Understanding and Choosing Metrics for Building Performance Standards

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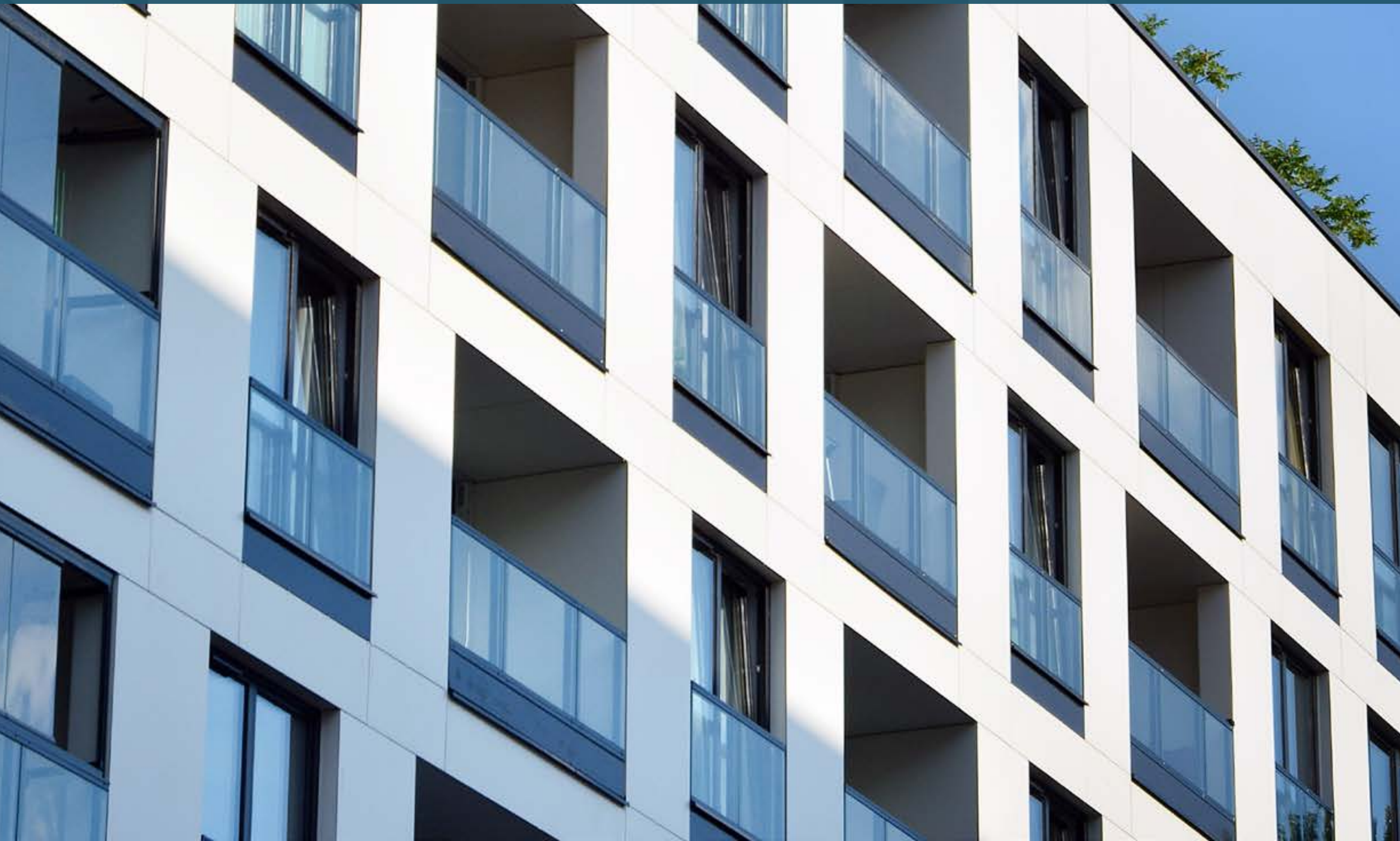

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Introduction

President Biden has called for net-zero emissions, economy-wide, by 2050. Accomplishing this will require increasing efficiency, vastly increasing renewable energy capacity, and transitioning from fossil fuels to clean electricity. Buildings have a critical role to play in achieving each of these objectives. This paper proposes a framework for determining which metrics are best suited for policies to move existing commercial and multifamily buildings forward on the path toward zero carbon emissions.

Choosing the right metrics is necessary for effective policies, but it is not sufficient to achieving a just and inclusive energy transition. Building performance policies — in conjunction with other complementary policies — must bring the benefits of improved performance to those living in affordable housing and historically underserved communities, and at the same time ensure that the cost of compliance does not create new burdens. Jurisdictions must consider the impact of policy decisions on equitable outcomes, particularly with respect to establishing performance levels, options for compliance, and penalties for non-compliance.

Commercial and multifamily buildings[1] account for about 21 percent of U.S. energy use and 19 percent of U.S. CO_2 emissions.[2] Numerous studies show substantial economic potential for greater energy efficiency in these buildings, but barriers such as lack of clear, consistent, and reliable information have hindered the market from eliminating energy waste. Local, state, and national partnership programs, such as the U.S. EPA's ENERGY STAR® program, have long worked to increase energy efficiency and reduce emissions by overcoming these barriers. A core part of the strategy promoted by ENERGY STAR is benchmarking and tracking whole-building energy use with simple, easy-to-understand metrics that drive action. A growing body of research, including analyses of data from several city benchmarking and disclosure policies that rely on ENERGY STAR Portfolio Manager®, documents that consistent benchmarking can improve energy efficiency from 1–4 percent per year on average.[3,4,5] To support the goal of net-zero emissions by 2050, an increase in average efficiency gains in this range must occur across the entire commercial buildings market every year, starting now; in practice, this will mean benchmarking and upgrades in millions of buildings. Today, buildings benchmarking in Portfolio Manager represent about 25 percent of the market by square footage and only about 5 percent by total number.

Stepping up energy efficiency across the commercial sector is essential to an economy-wide transition to clean electricity, a key step on the path to net-zero emissions by 2050. The required growth in clean renewable energy capacity to meet the anticipated demand — and associated grid infrastructure, like transmission and balancing of variable generation through storage and demand flexibility — is staggering. Recent analyses estimate that electric generation under a carbon-neutral pathway would need to increase by two- to three-fold by 2050, the majority of it from renewable energy sources.[6,7,8] One recent study estimates that achieving carbon neutrality by 2050 would require an annual rate of growth of U.S. renewable energy capacity greater than 100 gigawatts; in other words, more than three times the record-setting 2020 growth in wind and solar capacity (33 gigawatts).[9,10] The increased generation needed to meet the net-zero emissions goal would be even greater if not for the contribution of efficiency in the commercial sector to reducing energy use by one-quarter to one-third relative to projections under a business-as-usual scenario[11] — even while commercial building square footage is projected to grow by one-third.[12] Recognizing the importance of ramping up efficiency now, President Biden's plan includes upgrading four million buildings over four years.[13]

Commercial buildings also must contribute directly to the transition to clean electricity under a long-term decarbonization pathway. On average, these buildings obtain over 60 percent of their energy from electricity, about 35 percent from onsite fuels, and the remaining 5 percent from district energy.[14] The analyses of long-term decarbonization pathways referenced above require commercial buildings to increase the proportion of electricity they consume to 70–90 percent of total energy use.[15] The growing demand for clean electricity to power buildings, and an even greater share of transportation and homes, increases the pressure for greater levels of efficiency and renewable energy.

Just as important is the contribution commercial buildings can make to the growth of renewable energy. A recent EPA analysis found that the number of buildings in EPA's ENERGY STAR Portfolio Manager tool reporting onsite renewable energy has increased nearly ten-fold in the past decade — even so, they make up just about 1 percent of all buildings benchmarking in the tool,[16] consistent with a recent survey of onsite solar deployment in commercial real estate.[17] For buildings with limited roof space and other constraints, onsite renewable energy may not be the most cost-effective option. Every building, however, can procure electricity from offsite renewable sources and thereby help spur development of new renewable electricity capacity. Building owners can take advantage of the resources offered by EPA's Green Power Partnership to learn about the opportunities for procuring renewable energy, access technical assistance, and earn public recognition.[18]

To achieve carbon reductions from commercial building energy use, more and more jurisdictions are adopting or considering policies that require buildings to achieve energy, carbon, and/or other performance standards, commonly referred to as building performance standards (BPS). A critical challenge in developing such policies is the choice of metrics for which policymakers will establish baselines and performance levels that building owners will have to meet to comply with the standards. This paper provides a framework designed to help policymakers and commercial building stakeholders understand the key differences among metrics and choose those best suited to a BPS policy.

BPS policies have the potential to move commercial buildings toward zero carbon (in concert with policies targeted at design and construction of new buildings), but it is important to recognize that they represent just one of the tools available to policymakers. Targeted incentives, energy-pricing structures, restrictions on certain practices, and other types of policies may be more effective (and complementary) mechanisms for achieving specific objectives, such as addressing equity concerns, increasing the use of energy storage, or changing patterns of energy use. Likewise, a complementary voluntary recognition program for low-carbon buildings may be an effective way to spur early action and pave the way for all buildings to follow.

This paper is organized in several independent sections:

Section 1 outlines a framework for choosing which metrics are best suited to a BPS policy.

Section 2 provides an in-depth exploration of the various metrics for commercial buildings that are being discussed by policymakers, what they mean, and their implications for decarbonization and efficiency as well as what they might mean for building owners. This section also discusses how some of these metrics can (or cannot) be implemented today in EPA's ENERGY STAR Portfolio Manager tool.

Section 3 provides additional supporting analysis and discussion on two key topics: source versus site energy, and the interplay among electrification, emissions, and efficiency.

Prior to finalizing this paper, EPA separately published recommendations for metrics selection, drawing on the information and analysis presented below as well as input from policymakers and building owners. These recommendations and other EPA resources supporting effective design and implementation of BPS policies can be found at www.energystar.gov/buildings/BPS.♦

Section 1: Framework for Guiding Choice of Metrics for Building Performance Standards

Beginning with California's passage of a benchmarking and disclosure law in 2007, over 40 cities, counties, and states have adopted benchmarking and disclosure laws for existing buildings, affecting close to 100,000 buildings. These laws typically require commercial and multifamily buildings over a certain size to report energy and often water metrics to their respective government agencies, which then publicly release the information. All these laws rely on EPA's ENERGY STAR Portfolio Manager as the tool for benchmarking and reporting energy use.

With this history of energy benchmarking and disclosure and the increasing urgency of confronting the climate crisis, several jurisdictions, as well as the Federal Government[51], have turned their attention to building performance standard (BPS) policies to reduce greenhouse gas emissions from existing commercial and multifamily buildings. BPS policies require these buildings to meet a specific performance target, such as greenhouse gas emissions (adopted by New York City), site energy use intensity (St. Louis), weather normalized energy use intensity (state of Washington), or ENERGY STAR score above the local median (Washington, DC). For a detailed look at these policies, including the metric choices these jurisdictions have made, see this comparison from the Institute for Market Transformation (IMT)[19]. More extensive information is available on existing and emerging BPS policies from IMT, EPA,[20] ACEEE,[21] NASEO,[22] and others.

The choice of metrics is a critical and challenging step for cities, states, and other jurisdictions considering building performance standards.

To help guide this selection process, EPA proposes the following framework, starting with a set of overarching principles.

Principles for Potential BPS Metrics

EPA recommends that jurisdictions choose a set of BPS metrics for further evaluation based on the following principles:

Ensure energy efficiency. There is widespread agreement that achieving cost-effective energy efficiency is an essential step to reducing carbon emissions from buildings. Studies have consistently shown that inefficiencies in building systems waste energy, leading to greater emissions, costs to building owners, and additional energy system infrastructure needs. A strategic approach to energy management, which includes tracking, continuous improvement, and the use of efficient technologies, can reduce this waste, and save money for building owners. To move forward on the path to a decarbonized economy by 2050, we need to step up our efforts to achieve all cost-effective energy efficiency. Building performance standards should always include a metric targeted to energy efficiency and should not trade off efficiency with other goals.

Employ simple metrics to send clear signals. EPA's decades of experience moving the market to greater efficiency through ENERGY STAR and greater renewable energy through the Green Power Partnership are testament to the power of simplicity. EPA has consistently found that easy-to-grasp, clear metrics are critical to driving action. Each BPS metric should convey readily available information in a simple, understandable form, and send a clear signal to the market. For example, combining energy efficiency and renewable energy — both important to reducing carbon emissions — in a single metric such as net-zero energy can obscure the role that each play and may fail to drive the desired action.

Focus on actions directly within the control of building owners. Building owners can make a huge impact on emissions from their operations by increasing efficiency, procuring renewable energy, and transitioning from onsite use of fossil fuels to electricity. Policymakers should choose metrics that drive these actions and pursue other goals (such as increasing use of low/zero-carbon fuels for electricity generation) with the appropriate actors.

Encourage efficient electrification. Policymakers should consider approaches that encourage efficient electrification as they develop metrics for BPS policies and consider complementary policies (e.g., pricing and incentives for heat pumps) to help overcome cost and other barriers.

Make sure metrics are available. The perfect metric will not work if buildings cannot track, measure, and report it. Policymakers should make sure that chosen metrics are either available or can be developed and deployed in time for policy implementation.

Less is more. Policymakers should balance the need to send clear signals for each policy objective with the recognition that a long list of metrics may make implementation and compliance difficult. A BPS policy has the potential to achieve many positive outcomes, but getting to the end goal of zero- or low-carbon buildings (and/or realizing early reductions) may require complementary policies such as incentives for efficient electric technologies (such as heat pumps) and recognition for zero-carbon buildings.

