Does the metric matter? Comparing environmental and affordability metrics in building performance standards

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ABSTRACT

Building Performance Standards (BPS) are designed to reduce energy use and greenhouse gas emissions from existing buildings. BPS also have the potential to improve energy affordability at scale through reduced energy costs. However, all BPS policies to date use an environmental impact metric to measure performance. It remains to be seen whether using an affordability metric, such as energy burden, to design a BPS would produce meaningfully different outcomes. The objective of this study is to develop an affordability-focused BPS and compare its performance to an environmentally-focused BPS. Using Cincinnati, Ohio as a case study, a novel approach to BPS was developed that uses energy burden (EB) as the performance metric. This was then compared with a BPS that uses site energy use intensity (EUI) to answer two questions. First, who is impacted by each policy? Second, what are the overall benefits of each policy? Results show that the choice of performance metric matters substantially, as the EUI-focused BPS primarily targets energy-inefficient buildings across all income groups. In contrast, the EB-focused BPS more directly targets low-income households and produces larger energy, cost, and energy burden reductions for these groups, aligning more closely with jurisdictional equity goals. By analyzing BPS from both an environmental and affordability perspective, this paper explores how energy policy for existing buildings can be adapted to deliver the greatest benefit where it is most needed.

Introduction

Building Performance Standards (BPS) are designed to reduce energy use and greenhouse gas (GHG) emissions from existing buildings. They are policies that require existing buildings to meet a minimum performance target by a specified date. Buildings that do not meet the target must implement retrofits to improve their performance, and non-compliance with the policy may result in penalties or fees. Thus, BPS can benefit jurisdictions that adopt them by driving large-scale transformation of the existing building stock, leading to meaningful reductions in energy use and emissions (Webb and McConnell 2023). Recognizing such benefits, more than a dozen U.S. cities, counties, and states have already adopted a BPS (Institute for Market Transformation 2026), and many more jurisdictions are planning to adopt one.

A key component of a BPS is its performance metric. To date, existing BPS policies have relied exclusively on environmental impact metrics to measure building performance. These are typically either site energy use intensity (EUI) or GHG emissions intensity (GHGI), which represent a building's annual energy use or GHG equivalent emissions normalized by its floor area. Prior work suggests that the choice of metric is important. The U.S. Environmental Protection Agency (2022) compared a variety of BPS metrics based on key considerations for use, including what aspects are in the control of the building owner, and what data is needed for verification. Bohn et al. (2026) examined the use of energy and GHG metrics in a BPS and found that the choice of metric can significantly affect overall city-wide savings from the policy.

While BPS are typically designed to achieve environmental impact, recent work has begun to consider affordability impacts, as well. BPS have the potential to improve energy affordability at scale through reduced energy costs. Yet, they also risk negatively impacting affordability, as required building improvements could lead to rent increases, property redevelopment, and potential displacement of residents (Hart et al. 2020). Work to date has focused on alleviating potential negative impacts on vulnerable communities, which include low-income households, affordable housing residents, and communities already facing overlapping climate, economic, and social burdens (Sharrow et al. 2025). Three common approaches have emerged for addressing affordability in BPS: first, creating alternative compliance pathways for affordable housing and other priority building types, often through extended timelines, adjusted interim targets, or added flexibility; second, providing targeted technical assistance to affordable housing, including benchmarking support and no-cost energy audits; third, offering financial support, such as grants, low-interest loans, and dedicated incentive programs, to help building owners overcome upfront capital barriers (Jarrah et al. 2024).

Providing additional support and flexibility to these buildings is an important step, but a more direct approach to addressing energy affordability would be to embed it into the BPS itself. Prior research suggests this is worth investigating because environmental metrics alone do not always capture equity-related outcomes. Studies in other domains such as climate, transportation, and water policy show that conventional environmental metrics—like emissions reductions, efficiency, or infrastructure performance—can overlook how the benefits and burdens of these policies are distributed across vulnerable communities, unless explicitly addressed using an affordability metric (Cushing et al. 2018; Karam and Ryerson 2023; Cardoso and Wichman 2022). Yet, no work to date has examined whether using an affordability metric to design a BPS would produce meaningfully different outcomes.

The objective of this study is to develop an affordability-focused BPS and compare its performance to an environmentally-focused BPS. The analysis uses Cincinnati, Ohio as a case study. Cincinnati is a large urban area with stated climate and energy poverty goals for the buildings sector. A large dataset combining metered energy use, energy costs, building characteristics, and demographic information was first created. Then, a novel approach to BPS was developed that uses energy burden (EB) as the performance metric. This was compared with a BPS that uses site EUI to answer two questions. First, who is impacted by each policy? This was evaluated by examining the characteristics and performance of compliant and non-compliant buildings under each policy. Second, what are the overall benefits of each policy? Benefits evaluated include both household and city-wide energy and cost savings. By analyzing BPS from both an environmental and affordability perspective, this paper explores how energy policy for existing buildings can be adapted to deliver the greatest benefit to local households.

Methods

Cincinnati's climate and energy poverty goals

Like many cities who have already enacted a BPS, Cincinnati is a large urban area with ambitious climate goals. In 2023, Cincinnati adopted the most recent version of its climate action plan, the Green Cincinnati Plan (GCP), which committed Cincinnati to a city-wide goal of 50% reduction in GHG emissions by 2030, and carbon neutrality by 2050 (City of Cincinnati 2023).

The GCP also set a specific goal for the buildings sector of reducing total building emissions by 30% by 2030. While the GCP mentions benchmarking and BPS policies as potential actions towards this goal, Cincinnati has yet to enact either of these policies. However, for the past several years Cincinnati has been part of an initiative to develop BPS in Ohio, funded by the U.S. Department of Energy (Webb et al. 2024).

Cincinnati is unusual among other large U.S. cities in also having a stated energy poverty goal in its climate action plan. In 2016, Cincinnati was identified as having the 9th highest median energy burden among major U.S. cities (Drehobl and Ross 2016), and reducing energy burden has been an ongoing local priority since then. The prior version of the GCP, in 2018, included an energy burden goal, and the 2023 GCP also includes a specific goal to reduce the number of households experiencing energy poverty by 10% by 2028. The 2023 GCP treats energy poverty as synonymous with high energy burden, defining energy poverty as occurring when a household spends more than 6% of its income on utilities, which is the same high energy burden threshold suggested by Drehobl et al. (2020). Drehobl et al. (2020) also list Cincinnati among only a few cities with an energy burden goal, making it an especially pertinent case study for comparing the use of environmental and affordability metrics in policy.

