Building Performance Standards

A Technical Resource Guide

ASHRAE

U.S. Department of Energy

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Acknowledgments

Building Performance Standards: A Technical Resource Guide is the first in a series of guides developed by ASHRAE's Task Force for Building Decarbonization (TFBD) aimed at addressing the challenge of decarbonizing the building stock. This guide provides in-depth background information on building performance standards (BPS) to assist policy makers and the practitioners that support them in developing a BPS policy that advances decarbonization and energy efficiency in existing buildings.

The book was initially envisioned and outlined by the 21 members of the TFBD Building Performance Standards Working Group, representing jurisdictions that were early adopters of BPS policies, building energy industry experts and BPS thought leaders, and the U.S. Department of Energy (DOE) and its national research laboratories. The co-chairs of this working group, Adam Hinge and Andrea Mengual, would especially like to thank the other primary authors of this book—working group members that dedicated countless hours to crafting, writing, and improving this guide, while incorporating feedback from other working group members along the way: Harry Bergmann, Amy Boyce, Kim Cheslak, Bing Liu, Paul Mathew, Travis Walter, and Yunyang Ye. We would also like to extend a special thank you to Bing Liu for her leadership during the initial stages of the working group and guide development and for her support of the guide when she transitioned to the TFBD Executive Committee (ExCom).

The working group met biweekly for nearly a year to get this guide to completion. We would like to thank the families of the working group members and authors, as their dedication to this project meant late nights and time away from family activities. In addition, we acknowledge support from the working group members' employers: AKF Engineers, American Council for an Energy-Efficient Economy, BC Hydro, Bentley Systems, DOE, Guttmann & Blaevoet, Institute for Market Transformation, Kaiser Permanente, Lawrence Berkeley National Laboratory, New Buildings Institute, New York City Department of Buildings, Oregon Department of Energy, Pacific Northwest National Laboratory, Schneider Electric, Sustainable Energy Partnerships, Taylor Engineers, University of Salerno, and Washington State Department of Commerce.

The working group's efforts were guided by the TFBD ExCom under the leadership of ASHRAE Fellow Kent Peterson and the operational guidance of Blake Ellis, TFBD Operational Subcommittee chair. The TFBD provided the support needed to accelerate the time frame for publication of this guide, and ASHRAE staff members Cindy Michaels and Stephanie Reiniche were instrumental in executing that vision. As a highlight of the importance of BPS as policy tools for building decarbonization, the TFBD also helped secure a commitment that the guide would be free and accessible to all.

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In addition to the working group members, authors, and ASHRAE staff that made this book possible, several individuals played key roles in the guide's success. Among the working group members, Glenn Friedman, Dave Ribeiro, and Travis English provided especially helpful input to the authors. Significant thanks go to the peer reviewers that dedicated their personal time to thoroughly reviewing 75% and 90% drafts of the guide and for their feedback, which resulted in a much stronger and more valuable document than would have resulted otherwise. We would like to acknowledge and thank the 75% reviewers—Travis English, Glenn Friedman, Brendan Hall, Katy Hatcher, Cindy Jacobs, Sharon Jaye, Jamie Kono, Danielle Krauel, Toby Lau, Travis McDaniel, Erin McConahey, Steve Nadel, David Ribeiro, Lindsay Robbins, Danielle Spiegel-Feld, Amber Wood, Katrina Wyman, and Michael Zatz—and the 90% reviewers—Barry Abramson, Randall Higa, Brad Hill, Sharon Jaye, Ben Johnson, Chris Lee, Luke Leung, Victor Nino, Stephanie Reiniche, Peter Simmonds, Dominique Taudin, Thomas Yeh, and Bill Wang—for their contributions. A very special thank you goes to Amanda Webb, who provided extremely thorough and helpful reviews at both the 75% and 90% review stages. We are also grateful to Dan Kohan of Sensical Design for preparation of many of the figures in this guide.

We thank all who provided their experience, insights, and time in the development of this guide, though any errors are the responsibility of the authors.

We hope that this book provides inspiration and much-needed background to anyone interested in understanding and implementing BPS in their jurisdiction. It was created to equip readers with the information they may need during the development of a BPS policy to help them make informed policy design decisions that drive deeper existing-building decarbonization and provide equitable outcomes for all involved. At a time when we must use every avenue available to us to decarbonize our world, we believe BPS policies are one of the most powerful tools in our toolbox, and one that stands to have the highest impact.

Adam Hinge and Andrea Mengual
Building Performance Standards Working Group Co-chairs
December 2022

Abbreviations and Acronyms

BEPS	building energy performance standard
BPS	building performance standards
CBECS	Commercial Buildings Energy Consumption Survey
CO_2e	carbon dioxide equivalent
DOE	U.S. Department of Energy
ECM	energy conservation measure
eGRID	Emissions & Generation Resource Integrated Database
EPA	U.S. Environmental Protection Agency
ESPM	ENERGY STAR® Portfolio Manager®
EUI	energy use intensity
GHG	greenhouse gas
GHGI	GHG intensity
HVAC	heating, ventilating, and air conditioning
LBNL	Lawrence Berkeley National Laboratory
LEED	Leadership in Energy and Environmental Design®
N/A	not applicable
PNNL	Pacific Northwest National Laboratory
REC	renewable energy credit
RECS	Residential Energy Consumption Survey
TFBD	Task Force for Building Decarbonization

1

Introduction

1.1 What Are Building Performance Standards?

Building performance standards (BPS) are an emerging and increasingly important policy tool for jurisdictions looking to reduce the operational greenhouse gas (GHG) emissions of their built environment to meet their climate commitments. Unlike construction and energy codes, which only affect buildings at distinct events in their life cycle, such as new construction or major renovation, BPS aim to regulate and reduce the climate impact of existing buildings by establishing increasingly stringent targets that require buildings to improve performance throughout their lifetimes.

The decarbonization of the building sector, particularly as it concerns operational carbon emissions, is a primary policy driver of BPS adoption by jurisdictions in the United States. The pathway to building decarbonization involves many elements of building design and construction, operation, and occupancy. Building performance standards can contribute to decarbonization by regulating building operational performance and by actively seeking alignment with other policies in the jurisdiction, such as construction codes and policies encouraging decarbonization of the electrical grid. BPS are inherently flexible policies that jurisdictions can tailor to meet their overall policy goals, whether that is climate action, building sector energy reduction, or electrification—as well as related goals such as increasing energy affordability.

There are four key components of a BPS policy: 1) the scope of the policy in terms of the buildings that it covers, 2) the metrics used to measure performance, 3) the associated performance targets, and 4) the compliance time frame and implementation mechanisms. The first step in establishing a BPS policy is identifying the jurisdiction's goals and policy drivers motivating its implementation. This process will help policy makers understand the desired outcomes of the BPS and help inform the selection of metrics, stringency of the performance targets, compliance time frames, and desired impact on the building stock.

Throughout the BPS development process, it is critical that policy makers engage members of the real estate, design, and construction industries, as well as utilities and state and local government officials representing sustainability and regulatory departments. The process must include community-based organizations that represent their communities, particularly historically disinvested or under-resourced communities, to ensure they have a voice and can understand how BPS may affect building occupants. Community-based organizations can facilitate engagement with residents from disinvested communities, allowing for direct dialogue with decision makers and program designers. Resident engagement provides a better understanding of the needs of the community and the building occupants and tenants and better equips programs to tackle the challenges of energy efficiency upgrades in affordable housing.

1.2 Building Performance Standards Adoption

Although adoption of BPS is not limited to North America—as of the writing of this guide, jurisdictions that have adopted BPS include countries like the United Kingdom, The Netherlands, Scotland, and France and cities like Tokyo (IEA 2021)—this section provides a deeper dive into the BPS policies adopted to date in North America.

BPS adoption and implementation in the United States is happening at the local, state, and federal government levels, resulting in a broad range of approaches that are targeted to each jurisdiction's specific policy needs. As of December 2022, BPS policies were fully approved and adopted as local ordinances or laws in eight U.S. cities, one county, and three states, as well as at the federal level through the Federal Building Performance Standard (The White House 2022a), which applies to certain federally owned facilities. BPS policies were also being considered for implementation in more than 20 additional jurisdictions as part of the National Building Performance Standards Coalition (The White House 2022b). The map in Figure 1.1 shows where BPS have been adopted or are being considered for adoption as part of the National BPS Coalition and whether an energy- or emissions-based metric was adopted.

The existing BPS policies in North America are driven by each jurisdiction's objectives for emissions and energy goals for the building sector as well as affordability and health considerations. The policies vary in the metrics, scope (building types and sizes), compliance pathways, and compliance periods they use. Of the jurisdictions that have adopted BPS in the United States, only New York City and Boston have used a carbon-based metric instead of a site energy or source energy based metric. In the case of the BPS adopted by the City of Vancouver, Canada, the policy initially sets emissions targets for covered buildings and will eventually be expanded to include energy use targets (City of Vancouver 2022). Some of these policies require compliance starting in 2023, while others do not go into effect until 2030. Table 1.1 compares the BPS policies adopted in North America at the time of publication of this guide.

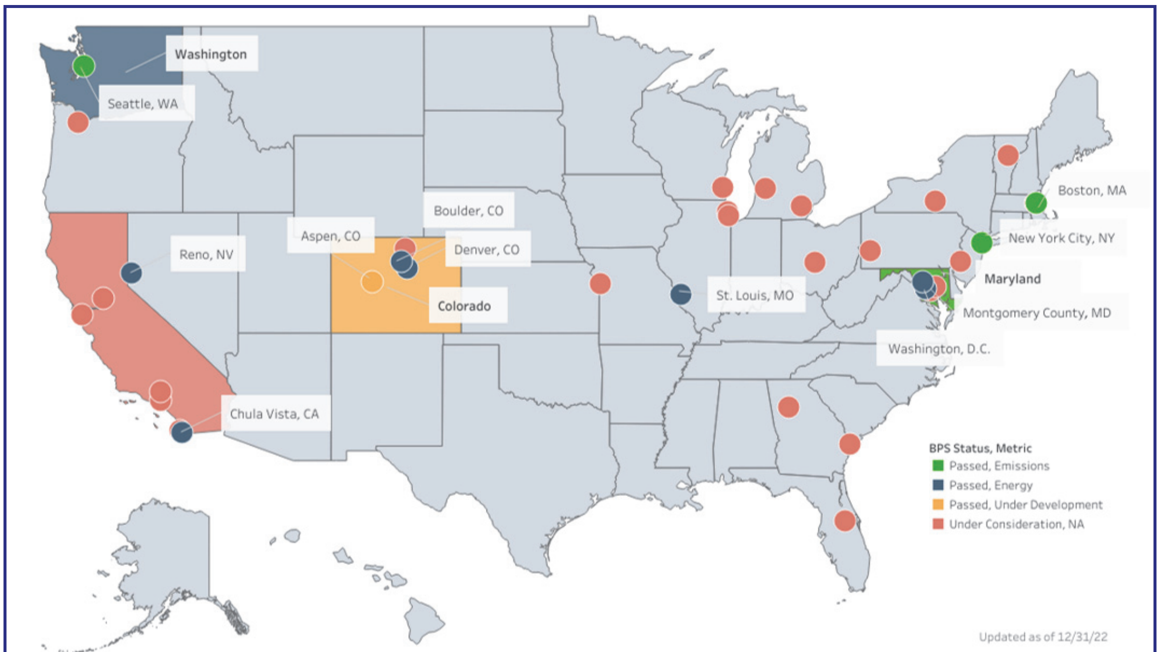

Figure 1.1 **Map of BPS adoption status across the U.S. as of December 2022. Only programs that are in place are labeled. (Image credit: PNNL 2022)**

Table 1.1 Comparison of BPS in North America

Jurisdiction[a]	Building Type Scope	Initial Compliance Period	Performance Metric(s)
Boston, Massachusetts, USA	Municipal buildings of any size Commercial buildings ≥20,000 ft^2 Multifamily buildings ≥20,000 ft^2 or 15 units	2025 for buildings ≥35,000 ft^2 [b]	Carbon dioxide equivalent (CO_2e) GHG intensity (GHGI)
Chula Vista, California, USA	Municipal, commercial, institutional, and multifamily buildings ≥20,000 ft^2	2023 for buildings ≥50,000 ft^2 [b]	Site energy use intensity (EUI) reduction target (%) or ENERGY STAR score
Denver, Colorado, USA	All commercial and multifamily buildings ≥25,000 ft^2	2024 for buildings ≥25,000 ft^2	Site EUI[c]
Montgomery County, Maryland, USA	Public, commercial, institutional, and multifamily buildings ≥50,000 ft^2 initially, decreasing to ≥25,000 ft^2 over time	2024 for public buildings ≥50,000ft^2 [d]	Site EUI
New York, New York, USA	All commercial and multifamily buildings ≥25,000 ft^2	2024	CO_2e GHGI
Reno, Nevada, USA	Municipal buildings ≥10,000 ft^2 Commercial and multifamily buildings ≥100,000 ft^2 initially, decreasing to 30,000 ft^2 over time	2026	ENERGY STAR score or site EUI
St. Louis, Missouri, USA	Municipal, institutional, commercial, and multifamily buildings ≥50,000 ft^2	2025	Site EUI
State of Colorado, USA	Public, institutional, commercial, and multifamily buildings ≥50,000 ft^2	2026	Under development
State of Maryland, USA	Public, institutional, commercial, and multifamily buildings ≥35,000 ft^2	2030	On-site GHG emissions[e]
Vancouver, British Columbia, Canada	Commercial buildings ≥100,000 ft^2	2026	CO_2e GHGI and heating (space and hot water) energy intensity
State of Washington, USA	Commercial buildings ≥50,000 ft^2 [f]	2026	Site EUI
Washington, District of Columbia (D.C.), USA	Municipal buildings ≥10,000 ft^2 Commercial and multifamily buildings ≥50,000 ft^2 initially, decreasing to 10,000 ft^2 over time	2026	ENERGY STAR score or source EUI

[a] See Section 1.5.1 for links to more details on these BPS policies.
[b] Building size threshold for compliance decreases in future compliance periods.
[c] Also includes an electrification requirement for space- and water-heating equipment.
[d] Compliance for different building types and sizes is phased over time.
[e] At the time of writing this guide, the state was still defining its BPS metrics.
[f] Multifamily and commercial buildings ≥20,000 will be covered starting in 2031.

The coverage of building performance standards across the United States stands to be significantly expanded by the efforts of the federal government and the National BPS Coalition; the combined footprint covered by the adopted and proposed BPS policies as of the time of publication of this guide represent one quarter of all commercial, federal, and multifamily buildings in the country (The White House 2022a). Participating partners of the coalition have committed to advancing legislation or regulation in their jurisdictions by Earth Day (in April) in 2024. Their participation includes developing policy road maps, identifying and acting on prerequisites for BPS and complementary policies, and sharing results and experiences to forge a community of practice and co-create policy.

1.3 Purpose and Content of this Guide

ASHRAE has developed this resource guide to provide a technical basis for policy makers, building owners, and other stakeholders interested in developing and implementing BPS. This guide focuses on North America, where BPS are already in place in several states and cities.

1.3.1 BPS Terminology

BPS adopted in the United States have been developed independently by each jurisdiction, resulting in a broad range of definitions of BPS and BPS-related terminology that may generate confusion for policy makers. For the purpose of this guide, BPS-related terms are explicitly defined as follows:

emissions conversion factor: A factor that can be used to convert a unit of energy into a unit of GHG emissions, where GHG emissions are typically expressed in mass units of CO_2e.

normalization: Used in the context of metrics and performance targets and measured building performance. *Metric normalization* refers to the process of adjusting metrics to a common scale or unit, such as building floor area. *Performance target normalization* refers to the process of adjusting the performance targets for a building based on specific factors that may influence its performance, such as weather, occupancy, and high-energy applications, among others.

performance target: The specific level of performance or performance threshold that buildings are expected to meet as part of the BPS. Used interchangeably with *target*.

policy makers: Representatives of the jurisdiction's governing body that develop and adopt the BPS; may include legislators, building department staff, council members, and others, depending on the jurisdiction.

policy scope: The buildings covered by the standard, i.e., buildings that are required to meet a performance target.

Scope 1 and Scope 2 emissions: In the context of emissions reporting, the scope of emissions is defined in terms of whether the reporting entity owns and controls the asset producing the emissions. Scope 1 emissions are direct GHG emissions resulting from fuel combustion from sources owned by the reporting entity (typically building owners in the case of BPS). Examples of Scope 1 emissions include those associated with combustion in boilers, furnaces, and similar equipment. Scope 2 emissions are indirect GHG emissions associated with the purchase of useful energy (electricity, steam, heating, cooling) that is used at the reporting entity's site but is not generated by assets controlled by the reporting entity. Scope 2 emissions are the result of energy use and are typically accounted for by the entity using the energy, not the entity generating it (EPA 2022). BPS emissions reporting is generally defined as emissions from operational energy use but does not include fugitive refrigerant leakage that is part of Scopes 1 and 2 in some international standards.

standard: Refers to the BPS policy, covering metrics, targets, compliance, etc., and not a specific performance level.

1.3.2 What's in This Guide

This guide is organized as follows:

- Chapter 2, "BPS Metrics," explains the variety of options for BPS metrics and some of the key issues in metric selection, including strengths, limitations, and implications around different metrics, along with an accompanying high-level overview of other related metrics.
- Chapter 3, "Establishing Performance Targets," provides a high-level description of the various approaches for setting BPS performance targets, including the applicability, data requirements, development process, and strengths and limitations of each approach. In addition, it provides considerations for target setting.
- Chapter 4, "Major Policy Considerations," outlines major considerations for policy makers when developing and adopting BPS. Key considerations include establishing pathways for buildings to achieve policy objectives, compliance alternatives, and alignment between BPS and energy codes.
- Chapter 5, "Analysis Methods for BPS Policy Design," provides methods for analyzing and understanding the influence of policy scope, metric selection, target setting, and other policy questions on BPS and understanding their influence on the policy. This chapter is primarily intended for technical stakeholders who are conducting the data analysis.

1.3.3 What's Not Covered in This Guide

This guide is the first in a series being prepared by ASHRAE's Task Force for Building Decarbonization (TFBD). The topics of these guides include building decarbonization, viewed from both the site energy and life-cycle perspectives; heat pump application, design, and operation in buildings; hospital decarbonization; and grid-interactive buildings for decarbonization. As a result, these topics are not covered in this BPS guide.

Because BPS focus primarily on a building's energy-consuming operations, the discussion of carbon emissions (generally expressed as CO_2e) in this guide is focused on operational carbon and excludes embodied carbon considerations such as construction or material end-of-life emissions. The forthcoming TFBD book *Whole-Life Carbon Guide for Building Systems* addresses embodied energy and carbon.

This BPS guide does not provide in-depth discussions of BPS policy implementation, tools for implementing different compliance approaches, or financing mechanisms that may be necessary to improve building performance.

1.4 Equitable Outcomes

This guide presents issues that are typically considered by a jurisdiction when developing a BPS policy to reduce energy use or carbon emissions of existing buildings. Many jurisdictions pursuing these policies will also aim to achieve other related goals through BPS, including those related to equity, health, water, and resilience, among others. Local governments in particular see their energy and climate policies as tools to advance a variety of priorities, such as economic development and pollution reduction. Policy makers in most jurisdictions considering BPS will take into account the ways in which BPS can achieve equitable outcomes through the policy's design and implementation. In doing so, most will aim to engage disinvested communities, try to ensure the design does not exacerbate inequities, and work to ensure resulting energy efficiency investments accrue to all community members.

To ensure widespread adoption of the BPS, jurisdictions developing a BPS policy should contemplate providing resources or programs to support building owners and operators with compliance; jurisdictions should also think about developing different compliance paths. This support can come in the form of companion policies or programs that provide financial support for certain building types, such as affordable multifamily housing, or in the form of technical resources and training that help reduce the burden on organizations trying to implement the standard. One example of the implementation of this type of companion program is the Washington, D.C., Affordable Housing Retrofit Accelerator, which was launched along with the enactment of the district's building energy performance standard (BEPS). This program was designed to provide direct technical and financial assistance to occupants of multifamily affordable-housing buildings in Washington, D.C., who typically face financial and capacity challenges to upgrade their buildings, so that they can meet the requirements of the BEPS. Services provided by the Accelerator program include energy audits, one-on-one guidance on how to comply with the BEPS program, and financial assistance for implementing upgrades (DCSEU 2022). Jurisdictions considering BPS are encouraged to evaluate how use of similar policies could enhance the BPS outcomes.

More information about equity considerations in affordability is addressed in Section 4.7 of Chapter 4.

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2

BPS Metrics

For any performance standard, selecting the metric by which compliance will be measured is a critical step. All other choices for developing BPS will be directly related to and follow the metric(s) chosen to measure performance.

Given that many jurisdictions are looking at BPS to help achieve carbon emissions reductions and building decarbonization goals, metrics and their associated targets should lead toward the end goal of decarbonization along with other important policy goals in the jurisdiction, such as prioritizing energy efficiency to help reduce energy bills. Because BPS focus primarily on a building's energy-consuming operations, the regulation of carbon emissions, generally expressed as carbon dioxide equivalent, or CO_2e, would be primarily measured based on operational carbon and exclude embodied carbon in building materials. Over time, as embodied carbon is better understood and categorized, this may change.

This chapter explains the variety of potential BPS metrics; the key issues in metric selection, including strengths, limitations, and implications around different metrics; and potential equity considerations. It also provides a high-level overview of other related metrics. This chapter is geared toward jurisdictions and policy makers considering or designing a BPS policy, as well as standards and codes developers, building owners, engineers, designers, and other stakeholders seeking to understand how different BPS have been established in North America.

2.1 Introduction to Metrics

2.1.1 Aligning Metrics with BPS Goals

BPS policies support multiple objectives depending on each jurisdiction's needs. These objectives include 1) increased energy efficiency or reduction in overall energy use; 2) decarbonization or electrification of building loads; 3) economic and equity goals, such as increases in green jobs, reduced bills for affordable housing, and improved indoor environmental health; and/or 4) increasing renewable energy generation to displace and replace fossil fuel consumption. These supporting objectives will result in carbon reductions to help meet local, national, and international climate goals.

The selection of the metric should be reasonably aligned with the end goals of the jurisdiction's adopted BPS. This alignment may be more complicated than selecting a carbon (greenhouse gas emissions) metric to achieve a decarbonization goal due to other factors such as ease of compliance and enforcement or variations in the grid's carbon intensity. As buildings decarbonize, often replacing fossil fuel energy use with electric systems, there are electric grid considerations in terms of the energy coming into the building and the grid's transmission, distribution, and generation needs. BPS need to recognize this interactivity. This chapter presents a number of potential grid integration metrics for jurisdictions to consider when developing BPS. The forthcoming ASHRAE TFBD book *Grid-Interactive Buildings for Decarbonization: Design and Operation Resource Guide* addresses this topic.

To align with long-term goals, individual building-level metrics need to be considered directly alongside projections for grid emissions and renewable energy production to account for actions that are within and outside of the building owner's control to achieve the goals and targets.

2.1.2 Metric Basics

A metric is a quantifiable measure used to track progress on an attribute—a measure of performance, in the case of BPS. A metric is often derived from one or more measures, usually multiple factors expressed as a fraction or ratio with a numerator and a denominator. As explained in Section 2.3.1.1, when site EUI is the metric, site energy usage (generally expressed as the sum of all energy sources consumed in the building for a year) is the numerator, and the denominator is the building's floor area.

The numerators of metrics attract the most attention because they are the primary metric for the policy. The numerator is used to gauge progress toward the final goal of energy or carbon reduction. For example, the numerator might be energy use or carbon emissions, each of which comes in multiple forms. More details on numerators are provided in this section for the metrics currently in use in BPS.

The denominator is most regularly floor area, but other measures might be used, such as occupancy (Selvacanabady and Judd 2017). Denominators are normalization factors that help adjust the metric to a common scale and help level the field for buildings with different characteristics. Most policies in place today use the common denominators of floor area and year; the exception is the ENERGY STAR® score, which normalizes a variety of factors into a simple score between 1 and 100 (EPA 2021b). In addition to including a denominator to adjust the metric to a common scale, the performance target for each metric could be further normalized to account for specific factors such as weather and building characteristics that may influence performance. Section 3.3 in Chapter 3 provides more detail on normalization. To provide a better understanding of the two most commonly used denominators, their definitions and some explanations are provided in the following subsection.

Table 2.1 shows key attributes for the metrics described in this chapter, jurisdictions where the metrics are used in current BPS, and other policies where the metrics are in use in North America.

2.1.2.1 Denominator: Floor Area

Floor area is the gross square footage of the building. The definition of floor area is not consistently used across standards and policies. Many jurisdictions with BPS reference the ENERGY STAR® Portfolio Manager® (ESPM) definition of conditioned floor area (EPA 2021b), though standards such as ANSI/ASHRAE/IES Standards 90.1 and 100 and ANSI/ASHRAE Standard 105 (ASHRAE 2022, 2018, 2021) use other definitions, including gross square footage, as included here. Where a jurisdiction is adopting standards that define floor area differently, alignment across those definitions is important for implementation of BPS. Normalizing by floor area creates a more level comparison among buildings of different sizes.

2.1.2.2 Denominator: Annual Period

Annual period is a twelve-month interval or single year—for BPS most commonly a calendar year. Annual accounting provides an additional normalizing factor in building performance. Given fluctuations in energy use based on building use and scheduling on a weekly basis, seasonal

Table 2.1 Key Attributes of Metrics for BPS

Category	Metric	Units (Numerator and Denominator)	Where Used
Metrics Currently in Use			
Energy	Site energy use intensity (EUI)	kBtu/ft^2/year	St. Louis, MO, USA Washington State, USA Denver, CO, USA ASHRAE/IES Standard 100 (ASHRAE 2018) State of Colorado, USA Montgomery County, MD, USA
	ENERGY STAR score	Normalized 1 to 100 score, based on statistical regression analysis of source energy use per ft^2/year	Washington, D.C., USA Chula Vista, CA, USA
Carbon	Greenhouse gas intensity (GHGI)	CO_2e/ft^2/year	New York, NY, USA Boston, MA, USA ASHRAE/IES Standard 90.1 (ASHRAE 2022) Vancouver, BC, Canada
Other Potential Metrics			
Energy	Energy cost	$	ASHRAE/IES Standard 90.1 *International Energy Conservation Code* (ICC 2021a) *International Green Construction Code* (ICC 2021b)
	Source EUI	kBtu/ft^2/year	ASHRAE/IES Standard 100 *International Green Construction Code* (ICC 2021b)
	Electrification ratio	Unitless calculation (electricity site energy / total site energy)	ESPM (as *percent site electricity*)
Grid integration	Grid peak contribution	kW/ft^2	Leadership in Energy and Environmental Design® (LEED®) Green Building Rating System (USGBC 2022)
	On-site renewable energy utilization	Unitless calculation (exported kW / generation kW)	ASHRAE/IES Standard 100 LEED
	Grid carbon impact	Unitless calculation	LEED
	Demand flexibility	Unitless calculation (energy shed kW / reference demand kW)	LEED

fluctuations, and changes in weather patterns, annual energy accounting accommodates fluctuations across a given year. Where carbon is a consideration, annualizing energy use reduces the metric's relationship to fluctuations of carbon intensity of the grid.

Annual data are the simplest to gather and provide, eliminating reporting barriers such as the need for more complex energy monitoring or calculations to translate utility bill data. If factors such as changes in weather are not accounted for in annual normalization or through another method, the data provide less insight into changes in energy consumption, since weather is outside the control of the building occupants and owner and may result in higher energy use in a very hot or very cold year.

2.1.3 Relationship to Other Policies

Every jurisdiction instituting a BPS policy has minimum building energy codes that regulate construction and renovation in its building stock. Many jurisdictions also have benchmarking and disclosure ordinances in place, as well as audit, retrocommissioning, and/or building labeling laws that affect existing buildings. During metrics selection, it is important to review the multiple ways in which a building is being asked to comply with other policies across the jurisdiction and determine where it makes sense for metrics to align. Equitable design in policy development requires that the metrics selected do not have negative unintended consequences nor that the metrics become highly complex in their reporting or application. Where metrics or reporting structures can align with other policies, BPS can be simpler—and it can be better for smaller building or portfolio owners that may not have the same staff resources as larger owners to track compliance across multiple metrics and reporting cycles.

Jurisdictions contemplating the potential impact of BPS should also examine the relationship of the BPS to their utilities. Those seeking metrics to drive multiple sectors of decarbonization across buildings and utilities will need to engage specifically and directly with utilities providing fuels and electricity to their buildings to understand the impact of those metrics on owners and energy providers and to determine if a BPS policy is the best policy to drive the change. Work to reduce energy poverty, increase resilience, and provide critical services can be addressed by BPS being carefully partnered with other policies.

More resources on benchmarking, disclosure, and other policies related to building performance are available, with some of the most relevant listed in Section 2.5 (see in particular EPA 2021a, ACCC 2021, and Spiegel-Feld and Wyman 2022). Section 4.6 of Chapter 4 provides more detail on the relationship between BPS and energy codes.

2.2 Key Considerations for Metric Selection

One of the first things to look at when selecting the metrics is what the building owner can control. The number one item under the control of building owners, and the performance that they can directly improve, is the energy consumption in the building. While energy consumption results in carbon emissions, the carbon emissions from electricity or some other energy carriers (district energy, heating, or cooling) can be outside the control of building owners and therefore difficult for them to manage and control under a standard. Electricity (and district energy) can be generated from a variety of different fuel sources, some very clean (wind, solar, or hydro) and some from fossil fuels that have a significantly higher carbon intensity (coal, oil, or gas). While a building owner may make voluntary purchases of renewable energy credits (RECs), those credits may not actually reduce local emissions as intended by a BPS policy.

The reporting and accuracy of all metrics can be more complicated in areas with a high amount of delivered fuels such as fuel oil or propane. While the tracking of when the fuel was purchased is a relatively easy exercise, determining when those fuels are consumed or used on site is more complicated. In many jurisdictions with benchmarking laws, delivered fuels go under- or unreported.

Verification methods to understand typical base heating and water-heating loads may be necessary to properly enforce site-energy reporting in those jurisdictions. Older buildings (as well as rural buildings) are more likely to continue to use delivered fuels, since these systems are costly to replace. Considerations for reporting and verification of these fuels should take into account equitable policy application for these buildings and owners.

