CONSORTIUM for BUILDING ENERGY INNOVATION

REPORT

Title: Intermediate and Advanced Level – A guide to Community-Wide Benchmarking Analysis

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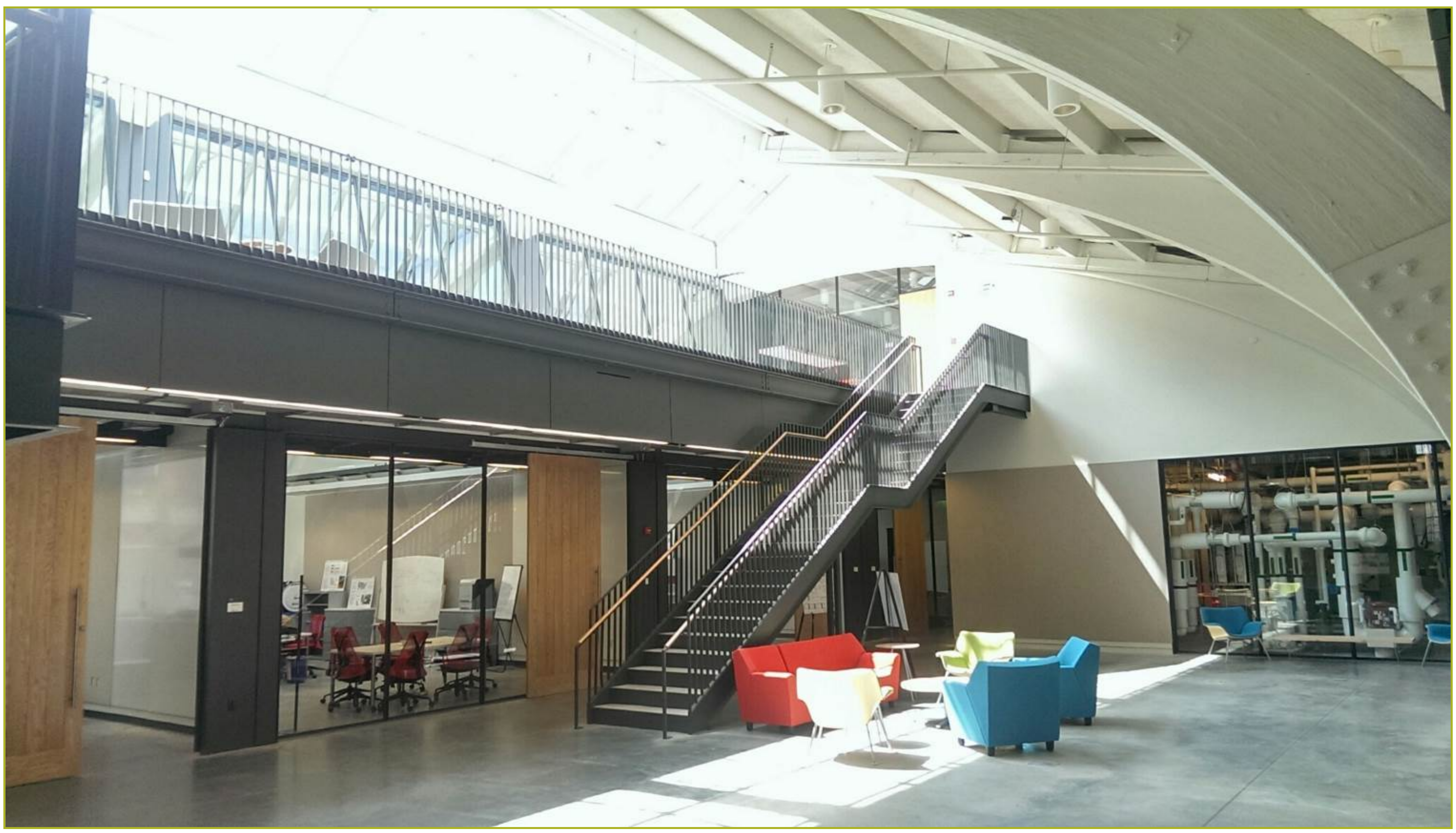
Report Author: Scott Wagner



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Report Abstract

Project objectives.

Intended for property owners, portfolio managers and government officials, the Intermediate and Advanced Level – A Guide to Community-Wide Benchmarking Analysis guides offer guidance on further approaches to understanding how the movement of Energy Star Portfolio Manager scores relate to specific fuel use types and to identifying and selecting a subset of inefficient benchmarked properties to target for energy efficiency measures. The advanced guide offers benchmarking program managers methodologies to track year-over-year changes in the efficiency of their benchmarked building stock and to develop a subset of "localized" peers to compared the efficiency of specific properties against.

Contact Information for lead researcher

Name: Scott Wagner
Institution: The Pennsylvania State University
Email address: swagner@engr.psu.edu
Phone number: 267-574-4239

Contributors

Ben Cohen - PSU

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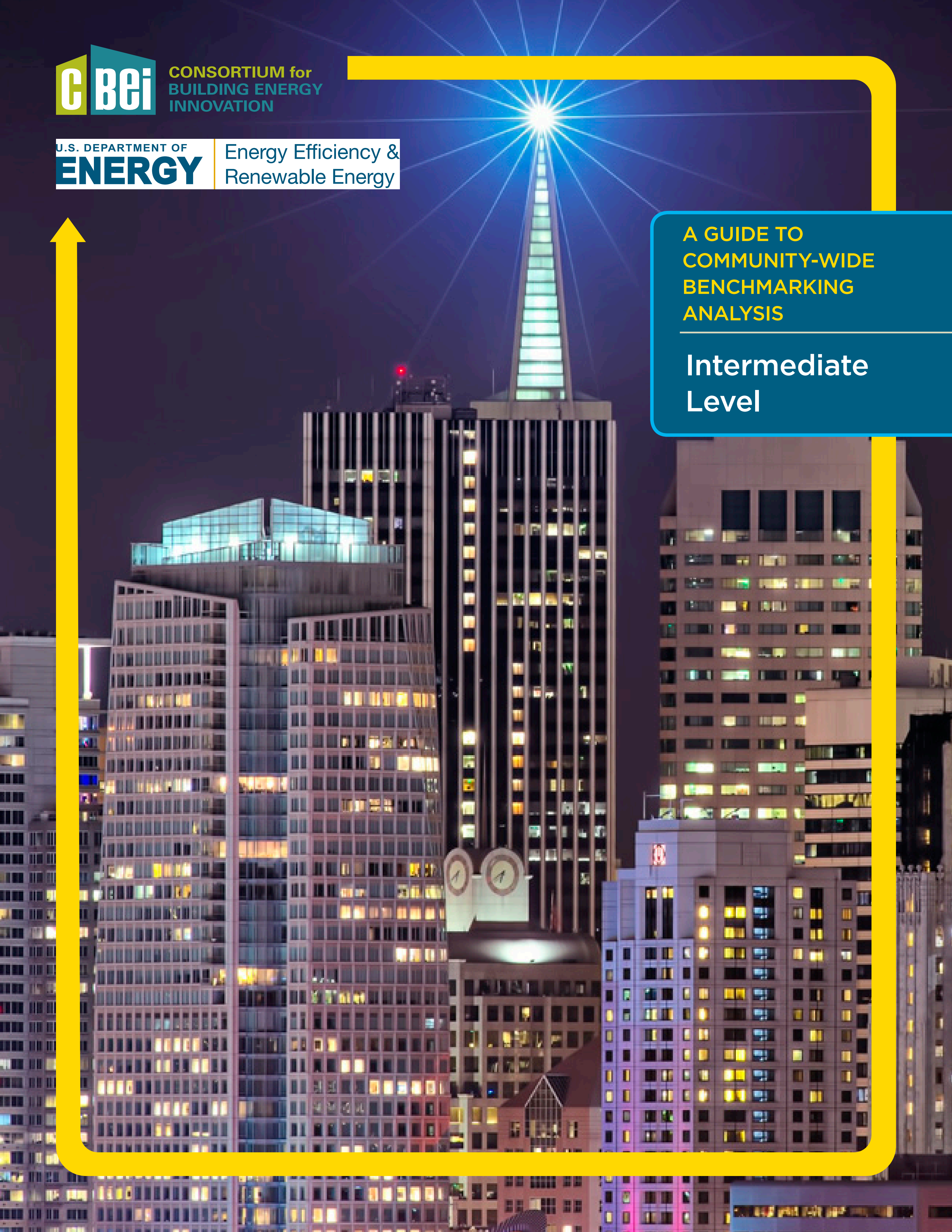

A GUIDE TO COMMUNITY-WIDE BENCHMARKING ANALYSIS

Intermediate Level

EXECUTIVE SUMMARY

Commercial buildings in the United States consume nearly half of all building-related energy use and roughly 20 percent of total energy consumption and greenhouse gas emissions. Experts have long believed that making the energy used by buildings more transparent is an essential step in helping to curb this enormous energy use. Benchmarking building energy usage makes this information available to the owner and/or the market.

Property and portfolio managers can use benchmarking to provide a measurement of how efficiently a building uses energy, compare their buildings to other similar buildings, and even to help identify building performance trends and opportunities for investment and energy savings. Several states and a host of local governments have adopted benchmarking policies, programs, and initiatives that include the comparative measurement of building energy performance across a portfolio of buildings.

Benchmarking a building (or a portfolio of buildings) simply aggregates energy consumption data. However, this exercise in data collection does not necessarily effectuate energy and cost savings. For benchmarking to have its maximum effect, the data that is collected must be accurate. Once accuracy is reasonably assured, the data can be analyzed to understand trends across space (e.g. within a city) and time (e.g. energy performance changes from one year to the next). While benchmarking data is useful to building owners, this guide holds the most value for benchmarking program administrators that will be assessing large collections of buildings in order to understand macro-level trends.

