Building Performance Standards: A New Paradigm for Building Retrofits

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ABSTRACT

Mandatory Building Performance Standards (BPS) play an important role in helping jurisdictions to decarbonize existing buildings. These policies set ambitious, long-term, efficiency or climate targets for larger buildings and are rapidly gaining in popularity. Ensuring that BPS programs create a strong impetus to retrofit existing buildings will be a key measure of the success of these policies. For building owners and managers, complying with BPSs is akin to learning to play quidditch when they were brought up on croquet – that is, BPS requires decision-making about whether and how to comply, and the relevant requirements may be challenging to interpret without assistance. The Building Energy Analysis Manager (BEAM) Optimizer was developed to help building owners navigate these complexities. The tool's algorithm analyzes retrofit decisions based on several BPS compliance metrics used across jurisdictions.

This paper will present a building retrofit case study using data collected by RMI and using the BEAM Optimizer tool. The same building is analyzed without BPS non-compliance penalties, with BPS non-compliance using energy use intensity (EUI) targets, and with BPS compliance using carbon intensity targets. The results illustrate how the BPS program design by jurisdictions drives investment decisions by building owners to comply with the BPS requirements and highlights the need for guidance to help building owners meet BPS goals.

Introduction

Buildings are a critical part of life in the US, as residents spend approximately 90% of their lives indoors (US EPA 1989). The building sector in the US is also the largest contributor to greenhouse gas emissions, at 35% of total energy-related emissions in the US (National BPS Coalition, 2024). To address this, various states and cities have been adopting more stringent building codes to ensure all new developments meet long-term climate goals. However, a significant portion of building sector emissions are from existing buildings. According to a report published by the American Council for an Energy-Efficient Economy, approximately 62% of the US building stock in 2050 will have been constructed before 2023 (Nadel and Hinge 2023). Decarbonizing these existing buildings is critical for states and cities to reach their climate goals.

Policies that set ambitious, long-term, efficiency or climate targets on larger buildings, known as Building Performance Standards (BPS), are rapidly gaining in popularity. At this juncture, four States (MD, CO, OR, WA) and the District of Columbia as well as a dozen cities and counties have enacted or are enacting BPS policies (Nadel and Hinge 2023). These policies can fundamentally alter the scope of retrofit projects for building owners in these jurisdictions. Non-compliance with these policies sometimes results in penalties, often in proportion to the size of the building or the shortfall relative to the target. BPS programs that include significant non-compliance penalties need to be included in building owners' financial analyses to accurately calculate project return on investment (ROI). Because BPS targets generally become more stringent over time, owners' retrofit analyses must also account for timing of project implementation relative to BPS milestones. This paper outlines key investment decision making factors for a sample building subject to no BPS policy, a greenhouse gas BPS policy and a consumption target. The sample building had gone through a detailed energy audit and building energy modeling exercise, providing a lengthy list of possible building improvements, their costs and savings.

BPS Policies in the United States

BPS policies are key levers that states or cities in the US can leverage to drive retrofits of existing building stock to meet long-term climate goals. BPS compliance adds new considerations to facility decision-making, which vary depending on policy details. Some policies set targets based on building energy consumption or energy consumption intensity, while other policies set targets based on greenhouse gas (GHG) emissions or GHG emissions intensity:

- Energy consumption intensity targets are generally based on regionally averaged building usage by building category, while accounting for operational factors such as occupancy or weather.
- Greenhouse gas emissions targets factor in consumption as well as the emissions rate for the different types of fuels involved, generally natural gas and grid electricity, occasionally liquid fuels or local district heating systems. For policies that include the emissions from electricity consumed by the building, the success of other environmental policies such as state level renewable portfolios or clean energy standards that drive grid decarbonization can influence the set of building retrofit measures selected.

