REGULATORY ANALYSIS

In performing a regulatory analysis, each rulemaking entity must provide the information requested for the regulatory analysis to be considered a good faith effort. Each regulatory analysis shall include quantification of the data to the extent practicable and shall take account of both short-term and long-term consequences. The regulatory analysis must be submitted to the Air Quality Control Commission Office at least five (5) days before the administrative hearing on the proposed rule and posted on your agency's web site. For all questions, please attach all underlying data that supports the statements stated in this regulatory analysis.

DEPARTMENT: Colorado Department of Public Health and Environment

AGENCY: Air Pollution Control Division

CCR: 5 CCR 1001-32

DATE: August 10, 2023

RULE TITLE OR SUBJECT:

REGULATION NUMBER 28: Building Benchmarking and Performance Standards

Per the provisions of 24-1-103(4.5)(a), Colorado Revised Statutes, the regulatory analysis must include the following:

I. A description of the classes of persons who will be affected by the proposed rule, including classes that will bear the costs of the proposed rule and classes that will benefit from the proposed rule;

Enacting a building performance regulation to increase energy efficiency and reduce greenhouse gas (GHG) emissions ensures that building owners participate in the reduction of emissions from the built environment. Consistent with statutory direction in sections 25-7-142(8)(a)(I), and 24-38.5-112, C.R.S., and the recommendations of the statutorily constituted Building Performance Standards Task Force, the Division is proposing building performance standards that will require covered buildings to implement measures that, taken together, are expected to achieve GHG emission reductions from this sector of 7% by 2026 and 20% by 2030, as compared to 2021 levels.

The principal classes of persons who may be affected by the proposed rule include owners, tenants, and customers of buildings subject to the proposed regulations — "covered buildings." Per statute, buildings covered under this rule are buildings with a gross floor area of fifty thousand (50,000) square feet or more that are occupied by a single occupant or a group of tenants. Building types not covered under this rule are a storage facility, stand-alone parking garage, or an airplane hangar that lacks heating and cooling; a building in which more than half of the gross floor area is used for manufacturing, industrial, or agricultural purposes as defined in the rule; and a single-family home, duplex, or triplex. The Division estimates that approximately 8000 buildings may be subject to the proposed regulation.

As discussed in greater detail below, the principal costs of the proposed regulations will come from implementing energy efficiency and/or GHG reduction measures at the covered buildings. The principal benefits will result from energy savings from these efficiency measures. Owners, tenants, and customers of covered buildings may all bear the costs and reap the benefits of the proposed regulations depending on the private business decisions and contractual relationships between affected classes (i.e., lease agreements). Owners will also be required to submit annual benchmarking reporting, which will create certain direct costs.

II. To the extent practicable, a description of the probable quantitative and qualitative impact of the proposed rule, economic or otherwise, upon affected classes of persons;

Based on the Division's analysis of the current rule proposal, with revised information from the Cost-Benefit Analysis, one of the benefits of this rule is the utility cost savings that may be realized by the building owner or payer of the building's natural gas and electricity. The electricity and natural gas savings resulting from this rule are estimated to be $4,577,040,161 and $577,557,481, respectively.[1]

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[1] *See APCD Cost-Benefit Analysis at p. 3*

Predicting the precise allocation of costs and benefits as between affected classes presents extreme challenges given the discretion and private decisions outside the State's purview. For instance, covered building owners might pass on some or all of the cost of complying with this rule to tenants, which could lead to higher rents. Additionally, it is speculated that building performance standard (BPS) and benchmarking programs could "harm equity priority communities through gentrification and housing displacement, while benefiting landlords."[2] Other issues may arise with communication and clarity of rule requirements, technological comprehension of reporting and compliance software, and funding for affordable housing and naturally occurring affordable housing.[3] In contrast, the energy efficiency measures implemented may lead to lower utility bills for the tenants. The net cost to the tenant, which is the difference between the higher rent and the lower utility bill, will depend on considerations such as how much of the cost the building owner pass on to the tenants, if the utility bill was already built into the rent, and the share of the cost that is covered by applicable state and federal programs, among others.

It is likely that the new rule will create new jobs in Colorado. According to the International Energy Agency, six to fifteen jobs are created for every $1 million USD spent on building efficiency[4], meaning approximately 10,616 to 26,540 additional building efficiency jobs could be created in Colorado from 2024 to 2050. The Division anticipates that future job growth will be closer to the scenario where six jobs are created for every $1 million.

Additionally, measures implemented to reduce GHG emissions will result in decreased pollution burden for the entire State of Colorado. A detailed analysis of the probable quantitative and qualitative impacts of the proposed rule can be found in the Division's Final Economic Impact Analysis and updated in the Cost Benefit Analysis.[5]

Lawrence Berkeley National Laboratory (LBNL) and Pacific Northwest National Laboratory (PNNL) provided the Division and CEO an analysis estimating the cost and savings resulting from implementing Colorado's proposed BPS regulation, see attached Colorado BPS Impact Analysis. The estimates from LBNL and PNNL show that there are considerable savings at the building stock level. The analysis identified the type and cost of various compliance measures available to building owners and applied those options to buildings according to their individual energy mix, showing not only economic but also technical feasibility. The methodology of the analysis does not include discounting analysis or the use of cost curves that could have applied to a greater number of buildings, did not consider the avoided cost of climate change, and used a different modeling tool from the one used in the EIA submitted by the Division. LBNL and PNNL determined that 71% of the buildings, representing 75% of the floor area, will see net savings or at least break even. At the sector level, one can expect that for each $1 in cost, building owners will see benefits worth $2.1 in energy savings. Although this analysis has not yet found a common theme across buildings that are not seeing savings, such buildings could see savings when other compliance options and the cost cutting impact of the various incentive programs are considered.

III. The probable costs to the agency and to any other agency of the implementation and enforcement of the proposed rule and any anticipated effect on state revenues;

Sections 24-38.5-112(1) and 24-38.5-112(1)(a) require the Colorado Energy Office (CEO) to implement a building performance program and to use "county assessor records and other available sources of information" to administer the building performance program. CEO must create a database of covered buildings and of owners required to comply with the building performance program; track compliance with the building performance program; maintain a list of noncompliant owners; and provide the Division a list of noncompliant owners. The Division will enforce the building performance program.