The Guide to Community-Wide Benchmarking Analysis will help the benchmarking program administrator prioritize and conduct the analyses of public and/or private building energy benchmarking data. The guide is presented in three levels – Introductory, Intermediate, and Advanced.

In general, the two analytical areas described in this Intermediate guide can lay the foundation for leveraging existing benchmarking data to drive energy efficiency retrofits. Understanding how large increases in ESPM scores can occur from saving electricity (as opposed to other fuels) helps inform energy managers about setting energy reduction goals in such a way as to maximize the number of ESPM points generated from retrofit programs.Furthermore, the 5-step selection methodology shown in this guide can help identify inefficient properties and allow energy managers to better target efforts at getting actual retrofits installed. Taken together, energy managers can gain a deeper understanding of why ESPM scores change from one year to the next, allowing for better evaluation of their retrofit programs.

Front Cover Photo Credit: Flickr User photoguyinmo, “Union Station in Kansas City Missouri at night”

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Chapter 1: Introduction

The Intermediate Level Guide to Commercial Building Benchmarking Analysis is a next step in understanding and using energy benchmarking data to increase the energy efficiency of benchmarked buildings. This guide is designed for readers already having a basic understanding of building energy metrics and parameters such as Energy Star Portfolio (ESPM) score, energy use intensity (EUI), annual cost per square foot, percent fuel share and site to source energy ratios. It is also assumed the reader understands that in terms of benchmarking properties, the energy efficiency of a property is associated with its Energy Star score, while the overall energy use of the property is associated with its EUI.

This guide offers information and guidance in two general analytical areas related to improving the overall efficiency of benchmarked building stock:

1. **By providing an understanding of how Energy Star scores increase in relation to what type of fuel is saved at a property (e.g., electricity, natural gas or purchased steam), the potential impacts of energy retrofits on measured building efficiency can be maximized.**
2. **By providing a methodology for identifying and selecting a subset of inefficient properties from overall benchmarking data, the potential results of targeted efforts to get retrofits installed can be maximized.**

This guide can also be used to lay the foundation for developing further understanding how Energy Star scores change from one year to the next and what impact efficiency initiatives have on benchmarked data tracked over time.

Note: while the data used for Chapter 2 of this guide is hypothetical, the data used for Chapter 3 is from Philadelphia's cleansed 2013 benchmarking dataset and is used for educational purposes only: it does not represent in any way the City's official benchmarking analysis.

Chapter 2: Understanding the Relationship between Energy Star Score and Energy Use

Once a benchmarking program has been established and benchmarking data has been collected on a portfolio of buildings, a next logical step is to begin using the data to develop and support a strategy to improve the energy efficiency of the benchmarked properties. One possible strategy for achieving improved energy efficiency is to set an energy reduction goal, for instance a 20% reduction in total property energy consumption, as a target to be reached by the properties in the benchmarking program. If Energy Star Portfolio Manager (ESPM) is the benchmarking tool being used for the benchmarking program, the type of energy saved (electricity, natural gas, fuel oil or steam) can have a significant impact on the number of Energy Star points gained when the energy reduction goal is attained.

In general, ESPM will generate a larger increase in Energy Star points for a given reduction in total property EUI if the fuel type saved is electricity as opposed to fuels such as natural gas, fuel oil or steam. This primarily has to do with ESPM using a source-to-site ratio of 3.14 for electricity generation and transmission when compared to source-to-site ratios of 1.05, 1.01 and 1.20 for natural gas, fuel oil and steam, respectively. As opposed to the other fuel types, a Btu of electrical energy saved at site-level will translate into 3.14 Btu of source energy saved at the point of electric generation and subsequent transmission to the property. (For natural gas, fuel oil and steam fuel types, the magnitude between site and source energy reductions are much smaller due to smaller site-to-source ratios.) This means that saving electricity at the site level will lower a property's total source EUI in larger increments when compared to the same site-level reduction in other fuel types.[1] And, since ESPM scores the energy efficiency of a property based on comparing a property's actual total source EUI to a normalized predicted source EUI, ESPM will generate a larger increase in the magnitude of the Energy Star score, for a given amount of site-level energy reduction, if electricity is saved as opposed to other fuel types. To be sure, site-level reductions in natural gas, fuel oil or steam fuel types will also generate increases in the Energy Star score, but the increase will be typically much smaller than those associated with the same reductions in electricity.

The various relationships between reduced energy use and increased Energy Star scores can be illustrated by running a series of Energy Star Portfolio Manager parametric runs at different fuel share ratios.

1 While a property's actual total source EUI is the sum of its various fuel-related source EUIs, the normalized predicted EUI used by ESPM to generate an Energy Star score is based on normalizing a mean source EUI (usually derived form CBECS) using non-fuel related normalization factors (for more information, see Energy Star Portfolio Manager's Technical Reference Manual, 2013).

ENERGY STAR PORTFOLIO MANAGER PARAMETRIC RUNS:

A series of parametric runs were performed using Energy Star Portfolio Manager for a theoretical office and K-12 school as a way of gaining an understanding of how Energy Star scores move relative to changes in both total property EUI and fuel share ratio. Initial parametric runs were made for basecase energy use levels of 100 and 80 kBtu/sf/yr for total property site energy use related to the office and K-12 school properties, respectively. In particular, parametric runs were done for the office property at fuel share ratios ranging from a 40%/60% split to an 80%/20% split of electricity to natural gas fuel consumption (basecase total property site energy use = 100 kBtu/sf/yr). For the K-12 school, fuel share ratios of a 10%/90% to a 50%/50% split of electricity to natural gas were used for the parametric runs (basecase total property site energy use = 80 kBtu/sf/yr).

For the measure cases in which the total property site EUI was reduced by 20% (office = 80 kBtu/sf/yr; K-12 school = 64 kBtu/sf/yr), parametric runs were performed using the same range of electricity to natural gas ratios as used in the basecases.

The data inputs used by ESPM to generate the predicted source EUI (e.g., gross floor area, # of main shift workers, weather conditions, etc.) were held constant from one parametric run to next so that the predicted source EUI would be the same for all parametric runs associated with either the office or K-12 school property type. This precludes any potential changes in Energy Star score that would occur from a change in predicted source EUI and allows for an analysis of just the impact different fuel share ratios have on Energy Star scoring. Figures 1 and 2 list the non-fuel ESPM inputs used for the office and K-12 school properties:

Figure 1. Non-fuel related inputs for ESPM Office Parametric Runs

OFFICE:

- Gross Square Footage = 100,000 SF
- Occupancy = 100%
- Weekly operating hours = 55
- Number of computers = 230
- Number of main shift workers = 230
- Percent that can be heated = 50% of more
- Percent that can be cooled = 50% or more

The Energy Star score for each parametric run was plotted against the associated site fuel share ratio and linear trendlines were applied to establish the linearity of the relationship

Figure 2. Non-fuel related inputs for ESPM K-12 School Parametric Runs

K-12 SCHOOL:

- Gross Square Footage = 100,000 SF
- Occupancy = 100%
- Energy consumption includes parking areas = No
- Athletic field with exterior lighting = Yes
- Heated swimming pool = No
- 25% or more of the students attend school exclusively for preschool/daycare = No
- Gymnasium floor area = 7,500 SF
- High school = No
- Number of main shift workers = 80
- Student seating Capacity = 1000
- Months in use = 10
- Weekend operation = No
- Number of computers = 175
- Cooking facilities = Yes
- Number of walk-in refrigerators/freezers = 2
- Percent that can be heated = 100%
- Percent that can be cooled = 100%

Table 1. Results of Energy Star Portfolio Manager Parametric Runs

PROPERTY TYPE	TYPE OF PARAMETRIC RUN	TOTAL PROPERTY SITE EUI - ALL FUEL TYPES COMBINED	FUEL SHARE - % ELECTRIC FRACTION OF TOTAL SITE ENERGY USE	FUEL SHARE - % NATURAL GAS FRACTION OF TOTAL SITE ENERGY USE	ENERGY STAR SCORE	R-SQUARED VALUE OF TREND LINE
OFFICE	Base Case	100 kBtu/sf/yr	40%	60%	68	0.9972
			50%	50%	59	
			60%	40%	50	
			70%	30%	42	
			80%	20%	35	
	Measure Case (20% Reduction in Total Site EUI)	80 kBtu/sf/yr	40%	60%	82	0.9991
			50%	50%	76	
			60%	40%	69	
			70%	30%	62	
			80%	20%	55	
K-12 SCHOOLS	Base Case	80 kBtu/sf/yr	10%	90%	82	0.9989
			20%	80%	70	
			30%	70%	57	
			35%	65%	50	
			40%	60%	43	
			50%	50%	32	
	Measure Case (20% Reduction in Total Site EUI)	64 kBtu/sf/yr	10%	90%	93	0.9894
			20%	80%	87	
			30%	70%	78	
			35%	65%	72	
			40%	60%	68	
			50%	50%	57	

between Energy Star score and site fuel share ratio. The R-Squared values for the trendlines were very close to 1, ranging from 0.9894 to 0.991. Since the trendline R-squared values are extremely linear, a very accurate prediction can be made about what the Energy Star score would be for any site fuel share ratio within the range shown.

Table 1 summarizes the set of parametric runs and shows significant differences in Energy Star scores for different ratios of fuel shares.

