PITTSBURGH 2030 DISTRICT ENERGY BASELINE: MOTIVATION, CREATION, AND IMPLICATIONS

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INTRODUCTION

Consider the task of tracking the energy use of an entire city while also working to reduce it by 50% in 17 years. How would you go about tracking and verifying such reductions? Further, how would this be accomplished in a city without a database of building-specific characteristics and no energy reporting law? To begin, let's consider what this task would look like for one building. Where to start? Let's try with a performance metric and point of comparison.

Just as cars gauge performance by MPG, and pitchers by ERA, buildings can use Energy Use Intensity (EUI) as a performance metric. Measured in Energy / ft^2 / year, EUI standardizes energy use per square foot, allowing for comparison between many buildings. EUI is a snapshot of building performance over one year's time. It is relatively easy to calculate a building's EUI if their energy usage is known, but in order to gauge performance over a longer period, a constant comparison point must be established so that evaluation is consistent. Called the baseline, this comparison point can be established as a past year, a future goal, or the average performance of similar buildings.

This paper covers the work of the Pittsburgh 2030 District team in formulating an energy performance baseline for each building in Downtown Pittsburgh for purposes of tracking energy use reduction towards the 50% reduction goals of The 2030 Challenge. Pittsburgh is a city with a large stock of aging buildings, without mandatory benchmarking laws, and no single publicly accessible real estate profile by property. Thus, the energy baseline methods included in this paper summarize efforts to create such an aggregated property characteristic database and associated energy baseline for Downtown Pittsburgh; it is the hope of the authors that these efforts will assist similar cities in mirroring 2030 District goal setting and achievement for building energy

KEYWORDS

2030 Challenge, energy use, energy performance, energy use intensity, energy efficiency, building performance, baseline, benchmarking, Energy Star, energy demand reduction

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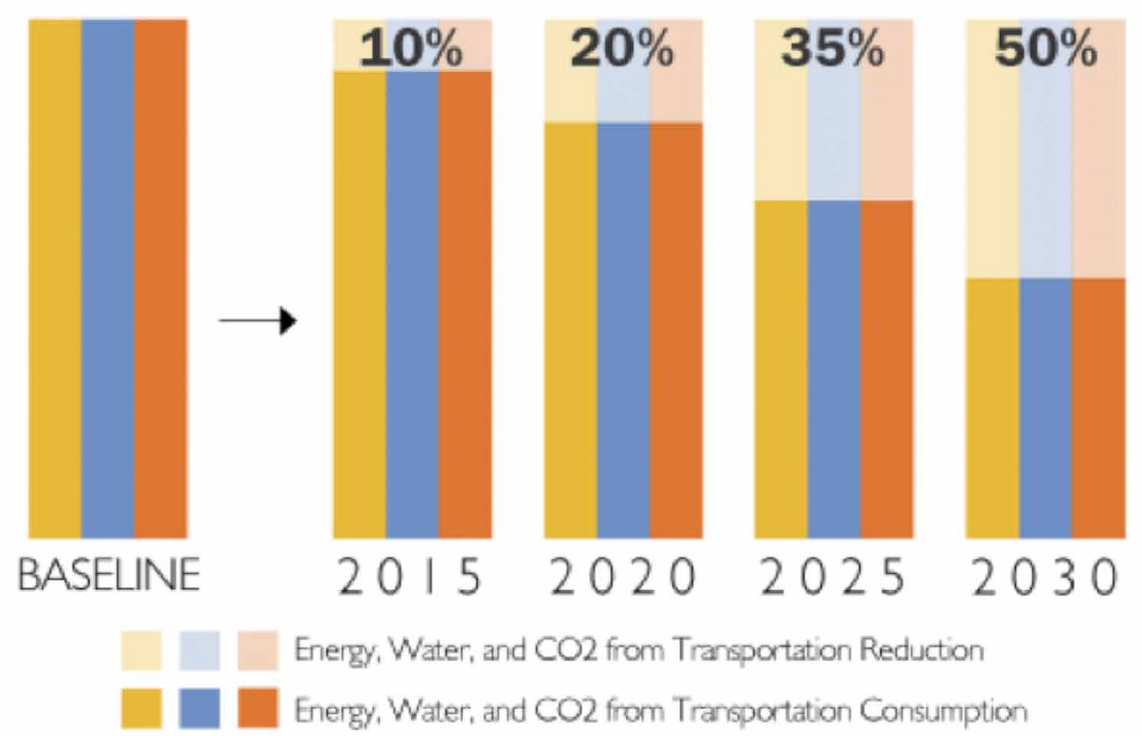
THE 2030 PITTSBURGH DISTRICT CHALLENGE

The Pittsburgh 2030 District is a voluntary, nationally recognized, yet locally driven community of high performance buildings working towards dramatic reductions in energy use, water consumption, and transportation emissions by the year 2030 (Green Building Alliance 2014a). Specifically, aligning with The 2030 Challenge for Planning illustrated in Figure 1, existing buildings in the District are working towards a 50% reduction in energy use, water use, and transportation-related emissions (below baselines) by the year 2030, with new construction achieving carbon neutrality by 2030 (Architecture 2030 2010).

FIGURE 1. The 2030 Challenge for Planning Reduction Goals for Existing Buildings (Architecture 2030 2010).

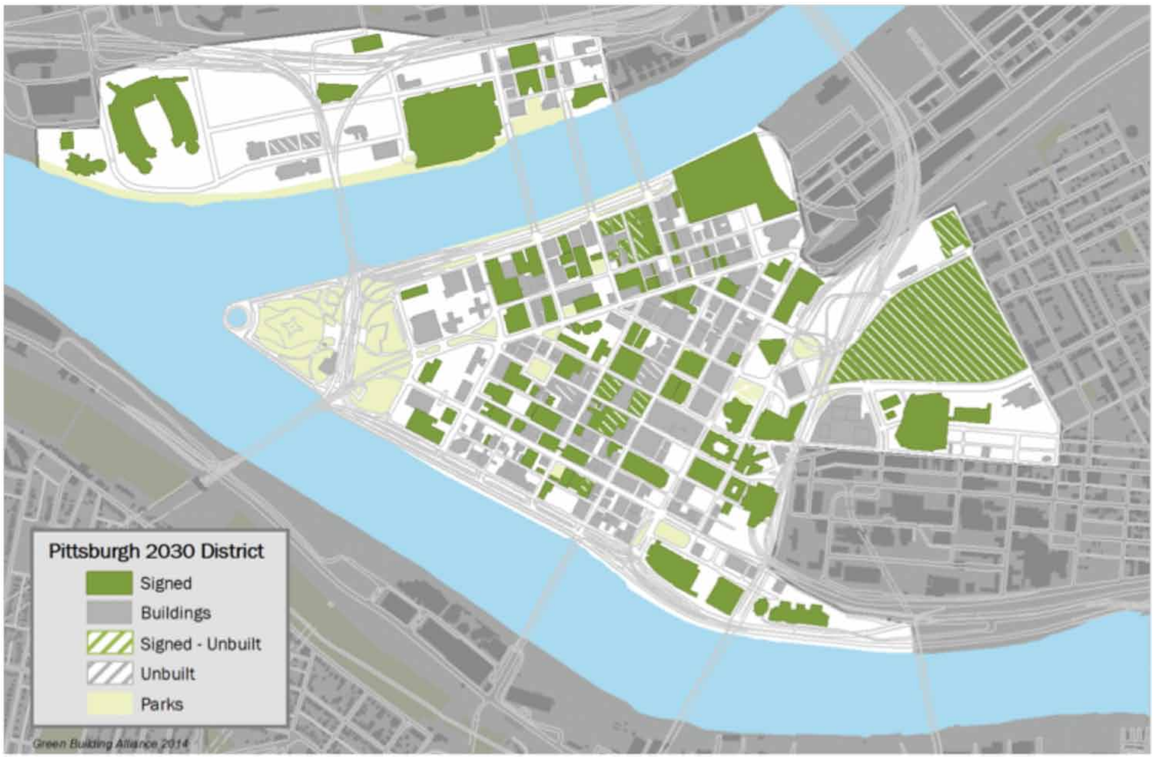


Achieving these reductions in a city with a large stock of older buildings presents a tremendous opportunity, but in order to track the possible impact of reducing energy 50% below baseline, a significant amount of property data had to be determined first. The Pittsburgh 2030 District's Downtown boundary includes over 58 million gross square feet of building floor area and an energy baseline had to be determined for each of Downtown's 452 buildings.

Using this method and assuming a primary building use, each building was assigned an estimated energy use baseline--and a predicted energy use reduction by 2030. Finally, all buildings were aggregated to create a District-wide energy baseline and predicted energy use reduction by 2030, assuming all buildings in the District were committed to (and reach) the 50% reduction goals of The 2030 Challenge for Planning. As
Figure 2 illustrates, through August 2014, the Pittsburgh 2030 District's Downtown boundary has commitments to work towards 2030 Challenge goals from 41 Property Partners who

represent 116 properties and 34.6 million square feet (58.5% of the Downtown District's square footage; 25% of the Downtown District's buildings). Separate from this analysis, the Pittsburgh 2030 District added an Oakland boundary in August 2014; that boundary and its commitments are not included in this paper.

FIGURE 2. Pittsburgh 2030 District Downtown Boundary and Committed Properties, September 2014.



Building Energy Use Metric: Energy Use Intensity

In determining how a building can achieve its 2030 Challenge goal of 50% reduction by the year 2030, one must first define both the metric of comparison *and* the building's baseline (i.e., starting point) it's trying to cut in half. Especially in recruiting Property Partners to participate in 2030 District programs nationwide, the detail of 50% reduction "below what" is an extremely important consideration.

2030 Districts nationwide quantify and compare building energy use through the energy use intensity (EUI) metric, which expresses a building's annual energy use as a function of its square footage in kBTU / ft^2 / year (Architecture 2030 2007). EUI is calculated by dividing a building's total energy usage over a given 12 month period by the building's gross square footage (i.e., all internal space that is heated and/or cooled). Normalizing energy usage allows for buildings of different sizes (but the same uses) to be compared; larger values indicate the most energy intensive use types.

