Temple Beth Avodah

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	Religious worship
Location	Newton
Year built	1970
Stories	3
Square footage	32,128
Energy use intensity (EUI)*	56.1 kBtu/sf/yr
Carbon emission intensity (CEI)*	2.7 CO2e kg/sf/yr
Decarbonization goals	Occupant thermal comfort, utility cost savings, regulatory compliance

Temple Beth Avodah, located in Newton, MA, is a three-story religious worship building that includes a temple and an administrative and school space. The building was built in 1970 with a major renovation in 1997 and an addition in 2019 to join the temple and administrative/school spaces together.

Existing Conditions

	Walls	Roof	Windows
Enclosure	Fair	Good	Fair
Heating	Gas-fired rooftop units (RTUs) (12) and three gas-fired boilers (installed 1997). Radiant perimeter heating		
Cooling	Direct expansion (DX) cooling RTUs (12) and a split chiller (installed 2019)		
Ventilation	Integrated into RTUs via enthalpy economizers. Two make-up air units on the school side. No CO2 control		
Hot water	100-gal gas-fired water heater (installed 1997)		
Lighting	98% LED lighting		
Controls	None		
Other	Gas range, walk-in cooler/freezer, dishwashing equipment in the kitchen		
Renewable energy	Rooftop solar PV system owned and operated under power purchase agreement (PPA)		

*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

New chiller installed recently

Retain chiller until it reaches end-of-life, and in the interim, install an air-to-water heat pump (AWHP) to operate in heating-only mode

HVAC systems are different types and ages

Different floors are served by different systems, allowing for phased one-to-one replacement of RTUs with heat pump RTUs, and deployment of an AWHP system to serve areas currently conditioned by the existing hydronic system

Limited controls

Prioritize installing occupancy sensors, dimmers, and temperature setbacks

Core Decarbonization Strategy

- HVAC upgrades offer opportunities to retain portions of existing hydronic heating system
- New equipment is staged over long term to align with system end-of-life and optimize upfront costs
- Adding building control strategies cuts down on overall energy consumption and equipment wear

Retrofit Measures and Energy Impacts

Measures

Energy Efficiency & Load Reduction

Foundational Efficiency and Load Reduction:
- Occupancy sensors
- Dimmers
- Temperature setbacks
- Weatherstripping
- Air sealing

Advanced Load Reduction:
- Window replacement

System Electrification

Electrification Enablers:
- Electrification infrastructure (subpanel capacity) should be further assessed

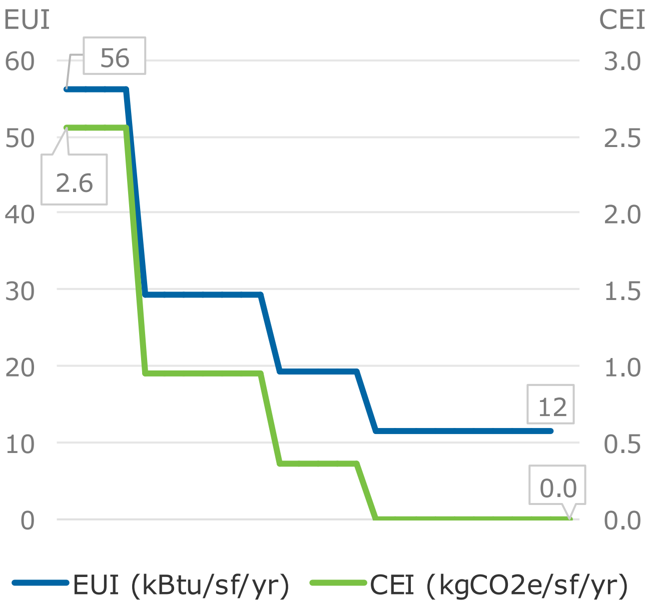
System Electrification:
- Heat pump RTUs replace single-zone RTUs
- AWHP system replace gas-fired boiler
- Heat pump domestic hot water (DHW) system