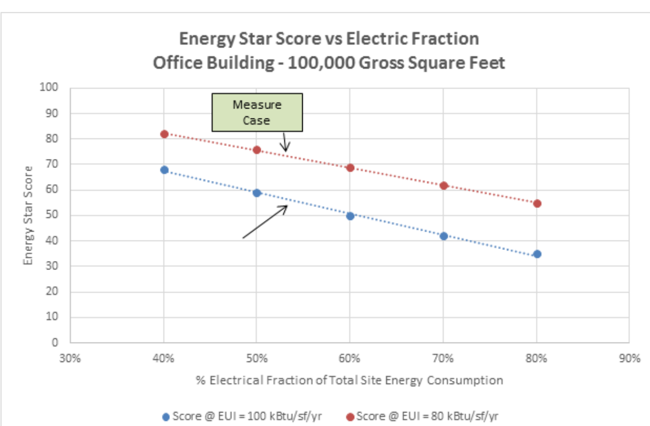

Figure 3. Results of ESPM Office Parametric Runs

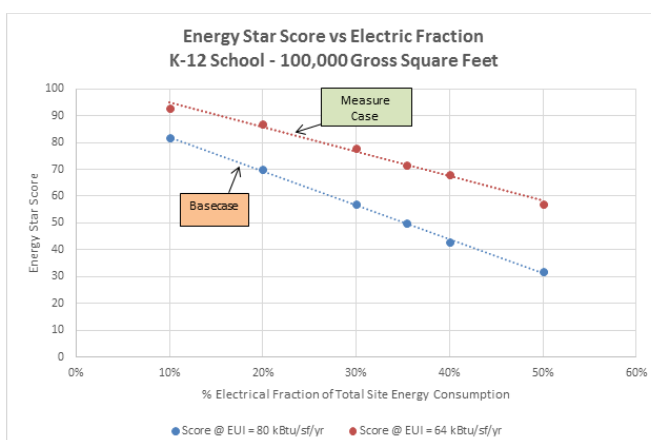

Figure 4. Results of ESPM K-12 School Parametric Runs

Figures 3 and 4 show the results of the various runs graphically for the office and K-12 School, respectively. The linear relationship between site fuel share ratio and Energy Star score for the given range of fuel share ratios (shown as % electric fraction of total site energy) is quite evident in these two figures. Energy Star scores can vary

ENERGY SAVINGS SCENARIOS BASED ON ENERGY STAR PORTFOLIO MANAGER PARAMETRIC RUNS

Three energy savings scenarios were developed as a way of gaining a deeper understanding of how Energy Star scores move based on what type of fuel is saved. That is to say, for a given reduction in a property's total site energy use (in this case a reduction of 20%) how many Energy Star points would be gained if all of the savings were associated with: 1) electricity only, 2) Natural gas only, and 3) combination of both electricity and natural gas. Each of the energy saving scenarios were assessed using the office and K-12 school properties defined for the Energy Star parametric runs, with both the office and K-12 school having basecase Energy Star scores of 50, and electricity/natural gas fuel share ratios of 60%/40% and 35%/65%, respectively. Figures 5 and 6 show the results of the three savings scenarios graphically for the office and K-12 school properties.

Savings Scenario 1: Point A to B; Total Energy Savings of 20%. Fuel share ratio remains the same between basecase and measure case.

Savings Scenario 2: Point A to C; Total Energy Savings of 20% - all savings are Electric. Fuel share ratio of electricity/natural gas changes for the office from the basecase of 60%/40% to the measure case of 50%/50%, while for the K-12 school, the ratio changes form 35%/65% to 19%/81%.

Savings Scenario 3: Point A to D; Total Energy Savings of 20% - all savings are natural gas. Fuel Share Ratio of electricity/natural gas changes for the office from the basecase of 60%/40% to the measure case of 75%/25%, while for the K-12 school, the ratio changes from 35%/65% to 44%/56%.

Table 2 summarizes the results of the three savings scenarios. The largest increases in Energy Star score occur when the total site energy reduction of 20% is all electric, with the office gaining 26 points and the K-12

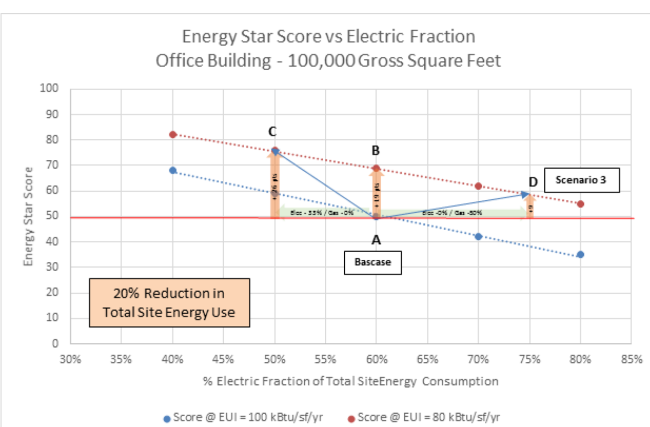

Figure 5. Results of Energy Saving Scenarios for Office Property

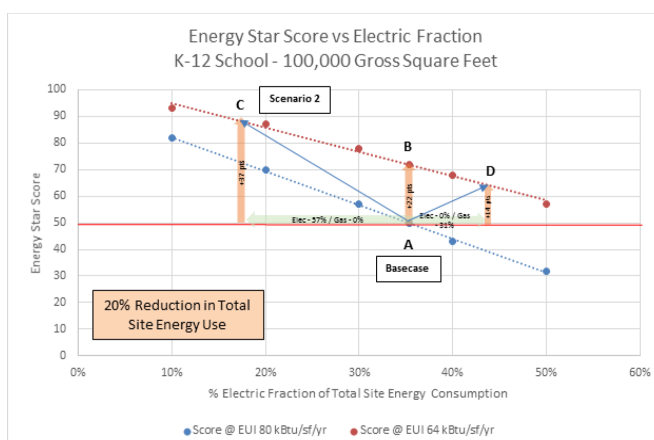

Figure 6. Results of Energy Saving Scenarios fork-12 School Property

Table 2. Energy Savings Scenarios Based on Energy Star Portfolio Manager Parametric Runs

TOTAL SITE ENERGY SAVINGS OF 20% = 20 KBTU/SF/YR SAVED FOR OFFICE AND 16 KBTU/SF/YR SAVED FOR K-12 SCHOOL								
	POINT:							
	A		B		C		D	
	Basecase		Savings Scenario 1: Same % Reduction for Each Fuel Type		Savings Scenario 2: All Sacvings Are Electric		Savings Scenario 3: All Savings Are Gas	
	Office	K-12 School	Office	K-12 School	Office	K-12 School	Office	K-12 School
Total Energy EUI (kBtu/sf/yr)	**100**	**80**	**80**	**64**	**80**	**64**	**80**	**64**
Electric EUI	60	28	48	22.4	40	12	60	28
Gas EUI	40	52	32	41.6	40	52	20	36
% Fuel Share:								
Electric	60%	35%	60%	35%	50%	19%	75%	44%
Gas	40%	65%	40%	65%	50%	81%	25%	56%
Energy Star Score:	**50**	**50**	**69**	**72**	**76**	**87**	**59**	**64**
% Electric Savings:	-	-	20%	20%	33%	57%	0%	0%
% Gas Savings:			20%	20%	0%	0%	50%	31%

school gaining 37 points (Scenario 2). When only natural gas is saved, the total site energy reduction of 20% produces much smaller increases in Energy Star scores, 9 points for the office and 14 points for the K-12 school (Scenario 3). When the fuel share ratio remains the same the between the basecase and measure case (Scenario 1), the Energy Star score increases by 19 points for the office and 22 points for the K-12 school.

In general, electricity-only energy reductions will generate significantly larger increases in Energy Star scores when compared to non-electric fuel types due to the larger reduction in source energy use arising from the 3.14 source-to-site ratio ESPM uses for calculating source electricity use.

IMPLICATIONS FOR BENCHMARKING PROGRAMS:

SETTING ENERGY REDUCTION GOALS:

For many municipalities, housing authorities or owners of large portfolios of buildings, the implementation of energy benchmarking programs are a first step in an overall energy reduction strategy designed to increase the energy efficiency of their building stock, usually by specifying energy reduction goals, as a way of reducing portfolio-wide energy use. If building stock energy efficiency is being measured by Energy Star Portfolio Manager scoring, understanding how the Energy Star score moves as a result of both overall energy reductions and changes in fuel share ratios can inform what types of energy reduction goals will producing the biggest increases in scores. For instance, in addition to setting a reduction goal of say, 20% of total energy use, there was a requirement to save the energy as electricity only; gains in energy star scores would be maximized. Conversely, since reductions in non-electric fuels will produce modest gains in Energy Star scores, minimizing the percentage of non-electric fuel savings allowed as a contribution to the overall reduction goal will result in larger increases in scores.

In reality, limiting energy savings to electricity only may not be practical for reduction strategies involving percent reductions in total energy use. For instance, in Scenario 2, a 20% reduction in total site energy use via an electric-only approach requires a 33% reduction in electricity use for the office property and a 57% reduction in electricity use for the K-12 school. Reducing the electric use of a K-12 school by 57% is not a trivial matter and could require a hefty investment in energy savings technologies; an investment many school districts may not be able to make. Hence, for many schools having relatively large non-electric fuel shares, a certain amount of non-electric fuel may have to be saved in order to meet the total site energy reduction goal. In light of this, Scenario 1 may offer a more reasonable way of setting reduction goals for schools. For Scenario 1, the fuel share ratio remained the same from the basecase to the measure case, meaning each fuel type was reduced by the same percentage (in this case both electric use and natural gas use were reduced by 20%). And, although the gains in Energy Star points were not as large as that in Scenario 2, the gains were significant enough that Scenario 1 may represent a good trade-off between what percentages of each fuel type should be saved. For example, a municipality may want to set an overall energy reduction goal of 20% of total site energy, but with a requirement that any non-electric fuel energy use can be reduced by no more than 20%.

