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Building Performance Standards and ASHRAE® Standard 100-2024

This *Engineers Newsletter* is intended to help readers interpret and apply the requirements of ASHRAE® Standard 100-2024 and similar Building Performance Standards (BPS). The 2024 version of Standard 100 changes the title, purpose, and scope to include a focus on carbon footprint reduction.

Terminology

The following are some common terms that will be used throughout the document.

Building Performance Standards (BPS). Outcome-based policies and laws aimed at reducing carbon impact of the built environment.

Energy Conservation Measures (ECM). Reduction of energy consumption of equipment or essential building services to reduce overall building energy use.

Energy Efficiency Measures (EEM). Implementation of strategies to improve the efficiency of energy use in order to reduce energy consumption and lower related costs.

Emissions Reduction Measures (ERM). Actions taken to reduce the release of pollutants and harmful substances into the environment.

Energy Usage Intensity (EUI). A building's energy use as a function of its size.

Greenhouse Gas (GHG). Gases present in the Earth's atmosphere that contribute to global warming.

Greenhouse Gas Intensity (GHGI). A building's greenhouse gas emissions as a function of its size.

Qualified Energy Auditor. A person having training and expertise in building energy auditing such as a professional engineer, certified energy auditor, or a person qualified by the AHJ (authority having jurisdiction).

Qualified Person. A person having training and expertise in building energy use analysis such as a professional engineer, certified energy auditor, energy manager, or a person qualified by the AHJ (authority having jurisdiction)

Introduction

One of the building industry's greatest challenges is to help reduce the energy and carbon footprint of the built environment. Buildings use 40 percent of all energy consumed in the US and over 75 percent of the electricity[1]. Of the buildings that will exist in 2030, 75 to 80 percent have already been built, and around 80 percent of the buildings already constructed are expected to exist in 2050[2]. For these reasons, existing buildings present one of the greatest opportunities for energy and carbon savings. The primary energy efficiency focus for the past several decades has been on new construction and major renovations as opposed to existing buildings. ASHRAE Standard 90.1, and the International Energy Conservation Code (IECC), have limited requirements for existing building energy consumption and carbon footprint. To address this, ASHRAE and some state and local jurisdictions have developed Building Performance Standards (BPS). ASHRAE Standard 100-2024 "Energy and Emissions Building Performance Standard for Existing Buildings" was created to be the model standard for jurisdictions looking to adopt a building performance standard. ASHRAE Standard 100 establishes energy and carbon performance targets for existing buildings, creates requirements for operations and maintenance (O+M), and establishes common enforceable language for jurisdictions to adopt.

Brief History

ASHRAE Standard 100 was not originally written as a building performance standard. The standard, originally published in 1995, primarily focused on existing building energy conservation through the identification of Energy Conservation Measures (ECM) and was titled "Energy Efficiency in Existing Buildings". The standard has been updated four times since then in 2006, 2015, 2018, and most recently 2024. The 2015 and 2018 versions changed the compliance path to be based on Energy Use Intensity (EUI), in addition to O+M requirements. The title, purpose, and scope were changed in the 2024 version to "Energy and Emissions Building Performance Standard for Existing Buildings" to meet the need to regulate building emissions in addition to energy consumption and is intended to standardize building performance codes.

Equations

Gross Energy Use = (Energy delivered to the building) + (On-site renewable energy produced and delivered to the building) – (Excess energy exported from the building for beneficial use)

Gross Floor Area = Sum of all space floor area within the building with no deductions for floor penetrations other than atria. It is measured from the exterior faces of exterior walls or from the centerline of walls separating buildings but excludes covered walkways, open roofed over areas, exterior terraces, roof overhangs, garages, and surface parking.

Annual Bulk Energy Use = (Measured inventory at the beginning of the 12 month period) + (Amount of the energy type delivered during the 12 month period) – (Measured inventory at the end of the 12 month period)

Energy Usage Intensity (EUI) = Gross energy use for 12 months (all types converted to kBTU) / Gross floor area (ft^2 or m^2)

Greenhouse Gas Intensity (GHGI) = (Total greenhouse gas emissions) / (Gross floor area)