The current direct costs estimated to be incurred by the State from this rule come from the anticipated governmental program administration costs. These costs are attributed to the implementation and maintenance of the rule and are expected to be $8,855,599.[6] The direct estimated total costs expected to be incurred by the government and buildings covered under this rule are $1,769,336,191.[7] Recognizing the potential increase in compliance assurance work to implement this program, the General Assembly approved expenditures for additional personnel beginning in Fiscal Year 2022-23. More information about future State full time employee cost expenditures can be found in the Energy Performance for Buildings Final Fiscal Note.[8]

Additional costs to the government may occur as public buildings begin to fall under applicability of the building performance standards; these costs were estimated and accounted for in the direct costs to buildings and not specifically addressed in the direct cost analysis to the government.

The proposal may result in a small increase in State revenues because of potential additional compliance and enforcement actions. The Division has not estimated the increase in revenues because it expects all affected businesses to comply with the proposed regulation. Additionally, the State will also gain revenue through the annual $100 benchmarking data submission fee that is required for all covered buildings who submitted their building's data or received a benchmarking waiver, unless the building is a public building, then the building is not required to pay the $100 fee.

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[2] *See CEO_REB_EX_001 at p. 9*
[3] *See CEO_REB_EX_001 at p. 9-11*
[4] *See https://www.iea.org/reports/energy-efficiency-2020/energy-efficiency-jobs-and-the-recovery*
[5] *See APCD Cost-Benefit Analysis*
[6] *See APCD Final Economic Impact Analysis at p. 3*
[7] *Id.*
[8] *See HB21-1286, Final Fiscal Note, July 29, 2021*

IV. A comparison of the probable costs and benefits of the proposed rule to the probable costs and benefits of inaction;

The legislature has acknowledged that climate change impacts Colorado's economy and directed that GHG emissions be reduced across the many sectors of our economy.[9] Further, the legislature has also realized significant economic benefits from reducing statewide GHG pollution, including "creat[ing] new markets, spur[ring] innovation, driv[ing] investments in low-carbon technologies, and put[ting] Colorado squarely on the path to a modern, resilient, one-hundred percent clean economy."[10] Delaying these reductions will prevent Colorado from realizing the full benefit of these advantages and lead to further environmental and economic harms from climate impacts.[11]

After completing the Cost-Benefit Analysis, the Division found that over the timeframe of 2024-2050, the electricity and natural gas savings from the implementation this rule are estimated to be $4,577,040,161 and $577,557,481 and the reduction costs from the inclusion of the social cost of carbon account for $1,239,234,731.[12] The energy savings along with the avoided social cost of GHG emissions is estimated at $6,393,832,373, creating a benefit of $3.60 for each $1 in cost.[13]

Given the statutory directives in Section 25-7-142, C.R.S. to adopt building performance standards rules, there is no lawful option of inaction. Further, in the absence of the proposed rule, the potential energy savings that would have accrued to ratepayers may never materialize. The GHG emission reductions attributable to the proposed rule may also not materialize and the global economic cost of those emissions, which is estimated through the social cost of carbon, would be incurred instead.

The costs and benefits of the proposed rule are further detailed in the Division's Final EIA and updated in the Cost Benefit Analysis.

V. A determination of whether there are less costly methods or less intrusive methods for achieving the purpose of the proposed rule; and

Per statute, the building performance standards must achieve sector-wide emission reduction goals of 7% by 2026 and 20% by 2030 from covered buildings. Accordingly, the Division has set targets for all covered buildings based on property type or standard percent reductions designed to accomplish these statutory objectives. Covered buildings will have to determine and implement individual building plans to meet these targets or seek adjustments as provided for in the rules. When developing the building benchmarking and reporting requirements, major attention was focused towards creating straightforward and flexible pathways for building owners/operators to implement and follow.

The proposed building performance standards were selected to provide the building owner a variety of pathways to comply while assuring that the emission reduction goals in HB21-1286 are met. The primary compliance pathway is meeting a State assigned energy use intensity (EUI) target based on property type of the building and achieved by reducing a building's overall energy consumption. The second compliance pathway assigns buildings a greenhouse gas intensity (GHGi) target by property type and allows a building owner the ability to use a singular method or combination of energy efficient implementation to reduce their building's energy use, efficient electrification of space and water heating, and/or the option to install or acquire renewable energy under certain circumstances. Importantly, these targets were set such that 40% of covered buildings are already expected to meet the 2026 targets and 20% expected to already meet the 2030 targets. For these "high performing" buildings and those close to these targets, this pathway is expected to be extremely cost-effective.

Further, buildings unable to meet the property type EUI or GHGi target can use a standard percent reduction target by reducing EUI or GHGi 13% in 2026 and 29% in 2030 relative to the building's 2021 baseline benchmarking data. Buildings utilizing this pathway may include older buildings or those with abnormally high energy use. This pathway will be most cost-efficient for owners of buildings able to make impactful modifications to their buildings or operations but for which the EUI or GHGi targets are more than 13% and 29% away in 2026 and 2030, respectively. These diverse compliance pathways allow building owners the ability to use a variety of options to meet their building performance standards.

Additionally, covered buildings may apply for a timeline or a target adjustment if the building owner demonstrates that the building's target or timeline is not feasible for the building. All adjustments will be reviewed and approved by CEO.

Other approaches taken by different states and cities follow similar building performance pathways and metrics but may differ slightly.[14] The major differences between the Division's proposal and the building standards of other cities and states might be

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[9] *See* § 25-7-102(2)(b), C.R.S. ("Colorado is already experiencing harmful climate impacts, including declining snowpack, prolonged drought, more extreme heat, elevated wildfire risk and risk to first responders, widespread beetle infestation decimating forests, increased risk of vector-borne diseases, more frequent and severe flooding, more severe ground-level ozone pollution causing respiratory damage and loss of life, decreased economic activity from outdoor recreation and agriculture, and diminished quality of life. Many of these impacts disproportionately affect rural communities, communities of color, youth and the elderly, and working families.").
[10] *See* § 25-7-102(2)(e), C.R.S.
[11] *Id.*
[12] *See APCD Cost-Benefit Analysis at p. 3*
[13] *Id. at p. 2*
[14] *See* APCD_REB_EX-007 (Nationwide Comparison of BPS Programs)

the goals of the building performance standards, the requirements for buildings, or what buildings are covered. However, all of the different building performance standards follow similar pathways towards energy reduction through some combination of energy efficient implementation, electrification, or substitution with renewables to meet emission or energy reduction goals. One common trend among building performance standards implementation is the phasing out of fossil fuel infrastructure for efficient electric infrastructure. This is also an important consideration for Colorado in meeting the GHG emission reduction goals.

