

BERDO Compliance Case Study

Comparing building improvements to meet emissions limits

The City of Boston Environment Department commissioned this study to show how a building owner can combine and/or phase building energy efficiency and electrification improvements to meet BERDO emission limits.

Building owners can work toward BERDO compliance by creating a best-fit approach to decarbonize their buildings through 2050. Decarbonizing a building may include energy efficiency improvements and the electrification of building systems. Owners may also need to buy renewable energy certificates to meet emissions limits over time.

This case study demonstrates how building owners and design teams can compare decarbonization options to find a solution that meets an owner's needs. The insights from this study consider that finding the right solution also involves capital planning, financial incentives, tenant needs, and space for new or upgraded equipment.

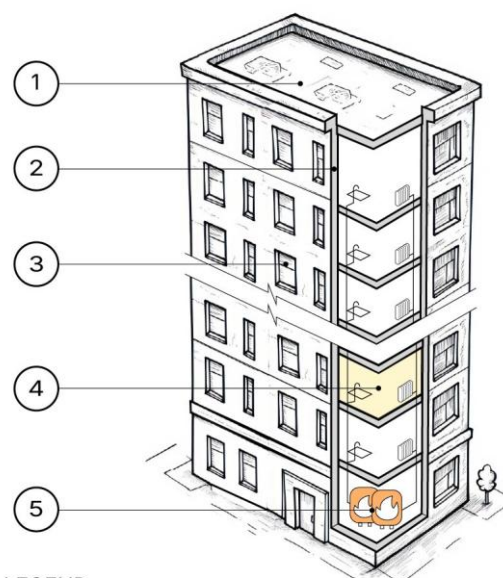
Building Description

This case study considers a single example building: a 1930s-era Boston high-rise (10-story) residential apartment building with 80 two-bedroom units. See Figure 1 to learn more.

The building's gas-fired boiler serves hydronic radiators. The domestic hot water (DHW) system and corridor make-up air unit are also gas-fired. Half of the units have air conditioning units.

Baseline Performance

The building's current energy use and emissions information is shown in Table 1. The building does not yet meet the 2025 emissions limit of 4.1 kg CO₂e/ft²/yr. Figure 2 shows a breakdown of the building's fuel and energy end uses. The building relies heavily on natural gas for heating loads; space heating is the largest contributor to overall energy consumption.



LEGEND

- 1 - Concrete roof, minimal insulation
- 2 - Mass masonry walls, no insulation
- 3 - Single-pane aluminum windows
- 4 - Incandescent lighting
- 5 - Gas-fired heating and hot water

Figure 1: Case study building description.

Table 1: Annual Baseline Building Performance

	Energy Use Intensity (EUI) (kBtu/ft ²)	Greenhouse Gas Intensity (GHGI) (kgCO ₂ e/ft ² /yr)*	Annual Utility Cost (\$)**	*BERDO emission factors 2025: natural gas – 53.11 kg/mmBtu, electricity – 249 kg/MWh.
Natural gas	59.5	3.2	\$76,852	**Average energy prices sourced for gas ¹ and electricity. ²
Electricity	19.5	1.0	\$137,601	
Total	79.0	4.2	\$214,453	