While this chapter discusses details about metrics issues with electricity grid and generation mix, many of those issues are also relevant to district thermal energy systems. District systems vary widely throughout North America, both in the breadth of users connected and the types of thermal energy delivered (e.g., hot water, either low or high pressure; steam; or chilled water), though district systems deserve attention in decisions about a BPS metric. Where jurisdictions have buildings connected to district energy systems, additional considerations such as the building site boundary, conversion factors, and specific rulemaking need to be considered (IMT 2021).

Using Multiple Metrics in One Jurisdiction

Jurisdictions may elect to use multiple metrics. There are two primary ways this can occur in BPS:

- Each building is subject to a single metric, but different metrics are applied by building type or size for a reason identified by the jurisdiction or a limitation of the primary selected metric.
  - Example: The Washington, DC, BPS metric is the ENERGY STAR score, though for building types where an ENERGY STAR score is not available, the equivalent metric is weather-normalized source EUI. Buildings that do not meet the standard have five years to reduce their energy use by 20%, as measured in weather-normalized site EUI.
- Each building is subject to multiple metrics because the selection of a single metric was identified as unable to achieve the specific goals outlined by the jurisdiction.
  - Example: Denver is seeking to reduce energy consumption and drive electrification. Both site EUI and electrification ratio are being considered to simultaneously signal the need for both.

An electrification metric ignores any potential operational cost increases in switching from gas to electric equipment. In many areas of the country, gas remains cheaper than electricity, so an electrification driver may create higher utility bills in the near term, raising energy affordability and equity concerns. Many buildings subject to BPS will have larger central-heating and water-heating systems, which can be more difficult to electrify. While central heat pump system technology is advancing so that it may be easier to convert central systems and while utility rate structures are changing to have less cost impact on all-electric customers, the application of electrification as a metric should consider technology and cost impacts depending on building stock and climate zone.

Selecting a metric must balance the energy or carbon impact with the ease of enforcement and compliance across the jurisdiction. No metric is perfect when looking at all of these criteria, and it may be that a combination of metrics serves jurisdiction goals better than a single metric. Data gathered from early adopters of BPS indicate that they may change metrics in the future, suggesting that metrics can evolve over time to meet changing needs. Switching metrics is complicated, may cause market confusion, and may not reward previously taken actions that were beneficial under the original metric.

2.3 Potential Energy and Carbon Metrics

There are many metrics that could define "building performance," though for the purpose of BPS the metric is generally focused on reducing energy consumption or building-energy-related emissions. Metrics currently used in BPS focus on direct energy and carbon reductions; these metrics on their own can advance a jurisdiction toward its building sector goals. There are additional potential metrics that focus on carbon and energy impacts through electrification and grid integration that could be used alongside energy or carbon metrics. While a jurisdiction could use an electrification or grid integration metric on its own, these metrics are not in use by any current BPS policy and may not be applicable broadly today.

2.3.1 Metrics Used in Existing BPS

Jurisdictions with BPS have adopted metrics that measure a building's energy consumption or carbon emissions. Energy metrics as a general rule establish a maximum energy use per floor area (the EUI), which is usually under the direct control of the building owner and occupants. Of all potential metrics, energy is the one that building owners and operators can most directly influence without needing to take into account other factors outside their control. Also, energy use information is generally readily available through benchmarking data and energy bills. Energy metrics can be presented as "site" energy or "source" energy. Site energy measures the actual energy consumed on the building site, measured by the building electric, gas, and other energy type meters, while source energy includes all production and delivery losses that are required to produce the energy that is delivered to the building.

On the other hand, where the focus is on using the policy as a tool to reduce greenhouse gas (GHG) emissions, a carbon-based metric is the most direct measurement of progress toward reducing building-sector emissions. Carbon metrics calculate a building's emissions based on its energy use, type of energy (electricity or fossil fuels), and source of electricity (grid or renewables).

The common metrics used in existing BPS are explained in the following subsections, along with the effect of choosing each in meeting the carbon goals of a jurisdiction. Some of the information in these explanations is adapted from the U.S. Environmental Protection Agency (EPA) guide *Understanding and Choosing Metrics for Building Performance Standards* (EPA 2022b).

2.3.1.1 Site Energy Use Intensity (EUI)

Site EUI is the site energy divided by the gross square footage of the building. In cases where the policy accounts for on-site renewable energy, this metric may be referred to as *net site energy*, the site energy consumed minus the energy generated, divided by the gross square footage of the building.

2.3.1.1.1 Numerator: Site Energy

Site energy is the amount of total energy consumed by a building. Site energy may be delivered to a facility in one of two forms: 1) primary energy, or the raw fuel burned on site to create heat and electricity (e.g., natural gas or fuel oil); or 2) secondary energy, or the energy product created from a raw fuel, such as electricity purchased from the grid or heat received from a district steam system. Site energy as a metric combines units of primary energy and units of secondary energy consumed at the site and therefore does not account for losses in generation and transmission/distribution of the secondary energy.

2.3.1.1.2 Impacts, Implications, and Considerations

Site energy is the most familiar form of energy consumption for building stakeholders and best reflects what owners can directly control and are responsible for, increasing the ability of the building owner and operator to control the outcome of the energy savings. Site EUI is a direct indication of energy efficiency that is easy to obtain and requires no interpretation: it is directly available from utility bills. Additionally, site energy can be a signal for efficient electrification since heat pumps and electric systems tend to have higher equipment efficiency than fossil-fuel systems and may indirectly assist with grid decarbonization by reducing overall building loads.

While site energy may be relatively easy to measure, understand, and control, it is not a direct measurement of GHG emissions. Site EUI lets owners and operators ignore the methods of energy production in their region and may not drive sector-wide decarbonization.

There are wide variations across the U.S. for the GHG emission rates in energy production, as shown in Figure 2.1 for different regions, as measured through the EPA Emissions & Generation Resource Integrated Database (eGRID) data explorer (EPA 2022a).

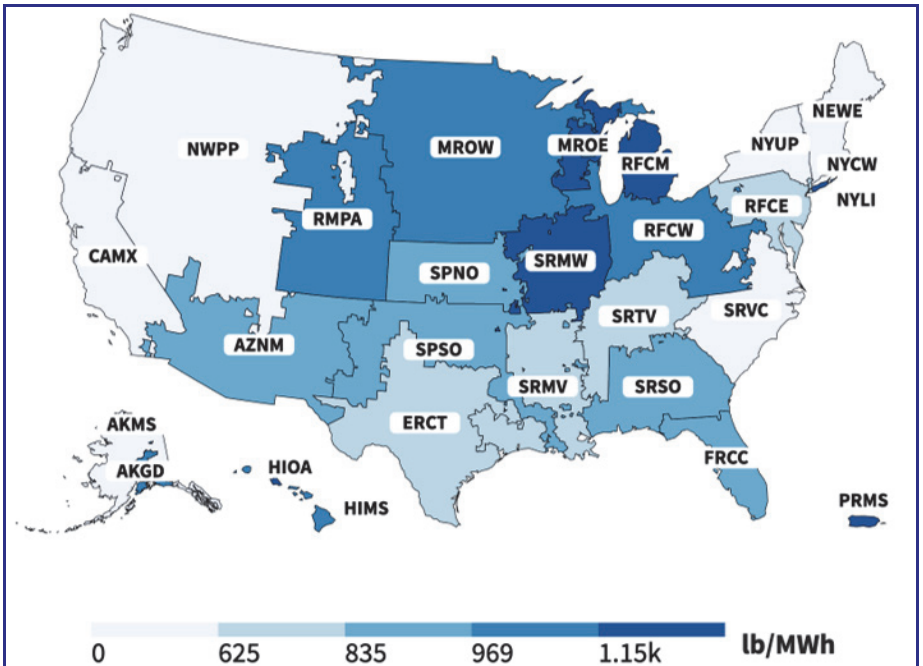

Figure 2.1 CO_2 total output emission rate by eGRID subregion, 2020. (Image credit: EPA 2022a)

Where a net metric is used, reviewing site EUI at the building scale on an annual basis may appear to be driving grid decarbonization, but on a time-of-use basis and at a utility scale this may result in increased carbon emissions due to the need for and use of peaker plants to meet peak demands that often occur when on-site renewable generation lessens.

Site energy can additionally become more complicated if jurisdictions look at using a net site energy metric, because the calculation will by definition need to account for on-site generation. The use of a net metric may obscure the efficiency of the building, which is critical to achieving overall carbon goals. In fact, it can result in inefficient buildings complying with the BPS due to a high amount of renewable generation, especially where off-site procurement is included in the net energy calculation. It may also result in significant inequity in the policy, as not all building owners have the same ability to install new renewable energy systems.

2.3.1.2 ENERGY STAR Score

ENERGY STAR score is a standard for evaluating the performance of commercial buildings (EPA 2021b). The U.S. Environmental Protection Agency ENERGY STAR score is a 1–100 scale-based ranking based on a statistical analysis of national, representative data sets of whole-building energy use and operational characteristics.

2.3.1.2.1 Relative Performance and Regression Analysis

Unlike the other metrics used in existing BPS, ENERGY STAR score does not fit the simple numerator/denominator framework. Instead, it uses multiple data points for calculation. It is based on a source EUI per square foot per year metric, normalized to a simplified 1–100 score based on regression formulas developed for the ENERGY STAR program.

2.3.1.2.2 Impacts, Implications, and Considerations

ENERGY STAR score is a way to evaluate the energy performance of one building against that of another (EPA 2021b). A building score lets the owner know where that building stands in comparison to similar buildings across the United States. For example, a score of 65 means the building is outperforming 65% of its peers. ENERGY STAR score is not available for all building types, but has been updated to cover more types over time and as additional data are available to set the scores. Building owners use ENERGY STAR score because the system has made it easy for them to compare buildings within their own portfolio or region and to quantify the impact of improvements.

ENERGY STAR score assesses how a building is performing as a whole, considering operational conditions required for the activities within the building, including its physical attributes, its operations, and how the occupants use it. The score normalizes for operational characteristics unique to different building types, such as hours of operation (different energy needs for a 40-hour-per-week operation versus one open 24/7), density of workers, presence of commercial refrigeration equipment, etc. The score also uses information about the building that owners or operators enter into the ENERGY STAR® Portfolio Manager® (ESPM) to compare the actual energy use to similar buildings. Calculations use source energy conversions, are weather normalized, and account for key building details. Using ENERGY STAR score as the metric allows for built-in normalization of raw EUI for a variety of factors that ENERGY STAR has determined to be the most important to distinguishing relative energy efficiency.

While ENERGY STAR score is based on source EUI, it uses national factors for electric and district energy grid mixes. Where local factors for these two energy sources differ significantly from the national average, the use of ENERGY STAR score may not drive the desired carbon reduction. Built into ENERGY STAR score are a variety of normalization factors, including floor area, occupant density, occupancy schedule, number of units, and number of bedrooms (depending on building type). Because the score compares a building to its peers, it does not represent a fixed threshold of a high-performance building in absolute terms. Where any given occupancy type is slow to change, over time the score may be relatively flat.

Because ENERGY STAR score is based on source energy, site-to-source conversion factors are updated periodically. The regression models used to calculate the scores are also updated when new data become available, typically every 5 to 10 years. As a result, a building's score can change when these factors and models are updated, which can present challenges in setting long-term goals.

Finally, ENERGY STAR score is not available for every building type. For jurisdictions with large cohorts of buildings not covered by an ENERGY STAR score, there may be a need to select two metrics. This has been done previously, but it may not provide the best solution for an adopting jurisdiction.

2.3.1.3 Source Energy Use Intensity (EUI)

Source EUI is the source energy divided by the gross floor area of the building.

2.3.1.3.1 Numerator: Source Energy

Source energy is the amount of raw energy needed to produce the energy consumed in a building, including losses in the generation, transmission, and distribution of all energy resources. Buildings use various types of energy for different systems. While all buildings use electricity for things like lighting and plugs, sources of space and water heating vary and can include electricity, natural gas, fuel oil, district steam, and others. Energy is delivered to buildings as 1) primary energy (fuel combusted to generate heat and/or electricity—for example, natural gas or fuel oil) or 2) secondary energy (energy created from a primary energy source—for example, electricity). When used as a measure of building performance, source energy combines each energy type to present it as one unit. To do this, source energy accounts for all energy back to the primary energy source and takes into account all losses from generation to transmission (EPA 2020).

2.3.1.3.2 Impacts, Implications, and Considerations

Conversion of site energy to source energy enables comparison of total energy sector footprint among buildings. Because electricity requires energy to be generated and transmitted, often multiples of the amount consumed on site, looking at electricity consumption through a site EUI lens only will make electricity seem to be a lower percentage of total energy consumption.

Source energy may provide an opportunity to tailor BPS to the regional conditions of current and future projected generation in addition to the fuels consumed on site. Where a higher percentage of electricity generation is from renewable sources, regions would have lower electricity source factors. Where generation is still driven by coal and other high-carbon-intensity fuels, regions would have higher electricity source factors. These source factors directly affect the impact of electrification at the building level.

Where jurisdictions opt to use source energy, they will need to select a conversion factor to convert site electricity consumption to source energy. This factor can be national, regional, or local. The differences between the three may be large depending on how electricity is generated within each boundary (Deru and Torcellini 2007). For jurisdictions using the ESPM to provide the source EUI calculation and conversion, the source conversion factor is limited to a national average. While other sources for conversion exist—such as Table 701.5.2 (Table 7.5.2), Source Energy Conversion Factors and CO_2e Emissions Factors, from *International Green Construction Code* (ICC 2021b), which presents electricity site-to-source conversion factors by eGRID subregion—an implementing jurisdiction would have to track and analyze the factors and engage with utility stakeholders for each target-setting cycle. For city-level applications, the eGRID subregion factors may be quite different from more localized factors.

A major complication in choosing source energy is that building owners generally control the energy consumed within a building but do not control the entire source energy profile of their buildings. Where local or regional emissions conversion factors are used, it may be difficult for owners with buildings in multiple cities and states to use this metric across their building portfolio, as reporting for the local BPS may differ from other corporate emissions reporting based on other protocols. Where building owners and facilities procure their energy from a non-utility source, the emissions associated with the generation of this energy may be better or worse than the conversion factor selected for enforcement. By using a conversion factor based on the source of this energy, it may incentivize building owners who procure their energy from a non-utility provider to look at purchasing cleaner energy, as long as such procurements could be accounted for in the reporting of performance.

In regions or jurisdictions currently heavily reliant on fossil fuel electricity generation, or in those with high transmission loss, a source energy metric may discourage electrification in the near term in favor of high-efficiency natural gas systems. As such, using source energy as the metric can discourage fuel switching to electricity and reward efficient gas equipment such as on-site cogeneration of electricity and heat. This same grid may experience variability in the site-to-source energy ratio over time, by either a cleaning of the grid energy generation or a reduction in transmission loss, or both. This variability will make it more difficult to set long-term targets for a source energy metric because it creates a moving target for building owners.

Though building owners are in direct control of the types of energy sources used in their buildings, replacing a fuel source (e.g., converting from gas to electricity) for major equipment is not a small or inexpensive undertaking. BPS are intended to drive owners to act on renovations, replacements, and retrofits, but metric selection should consider the potential impact on buildings and systems that may be unable to switch from a delivered fuel system or may be incentivized in the near term to replace those systems with utility gas.

2.3.1.4 Greenhouse Gas Intensity (GHGI)

Greenhouse gas intensity (GHGI) is the total GHG emissions divided by the building square footage.

2.3.1.4.1 Numerator: GHG Emissions

GHG emissions are a total accounting of emissions from the generation of energy types including electricity, district heating and cooling, cogeneration, and burning of fossil fuels on site. They are calculated through a methodology prescribed by the adopting authority, using local emissions conversion factors. All BPS adopted to date only regulate emissions from operational energy use and not embodied carbon in building materials.

2.3.1.4.2 Impacts, Implications, and Considerations

GHGI is the most direct metric when trying to tie the BPS to a GHG reduction goal. GHG is a powerful metric when considering the local impact of energy generation and the co-benefits of reducing local emissions, such as impact on public health, a consideration that is important for jurisdictions with high carbon and dirtier generation that compromises local air quality. Because reducing total emissions is an important climate impact goal, this metric can be in line with policy goals of GHG reduction if emissions conversion factors are forecast appropriately.

However, use of a GHG metric may be problematic in BPS, primarily because building owners generally do not control the entire emissions profile of their buildings. Building owners and occupants can regulate how much energy is used and what type of energy is used, and owners can increase their ownership of renewable power or RECs, but owners and occupants are not in a position to control the emissions factors associated with electricity generation because buildings are, for the most part, stationary. By using a GHG metric, a jurisdiction may be making building owners responsible for GHG emissions reductions that should be required of the utilities. While this issue is somewhat addressed by prescribing emissions conversion factors, the local or state government establishing the BPS may not have total control of the emissions profiles of buildings within its borders, as the GHG intensity of grid-supplied electricity could be influenced by decisions at the state and federal levels.

This metric is more difficult for building owners to understand compared to a metric like site EUI, where a building owner can look at the utility bill, because GHG metrics must be calculated using emissions conversion factors, which may or may not be known to building owners in advance, thus influencing their decisions around energy use. Total GHG emissions can become increasingly complex when buildings use sources beyond natural gas, fuel oil, and electricity. Sources such as green power procurements or low-carbon fuels like hydrogen will add complexity due to the fact that establishing emissions factors for these is not simple. To reduce complexity, a jurisdiction could set the electrical carbon emission multiplier by year or by compliance period in advance. This would ignore true grid emissions if set over a five-to-six-year compliance period but would significantly reduce complexity and compliance concerns.

There are many issues to consider when deciding how to convert energy use into GHG emissions. It can be reasonably straightforward for many fuels, but for electricity and district energy systems, the jurisdiction must decide whether to include transmission and distribution losses and how often to calculate the emissions conversion factor (annually or less often), along with a variety of other potential complications.

A GHG metric may lead to a problematic loading order of efficiency, electrification, and renewable energy generation. An inefficient building could achieve a low total GHGI score through the purchase of RECs to avoid most or all of the emissions from its electricity use. While market forces may hypothesize this would not happen, such a building would have a GHG emissions performance score that would obscure the inefficiency of the building due to the contribution of renewable energy. Where RECs are allowed for compliance, jurisdictions should carefully consider how RECs are accounted for to encourage the desired behavior, including where the RECs are generated, how they are retired, and if they are allowed one-for-one with energy efficiency.

Also of concern is an inefficient all-electric building on an increasingly renewable grid. In this scenario, the grid cleaning may do all of the work to achieve the BPS target, leaving the owner with no incentive to take steps to make their buildings more efficient. An undesirable result of using only GHG metrics is that stakeholders may be tempted to electrify buildings as they are and avoid capitally intensive load-reduction measures like envelope improvements due to their lower financial performance. A stock of inefficient electric buildings on a renewable grid will create increasing concerns for grid reliability and may require that grid infrastructure be built out more than would otherwise be necessary. Overlooking this efficiency pitfall could drive up electricity rates more than necessary, which is a critical issue in cities that have a disproportionate energy burden.

When electricity is increasingly generated from renewable energy sources, building electrification should correlate with a higher score on a GHG metric. Where the grid electricity has no near-term requirements to shift to clean or renewable energy sources, building electrification may be discouraged with the use of a GHG metric, leaving many owners to continue to select natural gas for heating and cooking loads. On the other hand, most owners have opportunities to procure their energy from lower-emitting sources through voluntary renewable energy source purchases. Moreover, requiring building owners to meet a GHG metric may create additional market pressure on regulators and grid operators to change the proportion of renewable energy used for electricity generation.

2.3.2 Other Potential Metrics

Beyond the energy and carbon metrics described in Section 2.3.1, jurisdictions also may consider additional metrics that help drive policy goals. For example, if a jurisdiction is trying to move buildings off fossil fuels and toward electrification, it may choose to use an electrification ratio or grid integration metrics such as grid peak contribution, on-site renewable energy utilization, grid carbon impact, or demand flexibility. Jurisdictions seeking to focus on energy affordability may opt for grid integration metrics or energy cost. All of these other potential metrics are discussed in the following subsections. None of these additional metrics have yet been adopted by any jurisdiction with a BPS policy, though some are being studied by leading practitioners to address other challenges with the primary metrics established for the BPS.

By adopting a grid integration metric, a jurisdiction is signaling its intention to consider the impact of the decarbonization relationship between buildings and their energy supply (Miller and Carbonnier 2020). No BPS established through December 2022 has adopted a grid integration metric, though many acknowledge the importance of addressing grid integration, especially where building electrification is a policy goal. Almost all of the metrics presented here are under the control of the building owner—though they may not be suitable for all jurisdictions, as many of the grid integration metrics are complex due to the need for calculations. Application of these metrics may be as primary or as secondary metric. While adding a second metric and target to a BPS policy may increase overall complexity, the right combination of metrics may be more impactful to jurisdictional goals than any single metric could be. Application of grid integration metrics should take into account the complexity of calculating and reporting along with their contribution to and impact on decarbonization.

2.3.2.1 Electrification Ratio

Electrification ratio is the amount of site energy electricity consumed by a building divided by the total amount of site energy consumed from all sources, including utility fossil gas and electricity, along with delivered fuels and on-site renewable generation. Where electrification is a stated goal but the selected metric does not explicitly incentivize electrification retrofits, this metric can be used in tandem with a primary metric to simultaneously drive energy reductions and electrification explicitly. This metric may support other co-benefits such as improved health and indoor environmental quality. Without careful analysis for target setting, however, this metric could unintentionally discourage improvements in electric efficiency. For example, a lighting retrofit would reduce the contribution of electricity to total energy.

Electrification ratio as a concept may also be adapted and presented as *percent site electricity* or *direct site emissions*. All versions of this metric focus on how much of the building energy is electrified.

2.3.2.2 Grid Peak Contribution

Grid peak contribution is the degree to which building demand contributes to load on the grid during system peak hours. Though the metric output appears simple (kW/ft^2), the calculation of the metric can present challenges. Where there is concern about electrification contributing to either dirtier overall generation or infrastructure capacity to meet peak demands, this metric can be combined with others to consider the building as part of the interconnected system that allows for decarbonization.

This metric would serve well where a jurisdiction is seeking to drive an intentional focus on reducing peak grid demand and therefore reduce carbon associated with electric generation from that type of demand spike. (This issue of building and grid integration will be covered in detail in the forthcoming TFBD book *Grid-Interactive Buildings for Decarbonization: Design and Operation Resource Guide*.) This metric will be critical to jurisdictions emphasizing electrification, as it may help to address concerns about the grid's ability to supply the electricity needed at peak times by actively reducing those peaks. Where combined with electrification and site energy metrics, grid peak contribution can support a holistic view of building sector decarbonization (Miller and Carbonnier 2020).

To illustrate what this would look like for a single region, Figure 2.2 identifies in red the top 5% of hours with the highest peak demand for the independent system operator (ISO) northeast grid region in 2017. To calculate a grid peak contribution metric, only those hours with the highest demand would be used (Miller and Carbonnier 2020).

Grid peak contribution metrics should be carefully considered for their impact on buildings that house vulnerable populations. For certain types of housing or assisted living facilities, the grid peak coincidence with very hot or very cold exterior conditions may not be as simple as adjusting thermostatic set points. Buildings used as community cooling or heating centers, which operate to support communities that may not have access to the necessary heating or cooling during extreme weather events, may need to be treated differently under this metric.

2.3.2.3 On-Site Renewable Energy Utilization

On-site renewable energy utilization is the ability of a building to consume the energy generated on its own site. To do this, the metric compares a building's energy demand profile to its on-site energy generation. Where the generation exceeds demand, that energy is exported. Exported energy is then compared to annual generation. A higher on-site renewable energy utiliza-

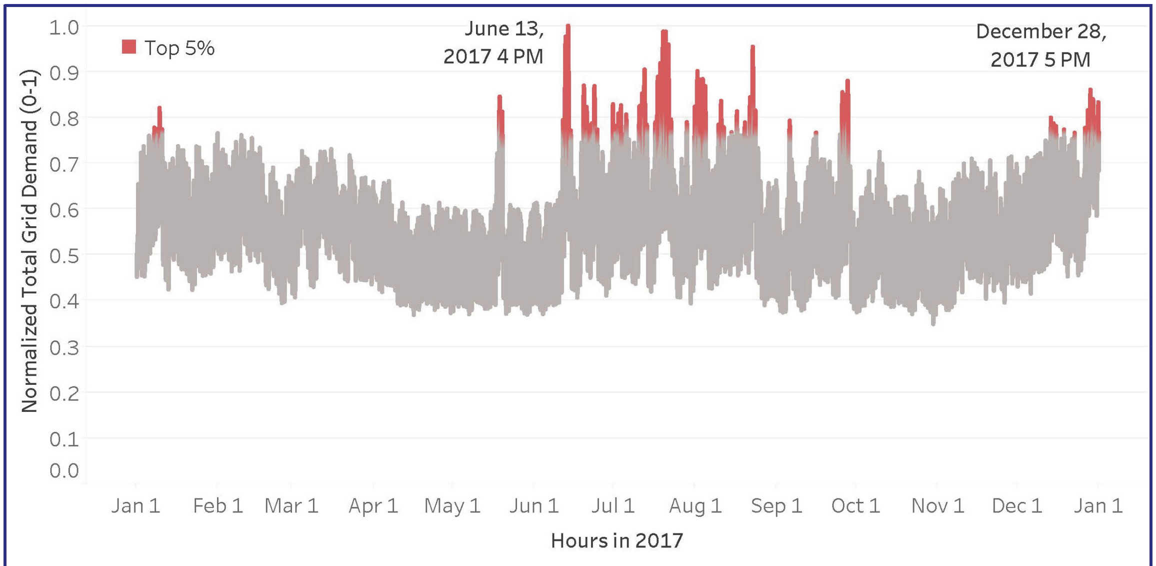

Figure 2.2 Normalized 2017 grid demand in ISO northeast region. (Image credit: Miller and Carbonnier 2020; reprinted with permission)

tion indicates that the building can consume more of its own generated energy (Miller and Carbonnier 2020).

Where there is concern about a potential disruption to grid infrastructure from an increase in distributed solar or other energy generation, this metric can be combined with others to consider the building as part of the interconnected system that allows for both on-site resilience and decarbonization. This metric can be important to encouraging on-site resilience, resolving concerns of utility infrastructure that may not have the capacity to deal with two-way energy flows, or reducing the impact of demand changes associated with renewable generation and demand curves, along with similar impacts of high-to-low renewable generation on grid operators and utility regulators. On-site renewable energy utilization contributes to increased grid stability by not requiring power plants to turn on and off, which can create instability, increase cost, and require dirtier fuels from peaker plants that only run limited hours per year during the times of greatest electric system peak.

On-site renewable energy utilization as a metric presupposes that the majority of buildings complying with a BPS policy have on-site renewable energy. Therefore, this metric may not achieve its intended goals where installation of on-site renewables is less common. Where a jurisdiction has some distributed on-site renewable energy generation, understanding what types of buildings would be impacted is critical. While imposing an additional metric on office buildings may not be considered burdensome, if most of the on-site renewable energy generation is focused on affordable housing, the policy design may create undue hardship for complexity of reporting from those owners. Buildings with no on-site renewable energy generation may need significant capital to install a new on-site renewable energy generation system, and urban areas with limited ability to generate on-site renewable energy may always result in high utilization.

2.3.2.4 Grid Carbon Impact

Grid carbon impact measures a building's hourly carbon impact by multiplying the building's hourly net demand and the marginal carbon on the grid over each of the 8760 hours of the year. The sole focus of this metric is decarbonization. Where electrification as a decarbonization strategy is in place, this metric would provide the equivalent grid consideration—asking buildings to focus on use of grid electricity when that energy is being produced at its cleanest (Miller and Carbonnier 2020).

The two data sets that create this metric have different units—the building's net demand profile is measured in kilowatts, and marginal carbon is measured in pounds of CO_2 per kilowatt-hour—making this metric particularly complex compared to other grid integration measures. *Marginal carbon* means the greenhouse gas emission intensities of the marginal generation (the last generators needed to meet demand). Marginal carbon varies across time and location and is constantly fluctuating as demand shifts. This may also be referred to as the *marginal operating emissions rate* (MOER) for that time and place. Adding to the complexity, many buildings and utilities are not accustomed to obtaining and providing information at an hourly level.

The grid carbon impact metric can be useful where a jurisdiction is seeking to have an intentional focus on grid decarbonization. Carbon impact may be used to encourage on-site energy production and storage, which would help reduce the impact of demand changes associated with the duck curve or similar impacts of high-to-low renewable generation on grid operators and utility regulators. These types of events require dirtier fuels from peaker plants, which would directly influence the scores associated with the grid carbon impact metric. Implementation of a metric like this would require a decision during policy design to use calculated impact, relying on data from an automated source such as a Green Button API connection (GBA n.d.) or similar source to drive investment on the utility side to deliver carbon signals, the capability to understand current and future emissions profiles, and likely new rate structures to test the infrastructure and building integration before being a core piece of a regulatory policy.

2.3.2.5 Demand Flexibility

Demand flexibility (DF) measures a building's ability to shed load over a specified period of time. The DF event time period may be chosen by the implementing jurisdiction. Typical periods that may be required for the measurement of this metric are 1 hour (short term) to 4 hours (long term). This range of DF event periods has been identified as optimal for balancing how building owners can respond to demand response signals with the carbon benefit of load shifting (Carmichael et al. 2021).

This metric is focused on the building's ability to interact with the grid more directly. Demand flexibility should be capable of being activated by an automated signal from a utility or third-party service provider. A building's ability to respond to this type of signal fully integrates the building with the grid infrastructure and creates a system by which buildings can be responsible for reduction of peak and needs of utilities adapt to changing conditions of cost, carbon, and climate impact. Different building typologies may be able to shed increasing amounts, and jurisdictions should consider using this metric to increase the target stringency over time to increase a building's load-shedding capability.

This metric requires the activation of a demand response signal from a utility or third party. Where no demand response signal is sent in a year, this metric cannot be used for compliance with BPS. For this reason alone, this metric should be considered as a secondary metric rather than a primary metric. Buildings that are not currently equipped to accept demand signals would require controls and systems to be upgraded to implement this metric. This metric is important to ensure that buildings are integrated with the ability of the grid to respond to price or carbon signals and can help buildings reduce their overall costs by placing them in a lower demand charge category. It can equally aid in carbon reduction by asking for load reduction to prevent the need for dirtier peaker plant electric generation.

2.3.2.6 Energy Cost

Energy cost is the measured value of energy delivered to a building to serve its functional needs. Energy cost is considered the total value of energy purchased to operate the building as reflected in utility bills. Energy cost ignores the type of energy delivered to the building and accounts only for the cost of that energy. Cost may or may not include fees associated with the connection to the utility-supplied energy source.

