MASSACHUSETTS CLEAN ENERGY CENTER

Turners Falls Middle & High School

This case study is part of the MassCEC BETA: Project Planning program, committed to helping a representative selection of commercial building types in Massachusetts reach net zero emissions by 2050.

Building type	Education
Location	Montague
Year built	1970
Stories	3
Square footage	133,357
Energy use intensity (EUI)*	78.5 kBtu/sf/yr
Carbon emission intensity (CEI)*	4.2 CO2e kg/sf/yr
Decarbonization goals	Occupant thermal comfort, utility cost savings, regulatory compliance

The school underwent a major renovation and addition in 2003, and the building enclosure is currently in fair condition. Since then, LED lighting upgrades have been implemented, though portions of the installation are now presenting a fire hazard. Heating is provided by gas-fired boilers. The 2003 addition is served by direct expansion (DX) cooling via rooftop units (RTUs), while the original academic wings lack cooling. The school has expressed a desire to expand cooling throughout the entire building. The existing rooftop solar PV system, now more than 20 years old, is nonfunctional and slated for replacement.

Existing Conditions

	Walls	**Roof**	**Windows**
Enclosure	Poor	Poor	Fair
Heating	Gas boiler: hot water distributed to unit ventilator in classrooms and RTUs/heat recovery units (HRUs) (single zone), heat pumps in select spaces		
Cooling	DX cooling at RTUs for select areas (no cooling at classrooms).		
Ventilation	RTUs, HRUs, and unit ventilators		
Hot water	500-gal indirect fired gas tanks (2)		
Lighting	Full LED lighting (old technology causing safety and fire hazard)		
Controls	Occupancy and daylight controls		
Other	Full commercial kitchen with gas appliances		
Renewable energy	Existing ~34 kW rooftop solar PV system (nonfunctional)		

*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

Reported thermal comfort concerns

Prioritize air sealing to reduce air infiltration. Upgrade unit ventilators in the classrooms to air-to-water heat pumps (AWHP) to include cooling

Nonfunctional existing solar PV system and aging roof

Remove existing Solar PV and consider increasing insulation at time of roof replacement. Install new and expanded solar PV system

Multiple HVAC systems serving different areas and low floor-to-structure height constraints

A multi-system approach will minimize intrusive and costly interior renovations, including AWHPs to replace hydronic heating systems (while adding cooling) and heat pump RTUs

Core Decarbonization Strategies

- AWHP system to replace existing boilers at end-of-life, adding cooling capabilities to classrooms
- Heat pump RTU/HRU equipment is phased to align with system end-of-life and manage upfront costs
- Air sealing, new roof, and new windows addresses thermal comfort concerns and reduces energy load for electrification benefits.

Retrofit Measures and Energy Impacts

Measures

Energy Efficiency & Load Reduction

Foundational Efficiency and Load Reduction:

- LED lighting and controls upgrades
- Demand control ventilation (DCV)
- Air sealing and weatherstripping

Advanced Load Reduction:

- Additional roof insulation (R-52)
- High-performance triple-pane windows

System Electrification

Electrification Enablers:

- Electrical service upgrade
- Low temperature hot water infrastructure upgrade

System Electrification:

- AWHP system to replace gas boilers
- Phased heat pump RTU/HRU replacement including heat recovery
- Heat pump domestic hot water (DHW) heater

Renewable Energy

Solar:

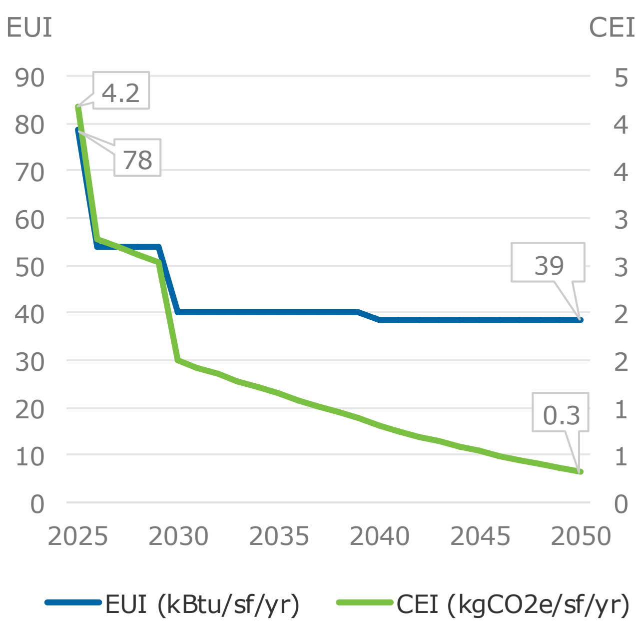
- Install new solar PV array (remove existing solar PV system)