UNDERSTANDING HOW THE EFFICIENCY OF BENCHMARKED BUILDING STOCK CHANGES YEAR OVER YEAR:

Since annual fuel share ratios can be calculated for each building benchmarked in a benchmarking program, program managers have the ability to track year-over-year changes in fuel type consumption for their benchmarked building stock as a whole. Changes in these fuel shares can then be compared to associated changes in the building stock's ESPM scores, allowing program managers to profile efficiency gains or losses of the overall building stock. For instance, if a subset of office properties showed a net reduction of 10% in total site energy use from one year to the next, the majority of which came from reductions in natural gas, there would only be a "modest" increase in ESPM scores. However, if the 10% net reduction was related to reduced electric energy use only, the associated increase in ESPM would be larger, implying the office properties had become much more energy efficient as a result of the same net reduction.[2]

In general, program managers can track the interplay of increases or decreases in site energy use and associated changes in ESPM scores at different levels (e.g., individual property level or property type level) to gain an understanding of how efficiency changes are occurring over time. They can also track and evaluate the potential impact efficiency initiatives, such as municipal programs aimed at commercial buildings, actually have on large sets of buildings.

2 It should be noted that the measure of efficiency of a building is its Energy Star score, not its annual site or source EUI. Also, for this example, the non-fuel inputs are assumed to not have changed from one year to the next.

Chapter 3: Methodology for Selecting Inefficient Properties as Candidates for Energy Efficiency Retrofits

One of the value propositions associated with establishing a benchmarking program is to use benchmarking data to drive an increase in energy efficiency retrofits that would not have otherwise occurred. In cases where benchmarking data is disclosed to the public, market forces (such as potential building tenants wanting to occupy more energy efficient building space as opposed to less efficient building space) can utilize and leverage benchmarking data to help buildings become more energy efficient. Furthermore, municipalities can utilize benchmarking data to identify buildings deemed energy inefficient for targeted outreach as part of, for instance, a commercial building retrofit program. This section describes 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.

This methodology also 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**
4. **High % Electric fuel share**

This methodology utilizes five different steps to identify a final subset of energy inefficient properties and can be applied to the set of properties associated with a particular property type. The five-step methodology is illustrated below using office and K-12 School properties from the cleansed Philadelphia 2013 benchmarking dataset.

STEP 1: SELECT PROPERTIES WITH ENERGY STAR SCORES OF 74 OR LESS

The first step in identifying inefficient properties is to parse properties having ESPM scores of 74 or less. A threshold score of 74 is used since ESPM considers properties having scores of 75 or higher as potentially qualifiers for Energy Star recognition. Hence, properties with scores less than 75 are assumed to be relatively inefficient.

From the cleansed 2013 Philadelphia benchmarking dataset, 82 out of a total 142 office properties and 128 out of 177 K-12 school properties have ESPM scores of 74 or less. Figure 7 shows a graphic representation of those properties having ESPM scores of 74 or less in relation to their annual EUI for office and K-12 school properties.

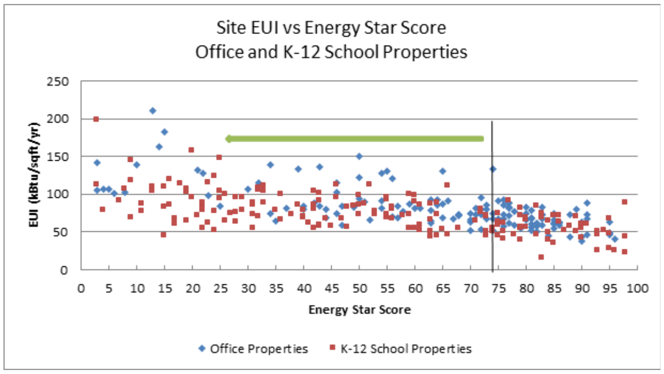

Figure 7. Selection of Office and K-12 School Properties with ESPM Scores of 74 or Less

STEP 2: SELECT PROPERTIES WITH SITE EUIS EQUAL TO OR GREATER THAN THE MEDIAN EUI

Using the subsets of properties identified in Step 1 as having ESPM scores of 74 or less, the next step is to calculate the median site EUI for each of these property groups. (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.)

For the office properties, 41 out of 82 properties had EUIs equal to or greater than the median value of 84.5 kBtu/sf/yr. For the K-12 school properties, 64 out of 128 properties had EUIs equal to or greater than the median value of 79.5 kBtu/sf/yr. Figures 8 and 9 show the subsets of office and K-12 school properties having EUIs above 84.5 and 79.5 kBtu/sqft/yr, respectively, from the data subset generate in Step 1. Select those properties having EUIs equal to or greater than the median value for each property type.

In general, properties with low ESPM scores and high EUIs represent more opportunity for saving energy than the converse, properties with high scores and low EUIs. A property with a low ESPM score is an indication that energy is being used inefficiently while the associated high EUI indicates the scale of potentially "wasted" energy.

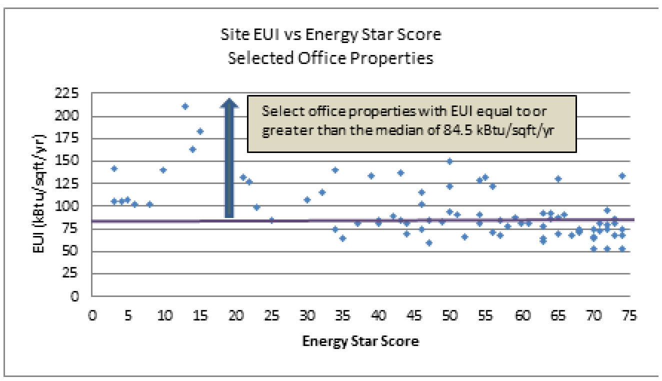

Figure 8. Selection of Office Properties Equal to or Greater than the Median EUI

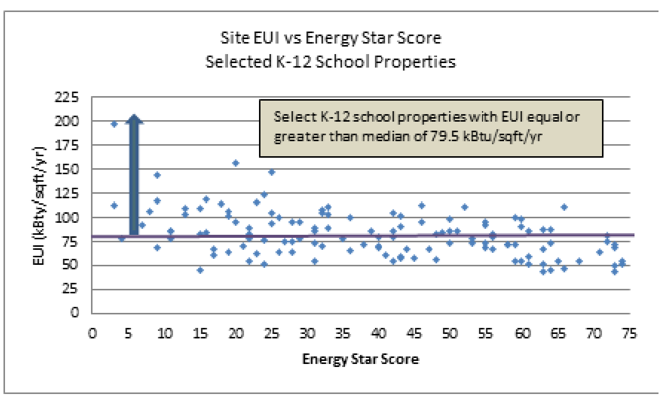

Figure 9. Selection of K-12 School Properties Equal to or Greater than the Median EUI

STEP 3: SELECT PROPERTIES WITH ANNUAL ENERGY COST PER SQUARE FOOT ($/SQFT) EQUAL TO OR GREATER THAN THE MEDIAN $/SQFT

Using the subsets of office and K-12 school properties selected in Step 2 (41 office properties and 64 K-12 school properties), calculate the median cost per square foot for each set of properties. (If actual fuel costs are not available, average fuel costs can be used – see Table 3 for the average fuel costs used for Philadelphia's benchmarking data.) Properties with high fuel costs typically offer shorter payback periods for retrofits, making the investment in a retrofit more attractive to the property owner.

Table 3. Typical Average Fuel Costs for Philadelphia 2013
Electric Rates =$0.0293/kBTU = $29.30/million BTU
Gas Rates = $0.0136/kBTU = $13.60/ million BTU
Fuel Oil Rates = $0.0205/kBTU = $20.50/ million BTU
Steam Rates = $0.0340/kBTU = $34.00/ million BTU

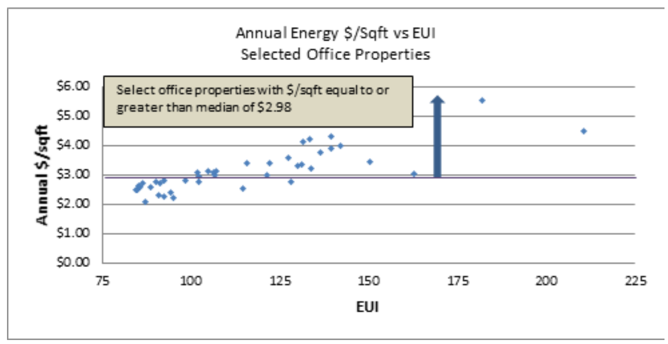

Figure 10. Selection of Office Properties Equal to or Greater than the Median Annual $/sqft

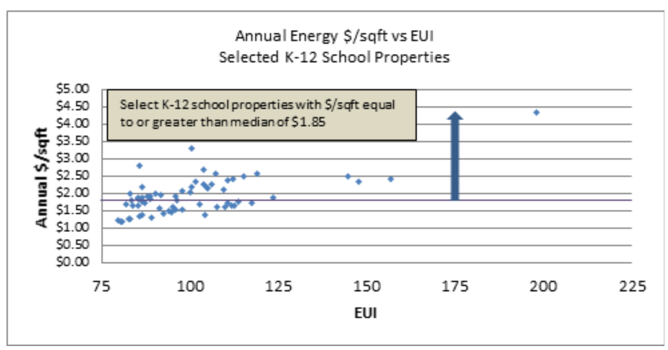

Figure 11. Selection of K-12 School Properties Equal to or Greater than the Median Annual $/sqft

Figures 10 and 11 show the subsets of office and K-12 school properties having annual $/sqft equal to or greater than the median value of $2.98 and $1.85, respectively, from the subsets generate in Step 2. For office properties, 21 of 41 properties meet this selection criteria, while for K-12 schools, 32 of 64 properties should be selected.

