Compliance Journeys: Using a Stock-based Modeling Approach to Analyze Maryland's Proposed Statewide Building Performance Standard

David Pudleiner, ICF
Ahmed Saber, ICF
Wade Shafer, Exelon
Mohamed Abdelsalam, ICF

ABSTRACT

The proposed Building Performance Standard (BPS) in Maryland would put the state on a clear path toward substantial greenhouse gas (GHG) emissions reductions from commercial and multifamily buildings (MDE 2023). However, the way building owners will comply and manage the cost of doing so is less clear. In this paper, we examine the lifecycle cost optimal compliance pathway for most of the affected building stock through building energy models. Government, utilities, and other stakeholders can use the findings to support cost-minded compliance across the varied building stock.

Twenty different electrification and efficiency measures were simulated across thousands of individual building models using National Renewable Energy Laboratory's (NREL) ComStock and ResStock tools. Nine commercial building types and multifamily units were studied. ComStock and ResStock data were expanded to include all meaningful combinations of measures using a proportional scaling interactive effect methodology that was validated against published measure package results. We conducted a lifecycle cost analysis for each measure combination using cost and retail energy rate assumptions from a recent Maryland EmPOWER proceeding, and explored sensitivities to retail energy rate assumptions.

The lifecycle cost optimal compliance path for each model was determined by finding the subset of measures that meet the BPS's greenhouse gas emission and energy use intensity requirements with the lowest lifecycle cost. We aggregated model results by building type to provide insight into lifecycle cost optimal compliance approaches. We also explored the distributive equity implications of compliance by comparing net compliance cost results across building types and decile groups.

Introduction

Over the past several years, Building Performance Standards (BPSs) have become an increasingly popular policy mechanism among state and local governments to advance their decarbonization commitments. In 2015, Boulder, Colorado became the first jurisdiction to enact a BPS, and since then 14 additional cities, counties, and states have enacted a BPS (City of Boulder 2015; IMT 2024). The usage of BPSs as a decarbonization policy was bolstered by the Biden Administration in 2022, with the formation of the National BPS Coalition (National BPS Coalition 2024). In total, 45 jurisdictions have joined the National BPS Coalition. Each of these localities have committed to enacting a BPS by either Earth Day 2024 for members of the first cohort, or Earth Day 2026 for members of the second cohort.

Maryland's BPS journey began in March 2022 with the passage of the Climate Solutions Now Act. It directed the Department of Environment to develop a BPS regulation and determined key elements of the forthcoming regulation—building types covered, required reduction in greenhouse gas emissions, the inclusion of an energy use intensity requirement, compliance deadlines, and alternative compliance mechanisms (Climate Solutions Now Act 2022). The current draft regulation, expected to be finalized in 2024, would require buildings 35,000 square feet or larger to both achieve an on-site emissions intensity of zero by 2040 and reduce their site Energy Use Intensity (EUI) within prescriptive limits (MDE 2023).[1] While not the only state to put a BPS policy in place – Oregon, Washington, and Colorado all currently have one on the books – Maryland would be the first jurisdiction to have a BPS that regulates both energy use and emissions (Building Energy Codes Program 2024). More than a third of the state's direct CO_2 emissions from buildings are covered by the proposed regulation, and it is estimated that the BPS would reduce the annual energy use of the applicable stock by 32% in comparison to existing conditions (MDE 2023).

Figure 1 summarizes the key features of Maryland's BPS. The key building types which are exempt from the regulation are public and private primary and secondary schools; historic, manufacturing, agricultural and federally-owned buildings; parking facilities (including electric vehicle charging); and separately metered commercial cooking and water heating. Restaurants and bars are also exempt from the regulation, but most of these facilities would already not have been applicable due to the BPS's 35,000 square foot size cutoff. Covered buildings face three compliance deadlines— 2030, 2035 and 2040 (MDE 2023). For both intensity metrics, the compliance requirements become increasingly stringent as the years progress. However, the two compliance requirements are determined in fundamentally different ways.

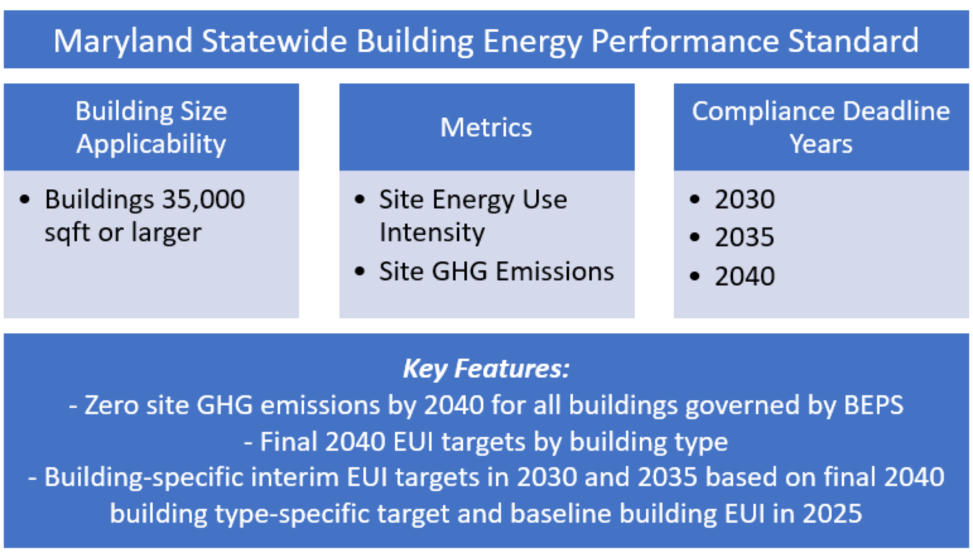

Figure 1. Summary of Maryland's Building Performance Standard

Site GHG emissions requirements are expressed as maximum allowed intensities and are specific to building types before 2040. In contrast, site EUI requirements are building-specific before they become building type-specific in 2040. The interim EUI compliance requirements, for years 2030 and 2035, are based on a straight-line trajectory from a building's baseline

[1] Maryland's draft BPS requires covered buildings to achieve zero net direct emissions by 2040. "Net direct" refers to on-site emissions and emissions associated with district heating services (if applicable). For simplicity, we refer to the BPS greenhouse gas emission requirement in 2040 as being zero on-site emissions.

performance (weather normalized metered EUI in 2025) to the final building type-specific EUI requirement in 2040 (MDE 2023). On-site generation is not included in either intensity metric.

