



Zero Over Time Report

Mid-Rise Multifamily Example

BERDO ID XXXXXX

Building Decarbonization Advisor Program
Boston, MA

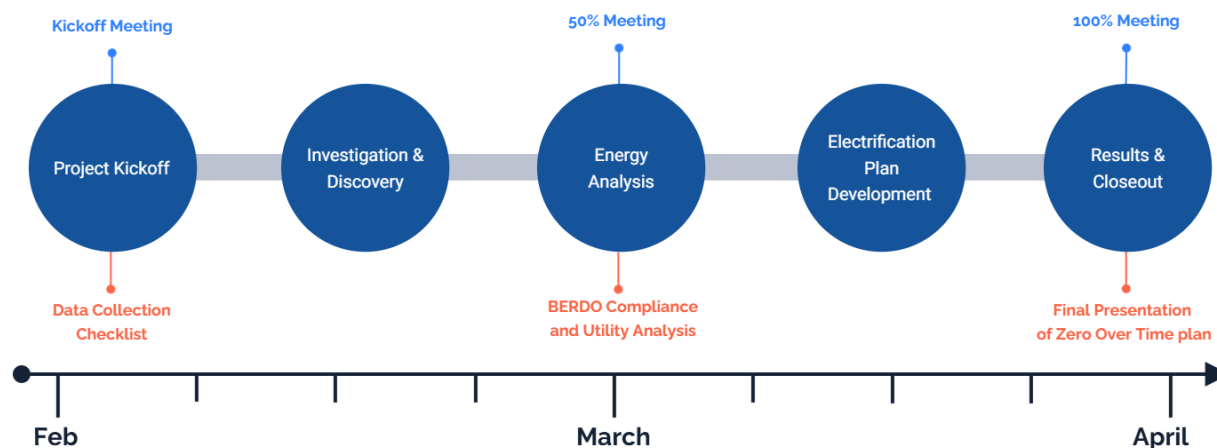
1. Project Scope and Overview

The primary objective of this study is to create a Zero Over Time (ZOT) plan to help with long-term compliance with Boston's Building Emissions Reduction and Disclosure Ordinance (BERDO). JB&B worked with the City of Boston as a Technical Advisor to provide this study as part of the Building Decarbonization Advisor Program.

The goals of this decarbonization study were fourfold:

- Create a plan for building electrification to help with long-term BERDO compliance.
- Evaluate utility data and BERDO compliance.
- Review building systems and develop one (1) electrification pathway for major HVAC and DHW equipment.
- Present the phased electrification solution in the form of a Zero Over Time (ZOT) plan.

Figure 1. JB&B's Project Approach



2. Current Building Overview

MID-RISE MULTIFAMILY EXAMPLE (BERDO ID XXXXXX) is a seven (7)-story multifamily residential building containing seventy-five (75) Residential Units spanning 50,000 gsf and including 7,000 gsf of Ground Floor retail space. The building consists of brick masonry with minimal insulation, double-pane punched windows and a rubber roof with minimal insulation. Space heating for the building is served by



gas-fired steam boilers via radiators and domestic hot water (DHW) is provided by tankless gas water heaters. The building does not provide cooling, but some Tenants (estimated 50%) have installed their own window A/C units. Each Residential Unit is currently equipped with a gas stove for cooking. See Table 1 for details.

Table 1. Building Systems Overview – MID-RISE MULTIFAMILY EXAMPLE

	Current State
Summary	Gas boilers for space heating, tenant A/C units, Gas water heaters for DHW
Space Heating	Gas-Fired Steam Boilers
Space Cooling	Tenant A/C
DHW	Tankless Gas Water Heaters
Cooking	Electric Stove
Windows	Double-Paned
Walls	Unknown
Roof	Rubber Roof

2.1. Recent and Planned Upgrades

The property has ongoing maintenance and upgrade plans to enhance energy efficiency, reduce emissions and improve overall building performance.

In 2020, the building also installed more efficient tankless gas water heaters for DHW, which has been factored into our analysis below.