Consider equity. In formulating any new policy, jurisdictions should consider the potential equity and justice implications at each step, depending on the specific needs of affected communities. The potential for equity concerns in the choice of metrics could arise if a particular metric requires building owners to purchase costly new equipment or services. Generally, however, other related policy decisions are more likely to affect equitable outcomes. These include the required performance levels, options for compliance, penalties for non-compliance, and the extent and magnitude of complementary programs that provide technical and financial support.

Importantly, this paper does not provide detailed guidance for establishing metric performance targets or their form, such as absolute level vs. percent improvement against a baseline. Because it can be difficult to separate the consideration of which metrics to include in a BPS policy from their compliance levels, however, EPA proposes that jurisdictions keep the following additional principles in mind as they explore BPS policies:

Allow for some flexibility to reflect local circumstances. Jurisdictions across the country have many differences in terms of building population, climate, and carbon intensity of the electricity grid, to name a few. While the principles above are universal, the required performance level and implementation path may need to vary to reflect local circumstances.

Be ambitious and create a clear path to compliance. The end goal of a BPS policy should be zero or very low carbon from buildings. But if building owners do not see a feasible path to that long-term goal — especially in the near and mid-term — the policy may fail. A strong BPS policy will set aggressive metric levels in the out years and a clear path for achieving them so that the affected buildings have certainty about the requirements and understand how best to make investments to get and stay on the path. In the near term, goals may need to be less aggressive to ensure that compliance doesn't create undue burden or require unreasonable investment.

Engage stakeholders early and often to help promote equity. It is critical to ensure that the benefits of a BPS policy as well as the implementation burden are equitable for all affected communities, building owners, and tenants. Engaging all stakeholders in the development of a BPS policy from the outset can help ensure that every voice is heard and considered in decision-making.

Narrowing the BPS Metrics Options

Choosing the most appropriate metrics that meet the principles outlined above is challenging in part because of the sheer number and variety of metrics. The list below includes common metrics in existing BPS policies or proposed by others.[23, 24] This list categorizes the metrics in terms of the primary outcome(s) they are intended to drive, but there are many interactive effects. The impacts of different metrics may overlap or, in some cases, push in opposite directions. A greenhouse gas emissions metric will likely result in buildings improving their energy efficiency, and an efficiency metric will likely result in lower emissions. But they are not a substitute for each other. If buildings face an emissions metric only, they may be able to meet it solely through renewable energy with little or no increased energy efficiency. Increasing procurement of renewable energy is a critical objective and should be done alongside, not instead of, efficiency. In addition, electrification could decrease onsite emissions but increase total emissions if the electric grid is primarily fossil fuel-based and remains that way as a BPS policy is implemented.

Energy efficiency metrics

- Site energy use intensity (EUI) and variations
- Source EUI and variations
- ENERGY STAR score

Electrification metrics

- Percent of energy use that is from electricity
- Onsite greenhouse gas emissions

Renewable electricity metrics

- Onsite green power
- Total green power (on or offsite)

Greenhouse gas emissions metrics

- Total greenhouse gas emissions
- Onsite greenhouse gas emissions
- Time of use emissions

Grid balancing-related metrics

- Peak demand
- Coincident peak demand

The sections that follow explore these metrics, organized by category. Each metric is evaluated against the following key considerations, built on the principles presented above:

- Simple
- Within control of building owner
- Favors electrification
- In Portfolio Manager
- Available for all buildings
- Standard normalization approach exists
- Data requiring verification

Energy efficiency metrics

The prior section proposed that jurisdictions choose a short list of metrics for BPS policies, and that one of those metrics focus exclusively on energy efficiency to ensure that buildings do not trade off efficiency with other objectives. This section presents a comparison of several energy efficiency metrics against key considerations for their use in BPS policies, followed by an extensive discussion. These metrics include the following:

Site energy use intensity (EUI)

- Normalized for weather
- Normalized for weather and business characteristics

Source EUI

- Regional conversion factor, normalized for weather
- Regional conversion factor, normalized for weather and business characteristics
- National conversion factor, normalized for weather

ENERGY STAR score

- National conversion factor, normalized for weather and business characteristics

Table 1 compares each of these metrics against the key considerations.

Non-normalized site EUI is the only metric fully within control of the building owner and not subject to change over time. As the discussion below explores, the site EUI metrics favor electrification regardless of the efficiency of the electric technology, while source EUI metrics favor electrification only when the most efficient technology is used. Normalized site EUI and regional source EUI (normalized or not) would require new methodologies. All the metrics would require some data verification, with those normalized for business characteristics requiring more than the others.

Below is an overview of the efficiency metrics and a discussion of national and regional source factors, normalization, and implications for electrification.

Overview

Site vs. Source Energy

Site energy represents the energy consumed at the building and typically matches what is on the energy bill. Source energy, on the other hand, includes site energy plus the losses incurred in generating and delivering energy in the form of electricity or fuel to the building. The calculation of source energy entails multiplying site energy by a conversion factor to account for those losses.

Source energy puts the different forms of energy used by buildings on the same scale, allowing equitable comparisons among buildings with different fuel mixes. Energy may be delivered to a building as either primary energy (i.e., the raw fuel burned to create heat and electricity, such as natural gas or fuel oil) or secondary energy (i.e., the energy product created from a raw fuel, such as electricity purchased from the grid or heat received from a district steam system). Source energy traces the heat and electricity requirements of the building back to the

Table 1: Key Considerations for Energy Efficiency Metrics

CONSIDER-ATION	ENERGY EFFICIENCY METRIC					
	Site EUI	Site EUI – normalized for business characteristics	Source EUI – regional factor	Source EUI – regional factor, normalized for business characteristics	Source EUI – national factor	ENERGY STAR Score
Simple	√	X	X	X	√	√
Within control of building owner	√	√ Energy use X Normalization factors may change over time	√ Energy use X Source factor changes over time	√ Energy use X Source and normalization factors change over time	√ Energy use X Source factor changes over time	√ Energy use X Source and normalization factors change over time
Favors electrification	√ Always, regardless of whether most efficient	√ Always, regardless of whether most efficient	√ Impact depends on regional grid fuel mix	√ Impact depends on regional grid fuel mix	√ Only when most efficient	√ Only when most efficient
In Portfolio Manager	√	X Would need to be developed	X Would need to be developed	X Would need to be developed	√	√
Available for all buildings	√	X Would need to be developed for business characteristics	X Would need to be developed by region	X Would need to be developed by region, incl normalization for business characteristics	√	X Available for 22 building types
Standard normalization approach exists	√ Weather	√ Weather X Business characteristics	√ Weather	√ Weather X Business characteristics	√ Weather	√ Weather and business characteristics
Data requiring verification	Meter data for all energy sources Building size	Meter data for all energy sources Building size + business characteristics	Meter data for all energy sources Building size	Meter data for all energy sources Building size + business characteristics	Meter data for all energy sources Building size	Meter data for all energy sources Building size + business characteristics

raw fuel input, thereby accounting for any losses and enabling a complete thermodynamic assessment of the building.

The ENERGY STAR Score

EPA's 1-100 ENERGY STAR score is a way to compare the energy performance of buildings, regardless of their business characteristics (e.g., hours of operation, number of workers), where they are located, or the efficiency of the utility that supplies their electricity. EPA develops the ENERGY STAR score by analyzing national survey data for each building type and creating a statistical model that correlates energy use to key business characteristics. A score of 75 or greater indicates that a building uses energy more efficiently than 75 percent of similar buildings nationwide and makes a building eligible to apply for ENERGY STAR certification. The score is available for building types for which appropriate data is available, which constitute about 65 percent of the commercial buildings market by square footage. The ENERGY STAR score is based on source energy use intensity.

Discussion

National vs Regional Source Factors

As a national program, EPA's ENERGY STAR uses a national site-to-source energy conversion factor. This factor reflects the average mix of raw fuels used to generate electricity on the electric grid nationwide. Because EPA considers there to be no losses when renewable fuels are used to generate electricity, the conversion factor decreases over time as the proportion of renewable electricity, nationwide, on the electric grid increases. (For example, the factor changed from 3.1 to 2.8 in 2018 to reflect increased penetration of renewable energy on the grid.[25])

The Energy Information Administration's (EIA's) 2021 Annual Energy Outlook projects that renewables will make up 42 percent of the national electric grid by 2050,[26] which is roughly correlated to an electric source factor of 2.19. EIA's low renewables cost projection bumps the renewable contribution to around 55 percent and results in a source factor of 1.92. The table below includes EIA's projections as well as higher renewable growth scenarios.

YEAR	% RENEWABLE ENERGY ON THE GRID	NATIONAL ELECTRIC SOURCE FACTOR
2030 (EIA)	35%	2.33
2050 (EIA reference case)	42%	2.19
2050 (EIA low renewables cost case)	55%	1.92
?	80%	1.41
?	100%	1.00

As the percentage of renewable energy on the grid continues to grow, EPA will regularly update the source conversion factor. Over time, source energy metrics will get closer to site energy.

It is technically possible to calculate regional source conversion factors that reflect the amount of renewable electricity used to generate electricity by region. The goal of doing this would be to create more targeted signals to drive investments in the most efficient space heating, water heating, and cooking technology in a particular region. To create an effective metric, it would be necessary to identify regional boundaries for determining each conversion factor. EPA's 26 eGRID subregions,[27] which are currently used to determine greenhouse gas emissions in Portfolio Manager, could be used, but these regions span diverse areas and are typically not granular enough to capture differences in the grid at the city (or even state) level. As an example, emissions factors for the Northwest U.S. eGRID subregion (NWPP) are the 6th lowest[28] out of 26 subregions, but the electric utilities that supply Seattle use zero-emitting hydropower to generate most of their electricity.[29]

EPA has explored the feasibility and implications of using regional source factors to develop ENERGY STAR scores. One outcome of such an approach is that building location would become the most important factor driving variation in EUI rather than how well a building manages its energy use. Buildings in cities with more renewable energy contributing to the generation of electricity might have average scores of 80 while those in cities with a more fossil fuel-powered electric grid might have average scores of 20.

Normalization

Whether and how to normalize energy use are important decisions. There are different reasons to consider normalizing a building's energy use, most notably to account for major variations in weather relative to a typical year and to account for buildings' varying business characteristics. The reason to consider normalizing a building's energy use for such characteristics is so that no building is penalized or rewarded because of the level of business activity it supports. For example, a retail store open 12 hours per day may use more energy per square foot to support the business that takes place inside it than a store that is open 8 hours per day. Without normalizing for such business characteristics, the store open longer hours — even if efficient — might look worse relative to a standard than the store with shorter hours. The need for normalization depends largely on the methodology and/or metric selected for use. It may be more important in a BPS that holds all buildings of a certain type to the same level of performance but not needed for a BPS that requires buildings to improve relative to their own level of performance.

While standard methodologies exist to normalize energy use intensity for weather, which can be adapted to any of the forms of EUI in the table, Portfolio Manager currently only provides weather normalization for site EUI, source EUI — national conversion factor, and the ENERGY STAR score. In addition, the ENERGY STAR score normalizes national source energy use intensity for key business characteristics, based on statistical analysis of nationally representative survey data. This approach allows EPA to differentiate the energy performance of buildings on a scale of 1-100, depending on how efficiently they use energy given their level of business activity. Knowing where they stand relative to other buildings on this scale helps building owners establish goals, identify the best opportunities for upgrades, and track improvement. Appropriate normalization requires that building owners track and apply the correct values for building operating characteristics. These vary by building type but often include hours of operation, number of workers and computers, and so forth. This then becomes data that may need to be verified under a BPS policy just as energy use would need to be verified for any of the efficiency metrics.

There is no established approach for normalizing site energy for business characteristics. EPA relies on source energy to enable apples-to-apples comparisons of the efficiency of buildings that use different fuel mixes and has not explored this type of normalization for site energy. Replicating the ENERGY STAR score approach on a site energy basis would entail new analysis to identify the key characteristics that impact site energy use intensity. And, just as in the development of ENERGY STAR scores, this analysis would only be possible where robust survey data exist, specific to each type of building. Normalizing source energy calculated with regional source factors would likewise require new analysis, which may have to be done on a regional basis (for which there may not be sufficient data for many regions/types of buildings). Analysis for normalizing site energy or regional source energy for business characteristics would need to be updated periodically to capture important changes in how buildings use energy on a site or regional source basis and would require verification of energy and business characteristic data.

If accounting for differences in business characteristics is deemed necessary for an effective and equitable BPS metric, there may be simpler ways to accomplish this. One possibility is to create multiple bins for each type of building so that those open longer hours, for example, are subject to a different EUI requirement than those open fewer hours. Jurisdictions can use data collected under benchmarking policies, if available, or they can gather data from the affected building community to determine the bins. Another possibility is to develop relatively simple adjustment factors to account for the most important business characteristics, such as a standard EUI allotment based on hours or workers above a threshold level. Jurisdictions should recognize that no approach to normalization will fully capture all the relevant differences among buildings and will need to weigh the merits against the challenges posed by various approaches, such as added complexity, data verification needs, and lack of metrics in Portfolio Manager.