In Maryland, the BPS, as drafted, is a mandatory policy. Most buildings that do not comply face a penalty for excess greenhouse gas emissions priced at the social cost of carbon, which starts at $230 per metric ton in 2030 (in 2020 dollar terms), plus civil penalties. Exemptions from penalties may be provided to affordable housing providers, buildings under financial distress, and unoccupied buildings (MDE 2023). Thus, covered buildings are expected to comply and the cost of doing so reveals the direct impact on large commercial and multifamily building owners. That is the area of interest in this paper, both average compliance cost as well as the distribution of net compliance costs across the building population. As other studies have already identified, equity is a key concern in the design of a BPS, to ensure that impacts are not especially borne by a particular segment of the building population (Eash-Gates and Takahashi 2022). Furthermore, this study seeks to investigate the shape of the supply curve of potential compliance measures and assess which measures are most cost-effective and impactful for helping the building stock comply with the proposed BPS.

A number of studies have investigated similar questions in other jurisdictions and provided a solid foundation upon which to construct the methodology for this study. Moe and Gibbs used a building stock analysis-based approach to examine the cost-effectiveness of efficiency and electrification upgrades for the city of Richmond, California as part of the Communities LEAP technical assistance program administered by NREL (Moe and Gibbs 2023). In this study, NREL's ResStock and ComStock tools were leveraged to assess the impact of upgrade measures across a representative building population. Since their development several years back, ResStock and ComStock have significantly increased the accessibility of this type of stock-based modeling approach to both researchers and private industry (NREL 2022; NREL 2023). These tools provide NREL a way to generate representative stocks of building energy models as granular as the county level, all the way up to producing a national-level building stock. Periodically, NREL releases new sets of results generated utilizing these tools, which encompass hourly simulation results for hundreds of thousands of models representing the national residential and commercial building stocks.

ComStock was also utilized by LBNL in their investigation of measure packages for helping commercial buildings in Washington State meet the upcoming BPS compliance targets (Regnier et al. 2022). This analysis examined an expanded set of 43 measures, far beyond the measure set currently available in the published ComStock datasets. Andrews and Jain utilized ComStock load shape data to translate annual energy consumption figures from benchmarking to hourly load profiles (Andrews and Jain 2023). This was then utilized to help determine the potential GHG reductions from a novel demand flexibility BPS.

Researchers have also explored BPS cost-effectiveness utilizing methodologies without the use of building energy simulation, such as Webb and McConnell's investigation of BPS feasibility for 10 cities across the U.S. (Webb and McConnell 2023). This analysis utilized a benchmarking approach to modeling, where different degrees of retrofits-such as light, medium and heavy-are assumed to have a given percentage impact on building EUI. This type of analysis is able to investigate macro cost-effectiveness of a BPS, but it does not model the impact of specific measures on the building population. A similar economic analysis was performed by Lawrence Berkeley and Pacific Northwest National Laboratories during the development of the Maryland BPS and found compliance to be net beneficial from 2025–2050, yielding approximately $4.4 billion of savings by 2050 (Walter et al. 2023). However, the savings are not evenly distributed. Within the distribution of net compliance costs, the top quartile experiences savings of at least $9.29 per square foot while the bottom quartile incurs net costs of $4.43 per square foot or more.

This study seeks to further investigate the cost-effectiveness of compliance with the Maryland BPS using a stock-based analysis approach anchored in NREL's ResStock and ComStock tools. With this methodology, we hope to demonstrate a replicable approach that can be readily adopted by other jurisdictions and steadily expanded and improved as the measure set and building types covered by NREL's tools continue to grow.

Methodology

The analysis in this paper employs a 'bottom-up' stock-based methodology that uses NREL's ComStock and ResStock building energy modeling tools. Both ResStock and ComStock can be utilized in two distinct ways: Leveraging the pre-run simulation databases available for download from NREL or using the tools to generate and run novel building energy simulation models. The first approach was utilized in this paper to yield insights quickly and demonstrate a methodology that could be later expanded to include novel simulations. The approach is summarized by the four key steps shown in Figure 2. The entire methodology was coded in Python to allow for an automated and easily repeatable analysis framework that could also be efficiently applied to other states using the appropriate set of pre-run simulation results from NREL. The approach is set up to determine the lifecycle cost optimal compliance pathway for each building in the building stock investigated, allowing for the investigation of the distribution of measure adoption, savings, and costs across the stock.

Figure 2. Summary of steps in the approach utilized for the building stock-based analysis of the Maryland BPS

Step 1: Determine the Design Space to Explore

First, we established the design space to explore based on the requirements of the Maryland BPS and the availability of measures and building types in the pre-run databases from ResStock and ComStock. The building types and potential upgrade measures included in the analysis are shown in Figure 3. On the residential side, only Multifamily buildings over 35,000 square feet (sqft) are applicable.[2] On the commercial side, ComStock contains a total of 14 different commercial building types, however, only 9 are applicable due to the size limitations and building type exemptions in the Maryland BPS. All of the applicable upgrade measures from the ResStock and ComStock Maryland state runs were investigated as potential energy efficiency and electrification upgrades that could help the buildings comply with the BPS. This resulted in a

[2] As ResStock does not model common area spaces, upgrades to potential common areas were not considered and this portion of the multifamily building was not modeled. This is more accurate for garden-style multifamily buildings but for fully enclosed buildings is an area for potential future refinement.

total of 5 individual measures for multifamily residential and 15 individual measures for commercial buildings. As the ResStock and ComStock measure libraries expand with new releases, potential additional measures could easily be incorporated into this analysis framework.

