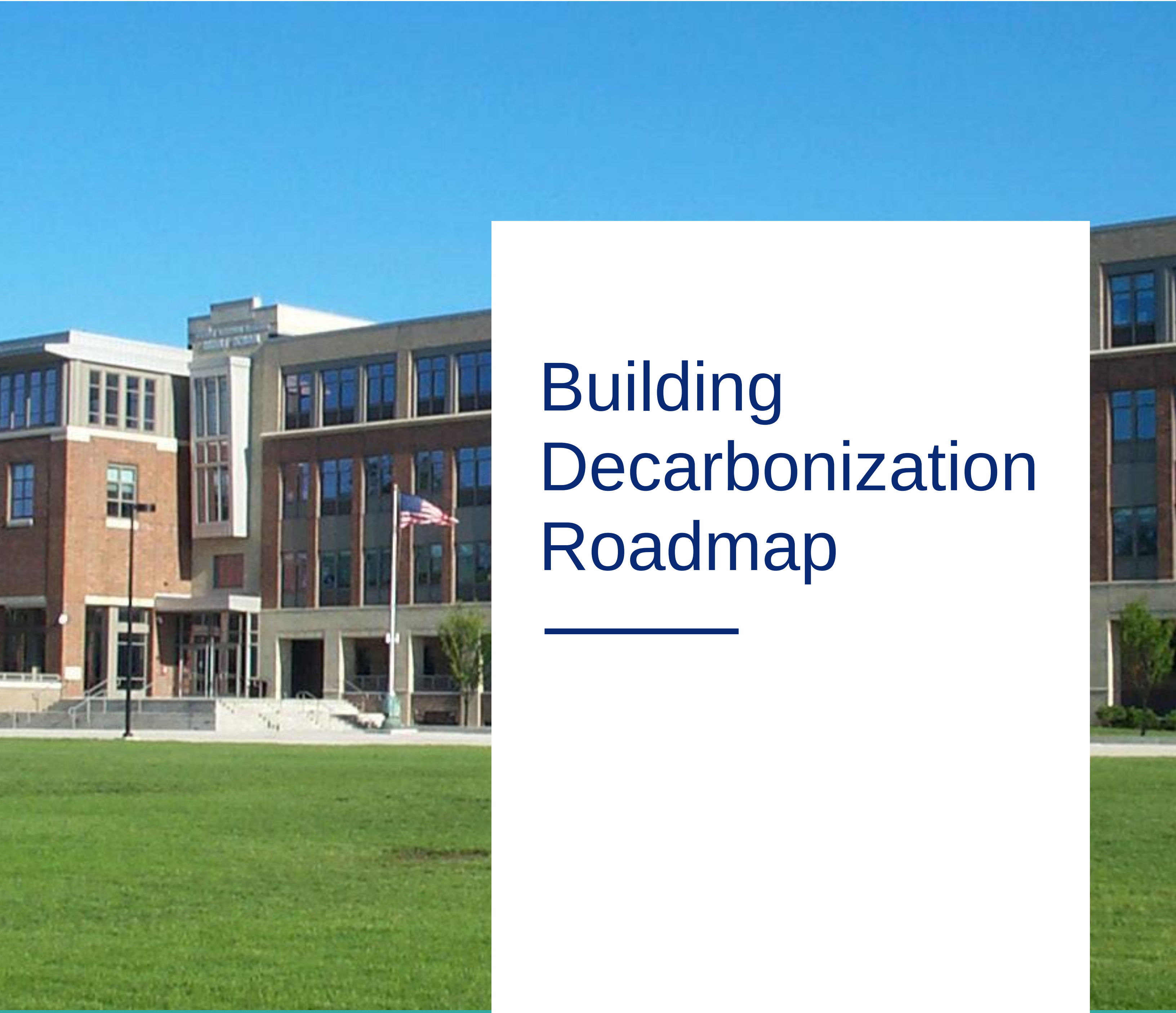


Building Decarbonization Roadmap

JULY 2023

Prepared for The City of Melrose Public Schools

Executive Summary

PowerOptions developed this Building Decarbonization Roadmap for reducing greenhouse gas (GHG) emissions from ten existing school buildings owned by the City of Melrose. Based on our analysis, the City of Melrose can **cost-effectively reduce its school building-related emissions to net zero by 2050**.