Energy cost is directly related to the building owner's and operator's primary considerations, making it a relatively easily understood metric for most stakeholders. Additionally, it is a common metric used in energy codes and energy modeling for code and new construction certification programs such as Leadership in Energy and Environmental Design® (LEED®) Green Building Rating System (USGBC 2022).

As a metric, energy cost prioritizes cheaper fuel over efficiency in BPS implementation. Currently, natural gas is less expensive than electricity in most locations in the United States, even in areas where the electric grid may be less carbon intensive than natural gas consumption on site. Because of this, energy cost could be categorized as a metric that disincentivizes electrification. Jurisdictions should consider the impact of energy cost as a metric where it may be inversely related to GHG emissions reductions.

Conversely, for areas where delivered fuels are still common in older buildings, either for primary or backup heating, the typically higher cost of these fuels may be an immediate penalty on owners that are less able to convert those systems to a utility-delivered energy source such as gas or electricity. Energy cost as a metric incentivizes switching those fuels, but supportive programs may be needed to aid in the cost of retrofits.

As the cost of energy varies over time, both long term and short term, volatility in the energy market due to natural disasters, political instability, or other disruptions may have an outsized and unpredictable influence on actual energy costs. This variability makes setting targets for energy cost increasingly complex, even in the near term. Jurisdictions taking on cost as a metric will also need to factor in the impact of time-of-use rates and how on-site renewable energy generation is accounted for within the metric or reporting. For these reasons, energy cost as a metric is unlikely to be successful in achieving either energy use or GHG reductions.

2.3.3 Summary of Metrics

Figure 2.3 summarizes the different metrics, comparing the metric's degree of complexity, amount of occupant and building owner control, and ability to favor electrification.

2.4 Non-Energy and Non-Carbon Metrics for BPS

The metrics presented in this chapter are for use by jurisdictions developing BPS to reduce energy use or carbon emissions from existing buildings. Other metrics being explored in jurisdictions include those addressing equity, affordability, health, water, and resilience, among others.

When establishing a BPS policy, it is important to ensure that its benefits (lower energy burdens, healthier indoor air quality, etc.) accrue to building owners and tenants throughout the community, regardless of the metrics selected. Key elements of building performance that might be considered include indoor environmental quality and health. Note that EPA has established minimum performance criteria for indoor environmental quality for a building to qualify for an ENERGY STAR building label, so in cases where ENERGY STAR has been established as the metric or where the ESPM is designated as the reporting platform, these criteria might be included in the BPS (EPA 2018).

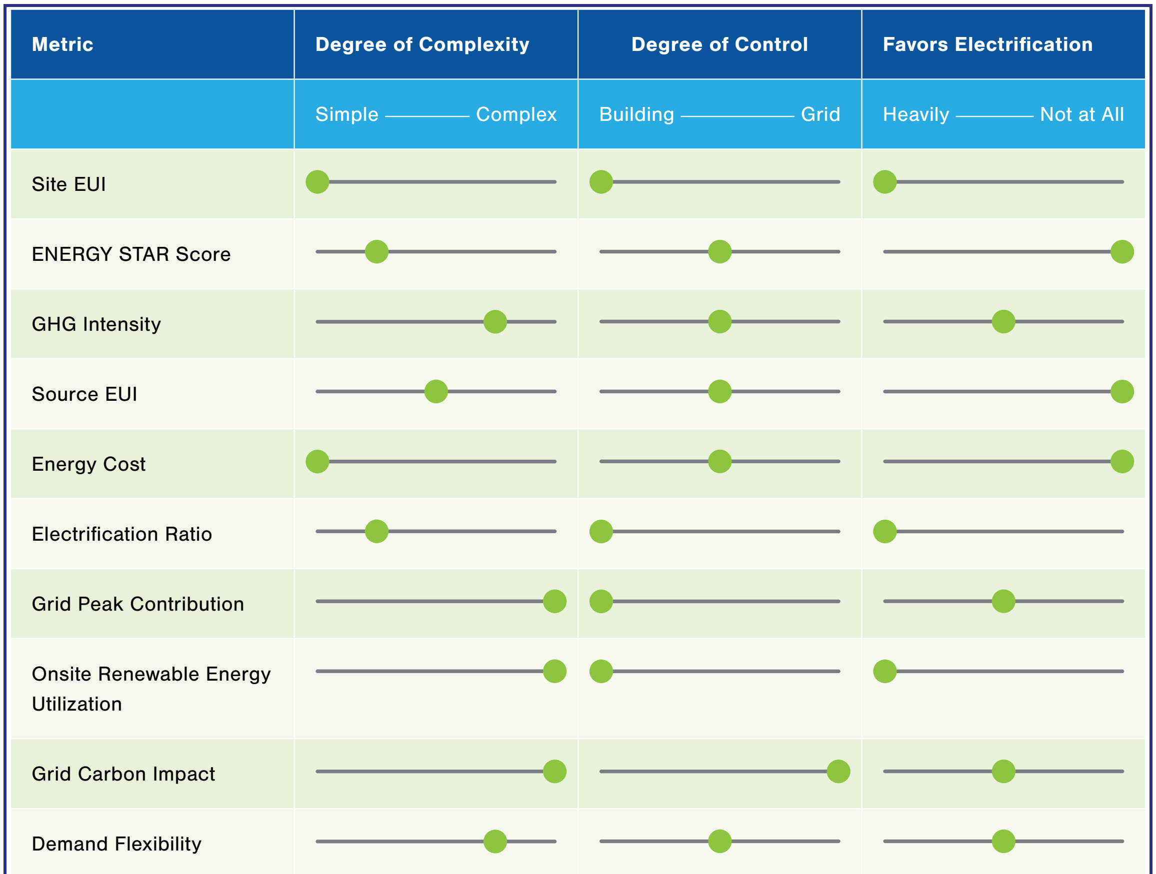

Figure 2.3 Metric summary.

Another metric that has been discussed is water efficiency or performance. For water efficiency, some buildings track water consumption normalized to specific metrics, i.e., floor area or apartment unit, though benchmarking of water performance is not as advanced as energy benchmarking and disclosure.

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3

Establishing Performance Targets

This chapter describes how to set specific performance targets for the BPS metrics discussed in Chapter 2. A BPS performance target denotes a specific level of performance that a building must meet to comply with the policy. For example, a BPS policy that uses greenhouse gas intensity (GHGI) as a metric may set a performance target of 8.5 kilograms of carbon dioxide equivalent per square foot per year (kg $CO_2e/ft^2/yr$) for office buildings. Office buildings reporting at or below 8.5 kg $CO_2e/ft^2/yr$ would be in compliance, whereas office buildings reporting above 8.5 kg $CO_2e/ft^2/yr$ would not. Performance targets in BPS may vary by building type, size, or other parameters, and may also vary over time. Figure 3.1 shows an excerpt of some Washington, D.C., BPS targets as an example.

This chapter describes various approaches and factors for setting BPS performance targets. For brevity, performance targets are generally referred to simply as *targets* in the rest of this chapter.

3.1 Scope of Performance Targets

The scope of a BPS policy defines the buildings that are covered by the standard. The process of developing the scope of a BPS policy should be informed not only by the objectives of the jurisdiction but also by specific considerations for target-setting that ensure an achievable performance target can be established for each covered building. The two primary factors to consider when establishing the scope of the BPS are the types of buildings that will be included and the size threshold above which buildings will be required to comply with the standard. The types and sizes of buildings included in BPS will have different impacts on the policy's ability to make progress toward a jurisdiction's goals. Including a larger variety of building types and reducing the building size threshold will increase the total number of buildings covered.

The following subsection discusses additional considerations for the selection of building types and sizes to include in the BPS scope as well as how other building characteristics may affect scope development.

3.1.1 Building Type

The building type is defined as a building's use category. These categories can be high level, such as office, multifamily, hotel, healthcare, etc., or can be further divided into subcategories based on the specific activities conducted at a building (e.g., a medical office). Building performance standards in the United States are typically geared primarily toward commercial and multifamily residential buildings, and generally exclude single-family homes. When selecting the types of buildings to be included in the BPS, jurisdictions should determine whether including a particular building type will have a significant impact on achieving the goals of the BPS and whether there are significant equity, cost, or other societal implications associated with that selection.

3.1.1.1 Building Type Categorization

There are two primary methods to categorize a building: 1) use of occupancy classifications as dictated by local regulations and building codes, and 2) methods described in published sources.

Examples of building categories in published sources include Section 302 of the *International Building Code* (ICC 2021a); the principal and subcategory building activities in the Commercial Buildings Energy Consumption Survey (CBECS; EIA 2022); the building area types in standards such as ANSI/ASHRAE/IES Standards 90.1 and 100 (ASHRAE 2022, 2018b) and ANSI/ASHRAE/ICC/USGBC/IES Standard 189.1 as included in the *International Green Construction Code* (ICC 2021b); and the property types in the ENERGY STAR® Portfolio Manager® (ESPM; EPA n.d.). If a jurisdiction has previously implemented a categorization method in existing benchmarking or other similar policies, continuing to use that method for the categorizations in the BPS where possible will help facilitate alignment among all policies that affect existing buildings and ensure that building owners and other stakeholders fully understand how their buildings are categorized and what targets they are expected to meet. Alignment in building categorizations can also help increase the compatibility of data analysis and tracking tools that support different energy efficiency policies and programs within the jurisdiction, including building energy codes and utility programs.

Property Type	2021 Building Energy Performance Standard	
	ENERGY STAR Score	Source EUI
Adult Education		110.4
Ambulatory Surgical Center		426.9
Aquarium		240.2
Automobile Dealership		124.1
Bank Branch	71	153.7
Bar/Nightclub		297
Barracks	56	141.4
Bowling Alley		206.6
Casino		240.2
College/University		180.6
Convenience Store with Gas Station		592.6
Convenience Store without Gas Station		592.6
Convention Center		192
Courthouse	71	153.7
Data Center	50	1.8 Total Energy kBtu/IT Energy kBtu
Distribution Center	19	103.7
Drinking Water Treatment & Distribution		5.9 kBtu/gallons per day
Enclosed Mall		170.7
Energy/Power Station		229.4
Fast Food Restaurant		886.4
Financial Office	71	153.7
Fire Station		185.5
Fitness Center/Health Club/Gym		206.6
Food Sales		592.6
Food Service		527.7
Hospital (General Medical & Surgical)	50	426.9
Hotel	54	183.9
Ice/Curling Rink		206.6
Indoor Arena		240.2
K-12 School	36	139
Laboratory		318.2
Library		206.4
Lifestyle Center		228.8
Mailing Center/Post Office		242.6
Medical Office	62	172
Mixed Use Property		229.4
Movie Theater		240.2
Multifamily Housing	66	110.7
Museum		240.2
Non-Refrigerated Warehouse	19	103.7
Office	71	153.7

Figure 3.1 Excerpt of BPS Cycle 1 targets for Washington, D.C. Note that the targets are in ENERGY STAR score (where applicable) or source EUI (in kBtu/ft^2/yr). (Image credit: DOEE n.d.)

3.1.1.2 Building Type Granularity

Building type granularity refers to the number and specificity of building types (e.g., having just one type, "Retail," for all retail buildings vs. having multiple types such as "Strip mall," "Big box retail," etc.). The granularity of the building types to be included in the BPS scope should be based primarily on the data available for target setting to ensure that each building included in the scope has a performance target that is reasonable for its characteristics. Although using high-level categories may ease the target-setting process, buildings with more specific activity types will have to be included in one of the broader categories and may have performance targets that do not entirely fit their uses. Conversely, using more detailed building categories will result in more specific targets for different building types but will require more effort in the target-setting and compliance and implementation processes for the BPS.

When using benchmarking data as the basis for setting performance targets, the jurisdiction should look at whether the BPS scope will cover building types beyond what the existing benchmarking policy covers and whether it will be able to obtain sufficient data to set targets for any new building types that are included. When using data from published sources to establish performance targets, the building types that the proposed BPS can cover will be limited by the granularity included in those sources. For example, ASHRAE/IES Standard 100 (ASHRAE 2018b) provides site energy use targets (electricity and fossil fuel) for 53 building activity types across 17 climate zones. Figure 3.2 shows an excerpt of the site EUI targets for different building types from the standard, including multiple subcategories of offices. If using this standard for target setting, the jurisdiction could adopt targets for either all or a subset of the building categories included in the standard. Prior experience with target-setting analyses using data obtained from Standard 100, the CBECS, and the ESPM suggests that more granular categories are preferable to simple high-level categories because they provide the opportunity for more detailed target setting to differentiate buildings.

		EUIs by Building Type by Climate Zone (kBtu/ft^2·yr)																
		ASHRAE Climate Zone																
No.	Commercial Building Type	1A	2A	2B	3A	3B Coast	3B Other	3C	4A	4B	4C	5A	5B	5C[a]	6A	6B	7	8
1	Admin/professional office	39	40	39	42	33	39	33	46	40	40	48	42	39	54	47	58	81
2	Bank/other financial	55	57	56	59	46	55	47	65	56	57	68	59	56	76	67	82	115
3	Government office	49	50	49	52	41	48	42	57	49	50	60	52	49	67	59	72	101
4	Medical office (nondiagnostic)	33	34	33	35	28	33	28	39	34	34	41	36	33	46	40	49	69
5	Mixed-use office	45	46	45	48	38	45	39	53	46	47	56	48	45	62	55	67	94
6	Other office	38	39	38	40	32	37	32	44	38	39	47	40	38	52	46	56	78
7	Laboratory	178	176	171	175	147	165	159	194	173	179	209	187	181	232	211	249	331
8	Distribution/shipping center	12	16	16	20	11	18	14	27	23	22	36	30	24	49	40	60	113
9	Nonrefrigerated warehouse	6	8	8	10	5	9	7	13	11	11	17	14	12	24	19	29	54
10	Convenience store	135	146	135	152	127	139	141	166	150	157	178	162	167	193	179	208	263
11	Convenience store with gas	108	118	109	122	102	112	114	133	121	126	144	130	135	156	144	168	212
12	Grocery/food market	112	122	113	127	106	116	118	138	125	131	149	135	139	161	149	174	219
13	Other food sales	34	37	34	38	32	35	36	42	38	40	45	41	42	49	45	53	66

Figure 3.2 Excerpt of Table 7.2a from ASHRAE/IES Standard 100 showing targets by building type. (Image credit: ASHRAE 2018; reprinted with permission)

3.1.1.3 Specialized Energy End Uses

Any jurisdiction's building stock is likely to include buildings with specialized energy end uses that can affect that building's ability to meet BPS performance targets. Examples include energy-intensive buildings such as power and district energy generation facilities, industrial facilities, and communications infrastructure, among others. These specialized energy end uses may also be present in portions of buildings that otherwise fit in more standard building categories, such as data centers housed within office buildings, communications equipment in multifamily buildings, swimming pools in schools, etc. The decision to include these buildings in the scope of the BPS will depend on whether the jurisdiction is able to establish performance targets for these building types and on the effect that including them will have on meeting the jurisdiction's policy objectives. If targets cannot be established, the jurisdiction has a few options to address the performance of these types of buildings:

- **Meter the specialized end use to exclude it from the overall building performance.** In cases where a smaller portion of a building has a specialized end use but the building can be otherwise categorized, the jurisdiction could consider requesting that building owners separately meter the specialized end use to exclude it from the building's overall performance. The building would still be required to meet the performance target that corresponds to its type. A less-costly version of this option would be to allow an estimate based on one-time measurements or calculations.
- **Exclude the buildings from meeting the BPS but require them to pursue an alternative compliance path.** Alternative compliance paths can include requiring buildings to implement a prescribed set of energy conservation measures (ECMs), conduct energy audits, create implementation plans, or demonstrate a percentage reduction from their current baseline, among others.
- **Provide an allowance for specialized end uses.** The allowance would be added to the base energy or greenhouse gas (GHG) target amount.
- **Exclude the buildings from the BPS entirely.** This may be the simplest approach, but it can also result in lost savings opportunities and be detrimental to the jurisdiction's objectives. Furthermore, it may become a loophole for buildings to be excluded from BPS.

3.1.2 Building Size Threshold

The building size threshold in the context of BPS refers to the minimum floor area of the buildings to be included in the scope of the standard at each compliance period, i.e., the date by which buildings need to meet the target. As with building type, the building size threshold selected for the BPS scope should be informed first and foremost by the jurisdiction's goals for the BPS. Although several of the existing BPS policies that have been adopted focus on buildings that are 50,000 ft^2 or larger, with the rationale that regulating the largest buildings has the most impact while affecting a relatively small number of buildings, there is no specific threshold that is guaranteed to work for every jurisdiction. Limiting covered buildings to those with larger individual floor areas may not include as much of the built area within a city as expected. The threshold for Washington, D.C., is 10,000 ft^2 and the state of Maryland set it at 35,000 ft^2.

The best approach to selecting the appropriate size threshold for a BPS policy is to conduct a comprehensive analysis of the jurisdiction's building stock, ideally using data collected through a benchmarking or other similar policy, to understand 1) the distribution of building sizes for different building types that will be covered by the BPS and 2) how selecting different building size thresholds influences the outcomes of the standard. Figure 3.3 shows the emissions impacts of including different size categories for Seattle's potential BPS (Walter and Mathew 2021).

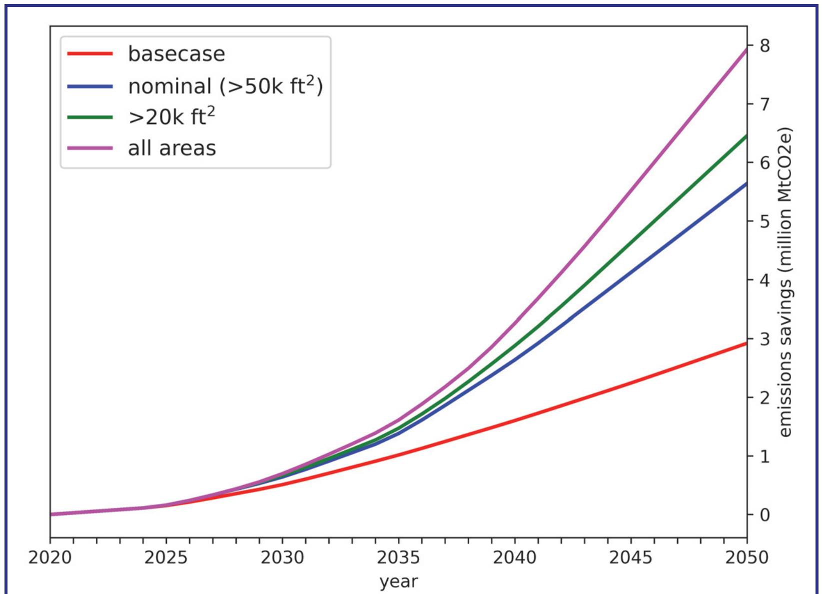

Figure 3.3 City of Seattle cumulative emissions savings for varying floor area ranges subjected to potential BPS. (Image credit: Walter and Mathew 2021; reprinted with permission)

Jurisdictions should take into account the following when selecting building size thresholds:

- **Should the size threshold vary by building type?** A jurisdiction may opt to select a single building size threshold for all building types or to select different thresholds for different building types. It is possible that the average sizes of different building types within a jurisdiction's building stock vary significantly and that selecting a single building size threshold will not provide sufficient coverage for all building types. For example, office buildings may be larger on average than multifamily buildings or schools, so selecting a larger building size threshold may exclude smaller building types from the BPS. In addition, buildings of different sizes or focused on different target categories (e.g., large vs. small offices, market-rate vs. affordable multifamily) may have different levels of financial and technical resources to implement BPS, so jurisdictions should consider the potential equity implications of the size threshold selected. By analyzing the distribution of building sizes by building type, a jurisdiction can better understand whether selecting a specific building size threshold will be sufficient to achieve the desired outcomes of the BPS.
- **Should the size threshold be adjusted over time?** Selecting larger building size thresholds for the first few compliance periods of a BPS policy (thus likely reducing the number of buildings that have to comply) and progressively reducing the thresholds over time may give building owners and the jurisdiction's enforcement body the opportunity to adjust to the policy and develop the capacity to administer it to a larger number of buildings. It may also give time to implement companion policies and ensure that financing mechanisms are further developed to help smaller buildings comply with the standard. Jurisdictions should analyze the impacts of timing on the cumulative emissions over the time frame of the BPS.

3.1.3 Building Ownership

Building ownership refers to the entity that owns and operates the building, such as public institutions and private building owners. Examples of public institutions include the city, state, and federal government or related agencies; transportation services; and public schools, colleges, and universities. Examples of private building owners include private corporations, condominiums, cooperatives, and individuals, among others. The jurisdiction should decide whether the BPS should cover all or only a subset of these building ownership types and whether all these building types should comply with the standard at the same time. An example of how this decision may impact a BPS scope is that a jurisdiction may choose to “lead by example” and opt to have buildings that are owned or occupied by local government agencies meet a more stringent performance target or be required to comply in a more compressed timeline than privately owned buildings. In addition, a jurisdiction may need to exclude buildings owned or operated by government entities outside of their control (e.g., federal buildings, which are covered by performance policies at the federal level).

Buildings with leased spaces (e.g., multifamily rental buildings, tenanted offices, and retail buildings) present a more complex situation in that the building owners have varying degrees of control over the energy use of leased spaces. Jurisdictions should contemplate including appropriate provisions in the BPS to ensure that building owners can work cooperatively with tenants to assess whole-building performance and take action to meet the BPS requirements.

3.1.4 BPS Scope—Examples in Practice

Table 3.1. provides examples of scope components found in existing BPS policies.

3.2 Approaches for Setting Performance Targets

Setting technically and economically achievable BPS performance targets that are aligned with a jurisdiction’s policy objectives requires careful analysis. The approach selected for target setting varies depending on the access to data and technical expertise available to each jurisdiction. Section 3.2.1 presents considerations applicable to all target-setting approaches, and Sections 3.2.2 to 3.2.5 present four approaches to setting targets (see Table 3.2 for the four approaches). In general, it is highly preferable to set targets informed by benchmarking data (i.e., the first two approaches in Table 3.2) because benchmarking data reflect the actual current performance of the

Table 3.1 BPS Scope Components and Examples from Existing Policies

Scope Component	Examples from Existing BPS
Building type	Common building types excluded from existing BPS include: • Single-family homes • Buildings known to be high energy users, such as industrial, power generation, and transportation facilities (Boston, MA, and Reno, NV) • High-performance buildings or buildings with “green” certifications (Chula Vista, CA, and Reno, NV) Other BPS policies provide special provisions for affordable multifamily buildings (New York, NY)
Building size threshold	Building size thresholds in existing policies range from 10,000 ft^2 for all buildings (Washington, D.C., starting in the third period of compliance, which begins in 2033) to 50,000 ft^2 for all buildings (St Louis, MO) Some BPS differentiate building sizes by building type (Chula Vista, CA, and Boston, MA) and others use a single building size regardless of building type (New York, NY; Denver, CO; and St. Louis, MO)
Building ownership	Some building ownership types excluded from existing BPS include: • City, state, and federal buildings (St. Louis, MO; New York, NY; and Chula Vista, CA) when covered by other policies • Transportation buildings and schools (Chula Vista, CA)

buildings; however, other approaches are available for jurisdictions that do not have access to that data or cannot obtain it in a timely manner.

These target-setting approaches are not mutually exclusive. Jurisdictions may consider combining multiple approaches to arrive at targets and validate that they are feasible and meet policy goals. When selecting one or more approaches, jurisdictions should consider the access to expertise. Most jurisdictions may not have the in-house expertise or staff resources to complete the analyses needed to set appropriate targets. Such jurisdictions can create a committee of experts in building science and other technical fields or hire a consultant team to select the appropriate target-setting approach and develop the recommended targets. This can be done before or after the BPS policy is adopted, depending on whether the jurisdiction has the flexibility to establish targets after the policy's adoption. Building owners and other stakeholders should be included in target-setting discussions to address the economic feasibility of targets. In particular, jurisdictions should include groups representing environmental justice, communities of color, and tenants' rights to ensure that the targets minimize negative impacts on underserved communities. Finally, it should be noted that setting targets can be quite time consuming both technically and in terms of stakeholder buy-in, and jurisdictions should allocate adequate time for this.

3.2.1 Considerations Applicable to all Approaches

3.2.1.1 Community Impacts of Target Setting

Community impact is important in target setting. For any approach, additional analyses and community engagement should be completed to understand not only the energy or carbon savings by sector and building typology but also how a certain target or set of targets may disproportionately affect a geographic area, small business owners, affordable housing, or other historically disenfranchised groups within the jurisdiction during a single compliance cycle or throughout the BPS implementation. Some jurisdictions have explored ways to create less-stringent paths or phase in BPS later for these communities. If a BPS policy can be paired with technical and financial support, it could set those buildings up for the greatest long-term reductions in cost, carbon, and energy savings, creating both physical and financial community assets for historically underserved populations. Note that in some cases these buildings may achieve an adequate return on investment without additional financial incentives.

Table 3.2 Four Primary Approaches to Setting Targets

Approach	Applicability
Targets derived from benchmarking data	Highly applicable for jurisdictions that have energy benchmarking ordinances providing measured energy performance data. GHG data can be derived from energy data.
Targets derived from sector-level goals	Jurisdictions with explicit quantitative building sector-level GHG or energy-use targets. Also requires benchmarking or other building energy performance data.
Targets based on published sources	Jurisdictions lacking building energy performance data. Jurisdictions desiring to base targets on published industry standards.
Targets derived from modeled performance	Jurisdictions lacking building energy performance data. Jurisdictions desiring more in-depth analyses of specific efficiency and decarbonization technologies and strategies to meet targets.

3.2.1.2 Mixed-Use Buildings

Mixed-use buildings are those that include more than one activity type and cannot easily be classified into a single category. It is recommended that these types of buildings be included in the BPS scope but that the jurisdiction consider adopting provisions for adjusting mixed-use building performance targets if the buildings meet specific criteria. Jurisdictions primarily have two types of approaches for assigning performance targets to mixed-use buildings, as adapted from ASHRAE/IES Standard 100 (ASHRAE 2018b):

- **Assign performance targets based on the building's primary classification.** This approach can be used when a significant majority of the building can be classified under a single category. Standard 100 allows this approach for buildings in which more than 75% of the gross floor area has a unique building activity, but jurisdictions can opt to require a different gross floor area threshold. Assigning performance targets in this way can simplify the process for building owners and regulators, but depending on a building's activity mix may not be fully representative of that building's type.
- **Allow targets to be calculated based on a weighted average of the targets for different building categories.** This approach can be used by any mixed-use building and requires that performance targets be calculated using weighted averages of the targets for each building type, based on floor area or other factor for each type. The weighting factor should match the factor used for performance target development. For example, if targets for each building type are normalized by area, then an area-weighted average is recommended. An example calculation of the total energy use intensity (EUI) target adapted from Standard 100 using gross floor area as one of the weighting factors is as follows:

$$\mathrm{EUI}_t = (A \times S \times \mathrm{EUI}_t)_1 + (A \times S \times \mathrm{EUI}_t)_2 + \ldots + (A \times S \times \mathrm{EUI}_t)_i + \ldots + (A \times S \times \mathrm{EUI}_t)_n$$

where

EUI_t	=	total allowed EUI over the building
$(A)_i$	=	percentage of the gross floor area with a single building activity *i*
$(\mathrm{EUI}_t)_i$	=	building activity target for space *i*
$(S)_i$	=	operating shifts normalization factor for space *i*
$(A \times S \times EUI_t)_i$	=	weighted space EUI target for space *i*

This equation can be changed to represent any performance metric chosen by the jurisdiction and any weighting factors.

The two options provided here are not mutually exclusive and can be included as options in the BPS to allow building owners to select the best alternative for their buildings.

3.2.1.3 Vacant and Partially Vacant Buildings

It is likely that a portion of the buildings included in the BPS scope will be either completely or partially vacant during one or more of the compliance periods. Jurisdictions have multiple options for setting performance targets depending on whether a building is completely or partially vacant:

- **Completely vacant buildings.** In the case of completely vacant buildings, jurisdictions can require the buildings to comply with the BPS during the appropriate period or exempt them from compliance. If the buildings are required to comply, the jurisdiction should consider whether the performance targets are to be based on the building's pre-vacancy activity or its future intended activity. Alternatively, the jurisdiction could treat vacant buildings as a separate building type covered by the BPS with a separate set of performance targets.

- **Partially vacant buildings.** Jurisdictions should consider whether vacant areas of an otherwise occupied building are to be included in the building's performance both when setting and when meeting the performance target. For example, the jurisdiction can exclude partially vacant areas up to a certain threshold and require that the remainder of the building comply. Alternatively, if the jurisdiction sets targets for vacant buildings, the target for a partially vacant building can be prorated accordingly.

3.2.1.4 Buildings with Shared Meters

When defining buildings covered by the scope of a BPS policy, the jurisdiction should determine how to account for buildings that share a single meter for any given fuel. One potential approach is to treat the buildings as a single building for the purposes of complying with the BPS, even if individually the buildings may not necessarily be covered by the scope due to exceptions related to building type or size threshold. The jurisdiction could also create exceptions for certain building types with combined meters (e.g., education campuses, hospital buildings) as needed. Alternatively, buildings could have the option to submeter the energy use for each building and opt to comply individually if applicable or if submetering would make it easier for individual buildings to comply with the BPS.

3.2.1.5 Economics of BPS Targets, Investments, Fees, and Penalties

Moving buildings to a significantly lower energy signature than their baseline normally requires investment. The economics of a building's energy-related expenditures consist of the following:

- **Annual energy costs in each year.** Under normal conditions, annual energy costs vary from year to year. Energy efficiency or alternate sourcing can reduce these costs. Purchased energy is also subject to cost escalation over time; investors need to assume the rates at which costs escalate.
- **Investments for energy-savings-related products and services.** Such investments include the costs of alternate energy source procurement, energy auditing, design engineering, equipment, products, construction or implementation, and project management.
- **Fees and penalties.** Fees and penalties for not complying with a BPS policy may be a component of policy adoption or administration.

Depending on the magnitude of the fees for not investing in energy-saving measures to meet BPS, owners may not have sufficient incentives to invest. Figure 3.4 is a basic illustration of cash flows for two scenarios. Case 1 includes annual energy costs, no investment, and a fee. Case 2 includes energy investment, energy savings, and no fee. Using life-cycle cost analysis, a tool frequently used in building energy assessments, these two cases have an identical net present value. Case 1 takes much less effort than case 2, leading to the same financial outcome.