Creating a multifamily buildings dataset

Figure 1 illustrates the overall methodology used in this analysis. First, an initial dataset describing the characteristics and energy performance of Cincinnati's multifamily buildings was developed by combining several data sources: tax assessor records from the Hamilton County Auditor, metered energy use and cost data provided by retail electric and natural gas suppliers, and supplementary building characteristics obtained from CoStar (Hamilton County Auditor 2025; CoStar Group 2025). Tax assessor data provided building characteristics at the parcel level, including a unique parcel number, street address, floor area, and property type. The metered energy dataset included twelve months of recent electricity and natural gas consumption and costs for each meter. These were geocoded and each meter was matched to a parcel, summed annually, and then aggregated to give annual energy use and costs for each parcel. Parcel-level data was assumed to represent building-level estimates for the purposes of this research. Data from CoStar provided additional building characteristics, including number of apartment units and property type. This compiled dataset was produced by Bohn et al. (2026) and contained 66,702 records. The initial dataset was then cleaned by removing records with missing property type and missing or zero floor area and annual total energy use.

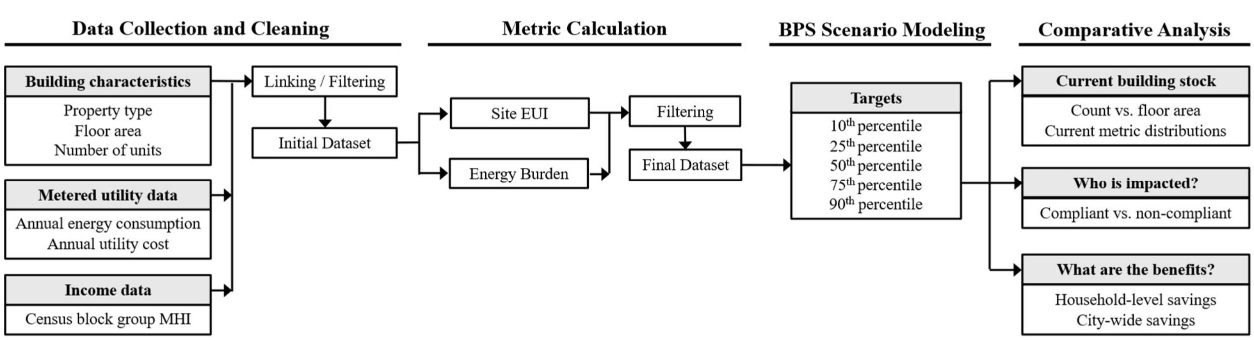

Figure 1. Diagram of data processing and analysis methodology

The compiled dataset was then further filtered to include only multifamily properties, resulting in a sample of 4,868 records. Filtering to multifamily properties left only the following property types in the analysis: Apartment (4–19 units), Apartment (20–39 units), Apartment (40+ units), Mixed use (Retail), Mixed use (Office), and Metropolitan Housing Authority (MHA).

Estimating median household income (MHI)

To estimate energy burden, income data were assigned to each multifamily building in the dataset using area-level income information. Census block group median household income (MHI) for Cincinnati was downloaded from the American Community Survey (ACS) and spatially matched to buildings based on census block group. ACS income data were used because it is a widely used source for estimating neighborhood- or small-area income conditions and has been used in prior studies, including Moore and Webb (2022) and Scheier and Kittner (2022). When available, the MHI within one mile of a property was also found through CoStar. When ACS income data was unavailable, CoStar income data were used as a supplemental source. This income data were then geocoded and matched with buildings according to their census block group. Afterwards, any buildings with missing or zero MHI were removed resulting in 4,180 records. These records were removed because energy burden could not be calculated without a valid income. This approach does not produce true household-level income. Instead, it assigns an area-level income value to each building and uses that value as a representative income estimate for all households in the building. This assumption was made because household-specific income data is difficult to obtain for large-scale policy analyses. The distribution of MHI within the Cincinnati multifamily building stock was then examined using percentiles. The 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles corresponded to $24,208, $35,203, $54,250, $80,000, and $108,000, respectively. Fixed income ranges were developed by rounding these percentile values into simpler, more interpretable categories. The final income ranges were: <$25,000, $25,000–$34,999, $35,000–$54,999, $55,000–$79,999, and >$80,000.

Calculating site energy use intensity (EUI)

Site EUI was chosen as the environmental metric for this study because it is used in many existing BPS and because it directly reflects the energy efficiency of a building. Existing site EUI for each building was calculated by dividing its total energy use by its floor area, as shown in Equation 1. Total energy use for each building was found by adding its annual electricity and annual natural gas consumption (if present). Buildings with missing or zero site EUI values, or site EUI values greater than 1,000 kBtu/ft², were set to be excluded to remove extreme outliers. However, no records met these criteria, so the sample size remained unchanged.

$$Site\ EUI = \frac{Annual\ energy\ use\ (kBtu)}{Total\ floor\ area\ (ft^2)} \qquad \text{(Eqn. 1)}$$

Another major assumption made in this research was to treat building-level site EUI as household-level site EUI. This assumption was necessary because the available metered utility data were aggregated at the building-level rather than provided for individual households. As a result, the analysis could not calculate separate site EUI values for each household. Instead, the building-level site EUI was interpreted as the average energy intensity and applied uniformly across households within each building. In reality, individual apartments may have different energy intensities due to variation in unit size, occupancy, equipment, and energy use behavior.

Calculating energy burden (EB)

Energy burden (EB) was chosen as the affordability metric for this study. EB was chosen because it aligns with Cincinnati's GCP goal, and because the distribution of EB has been explored previously in both Cincinnati and across the U.S. (for example, see Moore and Webb (2022) and Drehobl and Ross (2016)). Existing household-level EB (EB_{HH}) was estimated by converting building-level data to approximate household-level values. Total annual energy costs were divided by the estimated number of apartment units per building to get household-level energy costs ($Energy\ costs_{HH}$) as shown in Equation 2.

$$Energy\ costs_{HH} = \frac{Annual\ energy\ costs\ (\$)}{Number\ of\ apartment\ units} \qquad \text{(Eqn. 2)}$$

Apartment unit counts were taken primarily from CoStar. When CoStar unit counts were unavailable, the number of units was approximated using the larger of the electricity or natural gas meter counts associated with the building. These meter counts were included in the retail utility supplier data and were used as supplemental information to estimate the number of units per building. Finally, existing EB was calculated by dividing annual household-level energy costs by annual MHI as shown in Equation 3.

$$EB_{HH} = \frac{Energy\ costs_{HH}}{MHI\ (\$)} \times 100\% \qquad \text{(Eqn. 3)}$$

Due to the assumptions made, the EB values presented in the results should be interpreted as approximations of household affordability conditions rather than exact household-level burdens. Afterwards, buildings with EB values equal to zero or greater than 100% were excluded because these values likely reflected data limitations and denominator issues. After this filter was applied, the final dataset contained 4,171 records.

