Lee Middle and High School

Building Performance Exchange

MASS CLEAN ENERGY CENTER

This case study is part of the MassCEC Building Electrification and Transformation Accelerator (BETA): Project Planning program, committed to helping a representative selection of commercial building types in Massachusetts reach net zero emissions by 2050. This MassCEC funded resource and more are available via the Building Performance Exchange.

Building type	K-12 School
Location	Lee, MA
Year built	1961; 2002-2005 Renovation
Stories	1
Square footage	114,000
Energy use intensity (EUI)*	72.4 kBtu/sf/yr
Carbon emission intensity (CEI)*	4.3 CO2e kg/sf/yr
Decarbonization goals	Occupant comfort, lower utility costs

The Lee Middle and High School was built in the 1960s and underwent a major renovation in 2002-2005 including upgrades to the roof, windows, and mechanical system. The envelope is a steel and CMU construction. The façade is in fair condition with an assumed air infiltration that aligns with the building's age and construction. While the academic wings lack cooling, the school is not experiencing any comfort issues in the warmer months primarily due to the school's night flushing protocol.

Existing Conditions

Enclosure	Walls	Roof	Windows
	Fair	Fair	Fair
Heating	Natural gas boiler sourcing hot water (HW) heating to unit ventilators (classrooms), HW (and natural gas furnaces) to single zone rooftop AHUs/RTUs. No heat recovery.		
Cooling	DX cooling for select areas (common spaces). No cooling in classrooms.		
Ventilation	Ventilation air is supplied by AHUs/RTUs and through unit ventilators in classrooms.		
Hot water	900-gal direct-fired natural gas tanks		
Lighting	LED lighting with occupancy sensors throughout		
Controls	Demand Control Ventilation in gym and media room, limited temp set back capability (not optimized).		
Other	Full commercial kitchen with gas appliances		
Renewable energy	None		

*EUI represents the annual energy usage of the building divided by the total area. CEI is the amount of greenhouse gas (GHG) emissions divided by the total area.



Key Challenges & Solutions

A complex combination of existing HVAC systems

Install an Air to Water Heat Pump (AtWHP) to replace the natural gas sourced boiler/HW heating system (unit ventilators, AHUs/RTUs). Replace the gas furnace RTUs with Heat Pump RTUs. Include high efficiency heat recovery at all AHUs/RTUs. Owner opted to not add cooling at classrooms.

Funds allotted for 2026 roof replacement

Adding additional insulation at time of the roof replacement and selecting triple glazing for window replacement will improve occupant comfort and reduce utility costs, as well as enable future electrification of heating. Consider planning for any additional structure required for future solar system.

Core Decarbonization Strategy

- Packaged gas-fired RTUs creates an opportunity for cost-effective Heat Pump RTU replacements.
- Air-to-Water Heat Pump (AtWHP) system to replace existing boilers at end-of-life, minimizing disruption to existing piping and adding potential future cooling to classrooms
- Air sealing and new windows address air leakage to lower utility costs while minimizing costly upgrades to the building envelope.

Retrofit Measures and Energy Impacts

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Measures

Energy Efficiency & Load Reduction

Foundational efficiency:
- LED lighting controls upgrades
- Demand Control Ventilation (DCV) in applicable RTUs

Foundational load reduction:
- Air-sealing and weatherstripping

Advanced load reduction:
- Roof replacement with added insulation (R-50)
- Window replacement (triple glazing)

System Electrification

Electrification Enablers:
- Electrical distribution panel upgrade
- Low temperature hot water infrastructure testing

