STANDARD

ANSI/ASHRAE/IES Addendum e to
ANSI/ASHRAE/IES Standard 100-2018

Energy Efficiency in Existing Buildings

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FOREWORD

Addendum e adds a new informative annex that provides guidance to authorities wishing to generate performance targets based on local or emissions data. Normative Annex C, "Forms," of Standard 100-2018 provides the following instructions for completing Form B as stated in Note (g): "Fill in the activity energy target $(EUI_{t1})_i$ *from Table 7-2 (or table from AHJ) for each activity that has an area entered from Step 6."*

The current default target tables in Standard 100 (Tables 7-2 and A-1) were developed based on CBECS and RECS and have been shown to have some significant differences from targets derived for a particular building stock using localized energy benchmarking data or other sources. As an alternative to a lengthy research process to refine the existing target tables, this informative annex contains instructions for AHJs on how to derive energy targets from regionally specific data sets that may be more applicable to their building stock. Additionally, in light of increased interest in quantifying and understanding greenhouse gas (GHG) emissions related to building energy use, the annex provides a process for converting energy-based targets into GHG-based targets.

Addendum e to Standard 100-2018

Add new Informative Annex N as shown. (Note: For readability, markup has been omitted. All of the following material is new to the standard.)

INFORMATIVE ANNEX N
GUIDANCE FOR LOCALLY DERIVED BUILDING PERFORMANCE TARGETS

N1. INTRODUCTION

This informative annex provides guidance on how to generate *building* performance targets based on local energy benchmarking data. Jurisdictions with access to local energy benchmarking data can use it to create more locally applicable targets that can be tailored more closely to specific energy consumption or greenhouse gas (GHG) emission goals.

This standard provides *building* performance targets for many property types and climate *zones*. While these targets are based on a rigorous analysis of U.S. energy data (refer to Informative Annex J), they have the following limitations:

a. **Limited Localized Applicability.** Due to the lack of availability of regional data in the sources used to develop the targets, national target values were determined and then differentiated by climate *zone* using *building* energy modeling. This process may not be applicably accurate to specific regions. In addition, the conversion factors used to develop the *source energy* and GHG emission targets are national factors that may vary significantly from local or regional factors.
b. **Limited Coverage of Uncommon Building Types.** Some *building* types, such as laboratories, courthouses, and enclosed malls have relatively few representatives. For example, those three *building* types have less than 50 samples in the Commercial Buildings Energy Consumption Survey (CBECS) 2003 data set.
c. **Outdated Targets.** Due to the lag between CBECS and Residential Energy Consumption Survey (RECS) data collection and publication, as well as the time required for target analysis, the current targets are based on energy performance data collected in 2012 (CBECS) and 2015 (RECS) and may not be representative of the current *building* stock in a specific climate *zone*.
d. **Limited Normalization Options.** Adjustment factors are only provided for operating hours and don't account for other productivity factors, such as number of occupants, meals, beds, tenant vacancies, etc.

As an alternative to using the default targets presented in this standard, *authorities having jurisdiction* (*AHJs*) have the option to use local data to determine their own targets. These locally derived *building* performance targets can be set to achieve specific energy or emissions reductions.

Section N2, "Goals, Metrics, and Targets," is a general overview of the concepts behind setting performance targets and is aimed towards policy makers. Section N3, "Data Collection/Generation" and Section N4, "Energy and GHG Emission Intensity Calculations," address data calculation and target development and are primarily targeted toward consultants or jurisdictions developing specific performance targets. While not discussed in this annex, jurisdictions that are unable to use or collect local energy benchmarking data have several options for *building* performance targets. ASHRAE's *Building Performance Standards: A Technical Resource Guide* covers this topic in more detail. The first option is to use the default targets in Tables 7-2a through 7-2d, which are based on national data sets, with the limitations listed in Section N2. The second option is using *building* energy modeling to characterize the *building* stock. The final option is to use a combination of partially applicable data sets (such as a national data set or one from a nearby region) and *building* energy modeling.

N2. GOALS, METRICS, AND TARGETS

Jurisdictions seeking to implement ANSI/ASHRAE/IES Standard 100 are encouraged to develop their own locally relevant targets; this process assumes that a jurisdiction has the following:

a. One or more sets of *building* energy benchmarking data, relevant to the portion of the *building* stock for which the jurisdiction plans to establish targets
b. A policy goal for the *building* stock, such as to achieve a GHG emissions reduction goal of x% for each time increment, or an ultimate goal, such as zero or net-zero emissions

This informative annex provides the following guidance:

a. How to select metrics, which are the specific unit of measurement used to evaluate energy or emissions performance. The three metrics used in this standard are *site energy-use intensity* (*EUI*), source *EUI*, and greenhouse gas intensity (GHGI).
b. How to choose and verify the data used to create targets.
c. How to develop targets, which are the actual values of the metrics that *buildings* must achieve to comply with this standard (e.g., 50 kBtu/ft^2/year [480 MJ/m^2/year] for office *buildings*).

N2.1 ANSI/ASHRAE/IES Standard 100 Default Targets vs. Locally Derived Targets. Locally derived targets are preferred when the *AHJ* has sufficient data on local *buildings*. When an *AHJ* has *building* energy data for an entire jurisdiction, creating locally derived targets is valuable, as the data set represents the actual population rather than a sample population. The more data a jurisdiction has on the *buildings* covered, the more accurately the effects of any given target can be predicted. When an *AHJ* has limited *building* energy data, such as data mostly from one climate region (but little from another) or data mostly from limited property types (but little from other property types), more care needs to be taken when developing local targets. Table N2.1 shows a comparison of national versus locally derived data sets.

If an *AHJ* has limited *building* energy data and wishes to create local targets, the *AHJ* should first obtain *building* energy data through a *building* energy benchmarking program that collects sufficient data to be representative of the *buildings* subject to this standard. Alternately, the *AHJ* can pursue other strategies to select targets, such as *building* energy modeling or the use of other data sets.

N2.2 Metric Types. Metrics are the quantifiable unit of measurement used to assess a *building*'s performance. They include *site energy*, *source energy*[1], and GHG emissions. Each of these metrics has different advantages and disadvantages in terms of their complexity, treatment of different fuel sources, and treatment of off-site carbon-free electricity. ASHRAE's *Building Performance Standards: A Technical Resource Guide* provides a comprehensive description of the different metric choices and their implications, which are summarized in Table N2.2-1.

Table N2.1 Comparison of Target Development with National vs. Local Datasets

Data Source Locale	Advantages	Disadvantages
National	Ease of accessibility	• Timeliness of data • Insufficient data points for specific regions and *building* types • Less accurate for local *buildings*
State or Local	Direct applicability to a region or city	• Data may not yet exist • Data may be skewed, insufficient, or need to be supplemented

1. The U.S. Environmental Protection Agency (EPA) ENERGY STAR score is another common metric based on *source energy*.

Table N2.2-1 Comparison of Site Energy, Source Energy, and GHG Emissions Metrics

Concept	Site Energy	Source Energy	GHG Emissions
Data complexity	• Most relatable to *building* owners/operators/occupants. • Data are accurately measurable by third parties and/or *building* operators.	• Requires conversion factors for all energy sources. • Conversion factors can be created in multiple ways to achieve different results.	• Requires conversion factors for all energy sources. • Conversion factors can be created in multiple ways to achieve different results.
Treatment of different fuel sources	Typically incentivizes electricity use over fossil fuels or district-energy systems.	Can account for upstream energy losses of different fuel sources, depending on the conversion factor development methodology.	Accounts for carbon impact of different fuel sources directly, allowing direct translation to emissions goals.
Treatment of off-site carbon-free electricity	Off-site carbon-free energy (primarily electricity but could include biogas or other fuel sources) is considered the same as any other grid energy.	Conversion factors can be selected to treat off-site carbon-free electricity as zero, lower impact, or even higher impact compared to other grid electricity.	Off-site carbon-free electricity has zero emissions.

