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$^T_{A}$) 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.

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 applicable 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 dis-
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/ft²/year [480 MJ/m²/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

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

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1. The U.S. Environmental Protection Agency (EPA) ENERGY STAR score is another common metric based on source energy.
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, GHG I) results in different outcomes for

<table>
<thead>
<tr>
<th>Building</th>
<th>Floor Area, ft²</th>
<th>Fuel Mix</th>
<th>Site EUI, kBtu/ft²</th>
<th>Source EUI, kBtu/ft²</th>
<th>Greenhouse Gas Intensity (GHGI), lbs CO₂e/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP1</td>
<td>131,500</td>
<td>60% electric/40% natural gas</td>
<td>35</td>
<td>69</td>
<td>9</td>
</tr>
<tr>
<td>DP2</td>
<td>56,300</td>
<td>95% electric/5% natural gas</td>
<td>48</td>
<td>123</td>
<td>15</td>
</tr>
<tr>
<td>DP3</td>
<td>153,900</td>
<td>45% electric/55% natural gas</td>
<td>61</td>
<td>106</td>
<td>14</td>
</tr>
<tr>
<td>DP4</td>
<td>135,500</td>
<td>85% electric/15% natural gas</td>
<td>72</td>
<td>173</td>
<td>22</td>
</tr>
<tr>
<td>DP5</td>
<td>60,000</td>
<td>100% electric/0% natural gas</td>
<td>83</td>
<td>220</td>
<td>27</td>
</tr>
<tr>
<td>DP6</td>
<td>114,600</td>
<td>75% electric/25% natural gas</td>
<td>119</td>
<td>267</td>
<td>34</td>
</tr>
<tr>
<td>DP7</td>
<td>90,900</td>
<td>40% electric/60% natural gas</td>
<td>250</td>
<td>415</td>
<td>55</td>
</tr>
</tbody>
</table>

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

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

### Table N2.2-2 Example: Benchmarking Data Set

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

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

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, GHG I) results in different outcomes for
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 kBu/t/ft²/yr for offices and 27 kBu/t/ft²/yr for K-12 schools.

<table>
<thead>
<tr>
<th>Property Type</th>
<th>Median EUI, kBu/t/ft²/yr</th>
<th>% Energy Reduction from Meeting Median Site EUI</th>
<th>Target, kBu/t/ft²/yr</th>
<th>% Energy Reduction from Meeting Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>65</td>
<td>33%</td>
<td>44</td>
<td>50%</td>
</tr>
<tr>
<td>K-12 school</td>
<td>53</td>
<td>10%</td>
<td>27</td>
<td>50%</td>
</tr>
</tbody>
</table>

Figure N2.3 Example site EUI distributions for office and K-12 schools.
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/ft²/yr. An analysis shows that lowering the site energy target to 44 kBtu/ft²/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**

<table>
<thead>
<tr>
<th>Reporting Resolution</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual building</td>
<td>Simple to conceptualize; boundaries are drawn per-building, with some exceptions.</td>
<td>Owners may have difficulty establishing metering of all energy systems.</td>
</tr>
<tr>
<td>Campus/complex</td>
<td>Less work for portfolio owners; owners can implement district energy systems or other larger scale measures to meet goals.</td>
<td>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.</td>
</tr>
</tbody>
</table>

**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 EUIs 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:

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

where

- \(E_{\text{Site, Imported Energy Form } i}\) = site energy from Imported Energy Form \(i\)
- \(\text{SEF}_{\text{Imported Energy Form } i}\) = source energy factor for Imported Energy Form \(i\)
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:

Source Energy = \(E_{\text{Site,Grid Electricity}} \times SEF_{\text{Grid Electricity}} \times E_{\text{Site,Natural Gas}} \times SEF_{\text{Natural Gas}}\)

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

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:

