Decarbonization Planning Report

Affordable Housing Building in Boston

February 13, 2026

Submitted To:

City of Boston

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EXECUTIVE SUMMARY

The purpose of this Decarbonization Planning Report is to provide a roadmap that outlines the short and long-term improvements needed at 111,884 ft^2 affordable housing property in Boston to significantly reduce the buildings' energy consumption and carbon emissions. The New Ecology (NEI) team have strategically identified a path forward to achieve the necessary carbon emission reductions, improving building comfort, and minimizing capital and operating costs.

The two primary strategies for achieving net-zero carbon emissions are improving energy efficiency and converting fossil fuel-based building systems to electricity. Fossil fuels release significant carbon emissions during on-site combustion, while electric emissions occur at the power generation source. These grid emissions can be reduced through the development of low-carbon energy sources, such as solar, wind, hydro, nuclear, and emerging technologies. This plan integrates both approaches by prioritizing the most impactful and cost-effective energy load reduction and efficiency measures and then identifying the optimal timing for transitioning from natural gas systems to electric energy, based on the carbon emissions trajectory of the grid (i.e., the greening of the electric grid). It also considers the benefits of energy-saving strategies (e.g., wall insulation, air sealing, or new windows) and system efficiency in reducing overall energy use. These considerations are essential to make the transition to electricity financially viable, given that electricity is currently more expensive than natural gas on a per-unit basis.

NEI has created an implementation timeline, as shown below, that accounts for the pending capital projects, available utility resources, the end of the useful life of equipment, and greenhouse gas emissions. For additional information refer to the "Implementation and Funding" section of the report.

2026: 9% Energy Use Reduction, 8% CO_2e Emissions Reduction, 5% Utility Cost Reduction, 8% Water Reduction

- Perform an initial project that includes installing Energy Star Refrigerators, Energy Star Washers and Electrification of Dryers and Stoves.

2030: 54% Energy Use Reduction, 45% CO_2e Emissions Reduction, 5% Utility Cost Reduction, 10% Water Reduction

- Perform a capital project which includes enhancing wall insulation, enhancing roof insulation, high efficiency windows, air-sealing in dwelling units, air to water heat pumps, energy recovery ventilators, smart thermostats, heat pump water heaters and rooftop solar PV.

The energy and water conservation measures (ECMs), their associated savings, and the projected emission reductions for the property are detailed in Table 2. The initial project is expected to reduce energy consumption by 9%, water usage by 8%, and carbon emissions by 8%. Over time, the capital project measures will further decrease energy consumption by an additional 59%, water usage by 10% and reduce carbon emissions by another 52%. For a detailed description of the ECMs, please refer to the "Energy & Water Conservation Measures" section of the report.

As a result of these strategies, the development's emissions will decrease from 3.34 $kgCO_2e/ft^2$ to 1.42 $kgCO_2e/ft^2$, a reduction of 1.92 $kgCO_2e/ft^2$. Eliminating onsite fossil fuel use allows building-related emissions to decline in step with the decarbonization of the electric grid, enabling even greater reductions over time. By 2050, the development's emissions intensity are projected to be just 0.82 $kgCO_2e/ft^2$, a 2.52 $kgCO_2e/ft^2$ reduction from current levels. This significant decline is driven by both the transition away from fossil fuels and cleaner electricity generation.

Table 3 provides a breakdown of the financial impact of each measure. The initial project, which includes upgrades to the building envelope, is anticipated to lower utility bills by 14%. The measures in the capital project are expected to reduce utility bills by an additional 4%. Notably, these savings are achieved despite the electrification of the domestic water heating systems.

One of the funding sources is the LEAN program. This program offers funding through different pathways; one is focused on deep energy retrofits (DER) that reduce energy consumption by more than 40%. This funding source provides $35 per therm of total energy saved. The capital project is expected to achieve 59% energy savings. As a result, this incentive could cover up to 18% ($1,409,992) of the total project cost ($7.76 million). With the addition of a rooftop solar PV incentive ($134,885), total incentives could reach $1.54 million (20% of capital project cost).

The MA DOER Low- and Moderate-Income Housing Decarbonization Grant Program is an additional funding source; however, to qualify, the building must install non-combustion heating, hot water, and cooking technologies, on-site renewable energy generating sources. The program incentives are up to $40,000 per unit, and they will potentially cover up to 58% of total cost of the Initial and Capital project ($7.94 Million). Note that full electrification of the building systems may require upgrades to the electric service, which currently is a 12 to 18-month process.

The Climate Ready Housing program[1] is a state funded opportunity created through the 2021 Economic Development Bond Bill and expanded through the 2024 Affordable Homes Act to fund deep energy retrofits in existing multifamily affordable housing. Annual funding ($16 million) will be leveraged competitively to support 10-15 highly rated projects that represent achievable and replicable approaches to very low carbon emissions focused on existing building renovations (as outlined below). Massachusetts Housing Partnership (MHP) and MassHousing administer the program on behalf of the Executive Office of Housing and Livable Communities (EOHLC). MHP and MassHousing have engaged with LISC to further assist in program administration. Note that the 2025 application rounds are closed as of April 11, 2025, but future expansion of this incentive is possible.

As cities and governments advance carbon neutrality policies, this plan provides a clear, adaptable strategy based on the latest data, regulations, and funding opportunities. Regular updates will ensure the roadmap remains aligned with evolving financial and technological landscapes, maximizing sustainability benefits for the owner team and its residents. Table 1 shows the goals for the proposed decarbonization plan.

[1] https://www.lisc.org/massachusetts/our-work/green-homes/climate-ready-housing-program/

Table 1. Building Energy, Cost and Emissions at different stages of the decarbonization plan.

Stage	EUI (kBtu/ft^2)	Annual Utility Cost ($)	Operation Carbon Emissions Index (KgCO2e/ft^2)
Current Condition	58	$263,708	3.34
2026 values (After Initial Project)	52	$255,848	3.04
2030 values (After Capital Project)	22	$236,498	1.42
2050 values	22	$301,756	0.82

This report also provides a facility description and an analysis of historical energy and water consumption. Appendix A contains general notes about the analysis. Appendix B contains a summary of the existing conditions found during the building assessment performed on April 17, 2025, by NEI, and Appendix C contains lifecycle costing parameters.

Table 2 – Consumption and Cost Savings Summary

Description of Upgrade	Est. Annual Water Savings (gallons)	Property Water Savings (%)	Est. Annual Electricity Savings (kWh)	Est. Annual Natural Gas Savings (therms)	Property Energy Savings (%)[1]	Emission Intensity Reduction (kg $CO2e/ft^2$)[2]	Emission Reduction (%)
Initial Project							
Energy Star Refrigerators	-	-	20,475	-	1%	0.05	1%
Energy Star Washers	415,377	8%	8,761	1,243	2%	0.08	2%
Electrification of Dryers	-	-	(35,526)	3,510	4%	0.09	3%
Electrification of Stoves	-	-	(28,218)	2,488	2%	0.06	2%
Subtotal	***415,377***	***8%***	***(34,508)***	***7,241***	***9%***	***0.28***	***8%***
Capital Project							
Low Flow Toilets	506,328	10%	-	-	-	-	-
Enhance Wall Insulation	-	-	3,593	11,756	19%	0.57	17%
Enhance Roof Insulation	-	-	485	1,254	2%	0.06	2%
High Efficiency Windows	-	-	12,502	2,048	4%	0.13	4%
Air Sealing in Dwelling Units	-	-	284	552	1%	0.03	1%
Air Source Heat Pumps	-	-	(58,075)	9,962	12%	0.34	10%
Energy Recovery Ventilators	-	-	(44,967)	-	-2%	(0.10)	-3%
Heat Pump Water Heaters	-	-	(120,506)	15,419	18%	0.46	14%
Solar PV	-	-	99,915	-	5%	0.22	7%
Subtotal	***506,328***	***10%***	***(106,769)***	***40,991***	***59%***	***1.71***	***52%***
Total savings[3]	**921,705**	**18%**	**(141,277)**	**48,232**	**68%**	**1.99**	**60%**

[1] Water savings percentages are against total property water, Electricity, and gas savings percentages are against total property energy consumption. Projected savings account for the interactivity of some measures.
[2] Emission factors (Natural gas): 5.31 kg CO2e/therm. Emission factor (Electricity): 0.2491 kg CO2e/kWh – Based on the emissions factors/predictions published in the "Boston Building Emissions Performance Standard" which is recommended by BERDO.
[3] Numbers in brackets () represent negative values.