Table N2.2-2 Example: Benchmarking Data Set

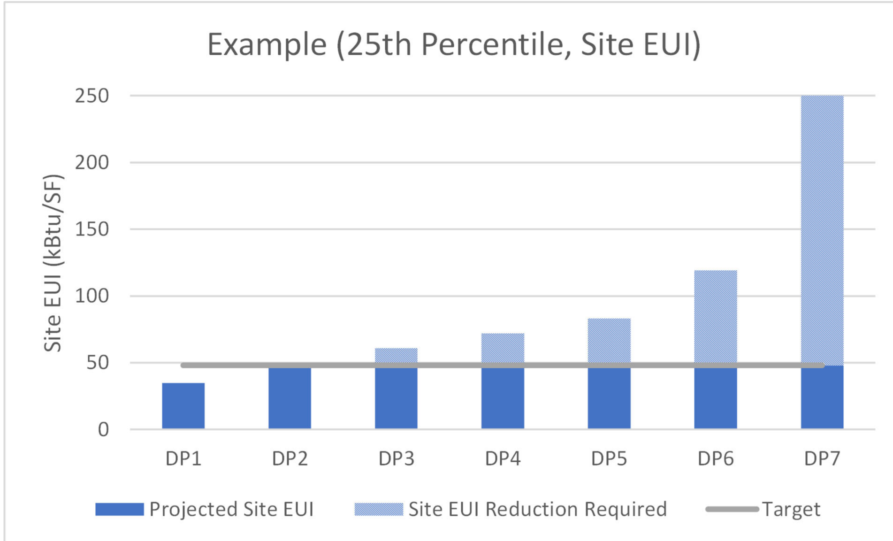
Building	Floor Area, ft^2	Fuel Mix	Site EUI, $kBtu/ft^2$	Source EUI, $kBtu/ft^2$	Greenhouse Gas Intensity (GHGI), lbs CO_2e/ft^2
DP1	131,500	60% electric/40% natural gas	35	69	9
DP2	56,300	95% electric/5% natural gas	48	123	15
DP3	153,900	45% electric/55% natural gas	61	106	14
DP4	135,500	85% electric/15% natural gas	72	173	22
DP5	60,000	100% electric/0% natural gas	83	220	27
DP6	114,600	75% electric/25% natural gas	119	267	34
DP7	90,900	40% electric/60% natural gas	250	415	55

Table N2.2-3 Example: % EUI or GHGI Reduction Required to Meet 25th Percentile Targets

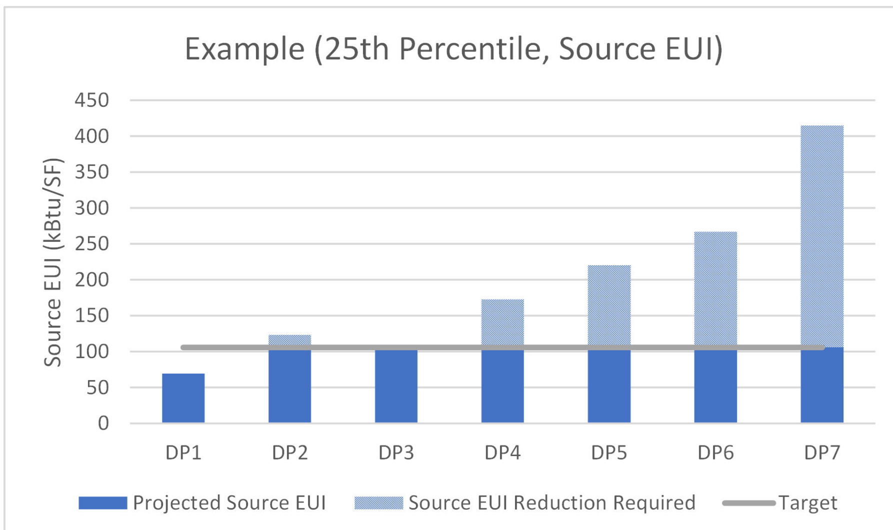
Building	Fuel Mix	% Site EUI Reduction Required	% Source EUI Reduction Required	% GHGI Reduction Required
DP1	60% electric/40% natural gas	0%	0%	0%
DP2	95% electric/5% natural gas	0%	14%	9%
DP3	45% electric/55% natural gas	21%	0%	0%
DP4	85% electric/15% natural gas	33%	39%	36%
DP5	100% electric/0% natural gas	42%	52%	49%
DP6	75% electric/25% natural gas	60%	60%	59%
DP7	40% electric/60% natural gas	81%	74%	75%

Metrics typically include a normalization factor, the most common of which is *building* floor area. Other normalizations or categorizations include *building* type, weather/climate, number of occupants, number of beds, and operating hours. Default targets in this standard utilize three metrics (*site energy*, *source energy*, and GHG emissions) and four normalization factors (floor area, *building* type, climate, and operating hours). Choosing and developing normalization factors are discussed in more detail in Section N3.1. Other performance metrics are also available. The ENERGY STAR Score is on a 100 point scale based on *source energy* and many *building*-specific normalization factors. California has developed time dependent value (TDV) targets, which are energy- and time-dependent source factors.

Example N2.2: Seven *buildings* have the characteristics listed in Table N2.2-2. Setting the target at the 25th percentile of each of the three metrics (site *EUI*, source *EUI*, GHGI) results in different outcomes for



(a)



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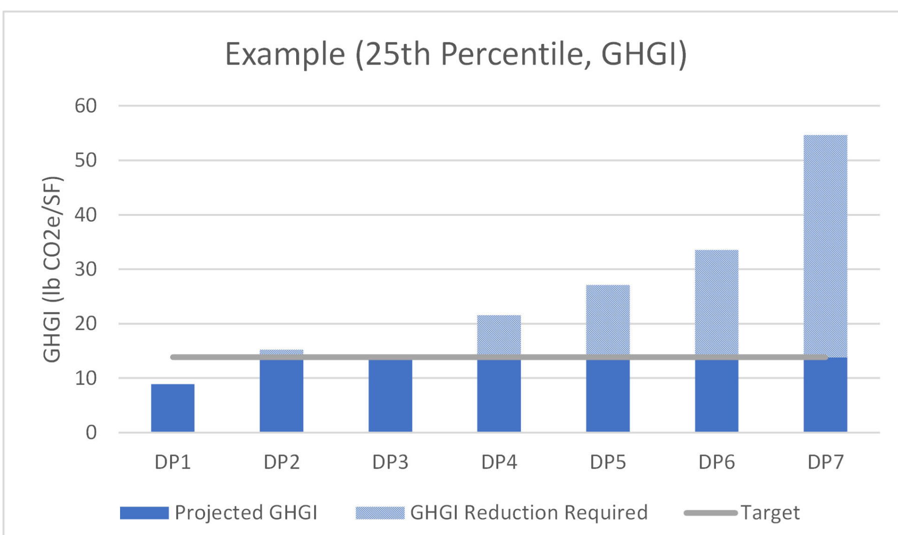

(c)

Figure 2.2-1 Example results of selecting 25th percentile targets for site EUI, source EUI, and GHGI metrics.

many *buildings*. Figure N2.2-1 shows the project *EUI* or GHGI required for each *building* to comply with a 25th percentile target.

Note that for site *EUI*, DP1 and DP2 have the lowest *EUI*, while for source *EUI* and GHGI, DP1 and DP3 have the lowest metric values. This difference is due to the difference in fuel mix among the *buildings*. Additionally, each *building* has a different reduction requirement, summarized in Table N2.2-3.

These values will vary greatly based on the conversion factors used for *source energy* and GHG emission conversions.

N2.3 Achievement of Goals through Target Setting. *Building* performance targets can be tailored to meet specific *AHJ* reduction targets.