Implications for electrification

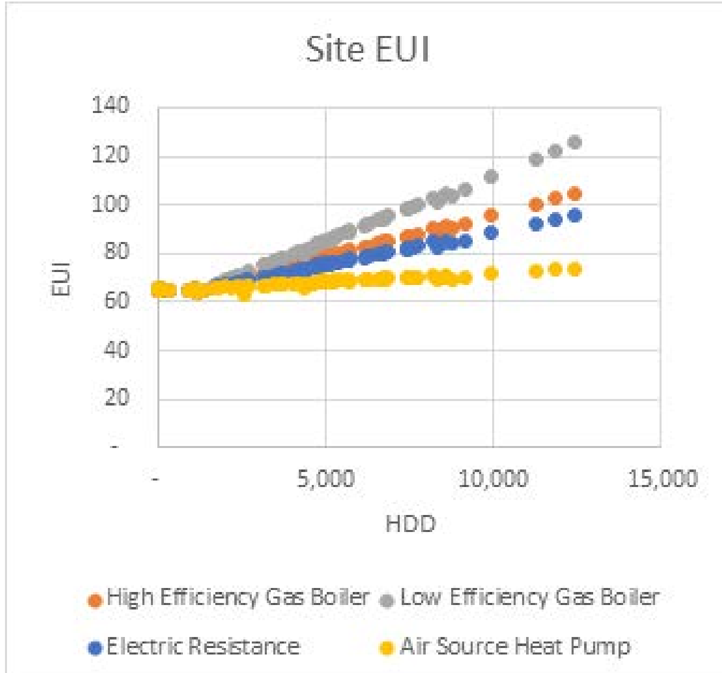
Before delving into a comparison of each efficiency metric against the principles and other key considerations, it is helpful to understand the interplay between site/source metrics and electrification. EPA looked at how heating technology impacts site and source energy and the ENERGY STAR score to clarify their interactions.

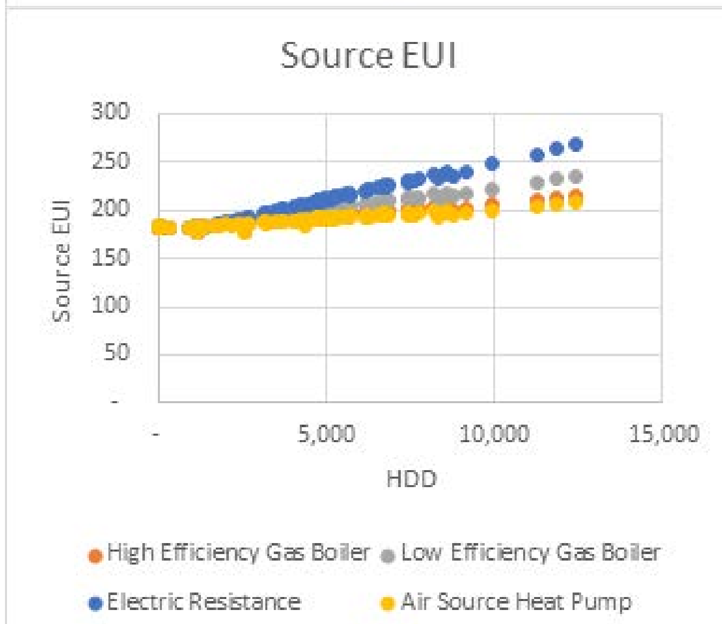
The two graphs here represent site and source EUI in a hypothetical 100,000-square-foot building, showing the impact of different heating technologies: high efficiency gas boiler, low efficiency gas boiler, electric resistance heat, and air source heat pump. The x-axis is heating degree days (HDD), starting from a more temperate climate (lower HDD) and moving to colder areas of the country. In both graphs, the EUIs diverge more as HDD increases and the contribution of heating to total energy use likewise increases. The first graph shows that site EUI is highest if the building uses a low efficiency gas boiler, followed by a high efficiency gas boiler, electric resistance heating, and finally an efficient electric air source heat pump at the lowest site EUI. The second graph shows that source EUI is highest for electric resistance heating and continues to be lowest for heat pump technology (using the current national average source energy conversion factor of 2.8). ENERGY STAR scores follow the same pattern as source EUI.

If the building switches from a natural gas boiler to an electric heat pump for space heating, it will use less energy per square foot, whether measured in terms of site or source energy, and will also have a higher (better) ENERGY STAR score. If the building instead switches from a natural gas boiler to electric resistance heating, it will still use less energy per square foot as measured on a site basis, but more if measured on a source basis. It will also have a lower (worse) ENERGY STAR score.

In other words, site EUI always favors electrification, even when delivered with inefficient technology, while source energy and the ENERGY STAR score favor electrification only when delivered with efficient technology. In fact, EPA analysis demonstrates that buildings that have earned ENERGY STAR certification tend to have a higher percent electricity. See Section 4 for more details. The colder the climate, the more pronounced these differences will be. Of course, an energy efficiency metric is not the only determinant of heating technology choices. Cost, including equipment, installation and operating costs, complementary policies such as incentives for heat pumps, and other factors play an important role.

EPA's current national source energy conversion factor of 2.8 is based on recent historical data, but the value of investments driven by BPS policies may be realized well into the future. Policymakers and building owners alike should be cognizant of the evolution of the electricity grid over the lifetime of such investments, rather than judging them on historical trends alone. As mentioned above, the national source conversion factor will change over time as the mix of energy sources used





in generation of electricity changes. As this mix approaches 100% renewable energy, site and source energy will be very similar and the source EUI graph above will be almost identical to the site EUI graph. And if the source factor is determined at a regional, rather than national, level, the picture may vary considerably depending on a building's location, until every region approaches 100% renewable energy.

Electrification metrics

Increasing electrification of building end uses is a critical part of the transition to zero carbon by 2050. How, where, and when electrification occurs can impact emissions, particularly in the short term. Electrification with inefficient technologies will increase demand (and the need for renewable electricity). It will also result in higher emissions in regions where electricity is generated with high-carbon fuels. Even in those cases, however, the long-term trajectory is expected to be toward low or zero emissions from electrical generation. Jurisdictions should understand the impact of electrification both in the short and long term and consider complementary policies where efficient electric technology faces significant barriers.

Generally, HVAC and water heating are the major uses of natural gas and other fossil fuels in buildings. Heat pumps are an efficient electrification option for HVAC and water heating that can avoid trade-offs in electrification and emissions, but they may not be feasible for every building. Heat pumps may have limitations in colder climates, and while electrification retrofit options for larger commercial buildings certainly exist, they are not as feasible today — technically or economically — as retrofit options are for smaller buildings. Technology advances and innovative approaches (along with decarbonized district energy generation) are making strides in overcoming these challenges, but in the near term, efficient electrification may be more difficult in colder climates and urban areas with very large commercial buildings.

This paper presents metrics that jurisdictions could adopt to encourage electrification. However, as the prior discussion highlights, electrification depends on adoption of specific technologies and therefore may also be addressed through complementary policies such as building codes, which are traditionally focused on technology choices.

Two metrics that may encourage efficient electrification include Percent Site Electricity and Onsite Greenhouse Gas Emissions

(GHG) Intensity. Table 2 compares the key considerations for each of these metrics.

Percent Site Electricity directly targets electrification. If a building that uses fossil fuels for heating has to meet a target for the percent of total energy consumption that is from electricity, the building owner may invest in electrification of heating and other systems that now use fossil fuels. However, depending on how the energy efficiency metric is set, Percent Site Electricity could provide a perverse incentive by encouraging an increase in electricity use without a concurrent decrease in onsite fuel use. Another important consideration is how to account for the role of district energy, which may be produced with electricity or fossil fuels.

Even though it measures emissions, an Onsite Greenhouse Gas Emissions Intensity metric serves to encourage a transition to electricity. Buildings that use fuels such as natural gas, oil, or propane will emit greenhouse gases when they combust these fuels for space heating, water heating, or cooking. A BPS metric that requires building owners to reduce the emissions from onsite combustion of fuels will encourage greater efficiency in these end uses and, depending on the target level of emissions, a transition to use of electricity.

Where a shift to electrification may not be feasible in the near term (for example, for large buildings and those in cold climates), buildings may consider switching to low-carbon fuels

Table 2: Key Considerations for Electrification Metrics

CONSIDERATION	PERCENT SITE ELECTRICITY	ONSITE GHG EMISSIONS INTENSITY (FROM COMBUSTION OF FUELS AT THE BUILDING)
Simple	√	√
Within control of building owner	√	√
Favors electrification	? If the energy efficiency metric effectively limits total energy use	√
In Portfolio Manager	√	√ For natural gas, fuel oil, and propane X Renewable fuels
Available for all buildings	√	√
Standard normalization approach exists	NA	X
Data requiring verification	Meter data by energy source	Meter data for onsite energy sources Building size Renewable thermal certificate(s)

from renewable sources. Examples include solar water heating and geoexchange applications and may include biogas and some forms of biomass (subject to verification/certification of environmental benefits).[30] To date, the adoption of these technologies and fuels has been small; in 2020, the use of biomass, wood, and landfill gas in commercial buildings was less than one percent of commercial energy consumption.[31] Certain types of buildings may be more suitable for these options than others. For example, K-12 schools are more likely to have the land to support a geothermal system, and buildings with constant water heating needs throughout the year, such as hotels and multifamily buildings, might find solar water heating to be a feasible option. In addition, there is an emerging market for the transaction of biomethane (renewable natural gas) through common carrier pipelines using a market instrument called a renewable thermal certificate,[32] which would function like a renewable energy certificate for electricity from renewable resources — this may become a viable option for buildings that have limited opportunities to significantly reduce their consumption of natural gas or other fossil fuels for space heating and cooling, water heating, and cooking.

Considerations for possible normalization of GHG emissions are discussed in the emissions section, following the discussion of renewable electricity metrics below.

Renewable Electricity metrics

A tremendous increase in renewable electricity capacity is needed to provide enough clean electricity to meet demand. Buildings can make an important contribution to this growth by increasing their procurement of onsite and offsite green power and/or renewable energy certificates (RECs).

The U.S. voluntary market defines green power as electricity produced from solar, wind, geothermal, biogas, eligible biomass, and low-impact small hydroelectric sources.[33] To claim the environmental benefits of green power, a building owner must retain or purchase the RECs associated with the power. RECs are "tradeable, market-based instruments that represent the legal property rights to the 'renewable-ness' (i.e., environmental attributes) of one megawatt-hour (MWh) of renewable electricity generation. A REC is issued for every MWh of electricity generated and delivered to the electric grid from a renewable energy resource. Electricity cannot be considered renewable without a REC to substantiate its renewable-ness. All green power supply options involve the generation and retirement of RECs."[34] EPA's Green Power Partnership (www.epa.gov/greenpower) provides more details about the purchase and use of RECs, including their legal basis and guidance on their appropriate use.

Two metrics that can encourage the procurement of renewable electricity include Green Power – Onsite and Green Power – Onsite + Offsite. To meet either of these metrics, building owners must hold the RECs for electricity claimed as renewable. The key considerations for each of these metrics are compared in Table 3 below. Note that these metrics can be implemented as absolute (e.g., MWh) targets or as percentage targets. Because the energy use intensity, electricity needs, and emissions for each building are different, establishing percentage targets for these metrics would likely be the most feasible approach. This could take the form of percentage of total electricity consumed.

Some organizations recommend subtracting onsite renewable electricity from the total energy consumed by the building. This is problematic because it obscures the efficiency of the building. Tracking onsite renewable electricity separately from other energy metrics enables both a measure of building efficiency considering total energy consumption and a measure of onsite renewable electricity generation/use/export. If a building has the necessary metering configuration, recording and tracking onsite renewable electricity metrics is relatively straightforward. However, buildings without the ability to meter each of the renewable energy flows cannot readily determine the amount generated, used, and exported, which is important for accurate energy and emissions calculations. EPA's recent report on onsite renewable energy in buildings[35] highlighted the need for building owner access to metered data and/or utility bills that track and report the flow of onsite renewable electricity into the building rather than just the net amount.

There are a few reasons that a metric that encompasses all the green power used by the building, whether generated on- or offsite, may be preferable to a metric that only reflects onsite green power. First, utility-scale green power, typically larger than that installed on an individual building's roof, may be more cost-effective. A metric that encompasses onsite generation and/or procurement of offsite green power allows the market to determine the best, most cost-effective approach for

Table 3: Key Considerations for Renewable Electricity Metrics

Consideration	Green Power – Onsite	Green Power – Onsite + Offsite
Simple	√ When the proper meters are in place	√ When the proper meters are in place for onsite component
Within control of building owner	√	√ Depending on policy constraints
Favors electrification	NA	NA
In Portfolio Manager	√ Green power generated, used, and exported X Tracking of specific RECs	√ Green power generated, used, exported, and purchased X Tracking of specific RECs
Available for all buildings	√	√
Standard normalization approach exists	NA	NA
Requires data verification	Meter data for onsite green power REC documentation	Meter data for all green power (onsite and offsite) REC documentation

each building. A second and related reason is that tall, narrow buildings and others that have limited roof space or shading may not have feasible options for onsite renewable energy but can procure renewable energy from nearby installations, from other renewable energy projects, or via renewable energy certificates. Finally, it may not always be clear what constitutes onsite green power — does it have to be on the building itself or can it be on adjacent land (and if so, how far from the building)?

Emissions metrics

A primary goal of a BPS policy is to reduce or eliminate greenhouse gas emissions from buildings. Key considerations for three potential greenhouse gas emissions metrics — total emissions intensity, total emissions intensity based on time of use, and onsite emissions intensity — are compared in Table 4 below. Although emissions intensity is the more common form of these metrics, such as the total emissions intensity metric buildings must meet under New York City's LL97,[36] it is possible to represent them in terms of absolute emissions.