Developing and analyzing BPS scenarios

BPS targets are often based on percentiles derived from the local building stock, by property type. For example, the standard target pathway in Washington, DC's BPS establishes targets by property type using the local median (50^{th} percentile) ENERGY STAR score (Institute for Market Transformation 2026). Following this, each building in the Cincinnati dataset was assigned a set of locally derived targets based on percentile. Ten locally derived BPS targets were generated for this study: targets set at the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentile of site EUI (EUI-BPS scenarios), and targets set at the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentile of EB (EB-BPS scenarios). Percentiles ranging from the 10^{th} to the 90^{th} were chosen for each metric to evaluate how increasingly stringent performance thresholds affect the results of the study.

After the targets were determined, the EUI-BPS and EB-BPS scenarios were compared through several analyses. First, the current building stock was analyzed to understand the distribution of existing site EUI and EB by property type and income range. Property type and size are key factors in determining the scope of a BPS. While many BPS include only the largest multifamily buildings (often around 25,000 ft² or larger), this analysis retained all multifamily buildings regardless of floor area. This allowed for an evaluation of the role of smaller multifamily buildings in BPS outcomes, a building type which may be important for addressing energy poverty goals, but which is typically excluded from BPS coverage. Income range provided comparisons of how BPS outcomes differ across lower-, moderate-, and higher-income households. Other variables such as building age were excluded from the analysis because prior work showed that building age was not a significant predictor of energy burden in Cincinnati (Moore and Webb 2022). Second, to determine who is affected by each policy, the characteristics and performance of compliant and non-compliant buildings were evaluated. Here, compliant (or "passing") buildings were those that currently meet the target, while non-compliant (or "failing") buildings were those that do not currently meet the target. The median energy reduction required for non-compliant buildings to meet each target was also calculated. To illustrate the relationship between existing site EUI and existing EB, a scatterplot showing both variables was examined. Third, to determine the overall benefits of each policy, household-level (median) and aggregated city-wide (total) energy and cost savings that would result from all failing buildings meeting their target were calculated. Evaluating both scales is important because BPS policies are implemented city-wide, but their benefits (or burdens) are experienced by individual households. The total savings were broken down according to property type and income range to understand how savings are distributed among households. The existing and new energy burden resulting from meeting each target was also plotted by income range, to evaluate whether meeting each target translated into meaningful burden reductions.

Results

Current building stock analysis

Small apartments (4–19 units) make up the largest portion of Cincinnati's multifamily building stock by count (74%) and also account for a large portion of floor area (38%). In contrast, large apartments (40+ units) are only a small share of the multifamily stock by count (6%), but account for an equally large portion of floor area (38%). Figure 2 illustrates this point by showing the breakdown of Cincinnati's multifamily buildings by count (Figure 2a) and total floor area (Figure 2b) according to property type. Since floor area scales with total energy use and emissions (larger buildings use more energy), this result highlights the importance of considering both larger and smaller multifamily properties in policy design. Addressing the larger apartment buildings (40+ units), as many current BPS do, offers good value, impacting a substantial portion of floor area by regulating a comparatively small number of buildings. But regulating only larger buildings would leave most multifamily properties and households unaffected. Addressing the smaller buildings (4–19 units) in a BPS or companion policy provides the opportunity to impact the majority of Cincinnati's multifamily buildings and residents.

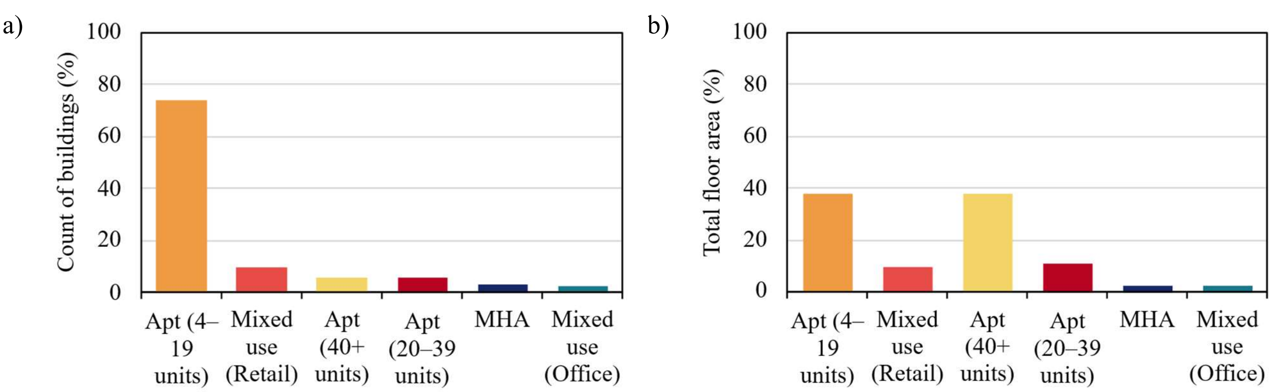

Figure 2. Breakdown of multifamily buildings by a) count and b) total floor area by property type

Distributions of existing site EUI and EB show that site EUI does not vary substantially by property type or income, while EB does. This suggests that the two metrics capture different dimensions of performance. Figures 3a-d present boxplots of existing site EUI and EB by property type and income range, with boxes showing the 25th and 75th percentiles, the center line showing the median, and whiskers showing the 10th and 90th percentiles. Figure 3a shows that MHA buildings (i.e., public housing) have the highest median site EUI, but also have a wide spread, indicating variation in performance. Among apartment buildings, median EUI decreases as building size increases, suggesting that larger multifamily buildings are generally more efficient. However, MHA and large apartments (40+ units) also include a noticeable share of highly inefficient buildings, with upper whiskers approaching 200 kBtu/ft². These high-EUI buildings represent properties likely to be targeted by an EUI-focused BPS and may offer substantial opportunities for energy savings. Figure 3b shows that median EB is highest in MHA buildings, followed by mixed-use buildings, while apartment buildings have lower EB values. Median EB for all property types remains below the 6% high threshold. Figure 3c suggests that site EUI does not vary by income level, while Figure 3d shows that EB varies substantially by income: households earning less than $25,000 have the highest burden, with most above the 6% threshold, while households earning over $80,000 have the lowest and least variable EB levels. Together, these results show why the choice of BPS metric is important. While site EUI identifies energy-inefficient buildings, it does not necessarily prioritize households experiencing the greatest affordability issues. EB however, directly reflects the combined effect of energy costs and income, making it more sensitive to the conditions faced by low-income households.