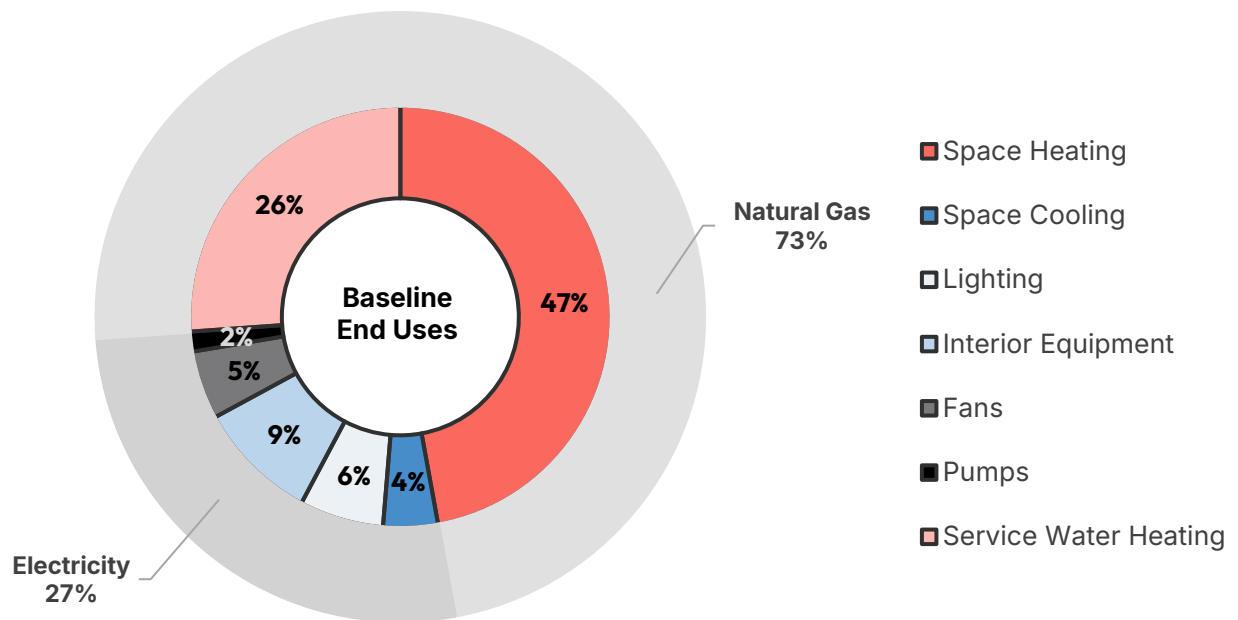


Figure 2: Breakdown of baseline building fuel use and energy end uses.

Compliance Cases

This study used energy modeling and other calculation methods to compare seven compliance cases for the example building (as described above). These cases examine different combinations of “action items” (see Table 2) that a building owner might consider to comply with BERDO. Table 3 summarizes the seven compliance cases and real-world considerations that may have informed each case.

The compliance cases assume:

- The action item(s) are completed prior to the compliance year.
- A building contractor provides recommissioning of building systems. Recommissioning allows the building to operate in a consistent, energy-efficient manner and improves long-term system reliability.
- Per BERDO rules, renewable energy certificates (RECs) can be used to mitigate only electricity emissions.
- Mechanical and enclosure upgrades or replacements may be neglected in some cases, but the replacement of failed components may need to occur between 2025 and 2050.



To read the key insights from this case study, see page 6.

Table 2: Action Items Considered for BERDO Compliance

					
Improve the building enclosure	Improve heating and cooling systems	Improve lighting (e.g., LEDs)	Purchase Renewable Energy Certificates (RECs)	Enroll in Boston Community Choice Electricity (BCCE)	Pay Alternative Compliance Payments (ACPs)

Table 3: Compliance Case Summary

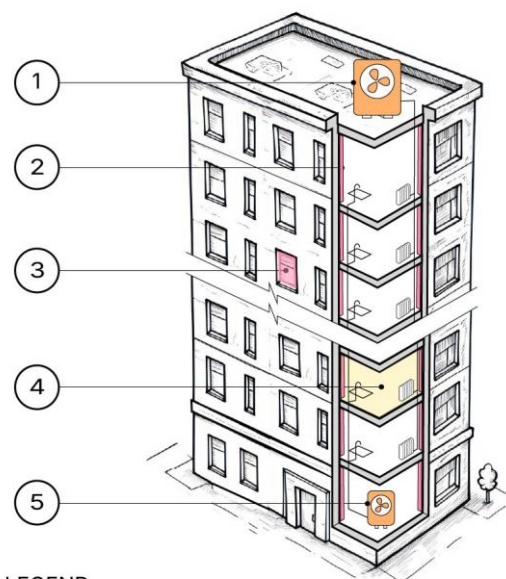
Case	Action Items by Year					
	2025	2030	2035	2040	2045	2050
Case 1 Baseline Case	 \$	\$	\$	\$	\$	\$
	Case notes: A like-for-like mechanical system replacement occurs in 2025. No other changes are made to the building's systems.					
Case 2	  \$	 \$	 \$	 \$	 \$	 \$
	Case notes: Tenants enroll in BCCE beginning in 2025. A like-for-like mechanical system replacement occurs in 2025. No further mechanical or enclosure upgrades are assumed through 2050.					
Case 3	 	 \$	 \$	 \$	 \$	 \$
	Case notes: The building owner initially invests in LED lighting upgrades after investing in mechanical upgrades in 2023 and is cautious to invest in additional upgrades.					
Case 4		 \$	 \$	 \$	 \$	 \$
	Case notes: Tenant thermal comfort complaints suggest the existing boiler may need to be replaced. Electrifying the heating system with a heat pump now may offer quality-of-life improvements and long-term compliance benefits.					
Case 5		 \$		No action	No action	\$
	Case notes: This case assumes that the existing gas boiler can operate for another 10 years, and the old windows are immediately replaced with double-glazed windows to overcome water leakage, air leakage, and operation issues. An electric heat pump is installed in 2035 for heating and DHW.					
Case 6		  	 \$	 \$	 \$	 \$
	Case notes: This case focuses on enclosure upgrades (triple-pane windows and interior wall insulation) because of the aging enclosure systems. The boiler continues to operate. Tenants enroll in BCCE beginning in 2030.					
Case 7	  \$	  		 \$	 \$	 \$
	Case notes: This case assumes the building requires both enclosure (windows) and mechanical (heat pump water heater) retrofits. Tenants enroll in BCCE beginning in 2030.					