Note that a metric reflecting GHG emissions from a building's total energy use may conflate the impact of efficiency, electrification, and renewable energy. For example, an inefficient building could achieve a low total GHG emissions value by purchasing enough renewable energy credits to avoid most or all of the emissions from its electricity use. In this case, the GHG emissions value would obscure the inefficiency of the building and the contribution of renewable energy.

The two metrics that would limit total greenhouse gas emissions are also inconsistent with the second principle, 'Focus on the actions within the control of building owners.' Emissions from the use of energy in buildings fall into two categories:

Table 4: Key Considerations for GHG Emissions Metrics

Consideration	Total GHG Emissions Intensity	Total GHG Emissions Intensity, Time of Use	Onsite GHG Emissions Intensity (from combustion of fuels at building)
Simple	√	X	√
Within control of building owner	√ Energy use and green power procurement X Building does not control electric grid emissions factor	√ Energy use and green power procurement X Building does not control electric grid emissions factor	√
Favors electrification	? Depends on electric grid emissions factor	? Depends on electric grid emissions factor	√
In Portfolio Manager	√	X	√ For natural gas, fuel oil, and propane X Renewable fuels
Available for all buildings	√	X	√
Standard normalization approach exists	X	X	X
Data requiring verification	Meter data by energy source Building size	Meter data by energy source Electricity time of use Building size	Meter data for onsite energy use Building size Renewable thermal certificate

emissions from combustion of fuels at the building; and emissions from the generation of electricity or district energy at the power plant that supplies the building. Building owners control the amount of electricity or district energy their buildings consume, but they do not control the emissions rate for generation of electricity from the grid or steam or other products from the district energy power plant. While they may have access to forecasts of future emissions rates for electricity generation, such forecasts are uncertain. Uncertainty about if or how these rates will change could make it difficult for building owners to determine the best investments, such as whether and when to electrify heating systems, or whether to invest in more efficient natural gas heating. The signal that a BPS metric sends to the market has long-term implications since these investments may be capital-intensive and occur infrequently.

Buildings have two options for mitigating these emissions: they can increase their energy efficiency and procure green power, either at the building itself or from offsite sources. To take advantage of cost-effective offsite green power options, buildings subject to a BPS policy would likely need the flexibility to procure green power from a large enough area (if not nationally).

The purported advantage of a total greenhouse gas emissions metric that matches real-time energy use to emissions is that it can more accurately reflect the actual emissions impact of energy when it is used. A utility may dispatch different generators, with very different emissions profiles, at various times of day depending on the total energy load on the system. There are several reasons, however, that a metric based on time of energy use is impractical and may not be effective for BPS standards today, including the following:

Data availability. Most building owners do not have access to metered hourly electricity consumption data, or the emissions data associated with it, either retroactively or looking forward. Such information would be needed to realize the potential benefits of a time-of-use emissions metric. Without it, owners cannot identify investments and behavior changes that would shift energy use from higher-emitting time periods.

Changes over time. The emissions profile for a given period will continue to change as the power grid evolves, making it very challenging for building owners to know what long-term investments would reduce emissions.

Cost. It would be very costly to create the infrastructure needed to provide building owners with verifiable real-time data, especially to reach all of those who might be affected by a BPS policy.

Need for demonstration. While it is true that emissions vary across time, there is no definitive evidence that a time of use emissions metric would significantly impact emissions reductions. Work is underway at EPA to explore this question.

Emissions that occur at the building, on the other hand, are relatively simple to estimate and within the control of the building owner. Moreover, they are generally from combustion of fossil fuels, such as natural gas, oil, or propane. A metric focused on emissions from on-site combustion directly addresses something the building owner can control, and it also may serve valuable, related purposes. The ways to reduce these emissions are to increase the efficiency of building systems that use fossil fuels, such as space and water heating and cooking, to shift from on-site combustion of these fuels to clean electricity, and to use low-carbon fuels or technologies. (See the prior section for a discussion of these options and associated challenges.)

Just as for energy efficiency metrics, whether and how to normalize greenhouse gas emissions are important decisions. According to the GHG Protocol Corporate Accounting and Reporting Standard,[37] reporting of absolute emissions is required while reporting of emissions intensity, such as emissions per product, is optional. The Protocol does not address normalization to account for weather variations, and EPA has not identified any instances of such normalization. It may be technically possible to weather-normalize GHG emissions by using weather-normalized energy use as the basis of the calculation. Likewise, it may be technically possible to use energy use normalized for business characteristics as the basis for estimating GHG emissions, with all the same considerations described in the energy efficiency metrics section above. Another type of normalization for GHG emissions would be to remove the impact of fuel mix and efficiency at the power plant. This would entail using a national electricity emissions factor, like what

ENERGY STAR does to convert site energy to source energy. However, it is not clear that such an approach would add useful information about the performance of the building to what a source energy metric already provides. Likewise, normalizing for business characteristics may not add to the information provided by a normalized energy efficiency metric.

Grid-balancing related metrics

To support a clean energy economy, the electric grid must be ready to effectively dispatch vastly greater amounts of renewable electricity than it does today. Building owners can help enable the changes needed by changing the patterns of energy use in their buildings. Metrics like peak demand or coincident peak demand have been proposed for inclusion in BPS policies.[38] Peak demand represents a building's highest electricity demand over a certain time period, and coincident peak demand represents a building's electricity demand at the electricity system's peak.

As Table 5 illustrates, these metrics have disadvantages that make them difficult to implement in a BPS. They are not simple because they require information that building owners may not have and because their definitions are unclear. EPA recently added "Electric Demand" to Portfolio Manager after many requests for tracking of demand or peak demand. We found that there is not a universal understanding of what these terms represent, and ultimately left it up to the user to track the information most useful to them. A metric that reflects a building's contribution to coincident peak demand poses an additional challenge because the system peak is not within control of the building owner. A BPS policy may not be the most effective way to achieve grid balancing objectives. Other approaches include utility pricing structure — often used today to manage peak demand — and policies that directly target the actions that reduce demand at certain times, such as requirements for onsite storage and participation in demand response programs. Such policies could be important complements to a BPS.

Table 5: Key Considerations for Peak Demand Metrics

CONSIDERATION	PEAK DEMAND	COINCIDENT PEAK DEMAND
Simple	X	X
Within control of building owner	√	X Building owner does not control demand on the grid
Favors electrification	NA	NA
In Portfolio Manager	√ Flexible 'Electric Demand' option that allows users to enter information they want to track (but not standardized)	X
Available for all buildings	√	? If electric system operator provides system peak demand
Standard normalization approach exists	NA	NA
Data requiring verification	Data for building's highest electricity demand period	Data for building's electricity demand at time of grid's highest electricity demand

Summary

While there is no single right metric that will provide the needed signal for efficiency, electrification, and renewable energy under all circumstances, EPA recommends evaluating potential metrics in terms of these principles:

Ensure energy efficiency. Building performance standards should always include a metric targeted to energy efficiency and should not trade off efficiency with other goals.

Employ simple metrics to send clear signals. EPA has consistently found that easy-to-grasp, clear metrics are critical to driving action. For example, combining energy efficiency and renewable energy into metric such as net-zero energy can obscure the role that each play and may fail to drive the desired action.

Focus on actions directly within the control of building owners. Building owners can increase efficiency, procure renewable energy, and transition from onsite use of fossil fuels to electricity.

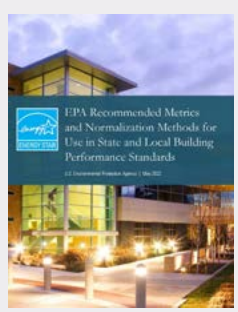
Encourage efficient electrification. And consider complementary policies (e.g., pricing and incentives for heat pumps) to help overcome cost and other barriers.

Make sure metrics are available. The perfect metric will not work if buildings cannot track, measure, and report it.

Less is more. Policymakers should balance the need to send clear signals for each policy objective with the recognition that a long list of metrics may make implementation and compliance difficult.

Consider equity. The potential for equity concerns in the choice of metrics could arise if a particular metric requires building owners to purchase costly new equipment or services.

Following these principles, EPA recommends jurisdictions adopt an energy efficiency metric. Jurisdictions may want to adopt a secondary metric as well, to further encourage efficient electrification and greenhouse gas emissions reductions.



Prior to finalizing this paper, EPA separately published recommendations for metrics selection, drawing on the information and analysis presented below as well as input from policymakers and building owners.

These recommendations and other EPA resources supporting effective design and implementation of BPS policies can be found at www.energystar.gov/buildings/BPS.

Section 2: Detailed Descriptions of Metrics

This section describes many — but certainly not all — of the metrics that jurisdictions could consider for building performance policies. The metrics listed below include those found in current BPS policies as well as a few that have been proposed elsewhere as appropriate for BPS policies. Similar to section 1, they are organized and addressed in the following categories:

- Metrics for Energy Efficiency
- Metrics for Electrification
- Metrics for Renewable Electricity
- Metrics for Greenhouse Gas Emissions
- Metrics for Related to Grid-Balancing
- Combined Metrics and Net-Zero Considerations

For each metric, there is a description, a reason for including it on the list, the implications, and the seven simplified evaluation criteria delineated in the first section of this paper:

- What is it?
- Why is it on the list?
- What are the implications?
- Simple?
- Within Control of Building Owner?
- Favors Electrification?
- In Portfolio Manager?
- Available for all Buildings?
- Standard Normalization Approach Exists?
- Requires Data Verification?

Metrics for Energy Efficiency

Simply put, energy efficiency is about using less energy to get the same job done — and in the process, avoiding high energy bills and unnecessary pollution.[39] There are many ways that policymakers and others define an energy-efficient building. It may be a building with energy-efficient equipment and/or designed to be energy efficient. EPA determines energy-efficient commercial and multifamily buildings according to their energy performance — the energy they actually use per square foot. Basing determinations of energy efficiency on actual energy use accounts for the interaction among building systems and how the building is used. Consequently, this list includes energy efficiency metrics focused on performance.

Site Energy Use Intensity

- **What Is It?** Site energy use intensity is the amount of heat and electricity consumed by a building as reflected in utility bills, divided by the gross square footage of the building. Site energy may be delivered to a facility in one of two forms: as primary energy, that is the raw fuel burned to create heat and electricity, such as natural gas or fuel oil; or secondary energy, that is the energy product created from a raw fuel, such as electricity purchased from the grid or heat received from a district steam system. A Site EUI 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.

- **Why Is it on this List?** Site energy is the form of energy consumption with which most building stakeholders are familiar. It is the value that building owners and managers see on their energy bills. As such, Site EUI provides an indication of energy efficiency, is easy to obtain, and does not require interpretation or manipulation.
- **What Are the Implications?** Site energy may not provide a complete representation of the impact of building energy consumption as it combines primary and secondary energy forms, and therefore may not allow for an equitable comparison among buildings with different energy mixes.
- **Simple?** Site EUI is a very simple metric.
- **Within Control of Building Owner?** Building owners are fully in control the amount of site energy they use.
- **Favors Electrification?** A site EUI metric favors electricity relative to most other fuels because it does not account for any losses in the generation and transmission of electricity. A building end use such as heating that uses electricity will generally have a lower EUI value on a site basis than heating that uses natural gas or other fossil fuels. A building that transitions from natural gas heating to electric heating — even inefficient electric resistance heating — is likely to lower its site EUI.
- **In Portfolio Manager?** Site EUI and Weather Normalized Site EUI are available in Portfolio Manager.
- **Available for all Buildings?** Site EUI is available for all buildings.
- **Standard Normalization Approach Exists?** Site EUI is normalized for building size. A standard approach exists to normalize all forms of EUI for variations in weather.
- **Requires Data Verification?** Data subject to verification for this metric includes the building location, type, gross square feet, and at least 12 months of metered energy data for all energy sources used in the building.

Site Energy Use Intensity – Normalized for Business Characteristics

- **What Is It?** This metric would adjust Site EUI for varying business characteristics such as hours of operations, number of workers, number of multifamily units, and the like.
- **Why Is it on this List?** Normalizing Site EUI for business characteristics would allow equitable comparison of buildings with different business characteristics.
- **What Are the Implications?** This could require a substantial amount of analysis, if based on a statistical approach like that used to develop ENERGY STAR scores for each type of building. This approach would be subject to the same restrictions and be possible only where sufficient national data exists. A simpler approach could be normalization for one business characteristic, such Site EUI per worker or Site EUI per hour of operation. Accounting for both workers and hours in one metric, however, is much more complex and would likely not be available for all buildings.
- **Simple?** It would likely not be simple to develop a methodology for normalizing Site EUI for key business characteristics. If such a method were developed, however, it might be simple for building owners to apply it.
- Within Control of Building Owner? Building owners are fully in control the amount of site energy they use. However, they may not fully control values of Site EUI normalized for business characteristics if the normalization factors are updated over time.
- **Favors Electrification?** Site EUI normalized for business characteristics would likely favor electricity in the same way that Site EUI does.
- **In Portfolio Manager?** Site EUI normalized for business characteristics is not available in Portfolio Manager.

- **Available for all Buildings?** Whether Site EUI normalized for business characteristics would be available for all buildings depends on the normalization methodology.
- **Standard Normalization Approach Exists?** A standard approach exists to normalize all forms of EUI for variations in weather, but there is no standard approach to normalize Site EUI for business characteristics.
- **Requires Data Verification?** Data subject to verification for this metric includes the building location, type, gross square feet, at least 12 months of metered energy data for all energy sources used in the building, and, depending on the type of building, business characteristic data such as hours of operation, number of computers, number of workers, and the like. Some of the business characteristic data is more difficult to verify than the basic building data.