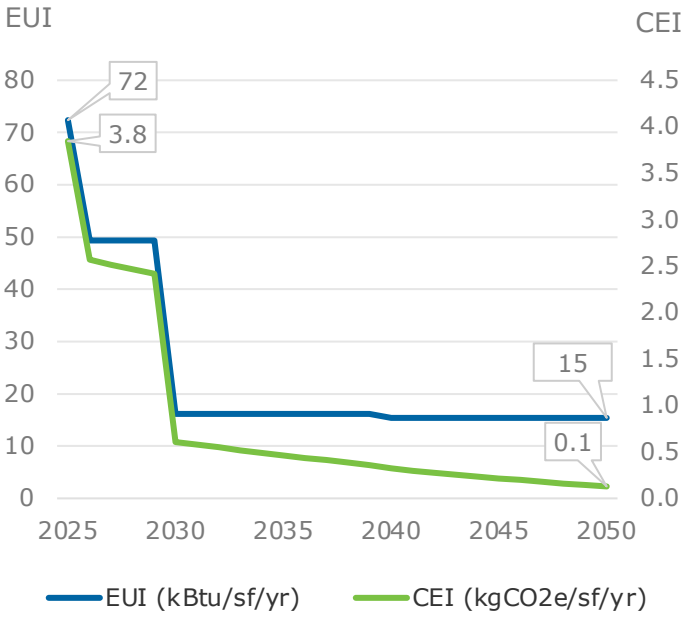
System electrification:
- Air-to-Water Heat Pump
- HP RTUs
- Heat recovery
- Heat pump domestic water heater

Renewable Energy

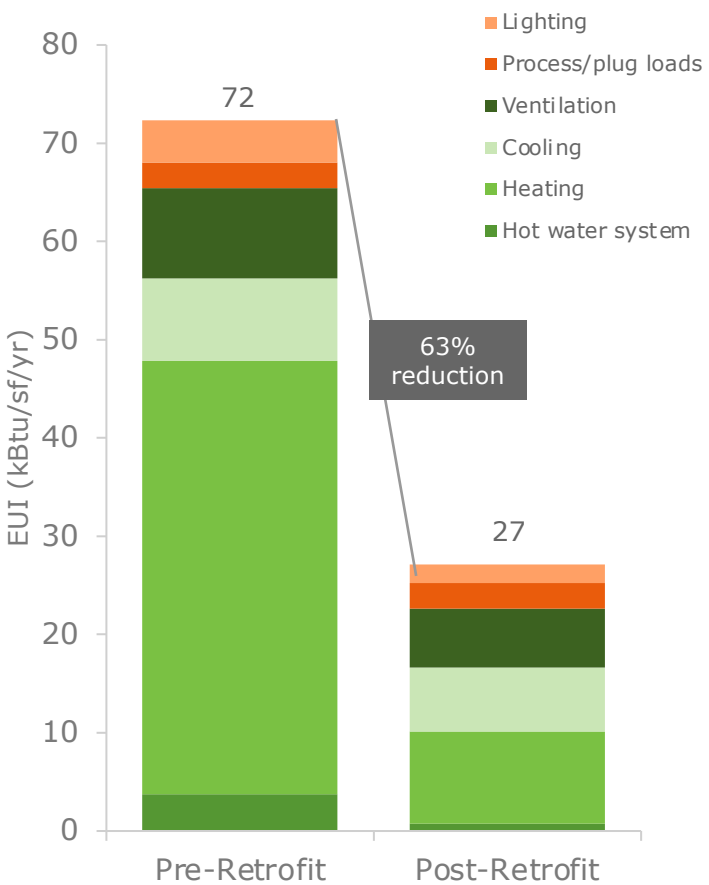
Renewable Energy:
- ~350kW system producing about 456,706 kWh annually

Performance Targets

The decarbonization approach prioritizes an all-electric mechanical system end of life replacement over a 10-year timeline (2025-2035). The recommended measures enable the property to reach an 63% EUI reduction (79% when accounting for the solar PV system) and up to a 93% GHG reduction to align with impending BERDO regulations. These efforts would yield the following results over time:



Annual Energy Use Impacts*



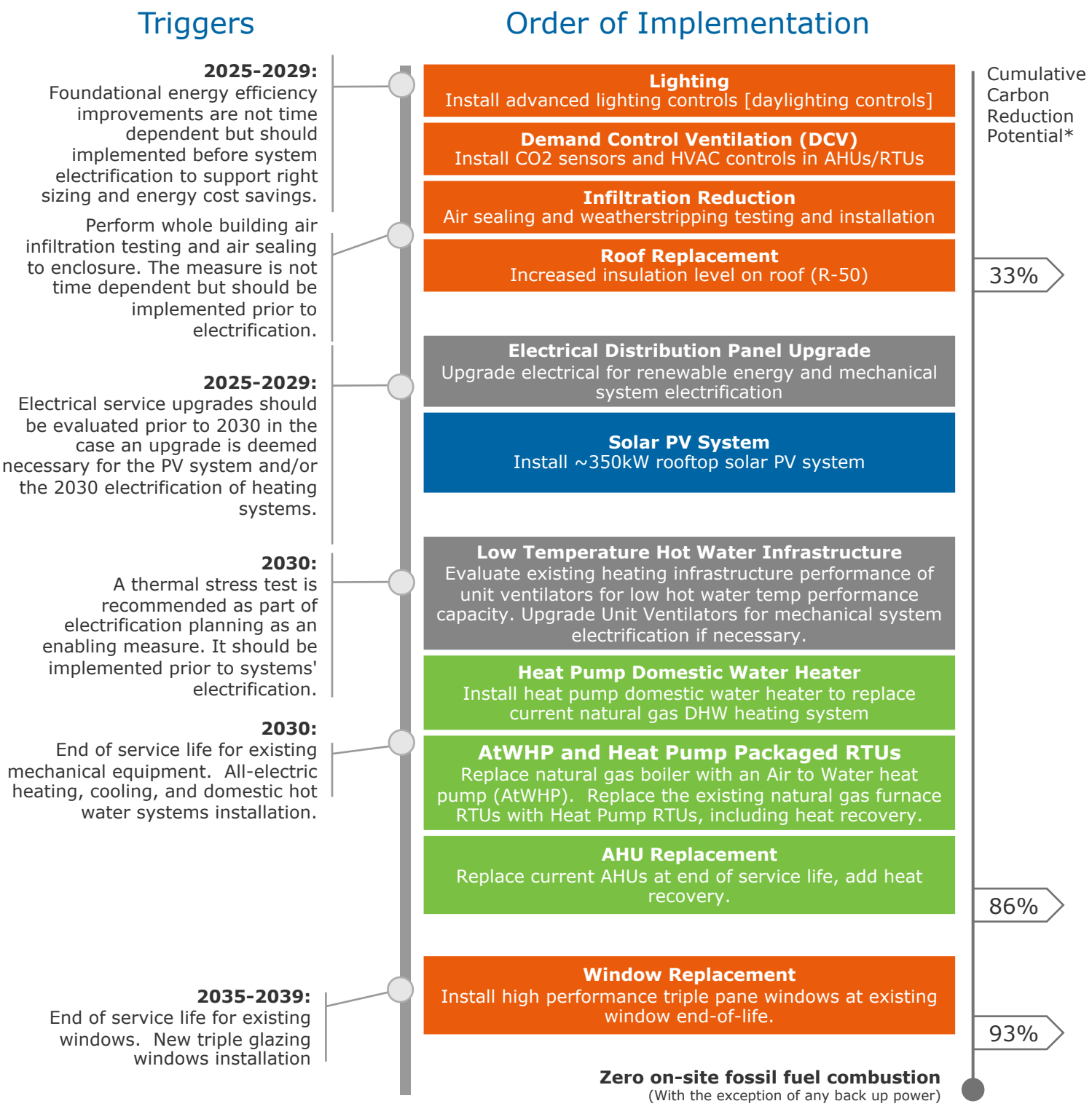
*The Post-Retrofit EUI represented in the graph above does not include additional energy use reductions from renewable energy systems.

*The annual energy use impacts graphic illustrates an EUI before and after once all recommended measures are implemented, except for any renewable energy. The CEI and EUI shown in the performance targets account for the added benefits of renewable energy.

Project Planning

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The graphic below presents a decarbonization pathway, organizing measures into bundled actions that are best implemented together. The expected cumulative carbon reduction potential from each bundle is noted on the right. The strategy to reach zero GHG emissions by 2050 focuses on maximizing energy efficiency, electrifying on-site combustion systems within a cleaning grid, and cost-effective on-site renewables. Key considerations or triggers are listed along a timeline to support informed decision-making, with bolded dates indicating recommended implementation years.



*GHG calculations are based on BERDO Version 3 emissions factors. Full decarbonization is dependent on statewide renewable energy adoption. GHG calculations include direct onsite combustion (Scope 1) and purchased electricity (Scope 2). For any renewable energy measures included in this plan, it is assumed that the owner will retain the Renewable Energy Credits (RECs) to claim the GHG reduction for reporting.