In determining a whole building's EUI, a single weighted EUI value can be calculated using the building's different use types; the method for performing this is provided in Equation 1 for a building with *N subspaces*:

Equation 1: Whole Building EUI Weighted Average Calculation

$$\text{Whole Building Baseline EUI} = \frac{\sum_{Subspace\ 1}^{Subspace\ N}(Baseline\ EUI * Gross\ Square\ Footage)}{Whole\ Building\ Gross\ Square\ Footage}$$

In most cases, calculating a whole building EUI using use type provides a more accurate portrayal of what a building's true energy use should be (i.e., assuming that a 30-story office building is 100% office versus 75% office, 15% retail, 5% data center, and 5% vacant). In the case of the Pittsburgh 2030 District, exceptions to this assumption have most often been encountered for assembly, entertainment, sports, and healthcare spaces.

A building's (or its subspaces') energy use is a summation of utility consumption that includes electricity, natural gas, steam, chilled water, hot water, and/or other sources (provided by third-parties or generated on-site; no Pittsburgh 2030 District buildings are currently generating on-site renewable energy, though several do use geothermal energy). All energy sources are converted to British Thermal Units (BTU) using common conversions. Utilities produced on site are already accounted for in the whole building energy consumption total and are therefore not included (e.g., hot water produced via an on-site boiler).

Generally, a lower EUI indicates better building energy performance. However, due to variances in occupancy and operating schedules, EUIs vary widely by building use type, so comparing a building's energy use to its own weighted baseline EUI is more accurate for short- and long-term comparisons, especially in relation to the 2030 Challenge goals of 50% reductions below baseline.

CBECS As National 2030 Energy Baseline

In 2007, to create a standard national baseline for buildings in pursuit of The 2030 Challenge, a consortium of U.S. organizations set The 2030 Challenge baseline as the 2003 Commercial Building Energy Consumption Survey (CBECS) (U.S. EIA 2008); these organizations included the American Institute of Architects (AIA), the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), Architecture 2030, the Illuminating Engineering Society of North America (IESNA), and the U.S. Green Building Council (USGBC), with support from the U.S. Department of Energy (DOE) (Architecture 2030 2007). Aligning with the national 2030 Challenge, 2030 Districts also use CBECS as the national median energy baseline against which whole building energy use reductions are measured—and below which the 50% reduction goal by 2030 is set.

Collected and analyzed by U.S. Department of Energy's Energy Information Association (EIA), the 2003 CBECS includes a representative dataset of U.S. building energy costs, consumption, and energy-specific characteristics (including building use type, size, number of computers, occupancy, etc.). As applied for The 2030 Challenge, CBECS data has been used to determine national and regional median whole building site EUIs.

CBECS data is the backbone for the U.S. Environmental Protection Agency's (EPA) Energy Star Portfolio Manager energy benchmarking tool, which is the interface that 2030 Districts nationwide use to accurately calculate baselines for individual buildings (U.S. EPA 2014d). Using Portfolio Manager, median energy usage data is available for 85 building use types (U.S. EPA 2013a). Use types not represented in CBECS (or not approximated well by the CBECS data) required special attention, as discussed subsequently.

Site vs. Source EUI

EUI can be reported using either "site" or "source" energy usage. The Pittsburgh 2030 District baseline uses site EUI, but it is important to understand the difference, as other measures of building performance like Energy Star and Leadership in Energy and Environmental Design (LEED) certification use source EUI (USGBC 2013; U.S. EPA 2014a).

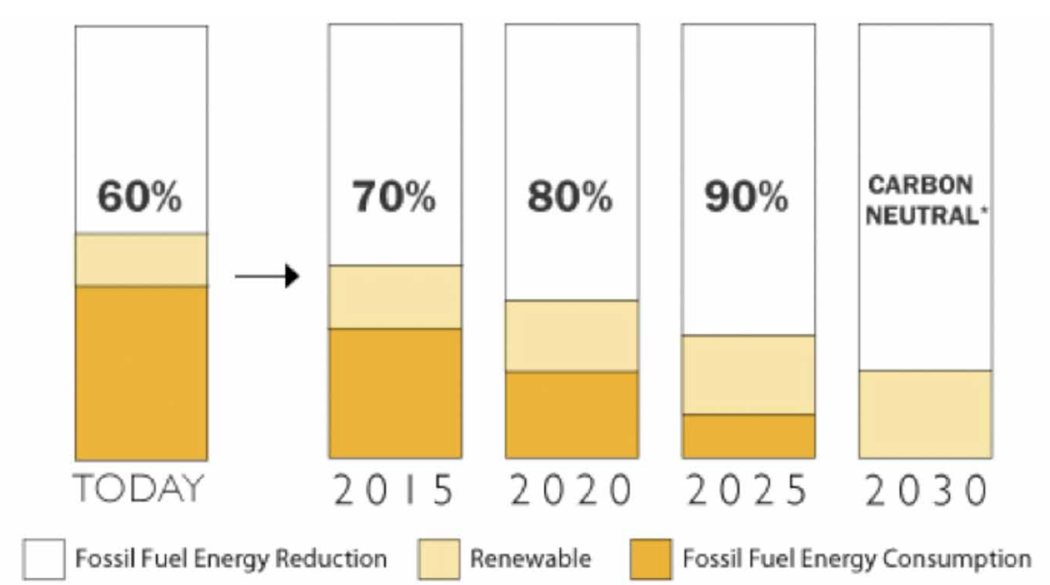
Site energy usage is most easily understood as the amount of energy on a building's utility bills; it is the amount of energy used on-site and commonly includes electricity, natural gas, propane, steam, and/or other utilities. Source energy is the amount of energy that must be produced so that a building can use a given amount of energy on site; source energy differs from site energy because it takes into account the inefficiencies associated with energy generation, transmission, distribution, and utilization.

Nationwide for electricity, average source EUI is around two times larger than site EUI, meaning that for every one unit of energy that building uses, two units of energy had to be generated at the source. This average factor is based on the national average energy mix, and can vary locally based on the proportion of energy that a building gets from electricity, natural gas, fuel oil, and other sources. Electricity generation generally has a large source to site ratio due to power plant inefficiencies and transmission inefficiencies (U.S. EPA 2014c). On the other hand, natural gas burned on-site to produce heat energy typically has a very low source to site ratio due to low transmission inefficiencies and low inefficiencies associated with the transfer of heat energy (U.S. EPA 2014c).

Because the goal of the Pittsburgh 2030 District is the reduction of individual building energy usage, Districts use site EUI instead of source EUI. Additionally, site EUI is better understood by most building owners and is more easily reported because it comes directly from utility bills.

Related to the site/source question, as shown in Figure 3, under The 2030 Challenge, a building pursuing the new construction/major renovation goal of carbon neutrality can use

FIGURE 3. The 2030 Challenge New Construction and Major Renovation Reduction Goals below Baseline (Architecture 2030 2010).



on-site renewable energy generation to contribute to its reduction below baseline; off-site generation could cover the balance of its final consumption – a load up to 20% of the building's baseline by 2030 (Architecture 2030 2010).

Though it's never been tested in practice, the working assumption of integrating renewable energy into The 2030 Challenge goals is that existing buildings could follow the same model as new construction for on-site renewable energy use, covering as much of their final consumption with on-site generation as they desire and/or are able (Vincent Martinez, personal communication, March 14-17, 2014). However, while existing buildings could also purchase off-site renewable energy or credits, these sources (unlike new construction) would not contribute to the building's goal of 50% reduction below the national median site EUI (a.k.a. 2030 energy baseline), but they would contribute to a 2030 District's larger greenhouse gas reduction impact.

METHOD

Tracking building performance—and, subsequently, tracking District performance—by EUI requires a standardized method of accurately correlating each District building to its corresponding national median baseline EUI. In the Pittsburgh 2030 District, most buildings are made up of a combination of several CBECS building use type classifications. As such, in order to calculate an accurate EUI for each a building, both a method to merge the EUIs of the CBECS use types along with an accurate space use and square footage profile were required; a summary of how both were achieved is discussed herein.

Every building commits to The 2030 Challenge goals individually – and thus has its own baselines below which it's trying to achieve reductions. As pioneered by Architecture 2030 in support of the Seattle 2030 District, Pittsburgh 2030 District convener Green Building Alliance (GBA) undertook the effort of developing a general summary of 2030 energy baselines by building type for the entire Pittsburgh 2030 District in 2013 (Seattle 2030 District 2012).

Due to the fact that Pittsburgh does not have legislated mandatory building performance regulations and participation in Pittsburgh 2030 District reporting is 100% voluntary, the Pittsburgh 2030 District as a whole only reports performance as a District aggregate. Thus, at the Pittsburgh 2030 District program level, there are two considerations for all discussions of goal setting and achievement: 1) each individual building and 2) the District as a whole (e.g., aggregate of all buildings).

As a result, in calculating the Pittsburgh 2030 District energy baseline, the scale distinctions above required that GBA estimate individual energy baselines for all 452 buildings in the Pittsburgh 2030 District *and* aggregate these baselines into a District-wide baseline below which aggregate progress could be reported. Complicating both the individual and aggregation pieces of this puzzle is that detailed property data (even in terms of simple square footage and building use type) is not publicly available in Pittsburgh. Additionally, while many of the existing 95 Downtown properties committed to The 2030 Challenge goals by November 2013 did provide the Pittsburgh 2030 District with property-specific size and use data, not all did – and the level of detail and accuracy among those that were able to vary widely.

Consequently, it was disproportionately complex to estimate individual building energy baselines (that are dependent on building use type and square footage) when there was no publicly available building use type and square footage information for each building. As summarized below, the resulting method used to do these estimations had to rely on a variety of highly variable sources, including Energy Star Target Finder for EUI and public and private real estate sources for property data.