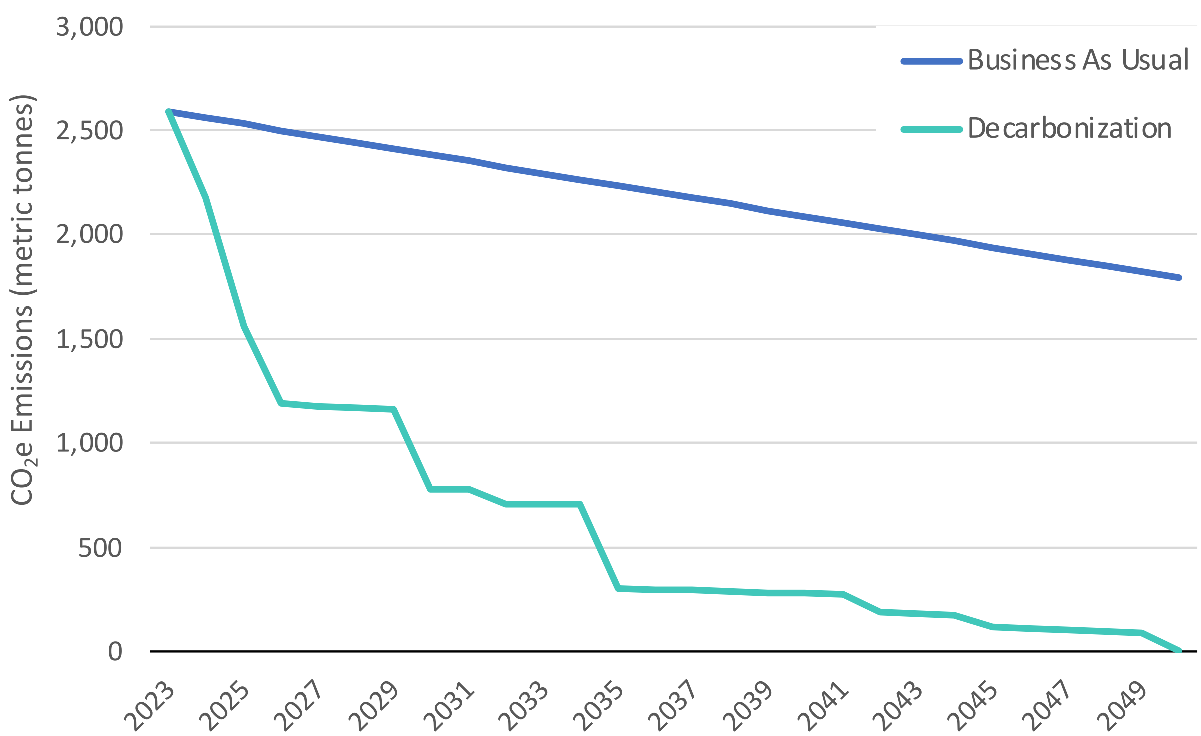
This analysis evaluates the following strategies to decarbonize the City of Melrose's school buildings: energy efficiency, electrification (fuel-switching away from fossil fuels to electric alternatives), on-site solar photovoltaics, and Renewable Energy Certificates. We use a combination of an in-house economic model, an open source virtual energy efficiency audit tool (US Department of Energy's BETTER), and Helioscope solar software to produce this roadmap.

By 2050, this roadmap is estimated to reduce the City of Melrose's GHG emissions from its schools by nearly 55,000 metric tons (MT) of carbon dioxide equivalent (CO_2e) and save between $3 and $10 million. Figure 1 below compares the emissions of a "business as usual" (BAU) scenario and our roadmap's Decarbonization scenario.