VI. A description of any alternative methods for achieving the purpose of the proposed rule that were seriously considered by the agency and the reasons why they were rejected in favor of the proposed rule.

To achieve the required emission reduction targets, the statute directed the AQCC to adopt building performance standards. It also directed CEO to appoint a Task Force to develop recommendations for the AQCC to consider when promulgating the rules for the State's building performance standards. CEO convened a Task Force of 18 members that represented diverse interests from across Colorado and the building sector including building owners, building operators, architects, engineers, building trades, utilities, local government representatives, and environmental groups.[15] The Task Force met monthly for a year to create the recommendations and considered many different methods to achieve the greenhouse gas emission reductions set forth in HB21-1286. Before choosing site EUI, beneficial electrification, renewable energy crediting, or a combination of the mix to be the pathways for compliance, the Task Force discussed other pathways for compliance. The Task Force recommended that EUI would be the best method given greater ease of understanding and implementation for covered building owners. The Division used this recommendation as a starting place and developed additional flexibilities for covered building owners while also ensuring that the proposed rules are designed to meet the statutory GHG reduction targets.

In the initial rulemaking proposal, the Division included electrification of fossil fuel powered equipment as a standalone compliance pathway. During the rulemaking process, the Division met with the Environmental Protection Agency (EPA) and the Department of Energy (DOE) to seek guidance on developing building performance standards and discussed the proposed electrification pathway. It was during this time that the Division was informed that EPA's ENERGY STAR Portfolio Manager had created a Building Emissions Calculator that could be used to measure a benchmarking building's greenhouse gas emissions by assessing type of energy used (electricity v. gas v. qualifying renewables). The Building Emissions Calculator allowed the Division to create a more expansive and inclusive GHGi compliance pathway than the standalone electrification pathway that would allow buildings to implement energy efficiency, replace fossil fuel equipment with high-efficiency electric equipment, and/or employ qualifying renewable energy generation and storage. The GHGi pathway allows buildings unable to meet the EUI pathway targets the option to implement other emission reducing strategies to meet compliance with the building performance standards that might be more beneficial or cost-effective. Therefore, the Division removed the electrification compliance pathway as a standalone compliance pathway in the proposed building performance standards.

The numerical changes in the performance targets stem from updates to three different factors: additional and cleaned benchmarking data; changes to future or new building energy metrics; and a correction of a miscalculation in the 2030 Greenhouse Gas Intensity (GHGi) targets. After the submission of the initial EIA, additional benchmarking data was submitted to the State that allowed the EUI and GHGi targets to be refined for better representation of Colorado-specific emission targets. After the submission of the final EIA, CEO and the Division were informed by CEO's consulting agency, Group 14, that the 2030 GHGi targets incorrectly used the 2026 emission factors, which resulted in revised targets once the correct 2030 emission factors were applied. Lastly, the new building energy use was adjusted in the analysis for the current targets based on information obtained from the U.S. Department of Energy's Pacific Northwest National Laboratory regarding projected EUI reductions for new buildings, as well as the City and County of Denver's Energize Denver requirements for new buildings. Future building energy demand must be accounted for in order to reduce sector-wide building emissions to meet the future emission reduction goals. The updates and revisions to these factors and metrics resulted in revised performance standards targets, as last provided in the Division's Rebuttal Proposal.[16]

In addition to the alternatives described above, the Division notes that Denver also provided an alternate proposal to the Division's proposal for consideration by the Commission.[17] The Division appreciates Denver's participation in the rulemaking and has made some revisions to the Division's proposal based on Denver's feedback and suggestions. However, the Division does not propose the adoption of Denver's alternate proposal because Denver's building performance standards were established to meet an overall goal of 30% reduction in energy use, which has not been shown to achieve the statutory GHG reduction goals of HB 21-1286. Also, the targets in Denver's alternate proposal do not align with the Division's statewide weather normalized targets and instead use targets specific for Denver's climate zone. The Division believes that Denver's alternate proposal will not meet the required emission reductions set forth in HB21-1286 and that the Commission should adopt the Division's proposal. The Division's proposed regulation is anticipated to meet the emission reduction goals through benchmarking, compliance pathways, and adjustment provisions that were drafted in response to specific provisions in HB 21-1286 and/or to support implementation of the regulation by CEO.

Additional alternative methods for achieving the purpose of the proposed rule are discussed in the Division's Cost Benefit Analysis.

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[15] *See COLORADO'S BUILDING PERFORMANCE STANDARDS (BPS) TASK FORCE RECOMMENDATIONS at 23-24*

[16] See [APCD Rebuttal Proposal]

[17] See [City and County of Denver Alternate Proposal]

Colorado BPS Impact Analysis

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Andrea Mengual, Matthew Tyler, and Kevin Madison - Pacific Northwest National Laboratory

August 8, 2023

Overview

This memo describes the methodologies used by Lawrence Berkeley National Laboratory (LBNL) and Pacific Northwest National Laboratory (PNNL) for estimating the impacts of Colorado's proposed Building Performance Standard (BPS) regulation. We first describe our data preparation procedure, then the estimation of costs of implementing measures. Next, we describe the model that estimates BPS impacts and conclude with a brief discussion of the results.