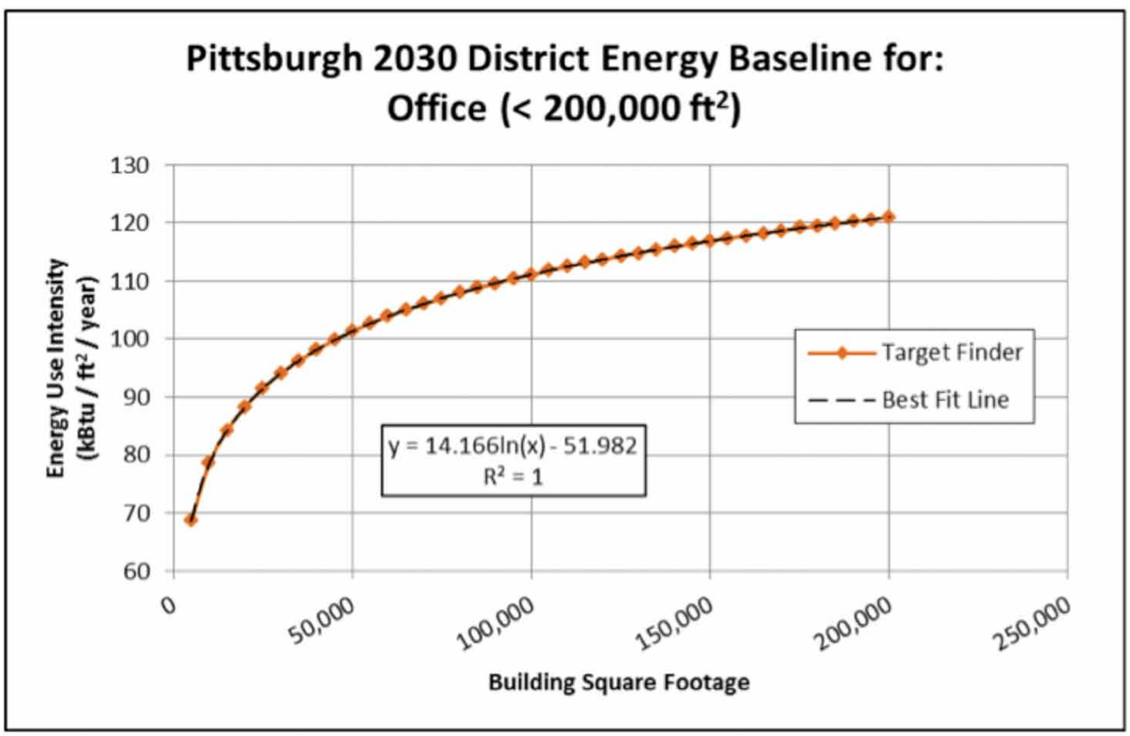
2030 Baseline Estimations by Use Type

Because CBECS data varies geographically, 2030 energy baselines must be individually determined for 2030 Districts across the country. The fastest interface through which CBECS data can be used to estimate whole buildings' 2030 energy baselines by use type is Energy Star's Target Finder tool (U.S. EPA 2014b). For the Pittsburgh 2030 District energy baseline estimates, Target Finder was used to determine estimated energy baselines for every building use type in Downtown Pittsburgh. Detailed building use information for all 452 buildings in the Pittsburgh 2030 District's Downtown boundary was not available. Thus, for the purposes of estimating national energy baselines for every building in the Pittsburgh 2030 District's Downtown boundary, Target Finder was used to determine static and variable baselines for a range of possible building square footages and use types. A summary of these baselines is provided in Table 1, which indicates that many building types have static baselines that do not change (regardless of building size). However, quite a few building use type baselines did vary based on building size. To best estimate variable baselines, best fit equations with the single variable of square footage were applied to Target Finder results, as detailed below.

Variable Baseline Equation Formulation

As an example of how each variable energy baseline was calculated, Figure 4 illustrates the detailed results of the variable Pittsburgh 2030 District energy baseline for spaces with a primary use type of "Office". The authors used Target Finder to estimate "Office" national

FIGURE 4. Pittsburgh 2030 District Variable Energy Baseline for Office Buildings.



median EUIs for spaces that ranged from 5,000 to 3,000,000 ft^2. Between 5,000 and 100,000 ft^2, Target Finder baseline estimates were recorded every 5,000 ft^2; above that a 50,000 square foot increment was used up to 3 million ft^2 (the largest single existing building in the Pittsburgh 2030 District).

As both Table 1 and Figure 4 indicate, above 200,000 ft^2, Pittsburgh 2030 District office buildings have a static baseline of 116 kBTU/ft^2. However, below 200,000 ft^2 Pittsburgh 2030 District office buildings demonstrate a logarithmic relationship as shown in equation form in Table 1 and graphically in Figure 4. As Table 1 shows, many variable baselines were logarithmic, while some were exponential.

TABLE 1. CBECS Energy Baseline Estimates for Single Use Buildings in Pittsburgh 2030 District (Green Building Alliance 2013; U.S. EPA 2014a).

BUILDING USE	ESTIMATED ENERGY BASELINE: MEDIAN SITE EUI (kBTU/ft^2/year)	
	STATIC	VARIABLE
Bank or Financial Institution	-	$Y = (3E-17) * SF^4 – (4E-12) * SF^3 + (2E-7) * SF^2 - 0.0039 * SF + 140$
Convenience Store	286	-
Courthouse	-	$Y = 16.664 * \ln (SF) - 61$
Entertainment (Public Assembly)	46	-
Entertainment (Recreation)	64	-
Fast Food	542	-
Fire or Police Station	82	-
Grocery Store	-	$Y= (6E-27) * SF^6 - (2E-21) * SF^5 + (3E-16) * SF^4 - (2E-11) * SF^3 + (6E-7) * SF^2 - 0.0091 * SF + 365$
Higher Education	165	-
Hospital	-	$Y = (3E-34) * SF^6 – (1E-27) * SF^5 + (3E-21) * SF^4 – (3E-15) * SF^3 + (2E-9) * SF^2 - 0.0006 * SF + 320$
Hotel	98	-
Industrial	200	-
K-12 School	-	$Y = - 11.39 * \ln (SF) + 219$
Library	156	-
Medical Office	-	$Y = 13.78 * \ln (SF) - 42$
Multifamily Housing	50	-
Nursing or Assisted Living	144	
Office (<200,000 SF)	-	$Y = 14.17 * \ln (SF) - 52$
Office (≥200,000SF)	116	-
Parking (Fully Enclosed)*	11	
Parking (Partially Enclosed)*	9	
Place of Worship	44	
Residence Hall/Dormitory	-	$Y = - 9.42 * \ln (SF) + 218$
Residential	95	-
Restaurant or Cafeteria	230	-
Retail (Enclosed Mall)	95	-
Retail (Non-Mall)	62	-
Retail Store	-	$Y = 9.05 * \ln (SF) + 8$
Service	61	-
Warehouse	-	$Y = 5.76 * \ln (SF) - 25$
Other	66	-

NOTE: Y = Energy Baseline Estimate; ln = Natural Logarithm; SF = Building Square Footage; * = Parking special case described below.

Using Energy Star Target Finder, constant and variable energy baselines were extracted for all building types in the Downtown Pittsburgh. For each use type, the full range of square footages in the District was manually entered in an incremental manner such that a size vs. energy baseline curve could be plotted for all building sizes in Downtown Pittsburgh. Graphs illustrating the best fit equations for each of these use types are provided in the Appendix.

CBECS Data Trends

Figure 4 and Figure 7 to Figure 15 in the Appendix indicate unique relationships between building square footage and site EUI for a number of building types. Some building types have constant site EUIs over the entire range of applicable building sizes, some show a positive exponential relationship, and others display a clear logarithmic relationship. Each of these relationships was found in the same manner as described previously—and the variable baseline equations provided in Table 1 must be used in direct conjunction with building square footages to find the building's energy baseline.

For office buildings specifically, the trend of note is that as a building's square footage increases approaching 200,000 square feet, a clear logarithmic relationship emerges. Once building size exceeds 200,000 square feet, building EUI becomes essentially constant, with energy usage per square foot staying the same regardless of building size. Reasoning behind this asymptote can be attributed to a number of factors beyond the scope of this paper. It is also of note that these results are observed when all other variables are held constant in proportion to size and national average attributes are used (e.g., hours of operation stay constant, but occupancy linearly increases with size).

Determining best fit lines for building use types with variable 2030 baselines made it possible to calculate an estimated 2030 baseline EUI for any size office building in the Pittsburgh 2030 District Downtown boundary. As Table 1 indicates, it was necessary to determine variable baselines for 10 building use types, each detailed further in the Appendix.

Property Data Acquisition and Estimation

As previously mentioned, there are two ways of reporting progress related to a 2030 energy baseline – at the individual building level and at the District aggregate level. For moving from the smaller to the larger, it was necessary for GBA to have building gross square footage and use type information for every building in the Pittsburgh 2030 District's Downtown boundary. Unlike in other locales, Pittsburgh property data is not consolidated in a single public (or private) database. Thus, GBA had to employ various methods of data acquisition and estimation to compile, estimate, and create it.

The primary local source of basic property data was the Allegheny County Office of Property Assessment, which collects parcel numbers, property location, owner details, assessed value, and most recent sale price—for the City of Pittsburgh and the 129 other municipalities in the County. For single-family residential properties, building characteristic information (e.g., year built, condition, square footage, etc.) is also available, but not for any other use type, including commercial, multifamily, religious institutions, and large civic properties (Allegheny County 2013). Additionally, the most recent available data from Allegheny County did not consider recently demolished or newly constructed buildings, so these needed to be added into the Pittsburgh 2030 District property tally. Any buildings demolished were assumed to be vacant land. As a result, GBA estimations are that there are 452 existing buildings in the Downtown District boundary.

Following the collection of an accurate District building count with associated addresses, the next goal was to determine a gross square footage for each associated building; there were 4 different primary strategies for acquiring building square footage:

1. Direct interaction with building owners,
2. Private commercial real estate sources, and
3. Allegheny County real estate information,
4. Estimations based on Allegheny County real estate information, and
5. Secondary sources.

Ideally, each building's square footage was available by use type within the property; unfortunately, this was not possible in most cases, at which time estimates had to be made as discussed below.

Property Details Acquisition Case 1 – Direct Interaction with Building Owners

By GBA's estimation, as of August 2014, there are 452 existing buildings in Downtown Pittsburgh, 116 of which are committed to The 2030 Challenge Goals. As part of this commitment, each building committed through November 2013 was asked to report gross square footage for their entire building, a primary building use type, and (if available), a more detailed breakdown of all building subspace use types and associated square footages. Buildings were also asked to supply information on the number of full-time equivalent occupants (if available). Buildings that were already tracking energy performance with Energy Star Portfolio Manager may also have estimated or provided real data for other building characteristics (including operating hours, number of computers, etc.).

For the remaining 80% of Downtown buildings, square footage and use type information was determined using a combination of sources. For example, if a building recently underwent a major renovation or real estate transaction, a simple internet search would yield accurate square footage information on all (or portions) of the building. Using such information, each space was assigned an accurate CBECS use type.

Property Details Acquisition Case 2 – Private Commercial Real Estate Sources

The private real estate and property management industry vociferously tracks and reports on aggregate office property square footage, rental rates, and occupancy rates in various markets. Traditionally, these pieces of detailed property information (and their accuracy) are closely guarded by private real estate entities—and heavily dependent upon the rentable square footage in a given office building. Due to GBA's connections in the real estate industry, a few key individuals shared both rentable and gross square footage information for Downtown Pittsburgh office buildings. In some cases, rentable or gross square footage was also publicly available from private real estate companies through transaction announcements of recently sold properties. In both cases, this information was either used to verify existing building characteristic information collected through the various property detail acquisition cases detailed in this article – or exactly as it was provided.