KEY FACTS

- **10 Buildings**
  - **Total 817,117 ft^2**
- **2022 Usage:**
  - **4,200 MWh**
  - **28,000 MMBTU natural gas**
  - **2,600 MT CO_2e**
- **2050 Usage:**
  - **2,400 MWh**
  - **No fossil fuels**
  - **0 MT CO_2e**

Figure 1. CO_2e emissions by scenario, 2023-2050.



Roadmap Timeline

The overarching roadmap timeline is shown below for the City of Melrose's ten buildings:

Building 1: *Beebe Elementary School*
Building 2: *Franklin Early Childhood Center*
Building 3: *Hoover Elementary School*
Building 4: *Horace Mann Elementary School*
Building 5: *Lincoln Elementary School*
Building 6: *Melrose High School*
Building 7: *Melrose Memorial Middle School*
Building 8: *Ripley Elementary School (SEEM)*
Building 9: *Roosevelt Elementary School*
Building 10: *Winthrop Elementary School*

2023

- Energy efficiency audit *(all buildings)*
- Reassess heating setpoints and equipment schedules (*all buildings*)
- Continue to reduce lighting and plug loads (*all buildings*)

2024

- Update or replace outdated building management systems (*Buildings 2-7 & 9-10*)
- Implement building management system (*Buildings 1 & 8*)
- Consider additional air sealing and insulation upgrades (*Buildings 2-6 & 8-10*)

2025

- Replace natural gas water heaters with heat pump water heaters (*Buildings 5 & 9*)
- Installation of heat pumps (*Buildings 2, 3 & 5*)
- Installation of on-site solar (*Buildings 1, 2, & 5)*

2026

- Upgrade windows (*Buildings 1 & 2*)

2027

- Installation of heat pumps (*Building 9*)
- Replace natural gas water heater with heat pump water heater (*Building 7*)

2028

- Upgrade windows (*Buildings 4-6*)

…Continued on next page…

2029

- Upgrade windows (*Buildings 8-10*)

2030

- Installation of heat pumps (*Buildings 8 & 10*)
- Replace natural gas water heaters with heat pump water heaters (*Buildings 1-3, 8 & 10*)
- Installation of on-site solar (*Buildings 8 & 10*)

2032

- Installation of on-site solar (*Building 9*)

2034

- Get quotes for ground-source heat pumps (*Buildings 6 & 7*)

2035

- Installation of ground-source heat pumps (*Buildings 6 & 7*)

2042-2045

- Installation of heat pumps (*Buildings 1 & 4*)

2050

- Purchase renewable energy certificates (RECs) to offset electricity emissions and reach the state of Massachusetts' goal of net zero by 2050 *(all buildings)*

Energy Efficiency

Energy efficiency (EE) refers to any upgrade to a building that reduces energy usage and, in many cases, costs. Because energy efficiency projects are cost-effective today, our roadmap recommends prioritizing it early in the roadmap to capitalize on energy savings for the remainder of the roadmap.

Based on one year of utility bills, the BETTER tool recommends at least the following **efficiency projects**:

- Reassess heating setpoints and equipment schedules within existing Building Management System (BMS) (*Buildings 2-7 & 9-10*)
- Implement BMS (*Buildings 1 & 8*)
- Retro-commission existing BMS and confirm it is working as installed and programmed in 2014
- Improve building envelopes and pursue additional air sealing (*Buildings 2-6, & 8-10*)
- Continue to reduce lighting and plug loads (*all buildings*)
- Upgrade windows (*Buildings 1-2, 4-6, & 7-10*)