Table 3 – Financial Summary

Description of Upgrade	Est. Upfront Cost Excl. Incentive	Est. Incentive	Est. Upfront Cost w/ Incentive	Est. Annual Cost Savings	% Cost Saving	Simple Payback (Years)	EUL[1] (Years)	SIR[2]
Initial Project								
Energy Star Refrigerators	$95,355	-	$95,355	$3,844	2%	24.8	20	0.6
Energy Star Washers	$2,800	-	$2,800	$13,459	5%	0.2	20	69.4
Electrification of Dryers	$3,548	-	$3,548	($3,542)	-1%	NA	20	-14.4
Electrification of Stoves	$125,775	-	$125,755	($3,081)	-1%	NA	20	-0.4
Subtotal	***$227,478***	***-***	***$227,478***	***$10,680***	***5%***	***21.3***	***-***	***0.4***
Capital Project								
Low Flow Toilets	$67,755	-	$67,755	$13,051	5%	5.2	20	2.4
Enhance Wall Insulation	$1,330,173	$260,633	$1,069,540	$11,149	4%	95.9	25	0.2
Enhance Roof Insulation	$889,317	$174,252	$715,065	$1,208	0%	591.7	25	0.0
High Efficiency Windows	$1,811,010	$354,847	$1,456,163	$4,171	2%	349.1	25	0.1
Air Sealing in Dwelling Units	$131,625	$25,790	$105,835	$545	0%	194.1	25	0.1
Air Source Heat Pumps	$1,755,000	$343,873	$1,411,127	($2,026)	-1%	NA	15	0.0
Energy Recovery Ventilators	$594,505	$116,487	$478,018	($8,441)	-3%	NA	15	-0.2
Heat Pump Water Heaters	$684,450	$134,110	$550,340	($8,885)	-3%	NA	15	-0.2
Solar PV	$499,575	$134,885[3]	$364,690	$18,756	7%	19.4	25	0.7
Subtotal	***$7,763,410***	***$1,544,877[3]***	***$6,218,533***	***$29,528***	***11%***	***210.6***	***-***	***-0.2***
Total savings	**$7,940,888**	**$1,544,877**	**$6,396,011**	**$40,208**	**16%**	**160.3**	**-**	**-0.2**

[1] EUL is the Estimated Useful Life in Years.

[2] SIR is the savings-to-investment ratio. Projects with negative SIR and simple payback will add utility costs but may have other benefits worth considering.

[3] This value is the incentive towards installation of Solar PV which includes $0.35/kWh of SMART Solar Credits and an incentive on 20% of total installation cost.

[4]This value represents the estimated LEAN DER incentives in addition to the solar incentives.

[5] Note that upfront costs include the cost for the specific measure and do not include additional work such as demolition, framing, siding, or additional trim or finish work that may be needed.

FACILITY DESCRIPTION

The property comprises 10 residential buildings with total of 117 units and is located in Boston, Massachusetts. The property was constructed in the late 1900s. A full description of the building is shown in Table 4.

Table 4 - Summary of Facility Description

Feature	Description
Dwelling Units	117 (17 – studio, 46 - 1 bedroom, 53 – 2 bedroom, 1 – 3 bedroom)
Gross Square Feet	111,884 ft^2
Stories	5
Exterior Wall Construction	Masonry exterior wall with no insulation in the cavity. (R-5)
Roof Type / Construction	Flat roof with 3” of rigid insulation over wooden deck with R-value of 20
Windows	Double hung windows with clear glass in vinyl frame
Heating System	Heating through hydronic baseboards connected to hydronic boilers.
Cooling System	Window AC units.
DHW System	Indirect fired water heaters.
Ventilation System	Switch-controlled exhaust fans in the bathroom of each apartment.
Range Fuel	Gas
Lighting Fixtures	Dwelling Units – LED Common Area – LED with occupancy sensors
Exterior Lighting Fixtures	LED
Low-Flow Water Fixtures	No
Laundry Room	Yes, 4 Washer/ 4 Gas Dryer

Overall, the building envelope is in fair condition. The building has insulated masonry walls with a brick façade without insulation as described in Table 4. The roof is flat with 3” rigid insulation over deck and has an R-value of 20. The windows are double hung with clear glass which makes them less efficient.

Heating for the dwelling units is provided by hydronic baseboards connected to hydronic boilers. Each building has its own boiler room with 2 boilers of model# KN-4 each. Hot water to the building is supplied by Grundfos pumps (model# MAGNA 40-120F 216). Each boiler is connected to a Grundfos pump (model# MAGNA 40-80F 216) which circulates water through the boilers.

Domestic hot water (DHW) in each boiler room is generated by one Turbomax in-direct fired water heaters (model# 109A-TXT) with capacity of 110 gallons each. Taco circulator pumps serve the hot water recirculation system throughout the buildings. The building currently lacks low-flow water fixtures. The flow rates are 1.28 GPF for toilets, 1.0 gpm for bathroom sinks, 1.5 gpm for kitchen sinks, and 1.5 gpm for showerheads.

Ventilation in the dwelling units is provided by witch-controlled exhaust fans in the bathroom in each apartment. However, testing reveals that flow rates vary across the building, indicating the system is unbalanced and requires maintenance. An unbalanced system can generate negative pressure in the building that increases the infiltration in the apartments.

The common areas feature LED fixtures with occupancy sensors. The dwelling units are equipped with LED fixtures, with ceiling-mounted lights in the entry, hallway, and kitchen. The bathrooms have LED vanity fixtures. Exterior lights have all been updated to LED fixtures.

HISTORICAL UTILITY CONSUMPTION ANALYSIS

NEI collected and analyzed historical data on site energy and water consumption to gain insights into energy trends. Summarized in Table 5 is the 3-year average, annualized billing data organized to show water, electricity, and gas consumption. The gas consumption is separated into a weather-independent component (Domestic hot water energy), and a weather-dependent component (heating the building). The electric consumption is separated into a baseload or weather-independent component (Lighting, plug loads, etc.), and a weather-dependent component (heating and cooling the building).

Table 5 - Historical Annual Utility Consumption

Utility[1]	Annual Consumption[2]		Annual Cost ($)[3]	Break-out Cost ($)	% of Total Cost	Your Building's kBtu/ft² or gpd/bedrm[4]	Benchmark kBtu/ft² or gpd/bedrm[4]	Carbon Emissions (kg CO_2e/ft^2)[5]
Total electricity	**473,160**	**kWh**	**$88,823**		**34%**	**14**	**12**	**1.05**
Baseload electricity	383,170	*kWh*		$71,930		11		
Space heating	28,609	*kWh*		$5,371		1		
Space cooling	61,380	*kWh*		$11,523		2		
Total natural gas	**48,232**	**therms**	**$42,971**		**16%**	**43**	**40**	**2.29**
Space heating	25,572	*therms*		$22,783		23		
Domestic hot water	16,662	*therms*		$14,845		15		
Gas dryers & stoves	5,998	*therms*		$5,344		5		
Total water	**5,117,931**	**gallons**	**$131,914**	**-**	**50%**	**82**	**60**	
Total	**6,438**	**MMBtu**	**$263,708[3]**		**100%**	**57**	**52**	**3.34**

[1] Gas, Electricity and Water usage is from June 2022 through May 2025.

[2] The analysis uses parameters that represent weather-independent energy use (or baseload), and weather-dependent energy use (or building heating or cooling). This produces an estimate of the building's heating, cooling, and baseload energy based on real-world data.

[3] NEI assumes the following blended rates: $0.1887/kWh electricity, $0.89/therm for natural gas, and $0.0258/gallon for water and sewer based on the average rates paid over the last year for utilities.

[4] The buildings have a total conditioned area of 111,884 square feet with 17 – studio, 46 1-bedroom, 53 2-bedroom, and 1 3-bedroom apartments.