1. Data Preparation

The analysis started with the covered buildings list (CBL) provided by the Colorado Energy Office in cooperation with Group 14, which contains data on building type, floor area, and energy consumption for 8,002 buildings. Building types correspond to ENERGY STAR Portfolio Manager (ESPM) property types [1]. We assigned each building a broader category using ESPM's definitions (e.g., the adult education, K-12 school, and pre-school/daycare types are all mapped to the education category). We removed 5% of the buildings that have exempt buildings type (e.g., manufacturing, industrial), or do not have targets (data centers, mixed use properties, and parking), or have floor area < 50k ft^2. In order to simplify the analysis, we treated all energy use as either electricity or natural gas use. Since only a small proportion of buildings use non-gas fuels (1.8% use district steam and 1.3% use district chilled water), we believe this simplifying assumption has a small impact on overall results. We manually inspected site energy use intensity (EUI) histograms for each building type and removed energy data for 1% of buildings with abnormally high or low site EUI. The resulting dataset contains 7,629 buildings, but due to incomplete benchmarking data collection, 39% of these buildings do not have building type or floor area data, and an additional 2% do not have energy use data. We filled in the missing building types by sampling from the 61% of buildings that do have building type, according to their prevalence (e.g., if 25% of the buildings with type data are offices, then each of the buildings with missing types has a 25% chance of being assigned the office building type, and likewise for the other buildings types). We filled in missing floor area data by sampling from the floor area distribution for buildings of the same type (or the same category, if there were fewer than 20 buildings with the same type). Similarly, for buildings without energy data, we sampled site EUI and electric/site ratio (i.e., the proportion of site energy use that is electricity) from the distribution for buildings with the same type (or category).

Next, we used data from the Commercial Buildings Energy Consumption Survey (CBECS) [2] and the Residential Energy Consumption Survey (RECS) [3] to get the proportion of gas used for space heating, water heating, and everything else. We used the subsect of CBECS corresponding to the Mountain division and the “Cool” or “Cold or very cold” climates. We used the subset of RECS corresponding to the state of Colorado and apartment buildings with 5 or more units. For both CBECS and RECS, we used only buildings whose primary space and water heating fuels are natural gas. We used these subsets of CBECS and RECS to compute the proportion of total gas consumption that is used for space heating and for water heating. We mapped the building types and categories from the CBL to the corresponding CBECS types (i.e., the PBAPLUS column in the CBECS microdata) or CBECS categories (i.e., the PBA column) first using EPA’s suggested mapping [4], but sometimes including more types when there wasn’t enough CBECS data (at least 1 record). For each building on the CBL, if its electric/site ratio is > 0.9, we assumed the building does not use gas for space or water heating, and assigned all gas use to the other category. For buildings with electric/site ratio < 0.9, we sampled space and water heating proportions from the subset of CBECS or RECS with the corresponding type, then used these proportions to split each building’s total gas use into the amount of gas used for space heating, water heating, and all other end uses combined.

The resulting dataset contains 7,629 buildings with 1.13 billion ft^2 of floor area, 50.1 billion kBtu electricity consumption, 37.1 billion kBtu natural gas consumption (80% for space heating, 15% for water heating, and 5% for everything else), and 8.64 billion kg of CO2 equivalent (kgCO2e) greenhouse gas (GHG) emissions.

We used projected GHG emissions factors for electricity and natural gas (provided by Group 14) in our analysis. Figure 1 shows the electric grid getting dramatically cleaner (especially between 2024 and 2030), nearly reaching zero by 2050.

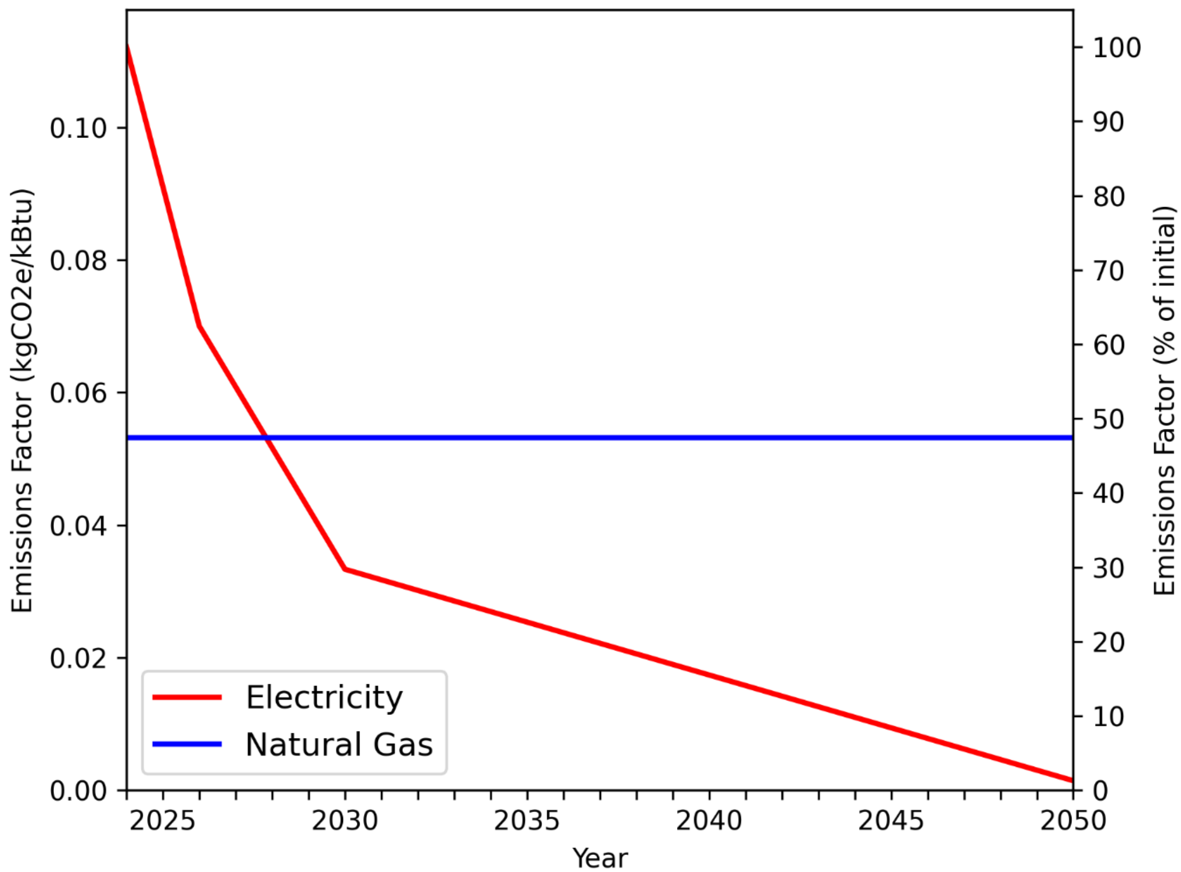

Figure 1: Projected GHG emissions factors.