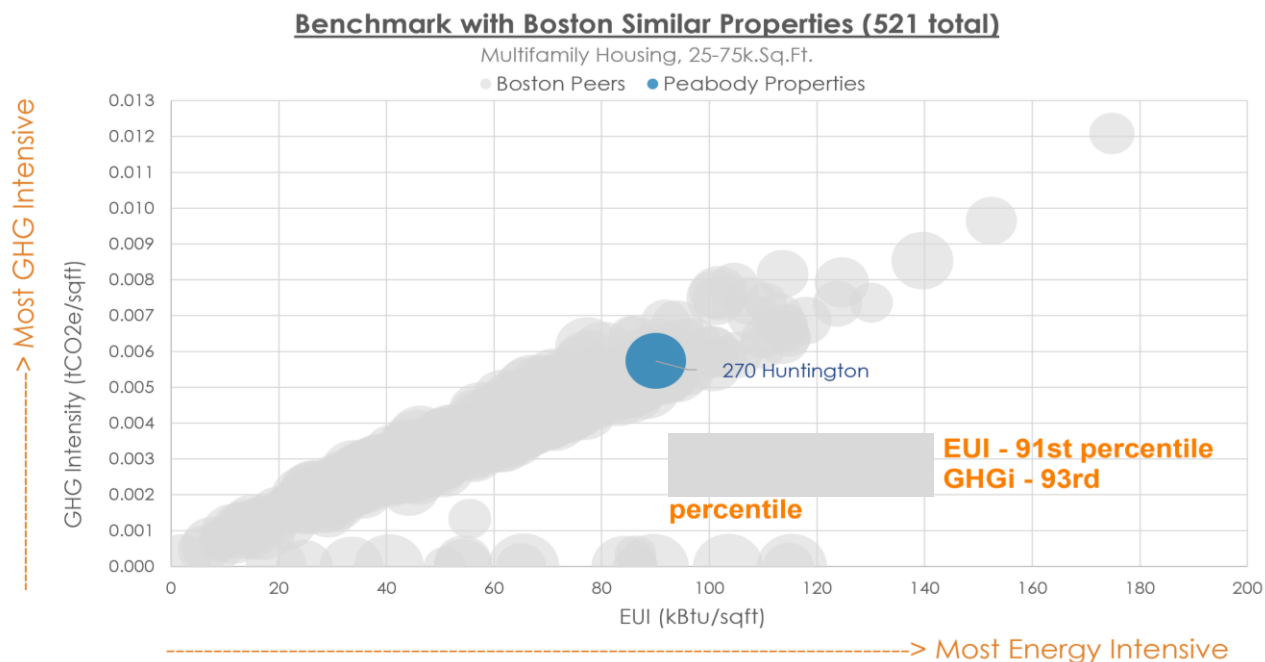
3. Benchmarking and Utility Review

3.1. Benchmarking

To better understand the current energy use and carbon emissions intensity of the building compared to other buildings in Boston, a benchmarking exercise was conducted using data from similar multifamily residential buildings between 25,000 and 75,000 sq.ft. These buildings have reported their energy and emissions data to the City of Boston for BERDO compliance. The results in Figure 2 below show that MID-RISE MULTIFAMILY EXAMPLE (BERDO ID XXXXXX) ranks in the 91st percentile for energy consumption and the 93rd percentile for carbon emissions intensity (GHG Intensity). This means the building uses more energy than 91% and emits more carbon than 93% of the multifamily buildings of similar size that reported their 2023 data to BERDO. To mitigate the impacts of BERDO compliance, significant improvements in energy efficiency, electrification and building envelope are necessary.



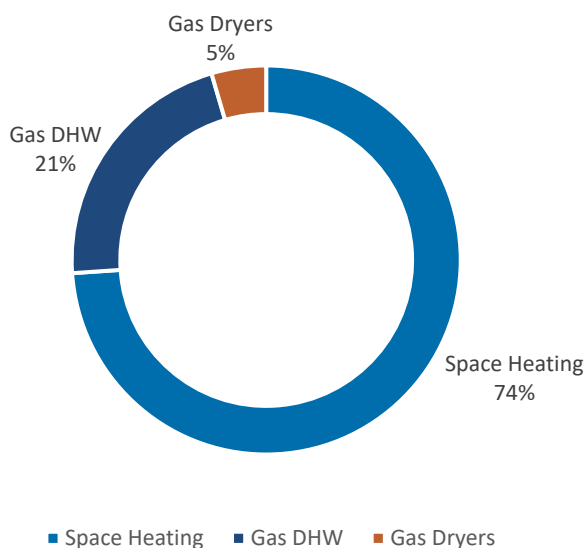
Figure 2. Boston Energy and Carbon Benchmarking – MID-RISE MULTIFAMILY EXAMPLE



3.2. Utility Review

The JB&B team conducted a utility review to determine how much electricity and fossil fuel the building consumes to better understand its energy use patterns and find opportunities to electrify building systems. JB&B focused especially on natural gas used for heating, hot water and cooking. The chart below shows how gas is used in the building with most of it being used for space heating. Therefore, replacing the current gas-fired space heating system with an electric space heating system should be the top priority to cut down on building emissions.

Figure 3. Fossil Fuel Consumption End Use Breakdown – MID-RISE MULTIFAMILY EXAMPLE



4. BERDO Overview

BERDO is a local law that aims to reduce air pollution and greenhouse gas emissions generated by large buildings in Boston. Owners of buildings subject to BERDO are required to report their buildings' annual energy and water consumption. Starting in either 2025 or 2030, they will also need to comply with building emissions standards (limits). The emissions standards set by BERDO decrease over time, with all buildings expected to reach net-zero emissions by 2050.

Beginning in 2025, Owners of commercial and multifamily residential buildings larger than 35,000 sq.ft. or thirty-five (35) Residential Units are required to meet the BERDO emissions standards set for their building's primary use type. Building Owners must submit annual reporting of energy consumption, water consumption and carbon emissions using Energy Star Portfolio Manager (ESPM) and the BERDO reporting form by May 15, of each year. See Table 1 below for BERDO's multifamily building emission caps over time.

Table 2. BERDO Emissions Standards for Multifamily Housing (kg CO₂e/sq.ft./yr)

Primary Use Type	BERDO Emissions Standards (kg CO ₂ e/sq.ft./yr)					
	2025 - 2029	2030 - 2034	2035 - 2039	2040 - 2044	2045 - 2049	2050+
Multifamily Housing	4.1	2.4	1.8	1.1	0.6	0
Retail	7.1	3.4	2.4	1.5	0.7	0

Per the BERDO Emission Compliance Guide, there are three (3) options to keep your building's emissions under its limit and in compliance. These approaches are also called compliance mechanisms.

