CONSORTIUM for BUILDING ENERGY INNOVATION

REPORT

Title: Quantification of the value of benchmarking to DSM programs

Report Date: April 29, 2016

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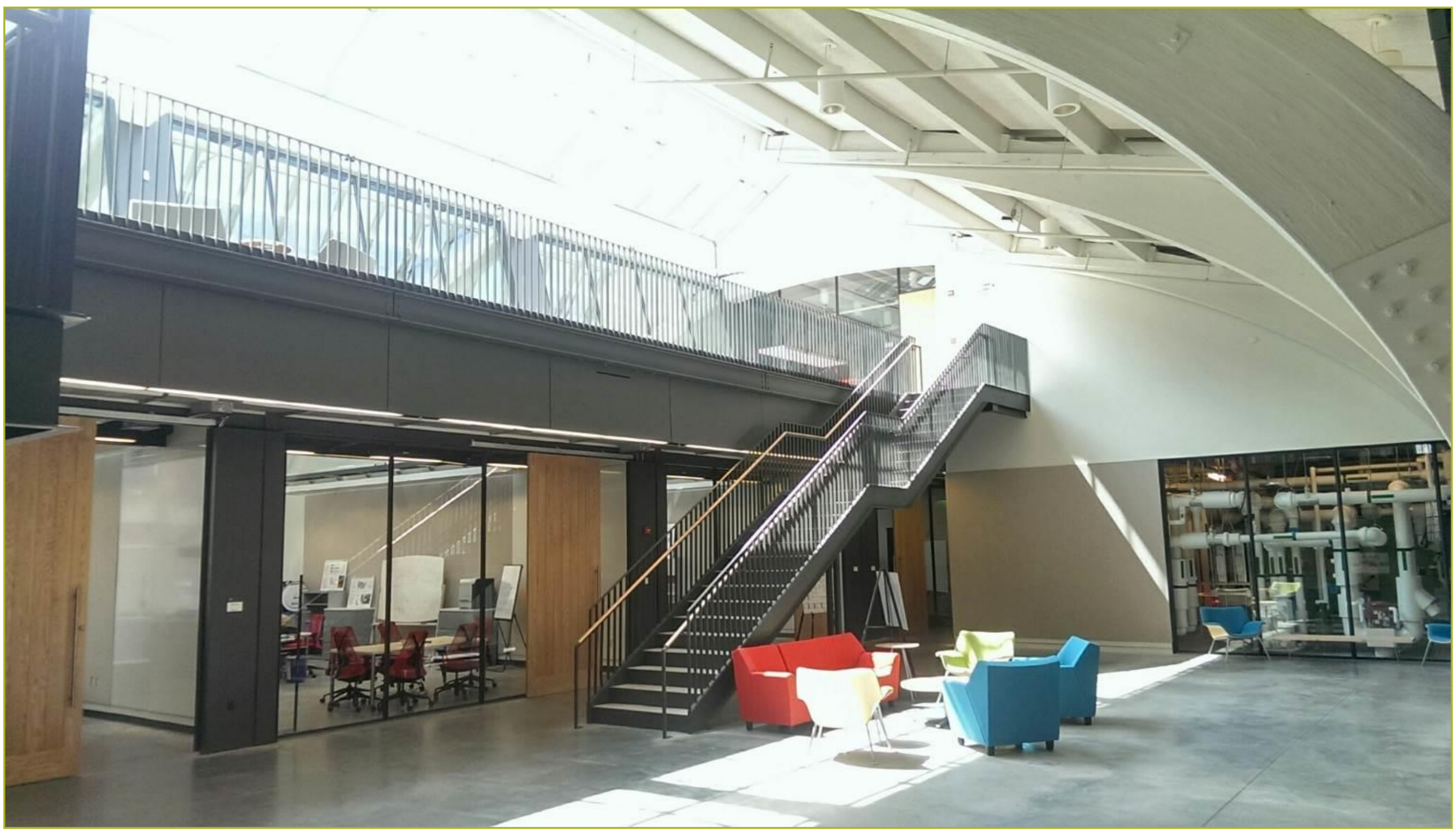

Funded by U.S. DOE

REPORT

Report Abstract

CBEI supported the Philadelphia region as it implemented its ordinance in 2012, acting as a neutral party to convene stakeholder meetings and providing technical expertise on the value of understanding how building energy performance compares regionally. CBEI used this experience to help develop solutions for regions to make use of benchmarking data. CBEI also collaborated with utility incentive program administrators to develop approaches for using benchmarking data to more specifically target buildings for incentives, making it easier for program administrators to reach the best candidates and therefore reduce the overhead cost of an incentive program.