Building Improvements

The building improvements used in this study to reduce energy use and emissions are summarized below and in Figure 3.

Building Enclosure

- **Replace windows:** In some compliance cases, the building's single-pane aluminum-framed windows were replaced. Replacement included thermally broken frames and double- or triple-pane insulated glazing units (IGUs). These IGUs reduce heat loss and solar gain, which benefits building heating and cooling needs. The durable seals and materials of the new windows reduce water leaks and increase airtightness. They also improve occupant comfort by reducing sound from the outside and blocking air drafts.
- **Increase airtightness:** Replacing windows and sealing between windows and the masonry wall can increase airtightness and reduce energy heating and cooling needs. In this study, the existing masonry wall was assumed to be relatively airtight, so no membranes or sealing were added on the wall face.
- **Add insulation:** Adding insulation to walls, roofs, and/or floors can reduce heat loss and improve tenant thermal comfort. Case 6 in this study added 4" of insulation to the masonry walls. This insulation would likely be added to the interior of the walls; adding insulation to the exterior would change the building's appearance.



LEGEND

- 1 - Electric heat pump (space heating)
- 2 - Insulation added to interior of walls
- 3 - Windows replaced and sealed
- 4 - LED lighting
- 5 - Electric heat pump (hot water)

Figure 3: Case study building improvements.

Mechanical System

- **Upgrade the central heating boiler to an electric heat pump:** Heat pumps can be much more efficient at heating than gas boilers. When combined with a gradually declining electric grid emission factor,³ heat pumps can be a compelling option to reduce GHGI. With this option, some building owners may encounter equipment space limitations or noise challenges in addition to an increased cost of electricity (per unit energy).
- **Upgrade the DHW boiler to a heat pump:** The DHW energy end-use is significant for residential buildings; it may be worthwhile to investigate this strategy for owners, which offers similar benefits and challenges as described in the heat pump discussion above.

Changes to the building's ventilation rates were not modeled. However, it is important that a building's mechanical design provides adequate indoor air quality (fresh air for occupants) when a building's airtightness improves. Improving a building's ventilation (or similar efforts) rate is likely to increase the mechanical system's installation and operating costs, EUI, and GHGI.

Lighting

High-efficiency LED lighting can be a low-cost retrofit to reduce electrical energy use. However, LED lighting produces less heat and increases the need for space heating in colder seasons. LED lighting may increase GHGI if the building heating system is gas-based.

Results Discussion

Figure 4 summarizes these two key metrics for each compliance case:

Annual building GHGI reductions by 2050:

The total reduction in GHGI. This metric is shown as a percentage compared to the present-day building performance.

Net Present Cost (NPC) by 2050:

The total NPC of action items and building utility expenses through 2050 in today's dollars (2025).