STEP 4: DETERMINE MEDIAN VALUE OF % ELECTRIC USE OF TOTAL ENERGY USE (ELECTRIC FUEL SHARE)

As is shown in Chapter 2, for a given reduction in site energy use, saving electricity as opposed to other fuel types will generate the largest increase in ESPM score. This also means that for the same amount of retrofit investment dollars, saving "x" Btus of electric energy as opposed to the same amount of, say, natural gas energy will produce a more efficient property. In light of this, properties with higher proportions of electric use compared to total energy use may offer better opportunities for larger increases in energy efficiency.[3]

Of the 21 office properties and 32 K-12 school properties selected in Step 3, the median % electric use is 77% for the offices and 18% for the K-12 schools.

STEP 5: DETERMINING A "REASONABLE" MINIMUM THRESHOLD FOR % ELECTRIC FUEL SHARE AS FINAL SELECTION CRITERIA

From the initial set of 142 office properties and 177 K-12 school properties, the selected subset of properties after Step 3 is now 21 offices and 32 K-12 schools. In terms of percentages, the selection process through Step 3 has reduced the number of inefficient properties identified to 15% (21/142) of the original set of offices and 18% (32/177) of K-12 schools. Using the median value of % electric fuel share as a final selection metric may produce a final subset of properties too small in number for certain property types. For instance, if the median value of 77% electric fuel share is used as the last selection criteria for the office properties (i.e., select office properties having % electric fuel share equal to or greater than 77%) then the remaining number of offices is just 10 out of 142 (7%). In order to garner a larger number of offices, the % electric fuel share criteria can be lowered to a more reasonable threshold. For the office properties, it was found that a 62% electric fuel share was reasonable and produced a final subset of 17 properties, or about 12% of the initial set of 142 office properties. **In general, a final selected percentage on the order of 10% of initial properties can be considered reasonable for expending resources to follow up with building owner/operators about performing energy retrofits.**

3 While this may not always be the case, retrofits applied to properties with a high percentage of electric use typically will be designed to lower electric consumption.

For the K-12 school properties, the median % electric fuel share was determined to be 18% and when used as the final selection criteria produced a final subset of 18 school properties, or about 10% of the initial set of 177 K-12 schools. Identifying 10% of the initial K-12 school properties can be considered appropriate; hence, the selection metric of 18% electric fuel share was used.

Figures 12 and 13 show the how the % electric fuel share criteria have been applied to the office and k-12 school properties identified from Step 3.

What Office and K-12 School Properties Were Actually Selected?

Figures 14 and 15 show what actual inefficient properties were selected out of the original property datasets of 142 offices and 177 K-12 schools using the selection methodology described in this chapter. The final set of inefficient properties, 17 offices and

Table 4. Selection Criteria for Determining Inefficient Properties

		OFFICE	K-12 SCHOOL
	Initial # of Properties:	**142**	**177**
Step 1:	# of Properties with Energy Star Score of 74 or Less:	82	128
Step 2:	# of Properties with Site EUI Equal to or Greater Than Median EUI:	41	64
	Median Site EUI (kBtu/sf/yr)=	***84.5***	***79.5***
Step 3:	# of Properties with $/sf Equal to or Greater Than Median $/sf:	21	32
	Median $/sf =	***$2.98***	***$1.85***
Step 4:	For # of Properties with $/sf Equal to or Greater Than Median $/sf, Median % Electric Fuel Share of Total Site Energy Use:	77%	18%
Step 5:	Selected Reasonable % Electric Fuel Share:	62%	18%
	# of Properties:	***17***	***18***

18 K-12 schools, represent those properties that have relatively low ESPM scores, high EUIs, high $/sqft and relatively high % electric fuel share. Properties with these four characteristics should provide, in general, the best investment opportunities for retrofits needing relatively short payback periods, while at the same time providing significant increases in ESPM scores. Moreover, this type of selection process generates a final set of properties that typically represents a fairly broad cross-section of the initial set of properties having ESPM scores of 74 or less and avoids selecting groups of properties with just high total energy usage or with just large amounts of building square footage.

Table 4 summarizes the selection process step-by-step and indicates the various criteria used to achieve the final set of inefficient office and K-12 school properties.

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CONSORTIUM FOR ENERGY INNOVATION
4747 S. Broad St.
Building 101, Suite 210
The Navy Yard
Philadelphia, PA 19112
215 218 7590

info@eebhub.org
http://cbei.psu.edu

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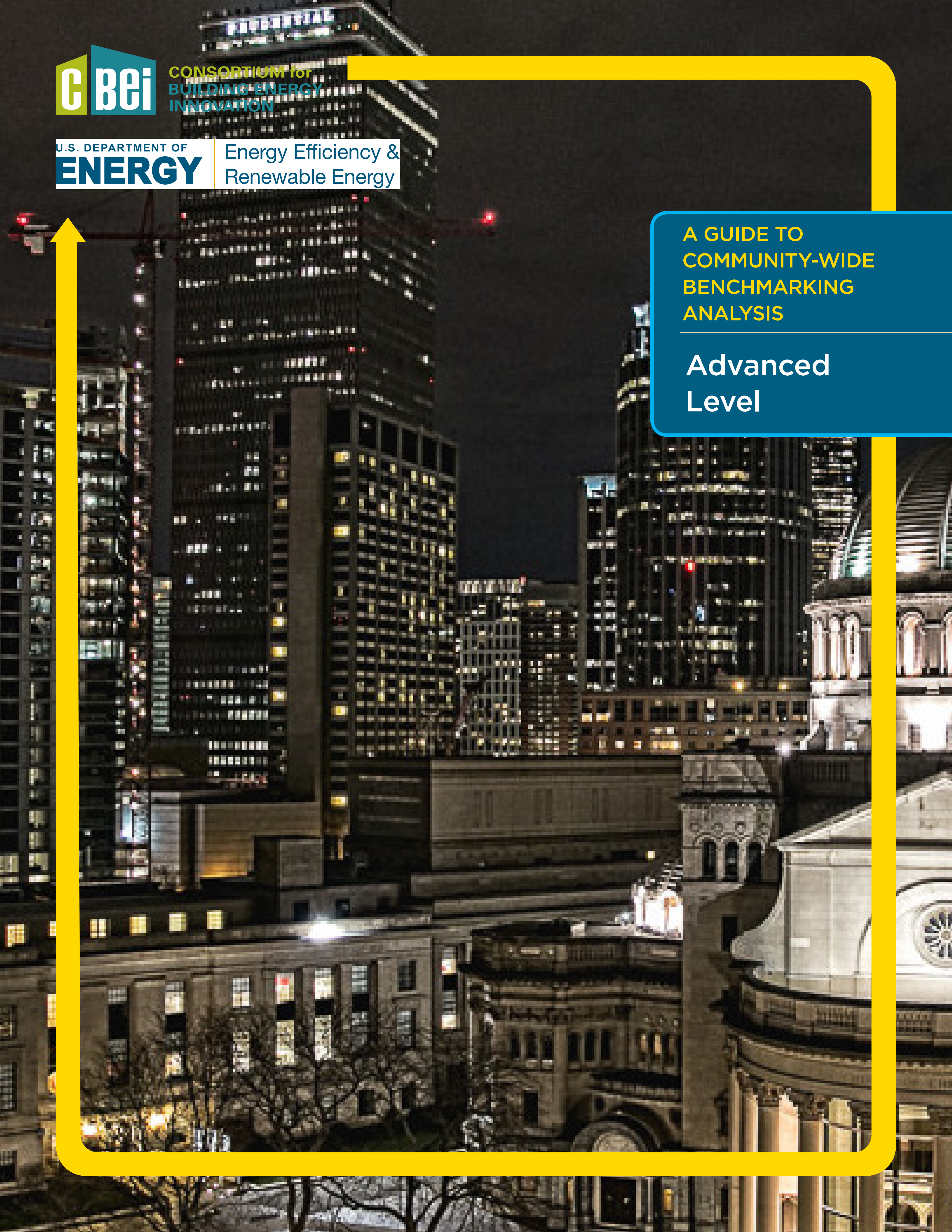
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

A GUIDE TO COMMUNITY-WIDE BENCHMARKING ANALYSIS

Advanced Level



EXECUTIVE SUMMARY

Commercial buildings in the United States consume nearly half of all building-related energy use and roughly 20 percent of total energy consumption and greenhouse gas emissions. Experts have long believed that making the energy used by buildings more transparent is an essential step in helping to curb this enormous energy use. Benchmarking building energy usage makes this information available to the owner and/or the market.

Property and portfolio managers can use benchmarking to provide a measurement of how efficiently a building uses energy, compare their buildings to other similar buildings, and even to help identify building performance trends and opportunities for investment and energy savings. Several states and a host of local governments have adopted benchmarking policies, programs, and initiatives that include the comparative measurement of building energy performance across a portfolio of buildings.

Benchmarking a building (or a portfolio of buildings) simply aggregates energy consumption data. However, this exercise in data collection does not necessarily effectuate energy and cost savings. For benchmarking to have its maximum effect, the data that is collected must be accurate. Once accuracy is reasonably assured, the data can be analyzed to understand trends across space (e.g. within a city) and time (e.g. energy performance changes from one year to the next). While benchmarking data is useful to building owners, this guide holds the most value for benchmarking program administrators that will be assessing large collections of buildings in order to understand macro-level trends.

The Guide to Community-Wide Benchmarking Analysis will help the benchmarking program administrator prioritize and conduct the analyses of public and/or private building energy benchmarking data. The guide is presented in three levels – Introductory, Intermediate, and Advanced.

In general, the two analytical areas described in this Intermediate guide can lay the foundation for leveraging existing benchmarking data to drive energy efficiency retrofits. Understanding how large increases in ESPM scores can occur from saving electricity (as opposed to other fuels) helps inform energy managers about setting energy reduction goals in such a way as to maximize the number of ESPM points generated from retrofit programs.Furthermore, the 5-step selection methodology shown in this guide can help identify inefficient properties and allow energy managers to better target efforts at getting actual retrofits installed. Taken together, energy managers can gain a deeper understanding of why ESPM scores change from one year to the next, allowing for better evaluation of their retrofit programs.