- **Reduce Energy Use in Your Building:** The most impactful approach you can take is to reduce your building's overall direct emissions through building retrofits or improvements. This includes:
 - Upgrading to high efficiency electric appliances
 - Replacing fossil fuels with electricity for heating and cooling systems
 - Improving insulation
 - Tightening window seals
 - Adding energy-efficient lighting such as LED bulbs
- **Obtain Renewable Energy: Reduce your building emissions from electricity with eligible renewable energy. Renewable energy can only be used to reduce emissions from electricity.**
 - **Boston Community Choice Electricity (BCCE):** Sign up for the Green 100 plan through the City of Boston's CCE program to receive 100% renewable electricity. Commercial and industrial accounts cannot exceed 1.5 million kWh/yr to be eligible.
 - **Solar Energy:** Solar generated on-site or anywhere in Boston can be used for compliance. If you are buying solar energy, or related energy credits, from a project outside of Boston, please reach out to the BERDO team to confirm its eligibility.
 - **Renewable Energy Certificates (RECs):** MA Class I RECs certify that the electricity was created using non-emitting renewable energy generated in New England.
 - **Power Purchase Agreements (PPA):** A PPA is a long-term contract to buy renewable energy. BERDO has specific requirements for PPAs.
- **Invest in Your Community's Decarbonization:** You can comply with emissions standards and mitigate your emissions from fossil fuel and electricity use by making an Alternative Compliance Payment (ACP). ACPs go into the new Equitable Emissions Investment Fund, which will fund future decarbonization projects in Boston's environmental justice communities. ACPs are payments of \$234 for every metric ton of CO₂e a building is above its emissions limit. ACPs can be made annually to



keep your building in compliance. Please note, ACPs are not the same as fines. An ACP is considered a compliance mechanism under BERDO.”¹

Buildings may be eligible for Flexibility Measures that adjust its emissions limits and pathway to net-zero emissions. Per the BERDO Flexibility Measures Guide², most options require approval from the BERDO Review Board and include the following:

- **Blended Emissions Standard:** Use a Blended Emissions Standard that takes into account the mix of primary uses present in your building(s). This allows you to have an emissions standard that is based on the size of different primary uses and may increase your emissions limit.
 - **When to Use:** If you have buildings with multiple primary uses
 - **Application Deadline:** Opt-in or opt-out during a verification year
- **Building Portfolio:** Group your BERDO buildings into a Building Portfolio and comply with a portfolio-level Blended Emissions Standard. Reducing emissions as a portfolio rather than building-by-building allows you to align your capital planning with BERDO compliance and gives you more flexibility to achieve emissions reductions over time
 - **When to Use:** If you have more than one BERDO building
 - **Application Deadline:** September 1*
- **Individual Compliance Schedule:** Create a customized emissions reduction timeline based on your own historical emissions. An Individual Compliance Schedule allows you to take advantage of emissions reductions that you have achieved prior to 2021 and adjust your emissions obligations based on your building operations.
 - **When to Use:** If you have been tracking and reducing building emissions for several years
 - **Application Deadline:** September 1*
- **Hardship Compliance Plans:** Demonstrate eligible technical or financial hardships for you or your building(s) and request an alternative emissions reduction timeline and/or more flexible emissions reduction targets.
 - **When to Use:** If your compliance is extraordinarily difficult for your building(s)
 - **Application Deadline:** Long-term Hardship July 1*; Short-term Hardship October 1*.

**Property owners are able to apply for the above BERDO Flexibility Measures on an annual basis for future filing years. Any modifications to deadlines are published by BERDO at the beginning of each filing year.*

For the purposes of this analysis, Alternative Compliance Payments (ACPs) were modeled at \$234/tCO₂e of excess emissions per the BERDO guidance, and renewable energy credit (REC) costs representing MA Class I RECs were modeled to be constant through 2050 at \$43/MWh electricity based on current market pricing.