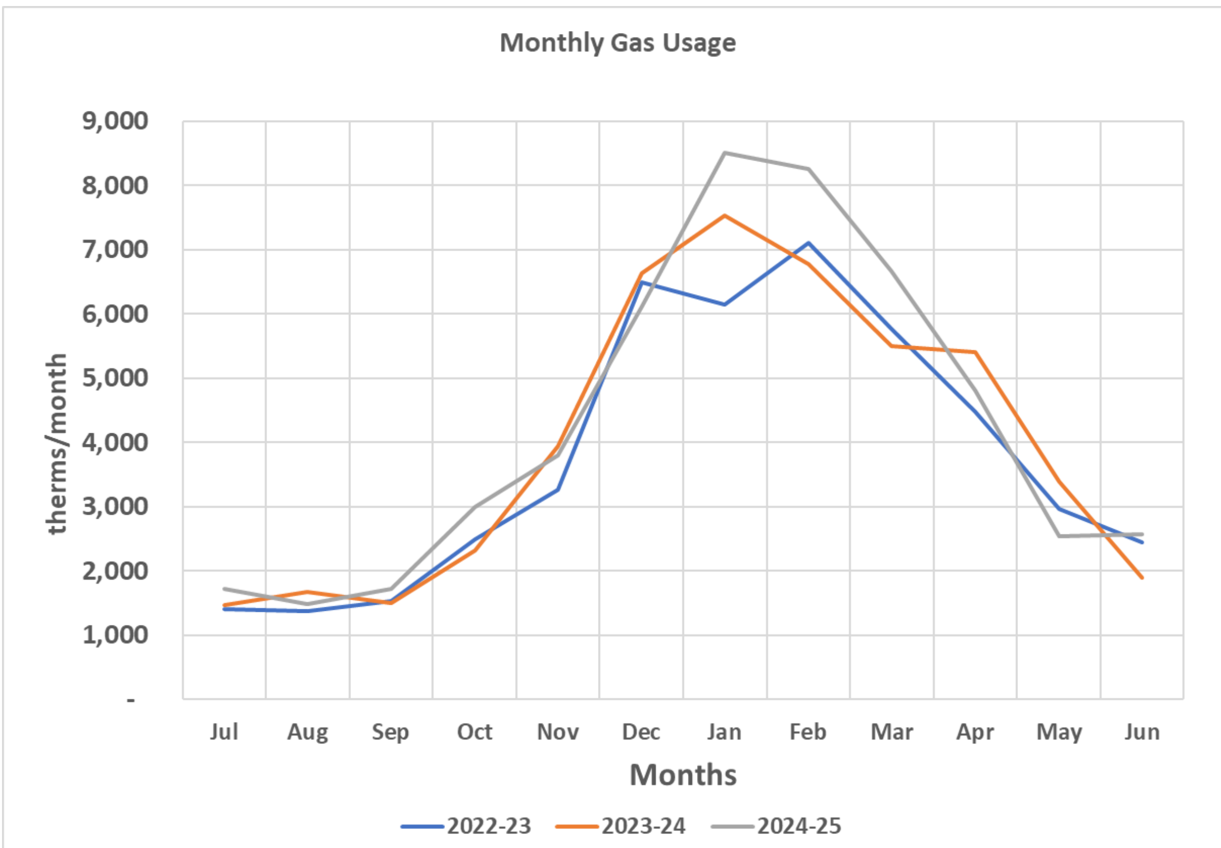
[5] Emission factors (Natural gas): 5.31 kg CO_2e/therm. Emission factor (Electricity): 0.2491 kg CO_2e/kWh – Based on the emissions factors/predictions published in the "Boston Building Emissions Performance Standard" which is recommended by BERDO.

In summary, the building has an energy use intensity index of 57 kBtu/ft², which is higher than the 52 kBtu/ft² average for similar buildings in the Northeast. The annual utility cost is approximately $263,708, and the greenhouse gas emission intensity is 3.34 kg of CO_2e per square foot.

Gas Consumption Analysis

Figure 1 shows the average monthly gas use in the building from June 2022 to May 2025. The gas usage varies each month with the lowest consumption between June and September (close to 1500 therms) and the highest consumption between November and May (close to 8,500 therms). Table 5 shows that the building has a gas use intensity of 43 $kBtu/ft^2$ which is higher than similar buildings in New England (40 $kBtu/ft^2$). This high usage is due to the use of inefficient heating and domestic hot water heating systems.

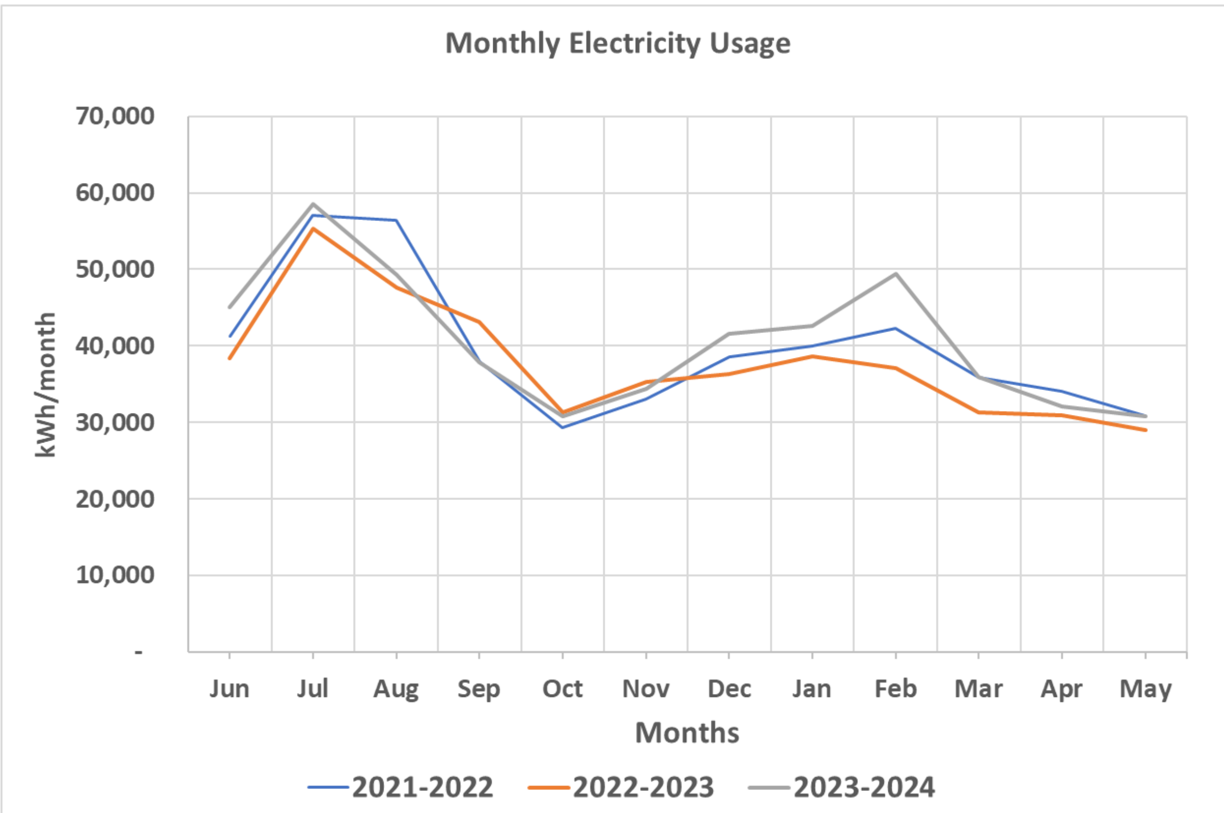
Figure 1. Average Monthly Gas Usage



Electricity Consumption Analysis

Figure 2 displays the average monthly electricity consumption in the building from June 2022 to May 2025, reflecting the combined data from common areas and dwelling units. The lowest usage occurs in October, at 30,000 kWh, while the highest is in July, at around 59,000 kWh. The summer surge is common in a building with electric space cooling. According to Table 5, the building's electricity use intensity is 14 kBtu/ft², which is higher than 12 kBtu/ft² average for similar buildings in New England. This higher usage is due to non-energy star rated window AC units and appliances.

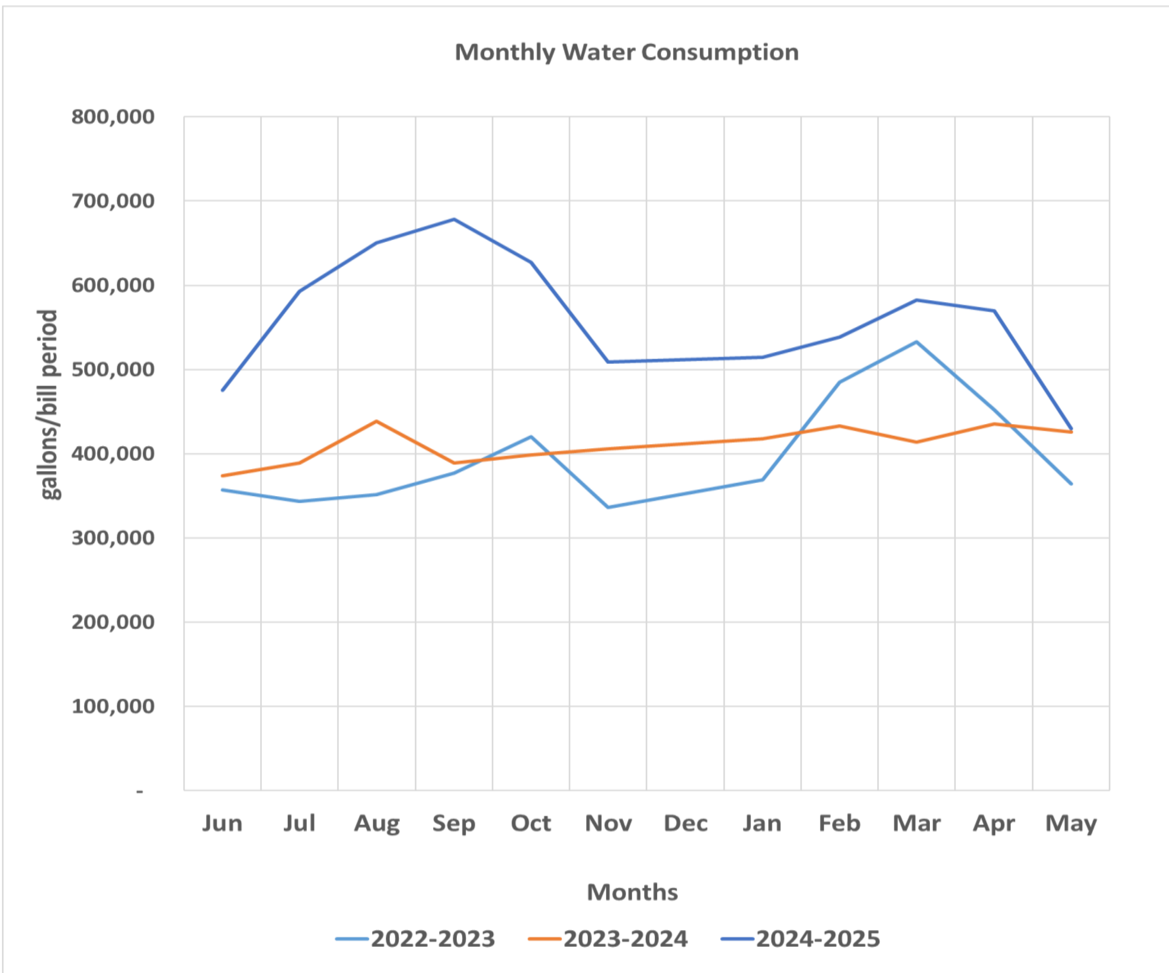
Figure 2. Average Monthly Electricity Usage