Owners may also be averse to energy savings investment because of the risks. Any building owner investing in energy or emissions reductions assumes financial risk. A typical process involves developing a series of ECMs, often as part of ASHRAE Level 1 or Level 2 energy audits (ASHRAE 2018a). Funding these ECMs entails two types of risk:

- **Cost risk.** Costs of ECMs can be inaccurate or subject to escalation and contingency. The estimates contained in energy audits are normally rough order of magnitude costs, not assured prices. For example, a savings strategy estimated at $100,000 may in reality cost $300,000 to complete.

- **Prediction risk.** Auditing energy calculations and/or energy models are not perfectly accurate (this is sometimes called the *energy-performance gap*). The calibrated models with the highest accuracy can carry a margin of error of 10% (or higher). Noncalibrated calculations are less accurate and riskier. For example, a measure that is predicted to save 30% of a building's energy may only save 10% in actuality.

For some buildings, it may be economically infeasible to achieve the targets, even from a life-cycle cost perspective (e.g., 40-year simple payback). In such cases, the building owners may need to use an alternative compliance path that requires them to reduce energy use and emissions as much as feasible, with appropriate justification. For example, they may be required to reduce their energy use or emissions by a certain percentage relative to their baseline.

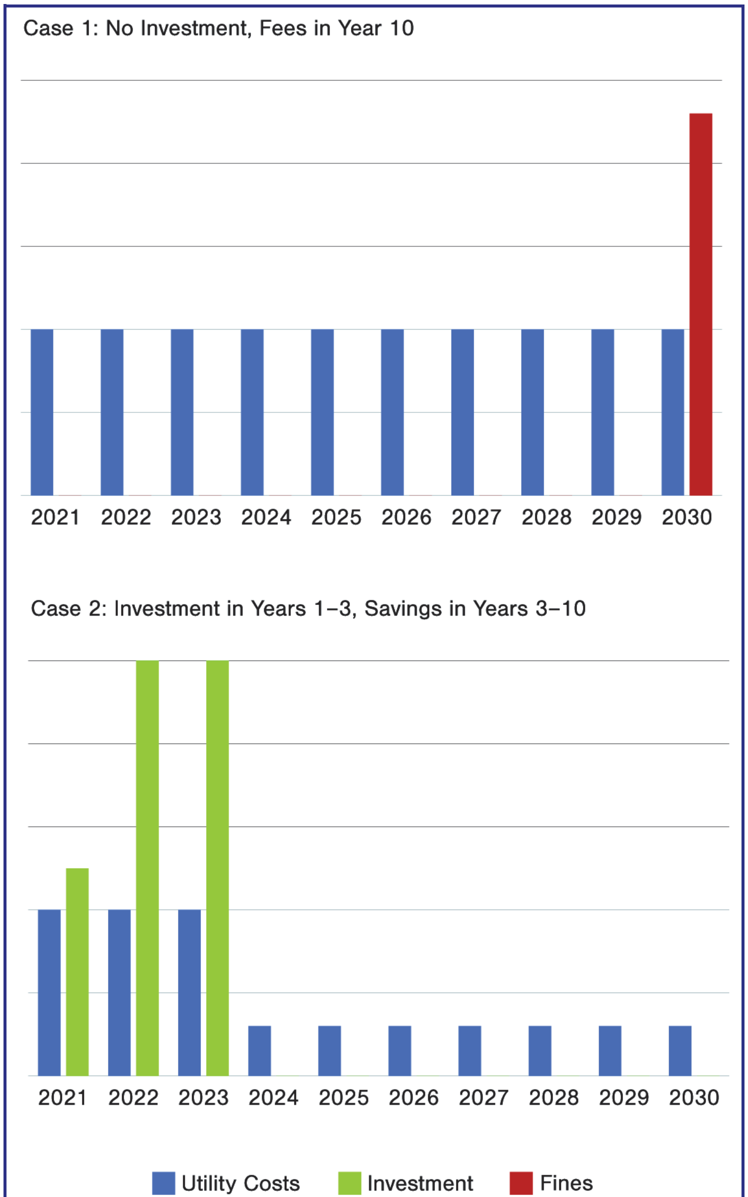

Figure 3.4 Energy and BPS related costs. Case 1 and Case 2 have equivalent net present values at 8% internal rate of return.

3.2.1.6 A Note on Building Performance Certifications

Building performance standards are policies intended to measure building performance. Buildings that have been awarded certifications under ENERGY STAR, LEED, or similar programs may not necessarily meet the performance targets set in the standard despite having received a certification, particularly if the certification is based on performance modeling and not on measured metrics (as is the case for LEED for new construction [USGBC 2022]). Additionally, certifications are generally for a single point in time and do not consider performance over time. In general, it is advisable to include these types of buildings in the scope of the BPS if their building type is covered and require them to meet the same targets as other buildings of the same type.

3.2.2 Targets Derived from Benchmarking Data

3.2.2.1 Applicability

The approach of deriving targets from benchmarking data is highly applicable for jurisdictions that have such data. It could also potentially be applied to other jurisdictions by imputing data from benchmarking data of a jurisdiction with a similar building stock and climate.

This approach requires at least one year of validated benchmarking data from a year without unusual real estate business cycle characteristics such as a pandemic. Note that the first year of benchmarking data in most jurisdictions often has data quality issues and it can take considerable effort to conduct cleansing of benchmarking data. One approach to mitigate data quality issues is to require third-party verification of the data.

3.2.2.2 Description

Many jurisdictions have benchmarking policies that require building owners to report the measured energy performance of their buildings annually. Benchmarking data provide a rich source of data for target setting because they represent the measured energy use of buildings in the actual jurisdiction and therefore have greater salience for stakeholders, and they cover almost all buildings in covered subsectors, i.e., they are not merely a sample. Almost all benchmarking policies in the United States require the use of the ESPM. These benchmarking data provide site EUI, source EUI, ENERGY STAR score, and estimated GHGI and often include measured energy use for individual fuels (electricity, natural gas, etc.), which can be useful when considering electrification or other decarbonization metrics. Any of these metrics could be used to set targets (see Chapter 2 for more information on the implications of different metric choices). Policy makers can set targets by selecting a particular percentile of the metric distribution for each subsector. For example, Washington, D.C., considered setting the target as the 50th, 40th, or 20th percentile of the ENERGY STAR score for each building type (Bergfeld et al. 2020) and then calculated the total reductions by subsector and for the whole stock.

3.2.2.3 Data Requirements

At a minimum, building performance data for the existing building stock will be required. Typically, this will be EUI, GHGI, and/or ENERGY STAR score, all of which are usually included in benchmarking data. At least one year of performance data is necessary to begin establishing targets, but additional data from prior years can be useful (especially if building performance may vary significantly from year to year, e.g., due to occupancy shifts in any given year such as during the pandemic of 2020). Performance data are only required for covered buildings, but performance data for other buildings in the jurisdiction can be useful, if available, for purposes such as comparing emissions savings from covered buildings to total emissions for all buildings in the jurisdiction.

In addition, basic information about the existing building stock may be required. Namely, data are needed for any characteristic that will be used to divide buildings into separate target categories. For example, because EUI can vary significantly by building type, the building stock may be separated into different categories based on building type (or groups of building types). Categories might also be defined based on building size, climate zone, occupancy level, operating hours, or other characteristics, meaning those data might be needed as well. Building types and sizes are typically included in benchmarking data but can also come from tax assessor data. Refer to Section 5.2.1 in Chapter 5 for more detailed descriptions of data sources that can be used in this analysis.

3.2.2.4 Development Approach

Building-level performance targets are calculated by dividing buildings into categories, computing distributions of building performance for each category, and then iteratively selecting a target, computing its impact, and revising the targets as needed to meet policy objectives.

The initial step after selecting a performance metric (e.g., GHGI) is to divide the covered buildings into categories (e.g., by building type) and compute the distribution of building performance for each category. (Figure 3.5 shows an example: the distribution for source EUI for large office buildings in Washington, D.C.) These distributions should be reviewed carefully to help jurisdictions understand how much performance varies within a category (e.g., a distribution with long tails could mean some buildings will need very large performance improvements to meet a target) and from one category to another (e.g., if two categories have similar performance, they might be combined into a single category to make compliance easier to track).

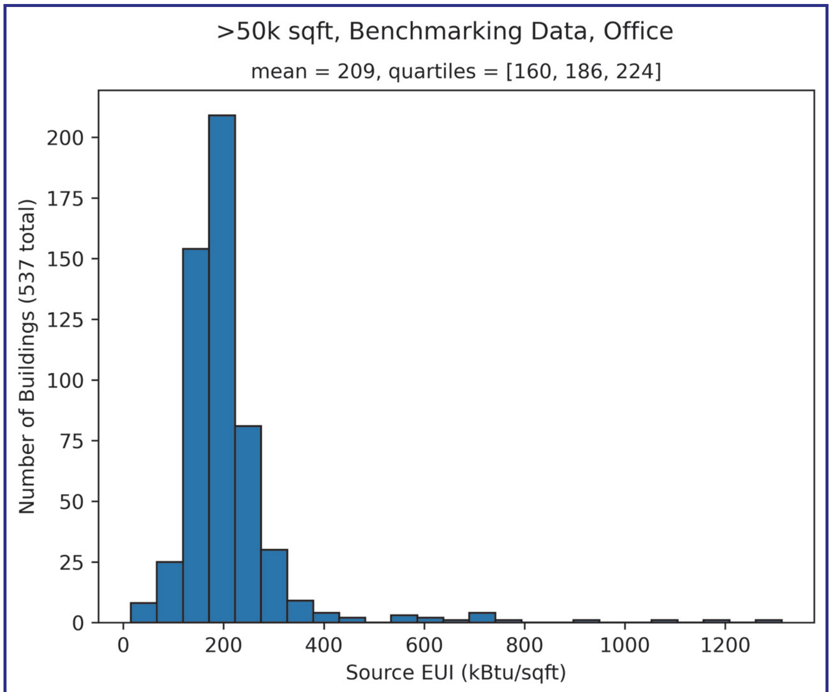

Figure 3.5 Example of distribution of source EUI for large office buildings in Washington, D.C. (Image credit: LBNL)

Next, the performance targets and compliance periods should be selected by analyzing the performance distributions and the effects that the targets and periods would have on those distributions in the future. This should be an iterative process in which candidate targets and compliance periods are selected, then their impacts are evaluated, then new candidates are selected, and so forth. Given a candidate target and compliance period (e.g., buildings must reduce GHGI to the 80th percentile every five years), some key impacts should be addressed:

- How many buildings will need to improve performance?
- By how much will they need to improve?
- How quickly will they have to improve?
- Which buildings (e.g., sizes or types) will have to improve?

If the candidate target and compliance period would require an unreasonable amount of performance improvement, if the timeline to implement the improvement is unrealistic, or if a particular category of buildings cannot achieve the required performance, then the target and period should be reselected and another iteration should be performed until targets and periods are finalized. Performance targets and compliance periods can be specified differently for each category of buildings, depending on how much performance improvement is realistically achievable by buildings in each category, as determined by a diverse set of stakeholders.

Note that benchmarking data could also be used to impute metric values for smaller buildings for which benchmarking data are not available. EUI generally does not strongly correlate to building size (e.g., see data in the DOE Building Performance Database, bpd.lbl.gov), so the distribution of EUIs for larger buildings could be applied to smaller buildings of the same type as a reasonable approximation.

3.2.2.5 Strengths, Limitations, and Impacts

Jurisdictions with active benchmarking policies and data can transition to BPS more easily than other jurisdictions. The BPS policy itself can be a natural extension or a continuation of benchmarking, and existing benchmarking data can be used to help set targets, using the same level of resolution by subsector as the benchmarking data. Reporting requirements (both the data being reported and the function of reporting) may be simpler because many building owners are already benchmarking performance. Overall, policy alignment with benchmarking should ease policy implementation and increase stakeholder buy-in.

Using benchmarking data for target setting can be helpful in getting BPS started. Because benchmarking data represent the actual performance of buildings in a jurisdiction, setting targets within these data inherently shows that these targets are achievable. The distribution of performance within a subsector can also allow for a data-driven basis for negotiating targets (e.g., 50th vs. 40th vs. 20th percentile). Since benchmarking typically involves normalization for various building characteristics (e.g., hours of operation), these could also be incorporated into the target-setting process for individual buildings. However, policy makers should weigh this against the added level of effort and transaction costs of compliance. Conversely, exclusive reliance on current benchmarking data may limit a jurisdiction's ability to set long-term targets. Benchmarking data represent the current and past levels of performance, and setting targets within this may be limiting if the current building stock lacks adequate representation of high-performing buildings. Jurisdictions relying on benchmarking for target setting may need to use a recalculated target-setting approach, which may cause unease in the periods between compliance cycles.

Benchmarking data can also be combined with other information about the affected properties, including ownership, permits, recent renovations, and tax assessments. These cumulative data could provide a deeper understanding of the potential for targeted support programs to ensure an equitable application of the policy. The simple fact that jurisdictions can directly identify which properties will fall above and below the BPS targets opens possibilities for support that cannot be provided under other target-setting methodologies.

Finally, this approach does not directly address long-term sector-level goals. Therefore, it is important to aggregate subsector-level impacts into sector-level impacts and evaluate the total against the overall sector-level goals to ensure the policy will have the overall impact the jurisdiction is seeking (see Section 3.2.3 for more information on setting targets according to sector-level goals).

3.2.3 Targets Derived from Sector-Level Goals

3.2.3.1 Applicability

The approach of deriving targets from sector-level goals is applicable for jurisdictions that have an existing policy with explicit quantitative goals for building sector reductions. It is also well suited for jurisdictions that have existing building performance data available, e.g., from benchmarking policies, since the derivation of subsector and building-level targets requires such data, as discussed in Section 3.2.2.3.

3.2.3.2 Description

This approach is essentially an extension of the previous approach of deriving targets from benchmarking data, with one key additional aspect: calculating the stock-level impact of building-level targets and aligning them with subsector- and sector-level goals.

Sector-level goals in this context refer to quantitative energy or GHG reduction goals for the building sector. Examples of sector-level goals include the following:

- Seattle's Climate Action Plan (City of Seattle 2018) specifies that building energy emissions reduce by 39% by 2030 and by 82% by 2050 relative to a 2008 baseline.
- New York City's Local Law 97 (NYC n.d.) aims to reduce emissions from the largest buildings by 40% by 2030 and by 80% by 2050.
- The City of Aspen has set science-based targets (City of Aspen 2017) for community GHG emissions reduction of 63% by 2030 and 100% (zero carbon) by 2050.

Jurisdictions that have already established sector-level goals may use these to derive building-level targets to meet those goals. In most cases, sector-level goals are at a high level—they cover the whole building sector and are usually 10 or more years in the future. Also, most sector-level goals are expressed as a percentage reduction from a baseline year. For BPS target setting, the task is to derive building level targets—which may be absolute or relative—that can meet these sector-level goals in whole or in part (i.e., if the BPS-covered buildings are only a part of the covered buildings for the sector-level goals).

3.2.3.3 Data Requirements

The data requirements for this approach are very similar to those for deriving targets based on benchmarking data (see Section 3.2.2.3). However, if benchmarking data are not available, building performance data for the whole building stock can be imputed using other data sources, for example, from the relevant subset of the Commercial Buildings Energy Consumption Survey (CBECS; EIA 2022) and/or the Residential Energy Consumption Survey (RECS; EIA 2020) or from benchmarking data from another jurisdiction with similar building performance. See Section 5.2.1 of Chapter 5 for more detailed descriptions of data sources that can be used in this analysis.

3.2.3.4 Development Approach

The first task of this approach is to develop a breakout of total energy or emissions by subsector, e.g., building type and size. This can be done by aggregating the benchmarking data into the relevant subsectors.

The next task is to derive subsector-level reduction goals from sector-level goals. Conceptually, the simplest approach is to apply the sector-level goals uniformly across all subsectors, i.e., if the sector-level goal is 80% GHG reduction by 2040, then all building subsectors (offices, hospitals, etc.) must reduce their GHG emissions by 80% by 2040. While this is conceptually simple, it is generally not feasible because it is difficult to apply BPS to every subsector. For example, it may not be practical to cover many smaller buildings, and many BPS ordinances are in fact limited to buildings above a certain size. In a similar way, some building types may be exempt for various reasons (e.g., complex building types such as specialty laboratories may be exempt for technical reasons, and federal buildings may not be legally subject to city or state codes). Therefore, policy makers first need to decide how much of the reductions for any non-covered subsectors need to be absorbed by the covered buildings of the BPS to meet sector-level goals.

For covered buildings, the next factor the jurisdiction needs to determine is whether different subsectors should have higher or lower reduction requirements. Some subsectors may have higher levels of efficiency and therefore fewer opportunities for further reductions. For example, in Washington, D.C., the local median ENERGY STAR score for office buildings is around 70 (vs. 50 nationally), driven by market demand for ENERGY STAR-certified buildings. That may not be the case for other building types in Washington, D.C., such as schools, where the median ENERGY STAR score is lower than 50.

In a similar vein, policy makers should determine whether the reduction requirements might vary by building size. In general, EUIs and reduction potential do not correlate strongly with building size and there is not an obvious technical reason to vary targets by building size. However, smaller buildings that are individually owned may have more organizational and economic barriers to achieving reductions and may need additional resources to ease their burdens.

Once the reductions for each subsector have been set, policy makers need to set building-level targets and assess the impact on sector-level goals. This is similar to the process described in Section 3.2.2.4. The benchmarking data, or equivalent data source, provide a distribution of energy use and GHG across the buildings within each subsector. Therefore, each building above the target will contribute a different amount to the total reduction for the subsector. Determining the target should be an iterative process: select a target and determine the reduction from each building, calculate the total reduction for the subsector and compare it to the required reduction for the subsector, then adjust the target as needed to meet the total required (see Figure 3.6). The iterative target-adjustment process should also incorporate equity considerations through stakeholder engagement. Figure 3.7 shows the impacts of different targets in an analysis conducted for the BPS in Washington, D.C.

As noted previously, sector-level goals usually have longer time horizons (e.g., 10 to 30 years out). BPS compliance cycles are on shorter time frames (e.g., 5 years). Accordingly, BPS targets need to be set on a trajectory to achieve the sector-level goals. A conceptually straightforward approach is to simply draw a straight line from the baseline year to the final year. However, policy makers may want to adjust the straight-line targets based on various considerations. For example, targets may be less stringent in the first compliance cycle to ease the overall process and ensure stakeholder buy-in then become more stringent in later compliance cycles. Historically underserved subsectors may need more time to meet targets. Where a carbon- or grid-related metric is used, the trajectory of BPS and grid carbon accounting will change over time and need to be

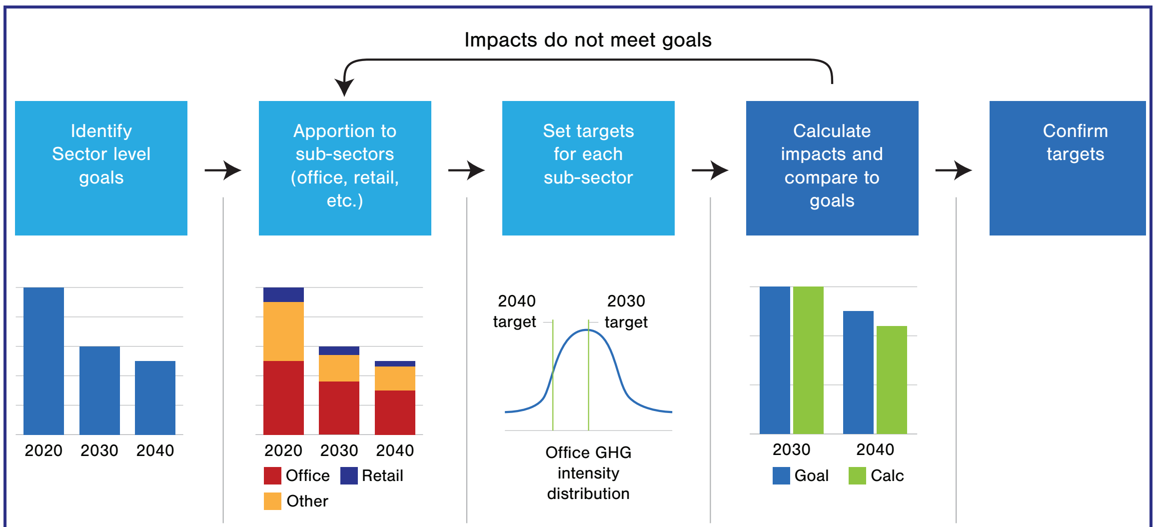

Figure 3.6 Process for deriving targets from sector-level goals.

accounted for in target setting. Note that different trajectories will have different impacts in terms of cumulative emissions, even if the end goal is the same.

3.2.3.5 Strengths, Limitations, and Impacts

The main strength of this approach is that it explicitly ties and aligns individual building targets with long-term sector-level goals. It also allows policy makers to review and determine tradeoffs and adjustments among subsectors based on meeting sector-level goals. By tying targets to existing policy goals, this approach also increases the potential for buy-in for BPS from the building community and other stakeholders. Being able to clearly show the direct linkage between the BPS and the overall goals should assist in the policy's adoptability and compliance. Finally, by focusing on sector-level goals, BPS have the potential to address multiple policy objectives through one ordinance.

One limitation of deriving targets from building performance data alone is that it does not explicitly consider the engineering and economic feasibility of meeting those targets, i.e., whether there are cost-effective technological solutions for buildings to comply with the targets. Therefore, it is important to obtain expert input from energy engineers and building owners on the reasonableness of the derived targets.

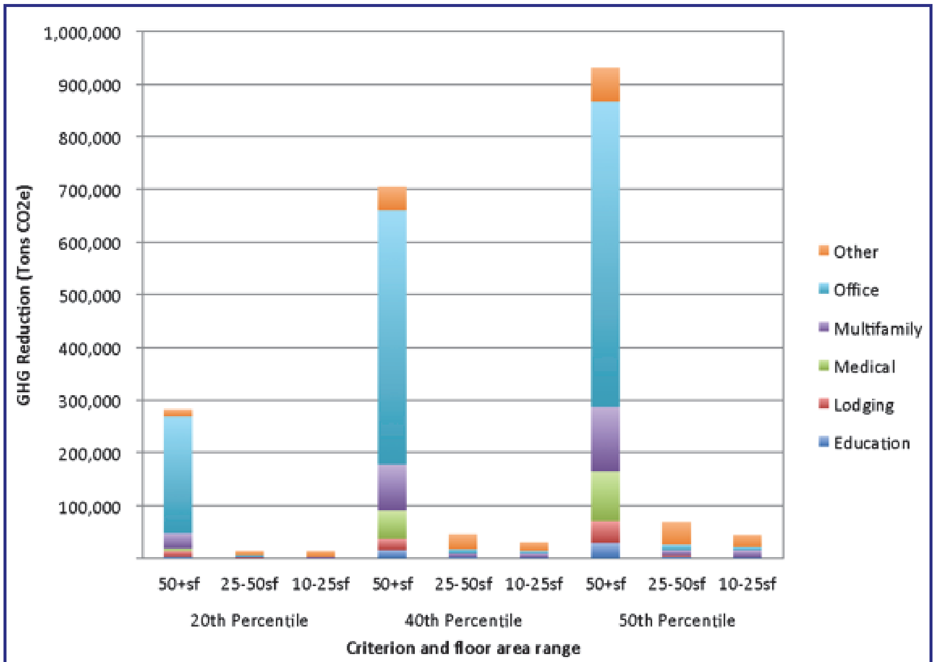

Figure 3.7 Subsector-level GHG impacts of different ENERGY STAR score percentile targets for the BPS in Washington, D.C. (Image credit: DOEE 2019)

Subsector-level goals that are applied uniformly across the whole subsector may inadvertently place a disproportionate burden on buildings in communities with historical disinvestment. An office building in a relatively affluent downtown may have received multiple upgrades over the years, whereas a basically identical building in another area of a jurisdiction may have suffered from lack of access to capital or being underused. The second building will effectively be asked to make larger gains during the same BPS compliance period since both buildings must meet the same targets. Where target-setting analysis can be used to understand this type of unintended consequence, jurisdictions should use data to develop supportive programs alongside targets.

3.2.4 Targets Based on Published Sources

3.2.4.1 Applicability

The approach of deriving targets from published sources can be used by jurisdictions both with and without benchmarking data. When existing data are not available and a jurisdiction is interested in implementing a BPS policy more quickly or in parallel with a benchmarking policy, published data sources can be used to establish BPS targets. When benchmarking data are available, the results of those data can be combined and compared with published data sources to arrive at the BPS targets that would be most representative of the performance of the local building stock.

3.2.4.2 Description

The two most relevant published sources for target setting are ASHRAE/IES Standard 100 (ASHRAE 2018b) and the ESPM Technical Reference "U.S. Energy Use Intensity by Property Type" (EPA 2021b). While there are other sources of building performance data, these two publications are notable in that they explicitly define targets that are based on statistical analyses of nationally representative building performance data. Table 3.3 provides additional information on these recommended published sources and their applicability to BPS target development.

3.2.4.3 Data Requirements

One major advantage of setting targets based on existing published sources is that in this approach the primary data requirement is basic information about the existing building stock,

Table 3.3 Published Data Sources for Target Setting

Source	Description
ANSI/ASHRAE/IES Standard 100-2018, *Energy Efficiency in Existing Buildings* (ASHRAE 2018)	This standard provides criteria that aim to improve the energy efficiency and performance of existing buildings. To comply with the standard, buildings must meet the specified energy performance for their building type or implement a mandatory set of energy efficiency measures whenever the target is not met. The metric and benchmarks may be set by the authority having jurisdiction. In addition, buildings must develop operations and maintenance and energy management plans. The standard provides EUI (site, source, and fuel-based) targets for 53 building types across all U.S. climate zones, including both residential and nonresidential buildings, based on CBECS and RECS data.
"U.S. Energy Use Intensity by Property Type," ESPM Technical Reference (EPA 2021b)	The ESPM is most commonly known and used as a tool for building owners to document and benchmark their building's performance against other buildings of similar type. However, the U.S. Environmental Protection Agency (EPA) also periodically publishes the median site and source EUIs achieved by different building types at a national level. These values are updated regularly and are typically derived from the CBECS, industry surveys, or similar data sources. The national median site EUI and source EUI values in this publication signify that half the buildings of each type use more energy than their corresponding median, while the other half uses less. It is important to note that these values do not account for variations in climate zone. In most cases, this is because there is not enough data to support development of credible medians by climate zone.

making it less data-intensive than other approaches. Each of the two published sources recommended in this subsection has its own data requirements:

- **ASHRAE/IES Standard 100.** This standard provides target EUIs for 53 building types, which were created based on the building's activity type. This means that rather than a single category for office buildings, EUIs are provided for multiple subcategories of offices, including administrative/professional office, government office, medical office (nondiagnostic), mixed-use office, and other office. To use this standard for target setting, jurisdictions need to be able to categorize each of their buildings into at least one of the 53 types provided, which will require more specific information about the activity of the buildings in their stock. Standard 100 allows buildings to be identified by more than one building type and have the target prorated by the area of each type of use. The standard also provides targets for these building types in each climate zone, so information on a building's location and climate zone may be necessary for jurisdictions that cover multiple counties and potentially multiple climate zones.

  In addition, Standard 100 provides a table of operating shift multipliers that enables users of the standard to adjust their building's energy performance to account for variations in the weekly operating hours of their building compared to what was used to develop the targets laid out in the standard. While knowing the operating hours of all buildings in the jurisdiction's stock is not essential for target setting, if the data are available, it may be useful to conduct analyses of the influence of operating hours on the overall outcomes of the BPS to determine whether targets need to be adjusted.
- **"U.S. Energy Use Intensity by Property Type."** In this resource, buildings are categorized based on three characteristics—broad category (education, food sales and service, healthcare, office, retail, etc.), primary function (mall, medical office, data center, preschool/daycare, etc.), and detailed function category (recreation buildings that are further divided into fitness centers, swimming pools, etc.). The resource then provides the national median source and site EUIs for each of the building types, using the most granularity possible (while ensuring credible results) from reference data sources such as the CBECS and other industry surveys. To use this resource for target-setting, jurisdictions need to be able to group their buildings into the detailed function categories provided. If detailed function information for buildings is not available, jurisdictions could divide buildings based on primary function or broad category, but this would require rolling the targets up into broader categories and result in loss of granularity. Using this resource, targets could be set for buildings with more than one building type by having the target prorated by the area of each type of use.

3.2.4.4 Development Approach

The first step in implementing this target-setting approach is selecting the published source that is most applicable to the jurisdiction. This selection will depend on the jurisdiction's needs and the data available for building categorization. It is recommended that jurisdictions weigh the strengths and limitations of each published source before making a selection.

Once the source has been selected, jurisdictions should decide which performance metric will be used for target setting. Both ASHRAE/IES Standard 100 and "U.S. Energy Use Intensity by Property Type" provide site and source EUIs that can be selected. Standard 100 goes one step further by providing electricity and fossil-fuel site energy use targets by building activity category, but these types of metrics are very dependent on building characteristics and system configuration. All of these are energy-based metrics but can be converted to carbon-based metrics by applying the appropriate energy-to-emissions conversion factors. Although the emissions conversion factors for fossil fuels are well understood and are widely published, conversion factors for electricity generation and any district energy systems used by the jurisdiction will have to be determined based on the local energy production fuel mix. See Chapter 2 for additional information on performance metric selection and the advantages and disadvantages of energy- and carbon-based metrics.

The next step is to divide covered buildings into categories that align with the chosen published source and to determine the target that corresponds to each building category. The categories can be broad or more granular depending on the information available, and the target selection will depend on this granularity as follows:

- If the building categories used by the jurisdiction align with the publication, then the published targets can be used directly.
- If the jurisdiction is using broader categories that do not directly align with the publication (e.g., using *office* as a broad category instead of the more specific *administrative/professional office* or other classifications), the published targets should be adjusted to align with the broader category. This can be done by identifying the published targets that should be included under a specific category and averaging them to arrive at a single target.
    - *Example:* A jurisdiction wants to assign a site EUI target to office buildings as a broad category using ASHRAE/IES Standard 100. The jurisdiction's buildings are located in climate zone 3C. The first step is to identify which of the building types included in Standard 100 will be considered by the jurisdiction to fall under the broader category of *office*. Table 3.4 shows an example of subcategories that could be chosen and their corresponding site EUIs. By averaging the site EUIs shown in Table 3.4, the jurisdiction can set a target of 37 kBtu/ft^2/year for office buildings. Alternatively, the jurisdiction could create a weighted average based on the relative proportion of each subcategory.