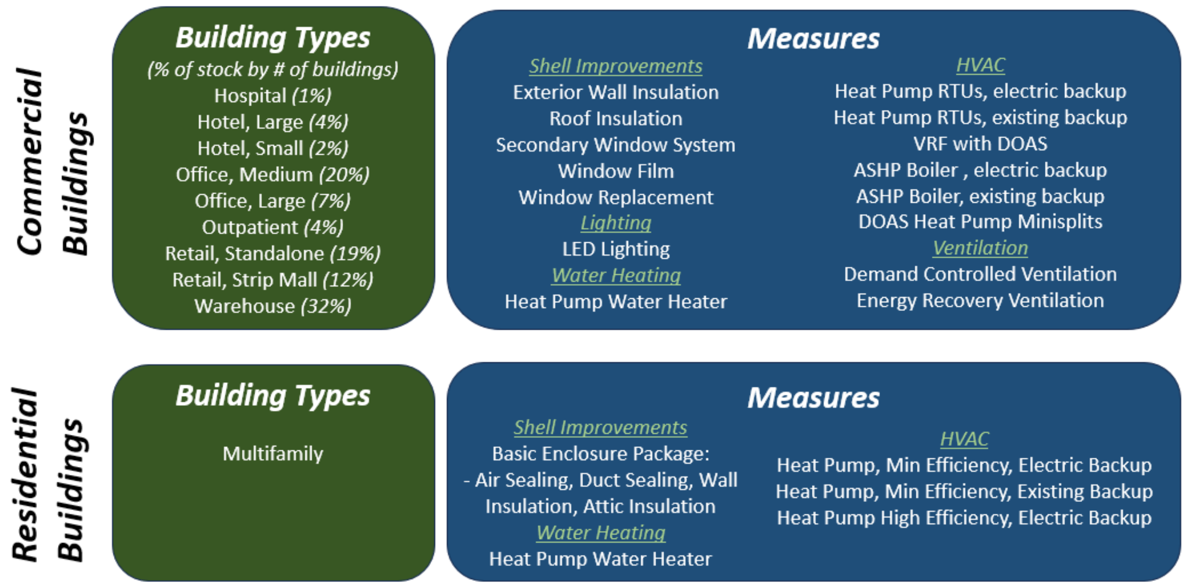

Figure 3. Building types and potential upgrade measures analyzed in the analysis

Step 2: Create Database of Measure Costs and Energy Impacts

Following the establishment of the design space, the next step was to create a database of measure impacts for each building. This resulted in a total of 2^n combinations of measures for each building, where n is the number of applicable measures. The applicability of each measure for each building was sourced from the NREL data, and mutually exclusive measure combinations, such as Secondary Window System and Window Replacement, were then removed from the database.

As part of the creation of this database, we employed a simplified approach to account for interactive impacts between measures and appropriately allocate savings between electrification and efficiency measures. For interactive impact accounting, a proportional scaling by end use method was adopted in which a linear model was used to estimate the combined savings figure, and the individual measure savings were calculated by proportionally scaling individual measure savings so that the sum matched the combined estimate from the linear model. This method was validated against the NREL pre-run measure package combinations and found to produce total savings estimates within 5% of the simulation-based results. To allocate impacts between electrification and efficiency measures, the total reduction in fuel consumption was proportionally allocated based on the individual fuel savings from each measure.

In addition to the energy impacts of measures, the other key data needed for the database is the cost of each measure for each building. This study utilizes a cost per square foot approach to estimating the measure costs and whenever possible, cost assumptions are sourced from EmPOWER Maryland Energy Efficiency Program 2024-2026 plans (EmPOWER EAG 2023). Gaps in this data were filled from a variety of sources, including: RSMeans, industry references, and Technical Reference Manuals (TRMs) such as the Illinois TRM and adjusted for Maryland as needed (RSMEANS 2023; ILEESAG 2022). Estimated costs associated with electric service upgrades were included for electrification measures as an adder on a per square foot basis.

Step 3: Establish Rate Scenarios to Investigate

For estimating bill impacts from measures, three different rate scenarios were explored. The core analysis and findings utilize a Base Case, which uses rate projections from the development of EmPOWER Maryland 2024-2026 plans (EmPOWER EAG 2023). Two sensitivity cases were then used to explore how sensitive compliance measure selection and net compliance costs are to future retail energy rates. One sensitivity case (Sensitivity Case #1) features retail electricity rates that are proportionally higher than retail natural gas rates relative to the Base Case. It relies on rate projections for PJM East in the 2023 EIA Annual Energy Outlook (EIA 2023). The other sensitivity case (Sensitivity Case #2) is informed by economywide decarbonization scenarios developed by E3 for Baltimore Gas and Electric’s service territory (E3 2022). It features escalating retail electricity and natural gas rates, but proportionally, electricity becomes cheaper relative to natural gas over time. Thus, the sensitivity cases bound the Base Case with electricity rates that are relatively more and less expensive than natural gas. Further details about the relative electricity and natural gas rates, along with a discussion of their impact on the net cost of BPS compliance, are found in the Results Discussion section of this paper.

Step 4: Optimize Each Building using Reverse Time-Lapse Approach

In order to estimate the lifecycle cost optimal compliance pathway for each building in the building stock, a unique optimization approach was developed which we have coined a “Reverse Time-Lapse Compliance Optimization.” This optimization algorithm has been developed to address the complex challenge of eliminating sub-optimal solutions in early BPS compliance years which install upgrades that are irrelevant for compliance in later years. For example, a building might install wall insulation to meet the requirements of milestone 1, only to find that a heat pump is required for milestone 2. Depending on the initial building EUI, the insulation investment may be unnecessary for later milestone compliance. To address this, the optimization algorithm employs a sequential approach, starting from the final milestone upgrades required in 2040 and working backward. This ensures that the pathway chosen represents the lifetime lifecycle cost optimal solution for building owners. For example, if 8 upgrades are selected for a commercial building in 2040 to meet its compliance obligation, then when selecting upgrades for 2035, the algorithm is only allowed to pick from that set of 8 measures rather than the full set of 15 measures. The same process is then repeated for 2030. By considering the entire timeline and optimizing for minimum lifetime net building owner cost, the algorithm ensures that the selected compliance strategy not only meets each milestone’s emission and energy use intensity thresholds, but also prioritizes the economics of the building owner.

Results Discussion

Compliance Measures Selected

Commercial and multifamily buildings adopt a mix of electrification and energy efficiency measures to meet the BPS’s ultimate emission intensity and EUI requirements in

2040, if they are not already compliant today.[3] Assuming that the gas system does not fully decarbonize, electrification of space and water heating is required based on the regulation's zero on-site emissions requirement for 2040. Electrification also reduces a building's EUI; however, for 85% of commercial and 39% of multifamily buildings, electrification alone is not sufficient to meet the BPS requirement.[4] Additional energy efficiency measures are needed.

Figure 4 below illustrates the mix of electrification and efficiency measures adopted across the commercial building stock to meet the 2040 intensity requirements. Nearly three quarters of affected commercial buildings adopt some type of electric air-source heat pump for space heating (the other quarter already employ compliant heating solutions). Almost 30% adopt electric air-source Heat Pump Water Heaters (HPWH). This relatively small share of HPWH adoption is due to the fact that a significant portion of retail and warehouse buildings have inconsequential hot water loads and make up a meaningful share of BPS applicable commercial buildings. Finally, a variety of efficiency measures are selected across the commercial building stock. LED lighting is the most frequently adopted measure owing to its attractive economics.[5]