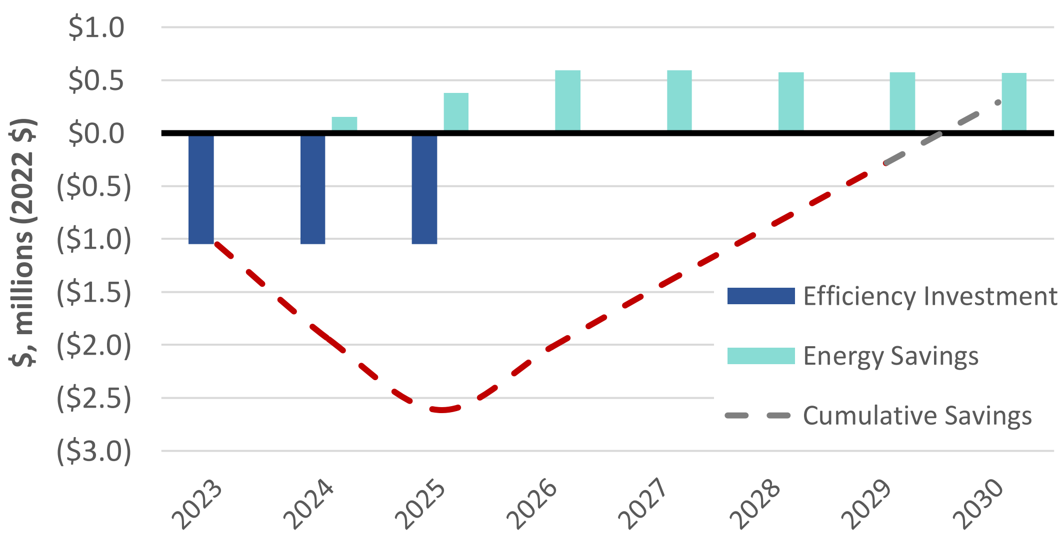
Energy Efficiency Impacts

***Investment**: $7.5m* **|** ***Incentives**: $4.4m*
***Net cost:** $3.1m*

***Year 1 Savings:** $150k*
***Annual Savings after Completion**: $550k*
***Payback:** 7 years*

Massachusetts offers strong incentives for commercial customers to implement certain energy efficiency projects. As a result, the up-front cost of efficiency projects is reduced by 58 percent and the **payback period is about 7 years**. Relative to operating "business as usual," the City of Melrose will **save about $550,000 annually on energy costs** by implementing efficiency projects (Figure 2).

Figure 2. Net savings from implementing energy efficiency projects, 2023-2030.



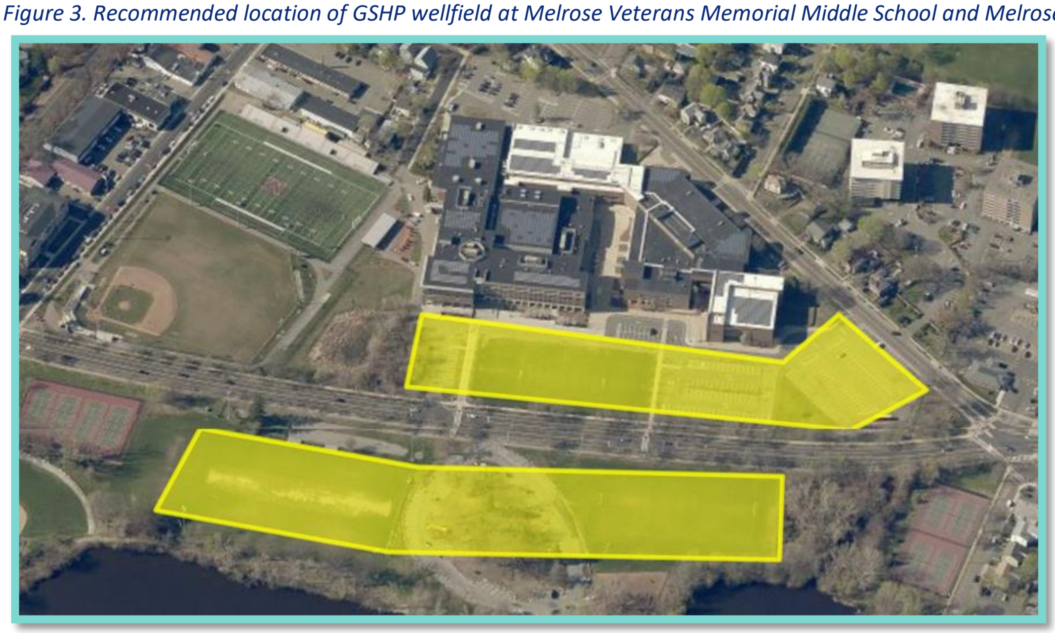
Electrification

After the buildings have been made as efficient as possible, the next step is to electrify existing fossil fuel equipment by converting space and water heating equipment to high-efficiency heat pumps and cooking ranges to induction ranges.