For energy use rates (i.e., the cost of purchasing energy from a utility), we started with the actual rates for Colorado, then projected them into the future using annual scaling factors based on projections from the U.S. Energy Information Administration's (EIA) Annual Energy Outlook 2022 energy rate projections through 2050. Figure 2 shows that neither electricity nor natural gas use rates change significantly over time. Note that the energy use rates are not adjusted for inflation.

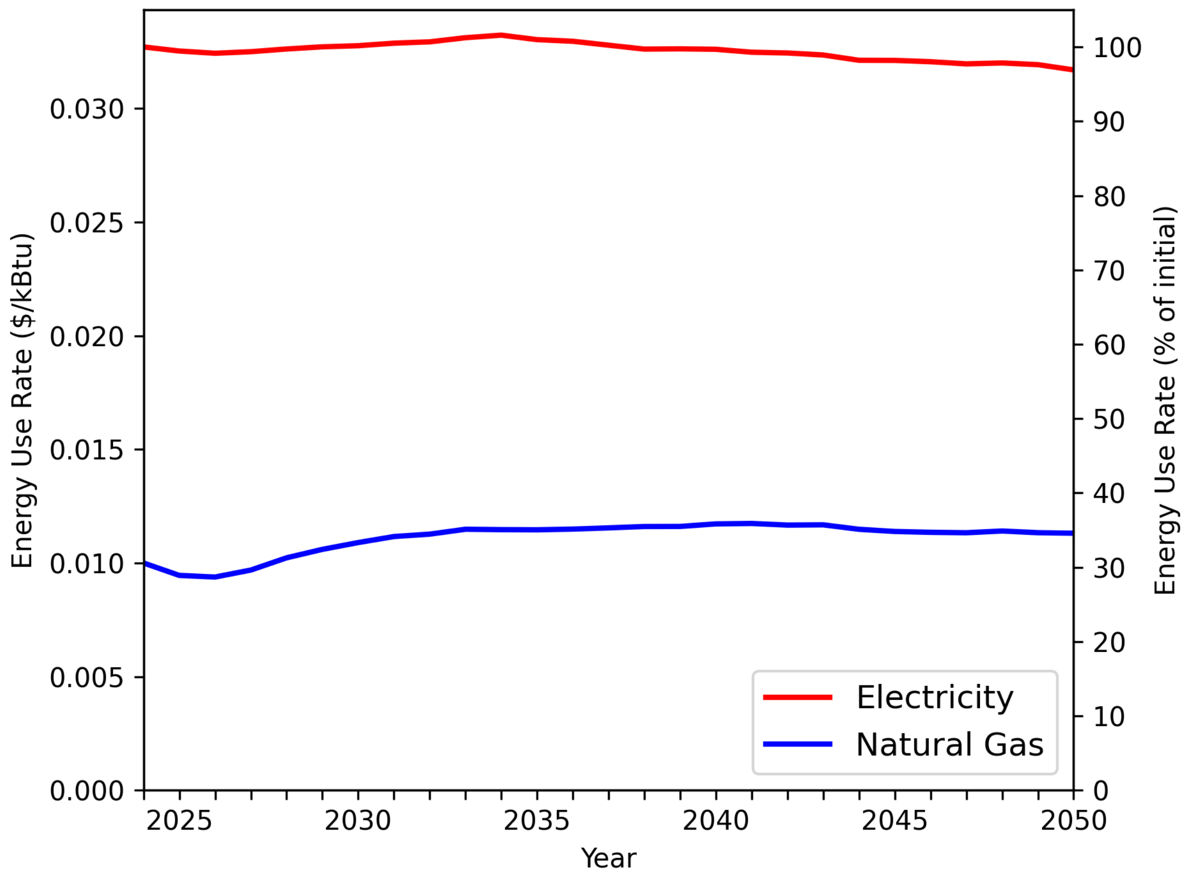

Figure 2: Projected energy use rates.

2. Measure Costs

PNNL used the following methodology for estimating the costs of implementing building modifications in four different categories: 1) energy efficiency measures (EEMs) for electric efficiency, 2) EEMs for gas efficiency, 3) electrification of gas equipment, and 4) like-for-like replacement of gas equipment.

EEMs for electric efficiency: These are measures that reduce electricity consumption without electrification or a change of fuel source. We performed a literature search to compile a list of potential EEMs with associated costs and savings. The literature search included studies performed for the implementation of building performance standards across the U.S. as well as research from the latest model energy code development, which include advanced efficiency measures and energy credit measures. This resulted in the following list of measures:

- Add Plug Load Control
- Add programmable, provide instructions to occupants on use
- Add R-10 Roof Insulation

- Add R-5.0ci Wall Insulation
- Add vestibule
- Adjust existing HVAC schedules to align with occupancy
- Central Temperature Controls
- Close Shaft Vents
- Commissioning: Stage 1: 1-month payback
- Commissioning: Stage 2: 1-year payback
- Commissioning: Stage 3: 3-year payback
- DOAS/fan control
- Efficient Elevator
- Envelope Leakage Reduction
- Fault Detection and Diagnosis
- Heat pump clothes dryer
- Improve Fenestration
- Increase daylight area
- Increase occupancy sensor
- Install an exhaust recovery ventilation unit
- Install low flow aerators in faucets and showers
- Install primary chilled water pump variable frequency drives
- Install smart plug load management tools
- Install submeters to incentivize tenants to reduce their energy use
- Install variable frequency drives on central distribution pumps
- Install variable frequency drives on condenser water pumps
- Install variable frequency drives on domestic water booster pumps
- Install variable frequency drives on heating hot water pumps
- LED conversion
- LED conversion for parking garage
- Light power reduction
- Residential HVAC control
- Residential light control
- SHW pipe insulation
- SHW shower drain heat recovery
- Thermostatic balancing valves
- Upgrade Exhaust Fans
- Upgrade In-Unit Appliances

This list of measures was reviewed and sorted by the building types in which they would be appropriate. For example, 27 measures were considered for multifamily buildings. Following an initial step of analyzing the range of energy savings expected for different building types based on the BPS impact analysis conducted by LBNL, we evaluated combining these measures into packages that could achieve different saving ranges. However, given the wide range of energy savings necessary for buildings to meet BPS targets, we determined that developing a cost curve using the EEMs identified would be a more effective way to apply costs to buildings in the impact analysis rather than using discrete packages. The cost curves were developed by sorting the measures from low to high cost per unit of EUI savings, which is a measure of cost-effectiveness, and by developing a regression curve that could represent the cost for deeper levels of savings. The intent is to consider that building owners will likely implement energy efficiency improvements starting with the most cost-effective measures and following the curve upward with decreasing cost-effectiveness. Figure 3 shows the cost curve for multifamily buildings and shows increasing costs per unit energy saved as the total EUI savings increases. Similar cost curves were also developed for office and non-refrigerated warehouse building types. We used the warehouse cost curve for all buildings other than multifamily and office buildings.