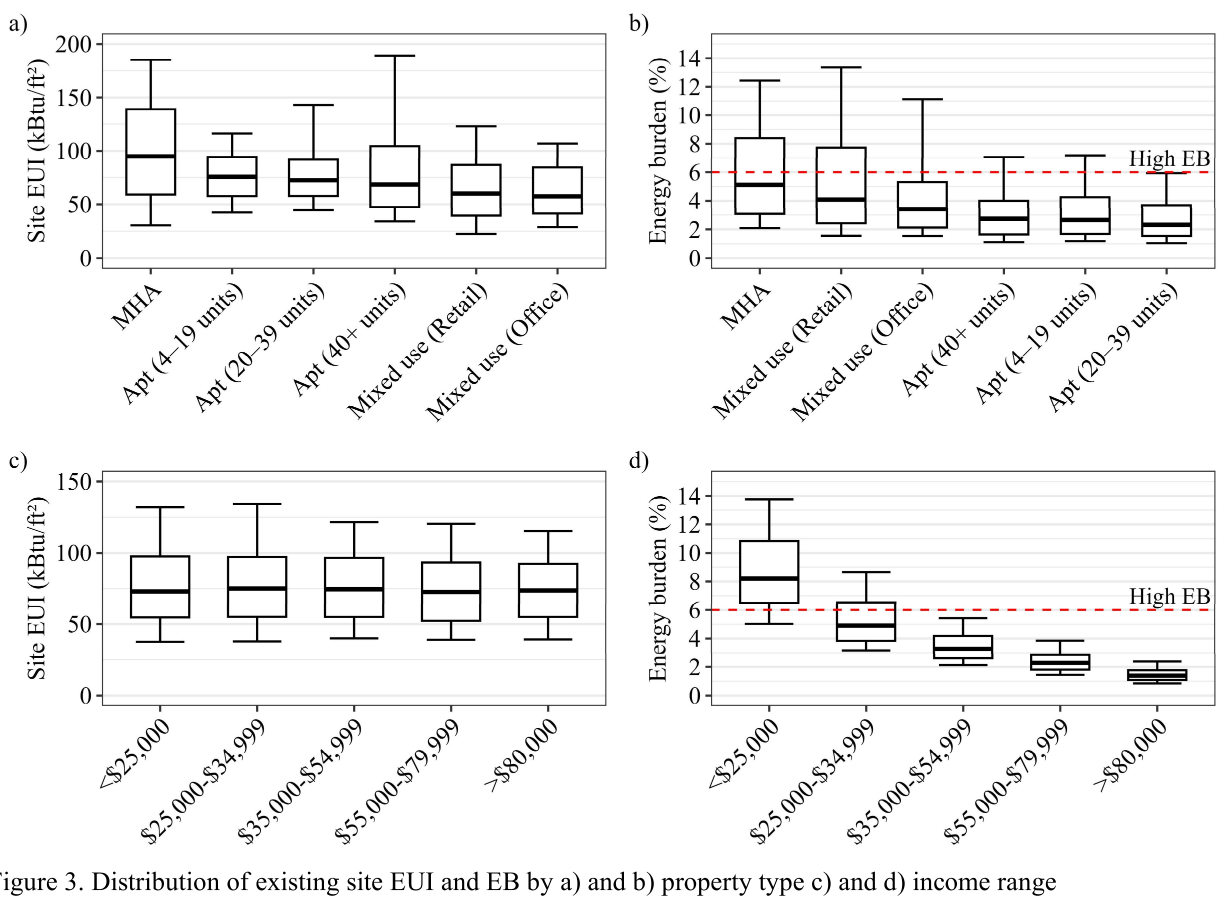

Figure 3. Distribution of existing site EUI and EB by a) and b) property type c) and d) income range

Who is impacted by each policy?

The choice of BPS metric shifts which households are targeted. Table 1a and 1b present results for the site EUI targets and EB targets, respectively. For each percentile, the tables report the target value, median existing site EUI, energy burden, MHI, and the energy reduction needed for buildings to meet their target. Results are grouped by compliance status, where buildings are classified as passing or failing based on whether they currently meet the target. Table 1a shows that the EUI-BPS scenarios primarily target energy-intensive buildings, with large differences in median site EUI between passing and failing buildings but minimal differences in median EB and income. In contrast, Table 1b shows that the EB-BPS scenarios target buildings by income, with larger differences in median EB and income between passing and failing buildings, but relatively similar site EUI. Overall, EUI targets apply more broadly across the building stock, while EB targets concentrate on lower-income households. In Table 1b the 90th percentile EB target is especially notable: the MHI of failing buildings is about $21,000, which suggests that even a relatively lenient target can remain difficult for some low-income households to meet. These tables also show that meeting the site EUI targets generally requires smaller median energy reductions, while meeting the EB targets requires larger energy reductions. This suggests that although income is the primary driver of energy burden, energy performance still influences compliance. Buildings with higher energy use tend to have higher energy costs, which can raise energy burden, especially for lower-income households. As a result, inefficient buildings in lower-income areas are more likely to fail EB targets, showing that energy efficiency remains an important strategy for reducing burden and improving compliance.

Table 1a. Summary statistics for each site EUI percentile target

Percentile	10th		25th		50th		75th		90th	
Site EUI target (kBtu/ft^2)	39		55		74		95		122	
Compliance	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
Median existing site EUI (kBtu/ft^2)	31	77	42	83	55	95	65	114	70	160
Median existing EB (%)	3	3	3	3	3	3	3	3	3	4
MHI ($)	54,500	54,500	55,083	54,091	54,931	53,750	55,083	51,786	54,931	50,262
Median energy reduction (%)	-	49	-	35	-	22	-	17	-	24

Table 1b. Summary statistics for each EB percentile target

Percentile	10th		25th		50th		75th		90th	
Energy burden target (%)	1		2		3		5		8	
Compliance	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
Median existing site EUI (kBtu/ft^2)	71	74	73	74	72	75	73	76	73	82
Median existing EB (%)	1	3	1	3	2	5	2	7	3	11
MHI ($)	109,564	51,020	95,137	42,208	79,274	35,653	64,053	26,816	56,438	20,905
Median energy reduction (%)	-	60	-	50	-	39	-	35	-	26