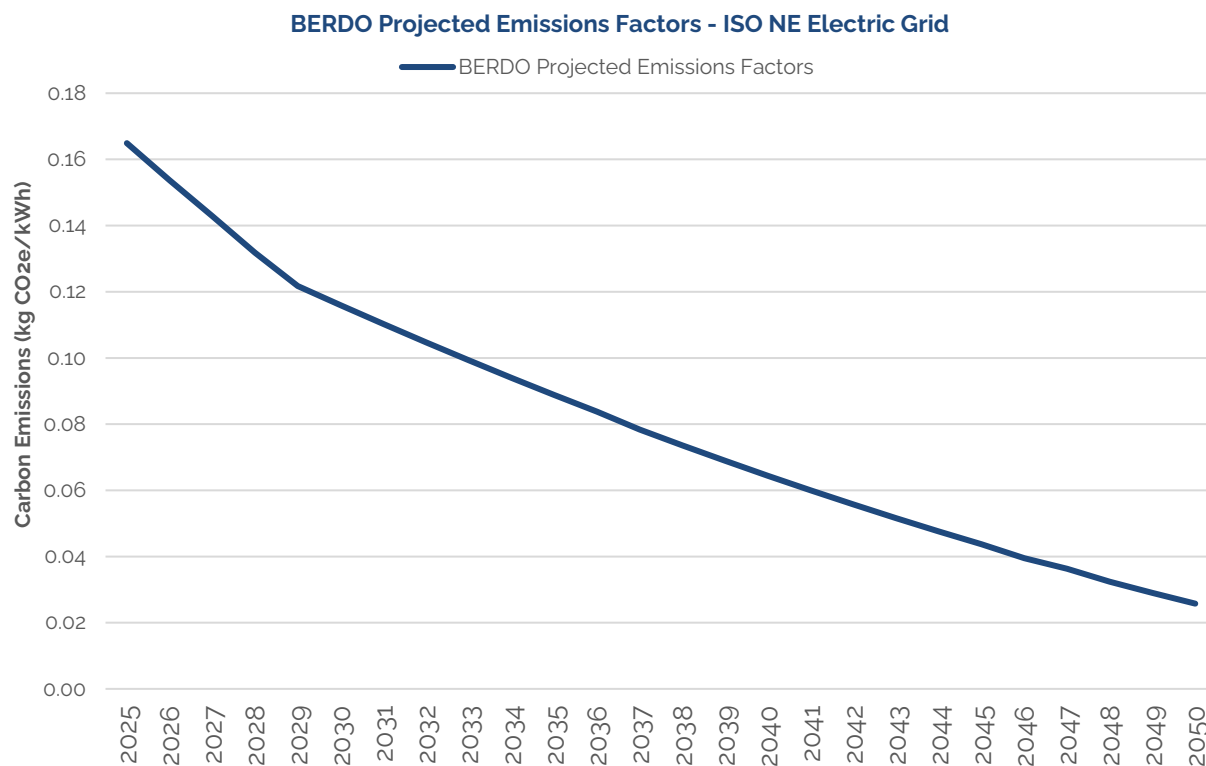
In addition to the energy-saving measures suggested for implementation in this report, buildings can take advantage of the decarbonization of the electrical grid. The grid decarbonization scenario used in this analysis is based on emissions factors published by the City of Boston alongside BERDO as of April 11, 2025, and is displayed in Figure 4 below.

¹ City of Boston. “How To Comply With Your Berdo Emissions Standard.” Report, 2021. https://www.boston.gov/sites/default/files/berdo/BERDO_EmissionsCompliance.pdf.

² City of Boston. “Flexibility Measures Under BERDO,” n.d. https://www.boston.gov/sites/default/files/berdo/BERDO_FlexibilityMeasures.pdf.



Figure 4. BERDO Projected ISO NE Grid Emissions (2025-2050)



5. Building Compliance Outlook

MID-RISE MULTIFAMILY EXAMPLE (BERDO ID XXXXXX) is expected to exceed its emissions limits set by BERDO beginning in 2025. As can be seen in Figure 5 below, the building's emissions are largely driven by gas consumption. As the grid decarbonizes, emissions associated with electricity are projected to diminish over time, while emissions associated with gas stay constant through 2050.

Starting in 2025, the building is projected to incur escalating compliance costs, with average annual compliance payments of \$2,148 between 2025 and 2029, \$23,941 between 2030 and 2034, \$30,236 between 2035 and 2039, \$37,694 between 2040 and 2044, \$43,035 between 2045 and 2049, and \$49,963 starting in 2050. Figure 5 below shows building emissions in relation to BERDO emission limits over time, and Tables 3 and 4 below summarize compliance status as well as ACP and REC compliance costs between 2025 and 2050 per two (2) payment pathways. The ACP Pathway uses ACPs to mitigate all emission overages and reach compliance. The REC + ACP Combined Pathway maximizes the amount of RECs that can be purchased based on MID-RISE MULTIFAMILY EXAMPLE's electricity consumption and then mitigates all remaining emissions using ACPs.



Figure 5. Projected BERDO Compliance with Utility Breakdown – MID-RISE MULTIFAMILY EXAMPLE