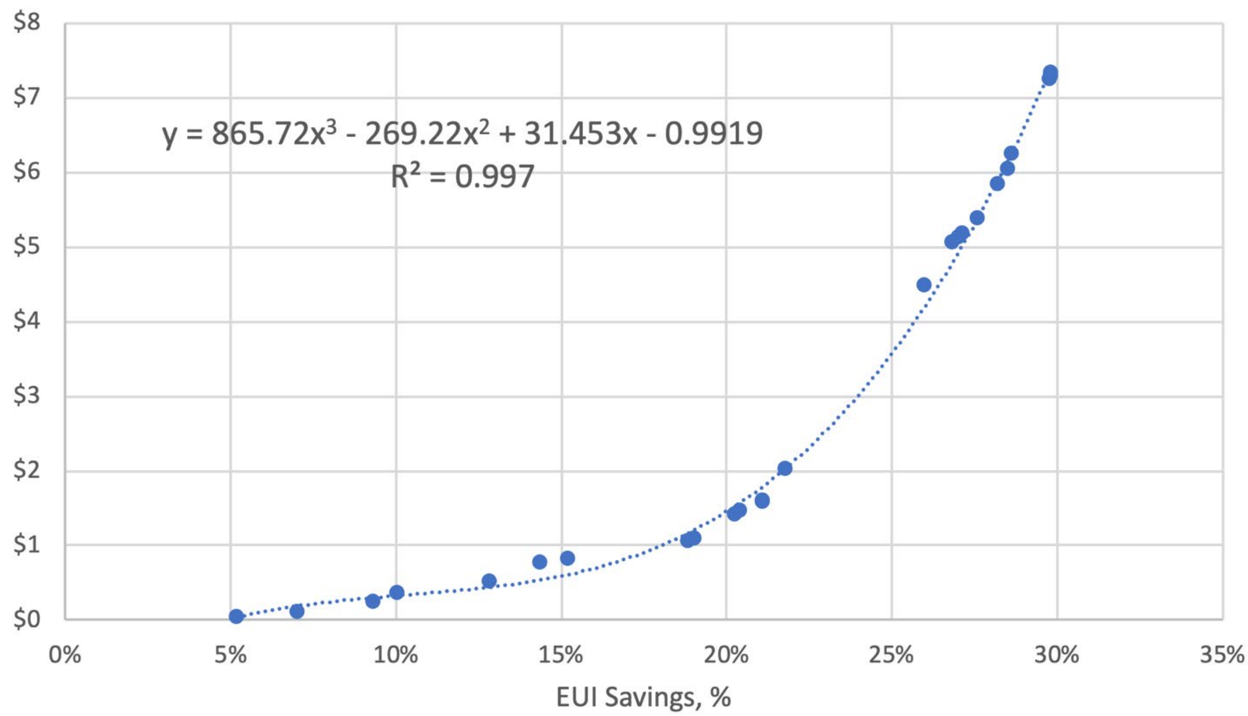

Figure 3: Electric efficiency cost curve showing cumulative cost ($\$/ft^2$) vs. EUI savings (%).

EEMs for gas efficiency: For gas consumption reductions due to efficiency, we assume building retro-commissioning with an estimated cost of $\$0.34/ft^2$.

Electrification of gas equipment: These are measures where natural gas-fired equipment is replaced with electric equipment, typically reverse cycle refrigeration equipment and heat pumps for space and water heating and other electric technologies for other gas-fired equipment such as food service equipment and clothes dryers. These costs are averages from a pilot analysis of strategies that would, over time, meet the BPS targets in Montgomery County, Maryland [5], but are adjusted to reflect costs in Colorado by applying regional scaling factors.

Due to the limited number of building investigations, costs can only be provided per square foot of floor area. For space heating electrification, we estimate a cost of \$8.27/ft^2 for residential buildings and \$12.24/ft^2 for commercial buildings. For water heating, we estimate \$5.02/ft^2 for both residential and commercial. For all other end uses, we estimate \$0.82/ft^2 for residential and \$0.11/ft^2 for commercial.

Like-for-like replacement of gas equipment: These are costs associated with replacing gas-fired space and water heating equipment with new gas-equipment when the equipment reaches the end of its useful life. When considering electrification at the same point in time, replacement with gas-fired equipment is likely the lowest capital cost alternative. For this reason, it is important to consider the marginal cost of electrification, i.e., the additional cost that would be required to replace equipment at its end-of-life with electric equipment rather than doing a like-for-like gas-fired replacement.

Replacement costs were developed from tools used to develop the state-level cost effectiveness for ASHRAE Standard 90.1-2019 [6]. These costs are the most representative since they reflect the most recent research of typical costs for equipment that would comply with Colorado energy codes currently in effect. Costs were normalized by site EUI so they could be applied to buildings with higher energy use, which is expected for most, older, existing buildings. Table 1 shows replacement costs for office, multifamily, and non-refrigerated warehouse building types. We used the warehouse costs for all buildings other than office and multifamily buildings.

Building Type	**End Use**	**Heating Type**	**Cost ($/kBtu)**
Office	Space heating	Boiler gas-fired	0.14
Multifamily	Space heating	Split A/C with gas heating	1.23
Warehouse	Space heating	PSZ with gas heating	0.01
Office	Water heating	Commercial gas storage	0.05
Multifamily	Water heating	Residential gas storage	0.11
Warehouse	Water heating	Commercial gas storage	0.10

Table 1: Like-for-like replacement costs for gas space and water heating equipment.

