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Performance Based Rating and Energy Performance Benchmarking for Commercial Buildings in India

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June, 2010

To be presented at
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PERFORMANCE BASED RATING AND ENERGY PERFORMANCE BENCHMARKING FOR COMMERCIAL BUILDINGS IN INDIA

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ABSTRACT

Performance based rating systems serve as an excellent baseline “report card”. They are useful for evaluating performance of existing buildings and to set meaningful targets for new buildings. It replaces guesswork with a scientific methodology to establish targets, evaluate performance and reward innovations. Over time, it helps to consistently improve the standards through healthy competition by shifting markets to better performing levels. In the US, LEED for Existing Buildings (LEED EB), ASHRAE’s BuildingEQ and the Green Globes Existing Buildings rating system reference actual building performance benchmarked against ENERGY STAR Target Finder. On similar lines, this research could help improve current rating systems in India by providing contextual benchmarks and targets across building types.

A database of existing buildings with record of their physical, operational and location characteristics and energy consumption and related parameters is a prerequisite for any performance based ratings. USA has been collecting such data in form of the Commercial Building Energy Consumption Survey (CBECS) for many years and has used it to develop ENERGY STAR and green building rating systems. This paper uses the first national level initiative in India to collect and rigorously analyze standardized energy use data for 760 commercial buildings. We use regression and distribution based methods to compute energy consumption benchmarks and at a performance based ratings for India.

Specifically, this study (a) Elucidates the need for benchmarking and performance based rating in the Indian context, (b) Discusses the framework for national level data collection, (c) Performs exploratory analysis of whole building energy use across different groups such as use types, climate, operating hours, size, etc. (d) Proposes a methodology for performance rating and benchmarking using regression and distribution analysis, (e) Establishes performance benchmarks and rating scales for building types, namely – offices, hospitals and hotels, and (f) Concludes with limitations and extensions for further work in the Indian context.

INTRODUCTION

The Indian building sector has witnessed huge interest in the field of energy performance in the last decade. The national Energy Conservation Building Code (ECBC) and green building rating systems such as Leadership in Energy and Environment Design (LEED-India) and Green Rating for Integrated Habitat Assessment (GRIHA) have further fueled this surge in interest. These codes and rating systems are based on design intent rather than actual performance during building occupancy. They are not designed primarily to rate energy performance of existing buildings and to reward their performance through a systematic evaluation and award scheme. Further, they do not provide defendable energy consumption targets for new buildings based on contextual data. T his has serious performance, market and policy implications.

Buildings, along with other consumers must continuously monitor and improve their performance in order to transit to an energy efficient economy. It is important to measure this performance against established benchmarks. The primary aim of this initiative is to improve the design, construction, maintenance and operation of buildings by measuring energy performance against established benchmarks, and recognize and reward exemplary performing buildings through a credible certification system (Hicks and Von Neida, 2005).

CONTEXT

Commercial buildings in India account for nearly 8% of the total electricity supplied by utilities. Electricity use in this sector has been growing at about 11-12% annually, which is much faster than the average electricity growth rate of about 5-6% in the economy (Bureau of Energy Efficiency). According to the 17th Electrical Power Survey of the Central Electricity Authority, electricity demand is likely to increase by approximately 40% in 2011-12 and 175% in 2021-22 as compared to 2006-07. The share of electricity use in the building sector has increased from 14% in the 1970s to nearly 33% in 2004-05.

In spite of the fast-paced growth of the commercial building sector in India, energy consumption data for the sector is largely unavailable in the public domain. Absence of macro-level data has been a barrier for the government to formulate effective, market-oriented policies and for the private sector to invest sufficient resources to make the buildings more energy-efficient. The creation of these benchmarks will help in identifying exemplary buildings as well as poorly performing buildings. The former can provide clues to designing and operating efficient buildings while the latter can be excellent targets for implementing energy efficiency measures. In some cases, benchmarking can replace energy audits that have been largely ineffective in turning potential into reality. With this in mind, the Bureau of Energy Efficiency (BEE), with technical assistance from USAID ECO-III project, embarked on an initiative to provide sector-specific energy consumption data and undertook the preliminary benchmarking initiative. With inputs from the BEE's technical committee members, the ECO-III team designed a standardized format for collection of building energy data. The data collection process began in December 2008.