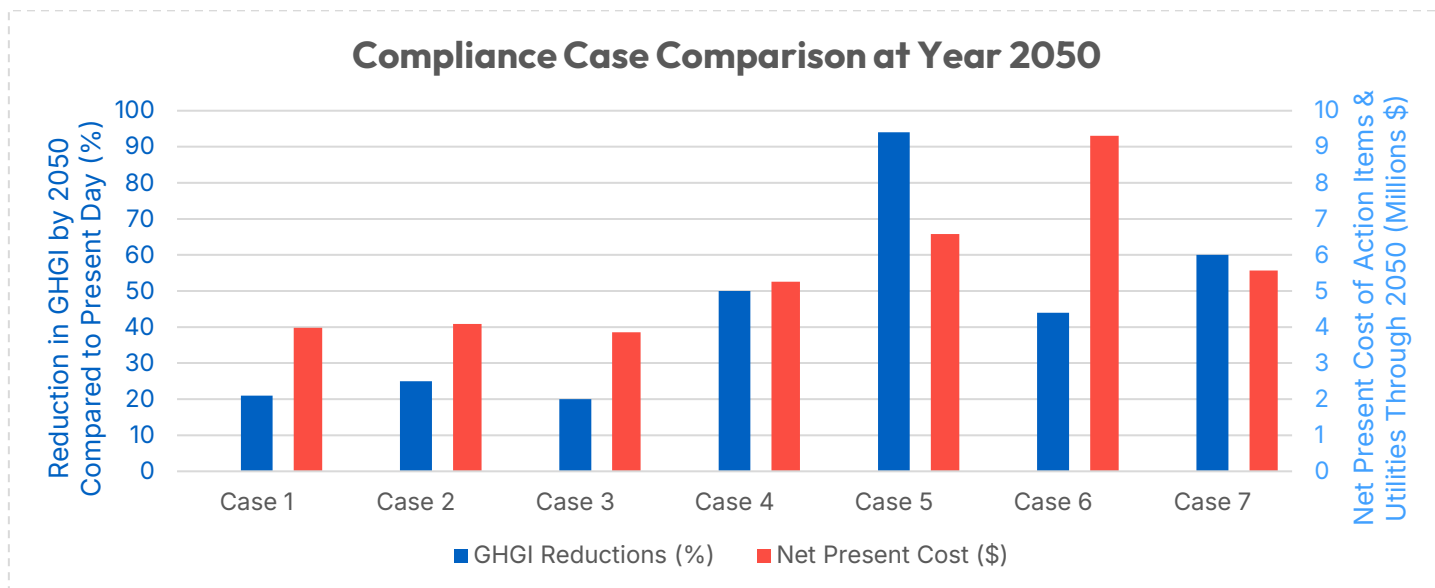


Figure 4: Compliance case comparison for GHGI and total cost of action items by 2050. See Appendix A for more detailed results and discussion.

Table 4 summarizes the basic outcomes of each case and why a building owner might choose each case.

Table 4: Case Study Outcomes		
Case #	Case Outcomes	Why an Owner Might Choose this Case
Case 1 (Baseline)	These cases rely on ACPs and RECs. Future shifts in ACP cost, utility pricing, policy changes, and extreme climate and/or electricity grid disruptions may affect building operations and costs.	The building owner may be unable to make improvements beyond immediate improvements. Further improvements may not be feasible due to capital costs or space limitations. The owner recognizes this decision will cause the building to operate inefficiently over time.
Case 2		
Case 3		
Case 4		
Case 5 and Case 7	Combining mechanical and building enclosure improvements creates a more efficient and integrated solution. These events significantly reduce energy use and emissions.	The upfront costs for mechanical and enclosure upgrades are offset by stable energy costs and lower long-term operating costs. Tenants are more comfortable in their spaces. The building owner recognizes these action items increase the building's long-term value.
Case 6	Improving only one system (the building enclosure) or neglecting heating and cooling (Case 7) offers limited long-term emissions reductions.	The building may have limited space or access for upgrades to all systems. The building owner chooses to use the BCCE and ACP to support long-term compliance.

Case Study Insights

- **Decarbonization Roadmap.** Each building required to comply with BERDO is different (in size, age, construction type, existing systems, tenant needs, etc.) and will require its own plan. Building owners may consider many possible action items for a single building. Developing building-specific decarbonization plans empowers owners to make informed decisions based on their building's needs, timeline, and financial context. This step is important to avoid one-size-fits-all solutions that may not deliver effective results.
- **Integrated Upgrades.** Combining building enclosure improvements and targeted mechanical upgrades minimizes the mechanical system sizing and capital costs while also reducing emissions. Improving enclosure airtightness also allows for more control over the indoor temperature, minimizes drafts, and enhances overall tenant comfort. Combining systems improvements can lead to the greatest reduction in GHGI.
- **Long-Term Outlook.** ACPs and RECs are financial options that may seem like simple routes to BERDO compliance, but they offer no improvements to building performance and energy efficiency, operational cost savings, or tenant comfort.
- **LED Upgrades.** These upgrades provide immediate energy savings, but they are a short-term solution. Other system changes are needed to further reduce energy consumption and achieve electrification. These upgrades also require tenant cooperation and buy-in.
- **Tenant Engagement.** Tenants may be key players in decarbonization plans. Some action items can increase tenant utility costs and cause upgrade-related disruption, while other actions may benefit tenants with reduced utility costs and improved comfort. Tenant buy-in of energy efficiency improvements can contribute to the success of a building's decarbonization plan, making tenant engagement and education important plan activities.

Additional Considerations

An Evolving Landscape

Utility/tax incentive programs and building codes may change over time. These changes could accelerate a building owner's need for electrification. These changes can also greatly impact the timing and selection of upgrades. A building decarbonization plan provides a guiding path but may need ongoing analysis and updates.