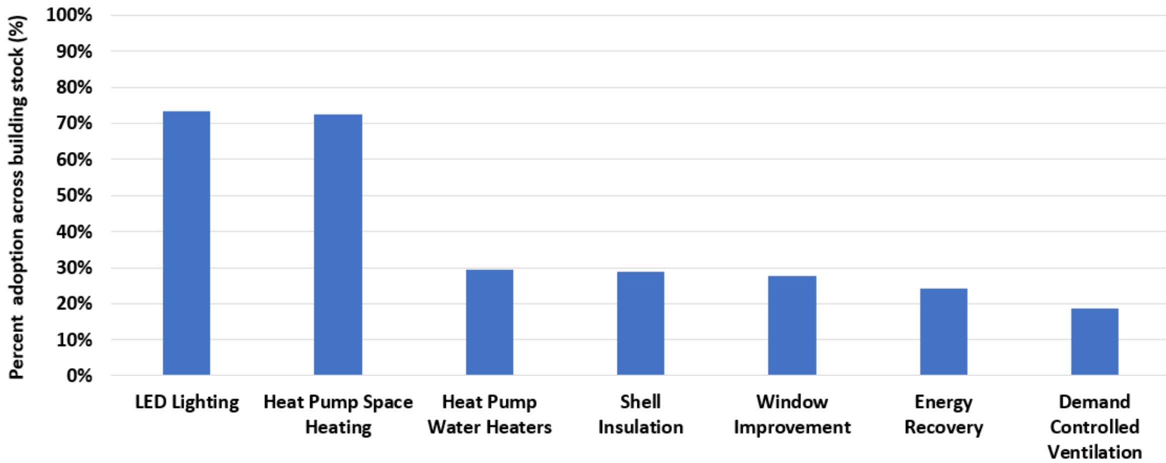

Figure 4. Percent of the commercial building stock that adopt each measure / measure type, 2040 BPS milestone

In the model simulation, LED lighting and electric air-source heat pump space heating are typically the first measures adopted across the commercial building stock. Though air-source heat pumps generally result in a net cost for commercial buildings, the Reverse Time-Lapse Compliance Optimization finds it to be an optimal measure for the first compliance milestone in 2030. Not only does an electric heat pump put a building on a path to meet the zero on-site GHG emissions requirement in 2040, it also meaningfully reduces EUI and helps meet interim EUI milestones. After 2030, electric air-source HPWHs are the most frequently adopted measure before the next compliance milestone in 2035. Like a heat pump for space heating, a HPWH reduces both intensity metrics.

Traditional energy efficiency measures are more widely adopted between 2030 and 2035 and between 2035 and 2040. Generally, the lifecycle cost-optimal compliance pathway focuses on electrification (via heat pumps) first and adds efficiency measures, like building envelope

[3] 12% of commercial and 23% of multifamily units examined already meet the 2040 greenhouse gas emission and EUI requirements because they are highly efficient and all electric buildings.
[4] Commercial number is significantly higher due to LED lighting, with LED lighting removed, the total is 45%
[5] LED adoption is high due to any building that does not have 100% LED lighting being eligible for the measure, this is not indicative of over 70% of buildings not using any LED lighting

improvements and energy recovery, when they are necessary for buildings to achieve increasingly stringent EUI standards in 2035 and 2040. However, it should be noted that this is in part a result of the cost per square foot methodology utilized, which does not account for the cost savings that efficiency can provide to HVAC (Heating, Ventilation and Air-Conditioning) electrification (since many efficiency measures can reduce required HVAC capacity).

The uptake of efficiency measures varies significantly by building type. For instance, while the population as a whole adopts window efficiency measures for 28% of the stock, nearly three-quarters of the modeled large hotel buildings adopt window efficiency measures. Another noticeable trend is that warehouses adopt efficiency measures significantly lower than the stock average, installing about 1 efficiency measure per building in comparison to the total stock average of 2.1 measures per building. This is reflective of the fact that the warehouse building type EUI average starts off 4 kBTU/sqft below the 2040 final deadline of 30 kBTU/sqft, significantly reducing the need for warehouses to adopt energy efficiency measures to meet the final EUI requirements. In addition, warehouse EUI is more dominated by lighting than other building types, allowing for the LED lighting measure to have a proportionally higher impact.

Adoption trends for multifamily measures have noticeable similarities and differences as compared to commercial measures. The implementation of multifamily measures and comparable commercial counterparts by 2040 is shown in Figure 5. Multifamily modeling results significantly differ from the commercial building stock in HPWH adoption; more than half of units adopt electric HPWHs before 2030 whereas only 15% of modeled commercial buildings adopt it before 2030. As Figure 5 shows, this trend continues through 2040 in which uptake of HPWHs in multifamily is over 2.5 times that of commercial stock. Heat pumps for space heating also show significant adoption prior to 2030, and like commercial buildings on average, most multifamily stock that will adopt a space heating heat pump by 2040 has done so by the first compliance deadline. Space heating heat pump adoption continues to grow over the later compliance periods and by 2040 64% of multifamily units have adopted one, again similar to the trend seen in commercial in which 72% implement this measure.

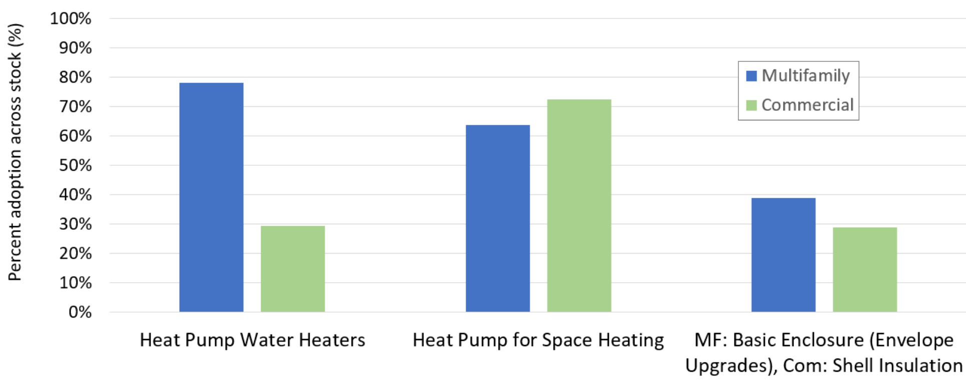

Figure 5. Percent of the multifamily versus commercial stock that adopts each measure, 2040 BPS milestone

Across every compliance milestone for multifamily, HPWH adoption exceeds electric heat pump adoption for space heating, which is in part due to HPWHs starting from a lower market share than heat pump space heating. Uptake of HPWHs is further boosted by the fact that on average they are more cost-effective than space heating heat pumps, making them the preferred option for all-electric multifamily units looking to reduce EUI. Building envelope improvements are selected by a relatively smaller share of multifamily units when additional

EUI reductions are necessary after electrification to comply with the BPS. By 2030, 25% of units install building envelope measures, and by 2040, 39% of the multifamily units adopt building envelope improvements.