Figure 1. Flowchart for buildings with performance targets

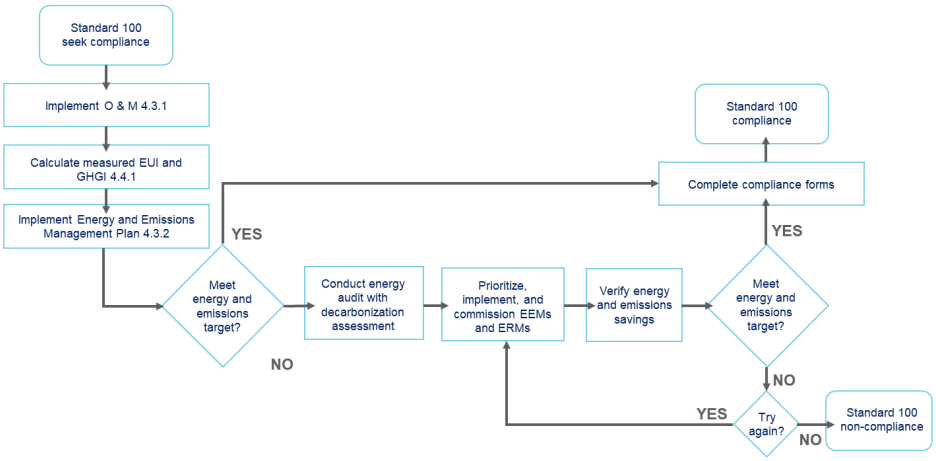
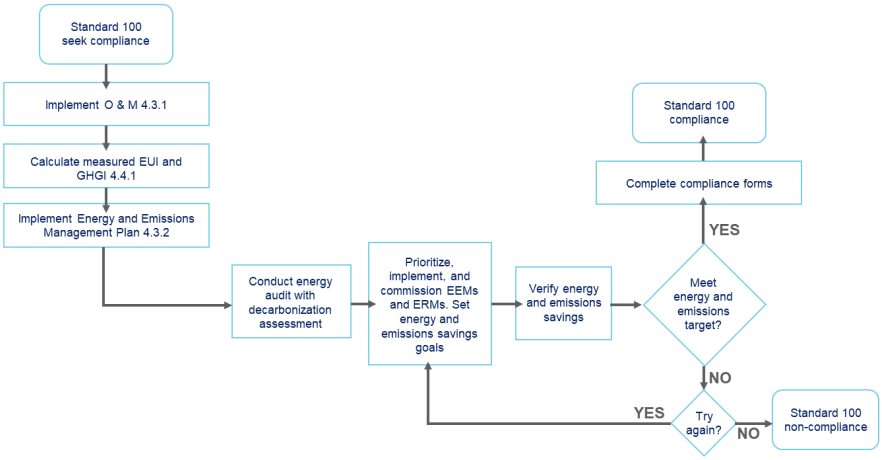


Figure 2. Flowchart for buildings without performance targets



Compliance Paths for Nonresidential Buildings

Buildings or a complex of buildings seeking to comply with Standard 100 must first determine if the building type or activity is listed in table 7-1 of the standard. All building types in this table have prescribed energy and emissions targets by climate zone in table 7-2. If the building has performance targets, it must first meet the O+M requirements and establish an energy and emissions management plan. Once those are satisfied, a "qualified person" must calculate the building's energy use and emissions for the previous 12 months in accordance with section 5.2. Since the building has set performance targets, the calculated energy and emissions are compared to the target (see Figure 1). If the target is met, compliance forms shall be completed and submitted. Buildings that do not meet the target must then conduct an energy audit with decarbonization assessment, which must identify Energy Efficiency Measures (EEMs) and Emissions Reduction Measures (ERMs) that are expected to reduce the building's EUI and Greenhouse Gas Intensity (GHGI) below the building target. If the audit does not identify sufficient EEMs and ERMs to meet the target, a more detailed audit must be completed. Once the required EEMs and ERMs are identified, they must be implemented and EUI and GHGI recalculated over the next 12 months to prove compliance.

Buildings without performance targets must meet the same O+M requirements and establish an energy and emissions management plan (see Figure 2). In addition to the O+M requirements, they must have a qualified energy auditor complete an audit with decarbonization assessment. An optimized bundle of ERMs shall be developed to maximize the energy and emissions reduction and must have a bundled payback of less than five years. The optimized bundle of EEMs and ERMs must then be implemented to prove compliance.

Operations and Management

The building manager must comply with section 6: Operations and Management (O+M) requirements. A formal written O+M program shall be implemented in accordance with Appendix C and ASHRAE Standard 180 "Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems." Recommended maintenance tasks can be found in Informative Appendix I of Standard 100. This appendix covers building envelope, domestic hot water, HVAC systems, refrigeration, lighting, controls, and power distribution and generation equipment. Equipment replacement must be in accordance with the capital management plan, which is required as part of the energy and emissions management plan. For example, when lighting is replaced, it must meet the most stringent energy efficiency requirements in both the federal equipment standards and in the applicable building codes.