The targets obtained for each category using this approach can be used directly in a BPS policy. However, it is important to consider the source of these targets and how that might impact their applicability to the buildings in a jurisdiction. For both ASHRAE/IES Standard 100 and "U.S. Energy Use Intensity by Property Type," the primary data source is the CBECS (though the ESPM publication uses separate industry-specific surveys for a number of property types), which collects information on the U.S. building stock at a national level and is updated periodically.

Table 3.4 Example of Site EUIs for Office-Related Building Activity Types from ASHRAE/IES Standard 100

Building Type Number	Commercial Building Type	Site EUI for Climate Zone 3C (kBtu/ft^2/year)
1	Administrative/professional office	33
2	Bank/other financial	47
3	Government office[a]	42
4	Medical office (nondiagnostic)	28
5	Mixed-use office	39
6	Other office	32
42	Post office/postal center	38

[a] A jurisdiction may opt to exclude buildings owned by municipal, state, or federal governments from its covered buildings. See Section 3.1.3 for considerations on building ownership as it relates to the scope of a BPS policy.

In Standard 100, the data from the CBECS is supplemented by building simulation modeling, whereas in the ESPM publication, the CBECS data (or industry survey data) is not manipulated further. Because of the periodic nature of the CBECS and other surveys, the targets derived from those data and included in the publications may not be the most current at the time the jurisdiction is using them (e.g., Standard 100-2018 uses the 2003 version of the CBECS, while the ESPM publication uses the most current version of the CBECS, which is 2012). As a result, the targets obtained directly from these sources may be too high for certain building types and may not result in sufficient impact to the building stock to advance the jurisdiction's goals. Because the publications aggregate CBECS data at a national or climate-zone level, it is also possible that the resulting targets will be lower than what is typically observed in a local building stock, potentially making it difficult to achieve the targets.

To address these challenges, jurisdictions could use the published targets as a starting point and modify them as additional data become available or as publications are updated. Several approaches can be used to achieve this:

- If benchmarking data are available, jurisdictions can compare the published targets to this data (Kono and Kono 2021) and adjust the targets up or down as needed. The extent and nature of the adjustments will depend on the granularity of the data obtained from benchmarking.
- If benchmarking data are not available, the jurisdiction can consider the following options:
  - Use the published targets as a starting point for the first compliance period and provide support and alternative compliance pathways to building owners that cannot comply. Use the performance data reported in the first compliance period to adjust the targets up or down as needed for subsequent compliance periods. Note, however, that target adjustment adds uncertainty for building owners looking to plan far into the future (see the related discussion in Section 4.1 of Chapter 4).
  - Assess the local building stock to determine existing or potential energy efficiency measures that are technically feasible for each building type. This could be done through energy audits or simulation studies, and the information can be used to determine the potential impact that a bundle of efficiency measures can have on the performance metric selected for the BPS (site EUI, source EUI, GHGI, etc.) and to estimate an appropriate percentage reduction for each published target. This is more likely to result in targets that are ambitious yet achievable for the first compliance period. Jurisdictions can use the performance data reported in the first compliance period to further adjust the targets as needed.

Once the initial performance targets have been selected, the next step is to determine the initial compliance period. If existing building performance data are available, jurisdictions should follow an iterative process of understanding the effect of different combinations of performance targets and compliance periods, as outlined in the sector-level goals and benchmarking data target-setting approaches (Sections 3.2.2 and 3.2.3). If existing building performance data are not available, it is recommended that jurisdictions use the steps outlined in this section to arrive at a set of initial performance targets and select an initial compliance deadline of 3–5 years after the implementation of the BPS. This should provide ample time for building owners to understand their building's current performance and identify compliance approaches. Jurisdictions can then use data from the initial compliance period to adjust the targets and compliance periods for each building category.

3.2.4.5 Strengths, Limitations, and Impacts

The primary strength of this approach is that it allows policy makers to point to a published standard when engaging with stakeholders. The primary limitation is that the targets are based on national-level data and therefore may not be representative of the jurisdiction's building stock, including age, climate, and design or operating characteristics. With a less-specific data set, buildings might still miss their targets if the target development did not account for sufficient normalization factors.

Where a jurisdiction is thinking of selecting a target based on GHGI or source EUI, published data like that of the ESPM is additionally limiting because it uses a national average for source energy, which does not reflect variations among regional electricity grids. Without reflecting the regional mix, carbon-based targets may be too lenient and jurisdictions will not see the benefit of savings anticipated from the BPS. Fuel switching is not adequately addressed in either publication. ASHRAE/IES Standard 100 provides electricity and fossil fuel targets based on CBECS data or modeling and does not consider the need for fuel switching or the changes in the use of these different fuels since the standard was developed.

Published sources such as Standard 100 have other advantages beyond just target selection, including an approach to normalization, compliance forms, and other requirements for compliance that may help advance the policy from development to implementation. Additionally, the ESPM is a widely understood tool, used in many jurisdictions for benchmarking compliance reporting, and therefore may help gain stakeholder buy-in.

Overall, this approach provides relatively quick access to BPS because it is straightforward to establish initial targets; but, it may require future benchmarking data to modify the targets in subsequent compliance cycles to be jurisdictionally appropriate in the long term.

3.2.5 Targets Derived from Modeled Performance

3.2.5.1 Applicability

The approach of deriving targets from modeled performance is applicable for jurisdictions that lack existing building performance data (Duer-Balkind et al. 2022) or that have existing data but would like to further tailor the targets to their building stock. This approach can also fill data gaps in any of the three previously described approaches. Additionally, this approach can support jurisdictions that need and have the capability to conduct a more in-depth analysis of efficiency and decarbonization technologies and strategies to meet targets.

3.2.5.2 Description

Building simulation is a long-standing method for assessing building performance that is increasingly used in the industry for design analysis and energy code compliance. Given sufficient and accurate inputs, building simulation can predict a building's performance under a specific set of conditions with a reasonable level of accuracy. This tool can be used in the BPS target-setting process to 1) develop targets when no other building performance information is available or 2) fill gaps in other target-setting approaches.

Many building simulation tools are available, with capabilities ranging from simplified rapid modeling that requires limited inputs to detailed modeling that allows modelers to incorporate specific details about the building envelope; HVAC systems; and operations. Some simulation tools allow modeling of only a single building at a time, while others allow large-scale modeling of a building stock with varying levels of detail. Individual building models can also be used to simulate a stock of buildings by creating representative buildings and extrapolating the results to the entire building stock. An example application of this methodology is the Commercial Reference Buildings models created by the U.S. Department of Energy (DOE n.d.-b). These models include 16 building types that represent approximately 70% of the commercial buildings in the United States and are used in energy modeling software research as well as energy code development and testing (Deru et al. 2011).

Both individual modeling and stock modeling can be used in BPS target setting. Individual building models can provide information on the potential impact of energy conservation measures (ECMs) on a specific building category, helping inform targets for those building types even when existing performance data are available. These more detailed building models can also be used to impute building performance for smaller buildings or for those with specialized end uses, filling gaps in targets set through sector-level goals or benchmarking. When no data are available, jurisdictions can use building simulation to create stock models of their buildings and use those results to conduct analyses on potential targets and compliance periods for different building categories.

3.2.5.3 Data Requirements

As with other approaches, the minimum data requirement for setting targets using modeled performance is basic information about the existing building stock (building occupancy classification, size, climate zone, etc.). However, in addition to data needed for dividing the building stock into separate target categories, a modeling-based approach also requires sufficient information to create building simulations that are representative of the categories being modeled. This information can include operating hours, occupancy levels, HVAC system type, efficiency and controls, lighting type and controls, and any other building characteristics that can be used to build a model. The level of detail required depends on whether the models are being used to fill gaps in existing data or to create a stock model. When using models to impute performance for specific building categories, a higher level of detail will result in more accurate models.

It is impractical for a jurisdiction to model every building when creating a stock model, so selecting the right representative buildings to model is important to reduce the modeling effort while simultaneously obtaining adequate target results. The building types selected should be dictated by 1) the common building types in the stock and 2) the building types that will be covered by the BPS. The building types can be as high level or as granular as needed and can include parameters such as building activity or operating hours (administrative office, 24/7 retail store, etc.). Once the building types are known, additional information about typical building characteristics should be collected to inform the representative energy models. Some of this information may be available from past code compliance and permit applications, but it is unlikely to be comprehensive or to be centralized and accessible. To fill gaps in the data, jurisdictions could consider asking building owners to share past studies of their properties (commissioning studies, energy audits, etc.) or to conduct separate surveys to obtain data. When attempting to collect data from a large number of buildings, jurisdictions may benefit from creating a standardized data scheme that allows them to document the necessary information in a consistent and repeatable way.

3.2.5.4 Development Approach

The first step in developing targets using a modeled performance approach is to collect data about the building(s) that will be modeled. The data collection process should be tailored to the modeling needs and the fidelity needed from the model. Details of the data requirements for different types of modeling needs are outlined in Section 3.2.5.3. This step should result in the selection of building types and key building characteristics to be modeled.

The next step is to select the modeling tool and methodology to be used to develop the models. The modeling tool should be able to accurately represent the characteristics that need to be captured for each building type based on the desired outcomes of the target-setting process. This is especially important when developing detailed models to fill gaps in other target-setting approaches. For example, if modeling a manufacturing facility, the modeling tool used should be capable of capturing industrial process loads. The modeling tool and methodology also should be able to model all the fuels and performance metrics that will be tracked by the BPS (including district energy) or produce sufficiently detailed results that can be easily converted into the desired fuels and metrics. For example, if a grid-integration metric that measures peak demand in kilowatts is being used, the modeling tool should be able to directly provide this input or allow the user to produce an hourly electricity demand profile from which the peak demand can be derived.

The models could in principle be calibrated against measured energy use for the buildings being modeled. This will help improve the outcomes of the modeling process and provide confidence in the results. However, this is a significant effort, and it may be unrealistic to collect performance data for a large number of buildings. Instead, jurisdictions could collect a statistically significant subset of data for the building types they are trying to model.

As an alternative to developing models from scratch, jurisdictions could use existing models such as the DOE Commercial Reference Buildings models (DOE n.d.-b) and modify them to fit the characteristics of the local building stock. Although this approach may provide a starting point for the target development process, it is limited to the specific building types covered by existing models. If the jurisdiction has access to the appropriate technical resources and budget, it is preferable to create new models to represent the different building types.

The models can be used to set BPS targets in multiple ways. The first is to incorporate the modeled results into the data set used in other target-setting approaches, such as targets based on sector-level goals or benchmarking data. When using either of these target-setting approaches, detailed building models can be used to estimate the savings potential from implementing a predetermined set of ECMs. These results can help jurisdictions understand the potential impact of requiring the implementation of prescriptive measures as part of the BPS or provide guidance on how much energy savings is feasible for each building type. Another approach is to use the building models to create a stock model of all the buildings in the jurisdiction, then use the results to conduct analyses on the distribution of performance across building types. This process would be similar to that conducted with benchmarking data (described in Section 3.2.2.4) and is intended to help inform both the performance targets and the compliance periods of the BPS. Modeled performance can be used to determine performance targets over the entire lifetime of the BPS policy and also to help jurisdictions understand the impact of companion policies on electrification, energy codes, and building operation requirements.

3.2.5.5 Strengths, Limitations, and Impacts

Targets based on energy modeling can better detail the level of performance improvement that is feasible for the jurisdiction's specific building stock. This specificity can create the potential to set progressive targets that account for the phasing in of energy efficiency improvements and varying levels of electrification in the target-development process and may allow for relatively simple future updates as the building stock changes. It can also provide detailed information on the impacts of different retrofit measures meeting a given target.

The largest limitation of this approach is that it requires significant time, budget, and expertise to conduct. Many jurisdictions may not have these resources available, requiring a contractor or outside expertise, which could become expensive. The baseline data required for analysis are also a potential burden, with a detailed level of data needed for the existing building stock that many jurisdictions may not have on hand. Even with detailed data, there may be a need to create customized building prototypes in place of the DOE models to better account for regional or local variations, adding more complexity and limiting potential replicability. Finally, as with all modeling, accuracy is always a limitation. Where jurisdictions can invest resources into such an effort, data resulting from the analysis could be used for cost studies and other analyses and reporting that may be requested by stakeholders in policy development, making those requests relatively easier to meet. However, as with any modeled data, the reliance on modeling rather than real building data will leave the analysis open to scrutiny and potentially decrease buy-in from the community.

Additionally, where jurisdictions attempt to use a modeling approach but do not fully account for variations in age, size, occupancy, or other key factors that are known to impact EUIs, some buildings may be given unachievable targets.

3.3 Normalization of Targets for Specific Factors

Buildings are complex systems, and their energy performance can be affected by a variety of occupancy, use, and environmental factors, such as operating hours, occupant density, plug-load intensity, weather, and others. Many of these factors can be challenging for an existing building to modify in order to meet a BPS performance target. Normalizing building performance to account for the impacts of some of these factors with typically large impacts can help ensure that buildings complying with BPS are fairly assessed against their targets. However, there is a trade-off between simplicity and degree of normalization. Jurisdictions should carefully consider this trade-off with stakeholders and determine a degree of normalization that is reasonable to implement in practice (EPA 2022).

A variety of normalization methodologies exist and are in use in a variety of energy applications. However, there are two common normalization calculation methods that are applicable in the context of BPS and can be used to adjust performance targets based on weather or building characteristics. The first is the method used to determine the target EUI (EUI_t) in ASHRAE/IES Standard 100, which allows targets for a given building to be adjusted based on operating hours. Section 3.2.1.2 shows the equation used in Standard 100 to determine the energy target in terms of site or source EUI for a given building. Figure 3.8 includes an excerpt from the standard showing target normalization factors for different building types based on weekly operating hours. The BPS policy in Washington State, which uses Standard 100, allows targets to be normalized for operating hours.

No.	Building Activity/Type	Weekly Hours: 50 or Less	Weekly Hours: 51 to 167	Weekly Hours: 168
1	Admin/professional office	1.0	1.0	1.4
2	Bank/other financial	1.0	1.0	1.4
3	Government office	1.0	1.0	1.4
4	Medical office (nondiagnostic)	1.0	1.0	1.4
5	Mixed-use office	1.0	1.0	1.4
6	Other office	1.0	1.0	1.4
7	Laboratory	1.0	1.0	1.0
8	Distribution/ship center	0.7	1.4	2.1
9	Nonrefrigerated warehouse	0.7	1.4	2.1
10	Convenience store	1.0	1.0	1.4
11	Convenience store and gas	1.0	1.0	1.4
12	Grocery/food market	1.0	1.0	1.4
13	Other food sales	1.0	1.0	1.4

Figure 3.8 Excerpt from Table 7-3 of ASHRAE/IES Standard 100 showing operating hours normalization factors for different types of commercial buildings. (Image credit: ASHRAE 2018; reprinted with permission)

The ESPM uses several normalization factors derived from multivariate regression to adjust the score of a given building. The factors include weather (in the form of heating and cooling degree-days), floor area, operating hours, number of workers per 1000 ft^2, number of computers per 1000 ft^2, and other factors that differ by building type (EPA 2021a).

Note that any given normalization factor may not be applicable to all building types. For example, even a factor such as operating hours—which applies to almost all building types—may not be relevant to hotels and similar facilities that operate 24/7. Therefore, it is important to determine the applicability of normalization factors separately for each building type. Depending on the factors for which normalization is required, jurisdictions may be able to extrapolate the methodologies described in this section, or a different normalization methodology may be required.

3.4 Adoption and Application of Target-Setting Approaches

Most of the current target-setting approaches used in the United States are not a pure application of any one of the approaches described above and, for many reasons, use a combination of approaches. The application of the approaches in selected U.S. jurisdictions as of the date of publication of this guide is described in the following subsections.

3.4.1 Current U.S. BPS Target Approaches

3.4.1.1 New York, New York: Sector-Level Goals

New York City's approach to the development of their BPS, known as LL97 (NYC n.d.), was set to meet the city's emissions reduction goal of 80% by 2050. The approach used a set of increasingly stringent targets, starting in 2024, to reduce energy use and building emissions toward the city's long-term goal. The city conducted an analysis to allocate reductions by subsector and set building-level targets that meet subsector- and sector-level goals. Different building occupancy classes are assigned GHGI limits that ratchet down during five-year compliance periods. LL97 allows for compliance through the purchase of renewable energy credits (RECs) and offsets while also creating penalties for noncompliance and variances for financial hardship, allowing for some flexibility in meeting the interim and final targets at both the building level and the sector level. The law also directed a study of a potential carbon trading system, which could create an incentive for buildings to exceed their targets and sell their carbon credits in an open market.

Carbon emissions related to grid carbon intensity within LL97 are based on an equation with preset grid emission factors. This means that the actual emissions in any given cycle may not match the equation, making it more difficult for the city to know if their sector-level goals are truly achieved. From the building-owner perspective, knowing the equation and conversion in advance, even if it does not exactly match reality, makes it substantially easier to plan to meet the targets in any given cycle, rather than needing to wait for real-time grid emissions data.

3.4.1.2 City and County of Denver, Colorado: Sector-Level Initial Goals

Denver used a hybrid approach for setting its short- and long-term targets (City of Denver 2021). Initial long-term targets for 2030 were set based on Denver's sector-level reduction goal of 30%, such that each building must meet its own reduction of site EUI to contribute to the overall goal. Individual buildings have their own requirements for custom trajectory and percent reduction under this model. These 2030 targets are complemented by interim short-term targets for 2024 and 2027 that are based on each building's individual 2019 baseline performance. Additional targets will be set in subsequent rulemakings to meet Denver's overall sector-wide goal of 80% GHG reductions by 2040, though it is not immediately clear that those targets will use the same method of target setting. Denver additionally has included target adjustment mechanisms, including a 10% EUI credit for buildings that are 80% electrified and an application process for normalizing target adjustments.

By using custom trajectories, Denver has ensured that buildings without as far to go are not asked to do more than possible. However, without insight into future targets (beyond 2030), owners of poorer-performing buildings may be reluctant to make major improvements that would exceed their assigned reduction for fear of not being rewarded for those efforts in future rulemaking. As a result, there is a risk that this approach may reduce the lifetime energy and carbon impact of the BPS policy by allowing the worst performers to consume more energy with more resulting emissions early in the BPS policy timeline and remain poorer performers for more of the total BPS timeline.

3.4.1.3 Washington State: Published Sources

Washington State began its work based on ASHRAE/IES Standard 100-2018 and established site EUI targets that are specific to Washington State (Washington State 2023). These targets were set at approximately 15% lower than 2009–2018 building averages after analysis and review by a technical task force and stakeholders. Washington State has the only current BPS that sets two different tiers of energy targets: one for older existing buildings and one for newer existing buildings. The newer buildings are those permitted for construction on or after July 1, 2016. Different than what is commonly associated with Standard 100, Washington's BPS policy does not publish a table of targets; rather, it requires each project's compliance target be calculated through a provided equation. Additionally, the state worked to revise implementation and compliance language in Standard 100 to fit the enforcement and compliance mechanisms for the state. This included adding definitions, removing language targeting residential buildings, adding the state-generated energy targets, and revising state compliance pathways.

Washington State's division of buildings into two age groups recognizes that more recently constructed buildings complying with more stringent energy codes should be able to achieve higher levels of performance than buildings of an older age. By differentiating buildings into different performance categories, the overall goals of the BPS across the building stock may be technically more easily achieved than asking very old buildings to perform the same as their more modern counterparts. This division also puts very recently constructed buildings at risk without some guarantee that new construction codes will deliver the defined levels of performance.

3.4.1.4 Washington, D.C.: Benchmarking

Washington, D.C., relied on its benchmarking program to use the ESPM platform for compliance along with the ENERGY STAR score provided for buildings (Council of the District of Columbia 2018). To set their targets, the district focused on the local median score by building type. For building types where an ENERGY STAR score is not available, policy makers opted to use a local median source EUI (or national median EUI for building types where there is too small a local sample), combining the benchmarking data approach with a published sources approach. While the targets for deemed compliance are based on ENERGY STAR score, the district offers three additional compliance pathways: a performance path (reduction of 20% site EUI), a prescriptive path (based on individual audit recommendations), and an alternative compliance path (subject to application and approval). In reviewing potential measures for the setting of prescriptive path compliance options, the district applied a small number of targets derived from modeled performance. This exercise did not produce a clear set of measures that could be applied uniformly to multiple building typologies and ages, leading to the individual prescriptive option currently available. The district will review data in an interim year to set new targets for future compliance cycles, with an eye toward achieving their sector-level climate goals.

While multiple paths give owners flexibility and certainty in the first cycle, these paths may or may not achieve the target score for a given compliance cycle, making target medians for future cycles difficult to predict. One stated goal of targeting the local median ENERGY STAR score or EUI is that the median may naturally ratchet up over time, but this "natural" progress is of course not guaranteed because percentile-based targets are more likely to stall without a strong pull from the top or a significant overachievement from the improving building stock.

3.4.1.5 St. Louis, Missouri: Benchmarking and Published Sources

The BPS in St. Louis requires that its standards be set at the 65th percentile of local building performance (City of St. Louis 2019). Targets for the first compliance cycle were set based on local data for most building types using site EUI, normalized for weather and operations characteristics. Certain types, including food service, library, and refrigerated warehouse, were identified in public comment responses as being better served by national 35th percentile values, still being held to that 65th percentile standard, due to a lack of available local data to set targets. Most properties will have four years from when the standards were approved to meet them. Qualified affordable housing and houses of worship will have six years to meet the standard. St. Louis also offers two alternative compliance paths: narrow the gap (reduce the gap from the 2018 baseline to the target by half), and a custom path (based on an energy audit). In addition, the city is offering an incentive for early adopters to invest in long-term compliance by achieving a target and meeting a 20% (two compliance cycles granted) or 50% (three compliance cycles granted) improvement over baseline. The St Louis targets will be reset at the end of each compliance cycle.

Like those in Washington, D.C., the targets in St. Louis have the potential to stall at the current 65th percentile numbers, which may be due to the limitations of the early adopter compliance cycle to naturally draw buildings over the target, moving the next 65th percentile. The use of a percentile target combined with the city's reliance on collecting and analyzing benchmarking data each cycle may have the unintended consequence of delaying or curtailing renovations that could have saved energy and carbon in the near term due to the long-term uncertainty associated with this type of target setting.

3.4.1.6 Boston, Massachusetts: Benchmarking and Modeled Performance

Performance targets for the City of Boston were developed using historical emissions data based on the city's benchmarking program data collected since 2013 to set emissions standards by building type for 4-year periods between 2025 and 2050, with the long-term target being zero (City of Boston 2021). The city partnered with a contractor to develop performance targets, with an initial analysis evaluating targets with granularity by building typology, size, percent occupancy, age, fuel source, and time-variant effects. This analysis was significantly aided by the initial benchmarking and audit policy: by the time Boston undertook target setting, the city had access to between 200 and 300 ASHRAE Level 2 audits (ASHRAE 2018a) from covered buildings. These audits helped create the modeled buildings in the analysis and ground truth cost estimates for meeting the BPS targets. The technical group eventually recommended that targets be based primarily on building types that were reviewed by a group of technical experts and resulted in the targets presented by the city.

The long-term target setting used by Boston gives certainty to the market, which should encourage long-term planning and investments by building owners. However, that certainty is based on statewide projections related to the cleaning of the electric grid, which may or may not stay on trajectory. Where the electric grid cleans faster than the projections, buildings may be given a free pass in any given compliance period. Where the grid does not meet the projections, buildings may struggle to meet BPS targets.

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4

Major Policy Considerations

Building performance standards require that the governing body or jurisdiction choose the appropriate metrics, set targets, decide which buildings will be covered, and select the compliance pathway options to meet the long-term goals of the policy. But how do covered buildings reach those long-term goals? Will the path be set from day one, or will it be reevaluated as the policy is rolled out? Will changes in compliance rates or the makeup of the electric grid factor in? Are all buildings covered in the initial phase, or will the number of covered buildings increase each cycle? The more guidance on building performance expectations a jurisdiction can provide, the easier it will be for owners and occupants to plan, but many variables exist along the way.

4.1 Setting Short-Term and Long-Term Targets

When defining the target level of performance for a metric and covered building, policy makers have two options: 1) establish a fixed set of targets, or 2) recalculate targets before every compliance period.

Fixed targets are set several cycles in advance and are not dependent on the results of the previous cycle. Fixed targets provide an advantage to stakeholders in that they allow for long-term planning, enabling building owners to look toward future targets and incorporate those goals into operational and capital planning (Cheslak 2020). The following example illustrates what a set of fixed targets might look like:

Primary and secondary education buildings must meet the following site EUI targets:

Site EUI Target, kBtu/ft²	***Deadline Year***
38	*2025*
34	*2030*
31	*2035*
27	*2040*
24	*2045*
20	*2050*

The final target in this example is representative of the long-term goal set by the jurisdiction for these building types. Owners must also meet intermediate goals, set at fixed intervals, providing feedback on progress for both the building owner and the jurisdiction.

Figure 4.1 shows the general compliance process for a BPS policy with fixed targets.

Recalculated targets are adjusted each cycle, incorporating the results of the previous period. Because the new targets are not set until after the previous cycle is complete, owners are left with uncertainty around the expectations for future cycles. Without set long-term targets, owners are less able to plan investments to meet these goals and may delay upgrades in order to avoid costly renovations that could end up falling short (Cheslak 2020). An example of a recalculated target is one where buildings must meet the local median energy use intensity (EUI) for each compliance cycle. Figure 4.2 shows a sample compliance process for a BPS policy with a recalculated target.

Setting a final target for each building type or size before starting out enables better planning with respect to the path to get there but does not account for discrepancies in compliance or major changes to the overall building stock along the way. Choosing recalculated targets allows for more flexibility as buildings adapt to the policy and makes it simpler to adjust for lesser performance, but it puts each cycle in a vacuum, which makes long-term planning more difficult for owners.

In Washington, D.C., for example, targets are based on the median ENERGY STAR® score for that property type, recalculated prior to each compliance cycle (Council of the District of Columbia 2018). The district's stated goal within its *Sustainable DC 2.0 Plan* (Government of the District of Columbia. 2018) is to reduce emissions and energy consumption by 50% by 2032; if the results of the initial cycle show that the built environment is not on track to meet that goal, it may be possible to adjust the targets of the second cycle. Increasing the stringency of targets after the initial compliance period may be necessary when considering climate goals; however, in this scenario, it

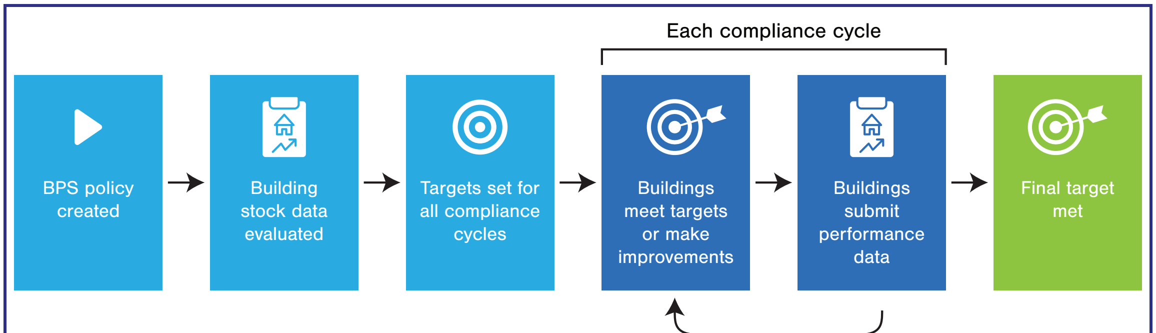

Figure 4.1 Example of a fixed target process.

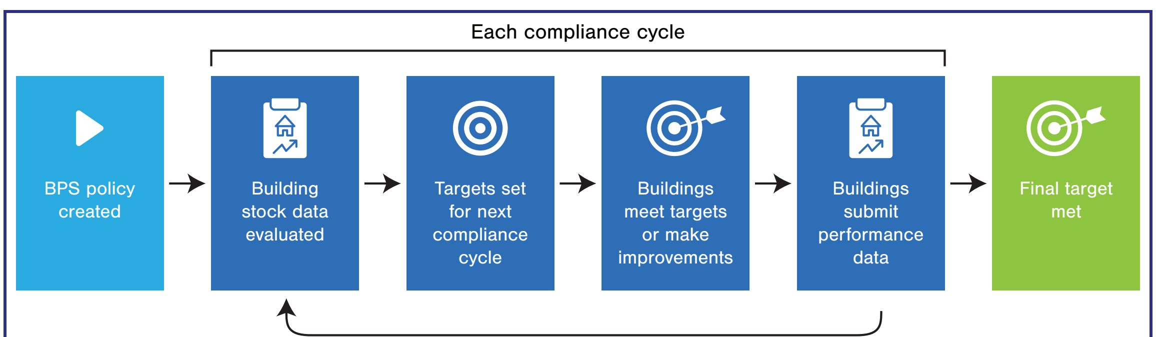

Figure 4.2 Example of a recalculated target process.

could result in unintended consequences. For example, as requirements are expanded to include additional buildings, those that were not part of the first cycle may be required to carry an additional burden due to the shortcomings of previously covered properties, and individual properties may face financial issues if a major capital improvement project intended to meet requirements past the first cycle falls short of the new goal.

With set long-term and interim targets, owners, operators, and tenants can plan and adjust their improvements to coincide with BPS compliance cycles. Capital budgets are often set well in advance and consider variables such as expected equipment life and tenant lease durations. Additionally, some building types may change ownership as often as every few years, further influencing planning decisions.

Establishing interim targets from the beginning benefits those responsible for the necessary building improvements; however, it can be challenging for those establishing the targets. Careful analysis of the existing building stock with respect to the jurisdiction's climate goals, as well as the estimated pace of new construction, is necessary to establish interim and final targets that will result in the anticipated energy and carbon savings. Starting from the final goal year, as set by the climate plan, and working backward to the first year that the BPS could realistically go into effect, the jurisdiction can decide how many phases will be necessary. The number and length of the intervals should be short and frequent enough to ensure that progress is on track but not so short that compliance becomes overly burdensome.