Effectiveness of Compliance Measures

The measures evaluated achieve the BPS's emission and energy intensity requirements for most, but not all, of the large building population studied. As shown in Figure 6 and Figure 7, compliance with the zero on-site emissions requirement in 2040 is higher than compliance with the concurrent EUI requirement for both commercial and multifamily buildings. Electrification of space and water heating addresses most on-site emissions. It eliminates emissions from the multifamily stock and 90% of the commercial building stock examined. With respect to interim emission intensity requirements, all multifamily units comply with the measures examined while commercial buildings fall from 98% compliance in 2030 to 96% by 2035 and 90% by 2040. Commercial buildings that fail to comply have residual emissions from supplementary space heating systems that do not have candidate substitute measures in ComStock. This is an important distinction for commercial buildings and shows that if large commercial buildings are truly going to get to zero on-site emissions, they are not only going to have to change the large, central HVAC systems that heat their building, but also the multiple small, supplementary systems, such as natural gas unit heaters, that are dispersed within a building.[6]

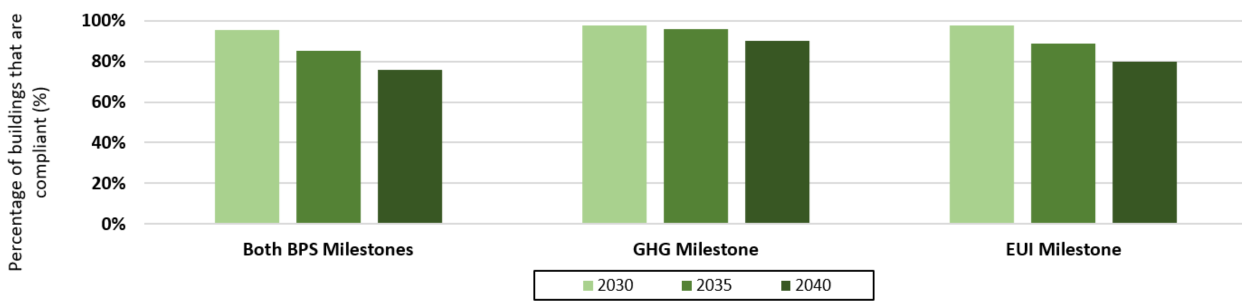

Figure 6. Share of commercial buildings modeled that achieve compliance with BPS milestones

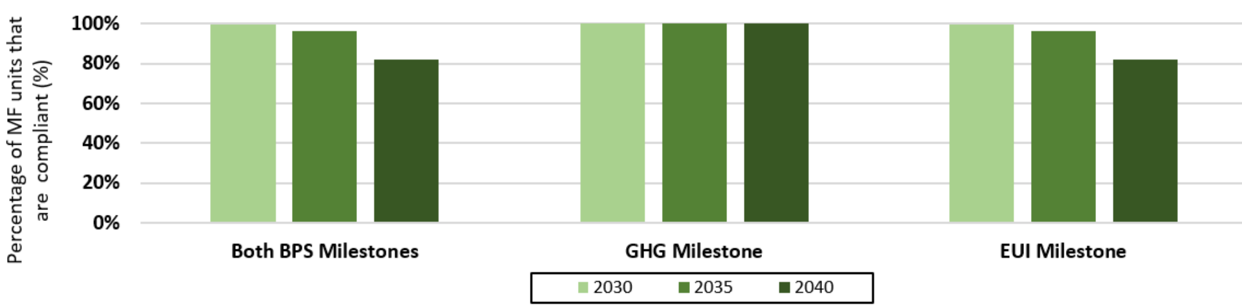

Figure 7. Share of multifamily buildings modeled that achieve compliance with BPS milestones

[6] Residential and commercial cooking, as well as commercial process loads, were not included in the GHG emissions target accounting owing to the lack of available measures in ComStock and ResStock to address them. Future studies could employ an expanded measure set that addresses them to yield more comprehensive results.

The EUI requirements are more difficult to achieve with the measures studied. In 2040, 80% of commercial buildings and 82% of multifamily units can meet the EUI requirement. Compliance starts at a higher rate in 2030 but falls through 2040 as the EUI requirement becomes increasingly stringent. In 2030, 97% of the commercial building stock studied and 100% of multifamily units meet the BPS's EUI requirement. As noted previously, electrification is a core element of this compliance, and so too are traditional efficiency measures for a small share of the building population. By 2035, compliance falls to 85% for commercial buildings and 96% for multifamily units. Additional electrification measures are employed over this period, along with efficiency measures for a small share of the building population. Finally, by 2040, EUI compliance falls to 80% of commercial buildings and 82% of multifamily units. Electrification alone is the cost-optimal path for EUI compliance for 15% of commercial buildings and 65% of multifamily units.[7] The remaining share of compliant buildings employ both electrification and efficiency measures.

One interesting difference in compliance success between similar building types is that of retail strip malls versus standalone retail stores. Approximately 97% of retail standalone stores are able to comply with the 2040 EUI milestone, however, only 15% of retail strip malls are compliant in 2040. This disparate outcome is due to the fact that strip malls have a higher baseload EUI from non-weather sensitive loads such as plug loads. Thus, the HVAC-centric measure set does not sufficiently address the efficiency improvements needed for this building type. In cases like these, additional measures beyond those considered in this analysis, for instance behavioral measures, are needed to achieve the EUI requirement.

Net Compliance Costs for Building Owners

BPS compliance is estimated to yield net lifecycle savings for 58% of commercial buildings and 60% of multifamily units as shown in Figure 8, in the Base Case retail rate scenario. For this portion of the building population studied, future energy purchases avoided offset the upfront capital cost and ongoing operating cost associated with compliance measures. Average net savings from compliance experienced across the building population studied are $0.19/sqft for commercial buildings and $0.03/sqft for multifamily units. This average outcome—nearly breakeven—underscores the need to understand the distribution of net compliance costs across the building population and not just on average.

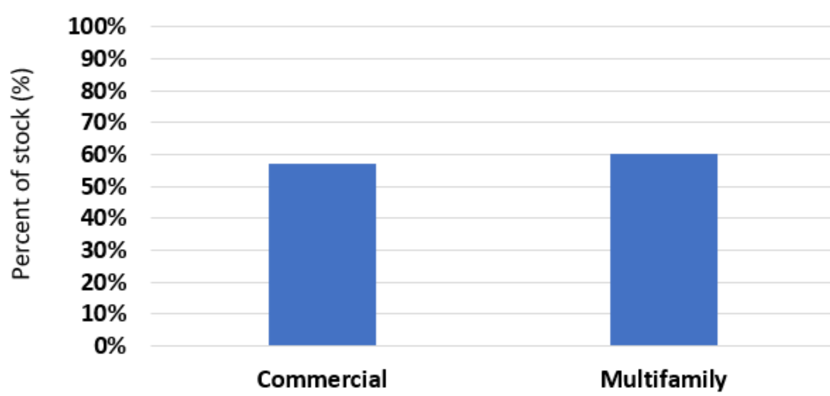

Figure 8. Share of building population that realizes net lifecycle savings from BPS compliance

[7] With LED lighting removed for commercial, this number is 55%.