Source Energy Use Intensity – Regional Factor

- **What Is It?** Source EUI – Regional Factor is total source energy used by a building, calculated with regional source conversion factors, divided by gross square feet of the building. Commercial and multifamily buildings use different mixes of energy including electricity, natural gas, fuel oil, district steam, and many others. This energy may be delivered to a facility in one of two forms: as primary energy, that is the raw fuel burned to create heat and electricity, such as natural gas or fuel oil; or secondary energy, that is the energy product created from a raw fuel, such as electricity purchased from the grid or heat received from a district steam system. To evaluate building energy performance, source energy expresses these different energy types in a single common unit. Source energy traces the heat and electricity requirements of the building back to the raw fuel input, thereby accounting for any losses and enabling a complete thermodynamic assessment.
- **Why Is it on this List?** Source EUI – Regional Factor would reflect the efficiency and mix of fuels used on the regional electric grid. Regions that use more renewable sources of energy to generate electricity and/or less high carbon intensity fuel sources such as coal, would have lower electricity source factors. This metric could allow local jurisdictions to better tailor their BPS policies to regional conditions.
- **What Are the Implications?** Conversion of site energy to source energy enables equitable comparison among buildings. Without this conversion, electricity may appear to be a much lower percent of total energy consumption even though the amount of energy needed to produce and transmit the electricity may be multiples of the amount used on site. EPA ENERGY STAR uses a national conversion factor for grid-purchased electricity based on the total mix of fuels used to produce electricity nationwide, since it is a national program. A regional or local conversion factor, based on the fuel mix used to produce electricity locally, may be quite different from the national factor. For example, in areas of the northwest, the factor may be close to 1.0, while in the midwest, it would likely be higher than EPA's national average factor of 2.8. It could also be challenging for building owners with properties in multiple regions to track and compare this metric across their buildings.
- **Simple?** This would be a somewhat complex metric to develop and implement. To develop Source EUI – Regional Factor for every eGRID region would entail an analysis of the fuel mix in each subregion. Jurisdictions in each subregion would then need to incorporate the factor into their metric(s). Individual cities or counties may want to use an even more granular electricity source factor than the subregional one, which could further complicate development and implementation of the metric.
- **Within Control of Building Owner?** Building owners control the amount of energy their buildings use, but they do not control the factors used to convert site energy to source energy. Their buildings' Source EUI – Regional Factor values will change if the source factors change.
- **Favors Electrification?** The relationship of Source EUI – Regional Factor to electrification depends on the regional grid fuel mix, which determines the factor. In most areas, it would favor efficient electrification.

- **In Portfolio Manager?** Source EUI – Regional Factor is not available in Portfolio Manager.
- **Available for all Buildings?** Source EUI – Regional Factor could be developed for all building types.
- **Standard Normalization Approach Exists?** A standard approach exists to normalize all forms of EUI for variations in weather.
- **Requires Data Verification?** Data subject to verification for this metric includes the building location, type, gross square feet, and at least 12 months of metered energy data for all energy sources used in the building.

Source Energy Use Intensity – Regional Factor, Normalized for Business Characteristics

- **What Is It?** Source EUI – Regional Factor, Normalized for Business Characteristics is total source energy used by a building, calculated with regional source conversion factors, and normalized for business characteristics, divided by gross square feet of the building.
- **Why Is it on this List?** Source EUI – Regional Factor, Normalized for Business Characteristics would combine the potential benefits of using a regional source conversion factor with the ability to account for differences in buildings' key business characteristics.
- **What Are the Implications?** With the regional conversion factor and normalization factors subject to change over time, it may be difficult to track progress against this metric. It could also be challenging for building owners with properties in multiple regions to track and compare this metric across their buildings.
- **Simple?** This would be a complex metric to develop and implement. In addition to requiring source factors for every eGRID subregion, this metric would require a normalization approach that is applied in each region.
- **Within Control of Building Owner?** Building owners control the amount of energy their buildings use, but they do not control the source or normalization factors. Source EUI – Regional Factor, Normalized for Business Characteristics could change as both source factors and normalization factors change.
- **Favors Electrification?** The relationship of Source EUI – Regional Factor to electrification depends on the regional grid fuel mix, which determines the factor. In most areas, it would favor efficient electrification.
- **In Portfolio Manager?** Source EUI – Regional Factor is not available in Portfolio Manager.
- **Available for all Buildings?** Whether Source EUI – Regional Factor normalized for business characteristics would be available for all buildings depends on the normalization methodology.
- **Standard Normalization Approach Exists?** A standard approach exists to normalize all forms of EUI for variations in weather, but there is no standard approach to normalize Source EUI – Regional Factor for business characteristics.
- **Requires Data Verification?** Data subject to verification for this metric includes the building location, type, gross square feet, at least 12 months of metered energy data for all energy sources used in the building, and, depending on the type of building, business characteristic data such as hours of operation, number of computers, number of workers, and the like. Some of the business characteristic data is more difficult to verify than the basic building data.

Source Energy Use – National Factor

- **What Is It?** Source EUI – National Factor is total source energy used by a building, calculated with national source conversion factors, divided by gross square footage of the building.
- **Why Is it on this List?** Use of Source EUI – National Factor facilitates comparisons across buildings located in different regions, important for a national program like ENERGY STAR.
- **What Are the Implications?** EPA ENERGY STAR uses a national conversion factor for grid-purchased electricity based on the total mix of fuels used to produce electricity nationwide, since it is a national program. This is particularly important for users of Portfolio Manager with buildings in multiple states.
- **Simple?** It is easy to obtain Source EUI – National Factor

by multiplying site energy values for each type of energy used at the building by its national source factor.

- **Within Control of Building Owner?** Building owners control the amount of energy their buildings use, but they do not control the factors used to convert site energy to source energy. Their buildings' Source EUI – National Factor values will change when the source factor changes.
- **Favors Electrification?** Source EUI – National Factor favors buildings that use electricity efficiently. A building's Source EUI – National Factor should decrease if a building transitions from a heating system that uses natural gas or other fuels to an efficient electric heat pump but will likely increase if a building transitions to inefficient electric resistance heating.
- **In Portfolio Manager?** Source EUI – National Factor is available in Portfolio Manager.
- **Available for all Buildings?** Source EUI – National Factor is available for all building types.
- **Standard Normalization Approach Exists?** A standard approach exists to normalize all forms of EUI for variations in weather.
- **Requires Data Verification?** Data subject to verification for this metric includes the building location, type, gross square feet, and at least 12 months of metered energy data for all energy sources used in the building.

ENERGY STAR 1-100 Score

- **What Is It?** EPA's ENERGY STAR 1-100 score is a way to compare the energy performance of buildings regardless of their business characteristics (e.g., hours of operation, number of workers), where they are located, or the efficiency of the utility that supplies their electricity. The score is based on econometric analysis of national, representative data sets of whole building energy use and business characteristics. A score of 75 or greater indicates that a building is more efficient than 75 percent of similar buildings nationwide and makes a building eligible to apply for ENERGY STAR certification. The ENERGY STAR score is based on source energy use intensity.
- **Why Is it on this List?** The ENERGY STAR score has been available for over 20 years, periodically expanding to additional types of buildings and undergoing updates as more current data becomes available. Thousands of buildings use the score because it provides a clear way to understand how efficiently a building uses energy without penalizing those with longer hours, more workers, etc. In addition, it offers a simple way to measure improvement, i.e., movement along the scale toward 100.
- **What Are the Implications?** While the ENERGY STAR score has several advantages in identifying efficient buildings and measuring improvement, there are a few considerations that are important to understand.
  - It is available for 22 types of buildings, representing most of the U.S. commercial and multifamily square footage, but not every type of commercial building.
  - It is based on a national source energy factor to provide equitable comparison of buildings across the country.
  - It is updated as new data become available (typically every four years).
- **Simple?** For those buildings that are eligible, it is relatively easy to obtain an ENERGY STAR score.
- **Within Control of Building Owner?** ENERGY STAR scores represent the efficiency with which buildings use energy, given their operational needs. Building owners can change their buildings' ENERGY STAR scores by taking action to increase (or decrease) the efficiency of their energy use. There are, however, aspects of the ENERGY STAR score that are outside the control of building owners. One is the factor used to convert site energy to source energy, which changes periodically to reflect the mix of fuels on the electricity grid (roughly every 3 to 5 years). Typically, this results in small changes to ENERGY STAR scores. Another is that EPA updates ENERGY STAR score models when new national survey data becomes available from the Energy Information Administration or other sources, a process that also results in score changes.

- **Favors Electrification?** The ENERGY STAR score favors buildings that use electricity efficiently. An EPA analysis found that buildings earning ENERGY STAR certification tend to have a higher percent electricity than buildings that do not. In addition, a building's ENERGY STAR score should increase if a building transitions from a heating system that uses natural gas or other fuels to an efficient electric heat pump.
- **In Portfolio Manager?** The ENERGY STAR score is available in Portfolio Manager.
- **Available for all Buildings?** The score is available for 22 building types for which appropriate data is available, which includes multifamily buildings and most of the commercial buildings market (about 65 percent by square footage). EPA strives to expand the list of eligible buildings as data and budget permit.
- **Standard Normalization Approach Exists?** The ENERGY STAR score is normalized for weather and business characteristics.
- **Requires Data Verification?** Data subject to verification for this metric includes the building location, type, gross square feet, at least 12 months of metered energy data for all energy sources used in the building, and, depending on the type of building, business characteristic data such as hours of operation, number of computers, number of workers, and the like. Some of the business characteristic data is more difficult to verify than the basic building data.

Metrics for Electrification

Electrification means switching from fossil fuels burned at a building to using electricity to meet a building's energy needs. Transition to greater use of electricity in commercial and multifamily buildings is important to take advantage of increasingly decarbonized electricity.

Percent Site Electricity

- **What Is It?** The percent of total site energy use that is electricity. It combines grid-purchased electricity with renewable electricity used at the building.
- **Why Is it on this List?** There is growing interest in electrifying space heating, water heating, and cooking, and other building end uses that today rely on natural gas or other primary fuels, in combination with cleaner electricity production.
- **What Are the Implications?** It is likely that a building that transitions onsite fuel use to electricity will increase its percent site electricity, making this metric potentially attractive to highlight and track electrification. However, a percent site electricity metric could provide a perverse incentive by encouraging an increase in electricity use without a concurrent decrease in natural gas or other onsite fuel use. Another important consideration is how to account for the role of district energy, which may be produced with electricity or fossil fuels.
- **Simple?** Yes, this is a simple metric to calculate and understand.
- **Within Control of Building Owner?** Building owners control the amount of electricity they purchase and/or generate.
- **Favors Electrification?** An increase in electricity use relative to other fuels increases the Percent Site Electricity. Generally, this should favor a transition to electricity. However, it is possible for a building to increase its Percent Site Electricity without decreasing its use of other energy sources, particularly if the building is not also subject to an energy efficiency standard.
- **In Portfolio Manager?** Percent Site Electricity will be available in Portfolio Manager soon.
- **Available for all Buildings?** Yes, Percent Site Electricity is available for all buildings.
- **Standard Normalization Approach Exists?** N/A
- **Requires Data Verification?** Data that would be subject to verification for this metric includes 12 months of energy data for all energy sources used in the building.

Onsite GHG Emissions Intensity

- **What Is It?** Onsite GHG emissions intensity measures emissions resulting only from fuels that are combusted onsite, such as natural gas and fuel oil (i.e., Scope 1 emissions[52]), divided by building gross square footage. (This metric is also listed in the Metrics for Greenhouse Gas Emissions section.)

- **Why Is it on this List?** The path to zero carbon requires decarbonization of the electric grid and electrification of end-use technologies. As buildings electrify, the combustion of fuels onsite and concomitant emissions will decrease. An Onsite GHG Emissions Intensity metric as part of a BPS policy can help spur this transition.
- **What Are the Implications?** As buildings increase their share of energy from electricity, their use of onsite fuels, and therefore onsite GHG emissions, will likely decrease. An onsite GHG emissions metric can highlight and track this transition. Fuels combusted onsite are typically used for space heating, water heating, and cooking. A building's need for these end uses is a major factor in its onsite GHG emissions but other factors play a role and merit consideration, such as:
  - In some areas, such as the northeast, fuel oil — with higher emissions than natural gas — has been a commonly used fuel, though its use has been declining.
  - Large buildings in cities with district energy systems may use steam or other district energy products instead of combusting fuels onsite.
  - Even in areas where many buildings are using electric heating technology, such technology may not be cost-effective for large buildings.
  - Buildings may have the option to use renewable or lower carbon fuels rather than fossil fuels to meet their heating and cooking needs.
- **Simple?** Onsite GHG Emissions Intensity is a simple metric to calculate and understand if conventional fuels are used at the building. It is more complex if low-carbon renewable fuels are used, as determining emissions factors for these fuels may not be straightforward.
- **Within Control of Building Owner?** Yes, building owners control the amount and type of fuels used in their buildings, which are the source of onsite GHG emissions.
- **Favors Electrification?** Yes, as electrification will most likely reduce onsite GHG emissions.
- **In Portfolio Manager?** Portfolio Manager estimates emissions from combustion of natural gas, propane, and other fuels used onsite. However, Portfolio Manager does not, as of now, account for low-carbon renewable fuels that may be used at buildings.
- **Available for all Buildings?** Onsite GHG Emissions is available for all buildings.
- **Standard Normalization Approach Exists?** Onsite GHG Emissions Intensity normalizes for building size. There are no standard approaches for normalizing this metric for weather or business characteristics.
- **Requires Data Verification?** Data subject to verification for this metric includes 12 months of data for all fuels combusted at the building and building gross square feet, as well as renewable thermal credits if used to reduce emissions.