Example N2.3: An *AHJ* wishes to reduce *building site energy* use for office *buildings* and K-12 schools by 50% by 2040. It has more than 200 office *buildings* and more than 100 K-12 schools with energy benchmarking data.

Analysis of the sample data (Table N2.3, Figure N2.3) shows that if *buildings* lower their *EUIs* to median values, total office *site energy* use will drop by 33%, and total K-12 energy use will drop by 10%. Further analysis shows that to achieve 50% savings in each group, the site *EUI* targets should be set at 44 kBtu/ft^2/yr for offices and 27 kBtu/ft^2/yr for K-12 schools.

Table N2.3 Example: % EUI or GHGI Reduction Required to Meet 25th Percentile Targets

Property Type	Median EUI, kBtu/ft^2/yr	% Energy Reduction from Meeting Median Site EUI	Target, kBtu/ft^2/yr	% Energy Reduction from Meeting Target
Office	65	33%	44	50%
K-12 school	53	10%	27	50%

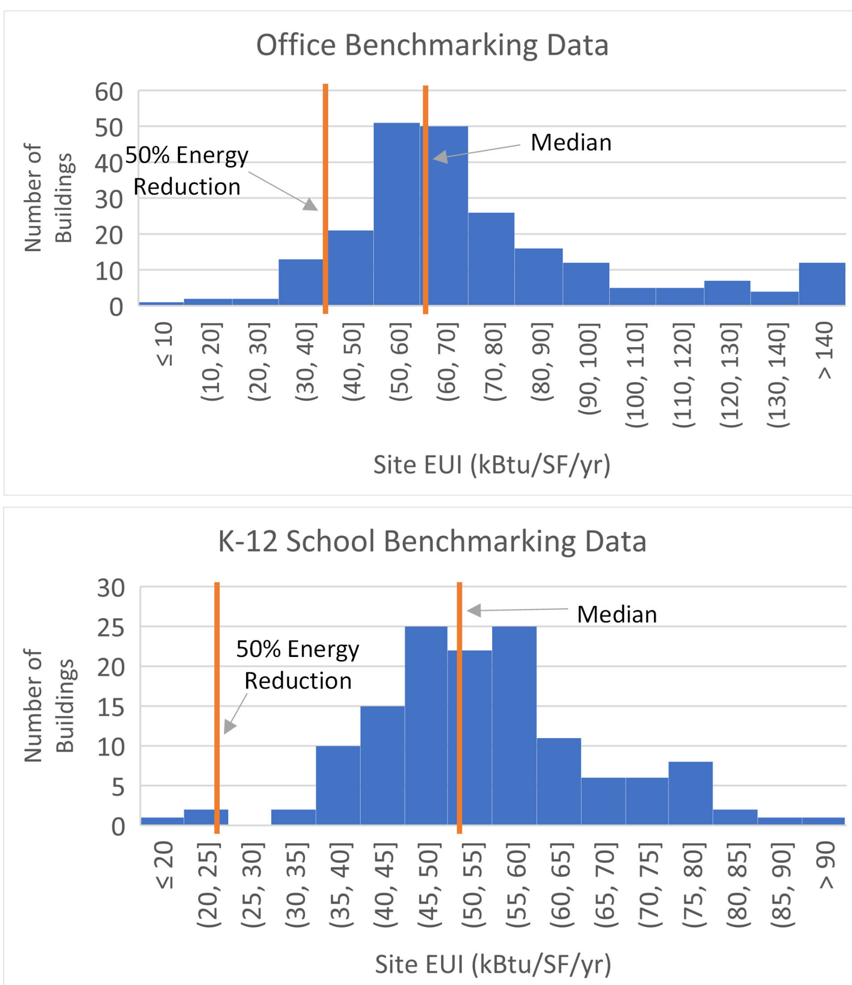

Figure N2.3 Example site EUI distributions for office and K-12 schools.

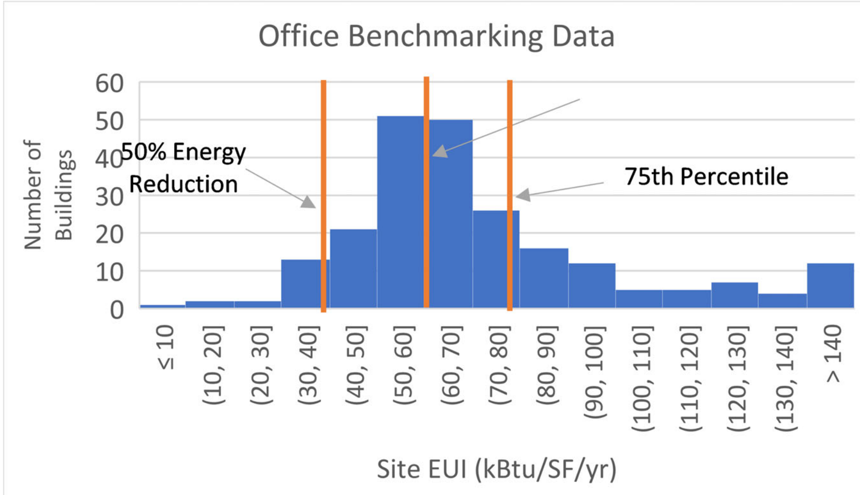

Figure N2.4-1 Example site EUI distribution—office buildings.

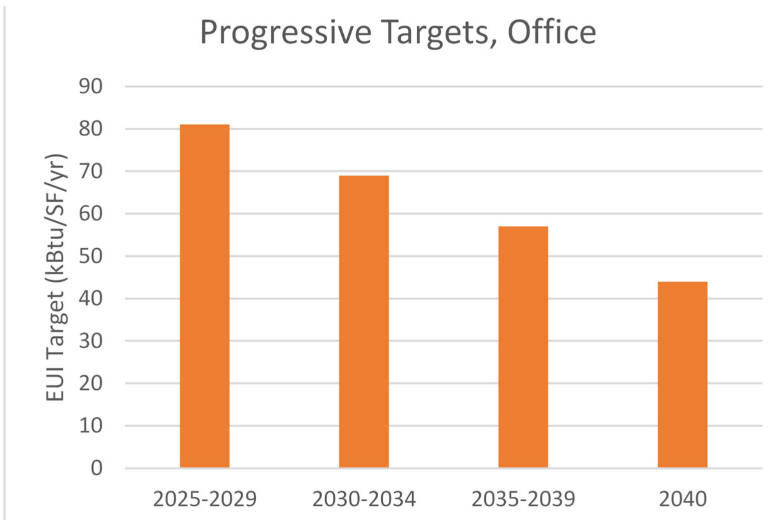

Figure N2.4-2 Example site EUI distribution—office buildings.

These values will vary greatly based on the conversion factors used for *source energy* and GHG emission conversions.

N2.4 Progression of Targets Over Time. To meet aggressive energy or emission goals, a jurisdiction may choose to set increasingly stringent requirements over time. One strategy is to set initial and final targets based on initial conditions and final goals, then to choose intermediate targets at specific intervals in between.

Example N2.4: A city has a goal of 50% *building site*/*source energy* use reduction by 2040. It chooses to set 2026 targets at the 75th percentile of *building* energy use such that only 25% of *buildings* need to take action for Year 1. For office *buildings*, the 75th percentile site *EUI* is 81 kBtu/ft^2/yr. An analysis shows that lowering the *site energy target* to 44 kBtu/ft^2/yr will result in a 50% reduction in total office energy use (Figure N2.4-1).

The city decides to set two intermediate targets, one at 2030 and a second at 2035. The intermediate targets are set at equal intervals between the initial and final targets, shown in Figure N2.4-2.