Jurisdictions looking to maintain the flexibility of adjustable targets while providing the structure of established long-term targets could mitigate the uncertainty by working with building owners who are looking to meet future requirements in good faith. Incentives for meeting more aggressive targets earlier in the process could be provided, with guarantees that future obligations are already met, even if the target changes in future cycles. Alternatively, a hybrid approach may be possible, with an established long-term target but flexibility in the specific requirements of each cycle.

One example of a long-term target with interim requirements is the Institute for Market Transformation (IMT) BPS model ordinance, which uses a trajectory approach (IMT 2021b). In this model ordinance, covered buildings are divided into groups according to property type, and for each property type the BPS administrating department sets a final performance standard that must be met by a specified date. In the ordinance, IMT recommends setting final performance standards 15–30 years in the future to allow time for buildings to align their performance targets with their capital improvement plans. In the majority of cases, this extended time frame will incorporate at least one major system upgrade project, such as the replacement of HVAC equipment or roofing. Interim targets are also set, recommended to be at 5-year intervals. While the final performance standards are the same for each property type, the trajectory to achieve interim standards varies for each individual building, depending on its initial performance level. Interim targets are derived from points along the path of a straight line drawn between a building's initial performance and its final performance requirement. All buildings are required to improve to some extent each cycle; however, buildings that begin furthest from the final target will have a much steeper trajectory and will require greater improvements each cycle to meet the interim requirements, as shown in Figure 4.3. Versions of this model have been included in the policies passed in Denver, CO, and Montgomery County, MD.

Denver's Council Bill No. CB21-1310 set a goal of 30% energy reduction of all covered buildings (those over 25,000 ft^2) by 2030, with the ultimate goal of zero emissions from existing buildings by 2040 (City of Denver 2021). Targets have been established for 2030, with initial and interim targets occurring in 2024 and 2027 for each individual building, based on a straight-line path starting from 2019 benchmarking values. Denver's timeline is ambitious and, while commendable, could be difficult to align with capital improvement cycles.

Figure 4.4 shows the default straight trajectory of a building's performance, moving from the baseline year to the final standard, as compared to the building's actual performance after each efficiency measure is completed. At each interim point, the building's performance exceeds that required at that specific point in time. Note that the upgrades described at each interim point are illustrative examples only; each individual building will need to determine the most appropriate actions for it to reach each its interim goals.

One complication of the trajectory approach is the need for dedicated tracking for each individual building for each interim compliance period. All buildings will have their own unique goal to meet for the cycles prior to the final compliance period, with what is acceptable varying not just

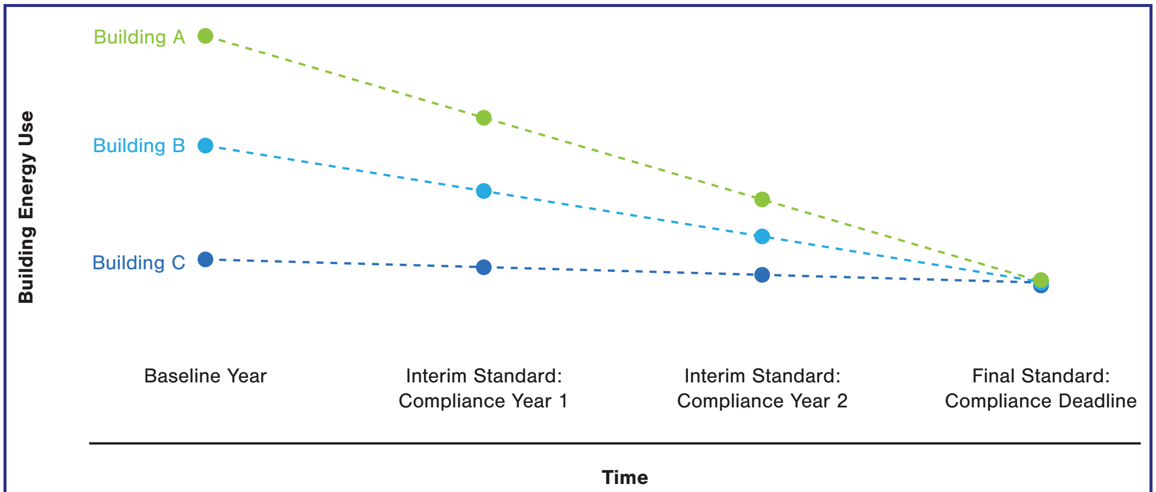

Figure 4.3 Example of an interim target trajectory. (Adapted from IMT 2021a with permission of Institute for Market Transformation)

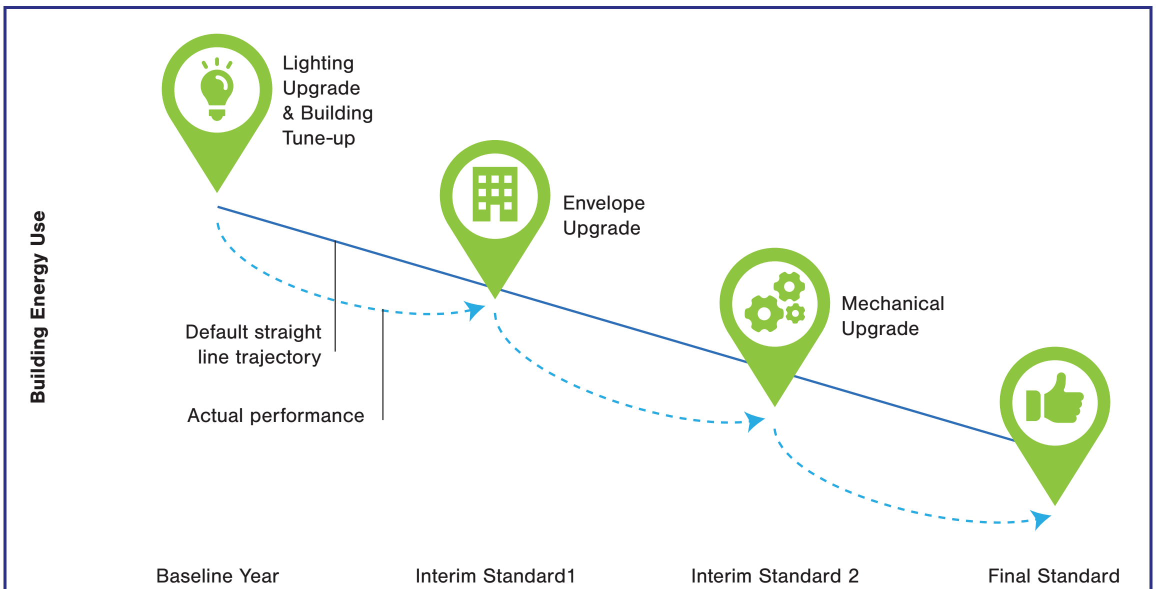

Figure 4.4 Example of a default straight trajectory. (Adapted from IMT 2021a with permission of Institute for Market Transformation)

by building type but for each individual address. Such tracking requires additional data management tools as well as additional staffing for interpretation and enforcement.

4.2 Alternative Compliance Paths

Not all buildings can directly meet the targets laid out by the local authority. Financial or technical barriers and challenges associated with ownership or tenant changes may necessitate workarounds to accommodate these special circumstances.

4.2.1 Allowances for Flexibility in Timing

Variations of the trajectory approach could include nonlinear trajectories, allowing for less-stringent targets initially and increasing requirements as the program ramps up. Another option for flexibility includes the Building Performance Action Plan (BPAP) as demonstrated in the IMT model ordinance (IMT 2021b). The BPAP allows owners facing unusual situations to propose a customized, alternative compliance plan but does not allow owners to use BPAPs to delay improvements unnecessarily. A well-designed plan provides owners with the flexibility to take advantage of existing equipment replacement, financing, and occupancy cycles to reduce or eliminate extra costs. For example, as shown in Figure 4.5, an initial lighting upgrade may reduce energy consumption sufficiently for the first compliance period but not beyond that. The building may be due for more extensive upgrades that the owner needs to group together for either logistical or financing purposes, so they request leeway for the second compliance period so that a major retrofit that includes both envelope and HVAC modifications can be undertaken prior to the end of the final compliance period.

St. Louis established a 6-year compliance cycle for affordable housing and houses of worship to provide flexibility to owners who may face financing and capacity restraints (City of St. Louis 2019). In Washington, D.C., delays may be granted to all properties demonstrating hardship for up to three years, and for affordable housing a longer delay timeline may be granted (Council of the District of Columbia 2018).

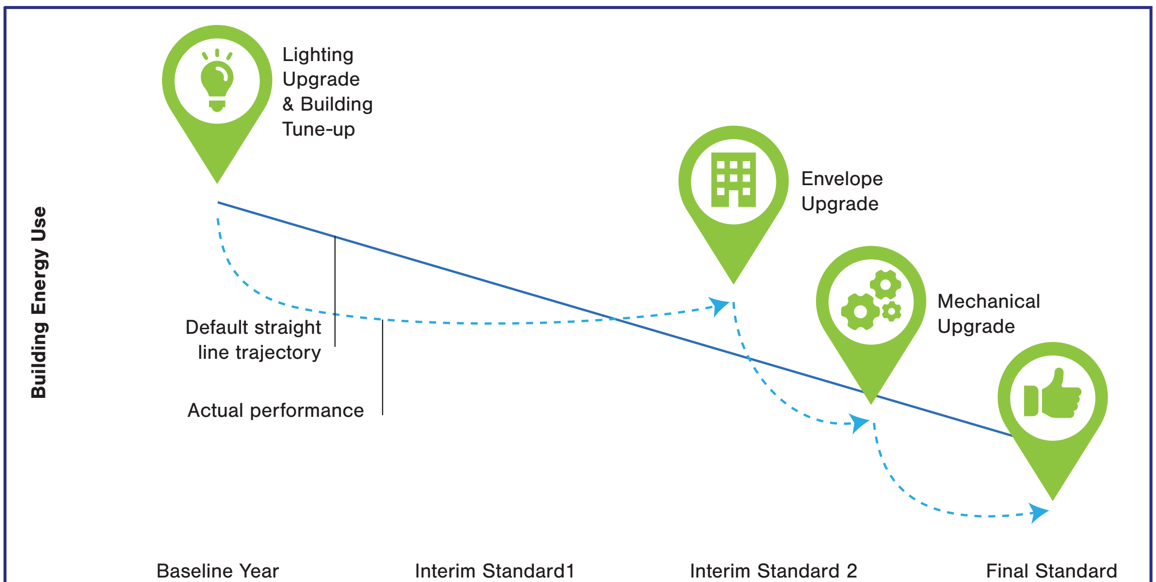

Figure 4.5 Example of timing flexibility. (Adapted from IMT 2021a with permission of Institute for Market Transformation)

When providing flexible options, it is critical to include a legal commitment that is tied to the building and disclosed when the property is sold. Real estate holdings can change ownership every few years, and it is imperative that future owners be aware of the improvement requirements that go along with the property. Options include the requirement that improvement plans be referenced in an attachment to the deed of said property at the office of the Recorder of Deeds or that they be included in any sales listings or contracts.

4.2.2 Portfolio Compliance

Another option may be to allow building owners to meet requirements through a portfolio of properties rather than on an individual building basis. This approach allows owners to consider the technical and financial feasibility of renovations across multiple properties and make the best choices to meet an overall goal. Such an approach may make more efficient use of funds and the available workforce, concentrating efforts on fewer, larger projects at one time rather than spreading smaller and less cost-effective efforts out among all buildings under the same ownership.

While this approach increases flexibility for the owner, it may create a situation where some properties do not receive needed upgrades. Owners may focus on properties with the highest potential for rent increases post-renovation, leaving inefficient or otherwise less-desirable properties to continue to degrade, which may disproportionately affect affordable or rent-controlled housing. This approach also adds to the complexity of tracking compliance on the part of the responsible department.

4.2.3 Prescriptive Pathways

While the basic premise behind BPS is compliance via measured performance factors, in some circumstances it might be too onerous to calculate what upgrades would be necessary to achieve the required performance increase. New York City allows affordable housing, some rent-controlled properties, and houses of worship to comply via prescriptive measures, bypassing the need for energy savings estimates. Washington, D.C., created a prescriptive compliance pathway that requires an energy audit and the implementation of energy efficiency measures designed to be comparable to the performance method; however, buildings following this path will not be penalized if performance targets are not met, reducing owner risk but in turn creating risk for the jurisdiction and its goals. With prescriptive pathways, the resulting savings are not predictable, and what produces significant results in one building may have little impact in another, making it difficult to determine equivalency between the performance and prescriptive options. While prescriptive measures may be necessary to accommodate some circumstances, creating funding sources for financially challenged properties or requiring performance-path approaches to meet missed targets may yield better long-term results.

4.2.4 Structured Approaches

The majority of BPS that have been enacted in the United States specify targets but leave it to building owners and their teams to determine how those targets will be met. Some cases, however, require additional structure and steps to compliance. These additional elements can aid in a building's ability to manage its energy use, but they also reduce the simplicity of the policy. Washington State, for instance, uses ANSI/ASHRAE/IES Standard 100 (ASHRAE 2018) as the basis for its BPS, which includes elements such as an energy management plan and operations and maintenance program for all buildings and requires further steps for noncompliant buildings, such as an energy audit, prior to implementing energy efficiency measures. Structured plans for noncompliant properties can help guide those properties to success, particularly for owners unfamiliar with practices such as energy audits and commissioning.

Another example of a potential structured approach is to use strategic decarbonization assessments. Strategic decarbonization assessments, as developed by Arup and Ember Strategies (Burt 2022), are a combination of an energy audit, a property condition assessment, and a discounted cash-flow analysis of different investment scenarios. The City of San Francisco and New York State (i.e., the New York State Energy Research and Development Authority, NYSERDA) have used this approach for decarbonization of large buildings, which could also be applied as a means to comply with BPS.

4.2.5 Offsets, RECs, and Carbon Trading

Where metrics include greenhouse gases (GHGs) or the use of renewable energy, it would be up to the policy makers to decide whether to allow compliance options such as GHG emission offsets or off-site renewable energy credits (RECs) to enable buildings to comply. Both New York City and Boston allow offsets or RECs to be used to aid in compliance, but with restrictions. For example, in New York City, GHG offsets are limited to only 10% of emissions and RECs can offset 100% of building emissions but must be purchased from energy generated in or directly sinking into the New York City grid (City of New York 2019). New York City also studied a carbon trading program that would allow buildings that exceed emissions requirements to buy credits from those that are below the limit, thus allowing the "portfolio" of all buildings within the city to satisfy the requirement as a whole (Guarini 2021). More directly, Boston allows alternative compliance payments based on the average cost per metric ton of carbon dioxide equivalent (CO_2e) (City of Boston 2021).

Offsets, RECs, and carbon trading as compliance approaches must be carefully considered by jurisdictions when implementing BPS. If the preferred action is to change the building's design and operation or to address other goals such as healthier housing, then offsets and RECs should not be encouraged. On the other hand, these approaches may offer lower costs of compliance and the potential to create revenue streams to invest in communities where assistance is needed.

4.3 How Metrics Affect the Compliance Path

BPS policies that are centered on a final target with predetermined interim requirements are more compatible with certain metrics. Site EUI, for instance, lends itself better to long-term target setting on an individual building basis, as it is the metric over which owners and operators have the most control. Site EUI targets are not subject to external variables the way source EUI, greenhouse gas intensity (GHGI), and ENERGY STAR score are, and they will not vary over time. All metrics other than site EUI are influenced by the makeup of the grid, with ENERGY STAR score further impacted by the current building stock and other factors that change over time.

To directly address the carbon impact of buildings, however, it might be necessary to use a carbon-based metric, either initially or in later cycles. Decarbonization goals may be better addressed with recalculated targets, evolving metrics, or even multiple metrics that combine to achieve a specific goal. If a jurisdiction uses GHGI as a metric, a building taking proactive steps to decarbonize, such as replacing on-site fossil fuel-based equipment, may actually increase their short-term GHGI, depending on the makeup of the grid. One option that could encourage a carbon-based metric in initial stages would be to provide incentives or allowances for early movers. Jurisdictions could also focus on energy reduction in initial policy rollout then shift, or add carbon metrics as the grid evolves. Using both site EUI and a site-specific carbon metric (i.e., an electrification metric or direct emissions metric) provides information on the two key strategies for achieving decarbonization: energy use reduction and shifting from fossil fuels. Chapter 2 provides more detail on the strengths and weaknesses of each metric.

Table 4.1 lists jurisdictions in the United States with existing BPS policies and their methods for establishing targets, their climate goals, and the time frames set for achieving those goals.

Table 4.1 Existing BPS Pathways, Goals, and Time Frames

Jurisdiction	Target Setting	Policy Goal and Time Frame
New York, NY	Absolute (GHGI)	40% for covered buildings by 2030, and 80% by 2050 (City of New York. n.d.)
Washington, D.C.	Recalculated (ENERGY STAR)	50% reduction in all emissions by 2032, relative to 2006 levels (Government of the District of Columbia 2018)
Boston, MA	Absolute (GHGI)	0 GHGI per building by 2050 (City of Boston 2022)
St. Louis, MO	Recalculated (Site EUI)	80% reduction in all emissions by 2050, relative to 2005 levels (City of St. Louis 2017)
Washington State	Recalculated (Site EUI)	45% reduction in all emissions by 2030, 70% by 2040, and 95% by 2050, relative to 1990 levels (Washington State 2022)
Colorado	Undetermined as of the date of publication of this guide	7% reduction in sector-wide emissions by 2026, and 20% by 2030, relative to 2021 levels (CEO 2023)
Chula Vista, CA	% Improvement (ENERGY STAR / Site EUI)	15% reduction in all emissions by 2020 and 55% by 2030, relative to 2005 levels (City of Chula Vista 2021)
Denver, CO	Trajectory (Site EUI)	0 GHG emissions of commercial and multifamily buildings by end of 2040 (City of Denver 2021)
Montgomery County, MD	Trajectory (Site EUI)	80% reduction in all emissions by 2027 and 100% by 2035, relative to 2005 levels (Montgomery County 2021)

4.4 Covered Properties

The required compliance path may vary depending on building type. Jurisdictions may require larger buildings or buildings owned by the local government to comply with BPS first, prior to expanding the requirements to cover most or all buildings in the jurisdiction. In Washington, D.C., for instance, district-owned buildings more than 10,000 ft^2 must comply with the initial cycle, whereas privately owned buildings are not required to comply unless they are over 50,000 ft^2. This approach has an advantage in that larger commercial or government buildings more often have the associated knowledge and resources necessary to evaluate the performance target and plan to meet it. Larger commercial buildings are more likely to have on-site engineers and more robust operating budgets, with more insight into how changes might influence building energy use, while government buildings may have access to a larger network of knowledgeable individuals. Starting with larger buildings may also open up more market opportunities early on, such as firms that specialize in preparing buildings to meet BPS, which would then be positioned to work with smaller buildings. Additionally, larger buildings may be better able to withstand the uncertainty that may surround the rollout of a new policy and its associated enforcement, and a phased approach could help reduce the burden on the staff administering the new policy.

A disadvantage of not including all buildings in the initial rollout relates to long-term target setting for the jurisdiction as a whole: if BPS targets are tied directly to climate policy and specific carbon-reduction goals, the uncertainty associated with a phased rollout would make it harder to calculate progress toward those goals. Presumably, meeting targets down the road will require effort from buildings of nearly all sizes and classifications. If the initial cycle does not result in the necessary decrease in energy/carbon, more may be required in later cycles, and from spaces that are less equipped to invest in major changes and that will have less time to meet the targets.

4.4.1 Exemptions

Some jurisdictions deliberately exclude certain building types from being required to comply with the BPS due to their unique energy usages or perceived difficulties in meeting the requirements. New York City, St. Louis, and Washington State do not require some industrial buildings to comply with their BPS, and Washington State exempts all residential buildings in the first round of rulemaking. As mentioned previously, in New York City exceptions are made for rent-controlled buildings (more than 35% of units) and affordable housing units, as well as places of worship, allowing them to comply via a prescriptive path instead.

While the exemption approach reduces the burden on those that might have financial or technical barriers to compliance, it also denies occupants the full benefits of high-performing buildings, in the case of affordable housing exemptions, or leaves significant energy savings on the table, in the case of industrial buildings. Instead, establishing programs to assist those with fewer resources allows those properties to benefit from BPS without placing an undue burden on the owners. Boston's Equitable Emissions Investment Fund uses funds obtained via policy enforcement to support projects benefitting environmental justice populations and affordable housing buildings (City of Boston 2021), and in Washington, D.C., the Affordable Housing Retrofit Accelerator provides technical and financial assistance to multifamily affordable housing buildings to aid in compliance (DCSEU 2022).

4.5 Building Electrification

One of the main drivers of BPS policy adoption is the need to reduce GHG emissions from the building sector to achieve climate goals. BPS policies can contribute to these reductions by encouraging not only a reduction in overall building energy consumption but, when carefully designed, also the electrification of building systems, which could ultimately lead to the displacement of fossil fuels. BPS policies are often adopted alongside complementary renewable energy policies that drive dramatic reductions in the GHGI of electricity in some regions. If reducing GHG emissions is a primary objective of the BPS, then the impact of different BPS metrics and the integration of electrification opportunities are key considerations for developing a BPS policy that simultaneously promotes building electrification. Chapter 2 provides more details on the impacts of different metrics.

The other key consideration for electrification through a BPS policy is how the policy identifies and leverages other opportunities for decarbonization that may arise during a building's life cycle. For example, buildings periodically undertake renovations, retrofits, and major capital improvements that may be good opportunities for promoting not only decarbonization but also electrification. These types of opportunities could be highlighted and promoted as part of the BPS or could be implemented through companion building electrification policies such as bans that prohibit the installation of new natural gas based equipment in buildings. These gas bans have been adopted for all new construction in San Francisco, Seattle, New York City, and other jurisdictions, and some jurisdictions have announced plans to consider regulations prohibiting the replacement of certain fossil fuel combustion equipment in existing buildings to further drive building electrification. Energy and construction codes could also be updated as companion policies to the BPS to promote the use of electric equipment in new buildings and major renovations if these benefit the overall goals of the BPS.

4.6 Alignment with New Construction Codes

Building performance standards are focused on existing buildings. However, for jurisdictions adopting BPS, it is important to recognize that once a newly constructed or fully renovated building is occupied, it becomes an existing building that will contribute to the jurisdiction's overall energy consumption or emissions, and this should be taken into consideration during the development of the BPS. A building's design and construction or major renovation presents the best opportunity for owners to create a low-energy and low-carbon asset that can help advance a jurisdiction's decarbonization goals and minimize energy costs in the long run.

The performance of a newly constructed or renovated building depends on both the energy design and construction code that was in place at the time of the building's construction as well as its operations and maintenance. Over the past few decades, the adoption of increasingly stringent building energy design and construction codes and standards by states and other jurisdictions has been one of the most effective policies to improve the energy efficiency of new buildings and buildings undergoing major renovations. Figure 4.6 shows the rate of improvement in performance of buildings (based on prototype building energy models) following the prescriptive compliance path of ANSI/ASHRAE/IES Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings* (ASHRAE 2019). However, Figure 4.6 also shows that a significant gap remains between the expected performance of buildings designed to comply with the latest edition of the standard and a net-zero level of performance that can be offset by on-site renewables such as rooftop photovoltaics. Figure 4.6 shows modeled performance of prototype buildings following a stan-

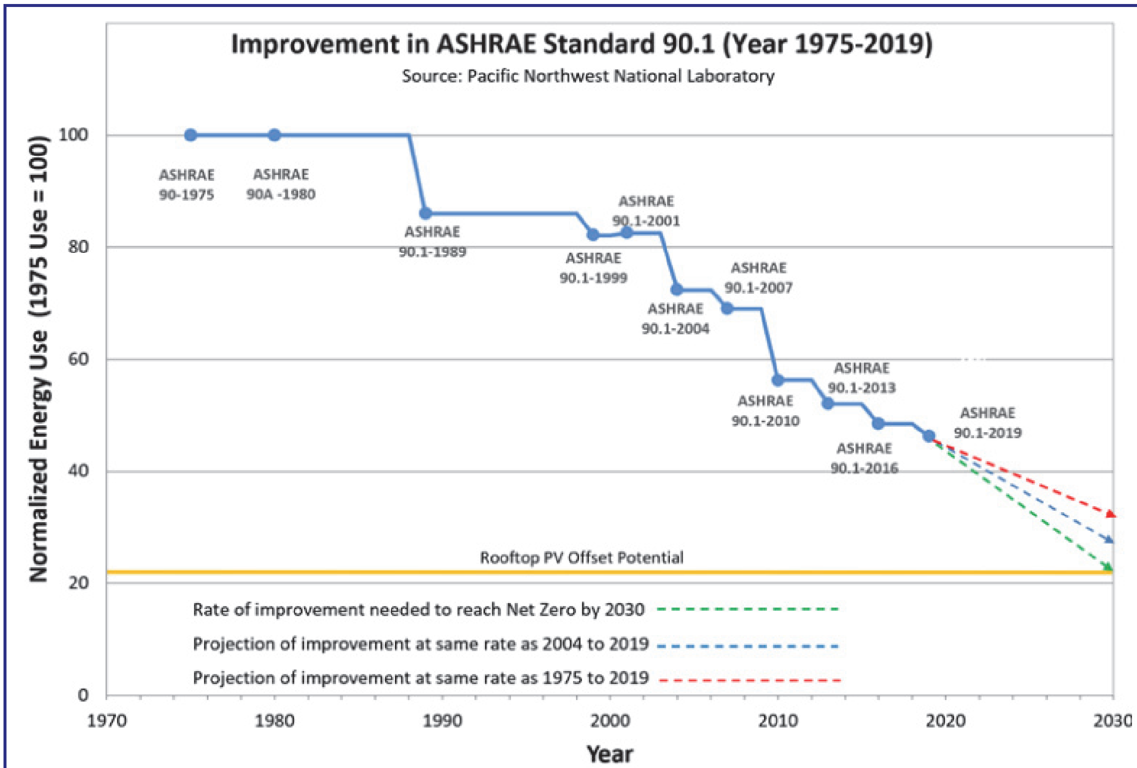

Figure 4.6 Improvement in ASHRAE/IES Standard 90.1 over time. (Image credit: Goel et al. 2021)

dard, not the metered performance that would be regulated by BPS; however, it is intended to illustrate how codes can improve building energy performance.

A code's ability to influence performance ends once a certificate of occupancy is granted, making it challenging for these policies to regulate buildings in the long term and requiring the use of alternative policies like BPS. Most energy codes used in the United States today allow for a prescriptive pathway to compliance that is based on certain building components meeting specific prescriptive requirements rather than estimating how the building performs as a whole. The energy code community has acknowledged the need to update the existing approaches to building energy code compliance to help both code enforcers and building owners alike understand how a new building has the potential to perform after it becomes occupied. The report *Roadmap for the Future of Commercial Energy Codes* (Rosenberg et al. 2015) provides a high-level review of code formats and a vision for next-generation performance-based codes that include building-specific prescriptive packages. These types of performance-based code compliance pathways require new building designs to meet predetermined performance targets when compared against a baseline, and they are gaining increasing traction in industry, with jurisdictions like Washington State and New York City having adopted such pathways for their local energy code compliance.

One of the challenges of performance-based compliance pathways in energy codes is that because compliance is determined through a comparison of the proposed design with a baseline using energy simulation, the building's actual post-construction performance does not play a role in compliance. Code-compliant buildings of similar types and in similar climate zones may see high variation in actual performance after construction because 1) codes allow significant design flexibilities in HVAC system types, fuel sources, construction materials, and other building characteristics; 2) a significant portion of building energy use is not regulated (e.g., plug and process loads, hours of use per week, occupancy, etc.); and 3) building operations are not regulated, so what is used in building simulation for code compliance may not align with the building's actual operations. In addition, about 30% of all new code requirements since 2004 are related to building controls, and successful configuration of those controls is not assured post-construction (Rosenberg et al. 2017). While the performance-based approach is useful for standardizing code development and enforcement, it ideally should be paired with predictive energy modeling that can provide an understanding of how the building is going to perform when occupied. To help ease the transition between new construction and BPS compliance for new buildings, jurisdictions should thoroughly review their energy codes to better understand how the metrics and targets set by these codes align with those being used in the BPS.

4.6.1 Metric Selection for Energy Codes and BPS

Performance-based energy codes and BPS policies require buildings to meet a specific performance target measured by a preselected metric. Most performance-based compliance pathways use energy cost as the metric, while BPS typically use an energy consumption (site or source) or emissions-based metric. Jurisdictions adopting BPS policies should seek to align the metrics being used in BPS and in existing codes (or codes planned for future adoption) to minimize confusion for building industry stakeholders and prevent competing priorities that might encourage different results in performance and detract from the overall goals of the policies.

4.6.2 Target Setting for New Buildings

Although at first glance it may appear that newly built buildings covered by a BPS policy should be subject to different performance targets than other buildings of the same type, it will be simpler for most stakeholders if jurisdictions implement a consistent set of targets to 1) facilitate the target-setting process and the measurement of the impact of the BPS on the building sector, 2) urge consistency across local standards-writing bodies, and 3) simplify enforcement of the BPS, especially for jurisdictions with more limited resources for enforcement. Setting different performance targets based on building age may have the advantage of decoupling existing building performance from new building performance, but would make the BPS more difficult to track and enforce.

When developing targets for a BPS policy, the jurisdiction should consider the stringency of existing new construction and retrofit codes to understand the extent to which recently constructed buildings will be able to comply with the BPS. For example, jurisdictions where energy codes for new construction do not exist or are insufficiently stringent may find that newer buildings fall behind on BPS compliance if the BPS targets are set based on the performance that is technically feasible for a certain building type. These issues may be especially noticeable in jurisdictions whose current code is several cycles behind the most recent editions of ASHRAE/IES Standard 90.1 (ASHRAE 2022) or *International Energy Conservation Code*® (ICC 2021). Even jurisdictions using the most advanced codes that include performance-based compliance pathways may see newer buildings fall behind on BPS compliance if the targets used to determine code compliance do not align with the targets in the BPS. New buildings in jurisdictions with BPS that require a percentage improvement over a baseline may also have challenges identifying and implementing interventions that can achieve the targeted percentage reduction.