Utilities expressed the need to utilize existing and new resources to help them strategically focus their rebate program target areas and enrich EE program initiatives. To address these needs CBEI developed new analysis for DSM programs (energy efficiency and demand response) based on benchmarking data to show the usability of benchmarking data for utilities. This report quantify how the analyses developed in the deliverable 6.4.1 helped improve targeting rebate customers.

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Project Milestones and Deliverables

Final BP5 Deliverables:

- D6.4.1 - Documentation of approach and recommendations for improving utility DSM programs through use of benchmarking
- **D6.4.2 - Quantification of the value of benchmarking to DSM programs**.
- D6.4.3 - Intermediate and advanced benchmarking data analytics guides describing methodologies for identifying buildings for potential utility rebates.
- "D6.4.4 - Package means and methods findings for new users and recorded webinar to share with and new and existing project partners

Milestones and Go/No-Gos:

M6.4.a	Engage one Utility partner to collaborate.	Commitment from one Utility.	✓
GN6.4.1	Detailed data plan	1) Description of data required, 2) List of data sets currently available, 3) Plan for data acquisition with roles and responsibilities of CBEI and utility program administrator	2 ✓
M6.4.b	Work with committed Utility partner/s to identify their needs and goals.	Report of needs and goals from utility partners	✓
M6.4.c	Preliminary analysis results quantifying value proposition for Utilities to support benchmarking programs.	Report on preliminary data analysis delivered to CBEI, DOE, and Utility. Report describes (A) methods and algorithms to utilize benchmarking data to improve DSM program outcomes and (B) quantitative analysis of value to utilities of building benchmarking based on ways in which utility has used benchmarking program.	✓
GN6.4.2	Preliminary data analysis	Analysis utilizing a sample data set to show that the proposed algorithms identify candidate buildings and provide recommended retrofits	7 ✓
M6.4.d	Final intermediate and advanced benchmarking data analytics guides	Report delivered to CBEI and DOE	✓
M6.4.d	Completion of final analysis. Package means and methods findings for new users and host webinar to share with new and existing project partners.	Delivery of final report describing (A) methods and algorithms to utilize benchmarking data to improve DSM program outcomes and (B) quantitative analysis of value to utilities of building benchmarking. Present findings in at least 2 public forums and document holding at least 4 additional knowledge transfer sessions that share these approaches with at least 5 additional utilities, at least 5 additional program implementers, and at least 5 municipalities.Submit packages and outcome report on webinar to CBEI.	✓

Introduction

The growing field of building energy benchmarking has opened the door to understand, on a city scale, how buildings use energy. Through an interdisciplinary collaboration between multiple Universities, multiple disciplines (Architecture, Engineering, Statistics, and Computer Science), and Industry, the CBEI project 6.4 team investigates new data mining and analysis techniques to improve strategies to target rebate customers through joint analyses of dataset traditionally analyzed independently. Additionally, the team identified statistically significant correlations between buildings attributes and energy consumptions and ENERGYSTAR scores of existing buildings. Such techniques are designed to lead towards refining design guidelines and recommendations for energy efficient retrofits and new construction. The findings are to be used to identify facility management recommendations that can reduce a building's energy consumption.

This report presents how the methods developed during this project can assist program manager in reducing the number of buildings they should focus their outreach effort to the buildings that would benefit the most. CBEI developed 2 methods detailed in deliverable D6.4.1 as well in various publications

1 Project Outline

Energy use data has become available at several different levels: "annual", "monthly", and "interval" energy use. While benchmarking data sets utilize annual data, monthly utility data is available through utility bills, and interval (sub-hourly) data has recently become available through smart metering. All three levels of energy use data will be addressed and used in this research to demonstrate the inferences that can be made from the varying data types and sources.