Metrics for Renewable Electricity

Procurement of renewable electricity provides buildings with a zero-carbon source of electricity, which may be particularly important in areas where the electric grid has not yet transitioned to low-carbon energy sources. Renewable electricity may be generated at a building (onsite) or generated elsewhere and purchased by a building (offsite). The term 'green power' refers to electricity generated from a set of renewable resources that meet voluntary market standards.

Green Power – Onsite

- **What Is It?** This metric measures the amount of electricity produced at and used by a building from renewable energy sources, typically solar energy and less commonly wind, for which the building owner retains the renewable energy certificates.
- **Why Is it on this List?** Building generation and use of renewable electricity can be an important contributor to emissions reductions. It is important to track renewable electricity metrics separately from other energy metrics, as it may have a zero emissions factor.
- **What Are the Implications?** Buildings that generate

renewable electricity can help to increase total renewable resources and reduce emissions. To claim the environmental benefits of green power, a building owner must retain the RECs associated with the power. Some organizations recommend subtracting onsite renewable energy — used onsite or generated — from the total energy consumed by the building. This is problematic because it obscures the efficiency of the building. Tracking onsite green power separately from other energy metrics enables both a measure of building efficiency considering total energy consumption and a measure of onsite green power generation/use/export. If a building has the correct metering configuration, recording and tracking onsite green power metrics is relatively straightforward. However, buildings without the ability to meter each of the renewable energy flows cannot readily determine the amount generated, used, and exported, which is important for accurate energy and emissions calculations. Another consideration is how the onsite green power contributes to total greenhouse gas emissions from building energy use. If the building retains the RECs associated with the green power used onsite, that energy can be considered to have zero emissions. If the building sells the RECs, however, emissions associated with that energy should be calculated the same way as emissions from grid purchased electricity.

- **Simple?** Having clearly defined metrics is critical to properly tracking renewable electricity. Users of Portfolio Manager can track each important energy flow with the set of metrics available. However, clear metrics are only as good as the data they represent. Obtaining good data for onsite renewable systems can be a challenge, as meters often do not support the direct measurement of the amount of green power used by the building, without which it is impossible to accurately gauge the efficiency of the building. And, because buildings must retain the RECs associated with their use of onsite green power to claim the environmental benefits, this metric requires robust tracking of RECs.
- **Within Control of Building Owner?** Building owners determine whether to install solar panels or other onsite green power systems. In some cases, however, the building owner does not actually own the system and may not fully control how much of the electricity is used onsite and how much is exported.
- **Favors Electrification?** NA
- **In Portfolio Manager?** Portfolio Manager includes the following metrics for measuring and tracking onsite renewable electricity:
    - **Green Power – Onsite.** This captures the power generated from an onsite renewable system and used by the building, when the building retains the RECs associated with that power. If the building sells the RECs, the power is no longer considered green.
    - **Green Power – Onsite and Offsite.** This captures total green power used by the building, whether generated on or off-site.
    - **Percent of RECs Retained.** This captures the portion of onsite renewable electricity for which the building holds the Renewable Energy Certificate(s).

  * Portfolio Manager does not currently enable tracking of specific RECs.

  * Portfolio Manager includes onsite green power in a building's energy efficiency metrics (Site EUI, Source EUI, ENERGY STAR score) with a source conversion factor of 1.0 and assigns it a GHG emissions factor of zero.
- **Available for all Buildings?** Yes
- **Standard Normalization Approach Exists?** NA
- **Requires Data Verification?** Data that would be subject to verification for this metric includes 12 months of data for green power generated and used onsite and the associated RECs.

Green Power – Offsite

- **What Is It?** This includes electricity from a range of renewable sources, including solar, wind, geothermal, biogas, eligible biomass, and low-impact small hydroelectric sources[40] that is generated outside of the building boundary. A building owner may procure the electricity directly from the generator, a third party, or the electric utility, or may purchase RECs.

- **Why Is it on this List?** Building purchase of offsite green power is an important contributor to growth of renewable energy capacity and emissions reductions.
- **What Are the Implications?** Buildings that purchase and use green power generated offsite can help to increase total renewable resources and reduce emissions. To claim the environmental benefits of offsite green power, a building owner must hold the RECs associated with the power. An important consideration is how the offsite renewable electricity contributes to total greenhouse gas emissions from building energy use. If the building obtains the RECs associated with the energy, the energy may be considered to have zero emissions, depending on the context in which the building is reporting its emissions. Green power purchases are treated differently than onsite renewable energy for the purpose of greenhouse gas inventory development.[41] If the building does not hold the RECs, the power is not considered green.
- **Simple?** Because there are many ways a building owner can procure offsite green power, measuring and tracking it may be complex in some cases. And, because buildings must retain the RECs associated with their purchase of offsite green power to claim the environmental benefits, this metric requires robust tracking of RECs.
- **Within Control of Building Owner?** Building owners determine whether and how much offsite renewable electricity to purchase.
- **Favors Electrification?** NA
- **In Portfolio Manager?** Portfolio Manager tracks Green Power – Offsite, which captures the offsite green power or RECs attributed to the building. In addition, when entering offsite green power in Portfolio Manager, users choose the renewable energy source from which the electricity was generated and may identify the power plant or eGRID region. Portfolio Manager does not currently enable tracking of specific RECs.
Portfolio Manager includes offsite green power in a building's energy efficiency metrics (Site EUI, Source EUI, ENERGY STAR score) in the same way as electricity purchased from the grid, with a source conversion factor of 2.8. Likewise, Portfolio Manager estimates GHG emissions from offsite green power using the same emissions factor as electricity purchased from the grid, in keeping with the GHG Protocol location-based inventory approach for scope 2 emissions[42].
- **Available for all Buildings?** Yes
- **Standard Normalization Approach Exists?** NA
- **Requires Data Verification?** Data that would be subject to verification for this metric includes 12 months of data for green power generated and used onsite, green power procured from offsite sources, and all associated RECs.

Metrics for Greenhouse Gas Emissions

The ultimate goal of building performance standards is to reduce or eliminate carbon emissions from energy used in buildings. There are several GHG emissions metric options, described below.

Total GHG Emissions Intensity

- **What Is It?** Total emissions of GHG gases resulting from operation of the building (Scope 1 + Scope 2[52]), divided by building square footage. This includes emissions from the generation of electricity and district energy used by the building as well as emissions from combustion of fossil fuels at the building. It may also include fugitive emissions from refrigerant leaks, for example from building refrigeration and heating and cooling systems.
- **Why Is it on this List?** Total GHG Emissions Intensity represents the overall climate impact of the building. Reducing total emissions is an important goal.
- **What Are the Implications?** There are several reasons that a total GHG emissions metric may be problematic in a BPS, such as:
    - Buildings generally do not control the emissions from generation of electricity on the grid or emissions from production of district energy. Therefore, holding buildings responsible for total GHG emissions reductions places the burden on entities that

may not have control over the fuels that are burned at the power plant.

- A total GHG emissions metric may conflate the impact of efficiency, electrification, and renewable energy. For example, an inefficient building could achieve a low total GHG emissions value by purchasing enough renewable energy credits to avoid most or all of the emissions from its electricity use — the GHG emissions value would obscure the inefficiency of the building and the contribution of renewable energy.
- Requiring buildings to reduce total GHG emissions could discourage electrification where grid electricity is generated with fossil fuels. (And there is no expectation of a shift to renewable fuels in the near term.) On the other hand, buildings generally do have the opportunity to procure their energy from lower-emitting sources. Moreover, requiring buildings to meet total GHG levels may bring pressure to bear on regulators and grid operators to increase the proportion of renewable energy on the grid.

- **Simple?** Total GHG Emissions Intensity can be a simple metric to calculate and understand if only conventional fuels and grid-purchased electricity are used at the building. Green power and low-carbon fuels add complexity, as determining emissions factors for these energy sources may not be straightforward. Estimating and tracking refrigerant leakage also adds complexity.
- **Within Control of Building Owner?** Building owners control the amount and type energy sources used in their buildings and their purchases of offsite green power or RECs, which can reduce their total GHG emissions intensity. The do not, however, control the emissions factors associated with grid-purchased electricity or district energy.
- **Favors Electrification?** In the long term, as electricity is increasingly generated with renewable energy sources, buildings that transition to electricity should see a decline in their total GHG emissions intensity. In the near-term, however, buildings in areas with relatively high electric grid emissions factors could experience higher emissions intensity values if using grid-purchased electricity for heating and cooking rather than natural gas.
- **In Portfolio Manager?** Portfolio Manager does provide a Total GHG Emissions Intensity metric, which includes emissions from onsite combustion, district energy, and grid-purchased electricity. There are important caveats, however. Portfolio Manager estimates GHG emissions from offsite green power using the same emissions factor as electricity purchased from the grid, in keeping with the GHG Protocol location-based inventory approach for scope 2 emissions,[43] and does not include tracking or emissions estimates for low-carbon fuels or refrigerants used at the building. EPA is exploring the addition of new and more flexible emissions functionality in Portfolio Manager to support the variety of emissions scenarios.
- **Available for all Buildings?** Total GHG Emissions Intensity is available for all buildings.
- **Standard Normalization Approach Exists?** Total GHG Emissions Intensity normalizes for building size. There are no standard approaches for normalizing this metric for weather or business characteristics.
- **Requires Data Verification?** Data that would be subject to verification for this metric includes 12 months of data for all fuels combusted at the building and total gross square footage.

Time of Use GHG Emissions

- **What Is It?** Emissions from the production of electricity vary as the fuel and technologies used to produce the electricity vary (by time and by location). Depending on the demand on the electric grid, different power plants may be used at different times. These plants can have very different emissions profiles. Each time that the emissions rate is averaged — for example, over a day, a month, a year — precision is lost.
- **Why Is it on this List?** If it were possible to use the emissions rate for each increment of time and match the rate to the energy used during that time, emissions estimates would be more accurate. Researchers are

exploring ways to make this possible at scale.

- W**hat Are the Implications?** The fact that this metric is likely to be more accurate than annual emissions may mean that current averaging approaches are less precise but not wrong. Additional research to compare real-world scenarios would help to answer this question. The more valuable use of real time emissions may be in predicting what emissions will be at certain time periods going forward, so that building owners can manage energy use to take advantage of periods of low emissions. While there has been some work in this area, much more is needed for this step to be reliable and available at scale. In the meantime, interest in advancing the technology and systems to allow real time matching should not delay deployment of existing approaches to measure and reduce GHG emissions from building energy use.
- **Simple?** This would be a difficult metric to implement. Currently, there are platforms that connect time of use energy data to emissions. However, they are in the demonstration stage and not yet widely available. Until there is a simple to use and understand platform that matches historical and predicted energy use to emissions, this metric will not be ready for use in a BPS policy.
- **Within Control of Building Owner?** Building owners control the energy used in their building, including when it is used. They do not, however, control the emissions from electricity and district energy production occuring when they use the energy. If they had reliable predictions of what emissions will during future time periods, they could change their energy use patterns to reduce emissions.
- **Favors Electrification?** Possibly, if building owners can reduce emissions with greater electricity use by managing when they use it.
- **In Portfolio Manager?** No, Portfolio Manager uses monthly energy data and annual emissions rates to estimate emissions.
- **Available for all Buildings?** No. Very few buildings have access to the necessary data.
- **Standard Normalization Approach Exists?** No.
- **Requires Data Verification?** Data subject to verification for this metric includes when electricity is used in the building and the coincident emissions from generation of the electricity.

Onsite GHG Emissions Intensity

See the Metrics for Electrification section for details about this metric.

Metrics Related to Grid-Balancing

These metrics focus on the role buildings can play in the functioning of a clean energy grid.

Peak Electric Demand

- **What Is It?** Peak Electric Demand is a building's highest electric demand over a certain period, for example the hour when the building used the most electricity over the course of a month.
- **Why Is it on this List?** If buildings shift their periods of highest electric demand, utility operators have greater ability to dispatch generation with lower emissions.
- **What Are the Implications?** This metric has been proposed for inclusion in BPS policies, but it is not clear that it would be an effective way to achieve demand reductions and other grid balancing objectives. Other approaches include utility pricing structure — often used today to manage peak demand — and policies that directly target the actions that reduce demand at certain times, such as requirements for onsite storage and participation in demand response programs. Such policies could be important complements to a BPS.
- **Simple?** The concept of peak electric demand is relatively simple. However, defining exactly what is considered peak and knowing when peak occurs are not.
- **Within Control of Building Owner?** Building owners have control over how much electricity is used in their buildings and (for the most part) when it is used. They can implement management controls to reduce peak

demand.

- **Favors Electrification?** N/A
- **In Portfolio Manager?** EPA recently added "Electric Demand" to Portfolio Manager after many requests for tracking of demand or peak demand. We found that there is not a universal understanding of what these terms represent, and ultimately left it up to the user to track the information most useful to them.
- **Available for all Buildings?** Yes
- **Standard Normalization Approach Exists?** N/A
- **Requires Data Verification?** Data subject to verification for this metric includes the period of highest electric use per month.