Water Consumption Analysis

Figure 3 shows the average monthly water use in the building from June 2022 until May 2025. From the figure below, water consumption in the years 2024-25 is higher than in other years. The highest usage was in September 2023 around 679,000 gallons, while the lowest usage was in November 2022, around 336,000 gallons. Table 5 shows that the building has a water use intensity (82 gallons per bedroom per day) higher than similar buildings in New England (60 gallons per bedroom per day). This higher consumption is the result of having non-low flow rates of showerheads and toilets.

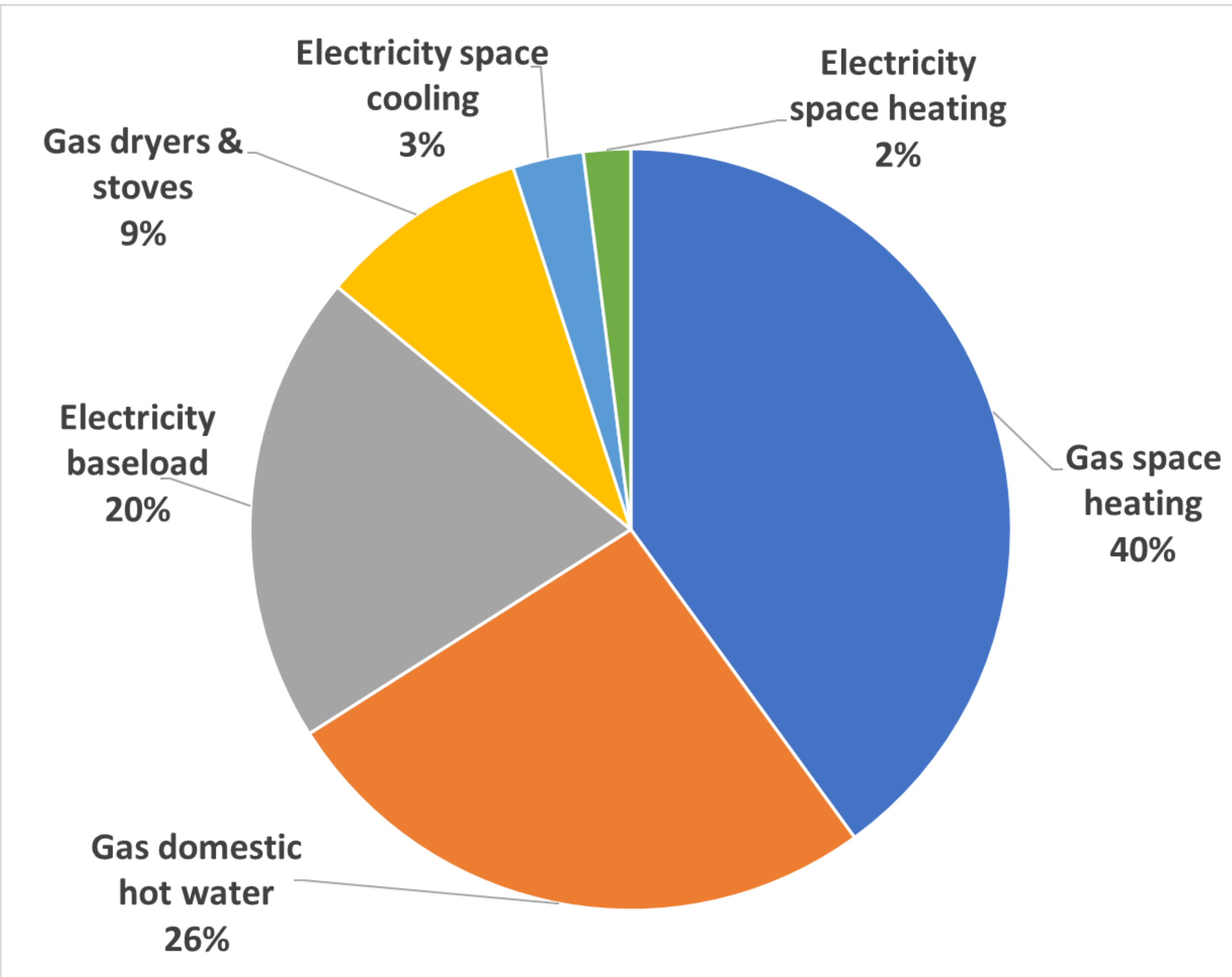
Figure 3. Average Monthly Water Usage



End Use Analysis

Figure 4 illustrates the building's energy consumption by end-use, which is used to calculate savings from energy measures and incorporates all available utility data. The building's three largest energy-consuming categories are gas space heating (40%), gas domestic hot water (26%), and electricity baseload (20%) These three categories together account for 86% of total energy usage. Therefore, implementing energy conservation measures (ECMs) that reduce heating demand, enhance the efficiency of gas-fired systems, and lower lighting and plug load consumption will have a significant impact on reducing overall energy use in the building.

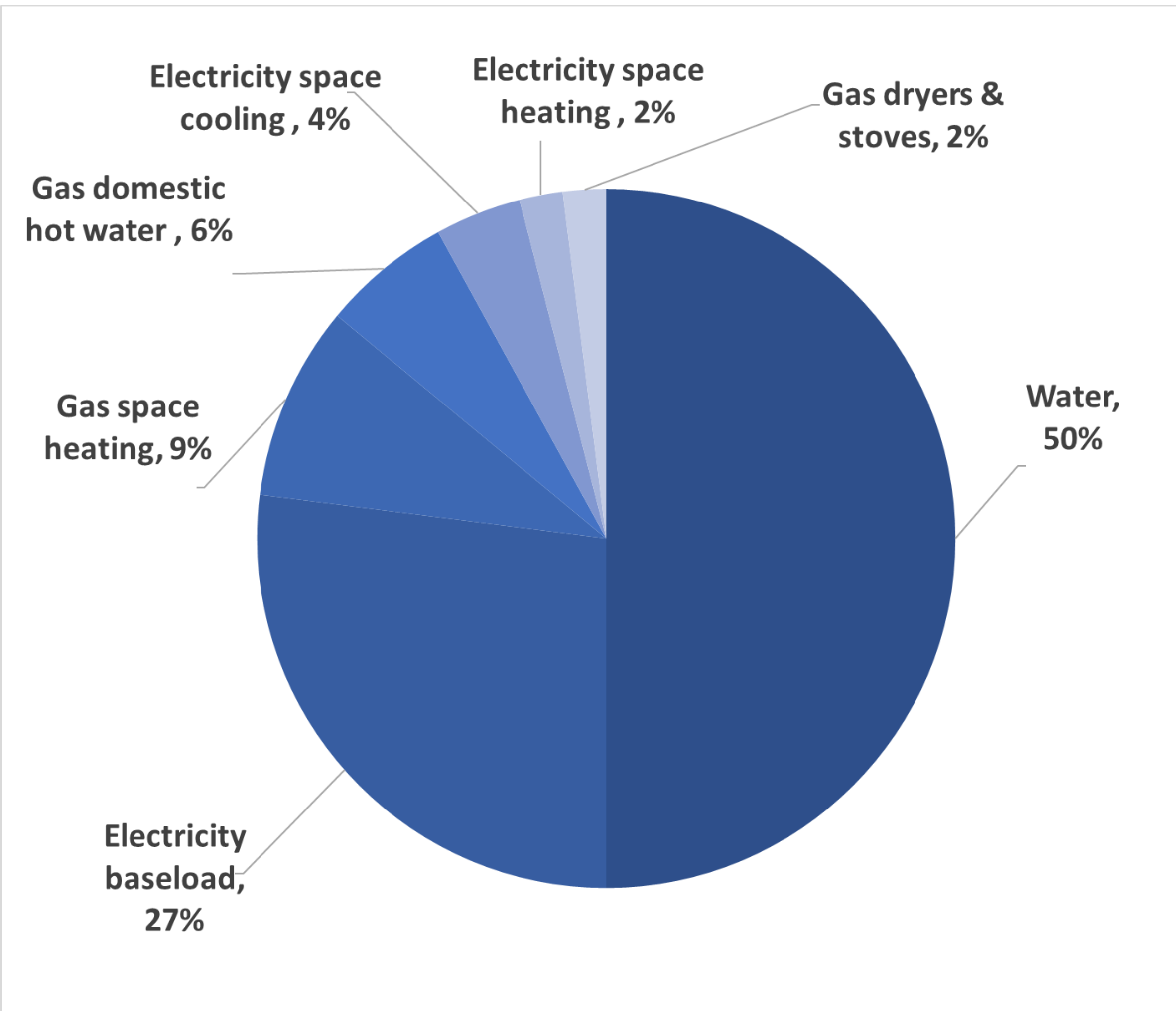
Figure 4. Estimated Energy Consumption by End Use