To ensure that the BPS targets established are aligned with code, it is recommended that the target-setting process include close collaboration between the BPS development team and code development and enforcement officials, who may be able to provide insight into the performance of new buildings under the existing codes. This collaboration could help ensure alignment in the following areas:

- **Policy goals.** Because both the energy code and the BPS serve the same jurisdiction, there should be coordination in the roles that they play in the jurisdiction's overall policy goals (climate action, building sector decarbonization, etc.) and in the plans and expectations for both in the near term and the long term. If, for example, the BPS use a GHG-based metric but the code allows like-for-like replacements of fossil fuel burning equipment, the building may not be able to meet future BPS requirements. Along those lines, methods to address emergency replacements should also be incorporated into the code when it is next revised.
- **Energy code performance.** Jurisdictions should evaluate whether buildings being designed and constructed under the applicable code will be able to comply with the BPS and consider updates to either the code or the BPS that can align the two. A performance analysis of new buildings could be conducted using data on new construction building compliance (where code compliance requires documenting proposed building performance) or using data collected through preexisting benchmarking ordinances, where applicable. This could help the jurisdiction understand the range of code-compliant new building performance under the existing codes, local conditions, and building use patterns and identify updates to both the code and the BPS that could better align the two (presuming the jurisdiction developing the BPS has the authority to alter the code). Where the data review does not demonstrate alignment between code performance and BPS targets, jurisdictions can evaluate code updates regarding electrification, on-site renewables, or high-performance technology requirements that can improve the performance of new buildings or examine whether the root cause is a lack of code compliance or enforcement.
- **Consistency in performance assessment.** In addition to ensuring alignment in the metric selection between codes and BPS, the use of consistent calculation methods to assess building performance in terms of these metrics is essential to the streamlined implementation of both for new buildings. Examples of calculations that should be aligned include the accounting of on-site and off-site renewables, site-to-source energy conversion rates, and emissions factors to convert from energy use to emissions.

The alignment of these elements of codes and BPS will help strengthen them both and result in more achievable targets for newly built buildings. With the implementation of sufficiently stringent codes, new-construction buildings could be expected to outperform the BPS targets for at least one compliance cycle, allowing new buildings to focus on operational improvements rather than retrofits to continue to improve their performance.

4.6.3 Code and BPS Compliance Considerations

As part of the collaboration between codes and BPS, there is an opportunity for the jurisdiction to review its code development and adoption cycles and align them with the BPS target adjustment and compliance cycles (or alternatively, align the BPS cycles with the code cycles). This would allow the jurisdiction to ensure that future codes are sufficiently stringent such that new buildings are able to comply with the BPS as targets are adjusted over time or to incorporate other requirements such as electrification into the code that, depending on the BPS policy, could help with compliance (again, presuming the jurisdiction has authority over code). Figure 4.7 shows a schematic of the common overlap between codes and BPS compliance cycles.

In addition, the implementation of a BPS policy will add compliance and reporting requirements to existing buildings. Leveraging the information submitted by buildings during their code compliance process could minimize additional reporting for BPS compliance. Codes may also be an avenue to implement metering requirements for new buildings that could help in tracking the appropriate metrics for BPS compliance.

4.6.4 Bridging the Gap Between Codes and BPS

When establishing BPS, jurisdictions should consider that newly constructed buildings that were built and occupied in the years preceding the BPS development may be compliant with the

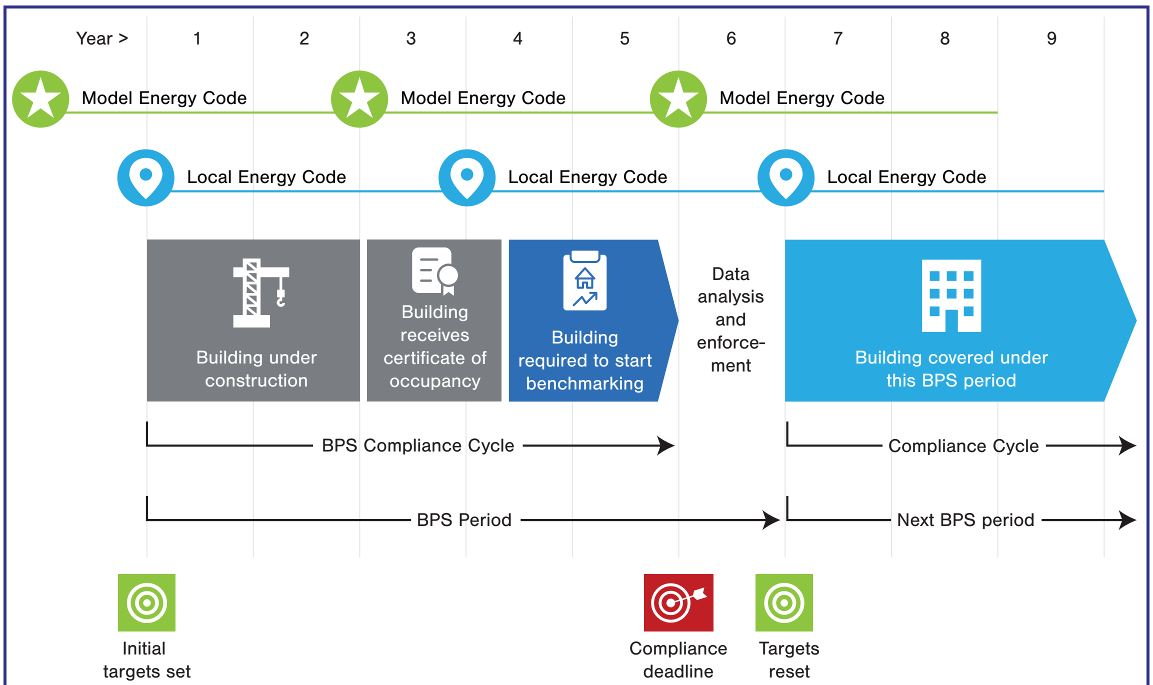

Figure 4.7 Example overlap of codes and BPS compliance cycles, based on a St. Louis BEPS Compliance Pathways Fact Sheet. (Data Source: City of St. Louis 2022)

applicable code at the time of the building permit but not with the proposed BPS. Similarly, buildings completed between the period when the BPS policy was developed and the first compliance period may also be noncompliant with the BPS, depending on the construction code they followed, how well the published targets align with that code, and how the building is operated. Although close collaboration between code officials and the BPS development team as described in Section 4.6.2 could help identify and address these issues through the target-setting process, educating building owners on the BPS and providing alternatives for compliance is also crucial to bridging the gap between code compliance and BPS compliance for new buildings.

To minimize the need for retrofitting newly built buildings, jurisdictions could consider establishing an initial set of performance targets such that buildings built within a specific period prior to the implementation of the BPS policy (within five years prior, for example) and within the period between the policy's implementation and its first compliance period are compliant with the BPS. Jurisdictions could also consider providing alternative compliance options for buildings constructed during these transitional periods, such as allowing noncompliant buildings to apply for extensions or recommissioning to try to bring them into compliance. If buildings are still not compliant after these concessions, retrofits may be required.

4.6.5 Training and Outreach

Training and education of building designers is important to bridge the gap between new buildings and BPS. Informing building owners, designers, operators, and occupants about the need to comply with multiple BPS cycles (that may have increasingly stringent targets) can help focus the design process on creating better-performing buildings. It may also be beneficial to educate building designers and owners on the value and options for building energy simulation during the design process. Compliance pathways for performance-based codes typically require an energy model to demonstrate compliance, but these types of models do not always reflect actual building performance once the building is occupied. A predictive energy model, based on the design and expected building operation for a typical meteorological year (given variations in weather), can help building owners understand the future performance of their buildings. This understanding can inform design and operational decisions to maximize building efficiency.

4.7 Cost and Economic Impact of Implementation

Buildings may require significant investment and upgrades to comply with BPS, with real risk of whether the investments will deliver the expected (and required) energy or carbon reduction. Such investments are not exclusively financial; compliance with a BPS policy also requires technical and staff resources to identify, implement, and manage any necessary building upgrades and to ensure the building is meeting reporting requirements. The levels of access that building owners have to these types of resources can vary significantly.

BPS implementation challenges are particularly pronounced for the affordable housing sector. Energy efficiency investments stemming from BPS compliance would benefit tenants living in affordable housing, as higher levels of energy efficiency can make units healthier and more comfortable for tenants while also reducing costs. However, financial and capacity constraints among affordable housing building owners and their staff present real challenges to achieving compliance while keeping units affordable. Nedwick and Ross (2020) lay out many of these challenges. Owners of affordable housing are less likely to have the upfront capital to invest in building energy efficiency improvements. Furthermore, owners of affordable housing and/or their facility staff may not have the technical know-how to understand and prioritize energy efficiency upgrades. Even when they do, pressing maintenance and repairs may take priority or prevent staff from exploring energy efficiency opportunities. In addition, the split incentive—where the owner pays for updates but the tenant benefits from a lower energy bill—leads to fewer energy efficiency investments in renter-occupied buildings. Navigating these financial and capacity constraints and providing the necessary up-front support are key to ensuring equitable outcomes from BPS. Additional information around energy equity, including energy burden, lack of access to capital, and other related issues is addressed by Hart et al. (2020).

Some building owners point out that it may be impossible for some buildings to meet ambitious BPS that require deep energy or carbon reductions. The level of investment required in some extreme cases could cost more than the demolition and reconstruction of the building. Therefore, jurisdictions developing BPS should consider hardship exemptions for buildings in these circumstances and provide alternative compliance options that may not necessarily include upgrades for buildings qualifying for such exemptions. On the other hand, some owners in less extenuating circumstances may choose to pay a fee rather than perform building upgrades if noncompliance penalties are too lenient. It is critical that the cost of decarbonization efforts be taken into consideration from both perspectives.

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5

Analysis Methods for BPS Policy Design

As discussed in the preceding chapters of this guide, BPS design involves a number of policy decisions such as the scope of covered buildings, selection of metrics, setting of targets, compliance timelines, and so forth. Each of these decisions impacts the policy's energy and greenhouse gas (GHG) reductions, cost-effectiveness, implementation effort, etc. Policy makers and stakeholders need credible, quantitative information on these impacts to evaluate trade-offs and make informed decisions on policy design. This chapter describes the technical methods available for data-driven analysis of BPS policy design choices and their impacts. *Note:* This chapter provides considerable detail on analysis methods and is primarily intended for technical stakeholders who are conducting the data analysis.

5.1 Analysis Objectives and Methods

The first step of BPS analysis is to articulate a set of policy questions that the analysis seeks to answer. These are driven by the policy-making process and stakeholder concerns specific to each jurisdiction. The analysis questions should be as specific as possible to appropriately scope and prioritize analysis tasks and select the appropriate methods. Table 5.1 provides examples of analysis questions for various policy design considerations.

There are a variety of methods available to examine these policy questions. The suitability of any given method depends on several factors, including data availability, desired accuracy, level of effort, and expertise required, among others. Broadly, these methods can be categorized as follows:

- **Stock models using empirical energy data.** These models typically combine tax assessor data with data on building benchmarking and other measured energy use to determine current energy use/emissions and then apply building-level target reductions to determine the impacts of different policies over time. The key strength of empirical models is that they are based on measured data from actual buildings. The key limitation is that it is very difficult to obtain or derive system and end-use data for each building and therefore this method may not be viable for policy questions requiring detailed system-level data and analyses.
- **Building stock energy modeling.** These models use basic building characteristics to develop simulation models to represent individual buildings in the stock, or a representative sample of them. Assumptions for building-system and component data used in the simulation are based on building age, type, or other basic characteristics. The energy data are then generated from the simulation model. The key strength of simulation models is that they allow analysis requiring detailed system characteristics and end-use data. The key limitation

Table 5.1 Examples of Policy Analysis Questions

Policy Design Consideration	Example Questions
Current energy/emissions of the building stock	What are the current energy use and emissions of the building stock, broken out by building type, age, floor area, etc.? What percentage of the emissions are from multifamily buildings greater than 20,000 ft^2?
Selection of BPS metrics and targets and impacts on the building stock over time	What is the total emissions reduction from setting site EUI targets corresponding to ASHRAE/IES Standard 100? What is the difference between using site EUI versus GHGI on total emissions in 2030 and in 2050? What is the impact of exempting hospitality and healthcare building types? What building types have the greatest potential to reduce the emissions for the building stock? What is the impact on cumulative emissions of starting compliance in 2030 versus 2025? What is the impact of setting different targets by age of building?
Impact of electrification and a changing grid	What is the impact on total emissions in 2030, 2040, and 2050 of requiring electrification-on-replacement for space heating and service hot water equipment? How does an electrification-on-replacement requirement compare to a GHGI requirement in terms of total emissions reduction? What is the impact of the changing emission rates of the grid on total emissions?
Alignment with energy codes for new and existing buildings	How much will code requirements for existing building alterations and additions contribute to meeting BPS targets? When will code-compliant newly constructed buildings be out of compliance with future BPS targets?
Normalizing building-level targets for operating conditions	How much should targets be adjusted for unusually high or unusually low operating hours and high-energy-use space functions? How much should targets be adjusted for weather conditions?
Types and levels of energy efficiency/electrification retrofits needed to meet BPS targets	What percentage of buildings will need to reduce energy use by more than 20%? What bundles of lighting and HVAC measures will achieve targets for retail/office/hotel buildings?
Cost-effectiveness of building retrofits to meet BPS targets	What are the expected costs for owners to meet the targets, and how does that vary based on their current level of performance? What is the expected return on investment to meet the targets? What are the cost-effective measures by covered building type?
Impacts of alternative compliance paths	What are the energy and emissions reductions from a fixed set of prescriptive measures and how do they compare to the performance-based targets? How much do total stock emissions reductions change if 10% of buildings follow an alternative compliance path?
Impact on communities	Where geographically are the worst-performing and best-performing buildings? What is the impact on any given neighborhood, town, or city in a single compliance cycle? What is the impact on certain community assets (schools, libraries, community centers, places of worship, etc.)? Are there neighborhoods with high proportions of disadvantaged or disinvested populations that need special considerations?
Noncompliance	What are the penalties for noncompliance? Will noncompliant buildings be offered alternative compliance paths? Will noncompliant buildings be allowed a chance to reevaluate compliance after a set time period? What mandatory measures will owners of noncompliant buildings be required to take?

is that the energy results are simulated rather than actual measured data, although they could be calibrated to measured data. Additionally, it takes considerable effort to develop and quality check simulation models and results.

- **Prototype building modeling.** This method simplifies the building stock to a limited number of prototypes (e.g. one per building type, climate zone, or age) with detailed design and operational characteristics, which are intended to be representative of the most popular buildings of a particular type, size, age, and minimum code-compliant design based on survey data, minimum code requirements, and engineering judgment. Prototype models cannot be used to conduct stock analyses but can be used effectively to address certain types of policy questions that do not require stock-level data. For example, prototype models could help answer questions related to the energy efficiency measures that are most applicable or cost-effective for a particular building type. Parametric analysis based on the prototype models also provides an effective way to study normalization for operating conditions. The key strengths of prototype building modeling are that the level of effort is relatively low compared with stock analysis, and the analysis process provides more transparency if preexisting prototype models are used.

Section 5.2 describes the data sources and data preparation processes that are applicable to all three methods, and Section 5.3 describes each method in more detail. Table 5.2 provides a general sense of the applicability of each of these methods for addressing most of the policy design considerations listed in Table 5.1. In some cases, multiple levels of applicability are listed because the applicability of the method depends on other factors (e.g., data availability). In these cases, see the methods' corresponding tables in Section 5.3 (Table 5.3, 5.4, and 5.5) for more details.

5.2 Data Sources and Tools for Common Analysis

This section describes the data sources and tools that might be useful for common analyses. For the data and tools required for a particular analysis method, see the subsection corresponding to that method in Section 5.3.

Table 5.2 Applicability of Methods for Analyzing Policy Design

Policy Design Consideration	Stock Model with Empirical Energy Data	Building Stock Energy Modeling	Prototype Building Modeling
Current energy/emissions of the building stock	High / Medium	High / Low	N/A
Selection of BPS metrics and targets and impacts on the building stock over time	High / Medium	High / Low	N/A
Impact of electrification and a changing grid	High / Medium	High	N/A
Alignment with energy codes for new and existing buildings	Low	High	High
Normalizing building-level targets for operating conditions	High / N/A	High	High
Types and levels of energy efficiency/electrification retrofits needed to meet BPS targets	Medium / N/A	High	High
Cost-effectiveness of building retrofits to meet BPS targets	N/A	High	High
Impacts of alternative compliance paths	N/A	High	Medium

5.2.1 Data Sources

5.2.1.1 Benchmarking Data

Benchmarking data include information for each building subject to a jurisdiction's ordinance requiring disclosure of energy performance data. Benchmarking data typically include use type, floor area, and energy use intensity (EUI) for each building. In most cases, annual site EUI and source EUI are included, and for other jurisdictions, weather-normalized site and source EUIs and individual fuel use intensities may also be included. Benchmarking data may include other performance metrics, such as GHG emissions and ENERGY STAR® score (EPA 2022b). In many jurisdictions, benchmarking ordinances only apply to large buildings (e.g., those with floor areas over 50,000 ft^2), and compliance rates are very high (i.e., the benchmarking data will include nearly all buildings in the classification specified by the ordinance).

5.2.1.2 Audit Data

Audit data generally contain detailed information about a building's spaces, systems, and energy consumption. For example, it might list each individual use type and its corresponding floor area (e.g., 3000 ft^2 retail on the ground floor with 70,000 ft^2 multifamily on upper floors). It might also split out energy use by fuels (e.g., electricity, natural gas) and end uses (e.g., HVAC, lights, plug loads), and the energy data might be monthly or hourly. Audit data often include information about individual systems (e.g., heating/cooling system types, ages, efficiencies) and general information on building use characteristics (e.g., occupancy, operating hours). While audit data are rich, relatively few jurisdictions have audit data available, and when they are available, they are usually only for a small subset of buildings and typically only include large commercial or multifamily buildings.

5.2.1.3 ENERGY STAR Portfolio Manager Energy Data

Energy data from the ENERGY STAR® Portfolio Manager® (ESPM; EPA 2022a) can be useful if a jurisdiction does not have benchmarking data available or if an analysis method requires energy data with higher time resolution than annually (e.g., monthly or hourly). These data typically include site and source energy and may also include individual fuels and individual meters. The data may be only annual totals but are often monthly or biweekly (depending on the fuel). ESPM energy data might not be available for as large a proportion of the building stock as benchmarking data, meaning more energy data imputation may be necessary. ESPM data might only use the Portfolio Manager ID to identify buildings, so matching records from ESPM energy data to other data sets (e.g., tax assessor data) might require additional effort.

5.2.1.4 Tax Assessor Data

Tax assessor data are available for most jurisdictions and typically include all buildings in the jurisdiction. The data generally only include building type and floor area (and other information not particularly relevant to these analyses). In some jurisdictions, tax assessor data contain information on individual units in a building rather than the entire building, so some aggregation may be necessary to use the data in a building-level analysis. Also, additional effort may be needed to match buildings in the tax assessor data set with buildings in other data sets (e.g., using addresses).

5.2.1.5 Commercial and Residential Buildings Energy Consumption Survey Data

The Commercial Buildings Energy Consumption Survey (CBECS; EIA 2022) and the Residential Energy Consumption Survey (RECS; EIA 2020) are data sets that represent the U.S. commercial and residential building stock, respectively. They contain measured data with weights assigned to each sample indicating the sample's prevalence in the population. They have detailed information on each building sample, including energy consumption by fuel and end use and system types and fuels (but not efficiency or age). The end-use data are calculated based on estimated breakdown assumptions instead of metered data. Since the data are a national sample, only the subset of the data with the same region and/or climate as the jurisdiction should be used. The analyst should also take care to properly account for the weight of each sample when including the sample in the analysis.

5.2.1.6 ComStock and ResStock

ComStock™ and ResStock™ (NREL 2022b, 2022c) contain data resulting from simulations of a sample of representative buildings derived from the U.S. Department of Energy (DOE) Commercial Reference Buildings models and Prototype Building Models (DOE n.d.-b, DOE n.d.-c.). Though the data are not real measured data, the results were designed to be representative of the building stock. The results include energy consumption split out by fuel and end use, and also include information on systems types, system fuels, and system efficiencies (but not system age). Only the subset of the data corresponding to the jurisdiction's region and/or climate should be used in the analysis.

5.2.1.7 Other Public Data Sources

There are a number of other public data sources available in addition to those mentioned in the preceding subsections. For example, there are local and regional data sets such as the Commercial Building Stock Assessment (CBSA; NEEA 2019) in the northwest and the Multifamily Statewide Baseline Study in the northeast (NYSERDA n.d.). The Building Performance Database (LBNL 2022a) is a crowdsourced database with almost 300,000 commercial buildings. However, some of these data sources may not be statistically representative of the stock.

5.2.1.8 Field-Based Data

Data on building characteristics such as building geometry, envelope composition, and building systems (HVAC, lighting and controls, etc.) can be obtained from existing building documentation, such as code compliance and permit applications, or other field-based studies conducted by a jurisdiction. These data are unlikely to be readily available and may need to be collected by collaborating with and surveying building owners.

5.2.1.9 Site-to-Source Energy Conversion Factors

When computing source energy from individual fuel consumption, site-to-source conversion factors are needed. Because the factor depends on the generation mix in a region, factors specific to the jurisdiction should be used. ENERGY STAR is a common source of these conversion factors (EPA 2020), though not the only source.

5.2.1.10 Greenhouse Gas Emissions Conversion Factors

To compute GHG emissions from individual fuel consumption, GHG emissions conversion factors (or more commonly *GHG emissions factors* or just *emissions factors*) are needed. Emissions factors are location specific due to the generation mix. In addition, they change over time as the generation mix changes. Because the future generation mix is usually not well known, emissions factors can be assumed to stay the same as current values at least for the near term. Alternatively, projections of future values could be used if the analysis results are likely to be highly dependent on emissions factors (e.g., for an electrification analysis). Cambium (NREL 2022a) is a common source for obtaining these factors.

5.2.2 Data Preparation

This section describes the steps necessary to prepare the data in a data set prior to performing the analysis.

5.2.2.1 Identifiers

An identifier is a string of letters and/or numbers that uniquely identifies a building. Identifiers can be tax lot numbers or in some cases a unique identifier assigned by the jurisdiction. Addresses may be used as identifiers if no other identifier is available, but correctly matching addresses across data sets can be error prone and cause additional effort. Each data set should be checked to ensure identifiers are unique within the data set. To combine data from different data sets (e.g., benchmarking data with audit data), the analyst must ensure that each of the data sets contains the same identifier. If a data set contains data at the space or unit level (rather than the building level), the analyst should make sure the data set includes building-level identifiers.

5.2.2.2 Building Characteristics

Building characteristics include design and operational characteristics such as floor area, building occupancy category, architectural layout, HVAC system type, and efficiency levels of various energy equipment and systems, as well as operating hours, occupancy schedules, and controls. Building characteristic data are the most difficult data to obtain and are rarely recorded consistently and comprehensively by cities and government entities. Combining building types into broader categories that align the building types likely to be used in the BPS policy is recommended. Building types and floor areas should be checked to ensure they are consistent with each other (e.g., if the data include a hospital that is 1000 ft^2, most likely either the building type or floor area is incorrect). Building characteristics may need to be aggregated to the building level if they are recorded in the data at the space, unit, or system level (e.g., different use types for different parts of a building or different occupancy levels for different units in a large commercial building). Floor area weighting typically make sense when aggregating, but other variables could be used.

5.2.2.3 Energy Data

It is important to quality check energy data. There can be errors in energy data (due to, for example, typos when self-reporting) that should be excluded from the data used for analysis. At a minimum, values that are abnormally low or abnormally high (based on engineering judgment or percentiles, or on statistical definitions of outliers) should be excluded. In addition, energy values can be checked against the building size and type to ensure they are reasonable (e.g., the energy consumption may seem reasonable, but the EUI may not, or the EUI may be reasonable, but not for the particular building type). The analyst should also check that the energy data in the particular year of concern are representative of most years (e.g., that the data did not come from a year with abnormal weather or strange occupancy patterns due to, for example, a pandemic).

Significant effort may be required to prepare energy data for use in the analysis (which will generally use annual totals). The analyst may need to aggregate monthly or biweekly data to annual totals and may need to sum up energy use from multiple meters with the same fuel type. When energy use data are provided as totals for individual fuels, the analyst may need to add up multiple fuels (perhaps with weighting factors) to get site EUI, source EUI, or GHG emissions. Energy data may also be used to compute other relevant energy-related metrics (e.g., the electric energy to site energy ratio).

5.2.2.4 Data Imputation

In many cases, the available data will contain information for only a subset of the buildings in the jurisdiction, or some data fields may be missing (or removed during quality checking) for some buildings. In these instances, it is recommended that the analyst impute the missing data to make the analysis easier. For example, benchmarking data may include buildings with a floor area over 50,000 ft^2, but the analyst may want to consider policies for all buildings over 20,000 ft^2. In this case, energy data for the 20,000 to 50,000 ft^2 buildings will need to be imputed. Alternatively, there might only be audit data available for a small subset of the large commercial buildings subject to the policy, and systems data for the other buildings will need to be imputed. The amount of data imputation necessary depends on the particular analysis being conducted (e.g., imputing systems data might not be necessary for a site-EUI-based analysis).

Data imputation commonly includes filling in missing data for some buildings by sampling values from a distribution learned from representative buildings that have data available (e.g., filling in site EUI for office buildings without energy data by sampling from office buildings that have site EUI data). When sampling from distributions, the analyst should confirm that the distributions are realistic and reasonable based on statistical reasoning (e.g., does the distribution contain enough data points? Does it have a strange shape?) and engineering judgment (e.g., is this distribution expected for this cohort of buildings?). When appropriate (and when the necessary data are available), it is recommended that the analyst split buildings into smaller, more representative categories before sampling from distributions (e.g., sampling office-building EUIs from the distribution for other office buildings rather than the distribution for all commercial buildings). Sampling from buildings of different sizes can be appropriate if the quantity being sampled does not depend on size (e.g., EUI) but may not be appropriate for other quantities (e.g., small and large buildings might not have the same types of systems installed).

Generally, data should be sampled from other buildings within the same jurisdiction (e.g., to ensure climate is considered), but data from other nearby jurisdictions can sometimes be used (e.g., filling in systems information using audit data from a nearby city with similar building ages, types, etc.). If there are no data for a particular jurisdiction or for similar jurisdictions, data can be imputed by sampling from national data sets such as the CBECS, the RECS, ComStock, or ResStock (EIA 2022, 2020; NREL 2022b, 2022c) (i.e., from the subset of the data set with the same region and/or climate as the jurisdiction). Finally, if national data sets are not appropriate (e.g., because the jurisdiction is rural and the national data do not include sufficient corresponding data to sample from), the analyst may use a combination of engineering judgment and/or expert opinion (based on knowledge of local energy codes or typical construction practices) to impute missing data.

5.2.3 Analysis Tools

Graphical user interface based data analysis programs (e.g., Microsoft® Excel®, Tableau) are good choices for jurisdictions with limited technical expertise or without sufficient funds to train an analyst to use more advanced tools. Though they are intuitive, these programs are sometimes lacking in their ability to automate analyses or to perform some statistical operations (e.g., sampling values from a distribution learned from data).

Full-fledged programming languages (e.g., Python, R) are good choices for jurisdictions with someone who is already proficient in them. They offer full capabilities with respect to analysis automation and statistical techniques.

For simulation-based methods, the analysis tool needs will depend on the type of simulation being conducted. For stock model development, the tool needs to have the capability to simulate and aggregate large quantities of building energy data to produce a stock model. Examples of these tools include UrbanBEM (Lei et al. 2021), CityBES (LBNL 2022b), and Virtual EPB (ORNL 2022). When modeling prototype buildings for more detailed analyses, whole-building energy simulation tools are good choices. While a wide variety of these types of tools is available on the market, examples of tools that can be accessed at no cost include EnergyPlus (DOE 2022), OpenStudio (DOE 2023), and eQuest (DOE 2018).

5.3 Analysis Methodologies

5.3.1 Stock Models Using Empirical Energy Data

5.3.1.1 Required Data and Tools

The stock models using empirical energy data method requires a list of covered buildings, which will typically come from tax assessor data. It also requires data for the performance metric, which will usually come from benchmarking data, the ESPM, or national data sets like the CBECS, the RECS, ComStock, or ResStock (EIA 2022, 2020; NREL 2022b, 2022c). If the performance metric is based on source EUI, site-to-source conversion factors may be needed. If the performance metric is based on GHG emissions, emissions factors may be needed.

The analysis software needs to perform basic data manipulation (filtering, lookups, etc.), calculation (arithmetic, means, percentiles, etc.), and plotting (histograms, scatterplots, etc.). It also needs to be able to perform the data imputation process (e.g., fitting a distribution to values, then sampling new values from the fitted distribution).

5.3.1.2 Analysis Method

Figure 5.1 shows a schematic of the general process for developing a stock model using empirical energy data.

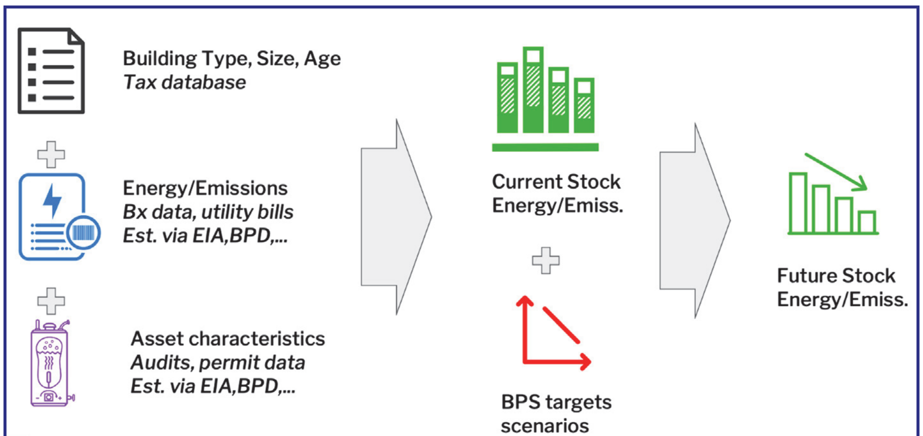

Figure 5.1 Schematic of analysis based on stock models using empirical energy data. (Image credit: LBNL)

The implementation of the analysis should be made flexible and easily configurable to allow exploration of different potential policy designs. For example, the definitions of building type categories might not be certain yet, and the analyst may want to run the analysis for different category definitions and compare the results. Likewise for the performance targets, the timelines for the compliance periods, which buildings are excluded, and so forth.