Cost Analysis

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Annual Utility Impacts

Measure description	Changes in annual utility costs		
	Electricity	Fossil fuel	Net total changes
Lighting	($2,100)	-	($2,100)
Process/plug loads	$4,900	($4,500)	$400
Ventilation	($14,100)	-	($14,100)
Cooling	($2,800)	-	($2,800)
Heating	$86,700	($90,700)	($4,000)
Hot water system	$7,600	($7,900)	($300)
Total from recommended measures	**$80,200**	**($103,100)**	**($22,900)**
Renewable energy	($93,400)	-	($93,400)

*Note: the estimated additional utility savings are based on a new owned 350kW solar PV roof system Additional solar PV parking canopy may be considered for additional savings, although not included in this study.

Lifecycle Costs*

Realizing the full value of decarbonization requires a long-term outlook that weighs upfront investments, operating costs, and financial incentives. BETA assessments identify the retrofit pathway that most effectively reduces GHG emissions, maintains comfort, and improves performance relative to upgrades an owner would already make (the business-as-usual (BAU) scenario). This comparison highlights long-term avoided costs and risks, as well as opportunities such as incentives that support pursuing the optimized decarbonization pathway.

Costs	BAU retrofit	Optimized decarbonization pathway	
Base building and envelope costs	$3,642,000	$474,000	Foundational efficiency and load reduction
		$4,540,000	Advanced load reduction
Mechanical costs	$3,057,000	$1,218,000	Electrification enablers
		$2,573,000	System electrification
Renewable energy costs	$0	$1,050,000	Renewable energy
Soft costs	$2,345,000	$3,449,000	
Total upfront costs	**$9,044,000**	**$13,304,000**	
Utility incentive opportunities	$0	$2,144,000	
25-year total accrued utility costs	$11,006,000	$6,374,000	
25-year accrued total operating costs	$12,531,000	$6,956,000	
25-year LCCA	**$33,679,000**	**$24,490,000**	

BAU scope:

- Roof replacement in 2026
- Natural gas boiler, AHUs/RTUs, DHW replacement
- Refurbish unit ventilators
- Electrification ready infrastructure based on future code requirements prior to 2050

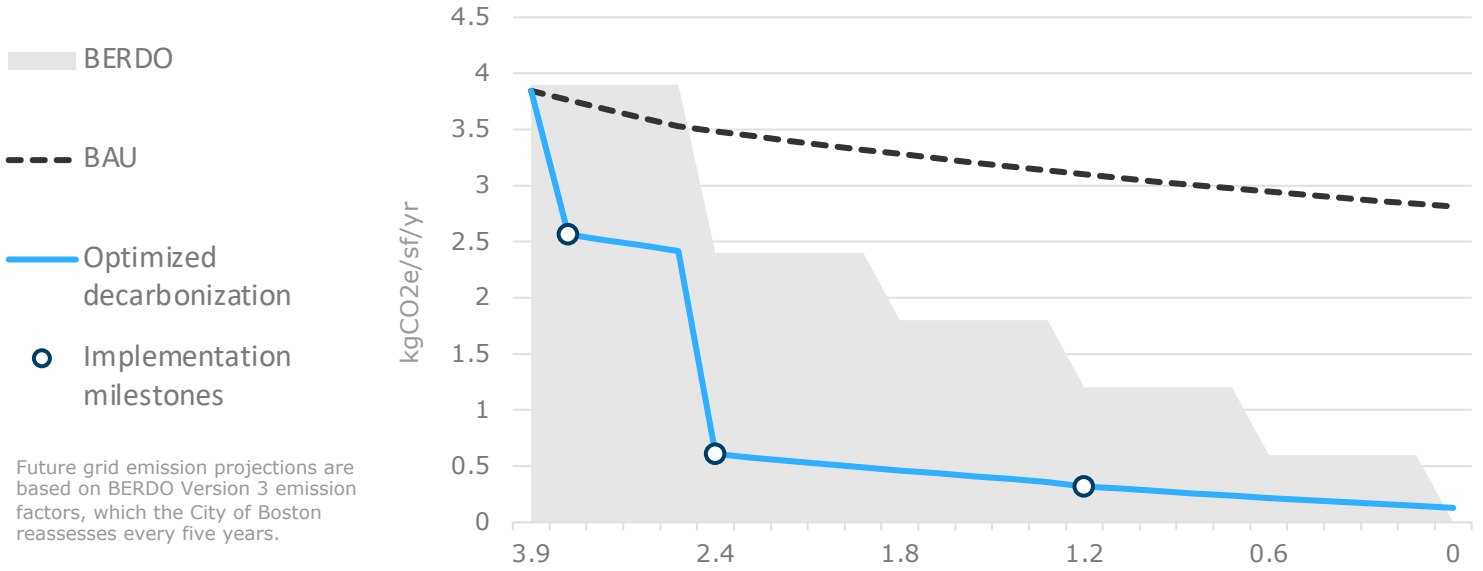
*All cost and incentive values are estimated based on industry data and rounded to the nearest $1,000. All incentives values are based on currently available programs and are subject to change over time. Forecasted operating costs include utility costs, maintenance costs, and noncompliance fees if relevant. Utility and maintenance costs reflect a 3% annual escalation rate. The BAU approach assumes necessary repairs and replacements that meet code compliance. In this case study, BAU represents the conventional natural gas or code-compliant versions of the decarbonization measures listed.