While both consumption and emissions target types encourage emissions reductions, they come with their own complexities that building owners must learn to navigate. For example, buildings facing policy targets set in consumption units face uncertainty about occupancy behavior whilst buildings facing greenhouse gas targets may also have to deal with uncertainties in fuel and grid emissions rates. Policymakers must weigh the pros and cons of the different types of metrics and make decisions based on their individual jurisdictional needs (US EPA 2021). This variation in BPS policies being implemented across US jurisdictions allows for an interesting investigation into how program design drives the investment decisions made by business owners that are seeking to comply. Table 1 summarizes the metrics and scopes applied to the major BPS programs across the US. Scope 1 emissions are those caused by sources that building owners have direct control over, and scope 2 emissions are those indirectly caused by building owners, as they are emitted where the purchased energy is produced (National Grid 2023).

Table 1. Metric and scope applied to major BPS programs across the US.

Jurisdiction	**The Metric**	**The Scope**
States		
Colorado	Site EUI (kBtu per sq.ft.) or carbon intensity (tons CO2 equivalent per sq.ft.)	Scope 1 & 2
Maryland	Site carbon intensity (tons CO2 equivalent per sq.ft.)	Scope 1
Washington	Site EUI (kBtu per sq.ft.)	Scope 1 & 2
Localities		
Boston, MA	Carbon intensity (tons CO2 equivalent per sq.ft.)	Scope 1 & 2
Chula Vista, CA	Site EUI (kBtu per sq.ft.)	Scope 1 & 2
Denver, CO	Site EUI (kBtu per sq.ft.)	Scope 1 & 2
Montgomery County, MD	Site EUI (kBtu per sq.ft.)	Scope 1 & 2
New York, NY	Carbon intensity (tons CO2 equivalent per sq.ft.)	Scope 1 & 2
Reno, NV	ENERGY STAR score (energy and water) or EUI and WUI	Scope 1 & 2
St. Louis, MO	Site EUI (kBtu per sq.ft.)	Scope 1 & 2
Washington, DC	ENERGY STAR Benchmark Score	Scope 1 & 2
Cambridge, MA	Carbon intensity (tons CO2 equivalent per sq.ft.)	Scope 1 & 2
Portland, OR	Energy use (ASHRAE 100)	Scope 1 & 2
Seattle, WA	Carbon intensity (tons CO2 equivalent per sq.ft.)	Scope 1 & 2

Source: Nadel and Hinge 2023.

BEAM Optimizer

BEAM is used by towns, cities, and states to manage their building energy policy goals, including streamlining benchmarking and building performance standard program management. Many states, including Colorado, New Jersey, West Virginia and the District of Columbia, and several dozen cities and towns rely on BEAM to manage these complex policies. To help building owners comply with increasingly complicated policies and energy reduction targets, BEAM includes a retrofit roadmap and planning tool which optimizes building improvements to meet these objectives at the lowest cost. The BEAM Optimization tool evaluates the suite of possible efficiency measures from a detailed audit or online analysis of the building's characteristics and generates a building-specific roadmap of upgrades. The pathway is designed to ensure that retrofits and investments made into the property help meet local emissions or consumption targets including building performance standards. The tool takes into account the remaining lifetime of existing energy systems, the cost and savings of individual measures, the lifetime of proposed systems, investment budgets and non-compliance penalties to recommend an appropriate sequence of investments for each individual building. The measures typically considered include HVAC and hot water system improvements with a focus on electrification, window, door, and weatherization upgrades, renewable energy, and battery storage solutions. The sequence of upgrades in the building roadmap matches the city-wide compliance timeline the building is subject to. From a technical standpoint, optimization is achieved via a dynamic programming algorithm. The goal of this approach is to simplify the compliance planning process for building owners to ensure that retrofits and investments made into their properties are always optimized and timed to meet local emissions or consumption targets.