DATA

The Commercial Building Energy Benchmarking exercise started with desiging of a standardized questionnaire for collection of whole building energy data. This included information such as connected load, electricty generated on site, electricty purchased from the utilities, built up area, conditioned area, number of people working, number of floors, type of air-conditiong and the load, climatic condition, operating hours, etc. The survey gathered complete information for 760 buildings which primarily included offices, hotels, hospitals and retail malls. India is divided into five major climatic zones., viz. warm and humid, composite, hot and dry, temperate, and cold. Data collected is fairly representative as it covered all the five climatic zones. Emphasis was also placed on covering both public and private sector buildings. The survey covered the buildings in metropolitan cities, Tier II and Tier III cities, as well as few smaller towns.

Comparing buildings based on annual energy consumption (kWh/sq. m.) is advisable so as to avoid any distortions that may arise from varying fuel prices and energy rate systems. Normalizing the energy consumption of buildings by their floor area provides an energy intensity measure that allows the comparison of buildings of different sizes. That said, floor area is also a source of error as it is often reported incorrectly. There are different ways of defining floor area and there are inconsistencies in the way it is calculated. We realized early on in the data collection process that it is important that our definition of floor area is consistent within the comparison (benchmark) data.

It is important that benchmarks are created for a similar period of time. The time period considered in this exercise is typically one year.

There were some exercises in the past to collect energy data for commercial buildings. However, there were not very successful because of several reasons such as:

- Failure in standardizing the terms used in the questionnaire as compared to the myriad terms that are part of the Facilities and O&M team's vocabulary;
- Lack of success in ensuring quality assurance during the data collection process;
- Inability to safeguard the identity of individual buildings and organizations contributing data;
- Inability to strike a balance between the ease and the depth of the data that needs to be collected.

BENCHMARKING AND RATING

Energy benchmarking is a process of creating a whole building energy consumption profile of a group of buildings characterized by their primary use, construction, physical, geographic and operating characteristics.. The rating is derived by assigning a score to the performance differential between the building under consideration and a benchmarked building in relation to all other buildings in the stock. A very important critique of this approach is that the entire population may be inefficient and would eventually lead to inefficient buildings being rated as efficient (Federspiel, Zhang and Arens, 2002). However, with this initiative, the idea is to identify and reward relatively efficient buildings in the population to gradually pull the entire building stock to a higher energy performance level.

Energy performance, just like energy efficiency can be evaluated using different and often conflicting measures (Soebarto and Williamson, 2001). The key components of various definitions include low energy consumption, energy efficiency, adherence to thermal comfort and internal air quality standards, provision of sufficient amenities, low life cycle costs of construction, operation, maintenance and demolition. This study evaluates performance based on the total energy consumption by the building, given a particular level of amenities and building related characteristics. Adhering to standards for thermal comfort, indoor air quality or provision of basic amenities, etc is currently not considered as a prerequisite. This is a serious limitation mainly due to poorly enforced standards and lack of data.

Benefits

Energy Benchmarking and Performance Based Rating replaces guesswork with scientific methodology to establish targets and evaluate and reward innovations. Over time, it helps to consistently improve the standards through healthy competition by shifting markets to better performing levels. The potential beneficiaries for Energy Benchmarking and Performance Based Rating System includes:

Designers, Owners and Users: Designers will have feasible targets for new and existing buildings enabling them to choose appropriate technology, products and retrofit measures; clients and auditors will have a standardized yardstick to measure the performance of their buildings; multi-facility operators like corporate entities, schools, hospitals and government agencies can compare performance of individual facilities to others, reward and learn from better performing facilities while, retrofit others, and estimate total feasible savings possible across entire operations.

Building Developers and operators: The benchmark and rating system provide a means to record energy efficiency achievements and help chart future direction. It helps assess the total potential savings and allows stakeholders in the sector to focus their efforts on development and use of appropriate products and technologies. The operating team can track the performance over time and across facilities to ensure that buildings are performing at desired efficiency levels.

Policy Makers: The rating system can be used to reward highly rated buildings through various monetary and non-monetary rewards. Poorly rated buildings can either be penalized or assisted to explore various energy conservation mechanisms or both. It can also help policy makers to ascertain the total national savings potential, evaluate expected impact of potential policy initiatives and shifts to alternative technologies.