N3. DATA COLLECTION/GENERATION

Data used to develop local targets need to be collected and analyzed carefully. Local benchmarking data have several potential weaknesses: limited data on uncommon *building* types or normalization factors. Local data may also suffer from incorrect entry by users both for energy use values and *building* characteristics.

Table N3.1 Comparison of Individual Building vs. Campus or Complex Benchmarking Reporting

Reporting Resolution	Advantages	Disadvantages
Individual *building*	Simple to conceptualize; boundaries are drawn per-*building*, with some exceptions.	Owners may have difficulty establishing metering of all energy systems.
Campus/complex	Less work for portfolio owners; owners can implement district energy systems or other larger scale measures to meet goals.	Portfolio owners are allowed to have multiple *buildings* that would not meet targets by themselves, which may be perceived as unfair to other similar *buildings* not located on a campus.

N3.1 Data Categorization and Normalization. Typical energy benchmarking ordinances require reporting *building* size, *EUI*, and other parameters of the *building* on an annual basis.

N3.1.1 Choosing Building Types. The first level of normalization of performance targets is dividing by *building* types, as different *building* types need energy for different purposes and therefore do not use energy in the same way. When choosing how to group *buildings* for setting performance targets, several factors should be considered:

a. The majority of *buildings* within a category should have relatively similar energy performance. A statistical analysis could be performed to determine if two populations are significantly different from each other. Some *building* types may have too high of a variance of *EUI* due to different *building* productivity (for example, different computer, refrigeration, or ventilation requirements) to be set as a single group.
b. When using representative samples of *buildings*, the grouping must have enough *buildings* to be appropriately representative of that population of *buildings*. If a jurisdiction has data on six fitness centers out of many (e.g., 100 or more) in the region for which it intends to establish a building performance standard, it cannot use a percentile-based method (refer to Section N3.2, “Data Verification/QA”) to appropriately estimate how other fitness centers should perform. However, if all *buildings* in the population have been benchmarked, the data on those *buildings* fully characterize the population and can be used to determine targets to achieve specific energy or emissions reduction goals.

If a jurisdiction’s benchmarking data are limited in scope (e.g., focuses only on specific *building* types or sizes, or on specific climate regions), special care must be taken to account for the lack of data. In some cases, the best solution may be to wait to collect energy benchmarking data for the *buildings* that lack data. In other cases, *building* energy modeling may be appropriate to account for differences between nationally and regionally available data sets.

When targets cannot be developed for a particular *building* or set of *buildings*, these *buildings* would follow the ANSI/ASHRAE/IES Standard 100 compliance process for *buildings* without targets.

One other consideration is whether to consider campuses or complexes of *buildings* with central energy plants as individual *buildings* or a campus (Table N3.1). Individual *buildings* within a campus may not be individually metered for district energy consumption or for other grid utility consumption. In this case, owners may want to meet their responsibilities via a portfolio of *buildings*, rather than on a *building*-by-*building* basis.

N3.1.2 Other Normalizations (Optional). Other normalizations can improve the specificity of performance targets but are not necessary to complete the locally derived *building* performance benchmarking process.

a. **ASHRAE Climate Zones.** Energy consumption and performance in *buildings* in “extremely hot-humid,” “very hot-humid,” “hot-humid,” “hot-dry,” “warm-humid,” “warm-dry,” “warm-marine,” “mixed-dry,” “mixed-humid,” “mixed-marine,” “cold-humid,” “very cold,” and “subarctic” zones will vary significantly. Grouping *buildings* by ASHRAE climate zone (see Figure J-1) will help normalize the data set with a measure that can be used for corresponding regions or locations. This only applies to jurisdictions whose covered *building* stock will span multiple climate *zones*.
b. **Building Size.** Classification of *buildings* by size will be helpful, as *buildings* of different sizes will require different levels of complexity. This metric could be the total gross floor area of the property, consistent with the ENERGY STAR Portfolio Manager metrics. This measure will help mitigate negative effects from grouping *buildings* of all sizes together.
c. **Operating Hours.** The energy consumption for all *building* types will vary based on the annual operating hours. This measure will impact the total energy required or expected for heating and cooling the *building* and also impact the number of hours other equipment, such as lighting, will operate and consume energy.
d. **Process-Specific Energy Uses.** Other normalization factors are units of productivity of a *building*, particularly those that drive energy-use trends, such as CT and MRI machines and ventilation rates in hospi-

tals, conveyor systems in airports, cooking equipment in restaurants, commercial refrigeration systems in grocery stores, etc.

N3.2 Data Verification/QA. It is important to perform a preliminary data exploration to better understand the data's characteristics and verify the data set's accuracy and consistency. A data analysis should be performed to ensure the data input for *EUI*s are accurate and reasonable. Potential data errors can be wrong energy units, incorrect area, incomplete energy data, etc.

Beyond missing data, the quality of existing data is important to accurately characterize existing *building* performance. Since benchmarking ordinances rely on self-reported data, some data may be missing or include entry errors or mistaken measurements. A jurisdiction can include collection measures and parameters to ensure higher quality data during benchmarking submission. Measures to assess data quality and to find resolutions may include the following:

a. Identifying duplicate records
b. Manual or automatic detection of outliers
c. Testing assumptions and checking distributions (normal or skewed)
d. Identifying useful raw data
e. Utilizing ENERGY STAR Portfolio Manager flags on missing data fields
f. Establishing flags on very high and low *EUI*, particularly on fuel sources with units that can be misinterpreted (e.g., klb. of steam vs. lb. of steam)

The best time for data quality control is during the benchmarking process, by following up with the *buildings* that have suspect or unusual benchmarking submissions. An additional measure to improve data quality is to require periodic third-party verification of benchmarking data as part of a benchmarking ordinance.

N4. ENERGY AND GHG EMISSION INTENSITY CALCULATIONS

The most common metric used in a *building* performance standard is the energy or emissions intensity of a *building*, represented as the annual energy use or energy-related emissions of a *building* divided by the floor area. *Site energy* is typically measured by a utility, energy supplier, or the *building* owner. *Source energy* is typically measured *site energy* multiplied by a *source energy* conversion factor. Emissions are also typically calculated from *site energy*, multiplied by an emissions conversion factor.

N4.1 Site Energy Conversion Factors and Calculations. A *building* performance metric requires *site energy* measurements for all forms of energy used at a *building*. Some forms of energy, such as electricity and gas, are metered by energy distribution companies on a continuous basis. Other forms of energy, such as propane or fuel oil, may only be measured during the occasional refill at a *building* site. For many benchmarking programs, the goal is to obtain annual data. To ensure accurate comparisons against other *buildings* over the time period (e.g., January 1 to December 31), measured energy should be normalized. If the energy supplier does not provide *building* specific energy use data on a timely basis, then the *building* will need to install its own energy metering equipment (sometimes called "submeters") to ensure proper, accurate, and timely measurements. Once annual data are collected, all forms of energy can be converted to kBtu (I-P) or MJ (SI) equivalents using the methodology found in Section 5.2 of this standard. Site *EUI* is calculated by dividing the energy use by the gross floor area (square ft. [I-P] or square metres [SI]).

N4.2 Source Energy Conversion Factors and Calculations. *Source energy* estimates are based on *site energy* measurements multiplied by *source energy* factors. *Source energy* factors quantify the impacts of upstream energy lost in the production and delivery of the energy to the *building*.

Before benchmarking, the *source energy* factors to be used should be established. The jurisdiction can choose national *source energy* factors, such as those used in the ENERGY STAR program; regional *source energy* factors, such as the United States regional *source energy* factors in ASHRAE Standard 105 Table K3-A; or local *source energy* factors. Local *source energy* factors can be calculated for each energy form using the methodology in ASHRAE Standard 105 Appendices J and K, or can be obtained directly from the utility or energy supplier.