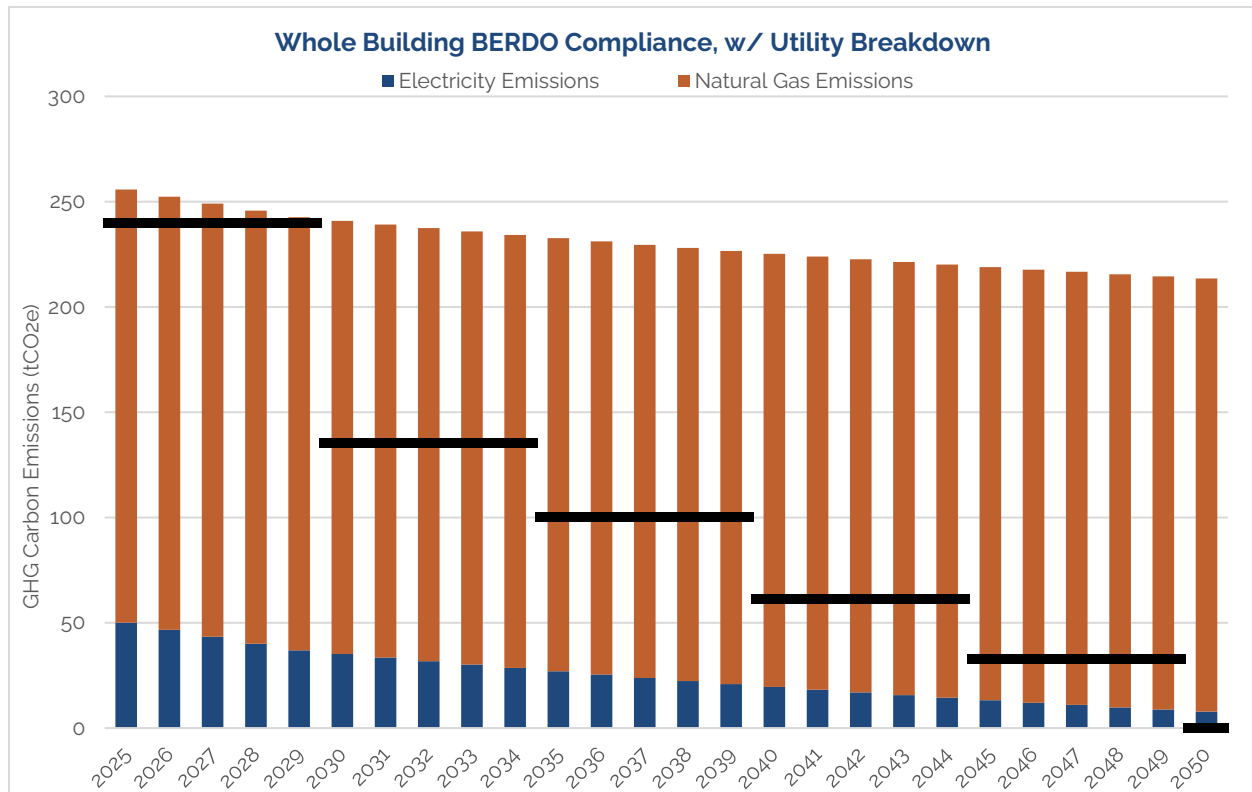


Table 3. Current BERDO Compliance, annual estimated ACP and REC Costs – MID-RISE MULTIFAMILY EXAMPLE

Reporting Period	Compliance Status	Average % Reduction Required for Compliance	ACP Pathway*	REC + ACP Combined Pathway**	
			Average Annual ACP Costs (No RECs)	Average Annual ACP Costs (With RECs)	Average Annual REC Costs
2025 - 2029	Non-Compliant	4%	\$2,148	\$0	\$2,396
2030 - 2034	Non-Compliant	43%	\$23,941	\$16,491	\$11,845
2035 - 2039	Non-Compliant	56%	\$30,236	\$24,645	\$11,845
2040 - 2044	Non-Compliant	72%	\$37,694	\$33,725	\$11,845
2045 - 2049	Non-Compliant	85%	\$43,035	\$40,465	\$11,845
2050+	Non-Compliant	100%	\$49,963	\$48,132	\$11,845
2025 - 2050 Cumulative Costs			\$735,236	\$624,760	\$260,723

*Alternative Compliance Payment (ACP): \$234/MT CO₂e

**MA Class I Renewable Energy Credits (RECs) at \$43/MWh are procured for all electricity consumption associated with excess emissions, and remaining fossil fuel emissions are offset using ACPs



Table 4. Current annual cost estimates, ACPs and RECs – MID-RISE MULTIFAMILY EXAMPLE

Year	ACP Pathway	REC + ACP Combined Pathway	
	ACP Costs (No RECs)	ACP Costs (With RECs)	REC Costs
	\$/Yr	\$/Yr	\$/Yr
2025	\$3,705	\$0	\$3,745
2026	\$2,907	\$0	\$3,154
2027	\$2,137	\$0	\$2,494
2028	\$1,353	\$0	\$1,711
2029	\$638	\$0	\$874
2030	\$24,730	\$16,491	\$11,845
2031	\$24,326	\$16,491	\$11,845
2032	\$23,932	\$16,491	\$11,845
2033	\$23,546	\$16,491	\$11,845
2034	\$23,170	\$16,491	\$11,845
2035	\$30,955	\$24,645	\$11,845
2036	\$30,597	\$24,645	\$11,845
2037	\$30,213	\$24,645	\$11,845
2038	\$29,874	\$24,645	\$11,845
2039	\$29,543	\$24,645	\$11,845
2040	\$38,301	\$33,725	\$11,845
2041	\$37,989	\$33,725	\$11,845
2042	\$37,685	\$33,725	\$11,845
2043	\$37,391	\$33,725	\$11,845
2044	\$37,105	\$33,725	\$11,845
2045	\$43,569	\$40,465	\$11,845
2046	\$43,273	\$40,465	\$11,845
2047	\$43,043	\$40,465	\$11,845
2048	\$42,766	\$40,465	\$11,845
2049	\$42,526	\$40,465	\$11,845
2050+	\$49,963	\$48,132	\$11,845
TOTAL	\$735,236	\$624,760	\$260,723

*Alternative Compliance Payment (ACP): \$234/MT CO₂e

**MA Class I Renewable Energy Credits (RECs) at \$43/MWh are procured for all electricity consumption associated with excess emissions, and remaining fossil fuel emissions are offset using ACPs

As can be seen in Tables 3 and 4, it is projected that the ACP Pathway will be the most cost-effective method of compliance each year until 2050 based on 2023 energy consumption data. ACPs necessary to bring MID-RISE MULTIFAMILY EXAMPLE (BERDO ID XXXXXX) into compliance through 2050 per the ACP Pathway are estimated to total \$735,236, and the cost of RECs and ACPs per the REC + ACP Combined Pathway to cover the same emissions limit overages are estimated to total \$885,483.