Front Cover Photo Credit: Flickr User mgstanton, "Boston at night"

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Chapter 1: Assessing and Tracking Changes in Benchmarking Data Year-to-Year

This advanced level to guide to analyzing municipal benchmarking data offers information on how to define, track and understand how benchmarking data can be used to assess time-varying changes in the overall efficiency of the building stock typically found in a municipality. Additionally, this guide also offers information on a methodology for "localized" benchmarking of properties.

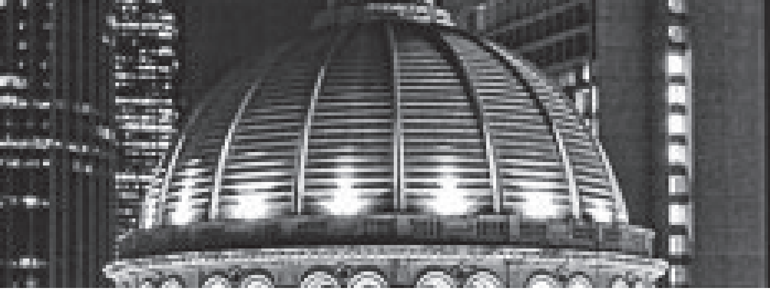
This chapter offers methodologies for cleansing and tracking benchmarking data for analysis of year-to-year changes in property energy use efficiency, total energy consumption and associated greenhouse gas emissions. Unde rstanding the relationships between energy efficiency, total energy consumption and greenhouse gas emissions will give energy managers and analysts the ability to profile overall changes in benchmarked building stock and measure impacts from efficiency initiatives.

DATA MATCHING AND CLEANSING

Using "raw" 2012 and 2013 Philadelphia benchmarking datasets, the following matching and cleansing criteria were applied to both datasets prior to subsequent analysis of properties with Energy Star scores. The impacts of the matching and cleansing

Table 1. Matching and Cleansing Criteria:

MATCHING AND CLEANSING CRITERIA:	# OF PROPERTIES IN ORIGINAL DATA SET	# OF PROPERTIES REMOVED
1. 2012 and 2013 properties matched by Portfolio Manager Property ID	1039	
2. Properties not reporting same square footage both years		85
3. Properties with different EPA calculated property types year to year		5
4. Properties with "Not Available" property type		7
5. Properties not reporting electrical consumption in one year or the other		70
6. Properties with no EUI in one year or the other		2
7. Calculated EUI does not match generated EUI in both years		54
8. Properties under benchmarking threshold of 50,000 square feet		37
9. Properties not eligible to receive an Energy Star score		211
10. Properties without an Energy Star score for both years or just one year		67
11. Properties with very low Energy Star scores (1 & 2) in either year		24
12. Properties with very high Energy Star scores (100 & 99) in either year		39
13. Properties showing a 50% or more change in site EUI one year compared to the other		25
14. Properties showing a change in Energy Star score of 40 points or more one year compared to the other		2
15. Properties showing a 40% or more change in the source-to-site energy ratio one year compared to the other		1
Final Number of Properties in Cleansed 2012 and 2013 Benchmarking Datasets		**410**



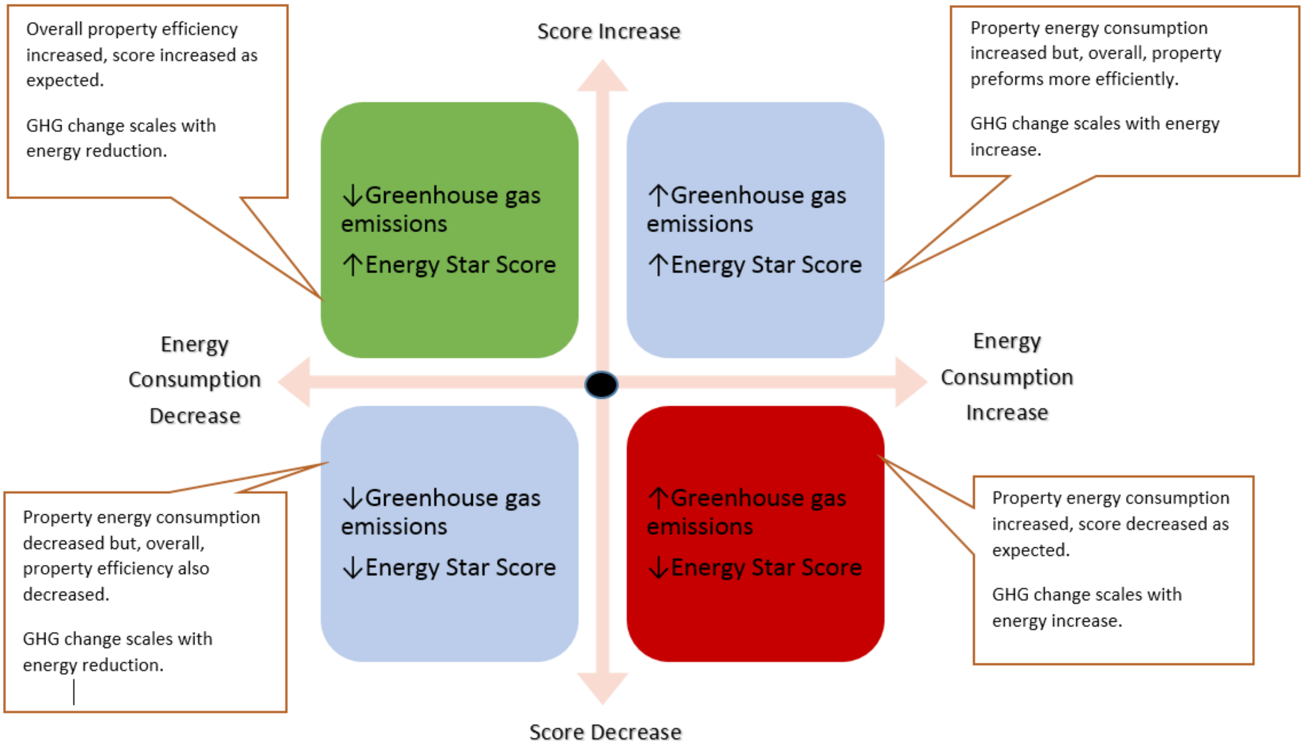


Figure 1. Scenarios of How Benchmarking Data Changes Year-to-Year

process are summarized in Table 1.[1] [2]

After applying the matching and cleansing criteria show in Table 1, the final subset of properly matched and cleansed data consists of 410 properties. In addition to having an Energy Star score, all 410 properties have site and source EUIs and a numeric value for greenhouse gas emissions (given in equivalent metric tons of CO2). By tracking the year-to-year changes in these four metrics, energy managers and analysts can gain an understanding of how both the energy efficiency and the associated greenhouse gas (GHG) emissions of their building stock changes over time.

BENCHMARKING, INCREASED ENERGY EFFICIENCY AND GREENHOUSE GAS REDUCTIONS:

Many municipalities have launched energy benchmarking programs as the first step in achieving goals of increased commercial building energy efficiency, reduced source energy use and reduced emissions of greenhouse gases. And as the overall efficiency of the building stock increases as the result of initiatives designed to achieve these goals, building stock Energy Star scores should increase and GHG emissions should decrease over time. Hence, an understanding of how Energy Star scores, energy use and GHG emissions change as the result of year-to-year comparisons is essentially to evaluating if, in fact, these goals are actually being attained.

It is important to note the EUI of a property represents how much energy was consumed by the property, while the Energy Star score represents how "efficiently" that energy was used.

Shown in Figure 1 are four scenarios which are likely to occur when studying changes in a property's energy consumption, benchmark score and GHG emissions in year-to-year comparisons. In general, the green square shown in Diagram 1 is the "best" outcome for a property when compared year-to-year: energy use went down, GHG went down, Energy Star score went up. Conversely, the red square is the "worst"

1 It is assumed that any duplicates and test/sample entries have already been removed from both the 2012 and 2013 datasets.
2 Calculated EUI is ratio of reported total energy use (kBtu) divided by reported property square footage and may not be the same as the reported EUI due to changes in space use characteristics and/or energy use during the year.

outcome: energy use went up, GHG went up, Energy Star score went down. There are two other scenarios, blue squares, where: 1) energy use went up, GHG went up, Energy Star went up, and 2) energy use went down, GHG went down, Energy Star score went down. Although the two scenarios represented by the two blue squares seem counter-intuitive, they do occur, but usually only involve a relatively small number of properties.

Note: when there is no change in benchmark score the property would be represented by the black circle. This often happens when overall energy consumption changes are very small.[3]

To clarify, year-to-year comparisons can be one year to the next comparisons or a base year compared to subsequent years. As various energy efficiency initiatives are deployed over time, comparisons of a base year to a subsequent year, say four of five years later, will typically reveal the largest impacts in changes of benchmarking data.

In general, when trying to achieve a goal such as a 20% reduction in commercial building energy use by 2020, energy managers and analysts would like to see most commercial buildings show, for comparisons of a base year to a subsequent year, benchmarking data changes corresponding to the green square shown in Diagram 1: energy use went down, GHG went down, Energy Star score went up.

To demonstrate the various relationships of greenhouse gas emissions and Energy Star score changes shown in Figure 1, a scatter plot of the annual change that occurred from 2012 to 2013 in GHG vs corresponding change in Energy Star score is shown in Figure 2, with normalized GHG change sorted from smallest to largest.[4] Negative GHG values on the left of the plot are a decrease in emissions from 2012 to 2013 and generally correspond to an increase in score. Positive GHG values on the right of the are an increase in GHG emissions and generally relate to a decrease in in score.

plot are an increase in emissions and tend to correspond to a decrease in score.