Decarbonization Benefits

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GHG Emissions Goals and Benchmarking

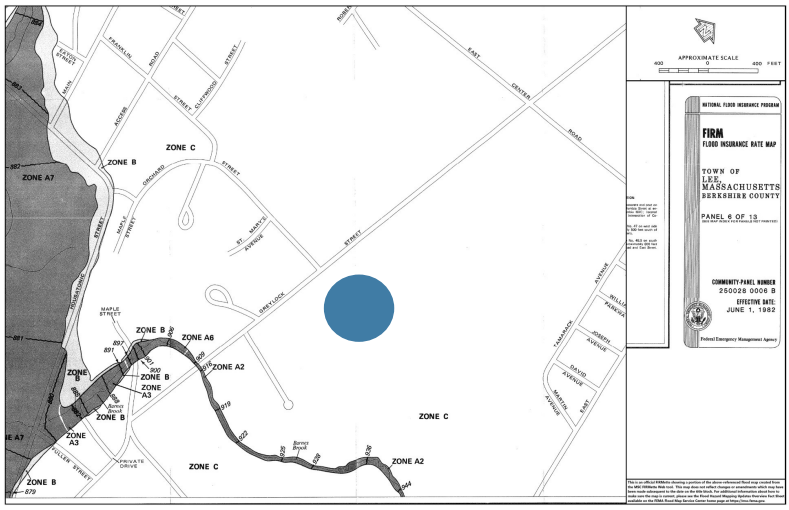
Boston's Building Emissions Reduction and Disclosure Ordinance (BERDO) applies to large existing buildings in the city and, outside Boston, serves as a useful benchmark for owners to proactively align upgrades with statewide goals. As Massachusetts targets net-zero GHG emissions by 2050, similar policies may be adopted statewide. Achieving "zero" depends on the pace of statewide renewable energy adoption, with any remaining gaps addressed through RECs or clean electricity aggregation programs.



Future grid emission projections are based on BERDO Version 3 emission factors, which the City of Boston reassesses every five years.

Resiliency Considerations

The facility is located outside of the current FEMA flooding zones but is near the affected area of the Housatonic River Flood Plain. Considering the potential for intense weather events, including extreme rainfalls in short timeframes, a climate change vulnerability assessment may be recommended, including flood proofing measures for both the site and the facility, such as the electrical service, generator and other energy systems equipment located at ground level. Future peak load reduction measures such as on-site battery storage may be a consideration for additional resiliency.



Next Steps and Best Practices

There are many potential strategies to reduce the operational GHG emissions of buildings. As a starting point, owners are encouraged to have a solid understanding of base building information, including current energy use, carbon emissions, and long-term property goals through 2050. The data and scoping developed through this assessment can be used by design teams, including architects and engineers, to begin shaping project plans and construction timelines, while also strengthening financing strategies and incentive applications. To move from assessment to action and ensure a clear, strategic path toward decarbonization, the following next steps are recommended.

- [x] Existing building conditions
- [x] Decarbonization assessment
- [ ] Supplemental assessments
  - Structural roof assessment
- [ ] Emergency protocols
- [ ] Assemble project team
- [ ] Structure financing stack