First, net compliance costs vary by building type owing to fundamental differences in building design and function across building archetypes. For example, some building types have more intensive space heating and cooling loads relative to their square footage owing to their function, like retail strip malls versus warehouses. Retail structures maintain a narrow thermal comfort band to provide customers with a pleasant shopping experience while warehouses have less stringent heating and cooling requirements across their much larger square footage. Thus, lower heating and cooling requirements across a larger square footage translates into low dollar per square foot heating and cooling costs and less dollar per square foot potential savings from electrification and efficiency measures. Figure 9 shows the average net compliance costs or savings by building type. Ultimately, the net compliance cost by building type and the relative share of building types in the overall population affects the distribution and average of net cost outcomes.

Second, net compliance costs vary by building according to their EUI compliance gap. The amount of EUI reduction required indicates what measures are required to comply (i.e., upfront expenditures) and what amount of future energy can be avoided (i.e., potential savings). In the building population data, baseline EUI is a proxy for the EUI compliance gap.

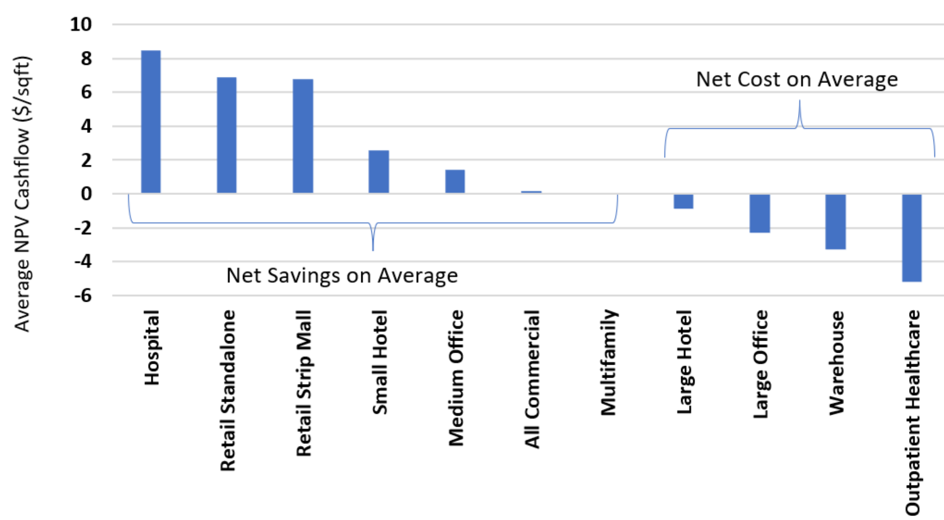

Figure 9. Average net lifecycle compliance cost by building type, 2040 BPS milestones

In the commercial building population studied, the relatively efficient and inefficient tails of the baseline EUI distribution incur net compliance costs while buildings just above the median baseline EUI realize net savings. Figure 10 illustrates average net compliance costs by decile bin for the commercial stock and Figure 11 shows the multifamily stock. The lower the decile bin, the more energy efficient the underlying buildings' baseline EUIs are. Examining the commercial results, buildings that start compliance from a relatively efficient position are projected to incur net costs (40^{th} percentile and lower). For these buildings, low-hanging efficiency measures have already been implemented or were included in their original construction. Thus, necessary compliance measures—namely electrification—yield less future energy savings relative to the rest of the building population, which ultimately results in a net cost outcome.

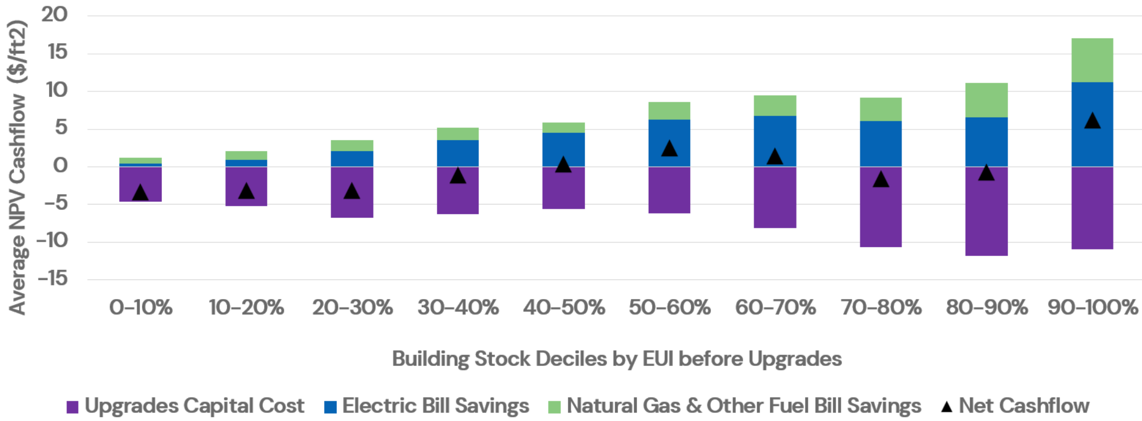

Figure 10. Average net lifecycle compliance costs for commercial stock by baseline EUI deciles, 2040 BPS targets

Above the 40th percentile, net compliance costs shrink and turn into net savings between the 50th and 70th percentiles. For these buildings, electrification and efficiency measures avoid enough future energy purchases to offset the upfront capital cost of measures and ultimately yield net savings. Above the 70th percentile, compliance tips back to being a net cost for building owners. In these cases, future energy savings fail to offset the total upfront cost of compliance measures required as these buildings have to dig deeper into less cost-effective measures for savings. Finally, for the last decile bin, sufficient future energy savings are realized to more than offset the upfront cost of the even more expensive compliance measures. This is a result of the significant increase in average EUI for this bin, which is double the difference between the 8th and 9th bins, 35 as compared to 17 kBTU/sqft (the 10th bin average EUI is 127 kBTU/sqft).

