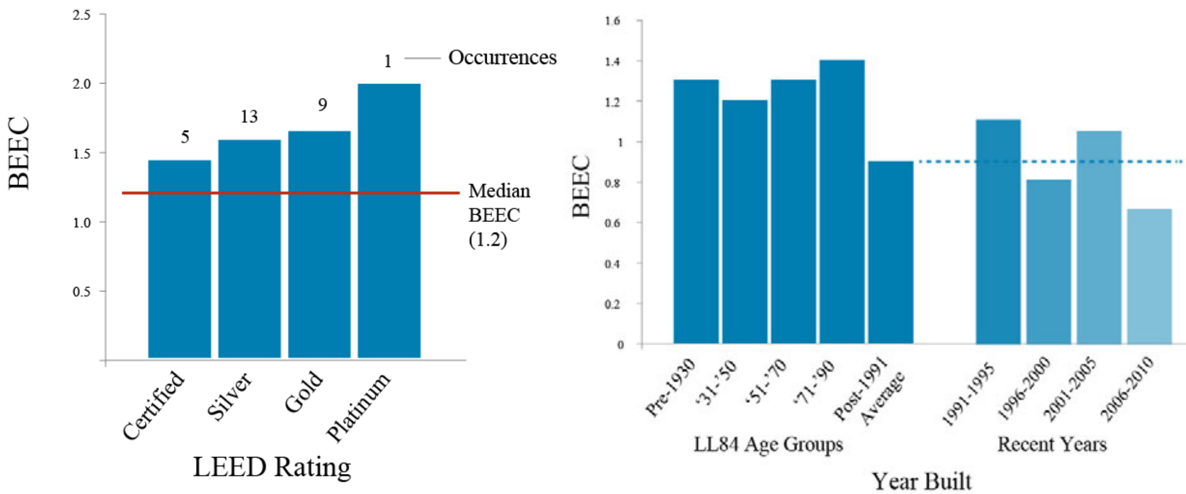


Figure 1. Building Economic Intensity Index to Source EUI. Source: Baumgartner, 2013.



Figures 2 and 3. Building Economic Energy Coefficient (BEEC) vs LEED Rating and BEEC vs Year Built (New York City available datasets. Source: Baumgartner, 2013.

Figure 2 shows BEEC vs LEED Rating (NC and CS only), publically available from the USGBC. Although too small a set to be statistically relevant, the trends of the graphs are clear: that the efficiency of the buildings increase with increased LEED rating. The Platinum building is represented by One Bryant Park, which has, of late, been under extreme attack in the media because of its high energy intensity. It is also worthwhile to note that the average BEEC for all LEED buildings, and at every certification level, is significantly above the median values.

Figure 3 shows the relationship of BEEC vs Year Built (New York City available datasets. The average BEEC is trending well below historical averages for buildings built after 1991. This is also a surprising trend. Intuitively, one would have expected that newer buildings would have attracted higher-contributing tenants. This is due to the general increased energy intensity of newer buildings, and the findings from the BEII graphs in Figure 8. The general trends in this set suggest that newer buildings, especially those built after 2006, are less efficient than mid-century buildings.

Whether the BEEC can be used as more than a novel metric remains to be seen; this study was made possible by the availability of both the Local Law 84 data and a substantial, highly accurate commercial database of building tenants. Given the trend towards similar energy disclosure policies in other major cities, it may be possible to complete a similar analysis for San Francisco, Philadelphia, and others in coming years. In the meantime, the results of the New York City BEEC study can be used to spur a broader conversation about the relationship between economic and environmental impact, and how that relationship should influence the City's energy policies moving forward.

Take for example, a high-intensity building for which no EnergyStar score can be calculated – a building which is undoubtedly more energy intense than the average commercial building but is contributing greatly to the city's economy. If a local energy law of the future requires all buildings to achieve a minimum EnergyStar rating or limits their EUI, a high intensity building will be impacted differently than less intensive buildings. It is critical that in defining the direction of the City's growth, an energy policy does not accidentally provide a disincentive for high-intensity, economically high-contributing tenants and in doing so, drive owners and their tenants out of New York City to smaller markets.

In addition to identifying trends and relationships between economic output and energy consumption, parallel studies could assess densification arguments. It is challenging to make zoning arguments for higher densifications (increased floor area ratio) without understanding the balance between the economic impacts of the buildings and their environmental impact. One might conclude that on an environmental basis, the city has little to gain through zoning changes that would facilitate the replacement of Class B building stock with Class A. However, this is clearly not the case: cities – and particularly high-density cities – are inherently lower impact than their suburban or rural counterparts.

Improvements can certainly be made with respect to this metrics, and the authors have been forthcoming about its technical hurdles moving forward. Two examples of technical hurdles can be highlighted. First, there is no clear way to capture occupancy counts in commercial buildings. As some building have turn-stile counts and smart-readers and are connecting these occupancies to system optimization programs, most building owners have very little idea of the occupancy in their buildings. Building occupancy was included within the CoStar® data-set, but it was acknowledged by the company that occupancy data was at a significantly lower level of accuracy than the tenant area data used in this study. There is also a general uncertainty by property owners in accurately accounting for population in commercial buildings due to frequent changes and inaccurate disclosure from tenants themselves.

Second, is the need for the separation of process or IT loads (data centers, studios, trading floors, etc) with the comfort and health conditioning loads in these buildings. Certainly a normalization across these uses should be understood before generalizations are made for any efficiency (BEEC definition) differences are made. Take two identical buildings, with the exact same program use, tenant types and EUI, but building #1 has a 10,000 sf data center building #2 does not (data center is off-site or on the cloud). Certainly building #1 shouldn't be penalized or seen as less efficient. This may also be a reason to identify not just the Source Energy use associated with the building energy (with upstream multipliers) but understanding Source Energy as the entire system needed to sustain that business. Another reason to attempt to identify not only the Source Energy

Next Steps

It is clear that there are a range of significant variables that need to be accounted for in comparing building performance, and that current protocols for comparing building performance do not adequately account for key variables that can skew the perceived results of these comparisons. The introduction of additional normalization protocols could substantially improve the value of these performance comparisons. For example, the introduction of a metric such as kBtu/sf/occupant hour (Occupant EUI) would generate a comparison that more effectively represents the relationship between building energy use and productivity. As data tracking and availability becomes more sophisticated, more meaningful building energy use comparison normalizations should become increasingly common.

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