The Impact of Different BPS Compliance Metrics

As illustrated in Table 1, BPS compliance requirements vary across jurisdictions and so the analysis required to verify compliance needs to account for relevant metrics. This section delves into comparing the analytics required using a case study building. Building A used as a case study for this analysis is a 105,918 sq. ft multi-family building that is seven stories high and located in Boston, Massachusetts. RMI team undertook a retrofit analysis to identify measures that met the payback criteria of the owner. The building owner and RMI team also evaluated cost-effective grid-interactive and efficient building measures through this retrofit analysis (Huang et al. 2023). The retrofit decarbonization measures for the portfolio were selected and packaged per building such that they meet a 6% return on investment threshold to meet the financial criteria outlined by the owner. The results for Building A from RMI’s analysis used in this case study correspond to Scenario 0 listed below where the penalties associated with BPS non-compliance were not included.

This paper further builds on the retrofit analysis for one of the buildings in the portfolio located in Boston, MA to account for penalties associated with BPS compliance requirements. The BEAM Optimizer was used to achieve this. BEAM optimizer started with the retrofit analysis results shared by the RMI team. A list of all possible building measures for the building, their associated cost savings and first cost information provided by the RMI team as an input. The BEAM Optimizer was used to run an analysis considering the policy objectives, the remaining lifetime of existing building systems, the cost, savings and lifetime of proposed systems, non-compliance penalty structures if the policy objectives are not met and budget restrictions. The analysis produced a result detailing the sequence of investments which will minimize costs over the duration of the BPS program for the building owner.

The study's objective is to illustrate how the policy metric adopted by the jurisdiction impacts the building retrofit analysis. The three scenarios analyzed in this paper are:

1. Scenario 0 – This scenario reflects the initial retrofit analysis done by the RMI team and it does not account for BPS penalties.
2. Scenario 1 – This scenario analyzes compliance options for a building subject to a carbon intensity policy.
3. Scenario 2 – This scenario analyzes compliance options for a building subject to a site energy use intensity metric.

Scenario 0: Baseline Scenario with No BPS Policy

The RMI team provided results from a previous study of large multi-family buildings. The analysis for this study used a whole-systems approach to identify efficiency measures that met the owner's payback criteria for retrofitting buildings for the multi-family building portfolio. This analysis did not account for penalties due to BPS non-compliance in Boston. The study looked at a portfolio of buildings across the northeastern United States with an emphasis on efficiency and grid-interactive solutions. Retrofit analysis undertaken by RMI team resulted in significantly less investment recommended relative to other buildings in the portfolio when penalties due to BPS non-compliance were not considered.

The owner aimed to achieve an aggregate 6% internal rate of return (IRR) on retrofit investments. Based on the investment criteria and the existing conditions of Building A, only a solar PV system was identified for investment. This is a less comprehensive retrofit recommendation than many of the other buildings within the portfolio received as a part of the analysis. As shown in Figure 1, the solar array reduces emissions by 16.5mtCO2e.