Battery Storage:

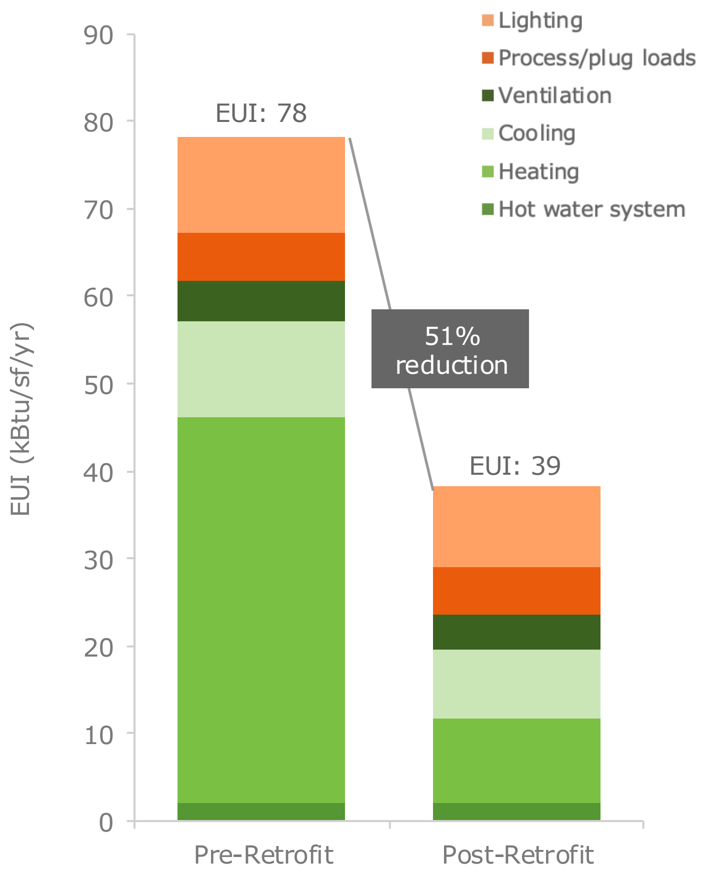
- Install ~200kW battery storage system

Performance Targets

The decarbonization approach prioritizes end of life equipment replacement and system electrification over a 15-year timeline. The recommended measures enable the property to reach a 51% EUI reduction and up to 81% GHG reduction. These efforts would yield the following results over time:



Annual Energy Use Impacts*



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

Triggers

Foundational energy efficiency improvements are not time dependent and may implemented prior to the electrification to support right sizing and energy cost savings

2030-2035: Conduct capacity evaluation of existing electrical service prior to HVAC electrification and installing new renewable energy systems

2030-2035: Coordinate new HVAC rooftop equipment location with future solar PV installation

2030-2035: Planning and design of the systems to be coordinated with HVAC and electrical service upgrades

2040: Remaining RTUs reach the end of their service life

Order of Implementation

Cumulative Carbon Reduction Potential*

LED Lighting Upgrade
Replace existing LEDs with more efficient, safe LED fixtures

Demand Control Ventilation (DCV) System
Install CO2 Sensors in all applicable spaces

Infiltration Reduction
Air sealing and weatherstripping

35%

Electrical Distribution Panel Upgrade
Upgrade electrical for mechanical system electrification

RTU/HRV Replacement (5 units)
Replace existing RTUs at end-of-life for large air volume spaces with heat pump RTUs

HRU Replacement (5 units)
Replace existing end-of-life HRUs for more efficient HRUs

Roof Replacement
Increase insulation level and remove existing solar array

DHW Electrification
Install heat pump DHW heater to replace current steam water heating system

Low Temperature Hot Water Infrastructure
Upgrade unit ventilators for mechanical system electrification (add cooling capacity to classrooms)

AWHP Installation
Replace existing gas boilers at end-of-life with an AWHP

Window Replacement
Installation of new triple-glazed windows

Solar PV System & Battery Storage
Install rooftop PV system & battery storage. The systems would represent an estimated 20.7% GHG emissions reduction

64%

RTU Replacement (remaining 2 units)
Replace existing end-of-life RTUs for large air volume spaces with more efficient Heat Pump RTUs

81%

Zero on-site fossil fuel combustion
(With the exception of any backup power)

*GHG calculations are based on Boston's BERDO Version 2.3 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

Annual Utility Impacts

Measure description	Changes in annual utility costs		
	Electricity	Fossil fuel	Net total changes
Lighting	($26,900)	-	($26,900)
Process/plug loads	$39,800	($6,200)	$33,600
Ventilation	($8,100)	-	($8,100)
Cooling	($42,400)	-	($42,400)
Heating	$117,700	($104,000)	$13,700
Hot water system	$29,200	($5,100)	$24,100
Total from recommended measures	**$109,300**	**($115,300)**	**($6,000)**
Renewable energy	($68,000)	-	($68,000)

Estimated additional utility savings from renewable energy are based on a new 300 kW rooftop solar PV system paired with a 200 kW battery storage system. The existing solar PV system is nonfunctional. A solar PV parking canopy may be considered for additional savings, though is 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 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 pathway.