Utility Cost

Figure 5 presents an analysis of the building's utility costs by end use. The three largest cost categories are water (50%), electricity baseload (27%), and gas space heating (9%). These three categories account for nearly 86% of the total utility costs. Therefore, implementing energy conservation measures (ECMs) that reduce lighting, plug load, water usage, and heating demand will significantly lower the building's overall utility expenses.

Figure 5. Utility Cost by End of Use



Carbon Emissions

Aggressive action is necessary to mitigate climate change by significantly reducing the carbon impact of our built environment. The City of Boston's Climate Action Plan[2] reports that existing buildings account for 70% of total greenhouse gas (GHG) emissions, so the carbon output of existing buildings must be addressed to meet the city's overall carbon neutrality goal by 2050. At the state level, Massachusetts has committed to reducing greenhouse gases by at least 45% below 1990 levels by 2030, and 85% by 2050 to achieve net zero emissions.

In 2013, the City of Boston enacted the Building Energy Reporting and Disclosure Ordinance (BERDO). 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[3] decrease over time, with all buildings expected to reach net-zero emissions by 2050.

Table 6 shows the declining emission intensity thresholds that different building types will be required to meet each year. Emissions standards are reported in kilograms of carbon dioxide equivalent per square foot per year (kgCO2e/SF/yr.).

Table 6. BERDO emissions goals for various residential properties

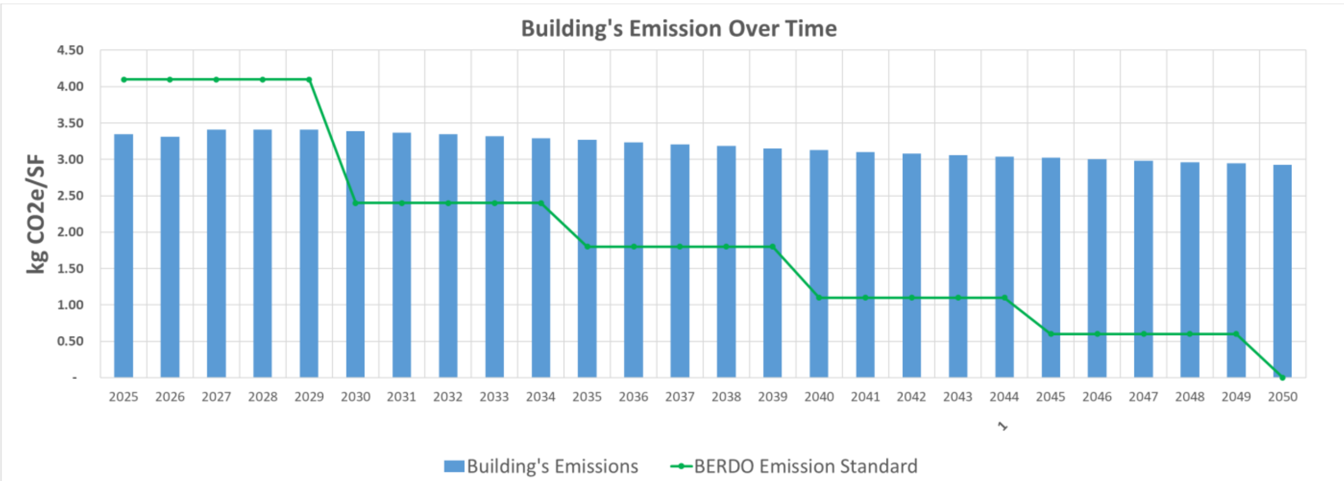
BUILDING USE	2025 - 2029	2030 - 2034	2035 - 2039	2040 - 2044	2045 - 2049	2050 -
College / University	10.2	5.3	3.8	2.5	1.2	0
Education	3.9	2.4	1.8	1.2	0.6	0
Food Sales and Service	17.4	10.9	8.0	5.4	2.7	0
Healthcare	15.4	10.0	7.4	4.9	2.4	0
Lodging	5.8	3.7	2.7	1.8	0.9	0
Manufacturing / Industrial	23.9	15.3	10.9	6.7	3.2	0
Multifamily Housing	***4.1***	***2.4***	***1.8***	***1.1***	***0.6***	***0***
Office	5.3	3.2	2.4	1.6	0.8	0
Retail	7.1	3.4	2.4	1.5	0.7	0
Services	7.5	4.5	3.3	2.2	1.1	0
Storage	5.4	2.8	1.8	1.0	0.4	0

[2] https://www.boston.gov/departments/environment/boston-climate-action

[3] https://www.boston.gov/departments/environment/building-emissions-reduction-and-disclosure#emissions-factors

Figure 6 shows the current building gas emissions and its comparison with the BERDO's emission requirements. The building will not comply with the emission requirements after 2030. Therefore, it is necessary to implement measures to reduce the building's carbon emissions.

Figure 6. Carbon emissions intensity at the property



ENERGY AND WATER CONSERVATION MEASURES

NEI team have developed a set of recommended upgrades for the capital project that will reduce energy and water use at the property. The energy, water, and cost savings for each ECM below are based on spreadsheet calculations, utility consumption data, information gathered during the site visit, and any available drawings and prior reports.

NEI has calculated energy and water use with a model of the building that includes detailed geometry, is calibrated to utility data, and normalized to average weather. Interactions between measures are included. Methods are based on the ASHRAE Handbook of Fundamentals.

Initial Project

NEI recommends performing an initial project in the year 2026 which will include the ECMs listed below. These ECM are recommended based on the current scope of work in the building, current condition of equipment, and prioritize measures with low implementation cost.

Energy Star Refrigerators

The current refrigerators installed in the dwelling units are not Energy Star rated and need to be replaced with Energy Star rated ones. NEI recommends that the refrigerators be replaced with Energy Star rated models. This measure will reduce the utility cost by 2%, energy use by 1% and GHG emissions by 1%. However, it will have a minimal impact on energy usage.

Energy Star Washers

The current laundry equipment consists of Non-Energy Star rated washers. NEI recommend replacing them with Energy Star rated washers. This measure will reduce the utility cost by 5%, energy use by 2%, water use by 8% and GHG emissions by 2%.

Electrification of Dryers

The current laundry consists of gas-fired dryers. NEI recommends replacing them with Energy Star rated electric dryers at the time of equipment replacement. This measure will reduce greenhouse gas emissions by 3% and energy use by 4% as it eliminates on-site fossil fuel combustion. However, because electricity is currently more expensive than natural gas, the measure increases utility costs by about 1% and results in a negative savings-to-investment ratio (SIR). While it does not provide direct financial savings, dryer electrification is an important step in meeting long-term decarbonization goals, improving indoor air quality, and positioning the building for compliance with BERDO requirements.

Electrification of Stoves

The existing stoves in each apartment are gas-fired. NEI recommends replacing them with Energy Star rated electric stoves. This measure reduces greenhouse gas emissions by 2% and energy use by 2% by eliminating gas combustion in the apartments. Similar to the dryers, however, the switch increases utility costs by approximately 1%, and the measure shows a negative SIR. Despite limited financial return, stove electrification has significant non-energy benefits, including improved indoor air quality, elimination of combustion-related pollutants (e.g., NO_2, CO), and enhanced resident health outcomes, particularly for children and vulnerable populations.