Existing Point Based Rating Systems: In the absence of energy benchmarking data in India, LEED India and GRIHA (the national rating system of India) lack the ability to incorporate real world statistics to set targets and evaluate performance. This initiative can help improve these rating systems by providing contextual benchmarks and targets across building types.

APPROACH AND PRINCIPLES

There are numerous approaches to Energy Benchmarking and Performance Based Ratings, each more suited to a particular situation. Widely used methods can be categorized into Point based rating, Raw data visualization method (Kinney and Piette, 2002), Regression based statistical method (Sharp, 1996, 1998), Simulation and Model based approaches (Federspiel et al., 2002), Hierarchical end use metrics (Sartor, Piette, Tschudi and Fok, 2000). Other methods include energy audits, experts' knowledge approach and self learning systems based on neural networks. For detailed review of these methods, see Kinney and Piette (2002), Matson and Piette (2005), and Olofsson, Meier and Lamberts (2004) and Sartor et al (2000).

In this study, we have used the regression and distribution based statistical approach originally developed by Sharp (1996, 1998). It is transparent, widely accepted and easy to adopt at policy level. Similar method is used by the US EPA which administers the Commercial Building Energy Consumption Survey (CBECS) since 1978 through the Energy Information Administration Division of the Department of Energy. They uses the CBECS database and linear regression techniques to compute the ENERGY STAR labels for commercial buildings. Hicks and Von Neida (2000) provides an overview of the US national energy performance rating system and the ENERGY STAR Building Certification Program. Based on various benchmarking systems we have derived the following principles for the Indian commercial building benchmarking and performance based rating system: (a) Evaluate energy performance for whole building, (b) Reflect actual billed energy data, (c) Provide comparison mechanism among peer groups, (d) Account for operational characteristics of the building and should not penalize for higher levels of service and amenities provided in the building (US EPA 2009), (e). Provide a simple metric to evaluate and communicate building energy performance between owners, occupants, lenders, appraisers and energy product and service community (Hicks and Von Neida, 2005).

METHODOLOGY AND RESULTS

The proposed method compares the whole building energy consumption of the building under consideration with a benchmark building of similar characteristics. A three step statistical methodology described below is used as a way around this problem.

1. Estimate the energy consumption of the benchmark building: The benchmark building is defined as a hypothetical building with similar use type, physical and operating characteristics and located in same

climatic zone as the candidate building. The estimate is derived through regression technique applied to a large dataset of surveyed buildings.

2. Compute performance index with respect to the benchmarked building: It is calculated as the ratio of actual electricity consumed by the candidate building to estimated electricity use by the benchmarked building. This ratio is termed as Building Performance Index (BPI). It indicates the relative efficiency of a building.

3. Compute performance score based on the relative performance of other buildings in the sample: The BPI of all buildings in the sample is used to create a distribution profile of relative performance. The distribution provides performance percentiles which can either directly be transformed into a 1-100 rating scale or be further grouped into star based rating method. Distribution based approach is robust to presence of outliers and extreme observations (Sharp, 1998). Extreme observations can occur due to error in data, use of highly efficient or inefficient technology by some buildings in the sample, or structure of the model used.

Energy Consumption of a Benchmark Building

A simple way to estimate the energy conservation of a benchmarked building is to have a table of benchmarked energy consumption for every possible candidate building that wants to be rated. This table can be created from a very large database of buildings with all possible variations in their use, physical, operational and location characteristics. However, this approach is not only logistically challenging but infeasible, as the possible number of variations is infinite. A practical approach is to use the statistical technique of regression which allows us to estimate the average consumption of buildings similar to a candidate building, using data from different buildings. This method focuses on the key drivers of energy consumption across different buildings and estimates their individual contribution to the total energy. In its most conventional form, the regression equation resembles equation 1 below

Energy use of a benchmarked building = function (building type, construction, physical, operational and location characteristics) ·····························Equation 1

Equation 1 estimates the energy consumption of a benchmarked building as a function of building type (dependent variable), and its construction, and physical, operational and location characteristics (independent variables).

Building type includes the primary function namely offices, hospitals and retail malls. It can be extended to other use types like education, retail, etc and also to sub-types within the primary use type like BPO offices, luxury hotels and multi specialty hospitals. Construction and physical characteristics refer to the design and construction aspects (e.g. size, orientation, shading, % glazing on the façade, and material and system properties that can make an impact on the energy use of the building). Operating characteristics refers to factors that define how the building is being used and includes the total operating hours in a year, number of employees working in an office, percentage of floor space that is mechanically conditioned. Location characteristics are the factors external to the building that affect its energy consumption like climate, degree of urbanization, etc... Some of the climate metrics that effect energy consumption include heating and cooling degree days, solar radiation, air temperature, humidity, cloud cover and wind speed and direction.