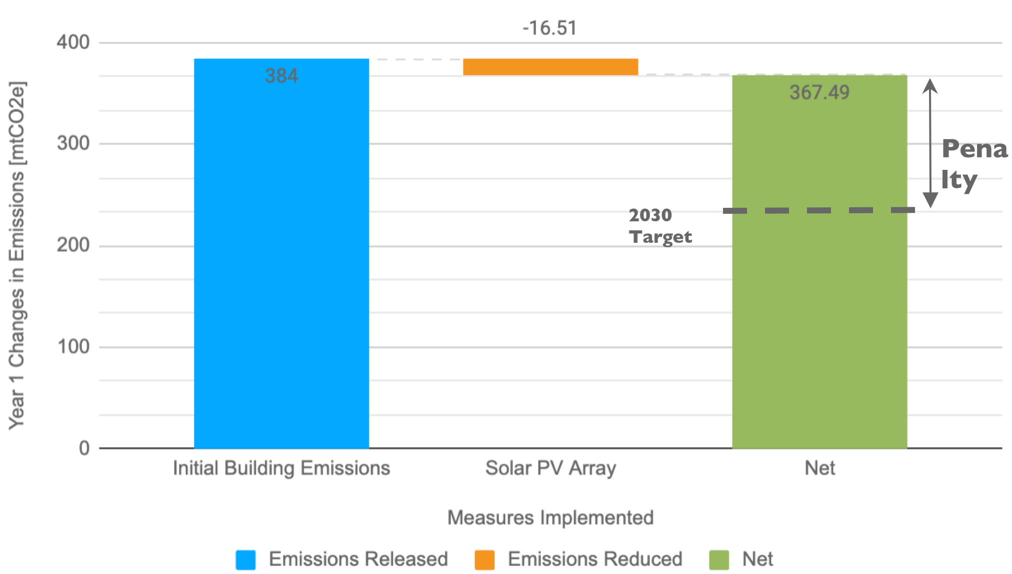

Figure 1. Scenario 0 emissions reductions per year.
Source: RMI.

Scenario 1: BPS Compliance Scenario Using a Carbon Intensity Metric

Building A is located in Boston, MA and needs to comply with the requirements of Building Energy Reduction & Disclosure Ordinance (BERDO) adopted by the city. BERDO requires non-residential buildings over 20,000 square feet or residential buildings with more than 15 units to achieve carbon neutrality by 2050, with interim greenhouse gas emissions intensity targets (emissions per square foot) every five years. The "alternative compliance payment", or penalty for not complying with the BERDO target is $234 per metric ton of CO2e in excess of the building's baseline. Contrary to other BPS programs, BERDO doesn't offer an alternative prescriptive compliance pathway, or building specific list of efficiency improvements agreed upon between the city and the building owner. BERDO does allow compliance across a portfolio of buildings with the same ownership, though this will be ignored in this analysis. We are also making the assumption that the penalties would be calculated and imposed as stated in the local ordinance. BERDO compliance will be influenced by the success of state-wide climate policies, notably the 2050 Clean Energy Standard which set a target of 80% clean energy on the Massachusetts grid by 2050 (MassDEP 2021). In comparison, the 2022 target is just north of 50% (MA DOER 2021). Because of the emphasis on greenhouse gas reductions and the companion Clean Energy Standard, building electrification will go a long way towards achieving compliance. Projections from the National Renewable Energy Lab were used for Massachusetts emissions rates (Gagnon 2023).

To comply with Boston's BERDO policy, Building A's annual emissions must drop to meet the targets highlighted in orange, as shown in Figure 2 below. The building's projected emissions (shown in blue) decrease in line with the electric grid emissions reduction rate[1] without any proactive retrofit measures. Nonetheless, the building falls out of compliance by 2030.

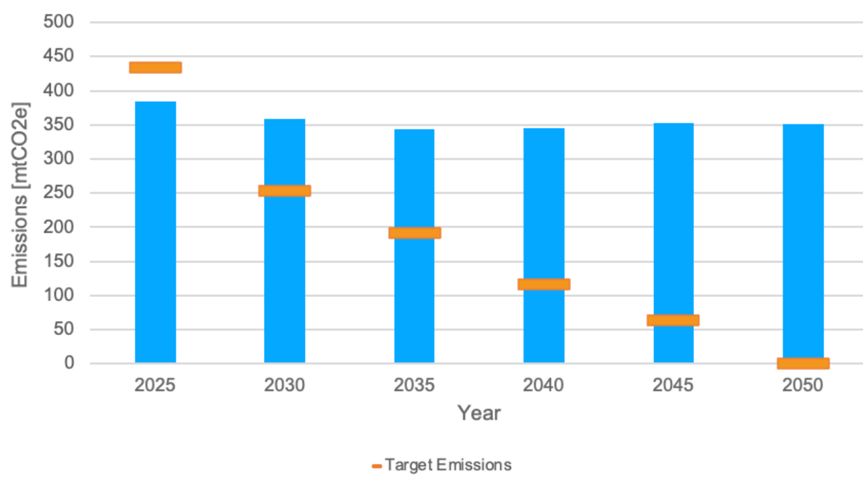

Figure 2. Scenario 1 forward-looking emissions analysis.
Source: BEAM.