Capital Project

After considering the existing conditions of the heating, cooling, and domestic hot water systems in the building, NEI recommends implementing a capital project in the year 2030 in order to comply with BERDO's emission standards. This capital project includes the following measures.

Low-Flow Toilets

Existing toilets observed on site averaged 1.28 gallons per flush (gpf). We recommend replacing them with 0.8 gpf high-efficiency models. This measure is expected to reduce utility costs by 5% and water use by 10%. However, it will not impact the building's reported greenhouse gas (GHG) emissions, as the carbon impact of water use is not currently included in emissions accounting. It is important to assess the building's plumbing system for compatibility before installing low-flow toilets to ensure proper performance.

Enhance Wall Insulation

Improving the building envelope will lower building energy loads and reduce operating costs as fossil fuel systems convert to electricity. The building walls have an R-value of R-5 with no insulation in the cavity and account for 42% of the total heat loss in the building. This R-value is below the recommended value by the most up-to-date Energy Code (R-13). Therefore, NEI recommends adding spray foam insulation in the cavity and a layer of 1" rigid insulation over it. This will increase the total R-value of the wall by R-14. This will reduce the utility cost by 4%, energy use by 19%, and GHG emissions by 17%. NEI recommends implementing this measure before the electrification of the heating system as wall improvement will reduce the required equipment size.

Enhance Roof Insulation

The existing roof is in fair condition, with an R-value of R-20 which is lower than the most up-to-date Energy Code requirements(R-30). Therefore, the capital project includes the addition of insulation above the roof deck to increase the roof assembly R-value to R-30 to reduce the heating and cooling load. This measure will reduce energy use by 2%, and GHG emissions by 2%.

Install High Efficiency Windows

The total glazing area of the building, which includes the windows and storefront doors, and has estimated U-value of 0.50 of contributes 30% of heat loss. Therefore, it is recommended to replace the windows with high-efficiency thermal windows with a lower U-value of 0.3. This will help to reduce the heating and cooling load before the electrification of the heating system and improve indoor thermal comfort. Based on current conditions, this measure will reduce the utility cost by 2%, energy use by 4%, and GHG emission by 4%.

Air Sealing in Dwelling Units

During the apartment inspection, unsealed gaps were noted at most plumbing penetrations beneath the kitchen and bathroom sinks, as well as around floor perimeters. The current recommendations include adding air sealing around electrical and plumbing penetrations, windows, and floor perimeters. This measure is expected to reduce energy use by 1%, and GHG emissions by 1%. However, it will have an minimal impact on the utility cost. Additionally, air sealing will help reduce noise, odors, and air contamination between apartments, enhancing indoor comfort. It is important to consider air sealing measures in renovation areas and throughout the building as part of the overall wall, roof, and window improvements.

Air Source Heat Pumps

The existing gas-fired hot water heating systems will need to be replaced once they get close to their end of useful life. NEI recommends replacing them with an air source heat pump system which is more than three times more efficient than the existing equipment. This new system will also be able to provide cooling as well. This measure would reduce energy use by 12%, and GHG emissions by 10%. However, the utility cost will increase by 1% due to the fuel switch from gas to electricity. Note that the electric service capacity should be assessed to decide if an electric service replacement or upgrade is required before installing the air-to-water heat pumps.

Energy Recovery Ventilators

The existing exhaust fans in bathroom will need to be replaced in the future after the end of their useful life. At this point, NEI recommends installing Energy Recovery Ventilators (ERV) in each apartment of the buildings. However, this new system will require new ductwork to distribute the fresh air from the ERVs to each apartment. This measure will increase the utility cost by 3%, energy usage by 2% and GHG emission by 3% as more energy will be required to condition the fresh air supplied by the ERV. Although increasing total energy use, providing ventilation is important to remove pollutants from indoor space for improved occupant health. Ideally, the ERVs are installed on the roof but the structural integrity of the roofs should be assessed before installing the new equipment.

Heat Pump Water Heaters

The building currently relies on indirect-fired gas water heaters. NEI recommends replacing this equipment with high-efficiency CO_2-based heat pump water heaters (HPWHs) at the end of their useful life. HPWHs are three times more efficient than gas-fired systems, and this measure reduces greenhouse gas emissions by 14% and energy use by 18%. However, because of higher electricity costs, annual utility expenses increase by about 3%, and the measure results in a negative SIR. Although not financially favorable on its own, water heating electrification is critical to achieving full building decarbonization, leveraging grid greening, and unlocking eligibility for incentive programs tied to non-combustion technologies.

Solar PV

A 77.84 kW PV system will fit the available area on the roof as is shown in Figure 7. This system would be able to generate on average 99.92 MWh per year. NEI recommend engaging with a solar PV company to evaluate the PV system installation and investigate the potential of including battery storage to improve the resilience of the building. The solar PV array would reduce the utility cost by 7%, energy use by 5%, and the GHG emission by 7%.

Note that we are considering that the building owns the system to take advantage of the complete GHG emission reduction. If the system is installed by a power purchase agreement (PPA), the savings shown above would be much lower.

Figure 7. Potential solar PV system on the roof of all buildings of the property.

MEASURE'S IMPACT ON HEALTH, RESILIENCE, EMBODIED CARBON, AND NOISE REDUCTION

Improve indoor air quality

Fuel-switching measures such as electrifying stoves, dryers, and domestic hot water systems remove on-site combustion from apartments. While these measures can increase utility costs in the near term due to the higher price of electricity, they provide significant non-energy benefits. Eliminating gas combustion reduces pollutants such as nitrogen dioxide (NO_2) and carbon monoxide (CO), both of which are linked to respiratory illness, asthma, and other negative health outcomes. This transition supports healthier indoor environments, particularly for children, seniors, and other vulnerable residents.

Safety

Gas appliances carry risks associated with leaks, incomplete combustion, and carbon monoxide exposure. Transitioning to electric systems eliminates these hazards, lowering the risk of fire, explosion, or long-term exposure to combustion byproducts. Even though electrification measures show negative savings-to-investment ratios (SIRs), their contribution to resident safety provides value beyond financial metrics.

Resilience

While fuel-switching increases reliance on the electric grid, pairing electrification with envelope improvements (insulation, air sealing, high-performance windows) reduces overall load and helps maintain livable indoor conditions during outages. Adding rooftop solar PV with battery storage can further enhance resilience by providing limited backup power for critical systems, even when the broader grid is down.

Embodied Carbon Emissions

Embodied carbon is an emerging area of focus within the construction industry. It refers to the carbon emissions associated with the entire life cycle of materials and processes involved in manufacturing, transporting, installing, and eventually disposing of or recycling these materials. When applied to energy conservation measures (ECMs), embodied carbon includes emissions from all stages of a product's life cycle.

Currently, most energy and emissions analyses in construction focus on operational carbon, which refers to emissions generated during the use or operation of a system—such as fuel consumption for heating. In contrast, embodied carbon encompasses emissions from materials, manufacturing processes, transportation, installation, and end-of-life stages.

Embodied carbon calculations today primarily address the structural components, enclosure systems, and finishes of a building. Non-permanent elements, such as HVAC systems and appliances, are typically excluded from these calculations. For the structure in question, which has no planned additions, steel and concrete-related emissions are not significant contributors.

The proposed envelope measures have the largest embodied carbon impact. Compared to double-pane windows, triple-pane units require a larger frame and an additional glass pane, increasing their weight and size. This results in higher embodied emissions from both manufacturing and transportation.

Similarly, additional wall and roof insulation can contribute significantly to embodied carbon. Certain materials, such as extruded polystyrene (XPS), have particularly high embodied carbon due to the use of blowing agents with a high global warming potential (GWP). Alternative rigid insulation materials—such as spray foam insulation, wood-fiber board, mineral wool board, and expanded polystyrene (EPS)-typically have lower embodied carbon impacts and may serve as more sustainable options.

Noise Reduction

Minimizing external noise transmission through the building envelope enhances indoor acoustic comfort and occupant well-being. Over-cladding with insulation increases the mass and density of exterior walls, effectively reducing sound transmission by absorbing and dampening vibrations. Air-sealing measures further mitigate noise infiltration by eliminating pathways for airborne sound, thereby e nhancing overall soundproofing performance.

Windows contribute significantly to noise reduction, with triple-pane designs featuring insulated glass and airtight seals offering superior acoustic insulation. Additionally, the use of laminated exterior panes can further attenuate sound waves, reducing the impact of external noise on the indoor environment. Implementing these envelope improvements collectively enhances the building's ability to limit sound intrusion while improving energy efficiency.

FUNDING AND IMPLEMENTATION TIMELINE

The property has units for low-income residents; therefore, the building is available to receive funding from the LEAN program. This program offers funding through different pathways:

- Direct install – Buildings can apply to the program and identify measures that can be implemented at no cost. One of the measures for buildings with electric baseboards is to replace them with air-source heat pumps. Note that this pathway does not include the improvement of the envelope with can lead to an increase of the utility cost.
- Deep Energy Retrofits (DER) that reduce energy consumption by more than 40%. This funding offers $35 for each therm saved, but the savings need to be achieved in one implementation. To qualify for this founding source both the Initial and capital project needs to be implemented.