Figure 4 helps explain why the two metrics target different households by showing the relationship between EB and site EUI. Figure 4 plots EB on the x-axis and site EUI on the y-axis, with dashed lines marking percentile targets for both metrics. Figure 4a colors observations by income range, and Figure 4b colors them by energy cost range. In Figure 4a, the points are widely scattered vertically across most EB values, suggesting a very weak relationship between site EUI and EB (Pearson's correlation coefficient r = 0.061). The EUI-BPS scenarios primarily reflect physical building efficiency, whereas EB-BPS scenarios capture energy-related household economic conditions. This means that relying on a single metric in BPS design can neglect some households that may be of interest because they meet the selected performance target. For example, buildings located to the left of the 50th percentile EB target line meet the EB target and would therefore be excluded from being retrofitted. However, this overlooks households with very high site EUI. The same issue occurs when only site EUI targets are considered. A clear horizontal pattern also appears across income groups. Lower-income households cluster farther to the right, indicating higher energy burden, even though their site EUI spans a broad range similar to other groups. Higher-income households cluster more to the left, showing consistently lower burden. This suggests that income is strongly tied to EB, but less clearly tied to EUI, echoing Figures 3c and 3d. In Figure 4b, energy cost groups also shift rightward as bills increase, which is expected because higher energy costs directly raise energy burden. The highest-cost households are spread across a wide range of EUI values, including moderate and high EUI. This suggests that high burden is not limited to the most energy-intensive buildings but also occurs where energy costs are high relative to household income.

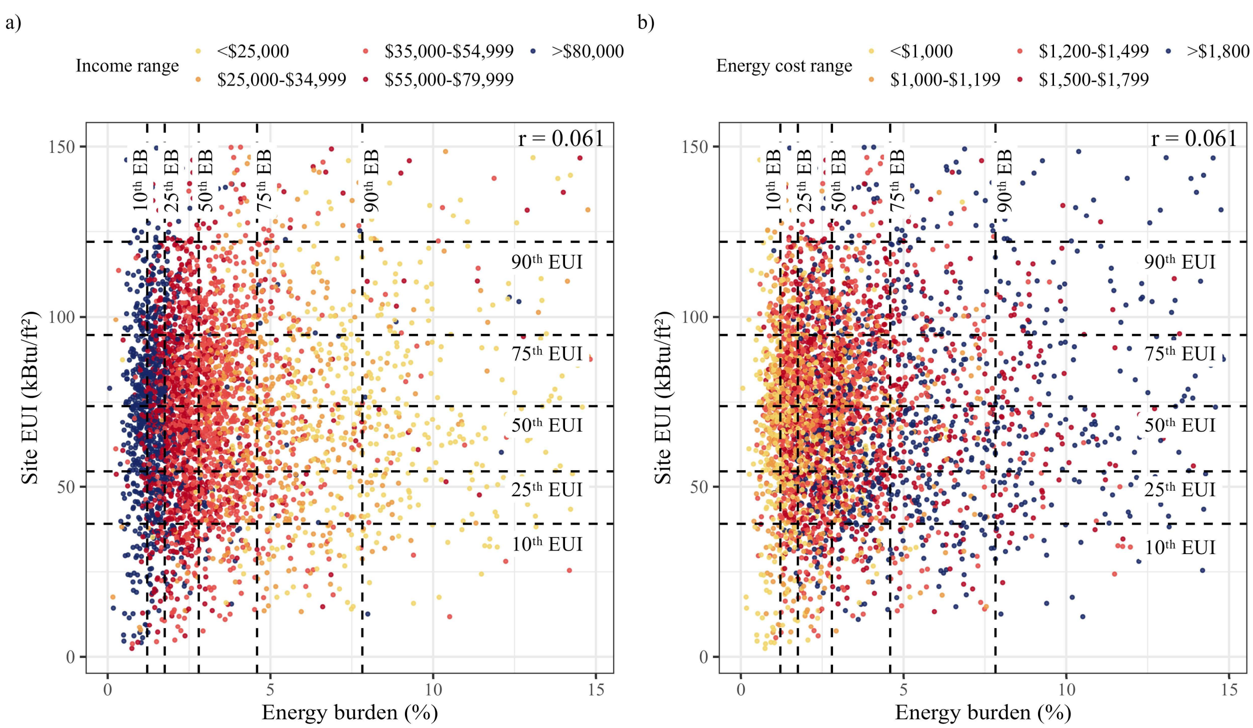

Figure 4. a) Site EUI vs EB by income range b) Site EUI vs EB by energy cost range

What are the overall benefits of each policy?

The EB-BPS scenarios provide greater energy and cost savings at the household-level than the EUI-BPS scenarios. This is indicated in Table 2a and 2b, which shows the household-level summary statistics for non-compliant buildings if they met their target. For each scenario, the tables report the new median site EUI, energy burden, energy savings, and cost savings (note that the energy savings percentage here is the same as the energy reduction percentage in Table 1a and 1b). Two important trends emerge from the tables. First, savings generally increase as the BPS scenarios become more stringent except for the 90th percentile site EUI target, where median savings are higher than the 75th percentile. This may occur because the non-compliant households for the 90th percentile target consist only of the highest-EUI households, which are farther from even the more lenient threshold. The 75th percentile target includes more buildings, and the majority may be only slightly above the target. Second, the EB scenarios (Table 2b) consistently provide greater household-level savings at a given percentile than the site EUI scenarios (Table 2a). This is because meeting the EB targets requires greater median energy reductions than meeting the site EUI targets, leading to greater savings. Lowering energy burden requires proportionally larger decreases in household energy costs and energy use. As a result, although the EB framework targets affordability rather than energy intensity directly, it actually produces deeper energy reductions.

Table 2a. Summary statistics for non-compliant households meeting EUI percentile targets

EUI percentile	10th	25th	50th	75th	90th
Median new site EUI (kBtu/ft^2)	39	54	74	94	122
Median new EB (%)	1	2	2	2	3
Median energy savings (kBtu)	26,512	19,463	13,428	11,899	16,449
Median energy savings (%)	49	35	22	17	24
Median cost savings ($)	685	473	324	277	401

Table 2b. Summary statistics for non-compliant households meeting EB percentile targets

EB percentile	10th	25th	50th	75th	90th
Median new site EUI (kBtu/ft^2)	28	36	43	47	55
Median new EB (%)	1	2	3	5	8
Median energy savings (kBtu)	30,212	25,842	22,343	21,226	19,521
Median energy savings (%)	60	50	39	35	26
Median cost savings ($)	871	746	643	653	574

The EB-BPS scenarios also provide greater city-wide energy and cost savings than the EUI-BPS scenarios. Figure 5 shows total energy savings in MMBtu and total cost savings in million dollars across all percentile targets for both metrics, displayed as stacked bars by property type (Figure 5a and 5b) and income range (Figure 5c and 5d). The results show that total energy and cost savings decline as the targets become less stringent, with the EB-BPS scenarios generally producing greater total savings than the EUI-BPS scenarios. By property type, large apartments (40+ units) contribute the largest share of both total energy and cost savings across all percentile thresholds under both metrics. This is expected because they represent a large share of total floor area. However, small apartments (4–19 units) produce the second-largest energy and cost savings. Although each building is smaller, this group made up the largest share of buildings and had relatively high site EUI, giving it strong aggregate savings potential, especially under stricter targets. These results suggest that adopting a lower floor area threshold in Cincinnati could allow a BPS to capture more aggregate energy and cost savings.