The methods set out in the report constitute a replicable strategy and can be applied to any region where benchmarking data is available..

The diagram below describes the organizational roles in obtaining, analyzing, and applying building information for the purpose of augmenting utility rebate programs.

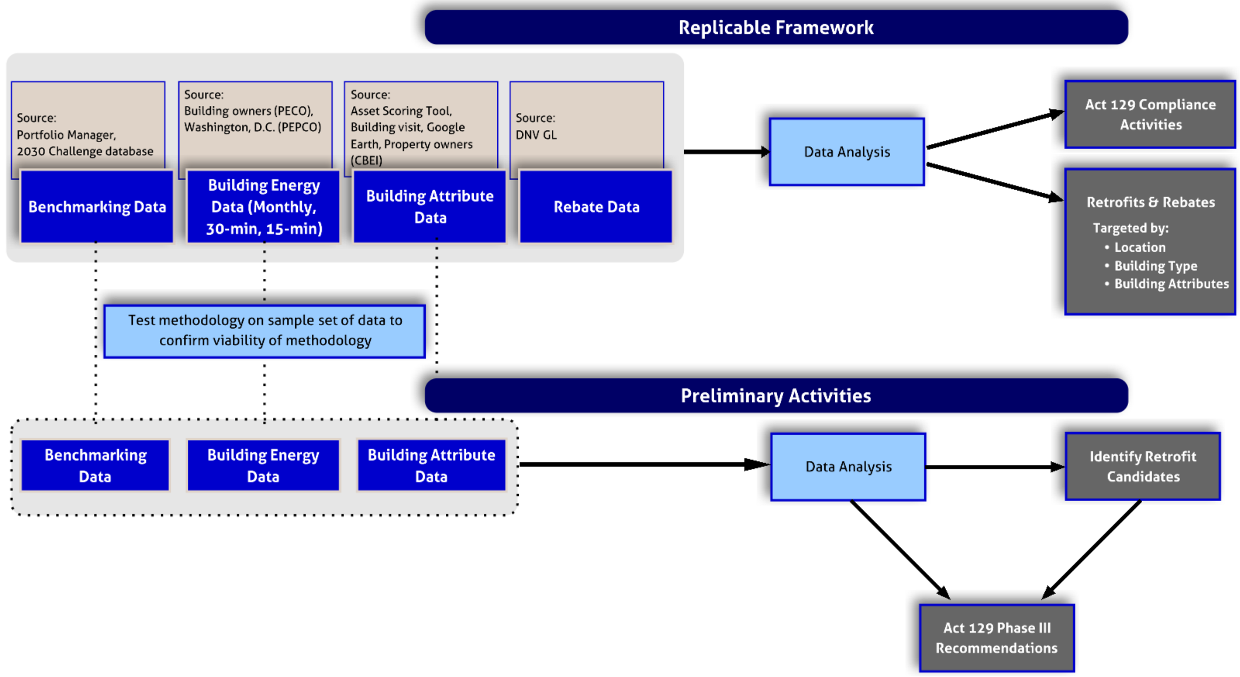

Figure 1 - Replicable framework for rebate analysis

The replicable framework laid out at the top shows that four types of data was combined for analysis and eventually applied to helping local utilities comply with Act 129 and informing national utilities as to the most worthwhile retrofits and rebates for their particular building stock through building-specific targeted retrofits. In addition, in order to test the methodology on a smaller scale to verify its viability, a sample set of benchmarking data, building attribute data, and building energy data (annual, monthly, and interval) was collected and analyzed.