3. Impacts Modeling

We constructed a model that predicts the behavior of each building from 2024 through 2050 under two different hypothetical scenarios: 1) a baseline scenario representing business as usual, and 2) a scenario in which the proposed BPS regulation is implemented. For each year, and for each building, the model predicts the building's energy reductions (for electricity and each gas end use) as the building implements efficiency, electrification, and/or like-for-like replacement measures. The model uses the GHG factors and energy use rates from Section 1, and the measure costs from Section 2.

1) In the baseline scenario, buildings are not subject to any BPS regulation and only make like-for-like replacements of gas systems and the end of their useful life. Each building replaces both their space heating and water heating systems (but no other gas systems) in one randomly selected year from 2024 to 2050 (i.e., we assumed that, on average, these systems have useful lifetimes of roughly 25 years, but we made no assumptions about how old the currently-installed systems are). We assumed the current space heating systems are 79% efficient, and are replaced with new systems that are 85% efficient. We assumed the current water heating systems are 85% efficient, and are replaced with new systems that are 93% efficient.

2) In the BPS scenario, buildings are subject to Colorado's proposed BPS regulation and implement measures to meet the site EUI or GHG intensity (GHGI) targets specified in the regulation. Each building is assigned four targets, according to its building type: a site EUI target to be met (or exceeded) by 2026, a GHGI target for 2026, a site EUI target for 2030, and a GHGI target for 2030. Alternatively, each building is also assigned a standard reduction for each metric (site EUI and GHGI) and for each compliance year (2026 and 2030). In 2026, the standard reduction is a 13% reduction from the initial value (both for site EUI and GHGI), and in 2030, the standard reduction is 29%. If the standard reduction is smaller than the reduction needed to hit the target, buildings are allowed to make the standard reduction instead of meeting the target.

In order to meet the targets (or make the standard reductions), we assume buildings will make reductions according to the following logic:

1. Reduce electricity use up to 10% (of the initial value) by implementing EEMs.
2. Reduce gas space heating use (not water heating or other) up to 20% (of the initial value) by implementing EEMs.
3. Reduce electricity use up to an additional 15% (of the initial value), i.e., 25% total, by implementing additional EEMs not implemented in step 1.
4. Reduce gas use (and increase electricity use) by electrifying gas equipment (space heating, water heating, and/or other).
5. Reduce electricity use as much as necessary by implementing additional EEMs not implemented in steps 1 or 3.

A building will complete as many of these steps (in order) as necessary, stopping when either of the targets (or standard reductions) are met. The reduction maximums in steps 1 through 3 apply cumulative to meeting both the 2026 and 2030 targets (i.e., if a building meets its 2026 targets by reducing electricity use 10% and gas use 12% via EEMs, that building may only reduce gas use an additional 8% and electricity use an additional 15% to meet its 2030 targets). We assumed each building will meet its 2026 targets by making all necessary reductions in a single randomly selected year between 2024 and 2026, and will meet its 2030 targets by making reductions in a single randomly selected year between 2027 and 2030 (i.e., buildings do not spread the reductions needed for meeting a particular target across multiple years).

When electrifying gas equipment, we assumed the same efficiencies as in the baseline scenario for the current systems (i.e., 79% for space heating and 85% for water heating). We assumed the new electric space heating systems will have a coefficient of performance (COP) of 2.5, new water heating systems will have a COP of 2.2, and other systems will have a COP of 1.0. When deciding which gas equipment to electrify (space heating, water heating, and/or other), buildings choose whichever individual end use (or combination of multiple end uses) that meets the target at the lowest implementation cost (see Section 2). If electrifying all three end uses does not meet the target, the building electrifies all three, then proceeds to step 5.

For both scenarios, the model results include, for each building and each year: energy reductions (due to electricity EEMs, gas EEMs, electrification, and/or like-for-like replacement), the resulting energy consumption (for electricity, gas space heating, gas water heating, and other gas end uses), and GHG emissions.

4. Results

In the baseline scenario, annual energy consumption from all buildings on the CBL decreases 3% from initial levels by 2050, with all reductions coming from replacing gas equipment at the end of useful life with new (and more efficient) gas equipment. Annual GHG emissions decrease 75% during the same time period, with essentially all of the decrease due to the electric grid getting cleaner.

In the BPS scenario, annual energy consumption decreases 29% from initial levels by 2030 (with the majority coming from gas), then stays constant through 2050. Figure 4 shows annual energy consumption from each fuel. Annual GHG emissions decrease 87% by 2050, with 73% of the decrease due to the electric grid getting cleaner. Figure 5 shows annual GHG emissions due to each fuel.