The function that estimates the energy consumption in equation 1 is not known a priori. Various parametric, semi parametric and non parametric functional forms were explored. Non-parametric methods do not make any assumptions about functional form are technically better but need large sample size. The conventional linear formulations were rejected because scatter plots shown in figure 1 hint at non linear relationship between the dependent and independent variables. Further, the effect of one independent variable on energy consumption depends on levels of other variables signifying presence of strong interaction as evident from conditional scatter plots. Thus, a log-linear functional form is used which allows for non-linear relationships and interaction effects among variables. The model was estimated using the Generalized Least Square Estimator that gives more robust estimate than the Ordinary Least Squares Estimator. Various regression diagnostic tests were done to ensure that the regression results were statistically acceptable.

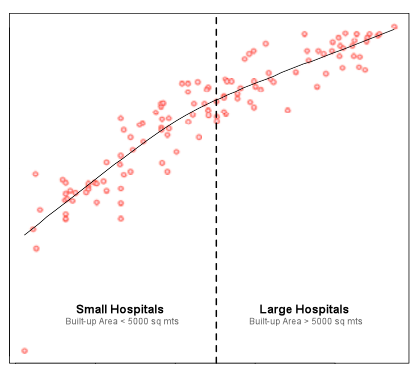

Figure 1: Scatter plot showing non linear relationship between energy consumption and built up area in Hospitals

All analysis was performed using the *R language and environment for statistical computing and graphics* (R Development Core Team, 2005)..

On account of shortage of space, we are presenting detailed analysis for office buildings only. Information was available for 320 office buildings across the country, out of which there were 91 buildings in the BPO category. An average office building had EPI of 175 kW/m^2/year and occupied 7,432 m^2 of space, of which 75 % was conditioned. It employed 540 people and operated for 10 hours a day, 6 days a week.

197 office buildings had information about all the key variables that are likely to affect energy consumption in a building. This smaller set was used to conduct the multi-variate regression analysis. Their relationship between variables is presented in figure 2 and the basic summary is presented in table 1. As a result of this analysis, total built-up area, percent conditioned space, total annual hours of operation, number of people employed were the key determinants; the climatic zone was not a significant factor affecting buildings' energy consumption.

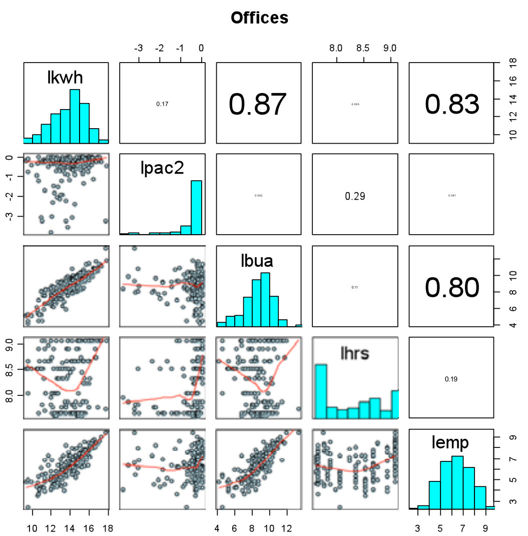

Figure 2: The scatter plot showing bivariate relationship among logarithm of key variables along with correlation coefficients

Table 1
Summary of key variables for office buildings

Var.	obs.	mean	median	s.d.	min.	max.
kwh	197	3457034	1421000	6274194	12321	48493801
pac2	197	0.69	0.75	0.25	0.02	1
bua	197	17110.38	7060	45015.55	70	578600
hrs	197	4575	4171	2521	2008	8760
emp	197	1286.12	550	1897.59	12	13000
epi	197	241	193	210	17	1800

Table 2
Regression for Office building

Equation: lkwh = climate + (lpac2 + lbua + lhrs + lemp)

Coefficients:

	Estimate	Std.Err	t value	Pr(>|t|)	
(Intercept)	3.25	0.93	3.47	0.00	***
Climate:Hot & Dry	-0.34	0.20	-1.66	0.098	.
Climate:Temperate	0.05	0.15	0.33	0.74	
Climate:Warm & Humid	0.14	0.12	1.20	0.23	
lpac2	0.44	0.07	6.09	0.00	***
lbua	0.78	0.06	12.75	0.00	***
lhrs	0.26	0.10	2.50	0.01	*
lemp	0.29	0.072	4.11	0.00	***

Signif code: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.6869 on 189 degrees of freedom

Multiple R-squared: 0.8516, Adjusted R-squared: 0.8461

F-statistic: 155 on 7 and 189 DF, p-value: < 2.2e-16

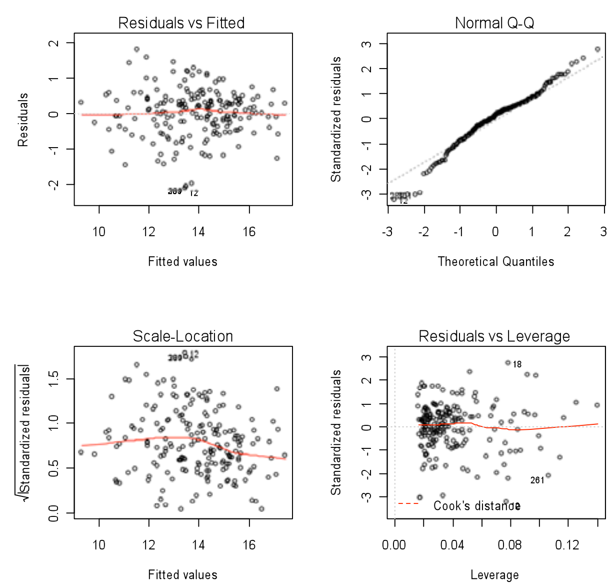

Figure 3: Graphs showing the statistical performance of the regression equation

Performance Rating Through Peer Group Comparison

The regressions equation1estimates how much energy a building should consume given its primary use, construction, physical, operation, and location characteristics, given our knowledge about existing building stock through the survey. The next step is to compute a statistic that we call Building Performance Index (BPI) to quantify the performance of the candidate building relative to the benchmarked building. BPI is defined as the ratio of actual energy consumed to the estimated consumption of a similar benchmarked building using the regression equation 1. BPI = 1 represents building with consumption levels equal to the benchmark building after normalizing for all operating and location characteristics. Buildings with BPI > 1 are relatively poor performing and vice versa. BPI of three means that the building consumes three times more energy than a comparable benchmark building, while a BPI of 0.5 indicated that the candidate building consumes only half of what a similar benchmarked building would consume. However, BPI by itself does not compare the performance of the candidate building with other buildings in the national stock. In order to derive a performance based rating compared to peer group, the BPI of candidate building is compared to BPI of all the buildings in the sample to compute a performance distribution. This performance distribution is then used to arrive at a performance based score.

Score Card

The BPIs for all surveyed buildings are first sorted and plotted on a graph to arrive at a cumulative distribution function (gray points in figure 4). This gives the distribution of the energy performance for the entire sample of similar primary function buildings. The X-Axis represents the BPIs while the Y-Axis represents the performance quantiles of all the buildings in the sample.

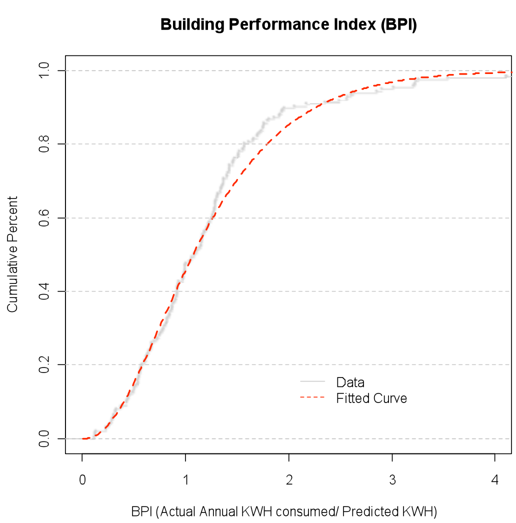

Figure 4: BPI calculated for all buildings in the survey is shown by grey dots. The red dashed line shows estimated performance percentile curve for rating.