2 Using Municipal Benchmarking Data to Identify and Target Energy Inefficient Buildings for Utility Incentives

2.1 Description

One of the value propositions examined in this project is the use benchmarking data to drive an increase in energy efficiency retrofits and associated rebates that would not have otherwise occurred for a utility. In cases where benchmarking data is disclosed to the public, utilities can utilize readily available benchmarking data to identify buildings deemed energy inefficient ("energy hogs") for targeted outreach as part of their commercial building rebate programs. The team developed a methodology for identifying subsets of inefficient properties based on ESPM data typically collected through a benchmarking program and applies to properties that received an ESPM score. (Based on conversations with DVN-GL staff in Fall 2015, the methodology described here was not used by their energy engineers when they assessed the value of benchmarking data to drive rebates.) The methodology uses certain selection metrics which guard against selection-bias such as selecting only very large properties or only properties with high total annual energy costs. The general goal of this methodology is to identify a subset of properties that have the following characteristics:

1. Low ESPM score
2. High EUI
3. High energy cost per square foot

The first step in identifying inefficient properties is to parse properties having ESPM scores of 74 or less. Properties with scores of 75 or higher are potentially qualifiers for Energy Star recognition, hence scores less than 75 are considered inefficient.

The next step is to calculate the median site EUI for this group of properties. The EUI is an appropriate selection metric since it represents total annual energy use normalized by square footage, meaning any size property can be selected.

Finally, using the subset of office properties selected in Step 2, the median cost per square foot for each set of properties can be calculated. If actual fuel costs are not available, average fuel costs can be used. Properties with high fuel costs typically offer shorter payback periods for retrofits, making the investment in a retrofit more attractive to the property owner.

2.2 Optimizing the building set to target for rebate program outreach

This three step method developed to identify the energy inefficient properties was applied to the 142 office buildings benchmarking dataset for Philadelphia for year 2013.

- Step 1: The first step shortlists the properties with ESPM score lesser than or equal to 74. Out of 142 buildings there were 82 buildings which had a ESPM score of 74 or less
- Step 2: The second step selects all the properties with site Energy Use Intensity (EUI) greater than the median EUI (kBtu/sq ft/yr) of the set of properties (82 in this case) remaining after Step 1. The median EUI of the 82 properties from step 1 is 84.5 kBtu/sqft -yr. Implementation of step 2 resulted in a dataset of 41 energy inefficient properties.
- Step 3: In this third and final step, the dataset created in step 2 is further filtered based on the median annual energy costs per unit area of all the properties from step 2. The set of 41 properties from step 2 have a median energy cost ($/sq) of $2.98. There are 21 properties (from 41 properties) that have annual energy costs ($/sq ft) greater than or equal to the median value.

Therefore, using this three step process, a total of 21 properties which constitute 15% of total dataset of 142 properties are declared as the most energy inefficient properties.

3 Analyzing Building Attribute Data to Target Buildings for Retrofits

3.1 Summary of the methods

Several methodologies were explored for comparing measured energy data to building attributes. These methods included ANOVA, Regression, LEAN Monthly, LEAN occupancy, and Machine Learning techniques. Analyses were conducted with interval, monthly, and annual energy data in order to understand which attributes could be found to be significant when different levels of data were available). This was done in order to establish a replicable model for both future research as well as benchmarking programs around the country that may be interested in analyzing energy data relative to building attributes.

In order to test this hypothesis, a large dataset was created. This dataset included 44 distinct building attributes (independent variables), which together amounted to over 5,500 data points. ANOVA statistical methods were used to analyze this data and discern statistical significance of relationships between building attributes and measured energy use. The results of this analysis were a series of significant impacts of building attributes on energy use, ranging from thermostat setbacks to WWR as indicated in table 5. These findings should be considered to be specific to the dataset, and while similar findings may be found in analysis of other data sets, variables such as climate zone, microclimate, and use type make these findings difficult to generalize. The methodology presented should primarily be considered useful to specific stakeholders within the region analyzed, in this case the greater Philadelphia and Washington, D.C. areas. After running over 240 statistical analyses, 34 significant relationships were found.