Source energy is obtained by multiplying the *site energy* of each energy form by its corresponding *source energy* factor:

$$\text{Source Energy} = \sum_i E_{Site,\ Imported\ Energy\ Form\ i} \times \text{SEF}_{Imported\ Energy\ Form\ i}$$

where

$E_{Site,\ Imported\ Energy\ Form\ i}$	=	*site energy* from Imported Energy Form *i*
$\text{SEF}_{Imported\ Energy\ Form\ i}$	=	*source energy* factor for Imported Energy Form *i*

Table N4.2 Example Source Energy Calculation Inputs

Imported Energy Form	Annual Site Energy, kBtu/yr	Annual Site Energy, MJ/yr	Source Energy Factor
Grid electricity	100,000	105,500	2.74
Natural gas	30,000	31,700	1.09

Table N4.3 Example GHG Emissions Calculation Inputs

Imported Energy Form	Annual Site Energy (kBtu/yr)	Annual Site Energy, MJ/yr	GHG Emissions Factor, lb CO_2e/kBtu	GHG Emissions Factor, kg CO_2e/MJ
Grid electricity	100,000	105,500	0.326	0.140
Natural gas	30,000	31,700	0.147	0.063

Example N4.2: A *building* has the energy use and *source energy* factors from ASHRAE Standard 105, Table K-2, shown in Table N4.2:

$$\text{Source Energy} = E_{Site,Grid\ Electricity} \times \text{SEF}_{Grid\ Electricity} \times E_{Site,Natural\ Gas} \times \text{SEF}_{Natural\ Gas}$$

$$\text{Source Energy (I-P)} = (100{,}000\ \text{kBtu/yr} \times 2.74) + (30{,}000\ \text{kBtu/yr} \times 1.09) = 306{,}700\ \text{kBtu/yr}$$

$$\text{Source Energy (SI)} = (105{,}500\ \text{MJ/yr} \times 2.74) + (31{,}700\ \text{MJ/yr} \times 1.09) = 323{,}623\ \text{MJ/yr}$$

This process is described in greater detail in ASHRAE Standard 105.

The jurisdiction may allow *buildings* that receive the same form of energy from multiple suppliers to use different *source energy* factors. For example, a *building* may receive regional grid electricity from the local distribution company and from a specific electric generation supplier through a power purchase agreement. In this situation, each form of electricity supply can be converted to *source energy* using the corresponding *source energy* factor (regional factor for electricity from the local distribution company and custom factor for the power purchase agreement supplier). Source *EUI* is calculated by dividing the energy use by the gross floor area (square ft. [I-P] or square metres [SI]).

N4.3 Greenhouse Gas (GHG) Emissions Calculations. This standard considers energy related GHG emissions only and does not consider GHG emissions associated with refrigerant leakage, processes occurring at the *building* (e.g., anesthetic gases in healthcare *buildings*), water, or other material usage. Energy-related GHG emissions are calculated similarly to *source energy* use; they are based on *site energy* measurements multiplied by emission factors. Emissions directly produced by combustion at the *building* are known as "direct emissions." Estimates derived for emissions-related processes used to deliver energy to the *building* are known as "indirect emissions."

Before benchmarking, the GHG emission factors to be used should be established. The jurisdiction can choose national GHG emission factors; regional GHG emission factors, such as the United States regional GHG emission factors in ASHRAE Standard 105 Table K3-A; or local GHG emission factors. Local GHG emission factors can be calculated for each energy form using the methodology in Standard 105 Appendices J and K, or provided by the utility or other relevant agency.

GHG emissions are obtained by multiplying the *site energy* of each energy form by its corresponding GHG emission factor:

$$\text{GHG Emissions} = \sum_i E_{Site,\ Imported\ Energy\ Form\ i} \times \text{GEF}_{Imported\ Energy\ Form\ i}$$

where

$E_{Site,\ Imported\ Energy\ Form\ i}$	=	*site energy* from Imported Energy Form *i*
$\text{GEF}_{Imported\ Energy\ Form\ i}$	=	GHG emission factor for Imported Energy Form *i*

Example N4.3: A *building* has the energy use and GHG emission factors from ASHRAE Standard 105, Table K-3, shown in Table N4.3:

$$\text{GHG Emissions} = E_{Site,Grid\ Electricity} \times \text{GEF}_{Grid\ Electricity} \times E_{Site,Natural\ Gas} \times \text{GEF}_{Natural\ Gas}$$

$$\text{GHG Emissions (I-P)} =$$

$$\left(100{,}000\ \text{kBtu/yr} \times 0.326\ \frac{\text{lb CO}_2\text{e}}{\text{kBtu}}\right) + \left(30{,}000\ \text{kBtu/yr} \times 0.147\ \frac{\text{lb CO}_2\text{e}}{\text{kBtu}}\right) = 37{,}010 \frac{\text{lb CO}_2\text{e}}{\text{yr}}$$

Table N5 Selected Bases for Target Development

Basis for Target	Advantages	Disadvantages
Mean	Straightforward and easily understood	• Can be skewed by outliers. • Not always a good indicator of central tendency.
Percentile/median	• Median is not affected by outliers, potential better indication of central tendency. • Indicates the percent of *buildings* that are required to improve.	For small or irregular data sets, percentiles far from the median are difficult to determine with certainty.
Individual percentage improvement (i.e., all *buildings* must reduce individual use by X%)	• Allows for specific overall energy or emissions reduction goals. • Eliminates extreme reduction requirements for outlying *buildings* (this may be an advantage or disadvantage). • Methodology is easy to understand.	• Each *building* will have its own target, which can be difficult to communicate or track. • High-performing *buildings* will still have to lower their energy use; may be perceived as punishing those that have already pursued major energy-efficiency upgrades.
Overall percentage improvement (i.e., set target at specific *EUI* to achieve X% overall reduction)	Allows for specific overall energy or emissions reduction goals.	• Deriving targets is more complex. • Does not indicate the number of *buildings* that are required to improve.
Zero GHG emissions	Aligns with long-term climate goals.	Requires significant changes in existing *buildings*. Should be paired with interim targets to ensure *buildings* make appropriate progress over time.
Targets requiring *building* simulation modeling	Can be used when data are unavailable or incomplete.	• Requires more effort to characterize *building* stock. • Simulated data quality is limited by the input data and simulation depth/methodology.

$$\text{GHG Emissions (SI)} =$$

$$\left(105{,}500\ \text{MJ/yr} \times 0.140\frac{\text{kg CO}_2\text{e}}{\text{MJ}}\right) + \left(31{,}700\ \text{MJ/yr} \times 0.063\frac{\text{kg CO}_2\text{e}}{\text{MJ}}\right) = 16{,}767\frac{\text{kg CO}_2}{\text{yr}}$$

The resulting GHG emissions are expressed in pounds (I-P) or kilograms (SI) carbon dioxide equivalent (CO_2e) per year. This process is described in greater detail in ASHRAE Standard 105. GHG intensity (GHGI) is calculated by dividing the GHG emissions by the gross floor area (square feet [I-P] or square metres [SI]).

N5. TARGET DEVELOPMENT PROCESS

Building performance targets (i.e., site *EUI*, source *EUI*, or GHGI) are a set of metrics that *buildings* must meet. Once *building* data have been collected, metric type has been chosen, and *EUI* or GHGI metrics have been calculated, it is time to choose specific targets. Several potential strategies for setting targets are summarized in Table N5.

N5.1 Getting Started

N5.1.1 Exploratory Data Analysis. When deciding on how stringent to set target levels, it is helpful to first perform an exploratory data analysis to determine the distribution of *EUI*/GHGI among *buildings* within each category. If there are *EUI*/GHGI ranges where a majority of *buildings* perform, it may be relatively feasible to achieve that performance for the higher *EUI*/GHGI *buildings*. A large spread of *EUI*/GHGI or two distinct peaks in the distribution may indicate that these properties have more inherent variability in performance or should be divided into more specific categories. The shape of the *EUI*/GHGI distribution may differ between *building* types, and understanding these distributions may help prioritize how stringently to set targets for each *building* type to achieve overall performance goals.