Note that the availability of the DER funding is limited for the projects due to complete before 2027, but availability of these funds in the future is possible.

Another funding option for the development is the MA DOER Low- and Moderate-Income Housing Decarbonization Grant Program. To be eligible, the building must implement non-combustion heating, hot water, and cooking technologies, as well as incorporate on-site renewable energy generation. The program incentives are up to $40,000 per unit. Applicants who are seeking funding of $1,000,000 or more must commit to providing opportunities for the local workforce. Like the LEAN DER all measures to qualify for funding should be implemented at the same time. Finally, it is possible to get DOER incentives over other incentives. For example, a group of measures with more than 40% and with full electrification and the installation of renewable energy can get DOER funding on top of the DER funding.

The Climate Ready Housing program[4] is a state funded opportunity created through the 2021 Economic Development Bond Bill and expanded through the 2024 Affordable Homes Act to fund deep energy retrofits in existing multifamily affordable housing. Annual funding ($16 million) will be leveraged competitively to support 10-15 highly rated projects that represent achievable and replicable approaches to very low carbon emissions focused on existing building renovations (as outlined below). Massachusetts Housing Partnership (MHP) and MassHousing administer the program on behalf of the Executive Office of Housing and Livable Communities (EOHLC). MHP and MassHousing have engaged with LISC to further assist in program administration. Note that the 2025 application rounds are closed, but future expansion of this incentive is possible.

The following table presents the implementation plan for the building. The table identifies each measure, what triggers its implementation, as well as the anticipated funding resource to cover its upfront cost.

[4] https://www.lisc.org/massachusetts/our-work/green-homes/climate-ready-housing-program/

Table 7. Energy Conservation Measures implementation schedule, motivation, and funding source

YEAR	ECM	MOTIVATION/TRIGGER	FUNDING SOURCE
2026	Initial Project	Operating Savings	Replacement Reserves
2030	Capital Project	Operating Savings / BERDO Compliance / Indoor Air Quality / Enhancing Comfort for Tenants	Replacement Reserves / LEAN DER Pathway / MA DOER funding / Climate Ready Housing

PROJECTED RESULTS

Figure 8 compares the trajectory of the building's carbon emissions without upgrades or electrification measures (represented by the red line) and the trajectory of the building's carbon emissions as the measures outlined in this plan are deployed (represented by the blue bars) against the BERDO requirements (represented by the green line). Note that the building's emissions remain below the BERDO requirements for all years, except in 2040, 2045 to 2050, with a total reduction of 75%.

It is important to highlight that we have based our analysis on assumptions regarding the overall reduction of carbon emissions from the electric grid, in line with projections from the "Boston Building Emissions Performance Standard" recommended by BERDO. By transitioning systems that currently use fossil fuels to electric power, we can capitalize on this reduction to decrease emissions specific to the building.

The estimated carbon emissions intensity in 2050 is 0.82 kgCO2e/SF, which is a reduction of 75% of the current carbon emissions 3.34 kgCO2e/SF. If we compare the baseline emission intensity in 2050 of 2.92 kgCO2/SF with the building's emission after the implementation in 2050, the reduction is 72%. The projections are the best available but still have a high degree of uncertainty. The actual progress of the grid in decarbonizing needs to be monitored over time, and the ZOT plan recalibrated accordingly.

Figure 8. Carbon emissions by year for the baseline building and upgraded building.

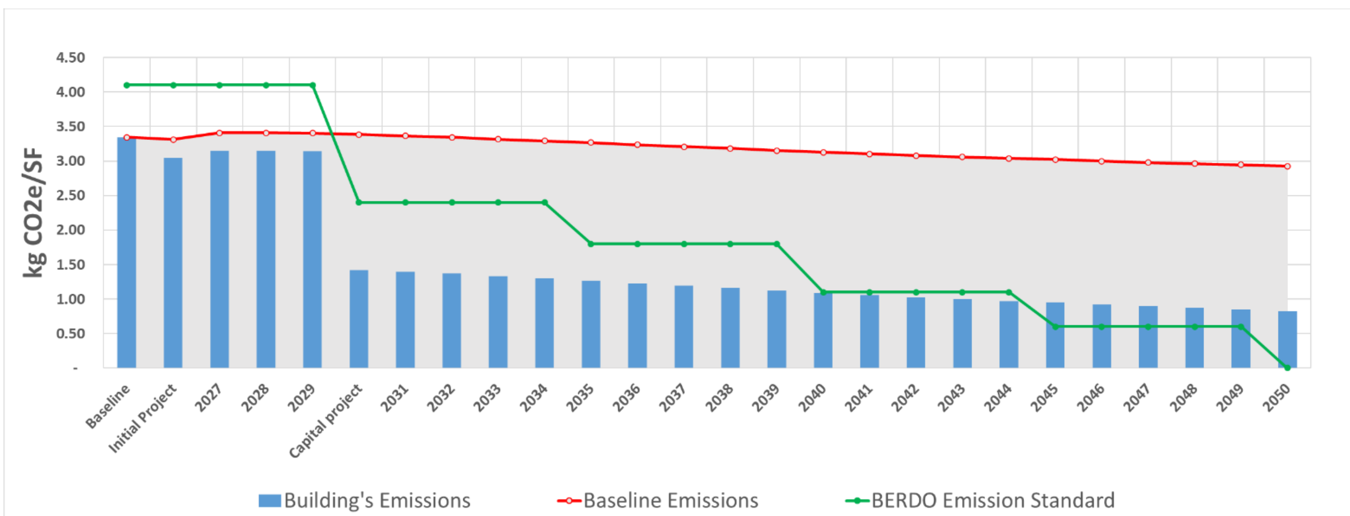


Figure 9 illustrates the change in operating costs as various measures are implemented over time through 2050. These costs are based on the property's energy bills, factoring in the U.S. Energy Information Administration's projected average annual price increases to estimate operating cost changes until 2050. Gas costs (as shown by the orange bars) are reduced as gas systems are removed from the building. Although electricity is more expensive than natural gas per unit of energy, the improvements in efficiency from these upgrades result in overall operating costs that are either reduced or only slightly increased.

It is important to note that by 2050, after all measures have been implemented, operating costs will be 14% lower than current levels, enabling the building to be fully electrified without increasing the annual operating costs. Additionally, when comparing the projected operating costs in 2050 for the building in its current state to those after the recommended measures are applied, potential savings could reach up to 16%.