Coincident Peak Electric Demand

- **What Is It?** Coincident Peak Electric Demand is a building's demand when electricity demand across the grid is the highest.
- **Why Is it on this List?** If buildings can reduce their demand when the grid's demand is highest, utility operators have greater ability to dispatch generation with lower emissions.
- **What Are the Implications?** This metric has been proposed for inclusion in BPS policies, but it is not clear that it would be an effective way to achieve demand reductions and other grid balancing objectives. Other approaches include utility pricing structure — often used today to manage peak demand — and policies that directly target the actions that reduce demand at certain times, such as requirements for onsite storage and participation in demand response programs. Such policies could be important complements to a BPS.
- **Simple?** Grid system operators may be able to match individual buildings' electricity use to the system's period of peak demand. However, it may not be simple for building owners to access this metric or determine what actions would improve it.
- **Within Control of Building Owner?** Building owners have control over how much electricity is used in their buildings and (for the most part) when it is used. They do not control demand across the electrical system.
- **Favors Electrification?** N/A
- **In Portfolio Manager?** No, Portfolio Manager does not include an option for tracking Coincident Peak Electric Demand.
- **Available for all Buildings?** This metric would be available only if the electric system operator provides values for system peak demand.
- **Standard Normalization Approach Exists?** N/A
- **Requires Data Verification?** Data subject to verification for this metric includes the building's electric demand coincident with the overall electric grid's period of highest demand over a given period (day, month, etc).

Grid-Interactive Efficient Buildings

The U.S. Department of Energy is leading research to make building equipment more intelligent through the Grid-Interactive Efficient Building (GEB) initiative. A GEB is an "energy-efficient building that uses smart technologies and on-site DERs [distributed energy resources] to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences, in a continuous and integrated way."[44] In the future, specific metric(s) may be available that distill the attributes of a GEB.

Combined Metrics and Net-Zero Considerations

These metrics combine energy efficiency and renewable energy and may, depending on the definition used, incorporate electrification as well. The terms 'zero' and 'net zero' are often used interchangeably, and usually mean that a building has procured enough zero-carbon energy to fully account for its total carbon emissions or energy use. Virtually every building uses energy, so can't truly be zero energy. These metrics are not discussed in prior sections of this paper but are included here in the interest of completeness.

Zero (or Net-Zero) Carbon

- **What Is It?** The World Green Building Council (WGBC) defines a net-zero carbon building as "a highly energy-efficient building that is fully powered from on-site and/or off-site renewable energy sources and offsets."[45] This definition is the basis of the WGBC's Net Zero Carbon Buildings Commitment, signed by 28 cities across the globe (including New York City, Seattle, San Francisco, and Washington, DC). There are many other definitions promulgated by other organizations and/or adopted by policymakers internationally.[46] These may incorporate life cycle building emissions, matching of energy use to real-time emissions, restrictions on offsite renewable energy use, and other factors.

- **Why Is it on this List?** Several organizations and policy makers have proposed that zero or net-zero carbon be a policy goal. Since a key objective of building energy policies is to reduce greenhouse gas emissions, a zero/net-zero carbon metric is a direct way to do that.
- **What Are the Implications?** One downside of a zero or net-zero carbon metric is that it may obscure the energy efficiency of the building. Despite the language in the WGBC and other definitions that a net-zero carbon building must be highly energy efficient, without a benchmark for that level of efficiency, it is possible that an inefficient building could produce or procure enough green power to be defined as net-zero carbon. Another important consideration is that it will likely be easier for buildings located in regions with lower emitting electricity generation (such as the Pacific Northwest or Upstate New York, where a significant portion of the electricity is generated with zero-emitting hydropower) to achieve net-zero carbon than similar buildings located elsewhere. Getting to zero carbon may also be easier for buildings with lower energy needs as compared to a high energy intensity building, such as a hospital, that has more emissions to avoid. The hospital will need to procure more green power than the less energy intensive building to avoid 100% of its emissions. (While it could be harder for higher energy intensive buildings under any energy or carbon metric, that can be mitigated through normalization or establishing bins.)
- **Simple?** Zero/net-zero carbon seems like a simple concept but determining whether a building has met the definition (of which there are several) requires that a building has accurate information about its procurement of energy, RECs, and options for avoiding onsite emissions and emissions from district energy. As described in the renewable energy sections above, the building must have metering in place to track the amount of green power generated onsite that it uses onsite as well as the RECs for both on and offsite green power use. For some definitions of net-zero carbon, the building must also be able to match its energy use temporally to GHG emissions. Options for avoiding onsite emissions and possibly emissions from district energy may include renewable fuels, offsets, or the emerging market for renewable thermal certificates. Robust accounting and documentation would be needed for each of these.
- **Within Control of Building Owner?** Building owners control the amount and type of energy used in their buildings. They do not control the emissions from electricity and district energy production, but (depending on the definition of net zero) can purchase RECs and offsets to avoid these emissions.
- **Favors Electrification?** This depends on the definition applied. If a building must be 100% electric to meet the metric, it will certainly favor electrification. Even if not, it may be easier to achieve zero carbon if a building is fully electric. Onsite and offsite green power is likely easier to obtain than offsets or other means of netting out onsite emissions.
- **In Portfolio Manager?** Portfolio Manager will calculate zero GHG emissions if a building uses electricity to meet 100% of its energy needs and meets all that need with onsite renewable electricity (consistent with the GHG Protocol scope 2 location-based inventory method[47]). Portfolio Manager does track offsite green power and, depending on the definition applied, it may be possible to calculate net zero carbon based on other metrics available in Portfolio Manager.
- **Available for all Buildings?** Yes
- **Standard Normalization Approach Exists?** N/A
- **Requires Data Verification?** Data that would be subject to verification for this metric includes 12 months of data

for all energy sources, onsite and offsite green power and the associated RECs, offsets, and renewable thermal certificates.

Zero (or Net Zero) Energy

- **What Is It?** The U.S. Department of Energy defines a zero-energy building as "[a]n energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable generated energy."[48] However, other organizations and policymakers have proposed alternative definitions which incorporate some of the same variations as the net-zero carbon definitions.
- **Why Is it on this List?** Several organizations and policymakers have proposed that zero or net-zero energy be a policy goal, despite not always having a common definition.
- **What Are the Implications?** EPA does not have a definition for zero or net-zero energy buildings because virtually every commercial and multifamily building uses energy, and it is important to understand the efficiency of buildings considering all the energy they consume on an actual, rather than net, basis. A zero or net-zero energy metric can obscure the energy efficiency of the building by combining energy use and renewable energy generation. Despite the language in the definition that a net-zero energy building must be energy efficient, without a benchmark for that level of efficiency it is possible that an inefficient building could produce or procure enough renewable energy to be defined as net-zero energy. In addition, this metric may allow fuels burned onsite to be balanced on an emissions basis by excess onsite green power generation, which is not a credible approach. Getting to zero energy may also be easier for buildings with lower energy needs as compared to a high energy intensity building, such as a hospital, that has more energy use to account for to achieve net zero. (While it could be harder for higher energy intensive buildings under any energy or carbon metric, that can be mitigated through normalization or establishing bins.)
- **Simple?** Zero/net-zero energy seems like a simple concept but determining whether a building has met the definition (of which there are several) requires that a building has accurate information about its use of onsite green power, tracking of RECs, and — if included in the definition, procurement of offsite green power. As described in the renewable energy sections above, the building must have metering in place to track the amount of green power generated onsite that it uses onsite as well as the RECs for both on and offsite green power use, if applicable.
- **Within Control of Building Owner?** Yes, building owners control the amount and type of energy used in their buildings.
- **Favors Electrification?** It may be easier to achieve zero energy if a building is fully electric.
- **In Portfolio Manager?** No, there is no zero/net-zero energy metric in Portfolio Manager. Through Portfolio Manager, EPA's ENERGY STAR program seeks to help building owners measure and compare the energy efficiency of their buildings, considering the total amount of energy needed to carry out the activities in the building. The concept of net-zero energy is not consistent with this objective.
- **Available for all Buildings?** Yes
- **Standard Normalization Approach Exists?** N/A
- **Requires Data Verification?** Data subject to verification for this metric includes 12 months of data for all energy sources used by the building, the quantity of green power generated onsite and exported, and all associated RECs. ♦

Section 3: Supporting Analysis and Discussion

This section provides additional background and analysis on two broad topics relevant to the choice of metrics for BPS policies:

- Site and source energy, and the calculation of the source conversion factor
- The interaction of electrification with emissions and efficiency

Site and Source Energy

Site energy represents the energy consumed at the building and typically matches what is on the energy bill. Source energy includes the amount of energy consumed at the building plus the energy needed to produce and distribute it to the building. Commercial buildings use different mixes of energy that may be delivered to a facility in one of two forms: as primary energy, that is the raw fuel burned to create heat and electricity, such as natural gas or fuel oil; or secondary energy, that is the energy product created from a raw fuel, such as electricity purchased from the grid or heat received from a district steam system. To evaluate building energy performance, source energy expresses these different energy types in a single common unit. Source energy traces the heat and electricity requirements of the building back to the raw fuel input, thereby accounting for any losses and enabling a complete thermodynamic assessment of the building.

Most buildings use electricity for lighting and other equipment. The reason that fuel mix varies by building is largely due to the choice of heating system. Another way to understand the relationship between fuel choice, source energy, and energy performance is to consider six different scenarios for heating systems in buildings, which are included in the figure below. For each scenario, the building operation and thermal envelope are the same. Therefore, the heat load for each building is identical. The differences among the buildings are solely in the type of heating fuel and the equipment used for heating. As a result of these differences, the buildings have different site and source energy consumption (using a national source conversion factor for electricity of 2.8), as shown in the table below. A comparison of these building scenarios using site energy does not recognize efficiency losses from the off-site energy generation, transmission, and distribution.

Building F, using inefficient electric resistance heat, consumes only 1,000 MBtu of site energy but 2,800 MBtu of source energy to heat its space. Compared to Buildings A and B, both using natural gas boilers, Building F looks better on a site energy

	Building A	Building B	Building C	Building D	Building E	Building F
Heating Fuel	**Natural Gas**	**Natural Gas**	**District Steam**	**Electric**	**Electric**	**Electric**
Heating System	Gas-fired Boiler 90% combustion efficiency 80% system efficiency	Gas-fired Boiler 70% combustion efficiency 55% system efficiency	District Steam 95% system efficiency	Geothermal COP=4.0	Air Source Heat Pump COP = 2.5	Electric Resistance Heat
Heat to Space (MBtu)	1000	1000	1000	1000	1000	1000
Site Energy (MBtu)	1250	1818	1053	250	400	1000
Source Energy (MBtu)	**1313**	**1909**	**1264**	**700**	**1120**	**2800**

Note that the U.S. source-site ratios were applied:

- *Electricity: 1 unit site = 2.80 units source*
- *Natural Gas: 1 unit site = 1.05 units source*
- *Steam: 1 unit site = 1.20 units source*

basis but is much worse on a source energy basis. Buildings D and E, on the other hand, are more efficient than Buildings A and B on a source energy basis because they are using heat pumps as their electric heating equipment.

Determining the Source Conversion Factor

Grid-purchased electricity is a secondary form of energy that is consumed at a building. It is generated through a variety of methods including the burning of fossil fuels (e.g., coal, natural gas, fuel oil), from nuclear plants, and from renewable sources including wind, hydropower, solar, geothermal, and biomass. To convert site electricity into source energy, we need to know the amount of energy lost during generation, transmission, and distribution of the site electricity.

In calculating source energy use intensity and the ENERGY STAR score, EPA uses a national source conversion factor. There are a few reasons why national source-site ratios are appropriate for ENERGY STAR metrics:

1. **Fixed Geography.** The geographic location is fixed for most buildings; there is no opportunity to relocate the building to a region with more efficient electrical production.
2. **Building Focus.** The key unit of analysis for Portfolio Manager is the building. It is the efficiency of the building, not the utility, which is evaluated. Two buildings with identical operation and energy efficiency will receive the same ENERGY STAR score regardless of their geographic location or utility company.
3. **National Program.** ENERGY STAR is a national program that provides efficiency benchmarks for all buildings. A national conversion factors enables comparisons of building efficiency independent of location.

The use of national source-site ratios ensures that no specific building will be credited (or penalized) for the relative efficiency of its utility provider. In some areas of the country, the percentage of renewable energy on the electric grid is much higher than in other areas, which would result in very different source energy factors if calculated at a regional level.

The current national source energy conversion factors in ENERGY STAR Portfolio Manager (for both the U.S. and Canada) are shown in the following table.

Energy Type	U.S. Ratio	Canadian Ratio
Electricity (Grid Purchase)	2.80	1.96
Electricity (Onsite Solar or Wind – regardless of REC ownership)	1.00	1.00
Natural Gas	1.05	1.01
Fuel Oil (No. 1,2,4,5,6, Diesel, Kerosene)	1.01	1.01
Propane & Liquid Propane	1.01	1.04
Steam	1.20	1.33
Hot Water	1.20	1.33
Chilled Water	0.91	0.57
Wood	1.00	1.00
Coal/Coke	1.00	1.00
Other	1.00	1.00

The factor for grid-purchased electricity is substantially higher than that for natural gas and other types of energy. In practice, this means that buildings heating with grid-purchased electricity may have higher source energy values than comparable buildings with natural gas heating (depending on the efficiency of their heating systems).

If the factor for grid-purchased electricity were calculated on a regional basis using data for EPA eGRID subregions, the factors would range from roughly 1.7 to 3.1.

Updating the Source Conversion Factor

The source-site ratios computed and applied in Portfolio Manager for grid-purchased electricity depend on several characteristics, including the quality of the fuels used to generate the electricity, the average efficiency of conversion from primary to secondary energy, and the transmission/distribution efficiency. Therefore, over time the ratios are expected to change as the national grid infrastructure and fuel mix evolve, just as it changed from over 3.1 to 2.8 in 2018 to reflect increased penetration of renewable energy on the grid.