Refer to the example in Section N2.3 (particularly Figure N2.3, "Example Site *EUI* Distributions for Office and K-12 Schools"), which shows an office *building EUI* distribution that has many outliers to the right. This distribution shape results in much greater energy savings potential for the office buildings compared to the K-12 school buildings when setting targets at the median. With targets set to achieve 50% overall

EUI reduction, the median office *building* must reduce its *EUI* by 32%, while the median K-12 school *building* must reduce its energy use by 49%.

In this scenario, the *AHJ* may choose to set targets to some percentage below the median for both property types. To achieve 50% overall *EUI* reduction, targets could be set at 29% below the median for both office and K-12 school property types.

N5.1.2 Calculating Impact. Targets are primarily established to achieve specific energy or GHG goals. For any given target, we can project the equivalent percent improvement, defined as the energy or emission reduction that would be achieved if all *buildings* met the specific target. The projected percent improvement can be calculated by first defining the *baseline* and projected energy or emissions:

$$\text{Baseline Energy/Emissions} = \sum_i \mathrm{DP}_i \times \mathrm{FA}_i$$

$$\text{Projected Energy/Emissions} = \sum_i \min(T, P_i) \times \mathrm{FA}_i$$

where

DP_i = performance metric value for *building i* (these values are the site *EUI*, source *EUI*, or GHGI)

FA_i = floor area for *building i*

T = target (this value is site *EUI*, source *EUI*, or GHGI)

Finally, find the percent improvement in energy or emissions using the *baseline* and project values:

$$\text{Project Percent Improvement} = 100\% - \frac{\text{Projected Energy/Emissions}}{\text{Baseline Energy Emissions}} = 100\% - \frac{\sum_i \min(T, P_i) \times \mathrm{SF}_i}{\sum_i \mathrm{DP}_i \times \mathrm{SF}_i}$$

N5.2 Mean-Based Targets. Set the target at the mean *EUI* for each property type.

Example N5.2: Consider creating targets for a group of seven *buildings*[2] ($n = 7$), ordered from lowest to highest *EUI* (Table N5.2-1).

The mean *EUI* is 95 kBtu/ft^2/yr. Setting the target at the mean *EUI* results in the site *EUI* reduction requirements shown in Table N5.2-2. Two *buildings* are required to lower their *EUI*, resulting in an overall percentage improvement of 25%.

N5.3 Percentile/Median-Based Targets. Define a desired percentile, *P*, (e.g., 25th percentile, which is the base requirement in this standard) of the existing *building* stock to represent the minimum performance standard to which all existing *buildings* shall reduce energy use or emissions. For each *building* category, sort data points by their value from lowest to highest. Set the target equal to the data point that corresponds to the desired percentile of the data set. There are multiple methodologies for computing a percentile value, so it is recommended to use your mathematical platform of choice to determine the percentile.

Example N5.3a: Consider the previous data set (Table N5.2-1) to determine a target based on the 25th percentile. For a data set with *n* data points and a desired percentile of *P*, the target will be the data point at position $[(P/100) \times n]$, where $[(P/100) \times n]$ is rounded to the nearest integer.

The 25th percentile data point at position $[(P/100) \times n] = ([(25/100) \times 7]) = 1.75 \approx 2$. Choose DP2 (48 kBtu/ft^2/yr) as the target. Setting the target at the 25th percentile, 48 kBtu/ft^2/yr, results in 50% projected percent improvement (Table N5.3a).

Example N5.3b: Consider the previous data set to determine a median-based target. Setting the target at the median (72 kBtu/ft^2/yr), results in 33% projected percent improvement (Table N5.3b).

N5.4 Individual Percent Improvement Targets. Instead of setting a specific *EUI* or GHGI target, instead define a desired percent improvement (e.g., 40%) that all existing *buildings* shall reduce energy use or emissions to. Each *building* will have its own target based on its own performance metric.

Example N5.4: Consider the previous data set. To establish a 40% individual percent improvement target, each *building* sets its target at 40% less than the *baseline* amount (Table N5.4). This methodology results in 40% project percent improvement.

N5.5 Overall Percent Improvement Targets. Define a desired percent energy use or emissions improvement target, *P*, (e.g., 40%) to be achieved across the *building* stock through energy use or emissions reductions by all *buildings* performing worse than the overall percent improvement target calculated below.

2. This example keeps the number small for simplicity's sake, but this small number of buildings is not recommended to create targets as it is unlikely to reliably characterize the *building* stock.

Table N5.2-1 Example Data Set

Building	Floor Area, ft^2	Site EUI, $kBtu/ft^2/yr$
DP1	131,500	35
DP2	56,300	48
DP3	153,900	61
DP4	135,500	72
DP5	60,000	83
DP6	114,600	119
DP7	90,900	250

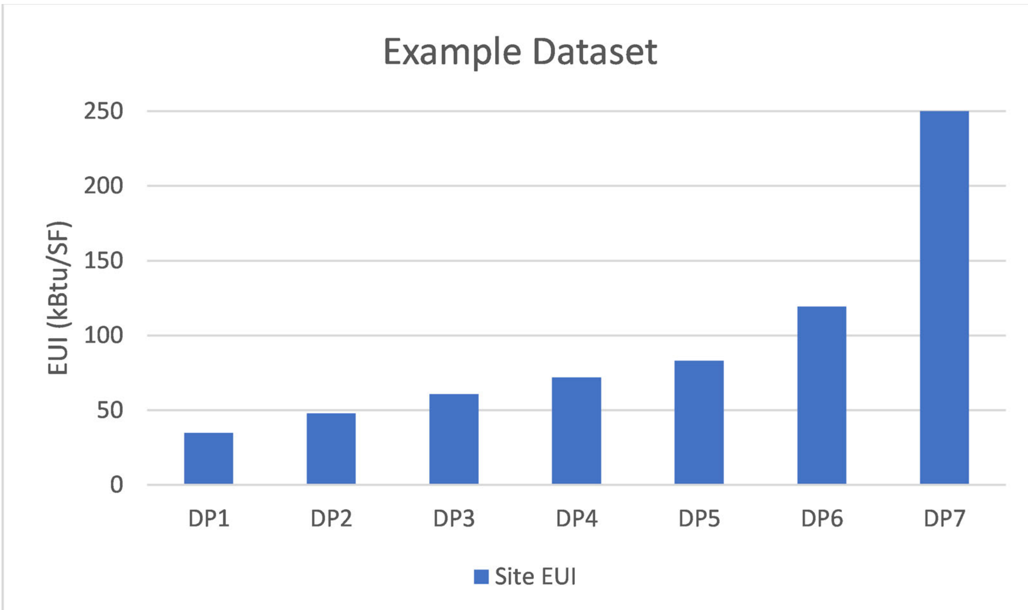

Figure N5.2-1 Example data set.