Table 1 - Type of Energy Data in Which Specific Building Attributes Can be Found

	Interval	Monthly	Annual
Lights on at night	●	○	○
Thermostat setbacks	○	●	○
Orientation	○	●	○
Building shape	●	●	○
Façade-area/floor-area ratio	○	●	○
Dark glass	○	○	●
Overall window/wall ratio	●	○	● (ES score)
WR by façade	●	●	● (ES score)

3.2 Summary of the statistical findings

As detailed in Deliverables 6.4.1 and other publications, statistical correlations were found between building attributes and energy metrics. In most cases, the results of this analysis corroborate existing knowledge of building design and management, as in the case of buildings that leave the majority of lights on at night compared with those that do not. This research shows that based on the average 100k ft2 office building and the cost of electricity in the Mid-Atlantic region, buildings that turn off their lights at night can save an average of $32,500 per year in utility costs. These savings could be gained either by installing lighting controls such as vacancy sensors, or programming building automation systems to turn out lights during unoccupied hours (both existing rebate options). The broader adoption of vacancy sensors or the adjustment of the Building Automation System (BAS) could be facilitated by targeted rebates.

The most significant results of ANOVA statistical analysis conducted in the course of this research are listed below.

1. Solution 1: Replace glazing on buildings with dark glass (T-Vis<0.5) will lower electric consumption.

   Finding1: Buildings with Dark glass (T-Vis <0.5) have a Higher Electric consumption than other buildings.

   Utilize PECO Glazing rebates or target "Energy Management System" Rebate to those building to reduce their energy use.

2. Solution 2: Provide new lighting schedule controller to turn light OFF at night to reduce the building EUI.

   Finding 2: Buildings with lights ON at night have a higher source EUI than others.

   Utilize PECO Custom Lighting Rebates to install a lighting schedule controller and program a night schedule for lighting systems.

3. Solution 3: Provide new cooling tower to building owners to significantly reduce energy use.

   Finding 3: Buildings with cooling tower use more electricity than others.

   Utilize PECO Custom incentive for process equipment and chiller in their smart idea program.

4. Solution 4:Install shading device on south and west façade to increase energy star score

   Findings 5: External shading on both the south and west facades is correlated with higher ES Score.

   Install External Shading on the South and West façade through PECO Smart Idea Custom Whole-Building System program.

5. Solution 5: Install new BAS and includes nighttime setback to lower the Building Site EUI.

   Findings 5: Buildings with High EUI most likely do not have a proper setback schedule and would benefit from using a rebate to program night and week end set back in their Building automation system.

   Propose the PECO "Energy Management System" Rebate to those buildings to reduce their energy use.

3.3 Applying these findings to target rebate customers

When searching our dataset of 117 buildings with building attributes for the presence of these 5 attributes, we found that 3 buildings have these 5 characteristics, 7 have 4 of this characteristics and 22 have 3 characteristics.
Therefore we recommend utility rebate program managers to focus on 32 buildings, reducing their audience to 28% of its original size.

Table 2: building list with their more than 2 attributes from our criteria list

Building	# attr.	Building	# attr.	Building	# attr.	Building	# attr.
BB	5	DP	3	AW	2	N	2
CX	5	DQ	3	Y	2	U	2
CT	5	X	3	Z	2	AP	2
AU	4	DR	3	AG	2	AR	2
S	4	AF	3	AO	2	DT	2
BC	4	CV	3	CR	2	DU	2
CD	4	R	3	CZ	2	CQ	2
DS	4	BR	3	CA	2	W	2
BG	4	BE	3	R	2	BQ	2
AL	4	D	3	L	2	CC	2
BF	3	E	3	G	2	M	2
BH	3	AY	3	K	2	AC	2
DE	3	DN	3	CK	2	AN	2
BO	3	AM	2	C	2	DZ	2
BV	3	BT	2	BS	2		
BA	3	AS	2	BW	2		
CU	3	DB	2	BZ	2		
CF	3	A	2	CE	2		
CG	3	DF	2	CO	2		
DO	3	BU	2	DX	2		

Conclusion

The CBEI team developed new analyses methods than allow utility rebate program managers to target a shorter list of buildings while focusing on those which will benefits the most from the programs and generate the most energy savings.
If program managers apply both of those methods to their territory they can improve their outreach effort by focusing on the buildings that will save the most energy and focus on 15% to 28% of their customers depending on the methods they select.