[1] The grid emissions rates from Cambium drop quickly between 2025 and 2035 and stay relatively constant after that date.

When BPS non-compliance penalties are considered, the building is at a risk of $1,045,044 in penalties on an undiscounted basis through 2050. This is a significant additional cost for the owner looking to make retrofit investment decisions.

The BEAM Optimizer doesn't have a return-on-investment threshold and will, at a minimum, pick all the measures which are cash flow positive over the lifetime of the proposed retrofit measure or policy program, whichever is shorter. Based on the information provided by the RMI team, measures implementing a solar PV system and battery storage system are cash-flow positive through 2050. The battery system increases electricity consumption due to the extra power required to charge it. Therefore, GHG emissions increased by about 0.1t/CO2e/year, but the associated carbon penalty is small. In addition, and to avoid penalties, the Optimizer also picked up the heat pump hot water system. By itself, the system would take close to forty years to pay off, however the 101mt CO2e savings which come with its installation avoid $24,000/year in carbon penalties, more than doubling the system's estimated energy savings and halving its payback period. Figure 3 summarizes the emissions reductions relative to the 2030 target, and the remaining penalty to be paid. An important caveat to the selection of measures is that they are evaluated individually and do not take into account the interaction between measures. It is also clear that the selected measures no longer meet the 6% IRR requirement outlined by the building owner.

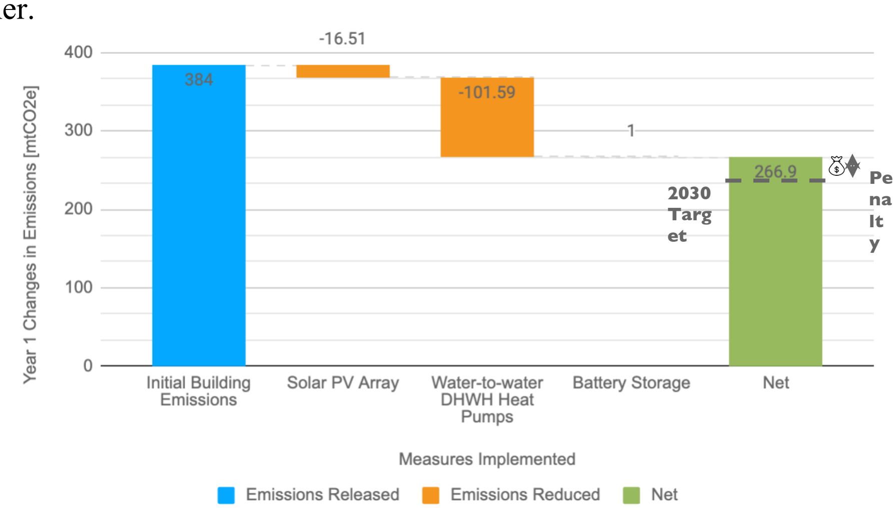

Figure 3. Scenario 1 emissions reductions per year.
Source: BEAM.

A fair question is why doesn't the Optimizer find more measures to install to fully zero out the building's emissions? Based on the information shared by the RMI team, an efficient space heating system, which would take the natural gas emissions to zero, would cost between two and four million dollars. The associated carbon savings are insufficient to offset both the costs of installing these systems and their additional electricity consumption.