Property Details Acquisition Case 3 – Allegheny County Real Estate Data

While the methods described in Cases 1 and 2 provided accurate and/or order of magnitude building square footage values for office buildings and Pittsburgh 2030 District Property Partners, a fair number of additional Downtown Pittsburgh buildings were still lacking enough property detail with which to estimate an energy baseline. Such situations required the use of the Allegheny County Realty Assessment (ACRA) database (Allegheny County 2013). In Allegheny County, Pennsylvania, property laws dictate that all single family residential structures provide detailed information on number of floors, bedrooms, and bathrooms, as well as overall structure square footage. Thus, in theory, for solely or primarily residential buildings, Allegheny County's square footage information could be utilized; in actuality, this data was not available for any Pittsburgh 2030 District properties – in part because the 2030 District model does not focus on single family properties.

The same cannot be said for non-residential buildings (including commercial structures), which are not required to report any building-specific information beyond use.

Property Details Acquisition Case 4 – Allegheny County Real Estate Data-Based Estimations

In the case of Downtown Pittsburgh, where most buildings are primarily and/or include non-residential space, determining an accurate total and use breakdown square footage estimate for each building could be a time consuming estimation process. However, while Allegheny County does not provide building square footage for non-residential structures, they do collect property parcel square footage, which in some cases is also the building's footprint. Thus, for all Downtown non-residential buildings, parcel square footage was compared to building footprint; if the two were close, the number of floors was determined for the building in question. Total building square footage was then estimated by multiplying the number of floors by parcel square footage.

For buildings whose footprints were not equivalent to the entire property parcel (e.g., a parcel that included both a building and parking lot), this parcel-based method could not be used. Instead, the building footprints were determined using GIS shape files from the City of Pittsburgh; total building square footages were then estimated by multiplying estimated building footprint square footage by number of floors in the building.

For both cases above, breaking down total building square footage by use type was estimated using Case 5 as described below. If more detailed use information was not available or deemed to be reliable, the entire building was assigned a single use type.

Property Details Acquisition Case 5 – Secondary Sources

For buildings with no primary sources of square footage or use type information, secondary sources were used. In some cases, Allegheny County real estate information provided valuable tax-related information, (including parcel square footage and owner's name), which did lead to primary source information on several occasions.

For high profile buildings, square footage and use breakdown information can easily be located on the internet via the building's own websites, existing real estate sites, news sources, or otherwise. Buildings in this category included almost all skyscrapers and sports facilities. Given the profile of these larger and public-facing buildings, more detailed property use information was generally available.

Complications began to arise in finding square footage and use breakdown information for lower profile buildings. Properties fitting this description were all subjected to an internet search. If the property had been put up for sale, renovated, or subject to any past noteworthy action, its square footage was almost always noted in associated newspaper databases, construction company websites, or owner websites.

Though additional methods for property information research were not highly scientific, these very internet-based sources were ultimately some of the only places to find property characteristics for Downtown Pittsburgh properties, as Allegheny County and the City of Pittsburgh do not currently require non-residential properties to publicly report this information.

Use type information for buildings in this category was harder to access. In many cases, the various use types were known (i.e., apartments on upper floors or types of commercial space on the ground floor), but the square footage breakdown of these use types was not. In order to find the square footage breakdown, an estimate was made by dividing total square footage (found as mentioned above) by the number of floors occupied by the various use types. This method assumed the following: 1) Each use type took up a whole number of floors (not partial floors) and 2) All floors in the building were the same square footage.

Property Details Acquisition Summary

Due to the fact that property data acquired through Cases 1 through 4 only covered a certain number of buildings, a large portion of building use types used in the Pittsburgh 2030 District baseline formulation had to be estimated using Case 5 methods. However, fewer than 24 (~5%) of the Downtown District's 452 buildings had their square footage estimated by Case 5. It is the nature of the data set described that the accuracy of the building information will continue to become more accurate as more district commitments are received.

Property Detail Application to Create Individual and District-wide Energy Estimates

Once square footage was determined through either acquisition or estimation for every building in the Pittsburgh 2030 District's Downtown boundary, an EUI baseline could be assigned for each individual building in the District--whether they were committing to District goals or not. Having a baseline estimate for every District building allowed GBA to do several things:

1) Provide committed and prospective Property Partners with their estimated energy baselines upfront;
2) Provide committed and reporting Property Partners with information about progress towards 2030 goal achievement;
3) Aggregate all buildings to create:
a) Estimated energy consumption for the entire Pittsburgh 2030 District and
b) Normalized consumption (EUI) for the entire Pittsburgh 2030 District; and
4) Project District-wide energy savings and associated air emissions reductions assuming different adoption and achievement rates of 2030 targets.

Estimating Individual Building Baselines Using Baseline Formulas

In order to apply the variable baseline equations to an individual building, the data collection methods described above were used to determine a building's use breakdown by square footage. Each space was then assigned its respective constant or variable baseline and Equation 1 was applied to each building. This method of calculating an energy baseline (or national median site EUI) was used for all buildings that did not have accurate energy baselines otherwise determined through more building-specific information reported in Energy Star Portfolio Manager.

Because most small commercial Pittsburgh buildings do not have the ability to entirely turn off HVAC systems on vacant upper floors, vacant space was classified as warehouse space. This was done so that vacant square footage would not be excluding from a building's total square footage. Including vacant area as a warehouse space allowed for zero occupancy while still including the effects of energy use related to heating and cooling. Buildings already directly reporting to the Pittsburgh 2030 Districts at the time of baseline creation overrode the need for this method for their properties.

Increasing Baseline Accuracy with Energy Star Portfolio Manager

It is important to mention that while inherent inaccuracies are present within the building data collection methods described above, baseline accuracy will continue to improve District-wide as more building data is collected. This ongoing process not only focuses on acquiring primary source square footage and use information for buildings that are not reporting to the Pittsburgh 2030 District directly, but also on updating and expanding the information that District Property Partners are currently sharing via Portfolio Manager.

Location, primary use type, and gross square footage are the only parameters that are mandatory to create a Portfolio Manager building. If a property does not overwrite other detailed building parameters in Portfolio Manager, national average values are used. Baseline accuracy can be improved if the user provides additional parameters including detailed building use breakdown and associated square footage, number of computers, operating hours, number of workers on main shift, and percentage heated and/or cooled. Providing such information allows a building to be classified more accurately--in turn narrowing in on the most accurate energy baseline possible.

Baselines for Individual Buildings that are Reporting

The Pittsburgh 2030 District encourages all Property Partners to use Portfolio Manager for data storage and reporting. Thus, for 2013, 84 buildings shared their energy performance data with the Pittsburgh 2030 District through Portfolio Manager, which was 85% of participating properties (Green Building Alliance 2014b). While GBA intends to continue to work towards 100% reporting compliance for future updates, 85% reporting compliance for a voluntary program is a strong first-year outcome.

When the Pittsburgh 2030 District Energy Baseline was publicly released in 2013 only 40 of buildings in the Pittsburgh 2030 District (<10%) had provided detailed energy use and building use information. As a result, Energy Star Portfolio Manager could be used to calculate actual 2030 energy baselines for each of these buildings. For these 40 buildings, these real baselines were used instead of the static or variable CBECS estimates, thus reducing uncertainty associated with the building use type assumptions detailed previously.

However, even though a Property Partner was both committed and reporting, due to the mid-2013 changes in Portfolio Manager described below (and especially due to the significant increase in building use types), GBA continues to work directly with buildings to increase baseline accuracy due to primary building use type and inclusion of more detailed building characteristic information.

Special Case: Parking

The method described above for finding an individual building's energy baseline is only applicable if the use types within the building have a corresponding CBECS use type; parking does not fall into this category. Whether independent or part of a larger structure, parking is dealt with outside of Portfolio Manager for several reasons. First, when a parking structure is entered into Portfolio Manager, the energy usage attributed to parking is subtracted from the building's energy usage because the Energy Star score (1 to 100) calculation only recognizes ordinary building uses (U.S. EPA 2013b).

This issue was a significant one for Downtown Pittsburgh because a significant number of large properties in the Pittsburgh 2030 District have integrated, or are solely, parking. If Portfolio Manager practice was followed to calculate the energy baseline of these structures, it would have been very difficult to compare the building's actual performance to its baseline because the baseline would not have accounted for all of the building's uses—parking would have been excluded. Unless the parking area of a building was separately metered, the building's actual energy usage would reflect that of the parking structure, while the baseline would not. Because of this, a method had to be developed to manually estimate site energy baselines for any buildings that were solely or had integrated parking.

Portfolio Manager's parking technical reference outlines how parking energy is subtracted when they calculate a building's energy baseline, which assumes the national median parking EUIs provided in Table 2 (U.S. EPA 2013b). Pittsburgh 2030 District used these average values, but instead of subtracting them from the building's energy usage, they were incorporated using the weighted average illustrated in Equation 1.

TABLE 2. Energy Star Adjustments by Parking Type in Site Energy (U.S. EPA 2013b).