The capital management plan must identify:

- EEMs and ERMs not selected for implementation
- Equipment and systems for replacement in case of failure that will result in the maximum reduction in energy use and GHG consistent with reasonable financial performance
- Estimated end of useful life for envelope, lighting, space heating and cooling, and water heating systems
- Sizing calculations for the replacement of heating and cooling equipment based on the building as modified by the EEMs implemented
- Opportunities for addition of updated system controls and demand response integration
- Restrictions on the use and application of electric resistance heat for space and water heating
- Recommendations on use of dual-fuel systems to ease building transition off fossil fuels
- Phase-out plan for all on-site fossil fuel combustion equipment (except equipment for standby or emergency use)

Energy and Emissions Management Plan

An energy manager shall be designated by the building owner to develop and maintain an energy and emissions management plan. The emissions portion of the plan shall consider GHG emissions associated with the building's energy consumption. Buildings smaller than 5,000 ft^2 are not required to have an energy manager or an energy and emissions management plan. The plan must include:

- An energy and emissions accounting system to record the energy use and GHG emissions
- In the initial year of compliance, the building's energy use intensity (EUI) and greenhouse gas intensity (GHGI)
- Annual updates of the gross energy use, EUI and GHGI
- For buildings with performance targets, annual comparison of the building's EUI to its EUI target and comparison of the building's GHGI to its GHGI target (see Equations sidebar on page 2)
- For buildings without performance targets, annual comparison of the building's EUI and GHGI to the adjusted EUI and adjusted GHGI established by its most recent energy audit with decarbonization assessment
- Documentation of original, current, and changes in number of occupants, weekly operating hours, or time of day occupancy, production rates, and energy-using equipment that would have caused a change in the measured EUI or GHGI
- Energy audit with decarbonization assessment reports and recommended energy efficiency measures (EEMs) and emission reduction measures (ERMs)
- A list of EEMs and ERMs that have been implemented and the dates of implementation
- Training plan for the O+M personnel to operate the building systems to achieve established indoor environmental targets with optimum energy efficiency
- A capital management plan

Calculating EUI and GHGI

The next step in compliance is calculating the buildings energy usage intensity (EUI) and greenhouse gas intensity (GHGI). To calculate EUI all energy consumed by the building over a 12-month period is summed, converted to kBTUs, and divided by the building gross floor area. To calculate GHGI each form of energy must be converted by multiplying the yearly consumption by the Greenhouse Emissions Factor (GEF) for that fuel type , summed, and then divided by the building gross floor area. See example compliance path management plan on pages 6 and 7.

Once EUI and GHGI have been calculated, they are compared to the building's targets (more on targets later). If the building meets the target, they can submit the necessary forms to demonstrate compliance with the standard. Buildings that do not meet their target must then conduct an energy audit with a decarbonization assessment.

Energy Audit with a Decarbonization Assessment

Buildings that have performance targets but failed to meet them must conduct an energy audit with decarbonization assessment. The goal of the assessment is to identify EEMs and ERMs that will lower the building EUI and GHGI enough to meet the target. A qualified energy auditor may determine the energy audit level that is appropriate for the building. The decarbonization assessment goes beyond the typical energy audit and identifies renewable energy, electrification, and other measures that will reduce building greenhouse gas emissions. The audit must identify a list of EEMs and ERMs for evaluation. Each EEM and ERM is evaluated to determine the impact on building energy consumption or greenhouse gas emissions. An adjusted building EUI and GHGI can then be calculated considering the savings from those EEMs and ERMs. If the adjusted EUI and GHGI meet the building targets,

those EEMs and ERMs should then be implemented. If the audit does not identify enough savings to meet the target, a more detailed energy audit must be conducted until the target is met.

Buildings without performance targets may comply with the standard by identifying and implementing an "optimized" set of EEMs and ERMs. The "optimized" bundle of EEMs and ERMs shall have a simple payback of less than five years. An "optimal" bundle of EEMs and ERMs often combines measures that have paybacks shorter and longer than five years to maximize the benefits at the lowest cost.

Local Targets

The standard has a detailed set of tables covering a wide range of building types and climates in the United States. Unfortunately, the source data, such as CBECS-2012 and RECS-2015, is often several years old when Building Performance Standards (BPS) are actually implemented. Jurisdictions outside of the United States or those that wish to have a more localized data set may want to create localized targets. Informative Appendix J "Guidance for Locally Derived Building Performance Targets" provides a method for creating localized performance targets using various data sources. Many jurisdictions already have a building benchmarking law that provides a quality data set that can be utilized to create building targets. The appendix includes examples from British Columbia and for US-based hospitals.