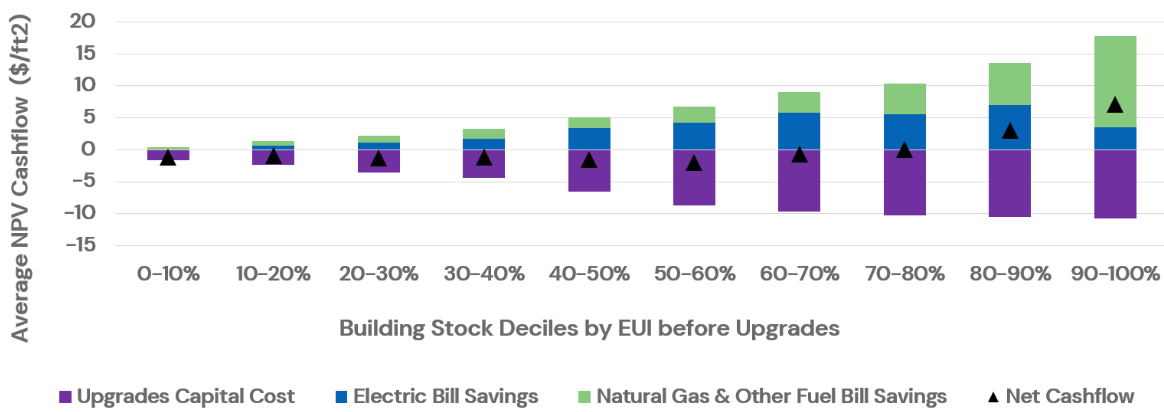

Figure 11. Average net lifecycle compliance costs for multifamily stock by baseline EUI deciles, 2040 BPS targets

Though decile views of average net compliance costs are shown for the overall building population, the pattern is similar within specific building types. Buildings that face relatively small EUI compliance gaps but need to electrify are projected to incur net compliance costs, while buildings at and above the median compliance gap are projected to be more likely to realize net savings.

In the multifamily unit population, units below the 80th percentile are estimated to incur net costs on average while those above are estimated to realize net savings on average when they comply with the BPS's 2040 EUI requirement as illustrated in Figure 11. One contributor to the net cashflow being negative for many deciles is the shared wall architecture of multifamily buildings, which lowers heating and cooling demands of individual multifamily units. Another is the relatively low rate of natural gas relative to electricity for the MDE rate scenario. Taken together, these factors reduce the return on investment for measures such as space heating heat pumps. Only the most energy intensive multifamily deciles realize net savings on average from the adoption of necessary compliance measures.

Net Compliance Costs for Buildings in Disadvantaged Communities

Commercial buildings located in disadvantaged communities do not exhibit a significant difference in the expected cost-effectiveness of BPS compliance. According to the disadvantaged community status markers in ComStock, the share of commercial buildings in disadvantaged communities that realize net savings from compliance is comparable to the overall building stock—59% in disadvantaged communities versus 58% in the overall building population.

Similarly, multifamily units in areas with household incomes that are below 200% of the federal poverty level do not show a significant difference in average net compliance costs from the overall population. The share of multifamily units in disadvantaged communities that find BPS compliance cost-effective is 62% versus the overall population average of 60%. The slightly higher share of multifamily units in disadvantaged communities that realize net savings is due to their slightly higher starting EUI, which results in proportionately higher bill savings from energy efficiency and electrification measures adopted.

While lifecycle net costs were not different on average for disadvantaged communities, it is important to keep in mind that often the biggest barriers to adoption for members of these communities are not whether an investment makes economic sense. Rather, the upfront capital and access to affordable financing are more prominent drivers. Therefore, disadvantaged communities may still face a disproportionately higher impact from compliance, even if this is not the case on a lifecycle cost basis (Jarrah, Garfunkle, and Ribeiro 2024).

Retail Rate Sensitivity: Net Compliance Costs

Whether building owners realize net costs or savings when complying with the BPS greatly depends on future retail electricity and natural gas rates. Various factors can influence future rates, such as those associated with the energy transition (e.g., increased electric system utilization, decreased gas system utilization, and carbon or methane fees). Therefore, some of the sensitivity results discussed below could prove more relevant as the energy transition unfolds.

Up until this point in the paper, results discussed are grounded in the Base Case retail rate scenario. To test the sensitivity of net compliance cost results to retail energy rates, two sensitivity cases are used. Generally, whether the upfront capital cost of electrification and efficiency measures are paid back over time depends on the volume and rate of future energy avoided. In these sensitivity cases, the volume of future energy avoided by individual measures is the same as in the Base Case, but the rate of avoided energy changes. Though the optimum measure package for compliance may change based on the updated net lifecycle costs, it was observed that the selection of measure packages for the stock did not significantly change. The zero GHG emissions requirement in 2040 does not provide much flexibility to choose between efficiency and electrification measures.

One sensitivity case (Sensitivity Case #1) is a future where retail electricity rates are higher than the Base Case and natural gas rates are lower. In relative terms, electricity remains about 3.5x more expensive than natural gas throughout the period studied, instead of gradually declining to being 2.0x more expensive than natural gas by 2050 like in the Base Case, as shown in Figure 12. Overall cost effectiveness results do not change meaningfully from the Base Case. The percentage of commercial buildings that realize net savings is nearly identical at 58% while the share of multifamily units that experience net savings is slightly lower (57% versus 60%).

The other sensitivity case (Sensitivity Case #2) considers a future where both retail electricity and natural gas rates are much higher than today, but on relative terms, electricity becomes much cheaper. In this scenario, retail electricity falls from a 2.0x premium relative to retail natural gas in 2030, to being cheaper by 2050. As a result, 98% of the commercial building population studied and 100% of multifamily units realize net lifecycle savings when they meet the BPS's emission and energy intensity requirements by 2040 (as compared to 58% and 60% in the Base Case, respectively). Electrification is more economically attractive when retail electricity becomes more similar in cost to retail natural gas and the rate of avoided energy increases. Efficiency measures also become more economically attractive when the cost of retail energy rises. Sensitivity Case #2 captures potential energy transition themes (e.g., increased electric system utilization, decreased gas system utilization, and carbon or methane fees).

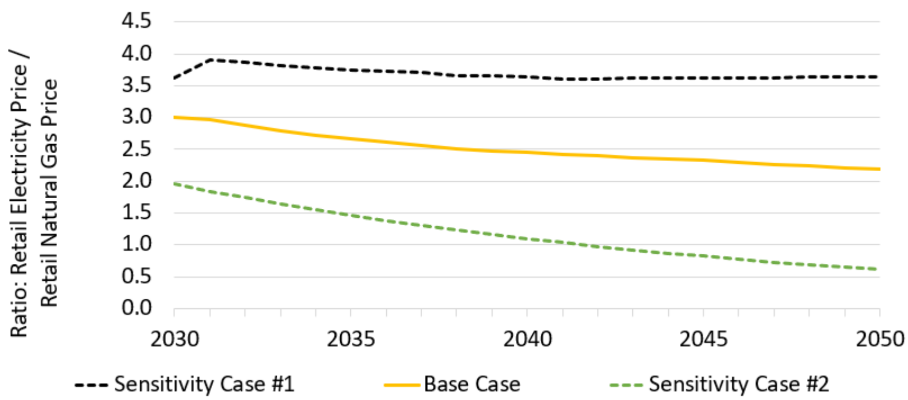

Figure 12. Retail energy rate ratios- electricity/natural gas-for each rate scenario examined

Conclusions

Most large commercial and multifamily buildings in Maryland adopt some combination of electrification and energy efficiency measures to cost-effectively comply with the state's forthcoming BPS. The analysis indicates that electrification of space and water heating is a common early step that buildings can take, as soon as 2030, to manage the lifecycle cost of compliance. From the optimum lifecycle cost perspective of this study, energy efficiency measures were not prioritized in interim milestone years as much as electrification. However, energy efficiency measures should not be underappreciated. Not only do they help nearly half of modeled commercial buildings and multifamily units achieve EUI requirements after electrification (excluding LED lighting), but they can also reduce the capacity and cost of HVAC equipment. This cost interaction is an additional dynamic to potentially explore in future work.