Flexibility Measures

This study did not consider flexibility measures for meeting BERDO compliance. Building owners may qualify for flexibility measures that adjust compliance limits or timelines. These adjustments are made based on eligibility, allowing for some flexibility in meeting the required standards.

Ongoing Maintenance

Regular commissioning reveals the true health of building systems and can guide better upgrade decisions. Preventive maintenance, unlike reactive fixes, can avoid costly failures and the risk of non-compliance. Building controls that are set appropriately also play an important role in reducing building energy use and emissions.

Hidden Costs

Strategic financial planning for retrofits is important for both BERDO compliance and cost management. Planning for potential hidden costs that can arise during retrofits (e.g., water damage, degraded framing) is especially important for older buildings.

Glossary

Alternative Compliance Payment (ACP)⁴: A compliance mechanism under BERDO. Owners have the option to pay ACPs to mitigate emissions from any type of energy or fuel use. The current cost of an ACP is \$234 per metric ton of CO₂e.

Boston Community Choice Electricity (BCCE)⁵: A [municipal aggregation program](#) that allows the City to secure electricity at a competitive rate on behalf of tenants, community members, and small business owners. The program aims to provide affordable and renewable electricity to Boston, ensuring that energy decisions are made locally and reflect the values of Boston's community.

Commissioning⁶: A quality-focused process for enhancing the delivery of a building project. This process verifies and documents that the building and its systems, controls, and building enclosure are planned, designed, installed, and tested, and includes operation and maintenance plans to meet specified requirements.

Energy Use Intensity (EUI)⁷: An expression of building energy use per year in terms of gross energy divided by gross floor area.

Greenhouse Gas Emissions⁸: A measure used to determine and compare the emissions of various greenhouse gases based on their global warming potential (GWP), including carbon dioxide equivalent (CO₂e) emissions from carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). The CO₂e emissions for a gas are calculated by multiplying the weight of the gas by its associated GWP.

Greenhouse Gas Intensity (GHGI): An expression of building GHG emissions per year measured as building GHG emissions divided by gross floor area.

Net Present Value (NPV): The difference between the present value of cash inflows and the present value of cash outflows over a period of time.

Renewable Energy Certificate (REC)⁴: An instrument that provides proof that one megawatt-hour (MWh) of electricity was generated from a renewable energy source and added to the electric power grid. Owners may use eligible RECs produced by non-emitting renewable energy sources to reduce or mitigate their emissions from electricity use.

End Notes

1. Information on Gas Supply and Delivery Charges. [https://www.mass.gov/info-details/information-on-gas-supply-and-delivery-charges#gas-supply-rate-information-\(gaf\)-](https://www.mass.gov/info-details/information-on-gas-supply-and-delivery-charges#gas-supply-rate-information-(gaf)-)
2. Electric Delivery Rates. <https://www.eversource.com/content/residential/account-billing/manage-bill/about-your-bill/rates-tariffs/electric-delivery-rates/egma>
3. BERDO Emissions Factors List. <https://docs.google.com/document/d/1blfWwuPSBevuTFo6T6iQkLYYlybWLdSjPa-JGKDnFeA/edit?tab=t.0#heading=h.1ydsr1ej197u>
4. BERDO Compliance Guide. <https://docs.google.com/document/d/19fewKPA4L0wNGvrr4I5tAZCCx2ODOeEBI09XaDvp9gA/edit?tab=t.0>
5. Boston Community Choice Electricity. <https://www.boston.gov/departments/environment/community-choice-electricity>
6. ANSI/ASHRAE/IES Standard 90.1-2022. (I-P). (n.d.). The American Society of Heating, Refrigerating and Air-Conditioning Engineers
7. ANSI/ASHRAE/IES Standard 100-2018. (n.d.). The American Society of Heating, Refrigerating and Air-Conditioning Engineers
8. ANSI/ASHRAE/IES Addendum k to ANSI/ASHRAE/IES Standard 100-2018 Energy Efficiency in Existing Buildings. November 30, 2023. The American Society of Heating, Refrigerating and Air-Conditioning Engineers

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Appendix A

Results Summary

Figure 5 and Figure 6 compare two key metrics for each compliance case:

- **Annual building GHGI.** Figure 5 shows how the trends in annual building GHGI for each case perform against BERDO-mandated emission limits through 2050.
- **Net Present Value (NPV).** Figure 6 shows an NPV analysis that compares the cumulative financial needs of each compliance case to the baseline (Case 1 Baseline) through compliance year 2050.