Parking Type	End Use	Engineered Allowance	Assumed Hours of Operation	Parking Area Site Energy
Open Parking	Lighting	0.15 W/ft^2	16 Hours/day	2.989 $kBtu/ft^2/yr$
Partially Enclosed Parking (No Walls)	Lighting	0.30 W/ft^2	24 Hours/day	8.967 $kBtu/ft^2/yr$
Completely Enclosed Parking (Walls)	Lighting	0.30 W/ft^2	24 Hours/day	8.967 $kBtu/ft^2/yr$
	Ventilation	0.29 W/ft^2 (On)	6 Hours/day	2.39 $kBtu/ft^2/yr$
		0.01 W/ft^2 (Setback)	18 Hours/day	
	Heating (if present)	0.009354 $kBtu/ft^2/yr/HDD_{Base40F}$	Based on Ventilation and Degree Days	0.009354 $kBtu/ft^2/yr/HDD_{Base40F}$

According to the Energy Star Performance Ratings Technical Methodology for Parking, partially enclosed parking structures use 0.30 W/ft^2, which is primarily attributed to lighting, as ventilation is assumed to occur naturally as a result of the open walls (U.S. EPA 2013b). The document assumes that the lighting in such garages is on 24 hours a day, seven days a week; equating to 8,736 hours of annual operation. From these two numbers a baseline suite EUI can be calculated as follows:

$$\textbf{Site EUI}\ (\text{kWh/ft}^2\text{/year}) = \frac{0.30\,\frac{W}{ft^2}\,x\ 8{,}736\,\frac{hours}{year}}{1000\,\frac{W}{kWh}} = 2.62\ \text{kWh/ft}^2\text{/year}$$

Converting this to kBTU/ft2/year using U.S. EPA conversion factor (U.S. EPA 2013b):

$$\textbf{Site EUI}\ (\text{kWh/ft}^2\text{/year}) = 2.62\ kWh\ \text{x}\ 3.412\ \frac{\text{kBTU}}{\text{kWh}} = \mathbf{8.94\ kBtu/ft^2/year}$$

If necessary, this unenclosed parking structure site EUI can then be converted to source EUI using the EPA conversion factor for electricity source-site Ratio of 3.34, which is averaged over the years 2000 to 2005 (U.S. EPA 2011a). Multiplying the open parking garage site EUI calculated above by this source-site ratio, source EUI for unenclosed parking garages is as follows:

$$\textbf{Source EUI}\ (\text{kWh/ft}^2\text{/year}) = \ 2.62\ kWh \ \text{x}\ 3.34\ \frac{\text{Source EUI}}{\text{Site EUI}} = \mathbf{29.87\ kBtu}/\text{ft}^2\mathbf{/year}$$

The same calculations can be performed for enclosed parking garages and open parking plots, yielding the results shown in Table 2 above.

Aggregated District Baseline

Once each building Pittsburgh 2030 District building was assigned either an estimated or actual site EUI baseline, it was possible to aggregate all buildings to determine a District-wide energy baseline. Because EUI is a normalized value (kBTU/ft^2), to determine a District-wide aggregate baseline, each individual building baseline was multiplied by that building's total gross square footage. The energy use and square footages of all 452 District buildings were respectively summed for the entire District—and a District-wide EUI was calculated by dividing total Pittsburgh 2030 District energy usage by total District square footage. The result was a District-wide EUI representing the District's normalized baseline energy usage, which can then be used to track and report against District-wide progress—and model impacts of Pittsburgh 2030 District efforts as buildings reach towards their 50% reduction goals.

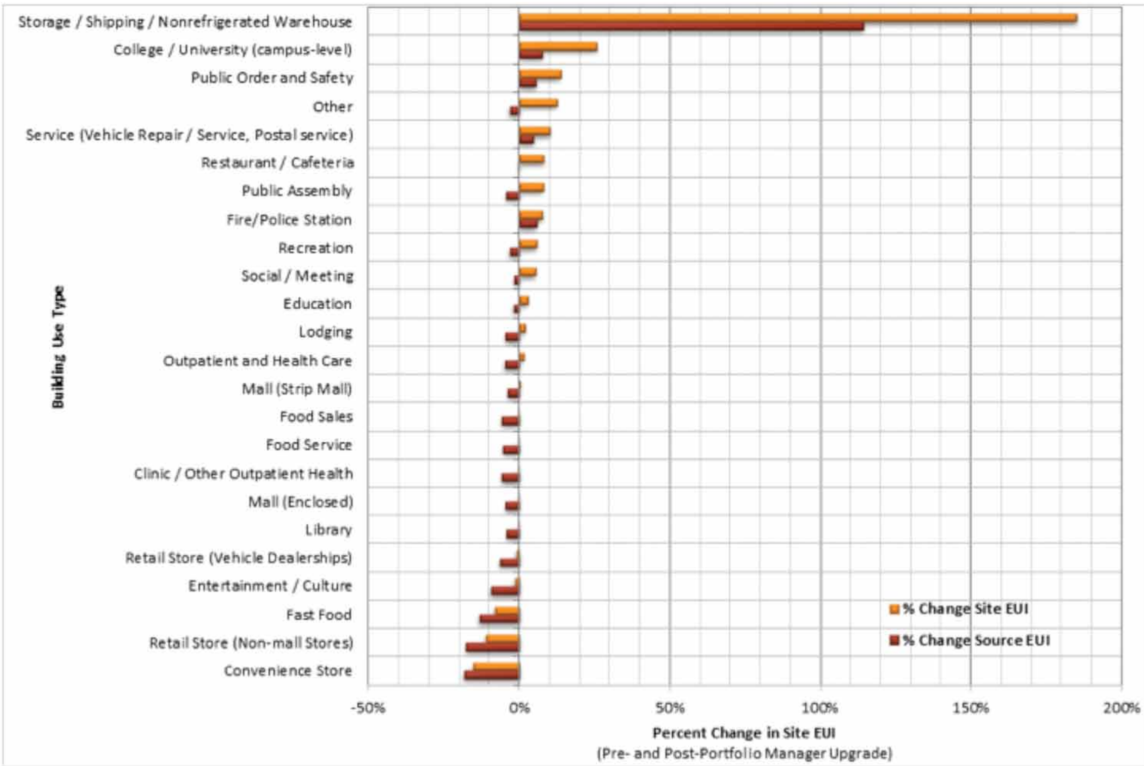
For example, actual carbon dioxide emissions avoided for the entire District in 2013 was estimated at 95.8 million pounds (resulting from avoidance of the use of 286 billion BTU, 66% of which were from electricity, 22% from natural gas, and 10% from steam). Given agreed upon emissions factors for air pollutants, the authors can very simply calculate actual and anticipated air emissions avoided given various levels of property commitments and success in reaching the District's 50% energy reduction goals by the year 2030. Full exploration of the impact of these reductions is outside the scope of this paper, but have cascading implications for health effects as the District's collective actions are achieved and measured over time.

National Energy Baseline Changes

However, as this project was being completed in mid-2013 using the Energy Star-dependent method described below, Energy Star Portfolio Manager was undergoing a tremendous back- and front-end overhaul (its first since 2000) (U.S. EPA 2009; U.S. EPA 2011b). As part of this refurbishment, EPA retooled how it referenced the 2003 CBECS data from a national average EUI to a national median EUI (U.S. EPA 2013c). As a result, seemingly small changes occurred in national energy baselines for almost every building type in the Pittsburgh 2030 District. However, as illustrated in Figure 5, the percent change for certain building types varied widely – and was much more significant for some building use categories than others.

Only building use types with static baseline EUIs were available for comparison in Figure 5; legacy values for variable baselines (i.e., those dependent on building square footage) were not publicly available for analysis (U.S. EPA 2013c). This shift in data was adopted into the working baseline calculation described above because it closely reflects the goals of the Pittsburgh 2030 District. The median baseline value is the midpoint of the CBECS data set,

FIGURE 5. Percent Change in National Median EUI Reported by Energy Star Portfolio Manager Pre- and Post- 2013 Portfolio Manager Interface Upgrades (U.S. EPA 2013c).



representing the amount of energy use which half of buildings nationwide exceed, while half do not. Improving building energy performance against the national standard is the goal of The 2030 Challenge, so it was decided that adoption of a nationwide median baseline helped to achieve a more accurate baseline in the 2030 context. As a result of this Portfolio Manager change, both Architecture 2030 and the Seattle 2030 District (who had already established their own national energy baselines using parallel methods to those described above) needed to update their energy baselines to reflect the change from national average site EUI to national median site EUI.

All of the results included in the method summary above reflect post-2013 Portfolio Manager interface upgrades.

CONCLUSIONS, IMPLICATIONS AND FUTURE WORK

Real estate market data and baseline energy consumption are critical to successful implementation of a 2030 District in any city. In addition to cities pursuing 2030 Districts, there is a general trend towards adoption of energy benchmarking at various scales in cities around the world. The result of the work described in this paper represents the most comprehensive source of building characteristics and performance metrics compiled to date for Downtown Pittsburgh. The development of this work is also a guide for others endeavoring to identify energy baselines – including through the establishment of 2030 Districts, in other cities that have scattered, sometimes non-existent, public building data.

Developing Baselines for Non-Standard Buildng Use Types

While this paper clearly shows that 2030 baselines can be estimated for any building in a 2030 District, the accuracy of each building's estimated baseline will not truly be determined until property-specific annual energy consumption and building characteristics are known. Even once this information is available, discrepancies between national median site EUI baselines and actual building energy use still exist, especially for certain types of building uses.

For example, for museums, the Pittsburgh 2030 Districts has discovered a rather large discrepancy. In theory, museums are classified under Energy Star's "Entertainment / Public Assembly" use type, attributing a national median site EUI to them of 56.4 kBTU/ft^2/ year—which is the same EUI as movie theaters and performing arts venues (U.S. EPA 2014b). However, when observing actual energy use for a museum in the Pittsburgh 2030 District, it is clear that this national baseline is not representative of the use type. Most obviously, museums with strict temperature and humidity controls (e.g., 24/7 HVAC systems that help maintain archival qualities for art and rare documents) can have EUIs as much as 400% larger than the national median site EUI.

The current national 2030 Districts Network workaround for buildings like museums that find themselves comparing to an out of magnitude baseline is for that building work towards reducing energy use 50% below their own 2003 energy consumption. Per The 2030 Challenge model, this solution works, but is less ideal for museums that have had very strong energy efficiency practices for many years, essentially "losing credit" for progress they may have made towards high energy performance if they were already performing better than an "average" like building in 2003.