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

where

\[
E_{\text{Site, Imported Energy Form } i} = \text{site energy from Imported Energy Form } i
\]

\[
\text{GEF}_{\text{Imported Energy Form } i} = \text{GHG emission factor for Imported Energy Form } i
\]

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:

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

\[
\text{GHG Emissions (I-P)} = \left(100,000 \text{ kBtu/yr} \times \frac{0.326 \text{ lb CO}_2\text{e}}{\text{kBtu}} \right) + \left(30,000 \text{ kBtu/yr} \times \frac{0.147 \text{ lb CO}_2\text{e}}{\text{kBtu}} \right) = 37,010 \frac{\text{lb CO}_2\text{e}}{\text{yr}}
\]
The resulting GHG emissions are expressed in pounds (I-P) or kilograms (SI) carbon dioxide equivalent (CO₂e) 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

<table>
<thead>
<tr>
<th>Basis for Target</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| 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. |

GHG Emissions (SI) =

\[
\left( 105,500 \frac{MJ}{yr} \times 0.140 \frac{kg \ CO_2e}{MJ} \right) + \left( 31,700 \frac{MJ}{yr} \times 0.063 \frac{kg \ CO_2e}{MJ} \right) = 16,767 \ \frac{kg \ CO_2e}{yr}
\]

The resulting GHG emissions are expressed in pounds (I-P) or kilograms (SI) carbon dioxide equivalent (CO₂e) 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]).
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:

\[
\text{Baseline Energy/Emissions} = \sum \text{DP}_i \times \text{FA}_i
\]

\[
\text{Projected Energy/Emissions} = \sum \min(T, \text{DP}_i) \times \text{FA}_i
\]

where

- \(\text{DP}_i\) = performance metric value for building \(i\) (these values are the site EUI, source EUI, or GHGI)
- \(\text{FA}_i\) = 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:

\[
\text{Project Percent Improvement} = 100\% - \frac{\text{Projected Energy/Emissions}}{\text{Baseline Energy/Emissions}} = 100\% - \frac{\sum \min(T, \text{DP}_i) \times \text{SF}_i}{\sum \text{DP}_i \times \text{SF}_i}
\]

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 \([\lceil P/100 \rceil \times n]\), where \([P/100]\) is rounded to the nearest integer.

The 25th percentile data point at position \([\lceil 25/100 \rceil \times 7]\) = \([25/100] \times 7\) = 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.

\[\text{2. This example keeps the number small for simplicity's sake, but this small number of buildings is not recommended to create targets as it is unlikely to reliably characterize the building stock.}\]
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:

$$P_i = 100\% - \frac{\sum_j \min(DP_{x}, DP_j) \times SF_j}{\sum_i DP_i \times SF_i}$$

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 $x$th 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:

$$\text{Overall Percent Improvement Target} = T_{spi} = DP_i$$

where

<table>
<thead>
<tr>
<th>Building</th>
<th>Floor Area, ft²</th>
<th>Site EUI, kBtu/ft²/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP1</td>
<td>131,500</td>
<td>35</td>
</tr>
<tr>
<td>DP2</td>
<td>56,300</td>
<td>48</td>
</tr>
<tr>
<td>DP3</td>
<td>153,900</td>
<td>61</td>
</tr>
<tr>
<td>DP4</td>
<td>135,500</td>
<td>72</td>
</tr>
<tr>
<td>DP5</td>
<td>60,000</td>
<td>83</td>
</tr>
<tr>
<td>DP6</td>
<td>114,600</td>
<td>119</td>
</tr>
<tr>
<td>DP7</td>
<td>90,900</td>
<td>250</td>
</tr>
</tbody>
</table>

Figure N5.2-1 Example data set.
The percent improvement target can be converted to an equivalent percentile to help contextualize the target. The equivalent percentile is calculated as follows:

\[
\text{Equivalent Percentile} = \left( \frac{t}{n} \right) \times 100
\]

where:
- \(t\) is the index of the data point corresponding to the \(P_i\) value closest to the desired percent improvement, \(P_{spi}\)
- \(n\) is the total number of data points 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:

\[
\text{Equivalent Percentile} = \left( \frac{t}{n} \right) \times 100
\]

where:
- \(t\) is the index of the data point corresponding to the \(P_i\) value closest to the desired percent improvement, \(P_{spi}\)
- \(n\) is the 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/ft²/yr, will nearly reach that goal. To reach 40%, the jurisdiction decides to set the target to 60 kBtu/ft²/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.
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 (EUIs) 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.