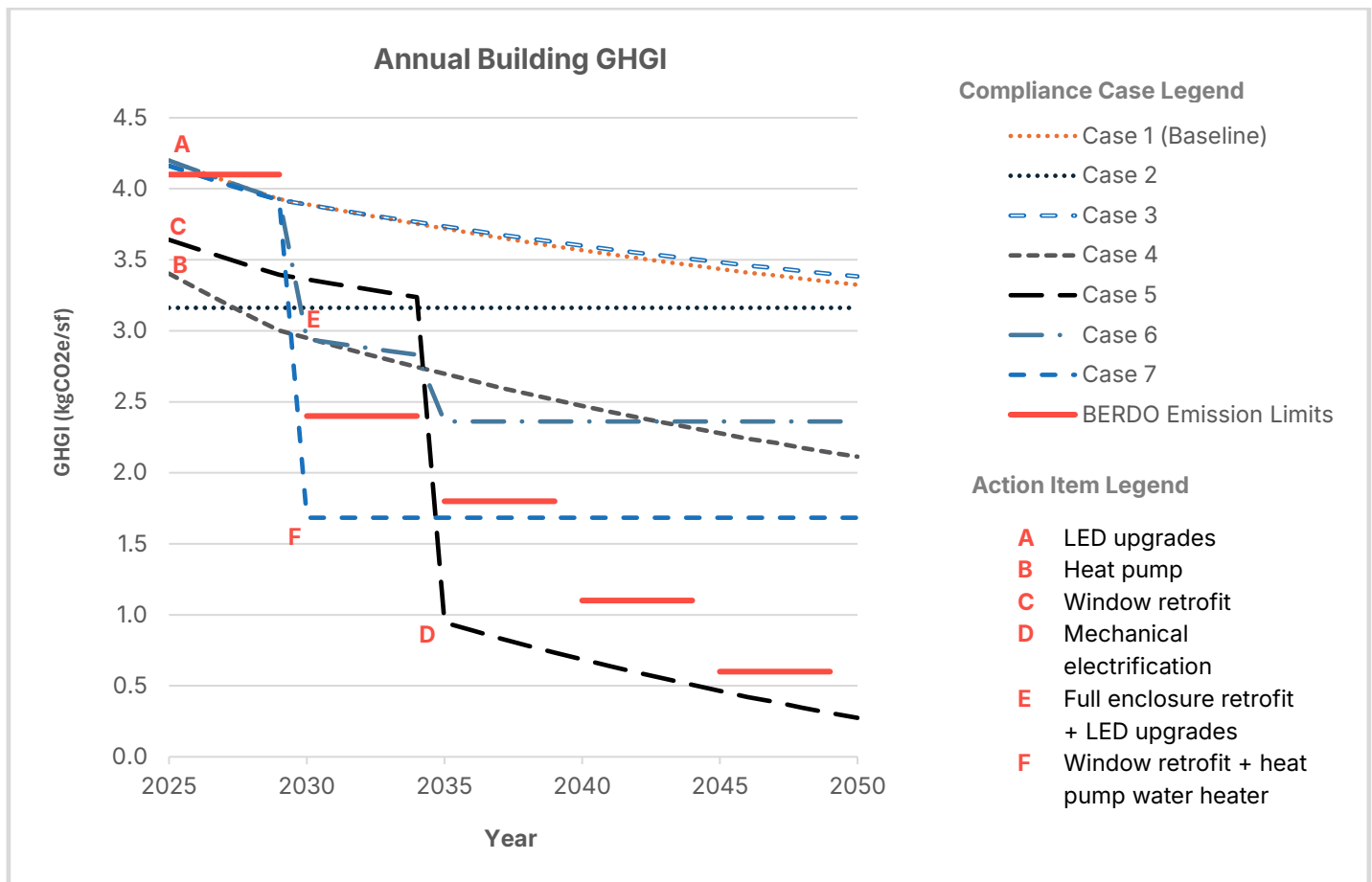


Figure 5: Building GHGI for each compliance case. Where each case's GHGI is greater than the BERDO emission limit, the emissions need to be mitigated by combining RECs and ACPs. The flat GHGI lines in Cases 2, 6, and 7 represent emissions from gas only; electricity emissions are zero due to enrollment in BCCE Green 100. The emissions factor for gas is assumed to be unchanged through 2050.

Modeling Approach and Assumptions

- Further information about this study may be obtained by contacting the City of Boston Environment Department at energyreporting@boston.gov or RDH Building Science Inc. at bos@rdh.com.