Figure 9. Operating cost variation over time

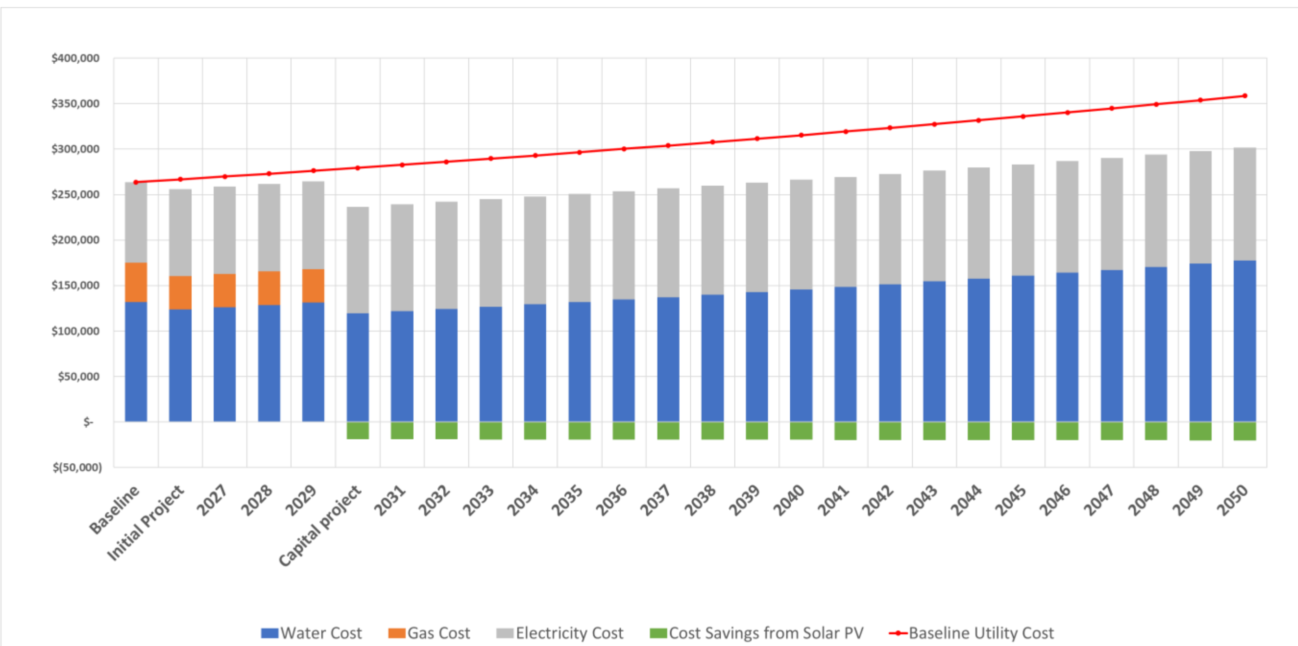
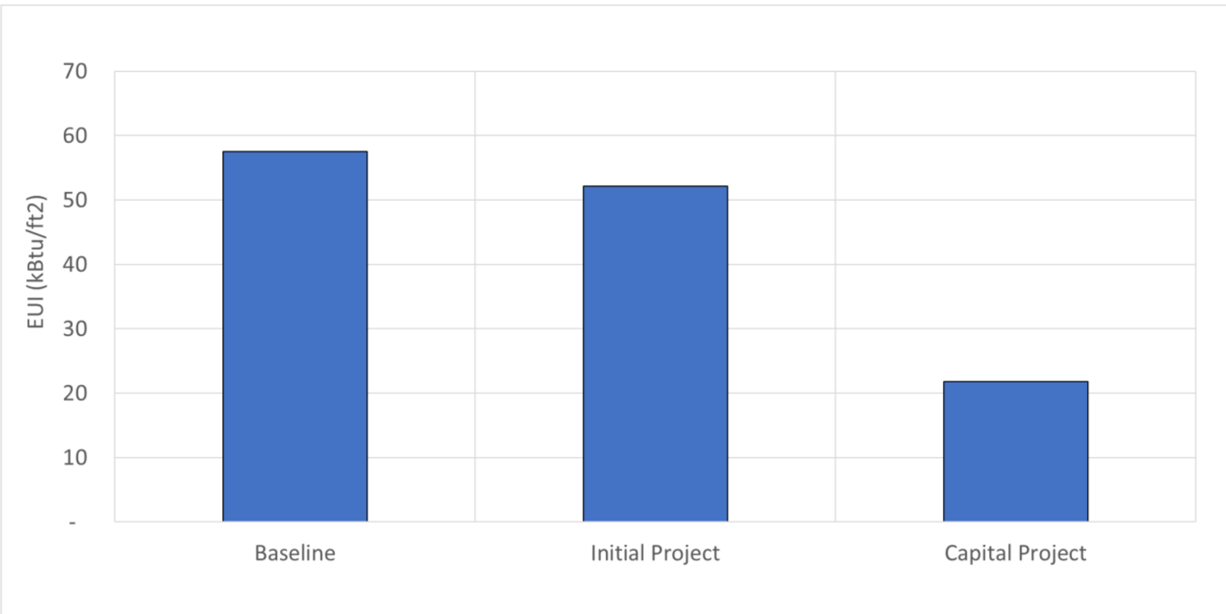


Figure 10 outlines the change in energy use intensity (EUI) as measures are implemented. The building EUI reduces from 58 kBtu/SF to 22 kBtu/SF after the implementation of all measures. The major EUI reductions are achieved after the implementation of the Capital Project which includes enhancing roof and wall insulation as well as electrification of heating and DHW system (30 kBtu/ft^2).

Note that the Energy Use Index (EUI) will not go to zero even though it is reduced. Electrification does not take the building to net zero energy, but it is a path to zero carbon emissions as the electric grid decarbonizes.

Figure 10. Energy use intensity variation by ECM



CONCLUSION

With careful planning and phased investment, the property can achieve substantial progress in energy efficiency, cost control, and carbon reduction. Ther Zero Over Time (ZOT) Plan outlined in this report positions the property as a strong candidate for long-term decarbonization strategy.

The recommended measures are projected to:

- **Reduce Energy Use Intensity (EUI) by 62%** through envelop improvements, electrification, appliance upgrades, and renewables.
- **Cut annual greenhouse gas emissions by 75% by 2050,** aligning with BERDO requirements and state climate goals.
- **Lower utility costs by 16% by 2050** compared to a “no-action” baseline, even as energy prices escalate over time.

If implemented all at once, the measures would achieve an **immediate 16% reduction in utility costs and a 60% reduction in emissions,** as detailed in Table 2 and Table 3. The phased approach of a 2026 initial project, and a 2030 capital project balances feasibility, funding, and system replacement cycles while still ensuring deep reductions over time.

APPENDIX A. GENERAL ASSUMPTIONS AND NOTES

Estimates

Cost estimates are based on the professional judgments of NEI. They are not based on bids and are estimated to be ±25%. This report does not constitute an engineering design of building systems. Additional design work and product choices may be needed before implementing any of the recommendations.

Calculation Data Sources

Water Research Foundation and Aquacraft, Inc. (Peter Mayer et al, 2013) In-Progress Results from the Residential End Uses of Water Update - WRF 4309. Water Research Foundation. Denver, CO.

Climate Data Normal Hourly, National Oceanic and Atmospheric Administration, https://www.ncdc.noaa.gov/cdo-web/search?datasetid=NORMAL_HLY

Energy Star Performance Standards for:

- Appliances
- Rooftop units

APPENDIX B. BUILDING INFORMATION COLLECTED DURING THE SITE VISIT

Dwelling Units Lighting

Unit	Room	Type of Lamp	# of Lamps per Fixture	Type of Fixture	Fixture Qty (if multiple identical)
Apt 1	Hallway	LED	1	Ceiling Mount	2
Apt 1	Kitchen	LED	1	Ceiling Mount	1
Apt 1	Bathroom	LED	1	Vanity	1
Apt 2	Entry	LED	1	Ceiling Mount	1
Apt 2	Living Room	LED	1	Ceiling Mount	1
Apt 2	Kitchen	LED	1	Ceiling Mount	1
Apt 2	Bedroom	LED	1	Ceiling Mount	1
Apt 2	Bathroom	LED	1	Vanity	1
Apt 3	Entry	LED	2	Ceiling Mount	1
Apt 3	Living Room	LED	2	Ceiling Mount	1
Apt 3	Hallway	LED	1	Ceiling Mount	1
Apt 3	Kitchen	LED	1	Ceiling Mount	1
Apt 3	Bathroom	LED	3	Vanity	1
Apt 4	Entry	LED	2	Ceiling Mount	1
Apt 4	Kitchen	LED	2	4’ Linear	1
Apt 4	Bathroom	LED	3	Vanity	1
Apt 5	Entry	LED	2	Ceiling Mount	1
Apt 5	Hallway	LED	1	Ceiling Mount	1
Apt 5	Kitchen	LED	1	Ceiling Mount	1
Apt 5	Bathroom	LED	1	Vanity	1
Apt 6	Kitchen	LED	1	Ceiling Mount	1
Apt 6	Entry	LED	1	Ceiling Mount	1
Apt 6	Hallway	LED	1	Ceiling Mount	2
Apt 6	Bathroom	LED	2	Vanity	1

Kitchen Water and Vent Fixtures

General Unit Information			Kitchen				
Unit	# Beds	# Bath	Vent Type	Vent Control	Vent Tested (CFM)	Water Fixture Rating (gpm)	Water Fixture Tested (gpm)
Apt 1	2	1	Window	-	-	1.5	-
Apt 2	1	1	Window	-	-	1.5	-
Apt 3	2	1	Local Exhaust ducted to outside	-	-	1.5	-
Apt 4	-	1	Local Exhaust ducted to outside	-	-	1.5	-
Apt 5	1	1	Window	-	-	1.5	-
Apt 6	3	1	Local Exhaust ducted to outside	-	-	1.5	-
Average						**1.5**	**-**

Bath Water and Vent Fixtures

Unit	Bath							
	Water Fixture Rated (gpm)	Water Fixture Tested (gpm)	Shower Rated (gpm)	Shower Tested (gpm)	Toilet GPF	Water Temp	Bath Fan Cont. CFM	Bath Fan Boost CFM
Apt 1	1	-	1.5	-	1.28	-	32	-
Apt 2	1	-	1.5	-	1.28	-	-	-
Apt 3	1	-	1.5	-	1.28	-	49	-
Apt 4	1	-	1.5	-	1.28	-	48	-
Apt 5	1	-	1.5	-	1.28	-	34	-
Apt 6	1	-	1.5	-	1.28	-	14	-
Average	**1**	**-**	**1.5**	**-**	**1.28**	**-**	**35**	**-**

APPENDIX C. LIFE CYCLE COST ASSESSMENT VARIABLES

The assumptions used in the life cycle cost estimate values are summarized below.

Item	NEI Assumption
Inflation Rate (per year)	2.0%
Discount Rate	4.0%
Escalation Rate for Utility Supply Costs (per year)	3.0%