By income range, Figures 5c and 5d show that under the EB-BPS scenarios buildings in the lower- and moderate-income ranges contribute a substantial share of total savings, particularly the <$25,000, $25,000–$34,999, and $35,000–$54,999 groups. This suggests that EB-based targets are more effective at directing savings toward buildings where affordability concerns are more likely to be present. However, the results also show that higher-income groups still contributed meaningful savings, especially under stricter thresholds.

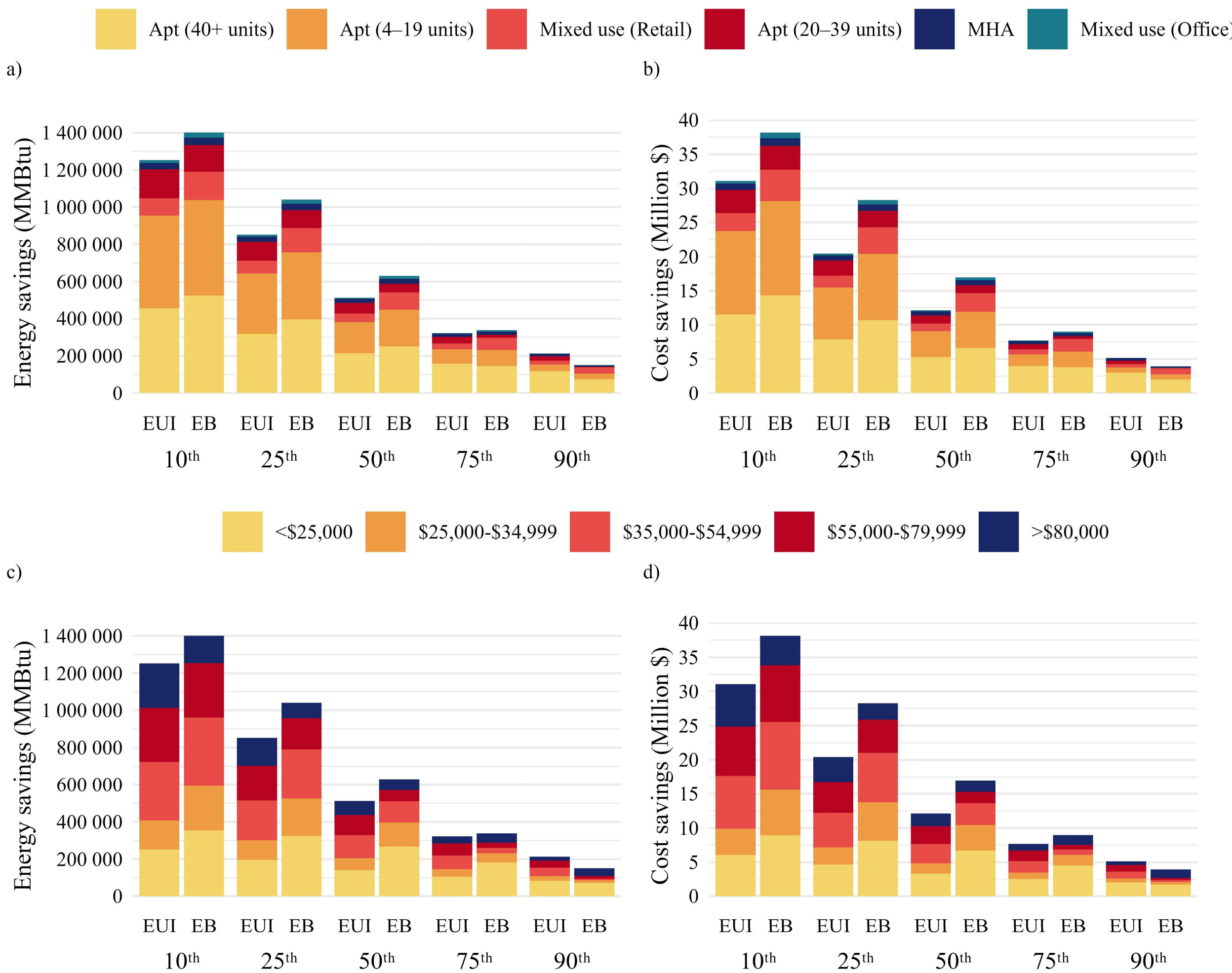

Figure 5. Total energy and cost savings for each scenario by a) and b) property type c) and d) income range

The EB-BPS scenarios produce larger reductions in energy burden overall, particularly for lower-income households. Figure 6 compares existing and new median energy burden for currently failing buildings across income ranges for each percentile target, with existing EB shown as a red circle and new EB shown as a blue dot. There are two important observations. First, meeting the EB targets flattens the distribution of EB, while meeting the site EUI targets does not. The blue dots under the EUI targets maintain a similar curved shape as the red circles, highlighting how meeting the site EUI targets reduces energy burden, but does not fundamentally change the distribution of energy burden across income groups (the lowest income households are still the most burdened). Second, at more stringent percentiles, the EB targets primarily reduce energy burden among lower-income groups. Beyond the 50^{th} percentile, however, EB targets affect a wider portion of the income distribution, resulting in burden reductions among households earning $55,000 and above. This occurs because the EB thresholds become less stringent and therefore apply to more households beyond the most burdened low-income group. As a result, less stringent EB targets spread reductions more broadly across the income distribution. It's also worth noting that the 90th percentile EB target is above the 6% GCP threshold, indicating that this scenario is too lenient.