---

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

<table>
<thead>
<tr>
<th>Building</th>
<th>Site EUI, kBtu/ft²/yr</th>
<th>Site EUI Reduction Required, kBtu/ft²/yr</th>
<th>% EUI Reduction Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP1</td>
<td>35</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>DP2</td>
<td>48</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>DP3</td>
<td>61</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>DP4</td>
<td>72</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>DP5</td>
<td>83</td>
<td>11</td>
<td>13%</td>
</tr>
<tr>
<td>DP6</td>
<td>119</td>
<td>47</td>
<td>40%</td>
</tr>
<tr>
<td>DP7</td>
<td>250</td>
<td>178</td>
<td>71%</td>
</tr>
</tbody>
</table>

Figure N5.3b Example: Impact of median-based target.
Table N5.4 Example: Impact of 40% Individual Percent Improvement

<table>
<thead>
<tr>
<th>Building</th>
<th>Site EUI, kBtu/ft²/yr</th>
<th>Site EUI Reduction Required, kBtu/ft²/yr</th>
<th>% EUI Reduction Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP1</td>
<td>35</td>
<td>14</td>
<td>40%</td>
</tr>
<tr>
<td>DP2</td>
<td>48</td>
<td>19</td>
<td>40%</td>
</tr>
<tr>
<td>DP3</td>
<td>61</td>
<td>24</td>
<td>40%</td>
</tr>
<tr>
<td>DP4</td>
<td>72</td>
<td>29</td>
<td>40%</td>
</tr>
<tr>
<td>DP5</td>
<td>83</td>
<td>33</td>
<td>40%</td>
</tr>
<tr>
<td>DP6</td>
<td>119</td>
<td>48</td>
<td>40%</td>
</tr>
<tr>
<td>DP7</td>
<td>250</td>
<td>100</td>
<td>40%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Building</th>
<th>Site EUI, kBtu/ft²/yr</th>
<th>Overall Percent Improvement if This Data Point Was Set to the Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP1</td>
<td>35</td>
<td>62%</td>
</tr>
<tr>
<td>DP2</td>
<td>48</td>
<td>50%</td>
</tr>
<tr>
<td>DP3</td>
<td>61</td>
<td>39%</td>
</tr>
<tr>
<td>DP4</td>
<td>72</td>
<td>33%</td>
</tr>
<tr>
<td>DP5</td>
<td>83</td>
<td>28%</td>
</tr>
<tr>
<td>DP6</td>
<td>119</td>
<td>18%</td>
</tr>
<tr>
<td>DP7</td>
<td>250</td>
<td>0%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Building</th>
<th>Site EUI, kBtu/ft²/yr</th>
<th>Site EUI Reduction Required, kBtu/ft²/yr</th>
<th>% EUI Reduction Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP1</td>
<td>35</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>DP2</td>
<td>48</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>DP3</td>
<td>61</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>DP4</td>
<td>72</td>
<td>12</td>
<td>17%</td>
</tr>
<tr>
<td>DP5</td>
<td>83</td>
<td>23</td>
<td>28%</td>
</tr>
<tr>
<td>DP6</td>
<td>119</td>
<td>59</td>
<td>50%</td>
</tr>
<tr>
<td>DP7</td>
<td>250</td>
<td>190</td>
<td>76%</td>
</tr>
</tbody>
</table>

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