Increased Commitment and Partner Energy Use Reductions

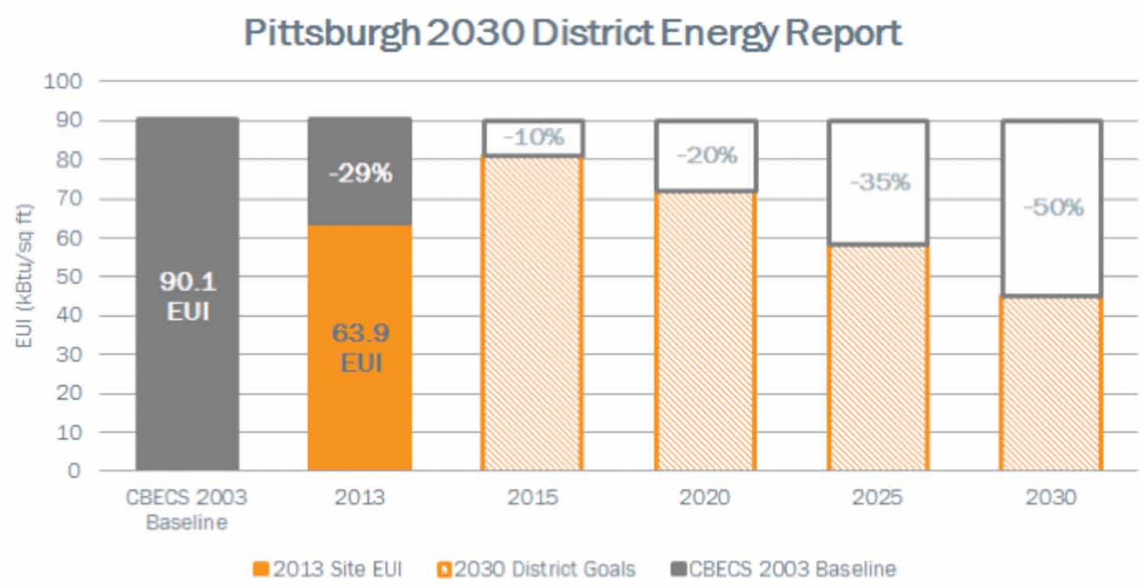
As commitments to 2030 Challenge goals continue to increase and more performance data becomes available, the Pittsburgh 2030 District's actual and estimated energy baseline will continue to evolve for each individual District building AND the District as a whole. As described above, the current Pittsburgh 2030 District baseline includes many assumptions including the individual building square footage, primary use type, use type breakdown, and energy use. For buildings that are not reporting, national median numbers were used in all cases.

Even for buildings that are committed to Pittsburgh 2030 District goals and reporting energy consumption, the presence of assumptions inherent to Energy Star Portfolio Manager (on items like the number of full time equivalent occupants, occupancy hours, and number of computers) cause these assumptions to be used in calculating building baselines instead of actual values. As each Pittsburgh 2030 District building updates this information, these individual buildings' baselines will also become more accurate.

Property Partner Energy Performance

When discussing The 2030 Challenge and Portfolio Manager simultaneously, terminology can be confusing. Whereas 2030 Districts are utterly dependent upon the word "baseline" when measuring towards the 50% reduction goal, Portfolio Manager actually lets buildings set their own "baseline year" against which they can compare. As a result, a non-regular Portfolio Manager user can easily misinterpret their building's progress towards its 2030 goals by looking at their "comparison to baseline" in Portfolio Manager. However, to truly compare a building's 12-month energy usage to its 2030 Challenge goals, buildings must compare their site EUI to the national median site EUI. It is for this reason that both the Pittsburgh and Seattle 2030 Districts provide individual buildings with performance progress reports on an annual basis; a sample Pittsburgh's 2013 Energy Report for a single building is provided in Figure 6.

FIGURE 6. Sample Pittsburgh 2030 District 2013 Energy Report for a Single Building (Green Building Alliance 2014b).



Portfolio Manager also allows buildings to enter actual energy and water consumption information. Provided that at least 12 months of energy information is included, buildings are able to compare their annual performance to their CBECS baseline. As a result, buildings committed to Pittsburgh 2030 District goals can use Portfolio Manager to report to the District directly. As participation in the Pittsburgh 2030 District is voluntary, all building performance information shared with GBA remains individually confidential unless otherwise specified by a Property Partner.

The CBECS survey has typically been updated every 5 years; however, the 2007 data was deemed to be "not representative of the commercial building population and therefore the 2007 CBECS sample as a whole did not meet EIA standards for quality, credible energy information" (U.S. EIA 2014a). The 2012 CBECS survey was completed; once EIA has processed the 2012 CBECS information, it will become the default performance comparison reference for Portfolio Manager (U.S. EIA 2014b). There is an impending need for collaboration with EPA on retaining existing comparisons to the 2003 CBECS data so that buildings can continue to calculate their 2030 Challenge baselines, as the 2003 CBECS data will remain the national baseline for all buildings pursuing The 2030 Challenge, whether in 2030 Districts, under the design version of The 2030 Challenge, or otherwise.

ACKNOWLEDGEMENTS

The Pittsburgh 2030 District's presenting sponsor is The Efficiency Network; its title sponsor is the EcoCommercial Building Network powered by Bayer. Since 2011, Green Building

Alliance has received generous funding for its Pittsburgh 2030 District efforts from Kresge Foundation, The Heinz Endowments, Richard King Mellon Foundation, Pittsburgh Foundation, and Roy A. Hunt Foundation; GBA is nonprofit organization with a wide variety of individual and corporate members and sponsors, along with private foundations and federal government grants.

REFERENCES

Architecture 2030 (2007). The 2030 Challenge Benchmark Set: Building Design Leaders Unite on Energy Reduction, Architecture 2030. <www.architecture2030.org/file_download/25/Press_Release_5_4_07.pdf>

Architecture 2030 (2010). The 2030 Challenge, Architecture 2030. <http://www.architecture2030.org/2030_challenge/the_2030_challenge>

Green Building Alliance (2013). Pittsburgh 2030 District Energy Baseline, Green Building Alliance. <www.2030districts.org/pittsburgh/news/pittsburgh-2030-district-energy-baseline-finalized>

Green Building Alliance (2014a). Pittsburgh 2030 District, Green Building Alliance. <www.2030districts.org/pittsburgh>

Green Building Alliance (2014b). Pittsburgh 2030 District Progress Report: 2013, Green Building Alliance. <www.go-gba.org/pittsburgh-2030-district-progress-report>

Allegheny County (2013). Real Estate Data CD, Allegheny County Departments of Real Estate and Property Assessment.

Seattle 2030 District (2012). 2030 District Performance Metric Baselines, Seattle 2030 District. <http://2030districts.org/sites/default/files/seattle/2030_District_Baselines.pdf>

U.S. EIA (2008). 2003 Commercial Building Energy Consumption Survey, U.S. Energy Information Administration. <www.eia.gov/consumption/commercial >

U.S. EIA (2014a). Frequently Asked Questions about the Commercial Buildings Energy Consumption Survey, U.S. Energy Information Administration. <www.eia.gov/consumption/commercial/faq.cfm#q1>

U.S. EIA (2014b). What CBECS data is Portfolio Manager using to create data for the 1-100 scores?, U.S. Energy Information Administration. Topic #23002-34125. <http://portfoliomanager.supportportal.com/link/portal/23002/23010/Article/34125/What-CBECS-data-is-Portfolio-Manager-using-to-create-data-the-1-100-scores>

U.S. EPA (2009). A Decade of Energy Star Buildings: 1999-2009, U.S. Environmental Protection Agency. <www.energystar.gov/ia/business/downloads/Decade_of_Energy_Star.pdf.>

U.S. EPA (2011a). Energy Star Performance Ratings Methodology for Incorporating Source Energy Use, U.S. Environmental Protection Agency. <http://www.energystar.gov/ia/business/evaluate_performance/site_source.pdf>

U.S. EPA (2011b). Portfolio Manager Upgrade: Project Fact Sheet, U.S. Environmental Protection Agency. <www.energystar.gov/ia/business/evaluate_performance/PM_updgrade_fact_sheet_3.pdf>

U.S. EPA (2013a). Energy Star Portfolio Manager: Property Types, Definitions, and Use Details, U.S. Environmental Protection Agency. <www.energystar.gov/buildings/sites/default/uploads/tools/PropertyUseDetailsandDefinition.pdf>

U.S. EPA (2013b). Parking and the Energy Star Score in the United States and Canada, U.S. Environmental Protection Agency. <www.energystar.gov/sites/default/files/buildings/tools/ENERGY%20STAR%20Score%20for%20Parking.pdf>

U.S. EPA (2013c). U.S. Energy Use Intensity by Property Type. Portfolio Manager Technical Reference. Portfolio Manager, U.S. Environmental Protections Agency. <https://portfoliomanager.energystar.gov/pdf/reference/US National Median Table.pdf >

U.S. EPA (2014a). What is Energy Use Intensity (EUI)? Understand Metrics. Energy Star, U.S. Environmental Protection Agency. <www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/understand-metrics/what-energy. >

U.S. EPA (2014b). Energy Star Target Finder. Energy Star Portfolio Manager Portfolio Manager, U.S. Envrionmental Protection Agency. <https://portfoliomanager.energystar.gov/pm/targetFinder>

U.S. EPA (2014c). Source Energy. Energy Star, U.S. Environmental Protection Agency. <https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf>
U.S. EPA (2014d). Use Energy Star Portfolio Manager. Energy Star, U.S. Environmental Protection Agency. <www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager. >
USGBC (2013). Energy and Atmosphere Credit: Optimize Energy Performance. LEED V4 Building Design and Construction Rating System, United States Green Building Council. LEED V4. <www.usgbc.org/node/2614273?return=/credits >

APPENDIX

As discussed under "Method" above, it was necessary to determine variable 2030 District energy baselines for 10 building use types in Downtown Pittsburgh; graphs illustrating the best fit equations for each of these use types are provided below. These variable equations were used along with the static baselines provided in Table 1 to estimate an energy baseline for every building in the Pittsburgh 2030 District's Downtown boundary.

FIGURE 7. Pittsburgh 2030 District Variable Energy Baseline for Bank/Financial Institutions.

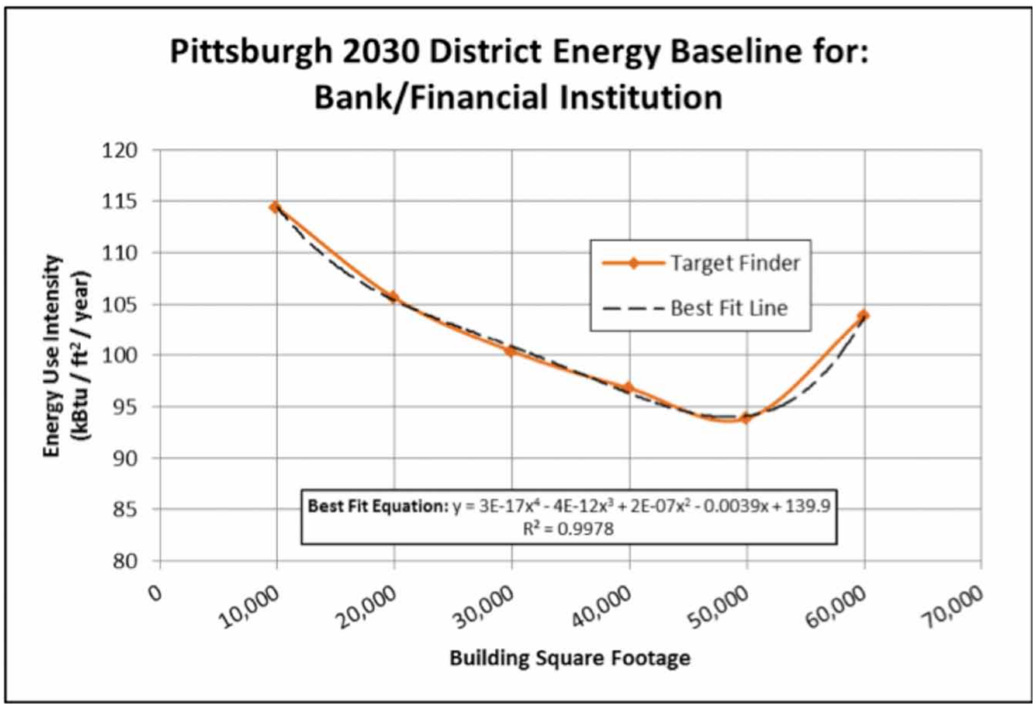


FIGURE 8. Pittsburgh 2030 District Variable Energy Baseline for Courthouses.