Renewable Energy

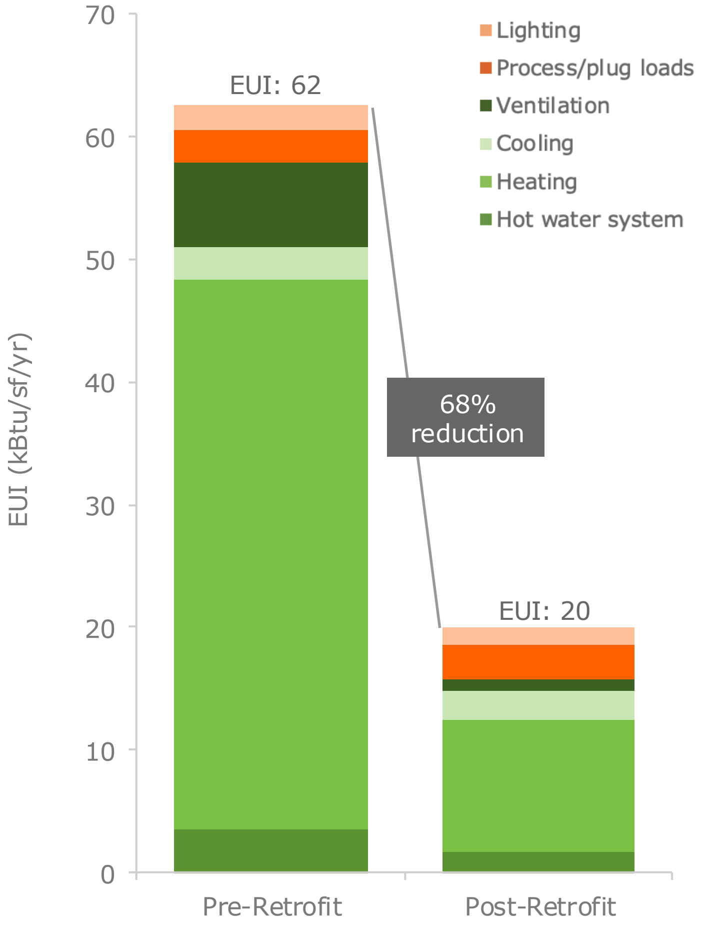
Solar:
- Existing solar PV array installed during 2023 producing ~70,000 kWh/yr (PPA)

Performance Targets

The decarbonization approach prioritizes phased, cost-effective replacement of HVAC and DHW system with heat pumps while preserving the existing hydronic heat distribution system. These efforts would yield the following results over time:



Annual Energy Use Impacts*



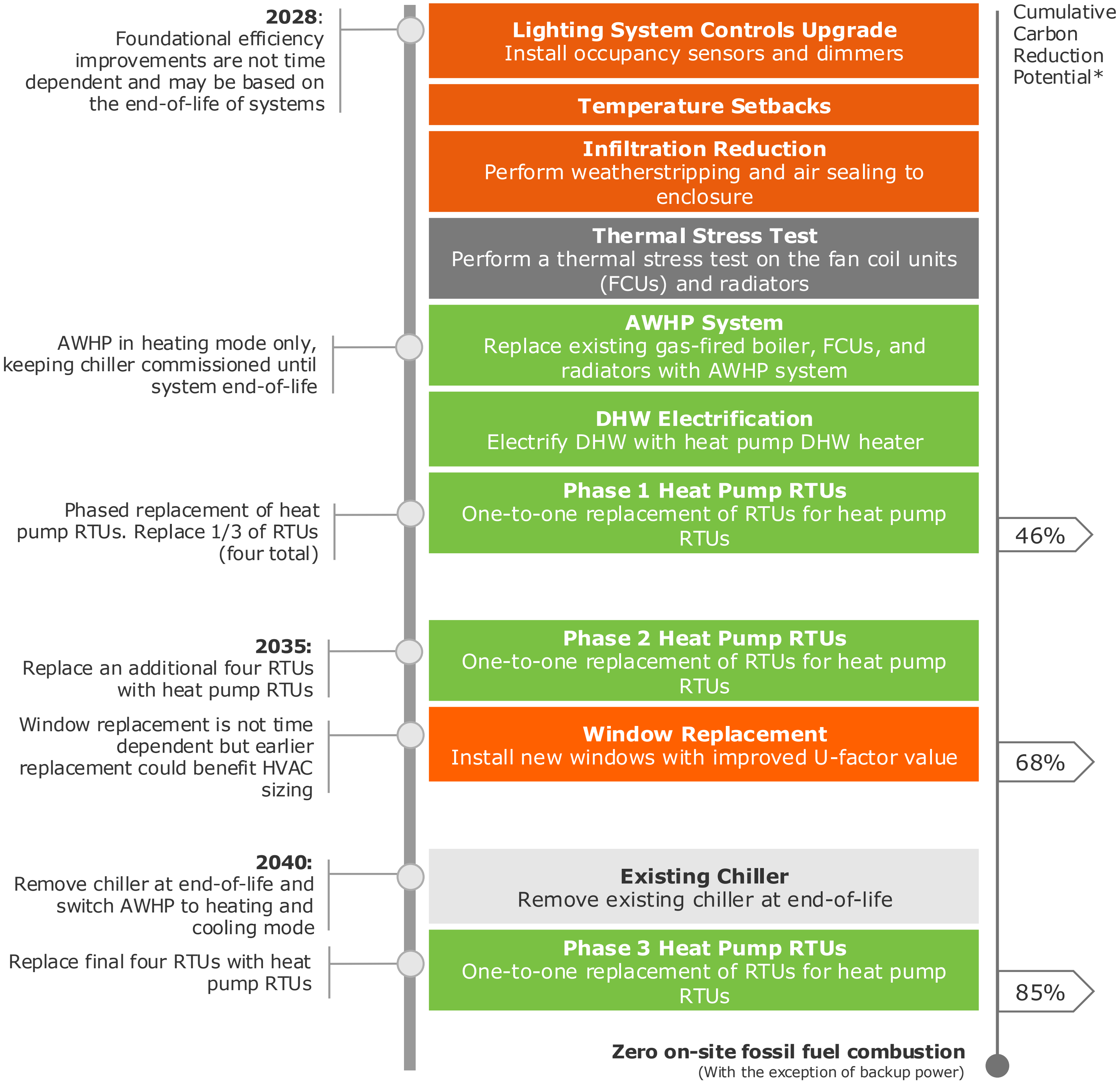
*The annual energy use impacts graphic illustrates an EUI before and after once all recommended measures are implemented, except for any renewable energy. The CEI and EUI shown in the performance targets account for the added benefits of renewable energy.

Project Planning

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

Order of Implementation



Cumulative Carbon Reduction Potential*

2028: Foundational efficiency improvements are not time dependent and may be based on the end-of-life of systems

Lighting System Controls Upgrade
Install occupancy sensors and dimmers

Temperature Setbacks

Infiltration Reduction
Perform weatherstripping and air sealing to enclosure

Thermal Stress Test
Perform a thermal stress test on the fan coil units (FCUs) and radiators

AWHP in heating mode only, keeping chiller commissioned until system end-of-life

AWHP System
Replace existing gas-fired boiler, FCUs, and radiators with AWHP system

DHW Electrification
Electrify DHW with heat pump DHW heater

Phased replacement of heat pump RTUs. Replace 1/3 of RTUs (four total)

Phase 1 Heat Pump RTUs
One-to-one replacement of RTUs for heat pump RTUs

46%

2035: Replace an additional four RTUs with heat pump RTUs

Phase 2 Heat Pump RTUs
One-to-one replacement of RTUs for heat pump RTUs

Window replacement is not time dependent but earlier replacement could benefit HVAC sizing

Window Replacement
Install new windows with improved U-factor value

68%

2040: Remove chiller at end-of-life and switch AWHP to heating and cooling mode

Existing Chiller
Remove existing chiller at end-of-life

Replace final four RTUs with heat pump RTUs

Phase 3 Heat Pump RTUs
One-to-one replacement of RTUs for heat pump RTUs

85%

Zero on-site fossil fuel combustion
(With the exception of 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	$3,195	-	$3,195
Process/plug loads	$7,661	-	$7,661
Ventilation	($10,050)	-	($10,050)
Cooling	$5,429	-	$5,429
Heating	$54,904	($23,619)	$31,284
Hot water system	$8,240	($1,910)	$6,330
Total from recommended measures	**$69,379**	**($25,529)**	**$43,849**