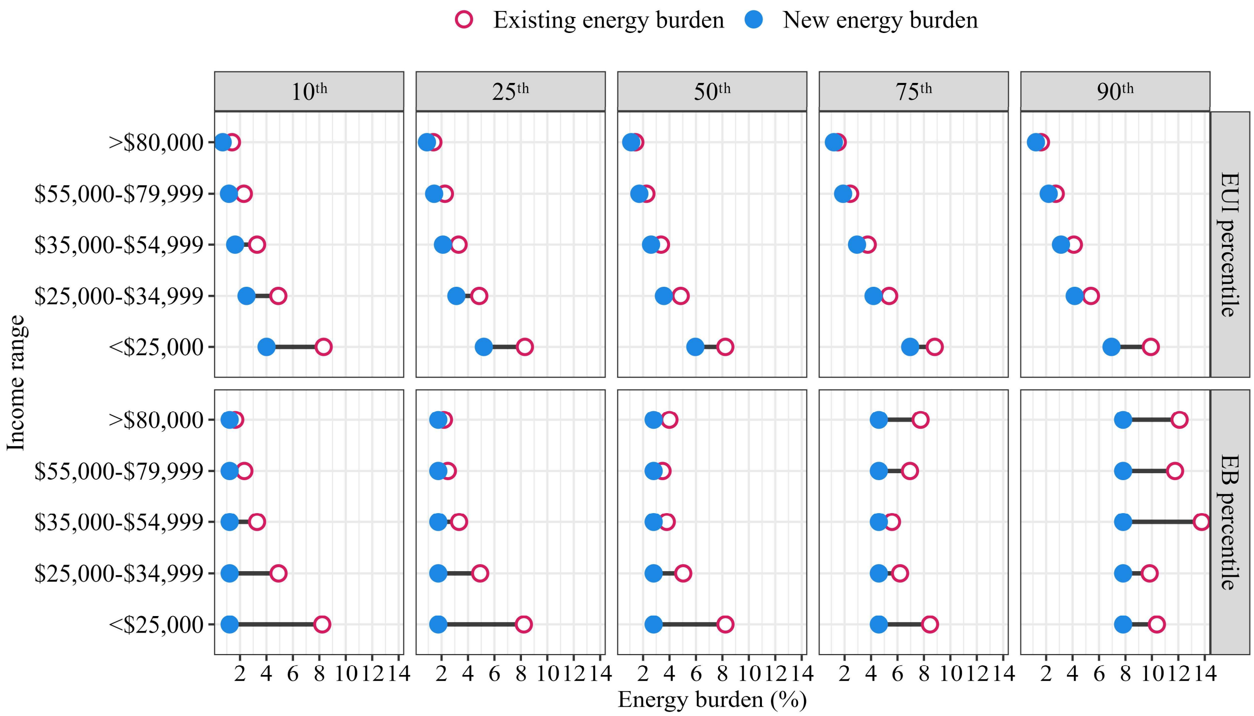

Figure 6. Existing and new median energy burden for currently failing buildings under each scenario

Discussion and Conclusion

The objective of this paper was to develop an affordability-focused BPS and compare its performance to an environmentally-focused BPS. Using Cincinnati, Ohio as a case study, a novel approach was developed where a BPS using energy burden as its performance metric was created and compared to a conventional one that uses site EUI. In doing so, two research questions were addressed. First, who is impacted by each policy? Second, what are the overall benefits of each policy? Results showed that the performance metric mattered substantially as the EUI-focused BPS primarily targeted energy-inefficient buildings across all income groups, producing broad city-wide efficiency improvements. In contrast, EB-focused BPS more directly targeted lower-income households, producing larger energy, cost, and burden reductions for these groups.

This study demonstrates that the choice of performance metric substantially influences BPS outcomes. The results showed that the EB-BPS scenarios delivered greater overall benefits compared to the EUI-BPS scenarios, primarily because meeting the percentile-based EB targets required deeper reductions than the corresponding site EUI targets. This overall result is consistent with prior BPS research showing that metric choice strongly shapes policy outcomes. Bohn et al. (2026) explored site EUI and GHGI as performance metrics to develop a BPS, and found that both metrics produced roughly equivalent emissions savings, but the GHGI metric yielded far less energy savings. Together, these findings suggest that percentile-based BPS targets are highly sensitive to the underlying metric used to define performance. Therefore, jurisdictions should select metrics carefully to ensure that the resulting outcomes reflect the policy's intended priorities.

The choice of metric also determines who gets prioritized under a BPS. The site EUI scenarios primarily targeted buildings based on energy intensity. As a result, lower-income households were less likely to be prioritized. In contrast, the EB scenarios not only targeted households based on energy affordability but also delivered deeper benefits through lower energy costs and larger burden reductions to lower-income households. This aligns with prior studies that explored equity-oriented allocation frameworks, which emphasize that policy benefits should be directed toward groups with greater socioeconomic need, rather than distributed only according to technical performance metrics (Karam and Ryerson 2023). Yet, even a better metric may still be insufficient on its own. A key finding in this study was that using EB did not necessarily capture buildings with high energy intensity. Choosing to develop a BPS using one performance metric may therefore neglect a portion of the building stock that still needs retrofitting. One solution to this dilemma would be to use EB as a primary metric alongside EUI as a complementary screening metric. EB could identify buildings where residents are more likely to need affordability-related support, while EUI could guide the scale and type of retrofits needed to improve building performance.

A broader implication of using EB as a performance metric is that cities would need to reconsider the scope of covered buildings and the data needed to define that scope. Many existing BPS policies focus on a relatively small number of large buildings, which can make implementation more manageable but may exclude a majority of the multifamily housing stock. In Cincinnati, small apartments (4–19 units) represented the largest portion of multifamily buildings and contributed the second-highest city-wide energy and cost savings after large apartment buildings. This suggests that smaller multifamily properties can offer substantial aggregate savings potential, even if each individual building is relatively small. Excluding these buildings from BPS coverage could therefore limit both the energy savings potential of the policy and its ability to reach households experiencing affordability challenges. In some cases, these smaller buildings may already be served by existing weatherization, utility, or other assistance programs. Including these buildings as part of a BPS or complementary policy would help maximize the impact of these programs towards meeting broader jurisdictional goals.

Using EB as a metric also raises the practical question about how cities would collect, and track household income data. Unlike site EUI or GHGI, EB requires an estimate of household income in addition to building energy use and energy costs. Affordability concerns are better captured when using individual household income distributions rather than median income, because median income can understate burdens for low-income households (Cardoso and Wichman 2022). Yet, collecting exact household income from residents would likely be intrusive and administratively difficult. Cities could use less intrusive approaches, such as ACS block group median household income (the method used in this study), affordable housing eligibility data, or self-reported income ranges, to identify buildings where affordability concerns are more likely to be present. Another approach would be to use building-level affordable housing indicators, such as subsidized housing, deed-restricted affordable housing, public housing, LIHTC properties, or naturally occurring affordable housing. These indicators are often readily available and may be easier for cities to incorporate into BPS implementation. However, they also have limitations because they may miss renter households with high energy burdens who live outside formally designated affordable housing. Therefore, when developing affordability-focused BPS it would be beneficial to first compare EB-based targeting with affordable housing-based targeting to evaluate whether these approaches identify the same buildings and households, or whether each captures different dimensions of affordability risk.