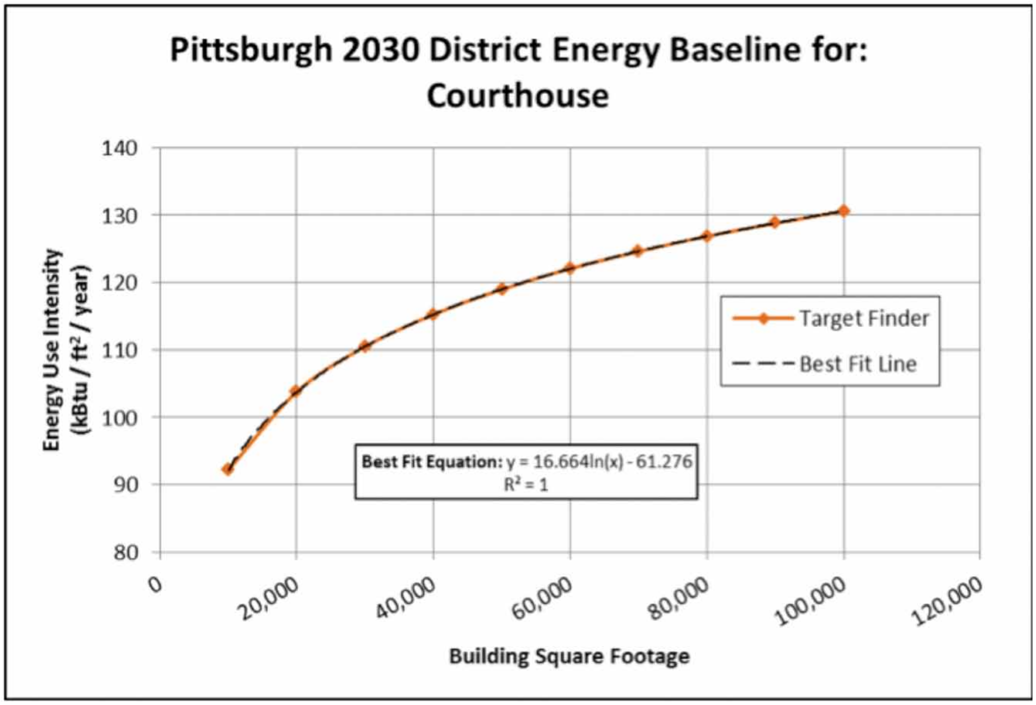


FIGURE 9. Pittsburgh 2030 District Variable Energy Baseline for Grocery Stores.

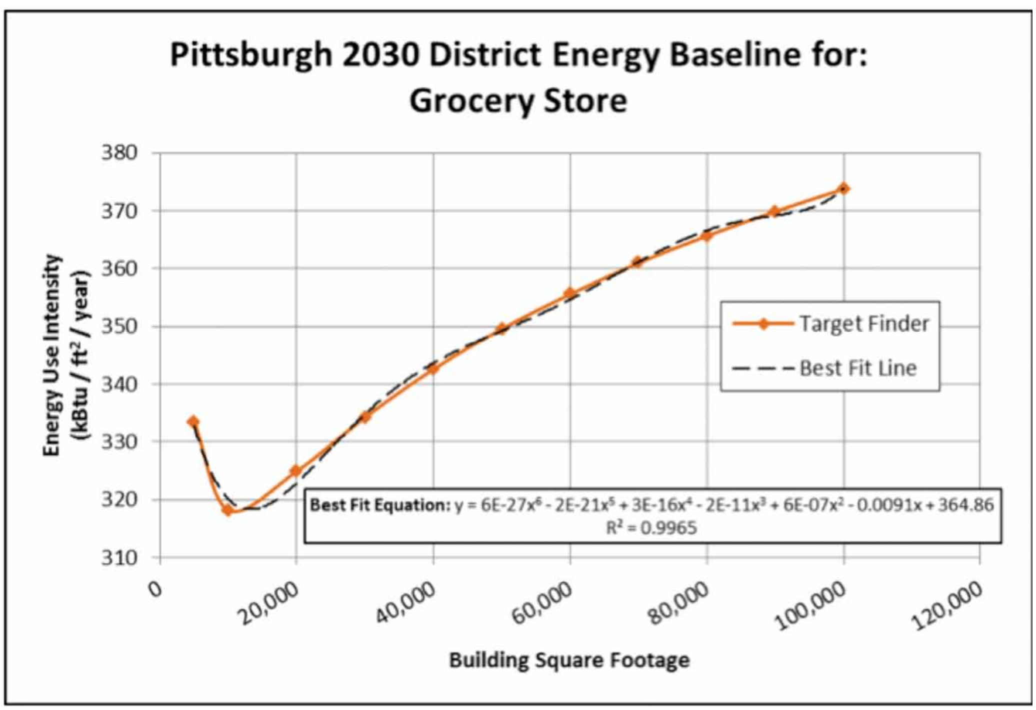


FIGURE 10. Pittsburgh 2030 District Variable Energy Baseline for Hospitals.

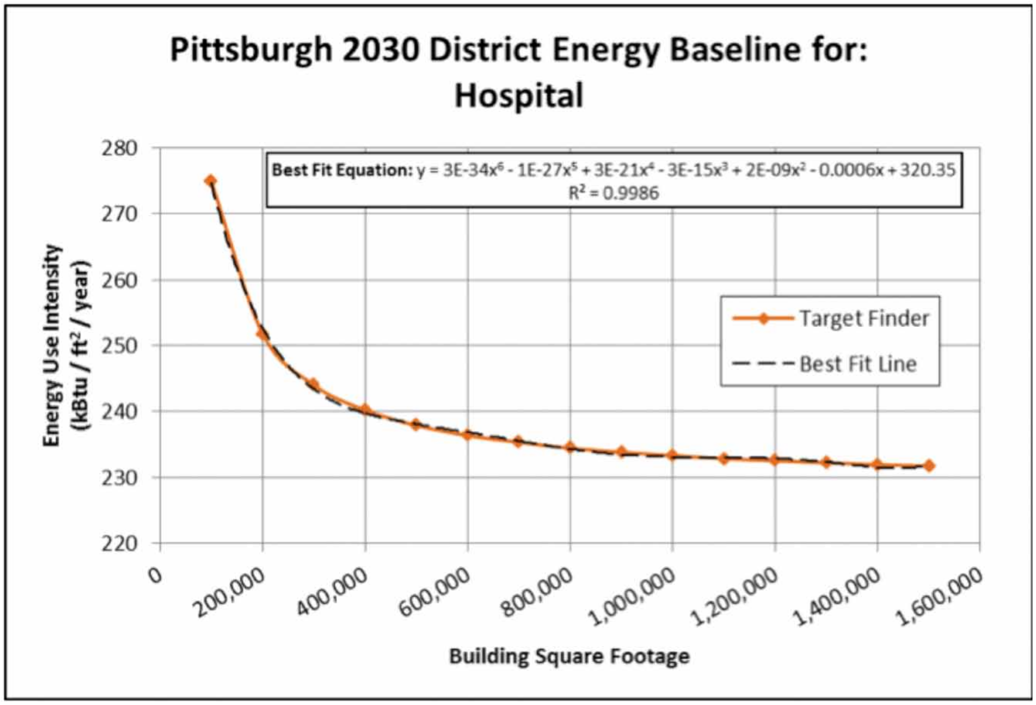


FIGURE 11. Pittsburgh 2030 District Variable Energy Baseline for K-12 Schools.

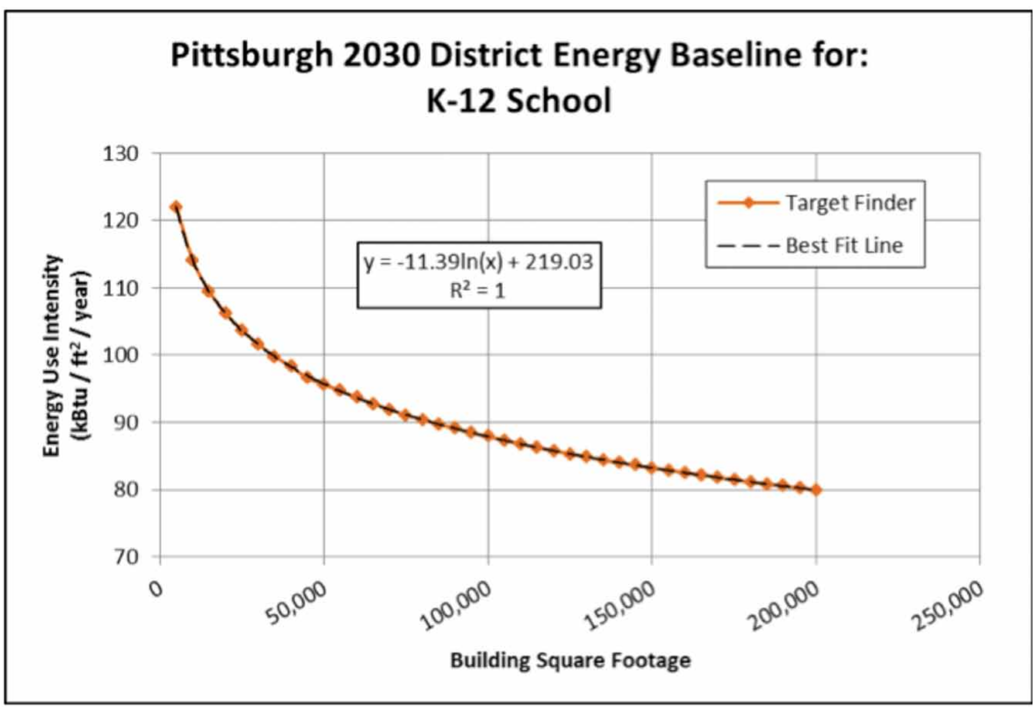


FIGURE 12. Pittsburgh 2030 District Variable Energy Baseline for Medical Office Buildings.