6. Zero Over Time Electrification Scenario

In order to reduce the impact of BERDO on MID-RISE MULTIFAMILY EXAMPLE (BERDO ID XXXXXX) over time, it will be vital that energy-efficiency and carbon-reduction measures begin to be implemented on site as soon as possible. Due to the nature of BERDO, buildings that are not in compliance will be expected to make payments to the city in the form of ACPs, but these payments do not improve the state of the building or aid in achieving future compliance.



A decarbonization scenario described in Table 5 below has been prepared in order to guide ongoing efforts to reduce the emissions associated with the building. This scenario includes replacing the current gas-fired steam boiler used for space heating with in-unit packaged terminal heat pumps; replacing the gas-fired water heaters used for domestic hot water with electric water heaters and storage tanks; replacing double-paned windows with triple-paned windows; and adding additional insulation to the envelope where feasible. In the case of MID-RISE MULTIFAMILY EXAMPLE (BERDO ID XXXXXX), it is recommended that insulation of exterior walls be carried out alongside installation of the packaged terminal heat pumps.

Table 5. Zero-Over-Time Electrification Scenario Summary – MID-RISE MULTIFAMILY EXAMPLE

	Current State	Electrification
Summary	Gas boilers for space heating, tenant A/C units, Gas water heaters for DHW	Packaged window HPs for heating and cooling Central DHW Electric Water Heater with Storage Tank
Space Heating	Gas-Fired Steam Boilers	150 Packaged Terminal Heat Pumps (window-mount)
Space Cooling	Tenant A/C	
DHW	Tankless Gas Water Heaters	Electric Water Heater with Storage Tank
Cooking	Electric Stove	Electric Stove
Windows	Double-Paned	Triple-Paned
Walls	Unknown	Add insulation as feasible
Roof	Rubber Roof	Add insulation as feasible

In addition to the recommendations made above, it will likely be necessary to upgrade electrical service to the building and electrical panels within each unit to 220V to accommodate the additional electrical load required. Electrical upgrades will need to be coordinated with each electrification project for space heating, domestic hot water and cooking equipment.

The tables and graphs below represent MID-RISE MULTIFAMILY EXAMPLE's (BERDO ID XXXXXX) BERDO compliance implementing the proposed decarbonization scenario. Because the building is expected to be non-compliant in 2025, the sooner the buildings can implement the measures discussed above, the better the properties will fare in terms of BERDO compliance.

Following the proposed decarbonization scenario and ZOT timeline below, MID-RISE MULTIFAMILY EXAMPLE (BERDO ID XXXXXX) is projected to remain in compliance between 2026 and 2045, at which point a small amount of excess emissions will need to be mitigated in 2045 before immediately moving back into compliance due to decarbonization of the electrical grid. The building will comply once again for four years until 2050. In 2050, BERDO emissions limits will be reduced to zero, meaning that any residual emissions which are not reduced using renewable energy will need to be mitigated using RECs or ACPs. MID-RISE MULTIFAMILY EXAMPLE (BERDO ID XXXXXX) is expected to emit 20 tons of carbon each year beginning in 2050, which is estimated to cost \$4,784 annually per the ACP Pathway or \$30,956 annually per the REC + ACP Combined Pathway to bring the building into compliance.



Figure 5. Zero-Over-Time Electrification Plan for BERDO Compliance – MID-RISE MULTIFAMILY EXAMPLE