For each *building* category, sort all data points in the data set by value from lowest to highest. For each data point in the sorted data set, calculate a corresponding value, P_i, representing the hypothetical percent improvement in *building* stock energy use or emissions if the data point were set as the target:

$$P_i = 100\% - \frac{\sum_i \min(\mathrm{DP}_x, \mathrm{DP}_i) \times \mathrm{SF}_i}{\sum_i \mathrm{DP}_i \times \mathrm{SF}_i}$$

where

i = index of the data point (i.e., $i = 5$ is the 5th lowest value)

P_i = hypothetical percent improvement if DP_i were the target

DP_i = performance metric value for *building i* (these values are the site *EUI*, source *EUI*, or GHGI)

SF_i = floor area for *building i*

DP_x = data point corresponding to the xth lowest value in the *building* category's data set

n = total number of data points in the *building* category's data set

Match the desired percent improvement target, P_{spi}, to the closest P_i value and calculate the overall percent improvement target, T_{spi}, as follows:

$$\text{Overall Percent Improvement Target} = T_{spi} = \mathrm{DP}_t$$

where

Table N5.2-2 Example: Impact of Mean-Based Target

Building	Site EUI, kBtu/ft^2/yr	Site EUI Reduction Required, kBtu/ft^2/yr	% EUI Reduction Required
DP1	35	0	0%
DP2	48	0	0%
DP3	61	0	0%
DP4	72	0	0%
DP5	83	0	0%
DP6	119	24	20%
DP7	250	155	62%

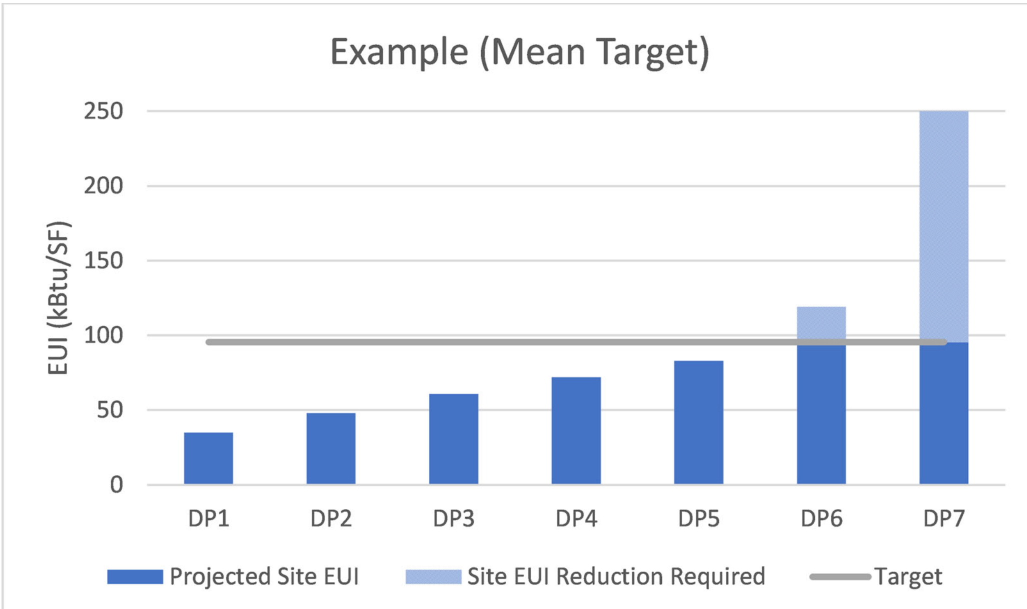

Figure N5.2-2 Example: Impact of mean-based target.

t = index of the data point corresponding to the P_i value closest to the desired percent improvement, P_{spi}

DP_x = data point corresponding to the xth lowest value in the *building* category's data set

Converting the percent improvement target to an equivalent percentile helps contextualize the target. Calculate the equivalent percentile as follows:

$$\text{Equivalent Percentile} = \frac{t}{n} \times 100$$

where

t = index of the data point corresponding to the P_i value closest to the desired percent improvement, P_{spi}

n = total number of data points in the *building* category's data set

Example N5.5: Consider the previous data set. For each data point, the projected percent improvement is calculated as if that data point were the target, shown in Table N5.5-1.

If the jurisdiction's goal is 40% overall savings, setting the target at DP_3, or 61 kBtu/ft^2/yr, will nearly reach that goal. To reach 40%, the jurisdiction decides to set the target to 60 kBtu/ft^2/yr (Table N5.5-2).

N5.6 Zero GHG Emissions Targets. A jurisdiction may choose to set a target to zero to correspond to a zero-emission goal. While the target development on this is easy, it is often paired with multiple interim targets, which can be based on any of the methods described previously.

Table N5.3a Example: Impact of 25th Percentile-Based Target

Building	Site EUI, kBtu/ft^2/yr	Site EUI Reduction Required, kBtu/ft^2/yr	% EUI Reduction Required
DP1	35	0	0%
DP2	48	0	0%
DP3	61	13	21%
DP4	72	24	33%
DP5	83	35	42%
DP6	119	71	60%
DP7	250	202	81%

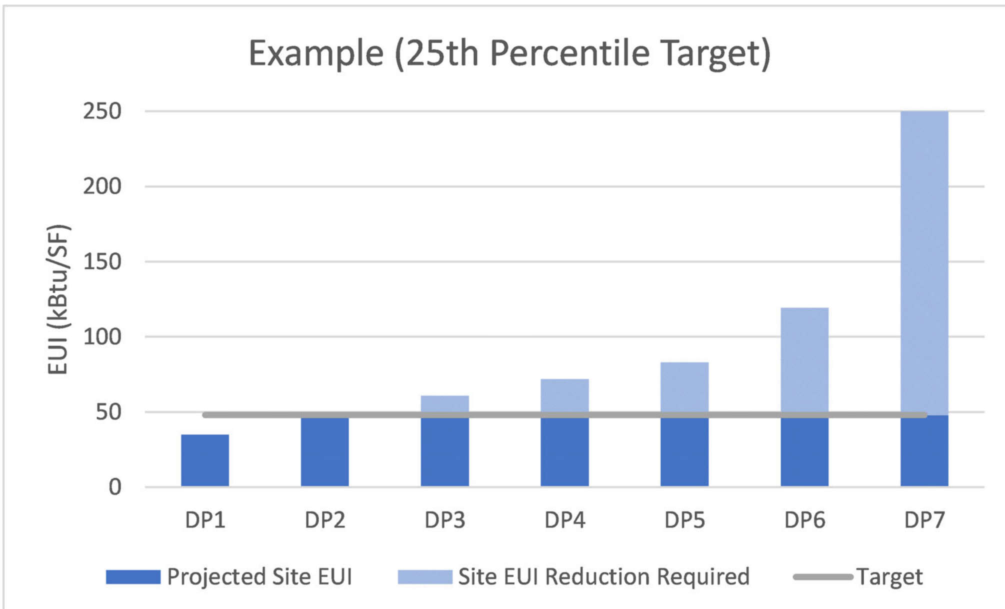

Figure N5.3a Example: Impact of 25th percentile-based target.

N5.7 Targets Requiring Building Simulation Modeling. Where *building* type data sets lack sufficient sample quality or sample quantity for each climate *zone* represented in the jurisdiction despite benchmarking efforts, *building* simulation modeling can be utilized to extrapolate targets from one climate *zone* to another. Calibrated *building* simulation models can be constructed to generate annual energy use intensities (*EUI*s) equal to targets developed from data sets with sufficient sample quality and sample quantity. The calibrated *building* simulation models can be adjusted and simulated using weather data from different climate *zones* to determine targets for data sets lacking sufficient sample quality or sample quantity. *Building* simulation modeling could also be utilized to extrapolate targets from one *building* type to another although the resulting targets will be less representative of the *building* stock given more significant discrepancies in design and construction standards across *building* types compared to climate *zones*.

Modeling a representative building for each building type requires extensive knowledge of the building stock and what programs, forms, construction types, internal loads, occupancies, and HVAC system types are typical for each building type. Calibrating the simulation models to equate annual EUIs and fuel mixes with the targets also requires extensive knowledge of the simulation engine and how model components should be adjusted to maintain sufficient validity. Implementing benchmarking programs is the suggested path to develop a comprehensive set of targets. Should building simulation be necessary, refer to Duer-Balkind et al. (2022)[3] and Informative Annex I.

3. Duer-Balkind, M.; A. Paleshi; R. Desai; K. Leung; L. Westerhoff; M. Lang. 2022. Setting Building Performance Standards with Limited Local Data. ACEEE Summer Study. https://aceee2022.conferencespot.org/event-data/pdf/catalyst_activity_32596/catalyst_activity_paper_20220810191632642_ee822729_989b_451d_ac97_09ebd933c33c.