Scenario 2 – BPS Compliance Scenario Using Energy Use Intensity (EUI) as Metric

Scenario 2 is a hypothetical scenario with Building A subject to a BPS with EUI as the compliance metric. These compliance target metrics do not apply to Boston but other jurisdictions, such as Washington state, St. Louis, Chula Vista, or Denver, are using this type of approach (Nadel and Hinge 2023). Scenario 2 was analyzed using Colorado's BPS policy. It is one strategy at play in the state's overall goal to reduce economy-wide emissions by 50% by 2030 compared to a 2005 baseline. To comply with Colorado's BPS policy, buildings over 50,000 square feet are given a choice to comply by meeting greenhouse gas intensity targets, remarkably like those set by Boston, or meeting energy use intensity targets by building type (Code of Colorado Regulations 2023). Building A was analyzed using the second option in this hypothetical scenario to illustrate how EUI targets may drive decision making different from greenhouse gas based targets. Targets are set for the first two compliance periods, 2026-2029 and 2030 and beyond. Colorado's BPS policy will continue past 2030 but hold future rulemaking sessions to re-evaluate targets.[2] A notable difference of this approach from BERDO is the structure of the penalties. Failure to comply with the policy can lead to a fine of $1/sq.ft plus $5,000. The penalty is a flat fee based on the building size and not calculated based on the departure from the compliance target. This type of penalty cannot easily be broken down into an avoided penalty by individual retrofit measure. Building A analyzed in this scenario would be required to meet the targets outlined in Table 3.

Table 3. Multifamily residential targets using EUI metrics.

	EUI 2026-30	EUI 2030-50
Multifamily residential	50.6 kbtu/sq.ft.	42.1 kbtu/sq.ft

Source: Code of Colorado Regulations 2023.

With the Colorado "flat" penalty set at $1/sq.ft, the Optimizer selects the same set of improvement measures as with the greenhouse gas based targets, namely heat pump water heater, solar and battery storage. As shown in Figure 4 below, those measures are sufficient to keep the building in compliance with the consumption targets between 2026 and 2029 but not quite enough to keep it in compliance beyond that. Because the penalty is binary, the building is hit with a $110,000 fine every year. That is, however, not quite enough to justify additional investments.

[2] As stated in the cited Code of Colorado Regulations, the CO Department of Public Health and Environment will reconvene to evaluate the efficacy of their rules in achieving targets and make necessary changes.

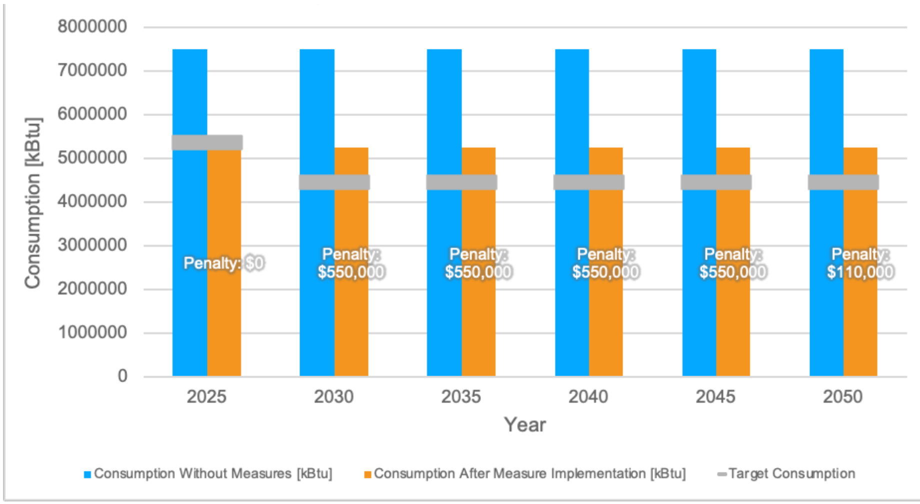

Figure 4. Scenario 2 forward-looking consumption analysis with measures implemented. *Source*: BEAM.

If the penalty is only slightly higher, the Optimizer adds a fourth measure, namely high-performance windows. At $3.4 million, this represents an expensive investment, but it reduces the EUI further to 11.5kBtu/sq.ft, enough to keep it below the target for the remainder of the period. The total cost of the solar PV, heat pump water heater, battery and window investments is $4.1million for a 46% energy efficiency gain. Given the structure of the target, that would be the most economic investment.