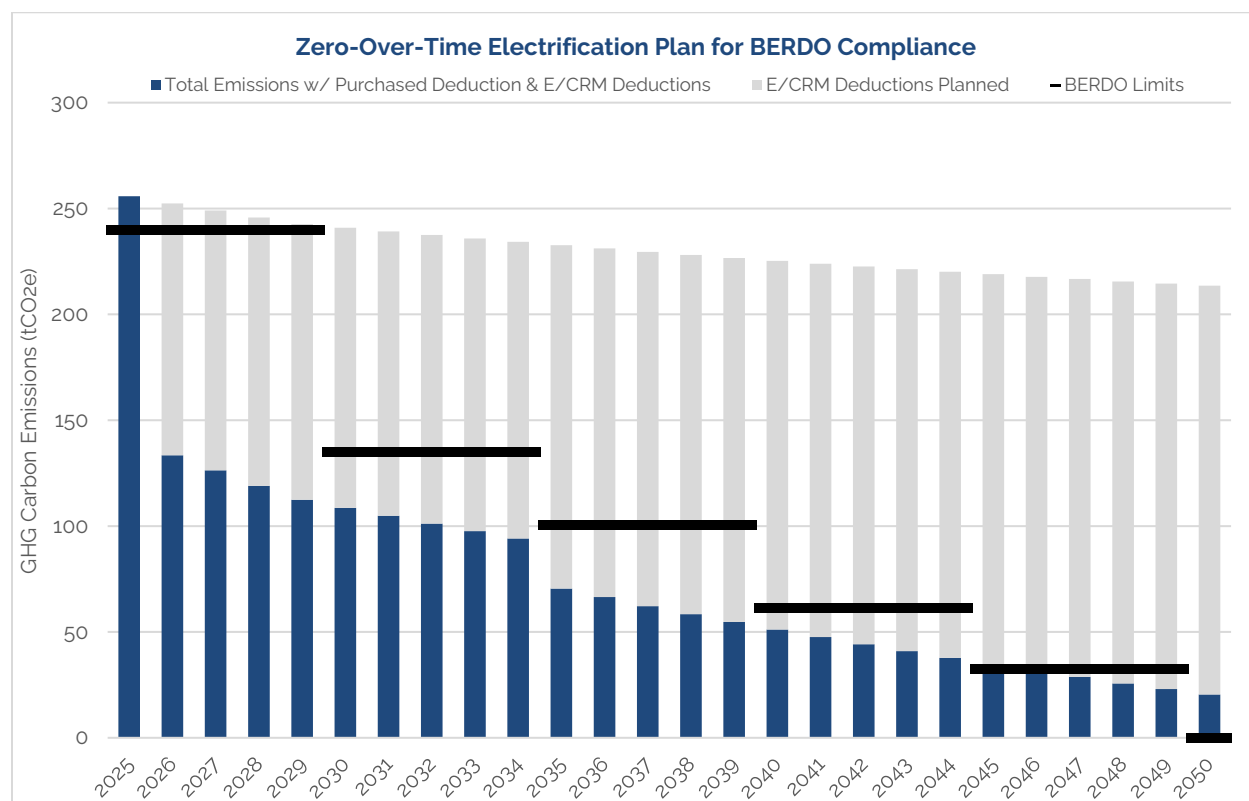


Table 6. Zero Over Time Electrification Plan for BERDO Compliance, annual estimated ACP and REC costs – MID-RISE MULTIFAMILY EXAMPLE

Reporting Period	Compliance Status	Average % Reduction Required for Compliance	ACP Pathway*	REC + ACP Combined Pathway**	
			Average Annual ACP Costs (No RECs)	Average Annual ACP Costs (With RECs)	Average Annual REC Costs
2025 - 2029	Partially Compliant	4%	\$741	\$0	\$749
2030 - 2034	Compliant	43%	\$0	\$0	\$0
2035 - 2039	Compliant	56%	\$0	\$0	\$0
2040 - 2044	Compliant	72%	\$0	\$0	\$0
2045 - 2049	Partially Compliant	85%	\$89	\$0	\$339
2050+	Non-Compliant	100%	\$4,784	\$0	\$30,956
2025 - 2050 Cumulative Costs			\$8,934	\$0	\$36,398

*Alternative Compliance Payment (ACP): \$234/MT CO₂e

**MA Class I Renewable Energy Credits (RECs) at \$43/MWh are procured for all electricity consumption associated with excess emissions, and remaining fossil fuel emissions are offset using ACPs



Table 7. Zero Over Time Electrification Plan for BERDO Compliance, Annual estimated ACP and REC costs – MID-RISE MULTIFAMILY EXAMPLE

Year	ACP Pathway*	REC + ACP Combined Pathway**	
	ACP Costs (No RECs)	ACP Costs (with RECs)	REC Costs
	\$/Yr	\$/Yr	\$/Yr
2025	\$3,705	\$0	\$3,745
2026	\$0	\$0	\$0
2027	\$0	\$0	\$0
2028	\$0	\$0	\$0
2029	\$0	\$0	\$0
2030	\$0	\$0	\$0
2031	\$0	\$0	\$0
2032	\$0	\$0	\$0
2033	\$0	\$0	\$0
2034	\$0	\$0	\$0
2035	\$0	\$0	\$0
2036	\$0	\$0	\$0
2037	\$0	\$0	\$0
2038	\$0	\$0	\$0
2039	\$0	\$0	\$0
2040	\$0	\$0	\$0
2041	\$0	\$0	\$0
2042	\$0	\$0	\$0
2043	\$0	\$0	\$0
2044	\$0	\$0	\$0
2045	\$444	\$0	\$1,696
2046	\$0	\$0	\$0
2047	\$0	\$0	\$0
2048	\$0	\$0	\$0
2049	\$0	\$0	\$0
2050+	\$4,784	\$0	\$30,956
TOTAL	\$8,934	\$0	\$36,398

*Alternative Compliance Payment (ACP): \$234/MT CO₂e

**MA Class I Renewable Energy Credits (RECs) at \$43/MWh are procured for all electricity consumption associated with excess emissions, and remaining fossil-fuel emissions are offset using ACPs

7. Zero Over Time Plan

Due to the property's current status exceeding its BERDO emissions limit starting in 2025, we recommend that building management begin implementation of the decarbonization and electrification measures discussed in the section above as soon as feasible to minimize the compliance payments required. Given the current standing of the building, we recommend the following timeline for implementation of our electrification option discussed above:

- 2025 - Upgrading electrical service to the building for future electrical service increases needed for HVAC and DHW electrification
- 2026 - Replacement of current gas-fired boiler with 150 packaged terminal heat pumps (one [1] per Bedroom and one [1] per Living Room); consider installation of exterior wall overclad insulation for brick masonry exterior walls