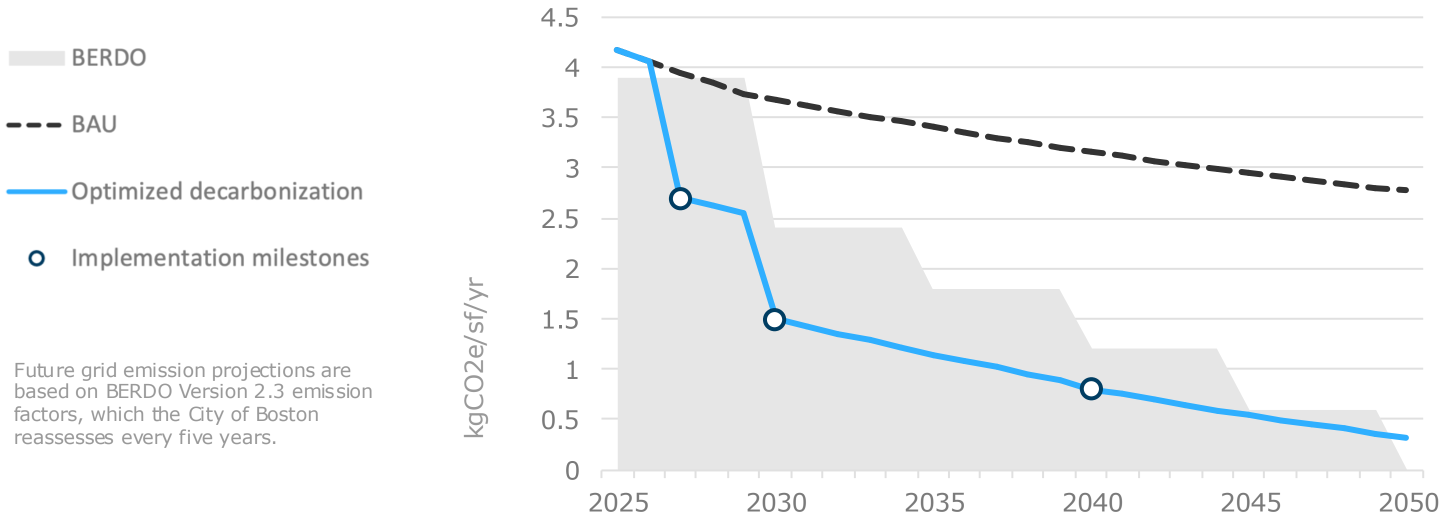
Costs	**BAU retrofit**	**Optimized decarbonization pathway**	
Base building and envelope costs	$4,494,000	$1,411,000	Foundational efficiency and load reduction
		$4,975,000	Advanced load reduction
Mechanical costs	$8,661,000	$2,134,000	Electrification enablers
		$5,143,000	System electrification
Renewable energy costs	$0	$1,173,000	Renewable energy
Soft costs	$4,604,000	$5,193,000	
Total upfront costs	**$17,759,000**	**$20,029,000**	
Utility incentive opportunities	$0	$1,121,000	
25-year total accrued utility costs	$21,548,000	$16,716,000	
25-year accrued total operating costs	$24,642,000	$18,667,000	
25-year LCCA	**$42,401,000**	**$37,575,000**	

BAU scope:
- Boiler and DHW system replacement
- RTUs/HRUs replacement
- Roof and window replacement
- Electrification ready infrastructure based on code requirements (fossil fuels are maintained as the primary heat source)
- No additional cooling
- Unit ventilator refurbishing or replacement

*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 gas or code-compliant versions of the decarbonization measures listed.

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 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.



Resiliency Considerations

The school is located outside of the current FEMA flooding zones (Connecticut River area), so future flood risk is expected to remain low. Future weather patterns are likely to affect electricity consumption, system loads, and peak demand. As temperatures are projected to rise by 2050, analysis indicates that overall electricity consumption could decrease by approximately 15%. In the event of periods of extreme heat and extreme cold, building enclosure improvements and on-site solar generation are expected to help moderate energy demand.

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
    - Thermal stress capacity test for hot water infrastructure
    - Evaluation of existing electrical infrastructure
- [ ] Emergency protocols
- [ ] Assemble project team
- [ ] Structure financing stack