Heat pumps (HP) are an efficient all-electric solution for a building's space heating and cooling needs. Heat pumps work similarly to an air conditioner, but they are more efficient and provide heating in the winter by operating in reverse. In contrast to fossil fuel heating equipment that has an efficiency of 80-95%, heat pumps have an efficiency ranging from 250% to 400%, meaning they produce more energy than is put into them. The two primary types are air-source heat pumps and ground-source heat pumps. Air-source heat pumps transfer heat to and from the outside air, whereas ground-source heat pumps, often referred to as geothermal heat pumps, transfer heat to or from the ground to heat or cool a building. Ground-source heat pumps are extremely efficient—even more so than air-source heat pumps—because the temperatures deep in the earth are constant year-round.

The ten buildings currently utilize natural gas boilers for space heating. Our recommendation is to replace these systems with ground-source heat pumps (GSHP) at Melrose Veterans Memorial Middle School and Melrose High School, and Variable Refrigerant Flow (VRF) heat pumps at the remaining buildings. VRFs are advanced heat pumps that can provide both heating and cooling at the same time to different parts of the building, and ductwork is not required in the buildings. We suggest GSHPs at two buildings due to their large size, which provides better economics for GSHP systems. We recommend starting these electrification projects around 2025 to maximize the remaining lifetime of the City of Melrose's heating systems.

Figure 3. Recommended location of GSHP wellfield at Melrose Veterans Memorial Middle School and Melrose High School.



Based on the current capacity of the City of Melrose's Middle and High School's heating systems, we estimate that the ground-source heat pumps will require about 150 wells and should be installed in 2035 to maximize the remaining useful life of the current gas boiler systems that were installed in 2014 (Melrose High School) and 2007 (Melrose Veterans Memorial Middle School). We recommend placing these wells in the area highlighted in Figure 3, which covers about 440,000 square feet. Since this project will take place over a decade in the future, there may be technological advances that reduce the ground surface area requirements and impact on the school footprint.

Heat pumps can also be used for water heating, in the form of a heat pump water heater, which transfers heat from the air into the water. Eight of the city's ten school buildings currently use natural gas tank water heaters for water heating; we suggest replacing these with heat pump water heaters (HPWH) in 2025, 2027, and 2030. Finally, we recommend replacing the natural gas cooking range at Melrose Veterans Memorial Middle School with an induction range.

Heat pumps are eligible for strong incentives through MassSave. Based on our suggestion above, we estimate that the total cost of the VRF and GSHP equipment and installation will be between $8,000,000 and $11,000,000. Based on current incentive levels through MassSave, **the net cost after incentives would be between $4,500,000 and $6,000,000**.[1] Today, The City of Melrose's utility bills sum to about $1,000,000 per year. After doing energy efficiency projects and converting to heat pumps, we estimate that The City of Melrose's utility bills will sum to about $400,000 per year, saving about $600,000 per year. If this investment were financed through an "electrification-as-a-service" model, the City of Melrose would not have to pay for the electrification project upfront; rather, they would have a fixed payment of between $380,000 and $600,000 per year for 15 years, in addition to the utility bill costs of $400,000 per year. Note that none of these cost estimates include the cost of removing any existing systems.

Electrification Impacts

HPs Investment: *$8-11m*
HPs Incentives: *$3.5-5m*
HPs Net Cost: *$4.5-6m*

HPWH Investment: *$880k*
HPWH Incentives: *$20k*
HPWH Net Cost: *$860k*

Induction Range Investment: *$1-1.4k*
Induction Range Incentives: *$500-750*
Induction Range Net Cost: *$500-650*

CO_2e reduced*: 25,000 MT CO2e by 2050*

[1] Note that federal incentives are also available if the electrification project is paired with energy efficiency projects to reduce the building's total energy consumption by over 25%.