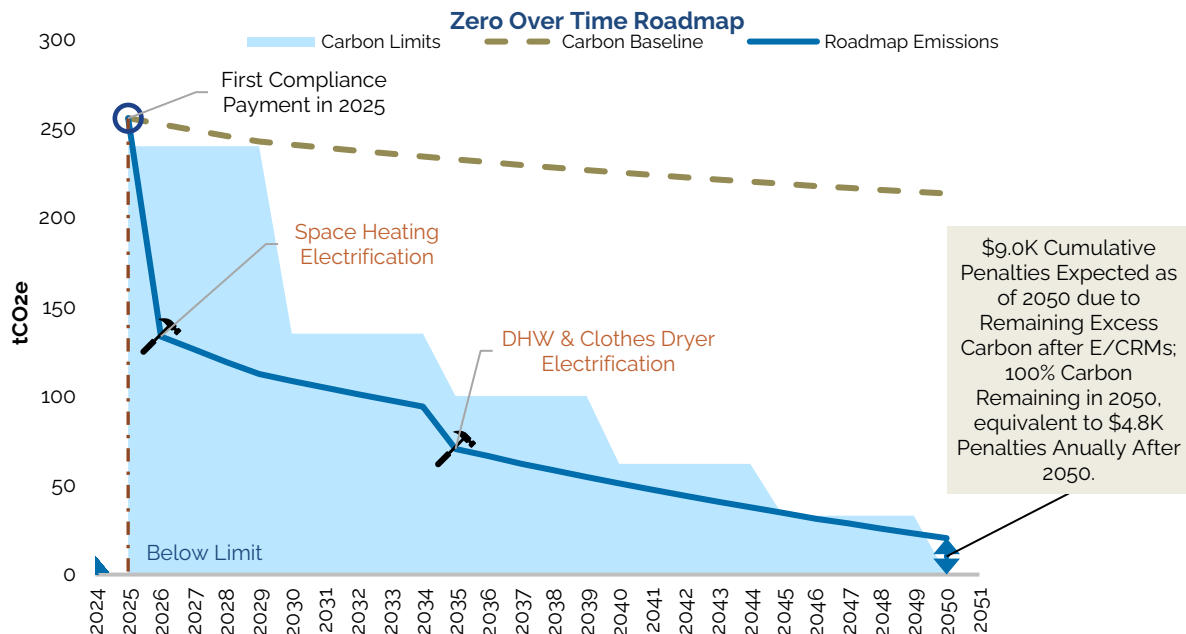
- 2030 - Roof replacement and installation of roof insulation
- 2035 - Replacement of current gas-fired water heaters with electric resistance water heaters with storage tanks for DHW service; replacement of gas clothes dryers with electric clothes dryers
- 2040+ - Consider replacement of windows to triple-glazing

Table 8. Zero Over Time E/CRM Savings Projections

E/CRM #	E/CRM Description	E/CRM Suggested Implementation Year	Projected Emissions Before E/CRM	Estimated Emissions After E/CRM	Net Emissions Savings	BERDO Emissions Limit	Over or Under Emissions Limit
			kg CO ₂ e/sq.ft./Yr	kg CO ₂ e/sq.ft./Yr	kg CO ₂ e/sq.ft./Yr	kg CO ₂ e/sq.ft./Yr	kg CO ₂ e/sq.ft./Yr
#1	Space Heating Electrification	2026	4.78	2.50	2.29	4.49	Under
#2	DHW Electrification	2035	1.76	0.82	0.95	1.87	Under
#3	Clothes Dryer Electrification	2035	1.76	1.56	0.2	1.87	Under
#2 + #3	DHW Electrification + Clothes Dryer Electrification	2035	1.76	0.62	1.14	1.87	Under

Implementing these measures per the schedule described above will yield the following reduction timeline:

Figure 6. Zero Over Time Roadmap – MID-RISE MULTIFAMILY EXAMPLE





8. Conclusion and Next Steps

In summary, MID-RISE MULTIFAMILY EXAMPLE (BERDO ID XXXXXX) is slated to exceed its emissions limits beginning in 2025 and is projected to remain non-compliant through 2050, unless decarbonization and electrification measures are implemented to reduce onsite energy consumption and improve the efficiency of the building at large. Our Zero Over Time roadmap offers a pathway that prioritizes electrification of major building systems to achieve compliance with BERDO beginning in 2026 and to move toward net zero emissions. If the ZOT plan is implemented, MID-RISE MULTIFAMILY EXAMPLE (BERDO ID XXXXXX) is estimated to comply with BERDO between 2026 and 2044 as well as between 2046 and 2049, with emissions limit overages in 2025, 2045, and then in 2050 and beyond.

As a next step, we would recommend that the owners of MID-RISE MULTIFAMILY EXAMPLE (BERDO ID XXXXXX) seek out further analysis through an MEP concept study with a focus on evaluating the building's existing electrical capacity and providing electrification design concept sketches as well as cost estimates for the proposed carbon-reduction measures. In addition, we recommend following up with available incentive programs, including LEAN and MassSave, which could aid with funding the recommended measures discussed above. Lastly, we recommend exploring opportunities for retro-commissioning and implementing low- or no-cost savings measures.

q:\projects\29941.r.001-city of boston-bldg decarb advisor program bdap zot study task 1 cohort 1\wp\reports\2025-05-08_bdap zero over time report_MID-RISE MULTIFAMILY EXAMPLE_kla-jr.docx