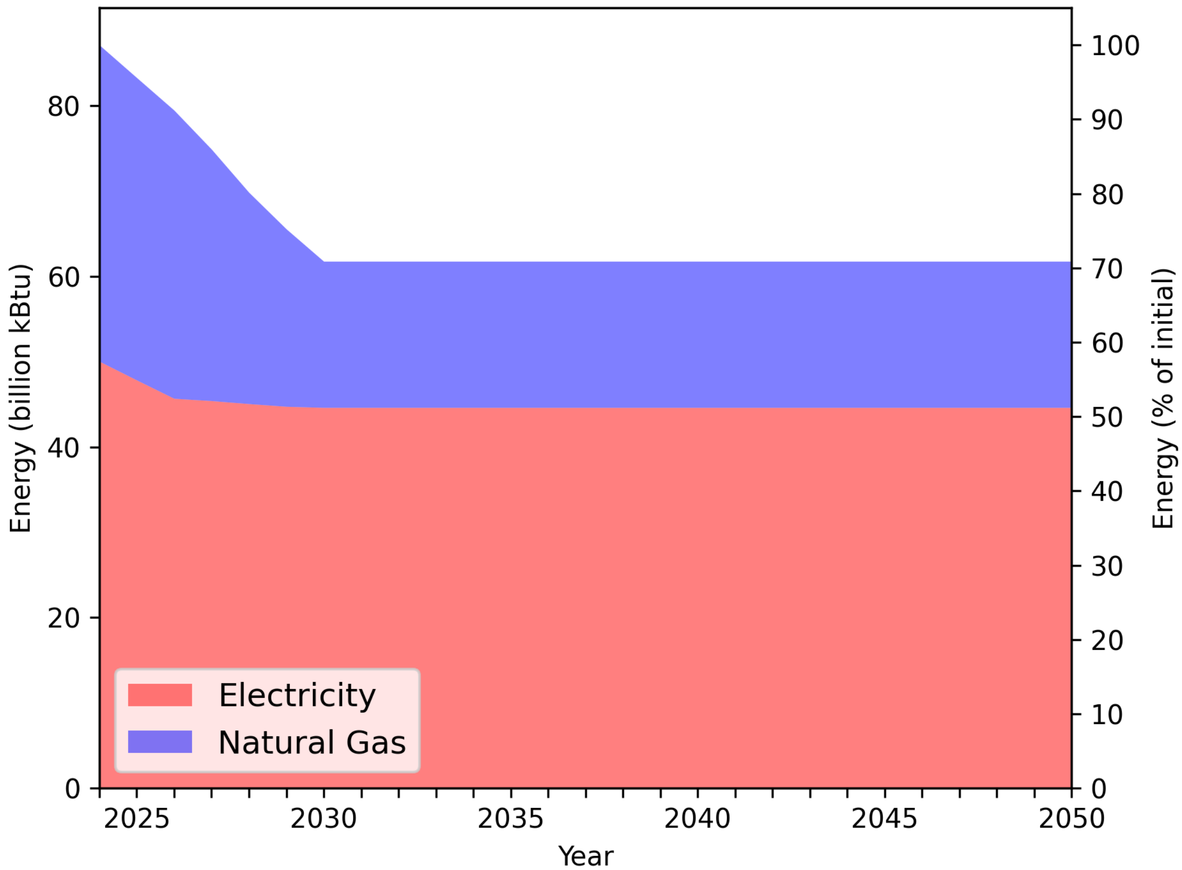

Figure 4: Annual energy consumption from electricity and natural gas in the BPS scenario.

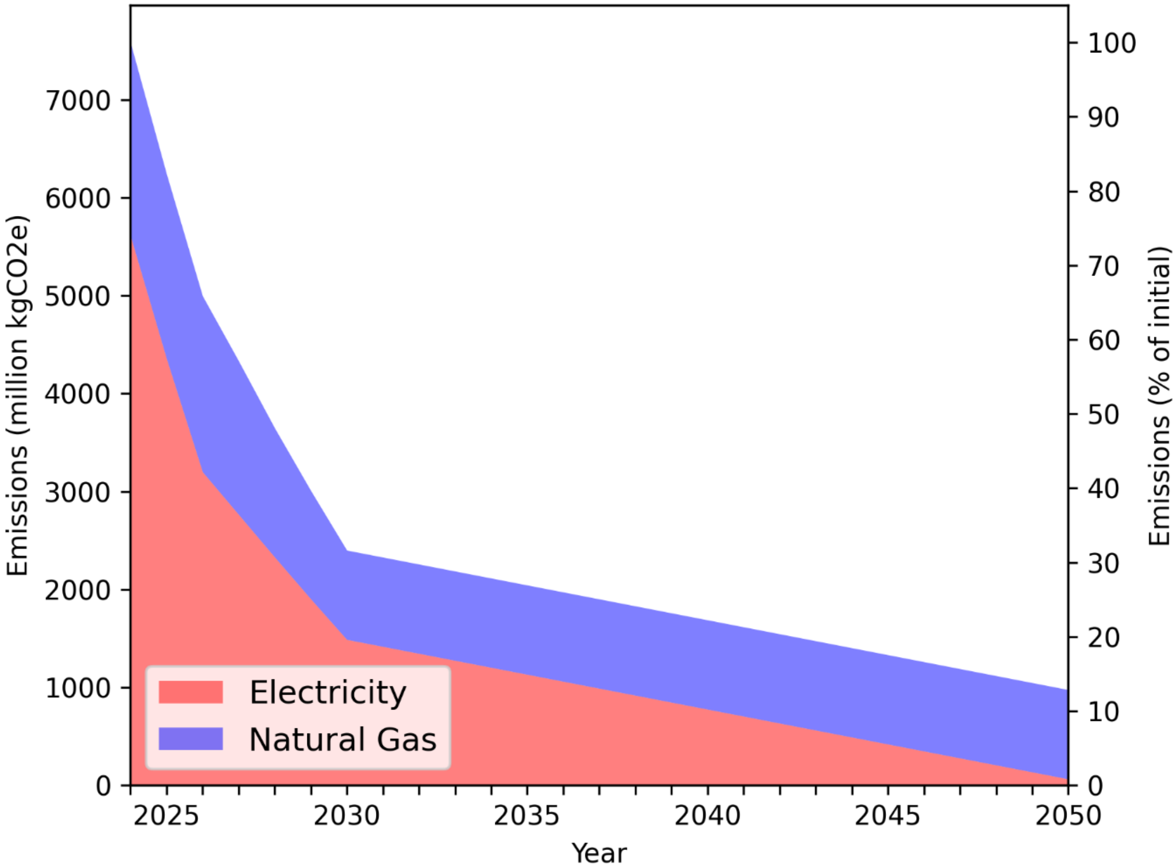

Figure 5: Annual GHG emissions from electricity and natural gas in the BPS scenario.

When considering the costs and benefits of the BPS scenario relative to the baseline scenario, the BPS reduces 2024-2050 cumulative energy consumption by 24% (560 billion kBtu) and reduces 2024-2050 cumulative GHG emissions by 28% (25.8 billion kgCO2e). In the baseline scenario, buildings spend \$5.56 billion on like-for-like equipment replacement and spend \$54.7 billion on energy costs, for a total cost of \$60.2 billion. In the BPS scenario, buildings spend \$1.92 billion on EEMs, \$5.29 billion on electrifying gas equipment, and \$45.5 billion on energy costs, for a total cost of \$52.7 billion. Thus, the BPS scenario reduces cumulative energy use by 24% and cumulative emissions by 28%, at a net savings of \$7.55 billion. At the building stock level, the BPS scenario has net cost savings, but this varies significantly by building: on average, buildings save \$5.34/ft^2, but 68% of buildings (72% of total floor area) have net savings, 2.8% of buildings (2.9% of area) break even, and 29% of buildings (25% of area) have net costs. Of the buildings with net savings, average savings are \$9.66/sqft. Of the buildings with net costs, average costs are \$4.37/sqft.

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