The exact method used will depend on the data available and on the policy questions. There are seven steps for analyzing the impacts of BPS performance metrics and targets with stock models using empirical energy data:

- **Step 1.** Select performance metric(s) relevant to the analysis question(s) (see Chapter 2).
- **Step 2.** Divide the covered buildings into categories that will have the same performance targets. For example, by building type (or group of building types), by floor area range (e.g.,

<20,000 ft^2, 20,000–50,000 ft^2, >50,000 ft^2), or by a combination (e.g., most categories are just by building type, but some building types are split by floor area).

- **Step 3.** For each category of buildings, compute the distribution of the performance metric and review it carefully. Note how much performance varies within each category (e.g., a distribution with long tails could mean some buildings will have to make significant performance improvements) and across categories (e.g., if two categories have similar distributions, perhaps the categories should be combined, making compliance tracking easier). Figure 5.2 shows an example histogram of site EUI for buildings of a particular type. There are several buildings whose site EUI is much higher than the majority of buildings; these buildings might need to make drastic performance improvements.
- **Step 4.** Start by selecting initial candidates for performance targets and compliance cycle timelines. Performance targets should be selected using a combination of the jurisdiction's policy goals and the performance distributions for each category of building. For example, if the overall goal is an 80% reduction in site energy use, one scenario might be four compliance cycles with a 20% reduction in site EUI during each cycle. If some categories have significantly higher energy consumption than others, their targets might be set lower. If some categories are less likely to be able to meet targets, their targets might be set higher. Several target formats are possible—for example, reducing a metric by a specified amount (e.g., 10 kBtu/ft^2) or particular percentage, reducing a metric to the mean (or a percentile) of the metric for other buildings in the category, reducing a metric by different amounts or percentages in different cycles (e.g., starting with more easily achievable targets), and various others. Alternatively, in the place of performance targets, a potential policy scenario could dictate that buildings must take other decarbonization measures (increasing electric/site ratio, electrifying space or water heating equipment, etc.).

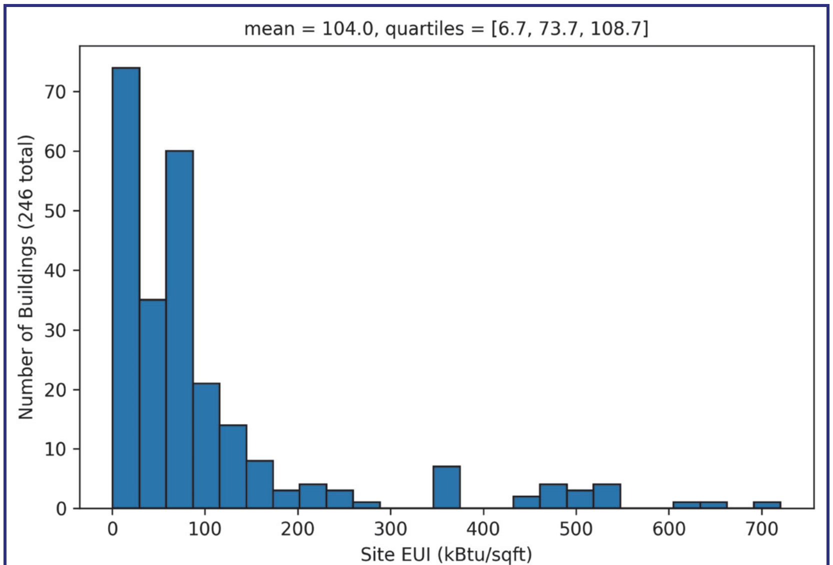

Figure 5.2 Example histogram showing the distribution of performance metrics for buildings in the same category. (Image credit: LBNL)

- **Step 5.** For the initial candidate performance targets and compliance cycles, construct a model that computes the energy consumption of each fuel for each building in each year from the current year until the end of the planned policy period (e.g., from 2025 to 2050). It is important to keep track of consumption of individual fuels because many common metrics (e.g., site EUI, source EUI, GHGI) are calculated from them. Also, some targets based on decarbonization might require individual fuel consumption. In some cases, the model will be simple: If the policy dictates a 10% reduction in site EUI in each cycle, and assuming site EUI reductions maintain fuel/site ratios, then computing the fuel reduction in the next year is a simple multiplication of 10% by the fuel use in the previous year. Some models can be more complex: if the target is based on greenhouse gas intensity (GHGI) and the grid emissions factors are changing over time (e.g., according to a Cambium model), then fuel/site ratios might change over time as well, and computing the fuel use in the next year is not as trivial. Similarly, if modeling a policy requires electrification of equipment, computing the next year's fuel use might depend on the age and efficiency of individual pieces of equipment, the building's fuel/site ratios, and the current year (e.g., because the new equipment's efficiency will depend on it); the model might also need to keep track of the systems currently installed in each building and their ages, efficiencies, and other relevant characteristics. In addition, some models might incorporate the idea that some buildings will fail to meet performance targets (e.g., if the necessary reductions are unrealistically high) or that different buildings might reduce their performance metrics at different times within the compliance period (e.g., some buildings might split the reduction equally from year to year, while some might have no reductions for a few years then larger reductions at the end of the cycle).

- **Step 6.** Exercise the model to compute individual fuel use for each building in each year of the planned policy period, then analyze the results. Depending on the policy objectives, different analyses will be more useful. For example, if the policy goals are simply to reduce emissions, start by plotting total emissions for all covered buildings over time and check whether the emissions targets are met. Check for higher or lower reductions early or late in the policy period (which might suggest changing targets in some cycles) or for long periods with no reductions (which might indicate some buildings have saved as much as they can). Also look at the amount of energy or emissions reductions due to each building category, each building type, each floor area, etc. For example, Figure 5.3 shows emissions reductions of the building stock broken out by floor area range. If some categories are reducing much more than others (relative to their initial consumption), it may mean their targets are set too low. If the analysis includes targets of multiple metrics (e.g., both site EUI and GHGI), then determine how much of the reductions are due to each policy (e.g., to see if maybe only one policy is necessary, or if one policy could be applied only to some buildings). To understand whether the reductions dic-

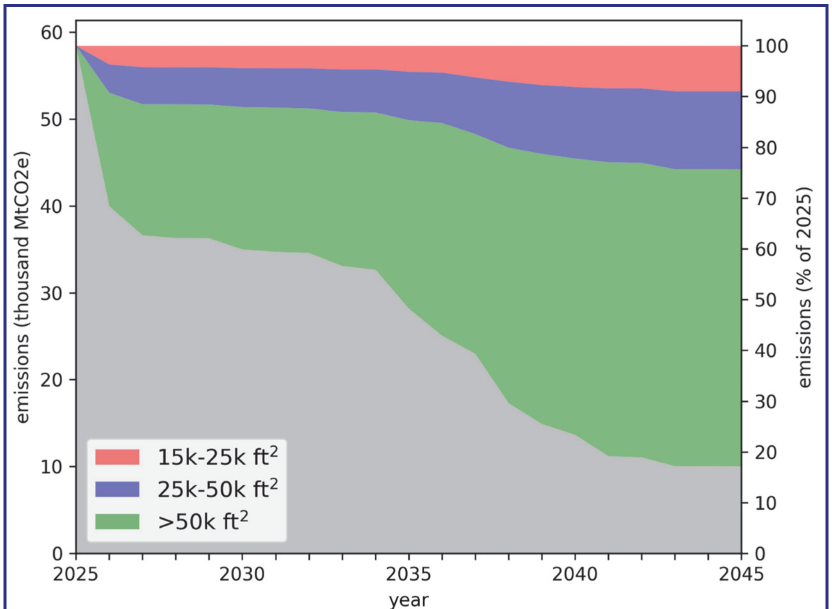

Figure 5.3 Example plot of emissions reductions over time, broken out by floor area range. (Image credit: LBNL)

tated by the policy are realistically achievable by buildings, it is recommended that the distributions across buildings of the reductions in each year, or in particular years with large reductions, be analyzed (e.g., if the model predicts many buildings will need to achieve large annual savings, the policy may need less stringent targets).

- **Step 7.** Iterate the steps of selecting performance targets and compliance cycles, using the model to predict the resulting energy use over time, then analyzing the results to understand the impacts of the policy. It is recommended that the model be run with different policy scenarios and the results be compared to help understand the trade-offs between, e.g., more stringent targets, the numbers and types of buildings needing to save the most, the resulting energy use and emissions (both by categories of buildings and by all the covered buildings combined), and the extent to which policy goals are met. As an example, Figure 5.4 shows the stock emissions reductions over time for scenarios corresponding to three potential policy implementations (with different scopes for an electrification requirement). Policy makers need to weigh the costs and benefits of each potential policy implementation based on these impacts and decide on the best policy for their jurisdiction.

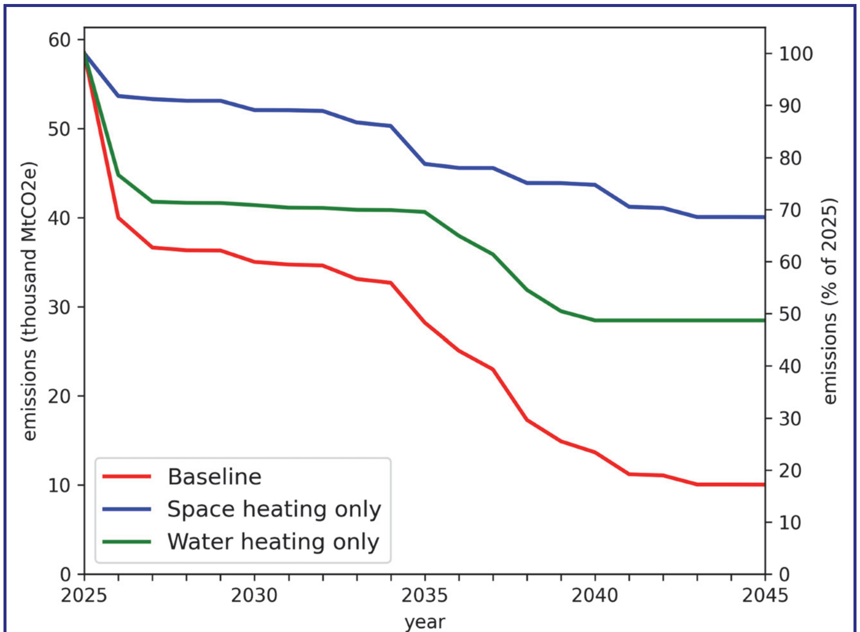

Figure 5.4 Example plot of emissions reductions due to different potential policy implementations (electrification of space heating only, of water heating only, and of both). (Image credit: LBNL)

5.3.1.3 Applicability to Policy Considerations

Table 5.3 describes the caveats and considerations to take into account when using the stock models with empirical energy data method to analyze BPS policy questions.

5.3.1.4 Example Applications

Some examples of jurisdictions that applied the stock models using empirical energy data method to analyze their BPS policy questions follow.

- **Washington, D.C.** The analysis used tax assessor data, benchmarking data, and the Building Performance Database (LBNL 2022a) to determine the distributions of building types and sizes, site and source EUIs, GHG emissions, and ENERGY STAR score. The analysis

Table 5.3 Applicability of Stock Models Using Empirical Energy Data to BPS Policy Considerations

Policy Consideration	Applicability	Caveats and Considerations
Current energy/emissions of the building stock	High	Especially well suited for jurisdictions with benchmarking data. If imputing data from other sources, applicability is medium.
Selection of BPS metrics and targets and impacts on the building stock over time	High	Especially well suited for jurisdictions with benchmarking data. If imputing data from other sources, applicability is medium.
Impact of electrification and a changing grid	High	High applicability if relevant system characteristics data are available from audit data or other sources. If such data are not available and EUI assumptions must be used, applicability is medium.
Alignment with energy codes for new and existing buildings	Low	Performance metrics for new construction would need to be derived separately to compare to BPS targets.
Normalizing building-level targets for operating conditions	High	High applicability if data are available for normalizing variables, N/A if not.
Types and levels of energy efficiency/electrification retrofits needed to meet BPS targets	Medium	Medium applicability if system characteristics data are available or can be imputed, N/A if not.
Cost-effectiveness of building retrofits to meet BPS targets	N/A	
Impacts of alternative compliance paths	N/A	

predicted the energy and emissions savings due to requiring buildings to meet several potential ENERGY STAR score targets. The analysis helped Washington, D.C., choose the scope of their BPS (i.e., which floor area ranges of buildings) and the BPS targets (i.e., which percentile of ENERGY STAR score) appropriate for their policy goals (Bergfeld et al. 2020).

- **Seattle, WA.** The analysis used tax assessor and benchmarking data to understand the city's building stock and energy consumption. It predicted energy and emissions reductions due to several potential policy implementations, including scope (which building sizes and types), timing (delayed implementation), and targets (amount of GHG reduction required). The analysis helped Seattle understand the impacts of their policy and how it interacted with other policies already in place (building tune-ups, Washington State BPS) (Walter and Mathew 2021).
- **Aspen, CO.** The analysis used tax assessor data to construct a model of the building stock and used the CBECS and the RECS to impute energy data (since measured data were not available). It predicted emissions savings due to various EUI and GHGI targets as well as electrification with various efficiencies. The analysis helped Aspen predict the impact of building type exemptions and the relationship between efficiency and electrification policies and current and future grid emissions factors (Walter et al. 2022).
- **Berkeley, CA.** The analysis used tax assessor, benchmarking, and audit data from Berkeley and a nearby city to build a model of the building stock and its energy use. The analysis used

the End-Use Load Profiles for the U.S. Building Stock data set from the National Renewable Energy Laboratory (NREL 2021) to model the systems installed in buildings. Emissions reductions due to electrifying equipment at the time of replacement were modeled. The analysis helped Berkeley understand the effects of subjecting different end uses to the replacement policy, new equipment efficiencies, and how an electrification by replacement compares to a setting-gas-use target (Walter et al. 2022).

5.3.2 Building Stock Energy Modeling

5.3.2.1 Required Data and Tools

The building stock energy modeling method requires basic information about the buildings to be modeled, including building type, location, size, and year of construction, which typically can be obtained from tax assessor data. The information does not have to be limited exclusively to covered buildings because a simulation-based stock model method can be developed for the entire building stock and support policy questions such as the selection of covered buildings. Although a simulation model could be developed using basic building information, additional data on building characteristics, systems, internal loads, and operating hours are required to enhance the accuracy of the resulting stock model. The data can include geometric data, such as the building's aspect ratio or window-to-wall ratio; envelope characteristics (e.g., exterior wall and roof insulation R-values, fenestration U-value and solar heat gain coefficient); and information on lighting, plug loads, HVAC, and hot-water systems (e.g., lighting power density, plug-load density, HVAC system type and efficiency). Detailed data are unlikely to be available for every building included in the model, and assumptions will likely be required to fill data gaps.

The analysis software used in this method needs to be able to accept the building characteristics as input for the simulation and model all the fuels and performance metrics that will be tracked by the BPS. Once the stock model is developed, additional software may be needed, as in the case of the empirical-based method, to allow for data manipulation, calculation, and plotting.

5.3.2.2 Analysis Method

Figure 5.5 shows a schematic of the general process for developing and leveraging a stock model using simulation. This method requires data collection, model input generation, and model development with calibration and validation where applicable. Once the stock model has been developed, the results can be used in various applications. There are three steps for analyzing the impacts of BPS performance metrics and targets using building stock energy modeling:

- **Step 1.** Collect the data described in Section 5.3.2.1 for individual building samples. In some cases, preexisting databases do not provide data for all buildings in a particular geographic area; instead, the data for typical building samples are collected and the weight for each sample is provided. The definition of weight varies by data source; hence, it is necessary to check the definition of weight in the selected data source and understand how to properly use it. For example, the 2018 CBECS provides 6436 building samples with their weights (EIA 2022)—by using the energy data provided in the database and their weights, it is possible to obtain the distribution of energy consumption in the commercial buildings in the United States. For jurisdictions not leveraging existing data sources for their analysis, a data collection process that focuses on a subset of buildings and gathers the distribution weights could help facilitate the analysis.
- **Step 2.** Once data have been collected, they has to be cleaned and converted into model inputs. For example, data sources may not contain building operation schedules in an hourly format that can easily be used in a simulation tool. Thus, a conversion method needs to be developed

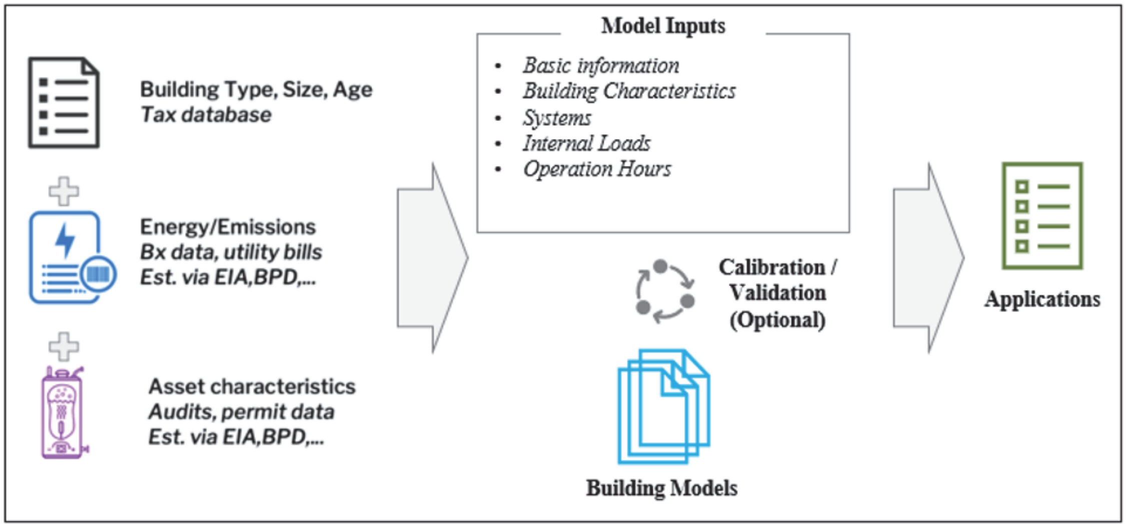

Figure 5.5 Schematic of analysis using building stock energy modeling. (Image credit: PNNL)

to get hourly operation schedules based on some simple operation information, such as weekly occupied hours. Similar conversions may be required to fill in any missing data.

- **Step 3.** After determining the inputs, the next step is to use simulation software to develop the models for the building stock. Because this method requires creating and evaluating models for individual buildings and aggregating the results, the software tool needs to be able to conduct large-scale simulation and analysis. Examples of such a tool include UrbanBEM (Lei et al. 2021), CityBES (LBNL 2022b), and Virtual EPB (ORNL 2022). While the specific input requirements, modeling approach, and outputs of these tools vary, they all generally follow four steps: 1) input preprocessing, 2) model generation, 3) model simulation, and 4) simulation results aggregation. Some tools use a modular approach that can be customized (with limitations) to produce the desired results. The tool used should be capable of generating results for each fuel use at an appropriate level of granularity that allows the model to be used to answer the jurisdiction's policy questions.

The quality of the model results largely depends on the quality of the input data and the extent to which the model can be calibrated to represent actual building fuel consumption. Wherever possible, models should be evaluated and calibrated using existing building energy data. There are various methods to calibrate building stock models using energy-related data in data sources, such as the pattern-based method and the auto-tuning method. For example, if monthly utility bill data for individual building samples are available, the pattern-based method may be a good candidate and a special calibration strategy may be used for each pattern category of monthly energy uses.

5.3.2.3 Applicability to Policy Considerations

Once the stock model has been created and, where applicable, calibrated, it can answer specific policy questions using a similar approach to a model developed from empirical data. The applicability of this method to particular policy questions depends on the accuracy and fidelity of the inputs used to develop the model. For example, if the model was calibrated using existing building performance data, it will better represent the performance of those types of buildings in

Table 5.4 Applicability of Building Stock Energy Modeling to BPS Policy Considerations

Policy Design Consideration	Applicability	Caveats and Considerations
Current energy/emissions of the building stock	High	Applicability is highest if the model is calibrated; otherwise, the results may not be aligned with the actual building conditions and the applicability is low.
Selection of BPS metrics and targets and impacts on the building stock over time	High	Applicability is highest if the model is calibrated; otherwise, the results may not be aligned with the actual building conditions and the applicability is low.
Impact of electrification and a changing grid	High	Can be conducted with or without relevant system characteristics from audit data or other sources but applicability is higher when such data are available.
Alignment with energy codes for new and existing buildings	High	Highly applicable to analysis of new building performance outcomes under different codes and standards and how those outcomes align with the BPS.
Normalizing building-level targets for operating conditions	High	Highly applicable whether data for normalizing variables are available or not, since simulation can be used to parametrically vary input parameters and evaluate building performance under different conditions.
Types and levels of energy efficiency/electrification retrofits needed to meet BPS targets	High	Highly applicable whether system characteristics data are available or not, since simulation can be used to model the impact of different technology mixes on the building stock.
Cost-effectiveness of building retrofits to meet BPS targets	High	Useful for cost-effectiveness analysis at the stock level, but more detailed analysis can also be done through building-level (by type) simulation.
Impacts of alternative compliance paths	High	Simulation can be used to model the impact of prescriptive measures for specific building types and to identify the package of measures that is best aligned with the jurisdiction's goals.

the stock and can be used with higher confidence to answer questions about energy or emissions of particular building subsets.

Table 5.4 describes the caveats and considerations to take into account when applying the building stock energy modeling method to analyze BPS policy questions.

5.3.2.4 Example Applications

An example of how modeling can be used to address the impacts of electrification is a study done in collaboration with the City of San Francisco (Hong et al. 2022). In this study, two districts dominated by commercial buildings (the Design District and Fisherman's Wharf) were selected to study how building electrification at the district scale influences annual building energy use and peak electric demand, as well as how energy efficiency retrofits can complement electrification to mitigate changes to peak electric demand, meeting policy objectives within the capacity of existing energy infrastructure serving the districts. CityBES was used to create EnergyPlus-based energy models for the various types of buildings in these districts. The baseline models are automatically calibrated with available and valid monthly utility bill data.

The electrification scenario shows that annual carbon dioxide (CO_2) emissions are reduced by 37% in the Design District and by 46% in Fisherman's Wharf. Most important to this study, Fisherman's Wharf shows a 109 kW (7.4%) increase in peak electric demand when buildings are electrified without other efficiency measures. The efficiency-only scenario shows that annual CO_2 emissions are reduced by 39% in the Design District and by 22% in Fisherman's Wharf. The combined scenario shows that annual CO_2 emissions are reduced significantly for the Design District (64%) and Fisherman's Wharf (63%).

The analysis shows that electrification of small and medium commercial buildings at district scale tends to increase electricity use and has varying effects on peak electric demand, which may in some cases exceed the capacity of the local power grid (the line segments or feeders or banks). However, such increases depend on the composition of building types in the district and may be offset by higher-efficiency equipment for cooking, space conditioning, and commercial laundry as well as building efficiency measures that reduce heating and cooling load and hot water use. Electrification may shift the time (e.g., from summer to winter) when the peak electric demand occurs for individual buildings or entire districts, especially for baseline buildings with heavy gas use for space heating during winter.

5.3.3 Prototype Building Modeling

5.3.3.1 Required Data and Tools

The prototype building modeling simulations are not expected to represent the entire building stock but rather a set of representative building samples, which will be subject to the BPS policy. A prototype model, like a model for a real building, needs a lot of design and operational details as its model inputs. Analysts choose the prototype method often because they already have a set of preexisting prototype models from other studies, for example, the DOE Prototype Building Models (DOE. n.d.-c). When creating the prototype building models from scratch or when modifying preexisting ones for BPS analyses, the analyst should have a clear purpose. For example, one analysis may need the prototype to represent a typical 30-year-old primary school to understand whether retrocommissioning or retrofits would help the building meet the BPS target and whether the packages are cost-effective for the building owner. Once the purpose is determined, limited data collection and engineering judgment can be used to make the model input decisions. Survey data such as that from the CBECS and the RECS (EIA 2022, 2020), if available, can help to verify that model inputs are within the range of the building type—for example, data like the range of the window-to-wall ratio, the envelope insulation level, and the popular types of HVAC systems and fuel types. The range of real building performance data is also helpful for determining whether the simulated prototype model results are reasonable. ASHRAE Research Project RP-1771 (Zuo and Wang 2022) is an example of prototype building modeling analysis that collect various data to verify the prototype simulation results.

5.3.3.2 Analysis Method

There are two steps for analyzing the impacts of BPS performance metrics and targets using prototype building modeling:

- **Step 1.** Using the data and preexisting prototypes as a starting point, the first step is to establish the baseline prototypes. The prototype building types and ages selected should adequately represent the typical buildings covered by the BPS policy. Decisions need to be made regarding whether to include the prototype's architectural design aspects, such as geometry and thermal zoning, energy systems and components (envelope, interior and exterior lighting, plug and process equipment, HVAC, and service water heating), occupancy, and system operation and controls. As the analysis purpose expands, the model inputs may change with more details, and one set of baselines can be expanded to include another baseline for a different HVAC system type. The analysis should be well documented to include how the model characteristics and inputs were determined and what they represent.

- **Step 2.** Once the baseline prototypes are established, parametric analysis is often used to evaluate the impacts of technology changes and policy on the building performance, measured in different energy metrics. From the building owner's perspective, the detailed prototype models allow measure package analysis and cost-effectiveness analysis to determine the feasibility of BPS implementation pathways and their impacts on the typical buildings. This approach has been adopted by analysts and researchers for policy analysis of building energy codes or technology evaluations and has been used for many years since the development of building energy modeling technology. Therefore, many research consultants and analysts can use their analysis skills to understand the simulation results.

When working with prototype models, the analysis can be expanded by leveraging parametric scripting approaches. The models and their results should be organized through some pre- and post-processing steps that help the analysts and BPS program managers communicate and visualize the results.

5.3.3.3 Applicability to Policy Considerations

Once the baseline prototype models are developed and verified by comparing the results with sample building measurements, the modeling analysis can provide many insights into the impacts of the BPS policy designs on the buildings. A unique benefit of the prototype model approach is that it allows the study of BPS and code alignment. By pairing preexisting code-compliant models with existing-building models developed through the prototype approach, a comparison between the two model sets can show the performance gap between existing buildings and new construction. Parametric analyses of the prototype models can also address some BPS policy considerations, such as generating normalization formulas from sensitivity analysis of operational parameters. Table 5.5 shows the applicability of the prototype building modeling to BPS policy considerations.

5.3.3.4 Example Applications

The City of Vancouver in British Columbia, Canada, used statistical analysis and energy modeling to derive distributions of energy performance, as well as energy and carbon savings, across 5 building types, 48 archetypes, and 10 decarbonization packages. The analysis also included lifecycle cost modeling and citywide emissions modeling, showing cost impacts and trajectories that incrementally drive deeper savings (Duer-Balkind et al. 2022).

DOE's Commercial Reference Buildings (DOE. n.d.-b) are frequently used to simulate energy savings associated with changes in energy codes and standards, particularly as it concerns the cost-effectiveness of proposed code changes (Hart and Liu 2015). In addition, the Commercial Reference Buildings have been used to support the development of the Advanced Energy Design Guides (AEDGs; ASHRAE n.d.), which provide recommendations for different building types to achieve 30% or 50% savings over the minimum requirements of ANSI/ASHRAE/IES Standard 90.1-2004. The AEDGs also cover how to design net zero energy multifamily buildings, K-12 schools, or small to medium office buildings.

DOE's Advanced Energy Retrofit Guides (AERGs; DOE n.d.-a) were created to help building owners and decision makers identify and implement retrofits to their buildings. These guides provide guidance on the most common retrofits for each building type and include comprehensive information on how to calculate retrofit cost-effectiveness. AERGs exist for five building types: office buildings, retail buildings, grocery stores, K-12 schools, and healthcare facilities. Two Prototype Building Models (DOE. n.d.-c) and three Commercial Reference Buildings (DOE. n.d.-b)

Table 5.5 Applicability of Prototype Building Modeling to BPS Policy Considerations

Policy Design Consideration	Applicability	Caveats and Considerations
Current energy/emissions of the building stock	N/A	
Selection of BPS metrics and targets and impacts on the building stock over time	N/A	
Impact of electrification and a changing grid	N/A	
Alignment with energy codes for new and existing buildings	High	Highly applicable for evaluating prototype buildings meeting current new construction codes as well as projected future codes.
Normalizing building-level targets for operating conditions	High	Highly applicable for detailed analysis of variables impacting normalization in a given building prototype.
Types and levels of energy efficiency/electrification retrofits needed to meet BPS targets	High	Highly applicable for evaluating the detailed and specific benefits of energy efficiency measures and electrification technology on a given building prototype.
Cost-effectiveness of building retrofits to meet BPS targets	High	Highly applicable for evaluating retrofit costs and energy savings in a given building type because the characteristics of the prototypes are well defined.
Impacts of alternative compliance paths	Medium	Medium applicability for evaluating scenarios for alternative compliance paths, such as prescriptive retrofit packages for a given building type.

were selected to conduct cost-effectiveness studies for existing building energy retrofits as part of AERG development. The study included both standard and deep-retrofit measures in five cities: Miami, Las Vegas, Seattle, Chicago, and Duluth.

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Understanding Building Performance Standards

Building performance standards (BPS) are an important policy tool for jurisdictions looking to reduce the operational greenhouse gas emissions of their built environments to meet climate commitments. BPS aim to regulate and reduce the climate impact of existing buildings by establishing increasingly stringent targets that require buildings to improve performance throughout their lifetime. BPS also can contribute to decarbonization by regulating building operational performance and by actively seeking alignment with other policies in the jurisdiction, such as construction codes and policies encouraging decarbonization of the electrical grid.

This guide—the first in a series developed by the ASHRAE Task Force for Building Decarbonization—provides a technical basis for policy makers, building owners, facility managers, design professionals, and other stakeholders interested in developing and implementing BPS. It is also a useful resource for engineers and other technical specialists who need to understand the ramifications of BPS on individual buildings or building portfolios.

More comprehensive than previously published documents on BPS, this guide provides deeper technical information on several topics. This content

- explains the variety of options for BPS metrics and some of the key issues in metric selection,
- provides high-level descriptions of the various approaches for setting BPS performance targets,
- outlines major considerations for policy makers developing and adopting BPS, and
- provides methods for analyzing and understanding the influence of policy scope, metric selection, target setting, and other policy questions on BPS and understanding their influence on the policy.

The focus of this guide is larger buildings, in the scope of ASHRAE's standards that cover buildings other than low-rise residential buildings, and North America, where BPS are already in place in several states and cities.

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