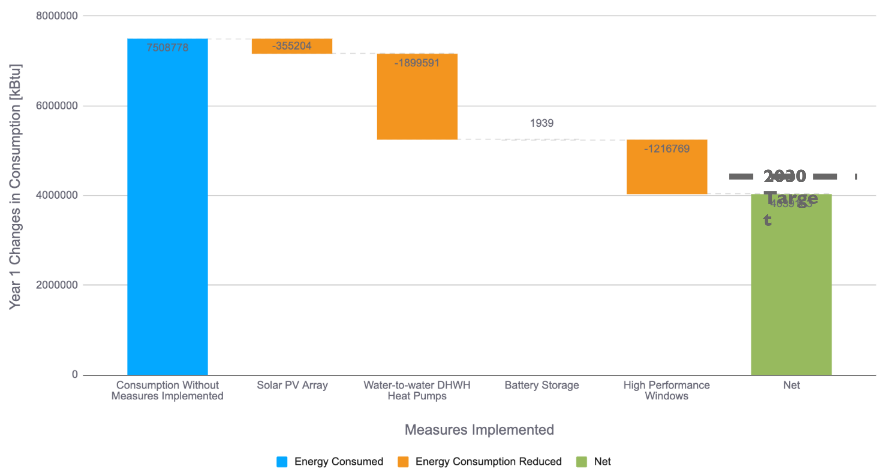

Figure 5. Scenario 2 changes in annual energy consumption by measures implemented in scenario 1. *Source:* BEAM.

As soon as deeper cuts are required, for example, a hypothetical requirement to further decrease consumption intensity by 20% between 2030 and 2035, the Optimizer ditches the efficient windows in favor of an investment in a full space and water heat pump system with solar PV, for a 65% net EUI efficiency gain.

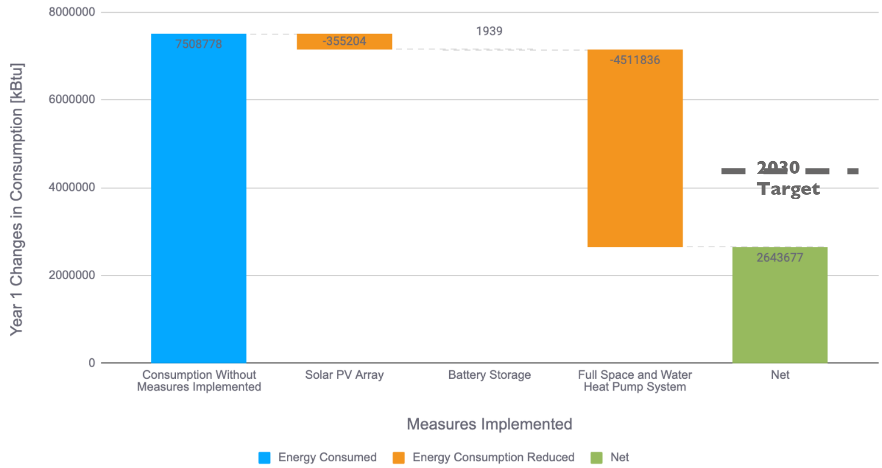

Figure 6. Scenario 2 building changes in annual energy consumption by measures implemented in scenario 2. *Source*: BEAM.

The scenarios, whose results are depicted in Figures 5 and 6, show how dependent the decision making is on the details of the policy. Therefore, the long-term certainty on the direction of the policy is incredibly important to the building's investment decisions. In the case of Boston's BERDO policy, the required reduction targets are laid out to 2050 and all converge on net zero at that date (Boston 2021). However ambitious, that approach has the merit of providing building owners with policy predictability and helps justify more ambitious investments. In the case of the Colorado BPS policy, the stated goal is to strengthen targets beyond 2030 but the longer-term targets are not yet law, thereby limiting building owner's ability to justify these deeper investments (Code of Colorado Regulations 2023).

Additional Notes on the Analysis

The Role of Discounting

Discounting plays an important role in driving the Optimizer's decision-making process, as it ensures the algorithm accounts for differences between present and future values. The higher the discount rate, the less future savings and penalties matter. In the scenarios outlined above, the base case penalties were calculated without factoring in discount rates. With penalties driving the selection of measures, a higher discount rate will make implementing efficiency measures less likely. For example, at a 10% discount rate, building A drops from its selection the battery storage and heat pump hot water systems.