As noted in Section 1, the Energy Information Administration's (EIA's) 2021 Annual Energy Outlook projects that renewables will make up 42 percent of the national electric grid by 2050,[49] which is roughly correlated to an electric source factor of 2.19. EIA's low renewables cost projection bumps the renewable contribution to around 55 percent and results in a source factor of 1.92. The table below includes EIA's projections as well as higher renewable growth scenarios.

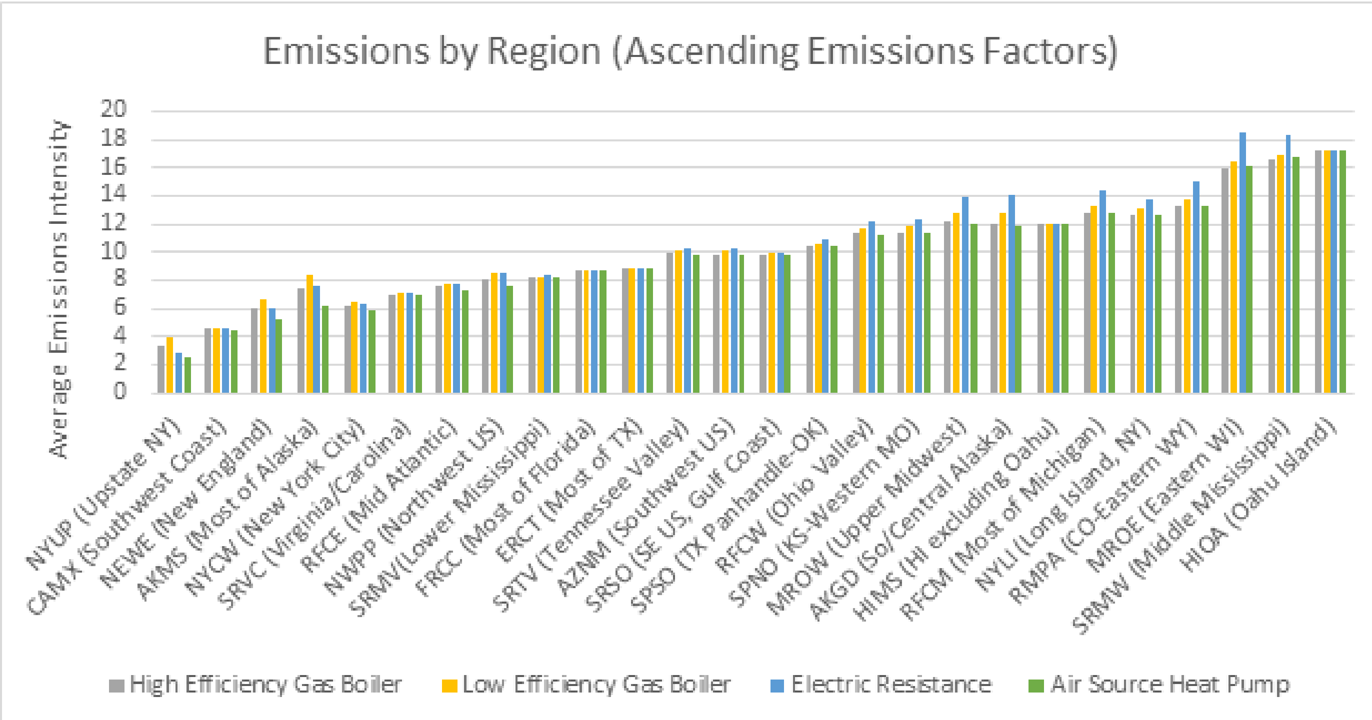
Year	% Renewable Energy on the Grid	National Electric Source Factor
2030 (EIA)	35%	2.33
2050 (EIA reference case)	42%	2.19
2050 (EIA low renewables cost case)	55%	1.92
?	80%	1.41
?	100%	1.00

As the percent of renewable energy on the grid continues to grow, EPA will regularly update the source conversion factor (approximately every 3-5 years). Over time, source energy metrics will get closer to site energy.

Interaction of Electrification with Emissions and Efficiency

The efficiency levels of electrification technologies are relevant not just for efficiency but also in terms of how they compare with fossil-fueled alternatives. The outcome of that comparison varies by region, depending on the carbon intensity of the electricity grid. The analysis presented below seeks to clarify these outcomes and help policymakers and building owners understand the related impacts of their technology choices.

The graph below compares the greenhouse gas emissions intensity of a hypothetical 100,000-square-foot building located in different EPA eGRID subregions.[50] Each eGRID subregion has



a different emissions factor associated with electricity generation, depending primarily on the mix of fuels used in a subregion's electric power plants. For each subregion, the graph compares the estimated emissions intensity of the hypothetical building when it uses different heating technologies (low efficiency natural gas boiler, high efficiency natural gas boiler, electric resistance heat, or air source heat pump). The subregions are ordered in terms of increasing emissions factor.

It is clear that the eGRID emissions factor is the most important driver in overall emissions, and that within each subregion, the efficiency of the heating technology can result in different ordering. In the eGRID subregions with high emissions factors and high heating load, such as Eastern WI (MROE), heat pumps result in lower emissions than electric resistance heating — by a substantial amount — but a high efficiency natural gas boiler results in the lowest emissions given today's eGRID subregion emissions factor. In areas with a low heating load on the other hand, such as Los Angeles (CAMX) or Oahu (HIOA), all the heating technologies look similar in terms of emissions intensity, likely because electric cooling loads dominate.

Overall, air source heat pumps result in the lowest, or equivalent to the lowest, emissions in 23 of the 26 eGRID subregion today. Of course, there are other factors that affect adoption of heat pump technology, including the relatively high cost of replacing existing natural gas or other fuel-based heating systems — though operating costs for heat pumps may be lower — and the current feasibility of heat pumps in colder climates and large buildings.

Building Energy Mix and ENERGY STAR Scores

Does using source energy as the basis for ENERGY STAR scores discourage electrification? To understand the impact on fuel mix of using source energy as the underlying metric for ENERGY STAR scores, EPA evaluated different scenarios using actual Portfolio Manager data.

To evaluate the performance of Portfolio Manager buildings that use a high percentage of electricity, EPA pulled a sample of 2,000 offices and 2,000 K-12 schools with data from 2018 or 2019. The samples were stratified based on Commercial Building Energy Consumption Survey (CBECS) regional and gross floor area (GFA) distributions.

Offices

The table below evaluates the 2,000 office buildings according to percent of site energy that is electricity: less than 70 percent, 70–90 percent, and over 90 percent. For all three bins, the office buildings have similar average ENERGY STAR scores, though they are highest for those in the over 90 percent category and lowest for those with less than 70 percent electricity. The current electric source factor of 2.8 does not appear to be disadvantaging office buildings with high percentages of electricity use.

% Site Electricity	Count of Offices	Average ENERGY STAR Score	% Currently Scoring >= 75
<70%	767	61	36%
70–90%	268	62	37%
>=90%	965	63	38%
Total	**2,000**	**62**	**37%**

About 19 percent of the offices in our sample had been ENERGY STAR certified in the past. Certified offices have an average percent site electricity mix of 83 percent, compared to 75 percent for offices that have never been certified. In all regions, certified offices tend to use a higher percentage of site electricity than non-certified buildings. This difference in average percent electricity use for certified and non-certified properties was found to be significant at the national level and for all regions except the West.

K-12 Schools

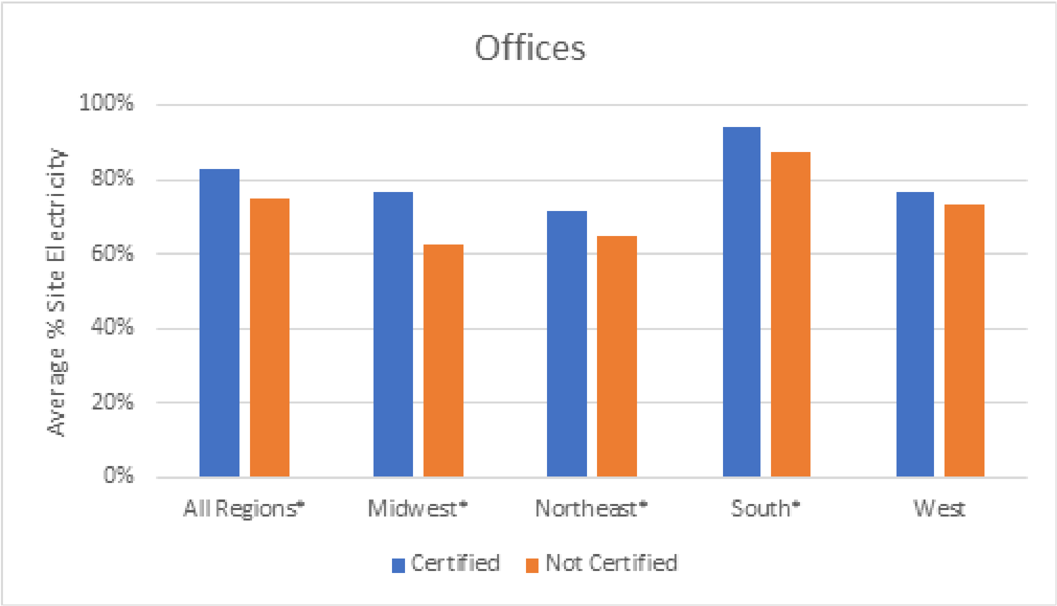
The table below evaluates the 2,000 school buildings according to same criteria for percent electricity: less than 70 percent, 70–90 percent, and over 90 percent. ENERGY STAR scores are highest for those schools in the over 90 percent electricity category and lowest for those with less than 70 percent electricity. As seen in the office building sample, the current electric source factor does not appear to disadvantage schools that use a high percentage of electricity onsite — in fact, quite the opposite.

% Site Electricity	Count of Schools	Average ENERGY STAR Score	% Currently Scoring >= 75
<70%	1,294	60	19%
70–90%	399	64	40%
>=90%	307	67	50%
Total	**2,000**	**61**	**24%**

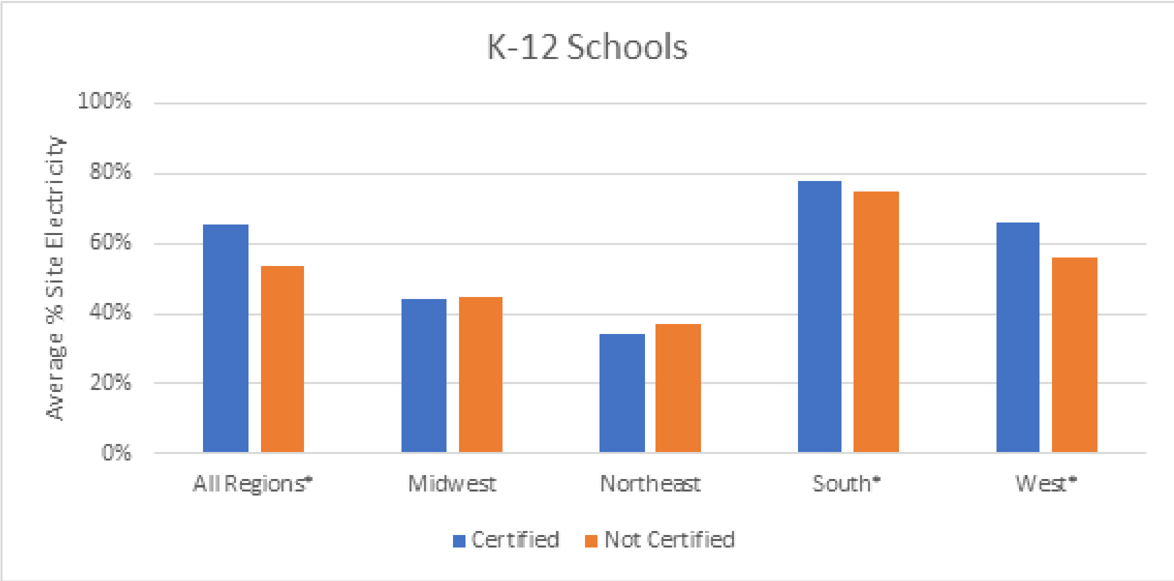
K-12 schools typically have more variation in heating load by region than offices, and it is important to compare electricity use to certification status at both the national and regional level. Schools in the Northeast and Midwest have relatively high heating loads and a larger percentage of their total site energy use is dedicated to heating, which is predominantly gas or oil. As a result, schools in these regions tend to have lower percent site electricity use than schools in warmer climates.

While the table below shows that there is more variation in percent site electricity use across regions than with offices, the differences between certified and non-certified buildings within each region remains minor. ENERGY STAR certified K-12 schools have higher average percent electricity use than non-certified schools at the national level, and in the South and West. The North and Midwest regions show that certified buildings have lower average percent electricity use than non-certified buildings, however these differences were not found to be significant.

This data indicates that the use of source energy to calculate the ENERGY STAR score does not penalize buildings that use electricity efficiently. In fact, EPA found that in many cases, certified buildings use a significantly higher percentage of electricity at the site than non-certified buildings. In this analysis, only certified K-12 schools in the Midwest and Northeast were found to have lower percent site electricity use than non-certified schools, and these differences were not found to be statistically significant. ♦



**Indicates a significant difference in the average percent site electricity between certified and non-certified offices*



**Indicates a significant difference in the average percent site electricity between certified and non-certified K-12 schools*

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