Most affected buildings are estimated to be technically capable of meeting the BPS's emission and energy intensity requirements with the electrification and efficiency measures studied, but a small portion would need to adopt additional measures, such as behavioral energy efficiency, to meet the EUI standard in 2040. Compliance is estimated to yield net savings for more than half of commercial buildings and multifamily units studied (assuming the Base Case retail rate scenario). However, net compliance cost outcomes vary by building type owing to fundamental differences in their designs and functions and by the magnitude of their EUI compliance gap. Large commercial buildings between the 50th and 70th baseline EUI percentiles and multifamily units above the 80th baseline EUI percentile are estimated to realize net savings on average. Other buildings are estimated to incur some degree of net compliance costs on average. However, the magnitude of net compliance costs, and the perceived weight of BPS compliance among building owners, greatly depends on future retail energy rates. If retail electricity becomes more expensive relative to retail natural gas, then BPS compliance would require net outlays from more building owners. If retail electricity becomes less expensive relative to retail natural gas through the energy transition, then a greater share of the large building population could realize net savings when they comply with the BPS.

Practically, our findings can inform approaches to supporting BPS compliance. First, public agencies, utilities, and other stakeholders could develop compliance frameworks that are tailored to building types and provide information and support for electrification and efficiency measures, timing, and sequencing that helps to manage the lifecycle cost of compliance. Second, future incentives for building electrification and energy efficiency could be calibrated to the needs of building types as they display somewhat different optimized lifecycle cost compliance paths. Notably, a few buildings may incur outsized compliance costs and may require extra assistance so that the uneven compliance impact is addressed. Both efficient and inefficient commercial and multifamily buildings face net compliance costs, while a portion of the large building population is estimated to realize net savings. Thus, a more equitably distributed compliance outcome could be accomplished if supportive incentives are used to level out net compliance costs across the building population, and if those most likely to experience a higher impact could be supported with targeted information and incentives. Finally, both electrification and energy efficiency measures require building owners to make upfront capital investments that may eventually be paid back through future avoided energy purchases. Financing mechanisms could better match compliance expenses with the energy savings they realize over time.

References

Andrews, A. and R. Jain. 2023. Evaluating building decarbonization potential in U.S. cities under emissions based building performance standards and load flexibility requirements. Journal of Building Engineering Vol 76, 1 Oct, 107375.

Building Energy Codes Program. 2024. Building Performance Standards. Accessed February. https://www.energycodes.gov/BPS

City of Boulder. 2015. Boulder Building Performance Ordinance. Ordinance No. 8071. Oct 20.

Climate Solutions Now Act. 2022. Md. Code, Envir. § 2-1601 (Maryland General Assembly 2022) (passed March 31).

E3 (Energy and Environmental Economics). 2022. "BGE Integrated Decarbonization Strategy". Accessed October 2023. https://www.ethree.com/wp-content/uploads/2022/10/BGE-Integrated-Decarbonization-White-Paper_2022-11-04.pdf

Eash-Gates, P. and K. Takahashi. 2022. "Boston's Net-Zero Building Performance Standard: Making a Policy that's Inclusive and Flexible." In *Proceedings of the 2022 ACEEE Summer Study on Energy Efficiency in Buildings* 9:31–44. Monterey, CA: ACEEE.

EIA (Energy Information Administration). 2023. Annual Energy Outlook. Accessed October. https://www.eia.gov/outlooks/aeo/tables_ref.php

EmPOWER Evaluation Advisory Group (EAG). Benefit Cost Analysis Summary. July 2023. See Washington Gas EmPOWER Maryland Energy Efficiency Program 2024-2026, Public Service Commission of Maryland, Case No. 9705. (August 2023) p. 10.

ILEESAG (Illinois Energy Efficiency Stakeholder Advisory Group). 2022. Illinois Statewide Technical Reference Manual Version 11.0. Accessed November. www.ilsag.info/technical-reference-manual/il-statewide-technical-reference-manual-version-11-0/

IMT (Institute for Market Transformation). 2024. Comparison of U.S. Building Performance Standards. https://www.imt.org/wp-content/uploads/2023/07/IMT-BPS-Matrix.pdf

Jarrah, A., E. Garfunkle, and D. Ribeiro. 2024. Nobody Left Behind: Preliminary Review of Strategies to Support Affordable Housing Compliance with Building Performance Standards. American Council for an Energy-Efficient Economy. Accessed February. https://www.aceee.org/research-report/b2401

MDE (Maryland Department of Environment). 2023. Building Energy Performance Standard Notice of Proposed Action, 23-230-P-I. https://dsd.maryland.gov/MDRIssues/5025/Assembled.aspx#_Toc153201705

Moe, A. and P. Gibbs. 2023. Equitable Electrification Analysis for Existing Buildings in Richmond, CA. National Renewable Energy Laboratory. Accessed February. https://www.nrel.gov/docs/fy23osti/86954.pdf

National BPS Coalition. 2024. About the National BPS Coalition. Accessed February. https://nationalbpscoalition.org/#cities

NREL (National Renewable Energy Lab). 2022. ResStock End Use Savings Shapes 2022.1 Release. Accessed September 2023. https://resstock.nrel.gov/datasets

NREL (National Renewable Energy Lab). 2023. ComStock End Use Savings Shapes 2023 Release 2. Accessed October 2023. https://nrel.github.io/ComStock.github.io/docs/data.html

Regnier, C., P. Mathew, L. Rainer and C. CaraDonna. 2022. Systems Packages for Washington State Building Performance Standard Incentive Program: Phase 1 Analysis. Lawrence Berkeley National Laboratory. Accessed February. https://eta-publications.lbl.gov/sites/default/files/systems_packages_for_wa_state.pdf

RSMeans. 2023. RSMeans Data Online. Accessed November. https://www.rsmeans.com/

Walter, T., J. Kace, A. Mengual, M. Tyler and K. Madison. 2023. Maryland Building Energy Performance Standards Impact Analysis. Maryland Department of the Environment.

Webb, A. and C. McConnell. 2023. Evaluating the feasibility of achieving building performance standards targets. Energy and Buildings, Vol 288, 1 June, 112989.