The red line indicates the inflection point of the normalized GHG curve (i.e., where the annual GHG change goes from negative to positive). The green line indicates the midpoint (205 properties) of the total number of properties (410). The offset of the green and red lines shows more properties with an increase in GHG emissions than a decrease for 2012 to 2103.

Figure 3 is a scatter plot of the change in Energy Star score for each property compared to its change in source EUI, with source EUI sorted from smallest to largest. Similar to Figure 2, positive changes in Energy Star scores from 2012 to 2013 are consistent with reduced energy use (negative change) and vice versa. The green line indicates the midpoint of the total number of properties, while the red line indicates the

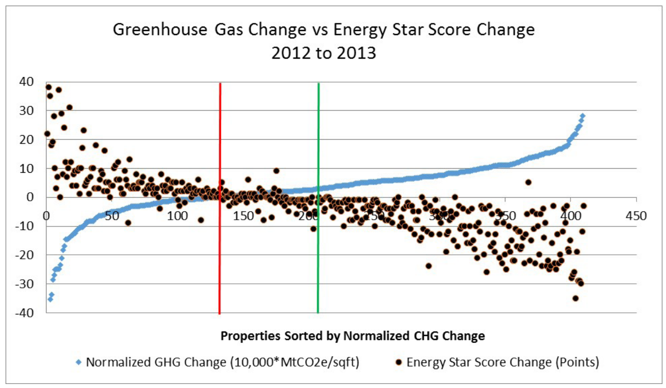


Figure 2. Changes in Normalized GHG emissions and Energy Sta score 2012 to 2013.

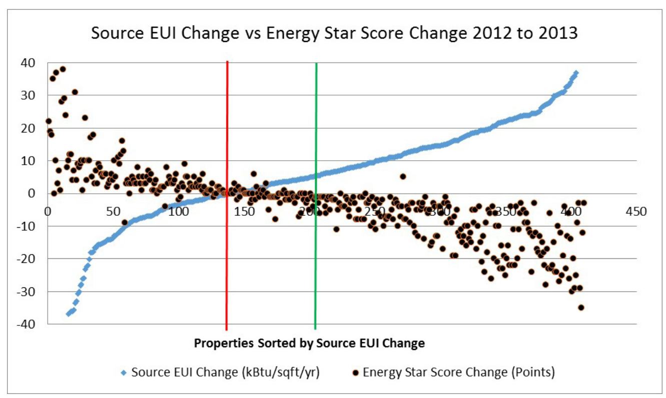


Figure 3. Changes in Source Energy Use and Energy Star score 2012 to 2013.

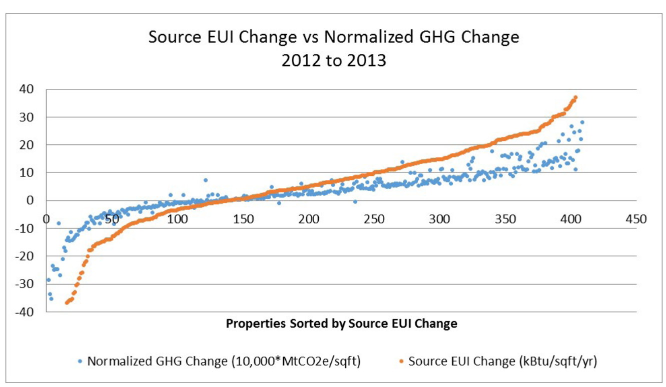


Figure 4. Changes in Source Energy Use and Normalized GHG 2012 to 2013.

3 For this analysis, the site and source EUIs are not weather-normalized values since actual greenhouse gas emissions "seen" by the environment include impacts from weather.

4 Metric ton CO2e emissions values were normalized by property square footage and a scaling factor in order to graphically show both metrics on the same plot.

inflection point of the source energy curve. Figure 3 shows more properties increased source energy use from 2012 to 2013 than those that reduced source energy use.

Because greenhouse gas emissions and source EUI are related to each other by the fue ar score.

Figure 4 is a scatter plot showing the relationship between source energy use and associated GHG emissions, with source EUI sorted smallest to largest. In general, GHC changes track similarly to source EUI changes. However, since source EUI is related to the fuel mix for a given property, properties with the same source EUI may have different amounts of GHG emissions based on different fuel mixes.

EVALUATION METRICS FOR YEAR-TO-YEAR COMPARISONS:

In addition to tracking changes in source EUI, GHG and Energy Star score via year-to-year comparisons, several other benchmarking metrics pertaining to the building stock as a whole should be tracked as well. The metrics shown below offer a more complete picture of how energy use, energy efficiency and GHG emissions can change year-to-year, and whether or not the building stock as a whole has seen improved efficiency.

1. **Number of Properties Having an Increase or Decrease in Energy Star Score: If the number of properties showing an increase in Energy Star score is greater than the number showing a decrease, this is one indication the overall efficiency of the building stock has improved.**
2. **Change in Total Sum of Energy Star Scores: Since the measure of a property's energy efficiency is its Energy Star score, a change in the total sum of scores for a set of properties will indicate the magnitude of the overall increase or decrease in building stock efficiency.**
3. **Change in Total Sum of Source Energy: An increase or decrease in total source energy use is another indicator as to whether building stock efficiency has improved.**
4. **Change in Total Sum of GHG Emissions: An increase or decrease in total GHG emissions is another indicator as to whether building stock efficiency has improved in such a way as to lower net emissions.**

Tables 2 and 3 show the magnitude and percent change for the 410 properties evaluated in the comparison of 2012 and 2013 benchmarking data. Figure 5 shows the change in three other common metrics used to evaluate changes in benchmarking data: median site EUI, median Source EUI and median Energy Star score.

Table 2. Changes in Magnitude of Energy Star Score, Source EUI and GHG Emissions - 2012 to 2013.

Change Type:	# of Properties	Total Property Square Footage (Million SF)	2012			2013			2012-to-2013 Change		
			Sum of Energy Star Scores	Sum of Source Energy Use (1000's mmBtu)	Sum of GHG (1000's MtCO2e)	Sum of Energy Star Scores	Sum of Source Energy Use (1000's mmBtu)	Sum of GHG (1000's MtCO2e)	Energy Star Scores	Source Energy Use (1000's mmBtu)	GHG (1000's MtCO2e)
Source Energy Use Down/ Energy Star Score up	123	31.27	6,568	7,731.48	336.8	7,424	7,273.46	318.6	856	-458.02	-18.1
Source Energy Use Down/ No Energy Star Score Change	13	5.20	902	1,757.68	83.8	902	1,727.35	83.0	0	-30.33	-0.8
Source Energy Use Down/ Energy Star Score Down	5	2.30	314	540.66	22.1	297	531.48	21.8	-17	-9.18	-0.3
Source Energy Use Up/ No Energy Star Score Change	21	5.13	1,359	856.48	37.2	1,359	875.00	38.6	0	18.52	1.3
Source Energy Use Up/ Energy Star Score Down	248	42.86	15,491	8,225.74	356.3	13,386	8,890.62	390.1	-2,105	664.88	33.8
Total	410	86.76	24,634	19,112.04	836.2	23,368	19,297.92	852.2	-1,266	185.88	15.9

Table 3. Percent Changes in # of Properties, Energy Star Score, Source EUI and GHG Emissions - 2012 to 2013.

Change Type:	2012-to-2013 Change			
	% # of Total Properties	**% Change in Energy Star Scores**	**% Source Energy Use (1000's mmBtu)**	**% GHG (1000's MtCO2e)**
Source Energy Use Down/ Energy Star Score up	30.0%	13.0%	-5.9%	-5.4%
Source Energy Use Down/ No Energy Star Score Change	3.2%	0.0%	-1.7%	-0.9%
Source Energy Use Down/ Energy Star Score Down	1.2%	-5.4%	-1.7%	-1.4%
Source Energy Use Up/ No Energy Star Score Change	5.1%	0.0%	2.2%	3.6%
Source Energy Use Up/ Energy Star Score Down	60.5%	-13.6%	8.1%	9.5%
Total		**-5.1%**	**1.0%**	**1.9%**

For the 410 properties in the 2012-to-2013 comparison dataset:

- **Median site EUI increased by 5.7 kBtu/sqft/yr**
- **Median source EUI increased by 8.2 kBtu/sqft/yr**

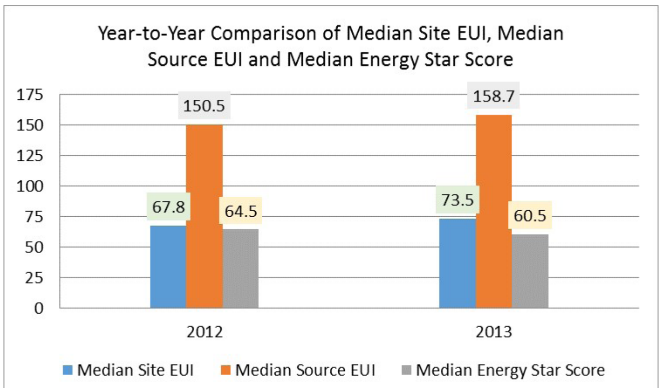


Figure 5. Median Values for Site EUI, Source EUI and Energy Star 2012 to 2013.

- **Median Energy Star decreased from 64.5 to 60.5**

Also,

- **Scores of 253 properties decreased by an average of 8.4 points**
- **Scores of 34 properties stayed the same**
- **Scores of 123 properties increased by an average of 7.4 points**

ASSESSMENT OF CHANGE IN OVERALL EFFICIENCY OF BUILDING STOCK 2012-TO-2013

Based on the evaluation metrics described above, an assessment can be made of the change in overall efficiency of the total building stock.