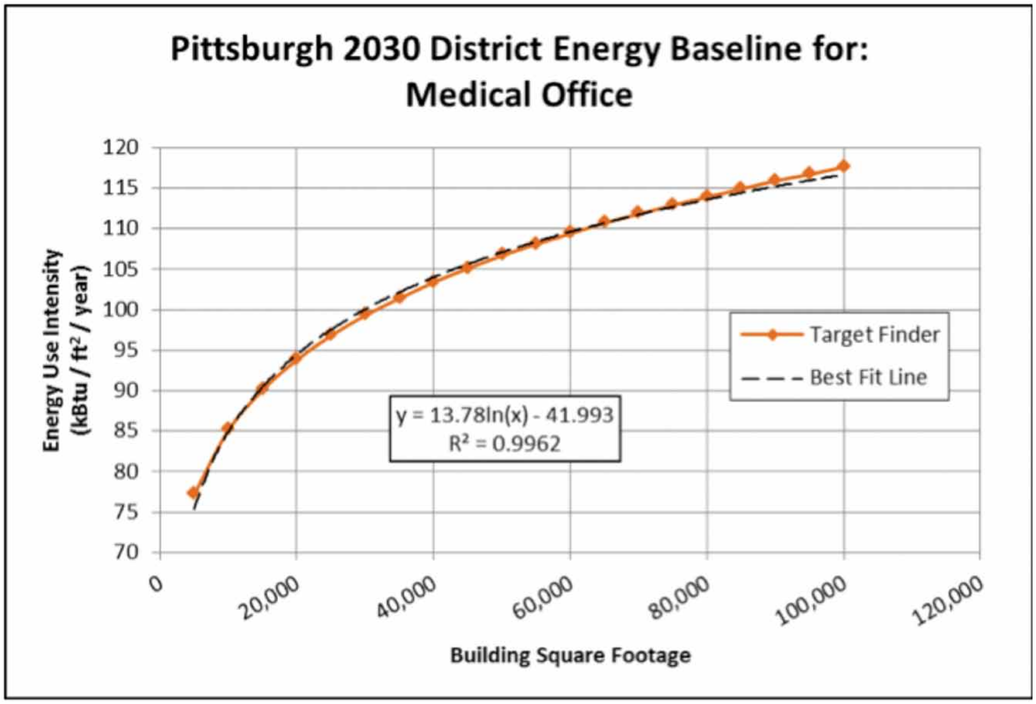


FIGURE 13. Pittsburgh 2030 District Variable Energy Baseline for Residence Halls / Dormitories.

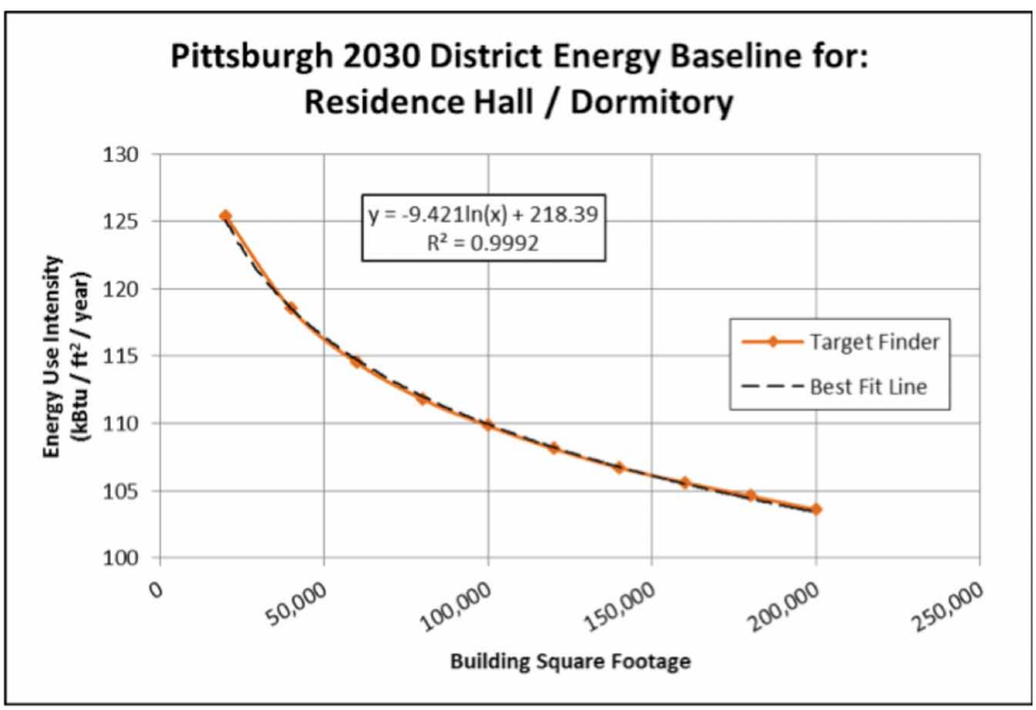


FIGURE 14. Pittsburgh 2030 District Variable Energy Baseline for Retail Stores.

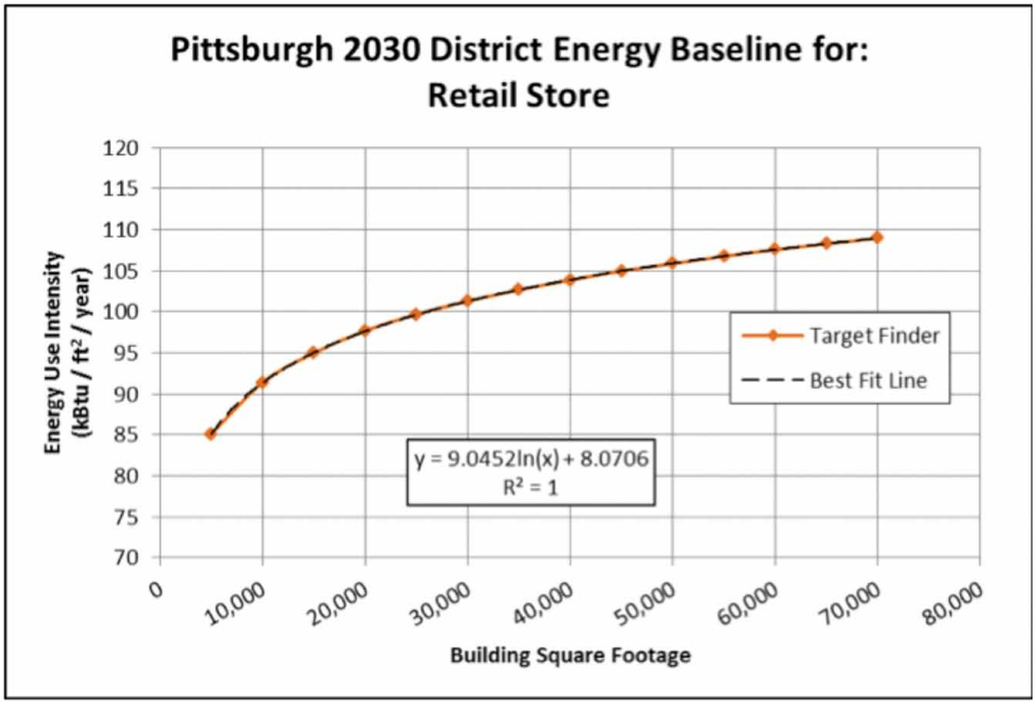
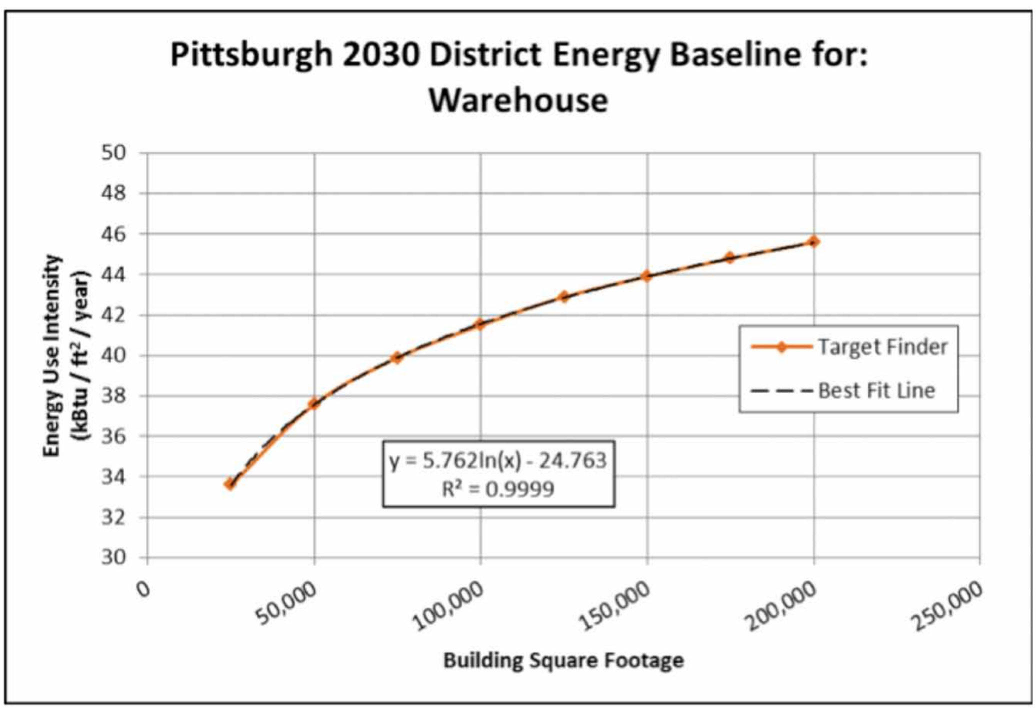


FIGURE 15. Pittsburgh 2030 District Variable Energy Baseline for Warehouses.



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RESEARCH ARTICLES