Vacant Buildings or Portions of Buildings

Vacant buildings pose a unique challenge for BPS since they are typically still conditioned but are difficult to establish targets. The standard requires that vacant buildings determine their compliance based on their pre-vacancy activity. If the total floor area of the non-heated, non-cooled, and non-illuminated part of the building is less than 30 percent of the gross floor area, it can be excluded, and both the EUI and GHGI targets determined will be based on the remainder of the building. For vacant spaces or buildings that are conditioned or illuminated, compliance will be determined after it becomes occupied and energy use data becomes available for 12 consecutive months.

Building Performance Standard Adoption

Until recently the primary users of Standard 100 have been consultants and building owners working on improving building energy efficiency. As of January 2024, four states and 11 cities have adopted a building performance standard, but only two reference Standard 100 as of this publication: Washington and Oregon. Compliance requirements vary from one jurisdiction to another and may be based on energy, carbon, or a combination of the two. Prior to the newest version of Standard 100, it was up to each jurisdiction to write the compliance paths. ASHRAE Standard 100 strives to create a common framework for jurisdictions written in mandatory and enforceable language.

While local laws vary, the process and duration for compliance that many jurisdictions adopt is similar. Over time, the targets for compliance may become more demanding, and additional building types may be included on the list of those required to meet these targets. This stepped approach allows jurisdictions to implement more stringent requirements as time goes on with the ultimate goal of meeting their climate pledges. Buildings that met the requirements during the early period of compliance may still need to make efficiency or emissions improvements to continue to meet the more strict requirements in subsequent periods. Within each BPS period, the process can be broken down into a data gathering/reporting period, EEM/ERM identification/implementation period, and a compliance period. During the data gathering period, 12 consecutive months of data are compiled and analyzed. Buildings that comply with their targets can skip right to compliance while continuing to monitor their energy consumption. Buildings that do not meet their targets have a period of time to conduct audits, identify the necessary EEMs and ERMs, and implement those projects. Finally, the compliance period is there to gather post implementation energy consumption to prove compliance. For buildings that do not meet their targets by the end of the compliance period, there is typically a fee, often based on the gross floor area of the building.

Summary

The built environment provides a significant area of focus when working towards promoting energy efficiency, renewable energy use, and sustainable practices. These goals can be achieved through upgrades to outdated HVAC systems, lighting, controls, and building materials. ASHRAE Standard 100, provides building owners and operators with the necessary guidance to clearly define and implement compliance plans to reduce their building's energy and carbon footprint. By prioritizing these strategies and implementing supportive policies, we can create a more sustainable built environment that significantly contributes to mitigating climate change.

By Scott Delo, Trane. To subscribe or view previous issues of the Engineers Newsletter visit trane.com. Send comments to ENL@trane.com.

References

1. Susannah Shoemaker, "NREL Researchers Reveal How Buildings Across United States Do—and Could—Use Energy, " NREL, last modified September 14, 2023, https://www.nrel.gov/news/features/2023/nrel-researchers-reveal-how-buildings-across-the-united-states-do-and-could-use-energy.html#:~:text=Buildings%20are%20responsible%20for%2040,of%20the%20nation's%20carbon%20emissions.

2. Jose Luis Blanco et al. "Call for action: Seizing the decarbonization opportunity in construction," McKinsey & Company, last modified July 14, 2021, https://www.mckinsey.com/industries/engineering-construction-and-building-materials/our-insights/call-for-action-seizing-the-decarbonization-opportunity-in-construction.

Resources

1. ANSI/ASHRAE/IES Standard 100-2024. Energy and Emissions Building Performance Standard for Existing Buildings. ASHRAE. Atlanta, GA. 2024.

2. ASHRAE "Building Performance Standard: The New Face of Standard 100." ASHRAE Journal, Vol. 66, no. 3, March 2024.

Example Compliance Path Management Plan

Space: 200,000 ft² mixed-use office building

Location: Western Pennsylvania

Zone: 5A

O+M requirements: Energy and emissions management plan and capital management plan have been completed and are documented. The building is currently 100 percent occupied.