A key challenge associated with an affordability-focused BPS is whether the energy reductions required to meet EB targets are technically and financially achievable. In this study, the EB-BPS scenarios required substantial energy reductions, particularly under more stringent targets. For example, the 50th percentile EB target required a 39% energy reduction but achieving reductions above 20% through retrofits is not common in practice. Prior work notes that typical retrofit savings in U.S. multifamily buildings range from approximately 6% to 24%, while research in the EU found average retrofit savings of 9% in residential buildings (Webb and McConnell 2023). Additionally, retrofit packages that can produce such steep savings such as combining weatherization and HVAC system retrofits, would involve significant upfront capital costs. Therefore, it is increasingly important to provide financial assistance, especially for low-income households. Sharrow et al. (2025) emphasized that equity-oriented BPS design should be paired with targeted assistance, including grants, incentives, technical support, and anti-displacement protections, to prevent compliance costs from falling disproportionately on low-income residents. Therefore, BPS implementation would need to shift from a purely building-performance framework toward a hybrid model that connects technical retrofit requirements with household affordability conditions.

There are several limitations to this study that could be addressed in future work. First, the analysis relied on different units of observation to calculate site EUI. Building-level site EUI was assumed to represent household-level site EUI, even though individual households within the same multifamily building may have different energy intensities. Future work should test these findings using household-level energy data to better capture within-building variation in energy use. Second, energy burden was also calculated using building-level energy cost data averaged across the number of units in each building, and ACS area-level MHI rather than actual household-level income. Because energy burden depends strongly on the income denominator, this approach may overestimate or underestimate burden for specific households. Future research should test these findings using observed household-level energy cost and income data to improve the precision of energy burden estimates and validate affordability-focused BPS targeting. Third, only one environmental metric, site EUI, was studied. Future work should examine how these results would change with a GHGI metric, as GHG-based targets may prioritize different buildings depending on fuel type, grid emissions factors, and electrification potential. Fourth, the analysis focuses on energy and energy cost savings without assessing financial feasibility. Future work should include net savings derived from achieving these targets by looking into capital costs, maintenance costs, and fluctuating utility costs. Finally, this study focuses solely on Cincinnati. Future research should test EB-focused BPS approaches in other cities across the country with high energy burden. Comparing results across multiple jurisdictions would help determine whether EB consistently identifies different buildings than EUI, whether it more effectively directs savings toward low-income households, and how local conditions influence the feasibility of using energy burden as a BPS metric.

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References

Bohn, Z., J. Nordloh, and A. Webb. 2026. "Applying ASHRAE Standard 100 to Develop a Local Building Performance Standard." *ASHRAE Transactions* 132: 921–29. Atlanta: ASHRAE. https://doi.org/10.63044/w26nor120.

Cardoso, D. S., and C. J. Wichman. 2022. "Water Affordability in the United States." *Water Resources Research* 58 (12): e2022WR032206. https://doi.org/10.1029/2022WR032206.

City of Cincinnati. 2023. "Green Cincinnati Plan." https://www.cincinnati-oh.gov/oes/climate/climate-protection-green-cincinnati-plan/.

CoStar Group. 2025. https://www.costar.com.

Cushing, L., D. Blaustein-Rejto, M. Wander, et al. 2018. "Carbon Trading, Co-Pollutants, and Environmental Equity: Evidence from California's Cap-and-Trade Program (2011–2015)." *PLOS Medicine* 15 (7): e1002604. https://doi.org/10.1371/journal.pmed.1002604.

Drehobl, A., and L. Ross. 2016. *Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities*. Washington, DC: ACEEE. aceee.org/research-report/u1602.

Drehobl, A., L. Ross, and R. Ayala. 2020. *How High Are Household Energy Burdens? An Assessment of National and Metropolitan Energy Burden across the United States*. Washington, DC: ACEEE. aceee.org/research-report/u2006.

Hamilton County Auditor. 2025. "Online Property Access." https://wedge.hcauditor.org/.

Hart, Z., R. Gahagan, C. Majersik, J. Miller, and B. Neely. 2020. "Understanding the Housing Affordability Risk Posed by Building Performance Policies." *In Proceedings of the 2020 ACEEE Summer Study on Energy Efficiency in Buildings* 9: 1–16. Washington, DC: ACEEE.

Institute for Market Transformation. 2026. *Comparison of U.S. Building Performance Standards*. January. https://www.imt.org/resources/comparison-of-u-s-building-performance-standards/.

Jarrah, A., E. Garfunkel, and D. Ribeiro. 2024. *Nobody Left Behind: Preliminary Review of Strategies to Support Affordable Housing Compliance with Building Performance Standards*. Washington, DC: ACEEE. aceee.org/research-report/b2401.

Karam, S., and M. S. Ryerson. 2023. "Operating at the Individual Level: A Review of Literature and a Research Agenda to Support Needs-Forward Models of Transport Resource Allocation." *Transportation Research Interdisciplinary Perspectives* 21 (September): 100887. https://doi.org/10.1016/j.trip.2023.100887.

Moore, D., and A. Webb. 2022. "Evaluating Energy Burden at the Urban Scale: A Spatial Regression Approach in Cincinnati, Ohio." *Energy Policy* 160 (January): 112651. https://doi.org/10.1016/j.enpol.2021.112651.

Scheier, E., and N. Kittner. 2022. "A Measurement Strategy to Address Disparities across Household Energy Burdens." *Nature Communications* 13 (1): 288. https://doi.org/10.1038/s41467-021-27673-y.

Sharrow, L., G. DiLauro, and M. Duer-Balkind. 2025. *Integrating Equity into Building Performance Standards*. https://imt.org/resources/integrating-equity-into-building-performance-standards/.

U.S. Environmental Protection Agency. 2022. *Understanding and Choosing Metrics for Building Performance Standards*. https://www.energystar.gov/sites/default/files/tools/BPS-White_paper_final.pdf.

Webb, A., S. Brown, J. Flarida, A. Lindburg, and N. Ziegler. 2024. "Overcoming Barriers to BPS: A Collaborative, Grassroots Approach to Building Performance Standards." *In Proceedings of the 2024 ACEEE Summer Study on Energy Efficiency in Buildings.* Washington, DC: ACEEE. https://www.aceee.org/sites/default/files/proceedings/ssb24/assets/attachments/20240722163110890_6486699f-0bff-4acb-9194-65d9de1c1ad8.pdf.

Webb, A., and C. McConnell. 2023. "Evaluating the Feasibility of Achieving Building Performance Standards Targets." *Energy and Buildings* 288 (June): 112989. https://doi.org/10.1016/j.enbuild.2023.112989.