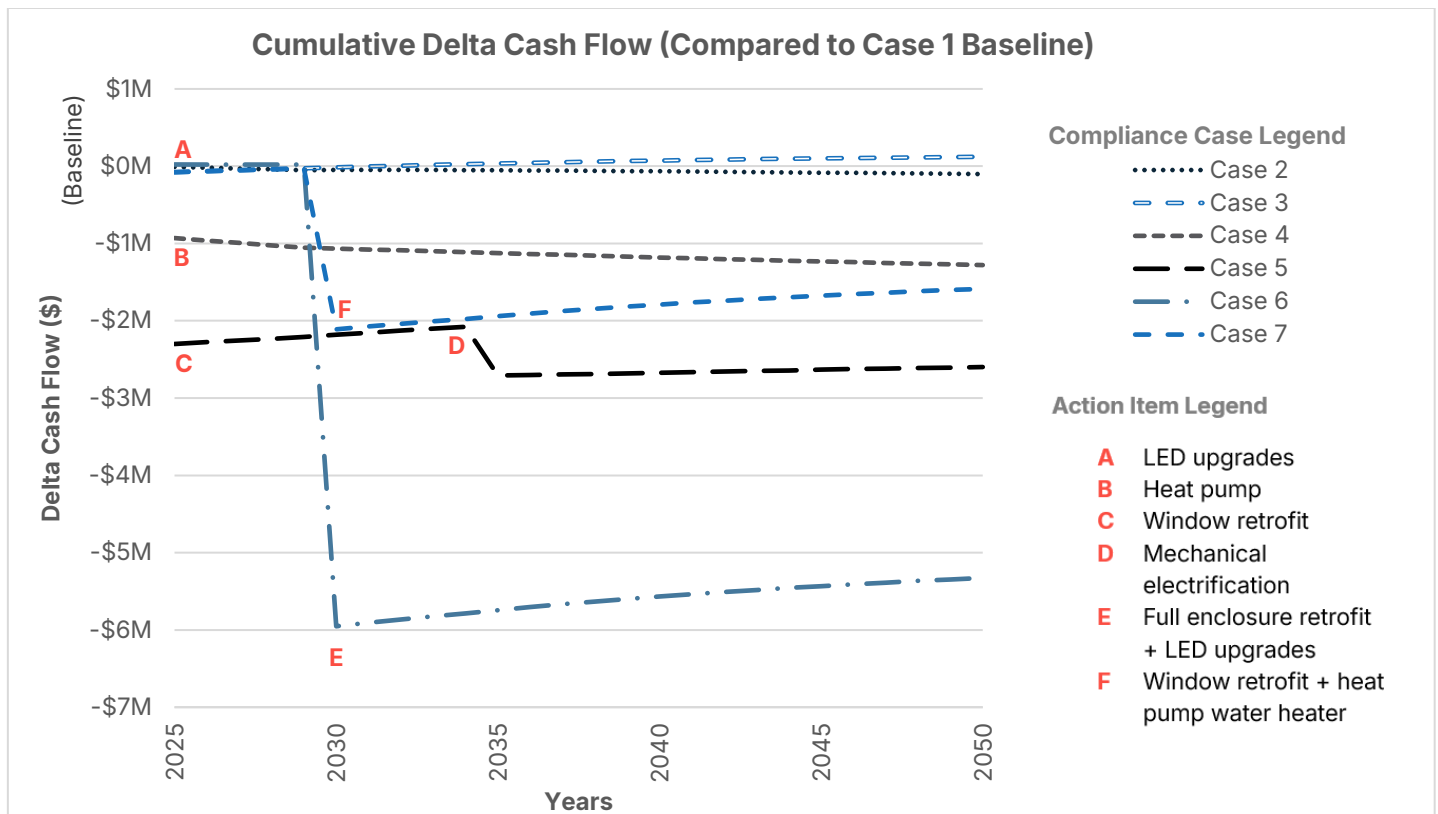


Figure 6: An NPV analysis showing cumulative delta cash flow for each compliance case compared to the baseline. Each case's total cost is shown relative to the Case 1 Baseline (\$0). These total costs reflect costs and savings due to operating expenses (e.g., utility costs), compliance costs (i.e., ACPs/RECs), and capital investments over time. Capital costs for each case are based on high-level estimates informed by the author's (RDH's) industry experience. These estimates represent a point-in-time perspective and should be considered preliminary. Actual costs may vary due to a variety of factors like fluctuations in labor and material rates, local market conditions, and inflation. As such, these figures provide a general sense of magnitude rather than definitive pricing and should be refined with project-specific costing and changes over time.

Discussion

The compliance cases for the example building revealed the following information.