The Role of Budgets

The funds for building investments can come from a loan or from capital budgets built-up over time. Using traditional return on investment metrics helps justify the proposed investments to internal decision makers and lenders alike. In this BEAM Optimizer analysis, we assumed that the owner of Building A has access to unlimited capital for improvement projects; as a result all decisions are taken in the first compliance period. The proposed measures cost respectively $61,000 for the battery system, $101,000 for the rooftop PV, and $631,000 for the heat pump hot water. When limiting the budget to $750,000 per compliance period, there is no way to install all three measures at the same time. To minimize costs, the decision algorithm will logically pick the most financially favorable measures first, in our case the solar and storage systems which are installed in 2025 and defer the installation of the heat pump hot water to the second budget period.

Discussion

Programs have been developed over the years to encourage building owners to retrofit existing buildings voluntarily, generally with limited success. Jurisdictions adopting policies to implement BPS are aiming to overcome this stagnation by setting mandatory targets for building performance. The BEAM optimizer was developed to help owners of existing buildings navigate complex BPS compliance pathways. The tool selects performance improvement measures that help minimize the costs of compliance with BPS programs. This paper presented an analysis that was undertaken on a multi-family building located in Boston, MA. The case study presented in this paper highlights how policymakers and building analysts can use innovative optimization algorithms to help clarify for building owners how to meet progressively more stringent consumption or emissions targets. By supporting building owners' efforts to conduct comprehensive financial analyses that factor in avoided penalties and seek to minimize compliance costs, jurisdictions should expect to see greater rates of compliance with their Building Performance Standards and ultimately greater success at achieving their 2050 emissions reduction goals.

A key takeaway for building owners is that traditional financial metrics such as return-on-investment or payback periods are no longer sufficient to make investment decisions in an environment with regulatory targets. At a minimum, the financial analysis needs to consider avoided penalties. However, this is only easy to implement if the avoided policy costs can be factored into individual investment decisions. For programs with building level penalties such as Colorado's dollar per square foot fine, breaking down the avoided penalty value by individual building measure is not possible. The BEAM Optimizer can factor in these types of penalties because it is looking for a solution which minimizes the overall cost of compliance.

The retrofit decisions recommended by the BEAM Optimizer depend critically on the duration and stringency of the policy. It is critical for building owners and operators to reduce uncertainty related to policy implementation. This includes having clear, long-term policy goals such as the Boston 2050 targets; policies that leave targets open ended past 2030 do not help building owners make costly investment decisions. It can also mean developing policies centered around policies building owners can influence. For this reason, analysts from organizations like the Institute for Market Transformation advocate for consumption-based targets or scope 1 GHG targets (IMT 2021). On the flip side, targets in greenhouse gas units allow jurisdictions to align building sector decarbonization with the city, county, or state's climate objectives. Since the economics of retrofitting buildings plays a major role in determining the success of BPS programs, model BPS ought to be accompanied by complementary incentive programs, financing mechanisms, and navigation to help building owners avoid penalties for non-compliance.

Another takeaway from the study is that penalty structures matter in driving decisions. Flat penalties or penalties calculated from the building size incentivize doing the bare minimum to meet the target, whilst penalties calculated from the departure from target create a stronger building-level decarbonization incentive.

Building Performance Standards are among the most ambitious policies implemented by cities, counties, and states to drive building decarbonization in the larger building stock. As more jurisdictions implement BPS, it is imperative to alter the frameworks through which typical retrofit investment decisions are made. These policies are most effective when policymakers acknowledge the resistance building owners and managers might feel around implementing a system that does not meet their desired return on investment. Additionally, building analysts can better support property owners in this process by factoring policy complexities into their evaluations and recognizing the industry's paradigm shift away from traditional analysis methods.

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