1. **Number of Properties Having an Increase or Decrease in Energy Star Score: The number of properties showing a decrease in Energy Star score was about twice that of those showing an increase.**
2. **Change in Total Sum of Energy Star Scores: There was about a 5% decrease in the total sum of Energy Star scores.**
3. **Change in Total Sum of Source Energy: There was a 1% increase in total source energy use.**
4. **Change in Total Sum of GHG Emissions: There was about a 2% increase GHG emissions.**

There were also increases in median site and source EUIs along with a decrease in median Energy Star score. While there was a decrease in GHG emissions of 19,205 MtCO2e for the portion of properties having an increase or neutral change in Energy Star score, these reductions were offset by an increase of 35,150 MtCO2e for the other properties, resulting in a net increase of 15,945 MtCO2e.

Given the results of these evaluation metrics, a reasonable assessment of the change in efficiency for 2012-to 2013 of the overall building stock would be:

Although there was an increase in efficiency for a significant number of properties, this efficiency increase was more than offset by a much larger portion of properties with decreased efficiency leading a relatively small decrease in overall building stock efficiency.

Chapter 2: Methodology for Localized Benchmarking

Described in this chapter is a methodology for assessing the energy efficiency in a localized context for certain property types used in Portfolio Manager. For example, ESPM requires the following inputs for office properties in order to calculate an Energy Star score:

- **Gross Square Footage**
- **% Occupancy**
- **Weekly operating hours**
- **Number of computers**
- **Number of main shift workers**
- **Percent that can be heated**
- **Percent that can be cooled**
- **Heating Degree Days**
- **Cooling Degree Days**

ESPM utilizes these inputs to normalize a mean source EUI for the full national population in the reference data (for that particular property type) to the defined conditions of the building being evaluated, along with heating and cooling degree days for the period being evaluated.[1] The resulting normalized source EUI is known as the predicted source EUI for the property and is compared to the actual source EUI of the property to generate an energy efficiency ratio.

Energy Efficiency Ratio (EER) =
Actual Source EUI/Predicted Source Energy EUI

Energy efficiency ratios of less than one indicate the property uses less energy than the predicted source EUI and vice versa. The Energy Star score is derived from comparing the EER to the national distribution of EERs from the reference data set for that property type. Portfolio Manager refers to this comparison as comparing the property to its "theoretical peer group." Each time one of the input variables is changed for a property (e.g., the property operates 55 hours per week instead of 45 hours per week), the property is compared to a new theoretical peer group. This allows ESPM to compare a property to itself, via its Energy Star score, after changes have been made to the property, or be compared to other properties across the nation.

1 While a property's actual total source EUI is the sum of its various fuel-related source EUIs, the normalized predicted EUI used by ESPM to generate an Energy Star score is based on normalizing a mean source EUI (usually derived form CBECS) using non-fuel related normalization factors (for more information, see Energy Star Portfolio Manager's Technical Reference Manual, 2013).

Although peer groups are theoretical in nature, the theoretical peer group is the same for any property that reports the same input parameters for the same property type.

DEFINITION OF LOCALIZED COMPARISON:

ESPM compares a property to its national theoretical peer group in order to generate an Energy Star score. However, Energy Star benchmarking data generated from a municipality's benchmarking program can be used to do comparison on a local level as well. Doing this allows us to answer the question: how does office property X in, say Philadelphia, compare to other office properties in Philadelphia that are just like office property X? In other words, all of the office properties in Philadelphia having the same characteristics (shown in bullets below) as found in office property X will constitute a local peer group that can be used to compare office property X against. (Note: since property X and its local peer group are all located in Philadelphia, they will all share the same number of heating and cooling degree days.)

- **Gross Square Footage**
- **Percent Occupancy**
- **Weekly operating hours**
- **Number of computers**
- **Number of main shift workers**
- **Percent that can be heated**
- **Percent that can be cooled**

Since all of the office properties in the local peer group and office property X have the same characteristics, they all have the same predicted source EUI. Hence, if all of the predicted source EUIs are the same, the predicted source EUI is a constant value for all of the properties in the local peer group and property X. This implies the Energy Efficiency Ratios (EER) for the local peer group and property X are all directly proportional to each property's actual source EUI. That is to say, the EER of a property now scales directly with the actual source EUI of the property, and since the EER is a measure of efficiency of a property, the efficiency of the property scales directly with its actual source EUI.[2] This concept can be demonstrated with this equation:

Energy Efficiency Ratio (EER) = Actual Source EUI/Predicted Source Energy EUI

Where: Predicted Source EUI is a constant

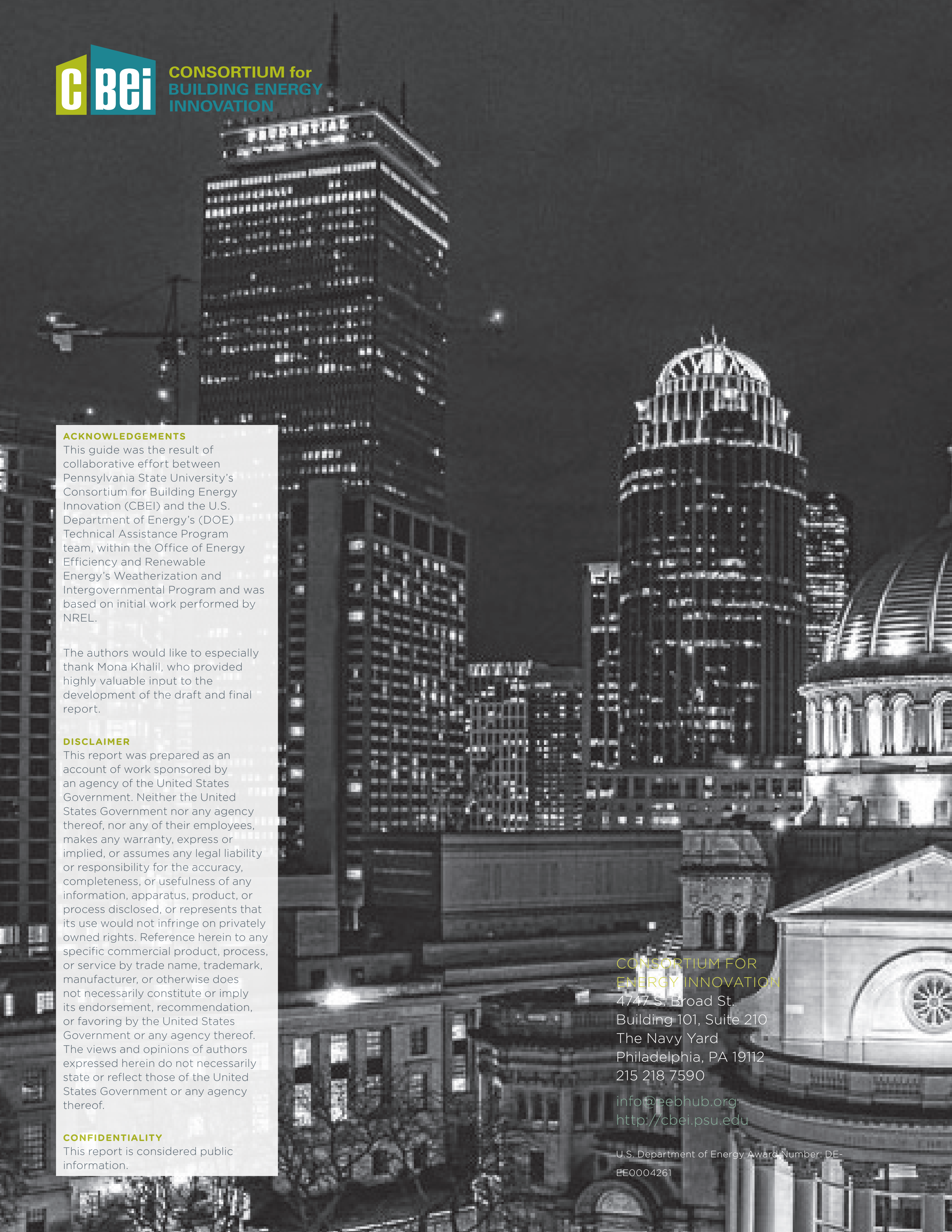
EUI AS A METRIC TO RANK LOCALIZED COMPARISONS

In order to find a "localized" comparison peer group, the ESPM database would have to be "mined" to find similar properties that have same characteristics. In most cases, this will leave a small number of properties that could be grouped together. For instance, in Philadelphia, a specific office building may only have 5 or 6 "localized" peers that have the same square footage, % occupancy, number of operating hours, number of workers and computers and percent that can be heated or cooled as it does. And while this number of "localized" peers may seem small, they actually represent the best set of properties to compare against.

ESPM OFICE BUILDING INPUTS:			
Gross Square Footage:	85,000 Sqft	Number of main shift workers:	90
% Occupancy:	100%	Percent area that is heated:	100%
Weekly operating hours:	55	Percent area that is cooled:	100%
Number of computers:	110		
	Source EUI:		
Property E	155.2		
Property G	179.9		
Property B	184.1		
Property A	193.6		
Property F	198.1		
Property C	203.8		
Property D	262.3		

Once the "localized" peer group has been defined, a ranking of each property's source EUI can be done for comparison to a specific property. Those properties with the smallest source EUI can be considered the most efficient and vice versa. Table 4 shows an example set of properties all having the same predicted source EUI, but varying actual source EUIs. In this example, Property A has a source EUI which ranks as the fourth most efficient property when compared to its six other local peers.

2 This is a one of the rare cases in which a property's EUI can be a measure of the efficiency of the property for a specific year.



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CONSORTIUM FOR
ENERGY INNOVATION
4747 S. Broad St.
Building 101, Suite 210
The Navy Yard
Philadelphia, PA 19112
215 218 7590

info@eebhub.org
http://cbei.psu.edu

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