A smooth curve (red line in figure 4) is fit to the cumulative distribution function using one of the many standard distribution functions such as gamma, normal, etc. depending on the shape of the curve. We have used a two parameter standard gamma function to estimate the curve through the data points.

The performance percentiles (F) calculated from BPIs using the above gamma function and is presented in table 3 for the office sector. This table converts BPIs into performance ratings on the scale of 1-100 with 1 being the best and 100 representing the worst performer. Each additional point on this rating scale means an additional 1% of the buildings perform better than the candidate building. For example, a building with a rating of 23 percentile means that 23% of the buildings in the sample perform better on energy consumption. A building with performance rating of 2 means that the building lies in top 2% of the buildings in terms of energy consumption after normalizing for all differences.

Table 3

A look up table for office buildings to determine percentile score based on BPI. This table is estimated from the gamma distribution given in equation 2. E.g. If the BPI for a building is 0.4, it ranks in top 10 percentile amongst its peers.

BPI	Percentile (F)	BPI	Percentile (F)	BPI	Percentile (F)	BPI	Percentile (F)	BPI	Percentile (F)
0.14	1	0.6	21	0.92	41	1.29	61	1.83	81
0.19	2	0.62	22	0.94	42	1.31	62	1.86	82
0.23	3	0.63	23	0.95	43	1.33	63	1.9	83
0.26	4	0.65	24	0.97	44	1.35	64	1.95	84
0.29	5	0.67	25	0.99	45	1.37	65	1.99	85
0.31	6	0.68	26	1.01	46	1.4	66	2.04	86
0.34	7	0.7	27	1.02	47	1.42	67	2.09	87
0.36	8	0.71	28	1.04	48	1.44	68	2.14	88
0.38	9	0.73	29	1.06	49	1.47	69	2.2	89
0.4	10	0.74	30	1.08	50	1.49	70	2.26	90
0.42	11	0.76	31	1.09	51	1.52	71	2.33	91
0.44	12	0.78	32	1.11	52	1.54	72	2.41	92
0.46	13	0.79	33	1.13	53	1.57	73	2.49	93
0.48	14	0.81	34	1.15	54	1.6	74	2.59	94
0.5	15	0.82	35	1.17	55	1.63	75	2.71	95
0.52	16	0.84	36	1.19	56	1.66	76	2.85	96
0.53	17	0.86	37	1.21	57	1.69	77	3.02	97
0.55	18	0.87	38	1.23	58	1.72	78	3.27	98
0.57	19	0.89	39	1.25	59	1.76	79	3.68	99
0.58	20	0.91	40	1.27	60	1.79	80	Inf	100

Limitations of Analysis

Given that this is the first attempt of its kind in the Indian context, the study has many limitations. We do not claim that the current data are perfectly representative of commercial buildings in India or that the predictions are perfect. We have performed rigorous data scrutiny to remove inconsistencies and errors and have attempted to capture the most important contributors to whole building energy consumption at a macro level. Key limitations of the data collection and analysis effort are listed below.

The current survey informs us about the percent of space that is conditioned in a building. However, it does not tell us about the operation schedule of HVAC system, the thermal comfort levels, and indoor air quality that is maintained. It is possible for a fully conditioned building to consume less energy and attain a higher score by not maintaining required comfort level throughout the year. This is a serious limitation.

The impact of climate is not satisfactorily apparent from the regression equations. Standard climate metrics like heating and cooling degree days were not found to be significant determinants of energy consumption in any of the building types. Possible reasons include building with large floor to surface area, variation in quality of indoor environment levels, and presence of significant proportion of non-conditioned space within the building.

Most of the buildings in the database are from predominantly urban areas. Impact of urban heat island effect, level of service, building schedule and equipment load are very different in semi-urban and rural settings. The cold climatic zone is poorly represented in the survey. Application of the results to these areas should be treated with caution.

The model is designed to perform best when the input parameters are within the support range provided by the sample dataset. If values of input data are very different from sample buildings, there will be a lower degree of confidence in the results.