Balancing energy efficiency, emissions reduction, and costs

- The simplest route to BERDO compliance appears to be ACPs and RECs, but they offer no improvements to building performance, building energy efficiency, or tenant comfort. Reliance on ACPs and RECs is purely a financial mechanism, as demonstrated in [Case 1](#), [Case 3](#), and [Case 4](#). In these cases, the building continues to operate inefficiently and remains vulnerable to future shifts in ACP and utility pricing, policy changes, and extreme climate and/or electricity grid disruptions.
- LED lighting upgrades are often considered an easy and low-cost solution for improving energy efficiency, but they aren't a long-term solution. In addition, the reduction in internal heat gains can slightly increase the heating demand in colder seasons, which can actually *increase* emissions. In [Case 3](#), their overall impact on emissions remains limited for two reasons: their ongoing reliance on gas-fired mechanical systems along with the slight increase in heating demand, and the expectation that the electricity grid will only gradually decarbonize through 2050. While LED upgrades offer immediate energy savings, their long-term effectiveness in reducing building-wide emissions is limited unless changes are made to other building systems.

- In **Case 3**, mitigating emissions beyond 2030 with RECs and ACPs is a relatively cost-effective solution (a positive NPV) compared to **Cases 4, 5, 6, and 7**. These cases include substantial capital investments in mechanical and enclosure upgrades. This is partially due to the relatively low cost of natural gas and a disproportionately higher cost of electricity (per unit energy) in Boston. The findings in **Case 3** also offer a “split incentive” where building owners carry the capital cost of the lighting upgrades while tenants capture the associated utility cost savings in their utility bills.
- **Case 4** and **Case 6** demonstrate that when specific upgrades, such as electrifying heating systems or implementing enclosure improvements, are pursued independently, they offer limited long-term emission reduction. The switch from a gas boiler to an electric heat pump in **Case 4** yields a 19% reduction in EUI but continues to rely on natural gas for DHW, which limits the long-term compliance benefits. Similarly, **Case 6** focuses solely on enclosure upgrades, incurring high capital costs but low GHGI impact due to unchanged fossil fuel systems.
- Bundling mechanical upgrades with building enclosure improvements (**Case 5** and **Case 7**) creates a more efficient and integrated solution. Increasing the building’s airtightness through enclosure upgrades and improving mechanical systems simultaneously significantly reduces energy consumption and emissions. Over time, the upfront costs of these upgrades are offset by stable energy expenses and lower long-term operating costs. This integrated approach also avoids oversizing new mechanical systems (which can be costly and inefficient), improves the building’s resilience to extreme outdoor temperatures, and improves indoor air quality and thermal comfort.
- Substantial enclosure retrofits and electrification require significant upfront financial investments (**Cases 5, 6, and 7**). Proactively identifying and securing incentives and financing options early in the planning process, such as tax credits or [Mass Save®](#) programs, can improve the NPV of projects. Incentives were not included in the analysis of the compliance cases.

Recognizing the role tenants play

- Tenant engagement is critical in upgrades like LED lighting, especially in apartment buildings (**Case 3** and **Case 6**). Depending on property type, LED uptake in dwelling units can be challenging since it requires tenant buy-in and commitment to install LEDs. Similar challenges can arise with window replacements (**Cases 5, 6, and 7**) and mechanical system upgrades (**Cases 4, 5, and 7**), where access to units, installation disruption, and operational changes depend on tenant cooperation and benefit from clear communication.
- Similarly, BCCE enables compliance as seen in **Case 2**, but it does not reduce energy use. In fact, tenants may face higher utility bills due to premium electricity rates. BCCE is best leveraged as a complementary strategy when paired with physical upgrades, as in **Case 6** and **Case 7**, to reduce overall consumption and minimize passing the cost burdens onto tenants.

Upgrading systems for energy efficiency and emissions reduction

- Window design trade-offs (**Cases 5, 6, and 7**) were analyzed (but not reported), including both low and high solar heat gain coefficient (SHGC) options. Higher SHGC supported better compliance performance, although the ideal choice may vary by project.
- Cases that implemented some element of mechanical system electrification (**Cases 4, 5, and 7**) also assume that locating such a system is possible in the building itself or elsewhere on the property. In the latter situation, it was assumed that the added noise from condensing units had been adequately discussed with city officials and/or neighborhood stakeholders.

On-site solar (photovoltaic or PV) systems were not included in this analysis, but PV presents an opportunity to reduce grid dependency further and improve compliance. Roof-mounted PV systems will have a proportionally smaller overall impact on electric emissions mitigation as the number of building stories increases, given that the roof area represents a smaller overall percentage of the building’s gross floor area.