Determine if the building meets the EUI and GHGI targets. Using tables from the standard we are able to determine the following:

- Table 7-1 - mixed use office buildings are building type number 5
- Table 7-2a - the site EUI target = 35 kBTU/ft²
- Table 7-4a - the GHGI target = 9.3 lb CO_2e/ft²

The building records 12 months of utility bills including electricity and delivered propane. The following is the breakdown of the utilities usage:

- 12 month consumption of electricity = 1,100,000 kWh
- Propane on hand at the start of 12 months = 6,000 gallons
- Propane delivered over 12 months = 55,000 gallons
- Propane on hand at the end of 12 months = 7,500 gallons

Utilities Calculations

kBTU/yr electricity = 1,100,000 kWh x 3.412 kBTU/kWh = 3,753,200 kBTU/yr

Propane consumption = 6,000 gallons + 55,000 gallons – 7,500 gallons = 53,500 gallons

kBTU/yr propane = 53,500 gallons propane x 91.6 kBTU/gallon propane = 4,900,600 kBTU/yr

Building EUI Calculation

EUI = total energy consumption / building area, ft²

EUI = (3,753,200 kBTU/yr + 4,900,600 kBTU/yr) / 200,000 ft²

EUI = 43.27 kBTU/ft²

Building GHGI Calculation

Electrical Grid emissions factor for RFC west = 0.395 lbCO_2e/kBTU

Emissions factor for propane = 0.138 lb CO_2e/kBTU

GHGI = ((yearly electricity consumption x electrical grid emissions factor) + (yearly propane consumption x emissions factor for propane)) / 200,000 ft²

GHGI = ((3,753,200 kBTU/yr × 0.395 lb CO_2e/kBTU) + (4,900,600 kBTU/yr × 0.138 lb CO_2e/kBTU)) / 200,000 ft²

GHGI = 10.79 lb CO_2e/ft²

Comparison

Target EUI = 35 kBTU/ft²

Actual building EUI = 43.27 kBTU/ft² **DOES NOT MEET! Reduction needed: 8.27 kBTU/ft²**

Target GHGI = 9.3 lb CO_2e/ft²

Actual building GHGI = 10.79 CO_2e/ft² **DOES NOT MEET! Reduction needed: 1.49 lb CO_2e/ft²**

Since the targets were not met, an Energy Audit with Decarbonization Assessment must be conducted.

Below is a list of ECMs and ERMs identified.

Number	ECM/ERM	Electricity Savings (kWh)	Propane Savings (gallons)	EUI Impact	GHGI Impact
1	Select lighting retrofit	175,000	-1,800	2.16	1.07
2	AHU control upgrade with DCV	200,000	3,000	4.79	1.54
3	Air-cooled chiller replacement in kind	50,000	0	0.85	0.34
4	Air-cooled chiller upgrade to air-to-water heat pump	-355,000	40,000	12.26	0.14

According to the capital management plan, the existing air-cooled chiller is 22 years old and in poor condition.
The building owner has two choices:

1. Replace the air-cooled chiller with a new slightly more efficient model or,
2. Change the air-cooled chiller out for an air to water heat pump.

As shown in the table above, there is slightly more carbon savings if the chiller were replaced in-kind. Unfortunately, the building EUI target cannot be met with the savings identified unless the chiller is changed to an air to water heat pump. Fortunately for the building owner, the building has existing condensing propane boilers and coils that are sized for 120°F hot water supply temperature. Replacing the air-cooled chiller with an air to water heat pump will eliminate much of the propane usage. Since this is a cold climate, the AWHP will not be able to meet the hot water supply temperature for all hours of the year. The existing propane boilers shall remain in place for supplemental heat and as a backup for extreme weather events where the AWHP won't be able to operate. For more information on using air-to-water heat pumps see Trane application guides "Modular Air-to-Water Heat Pumps"(APP-APG021*-EN) and ACX Comprehensive Chiller-Heat System (SYS-APG003*-EN).

Example Compliance Path Management, continued

Number	ECM/ERM	Electricity Savings (kWh)	Propane Savings (gallons)	EUI Impact	GHGI Impact
1	Select lighting retrofit	175,000	-1,800	2.16	1.07
2	AHU control upgrade with DCV	200,000	3,000	4.79	1.54
3	Air-cooled chiller replacement in kind	50,000	0	0.85	0.34
4	Air-cooled chiller upgrade to air-to-water heat pump	-355,000	40,000	12.26	0.14

The building owner chooses to implement ECM/ERMs 1, 2, and 4.

The adjusted EUI and GHGI can be calculated:

Adjusted EUI = 43.27 kBTU/ft² – 2.16 kBTU/ft² – 4.79 kBTU/ft² – 12.26 kBTU/ft²

Adjusted EUI = 24.06 kBTU/ft²

Adjusted GHGI = 10.79 lbCO_2e/ft² – 1.07 lbCO_2e/ft² – 1.54 lbCO_2e/ft² – 0.14 lbCO_2e/ft²

Adjusted GHGI = 8.04 lbCO_2e/ft²

EEM/ERMs 1,2, and 4 shall now be implemented in the building. Energy consumption and emissions during and post construction will be monitored to verify that the building continues to meet the required targets. Documentation can be completed and submitted to the authority having jurisdiction.

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