Table N5.3b Example: Impact of Median-Based Target

Building	Site EUI, kBtu/ft^2/yr	Site EUI Reduction Required, kBtu/ft^2/yr	% EUI Reduction Required
DP1	35	0	0%
DP2	48	0	0%
DP3	61	0	0%
DP4	72	0	0%
DP5	83	11	13%
DP6	119	47	40%
DP7	250	178	71%

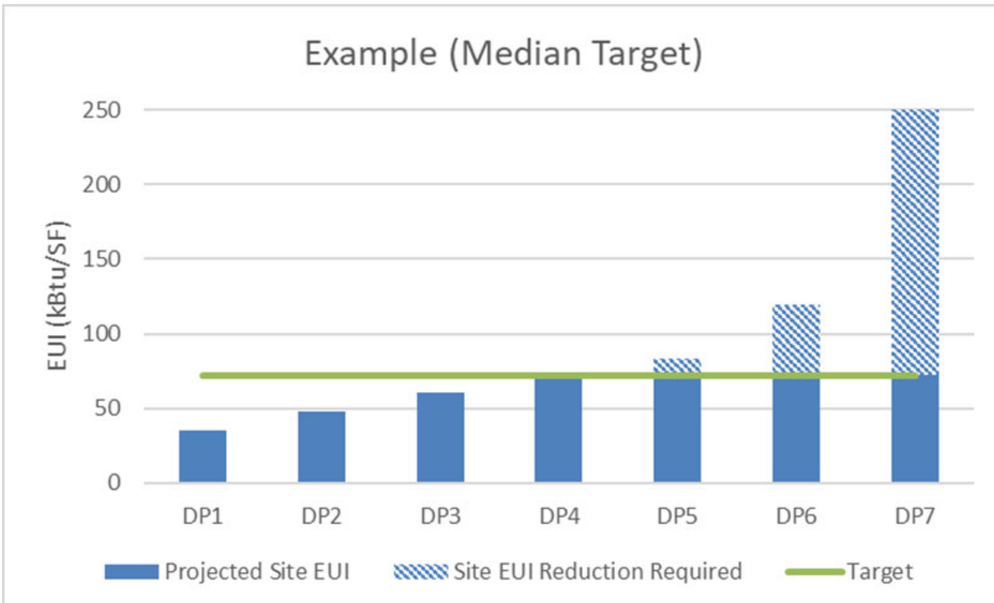

Figure N5.3b Example: Impact of median-based target.

Table N5.4 Example: Impact of 40% Individual Percent Improvement

Building	Site EUI, kBtu/ft^2/yr	Site EUI Reduction Required, kBtu/ft^2/yr	% EUI Reduction Required
DP1	35	14	40%
DP2	48	19	40%
DP3	61	24	40%
DP4	72	29	40%
DP5	83	33	40%
DP6	119	48	40%
DP7	250	100	40%

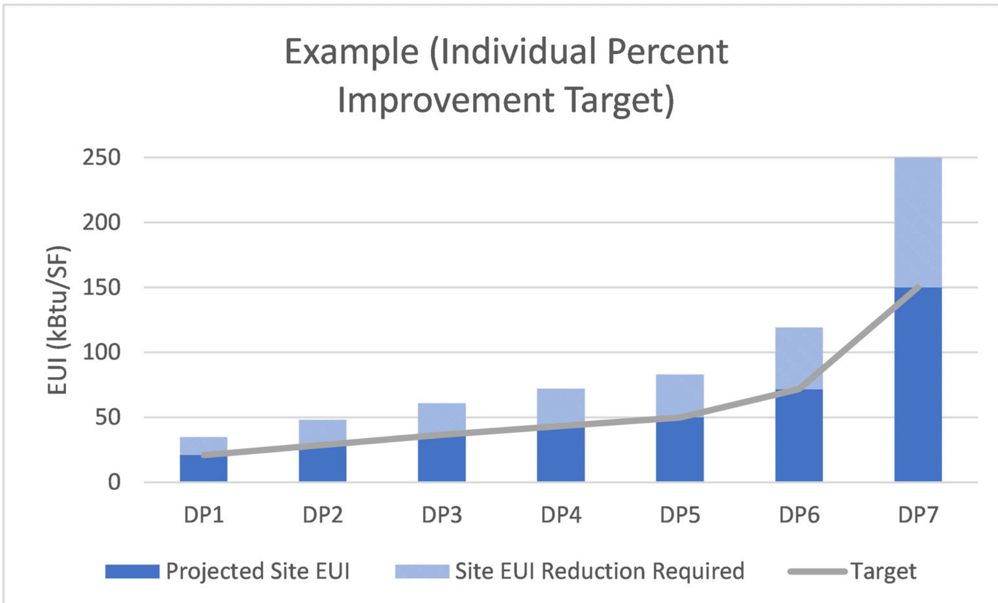

Figure N5.4 Example: Impact of 40% individual percent improvement.

Table N5.5-1 Example: Overall Percent Improvement for Targets Set at Each Data Point

Building	Site EUI, kBtu/ft^2/yr	Overall Percent Improvement if This Data Point Was Set to the Target
DP1	35	62%
DP2	48	50%
DP3	61	39%
DP4	72	33%
DP5	83	28%
DP6	119	18%
DP7	250	0%

Table N5.5-2 Example: Impact of 40% Overall Percent Improvement

Building	Site EUI, kBtu/ft^2/yr	Site EUI Reduction Required, kBtu/ft^2/yr	% EUI Reduction Required
DP1	35	0	0%
DP2	48	0	0%
DP3	61	1	1%
DP4	72	12	17%
DP5	83	23	28%
DP6	119	59	50%
DP7	250	190	76%

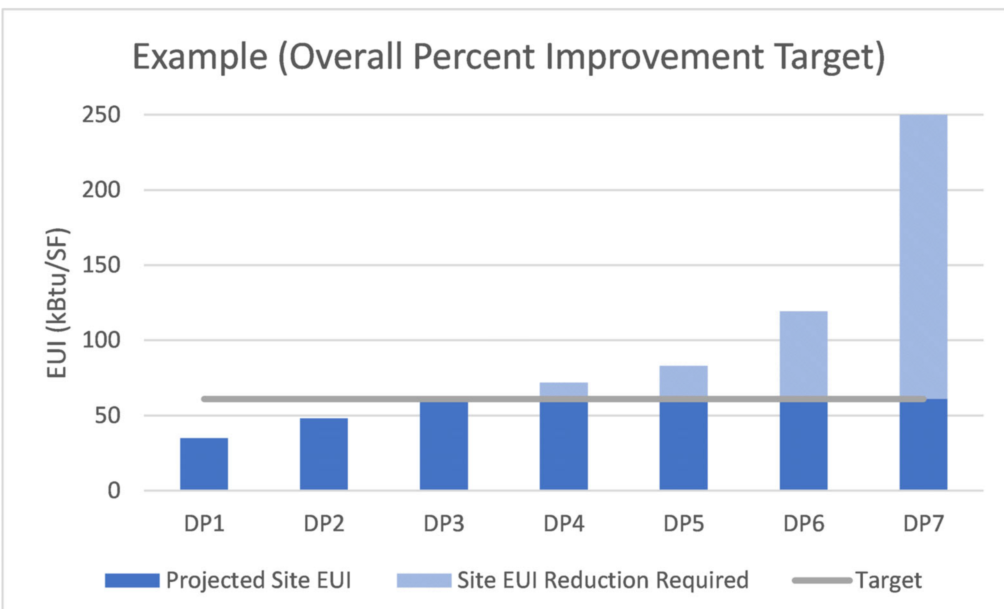

Figure N5.5 Example: Impact of 40% overall percent improvement.

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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8/23