Next Steps

The study provides adequate information through equations and tables to implement a performance based rating scheme. It is mature enough to be taken to the next level of web-based administration and implementation with proper design of database to interact, update, store and retrieve information and results. The following steps will help to further improve the results:

- It is important to define the characteristic of buildings that will be considered eligible for the rating scheme. This would require establishing lower and upper bounds on building size, operating hours, percent conditioned space, etc. The sample should then be balanced and appropriately distributed over this range across cities, climatic zones and urban and rural settings.
- The survey can be improved by including more information, enhancing data reliability, ensuring balanced coverage, and increasing sample size. The questionnaire should be expanded to include information on year of construction, envelope characteristics, building orientation, occupancy schedule by shifts, and system and equipment load. Data reliability can be improved by use of electronic means to administer survey including geo-coded images. The survey may also include a copy of utility bill to certify energy consumption, property tax filing to ensure correct floor area, system and energy audit reports for building loads. Ideally, adhering to thermal comfort standards, maintaining indoor air quality standards and energy audits should be made prerequisites. A related best practice that may be incorporated over time, would be to have an accredited ESCO or a licensed professional evaluate and certify – for buildings that are rated – the building physical and operating characteristics and energy consumption, as well as conformance to acceptable standards for indoor environmental quality. Larger and balanced datasets will help derive ranking based on a large set of parameters that we believe are important but are not reflected in the current analysis for lack of sufficient data.
- We have used Generalized Least Squares Estimator to estimate the regression equation. It is more robust to presence outliers and heterogeneous samples than the Ordinary Least Square Estimator. Better analytical methods needs to be explored to address the effect of climate, problems of multicollinearity between key parameters, imbalanced sample, etc. The analysis may also be extended to the use of quantile regression estimator which is more robust in ranking performance as it is based on the principle of median rather than averages.
- A dedicated team of professionals need to work together to design and administer the survey, conduct analysis, manage database and champion the process. Addition of further buildings to the database will change the current model parameters and hence the rating levels. This will require robust database management system, updating of models and policy related to maintaining different versions of rating systems to keep up with the growth in the commercial building sector leading to more effective policy setting.
- Buildings are rated based on the total energy consumed during the year. However, variation in weather conditions can affect consumption levels by up to 15% based on some rough estimates. Once the database is established, the benchmarking should be performed based on some average values of last few years. This implies that the survey needs to be repeated periodically. CBECS is repeated every three years. It is recommended that organizations such as the Bureau of Energy Efficiency should take the initiative to administer the survey every two years

and request two years of data in the beginning before transitioning to three years.

Potential Methodological Advancements

This section lists methodological improvement that are currently not possible due to data unavailability and complexity of interpretation and implementation. However, in the long term, they may help us to switch to a holistic and sustainable approach. These include the transiting to source energy from site energy, using self learning models and hierarchical benchmarking.

We are using net electricity consumed (or site energy) as a metric for energy consumed. Many buildings use onsite diesel or gas generators to produce energy. By ignoring fuel mix in the current study, we are omitting transmission and distribution losses, and hence, underscoring the total energy savings potential at a societal level. Use of source energy may be a better metric for future extensions.

The current analysis focuses on the whole building energy use. It becomes difficult to differentiate between the impact of equipment, building operation and design on overall performance. It may be possible that the worst building gets best rating because it uses the most efficient equipment. Hicks and Von Neida (2005) observes that most of the ENERGY STAR rated buildings under US EPA "understandably use highly efficient equipment, they are most similar to the poorest performing buildings from a technology perspective". Mathew, Sartor, Geet and Reilly (2004) propose hierarchical benchmarking mechanism as a solution to this problem, where increasing level of details are addressed at each stage enabling identification of the factors contributing to good and worse performance within the same building.

CONCLUSION

Performance based benchmarking creates a unique database that helps establish nationwide energy savings potential. The database can be easily updated with development of building design and technology to constantly push new frontiers and aim for higher benchmarks. It encourages aggressive energy reduction policy goals by providing measurable efficiency gains across use types and regions.

This study is the first systematic attempt to understand energy consumption in commercial building in India using real data from 760 buildings. It evaluates energy performance for the whole building incorporating actual energy consumed. Variations in use, type, physical, location and operational characteristics are accounted through statistical procedures and real data. The rating method is transparent in clearly elaborating the process to arrive at the benchmarks. The knowledge of the process does not encourage gamesmanship. It is rigorous to account for all possible variations and factors permitted by data in a scientific manner. It can be easily extended to include more building parameters (e.g. shape, orientation, equipment load). It is versatile to be applied to more use types (retail, institutional, etc) and rural buildings without bringing about any fundamental change in methodology. Finally, the scoring system can be translated into any desired grading scheme – continuous (percentile based) or segmented (quartile or star based).

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