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	$483,000	$110,000	Foundational efficiency and load reduction
		$530,000	Advanced load reduction
Mechanical costs	$783,000	$0	Electrification enablers
		$1,261,000	System electrification
Renewable energy costs	$0	$0	Renewable energy
Soft costs	$127,000	$190,000	
Total upfront costs	**$1,393,000**	**$2,092,000**	
Utility incentive opportunities	$0	$410,000	
25-year total accrued utility costs	$2,398,000	$2,512,000	
25-year accrued total operating costs	$4,902,000	$4,925,000	
25-year LCCA	**$6,295,000**	**$17,201,000**	

BAU scope:

- RTU replacement
- Boiler replacement
- Double-pane windows
- Gas-fired DHW heater
- Roof replacement
- Lighting replacement

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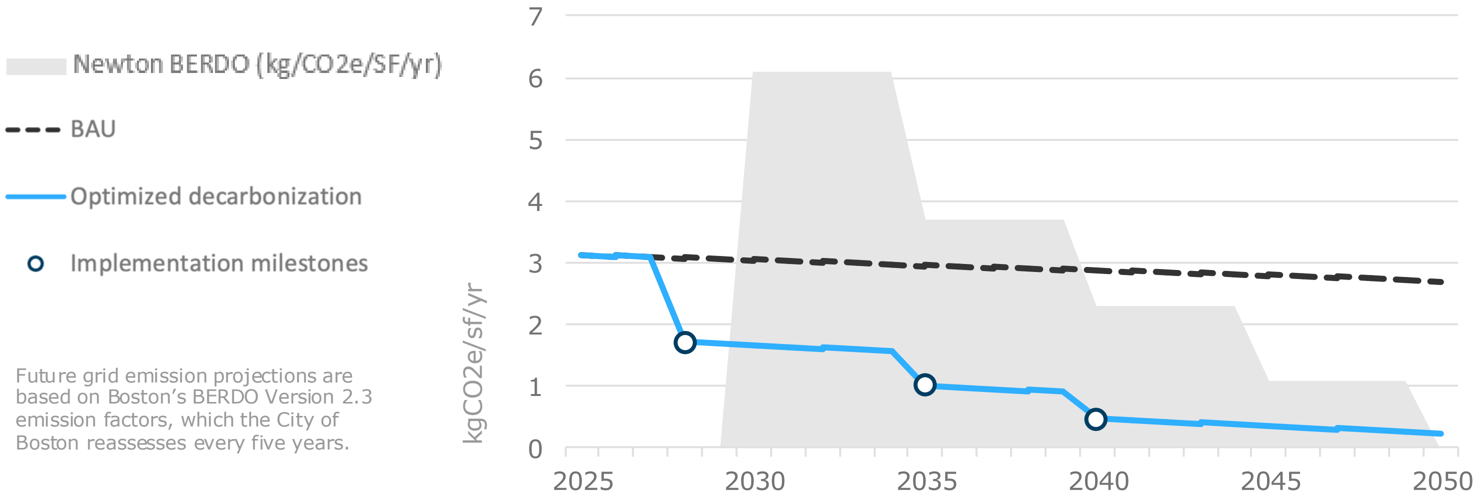
*All cost and incentive values are estimated based on industry data and rounded to the nearest $1,000. All incentives values are based on currently available programs and are subject to change over time. Forecasted operating costs include utility costs, maintenance costs, and noncompliance fees if relevant. 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.

Decarbonization Benefits

Emissions Goals and Benchmarking

Newton’s Building Emissions Reduction and Disclosure Ordinance (Newton BERDO) applies directly to large existing buildings in the city of Newton and serves as a useful benchmark for emissions planning. 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.



Future grid emission projections are based on Boston’s BERDO Version 2.3 emission factors, which the City of Boston reassesses every five years.

Resiliency Considerations

The temple is located outside of, but relatively close to, the current FEMA flooding zones (Sawmill Brook 3 Area). Considering the potential for intense weather events, including extreme rainfalls, 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. The existing solar PV provides for 14% of the current annual energy use. Future solar PV expansion (with battery storage) on site may be a consideration for additional resiliency.

Existing rooftop solar array.

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.

- ☑ Existing building conditions
- ☑ Decarbonization assessment
- ☐ Supplemental assessments
  - ○ Thermal stress test
  - ○ Evaluation of existing electrical infrastructure
- ☐ Emergency protocols
- ☐ Assemble project team
- ☐ Structure financing stack