Solar

Using Helioscope software, PowerOptions evaluated the City of Melrose's options for on-site solar PV. We suggest installing on-site rooftop solar systems at:

- Beebe Elementary School (136 kW)
- Franklin Early Childhood Center (103 kW)
- Lincoln Elementary School (223 kW)
- Ripley Elementary School (125 kW)
- Roosevelt Elementary School (210W), and
- Winthrop Elementary School (100 kW)

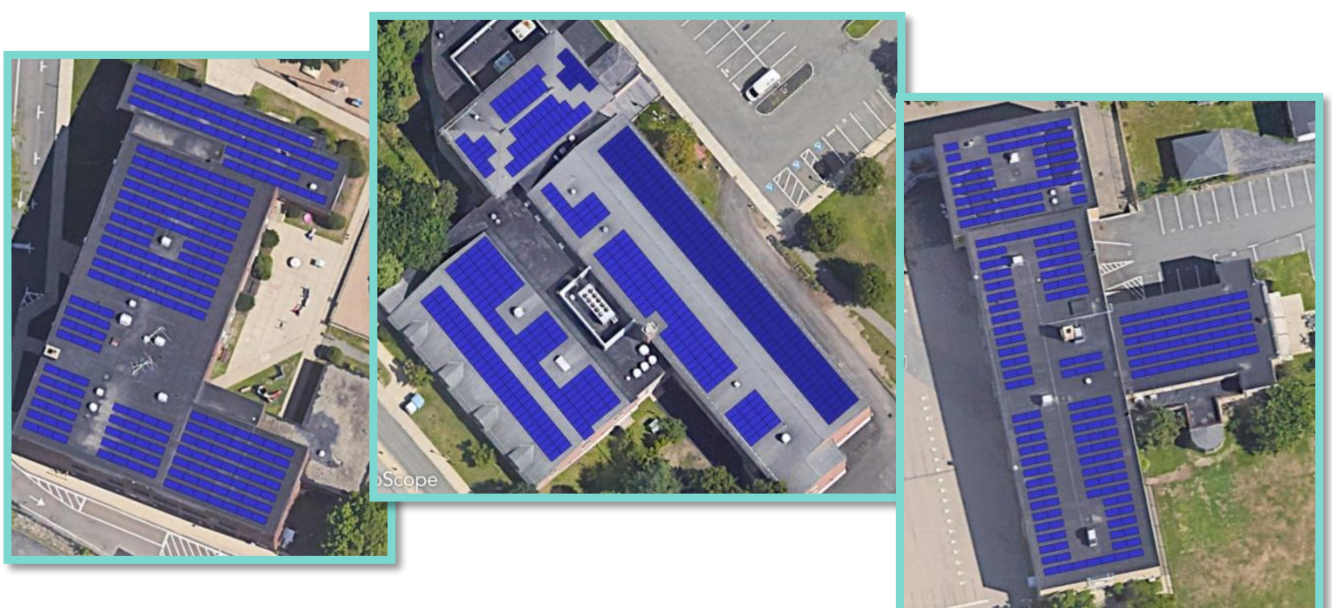
<u>Solar Impacts</u>

On-site Solar Generation: *1,000 MWh/year*
Average PPA Rate: *$0.14/kWh*
CO_2e reduced*: 4,000 metric tons by 2050*

This assessment assumes a Power Purchase Agreement (PPA) to align with the financing model of existing systems at Melrose Veterans Memorial Middle School and Melrose High School. We recommend installing these systems as soon as 2025, so that installation aligns with the end of the lifespan of the current roofs at the Beebe, Franklin, and Lincoln Schools. In a PPA, there is no upfront cost for the project; instead, the City of Melrose will purchase the electricity generated from the systems at a fixed price of $0.14 per kWh. If the city decides to own the on-site systems, the upfront cost after Massachusetts SMART incentive contributions would be about $1,500,000.

The six solar systems are collectively expected to produce over 1,000 MWh of electricity annually. The avoided cost of purchasing this electricity from the grid is expected to be about $115,000 per year, saving the City of Melrose **over $2 million in electricity costs through 2050.** Furthermore, these systems will avoid nearly 4,000 metric tons of CO_2e emissions through 2050.

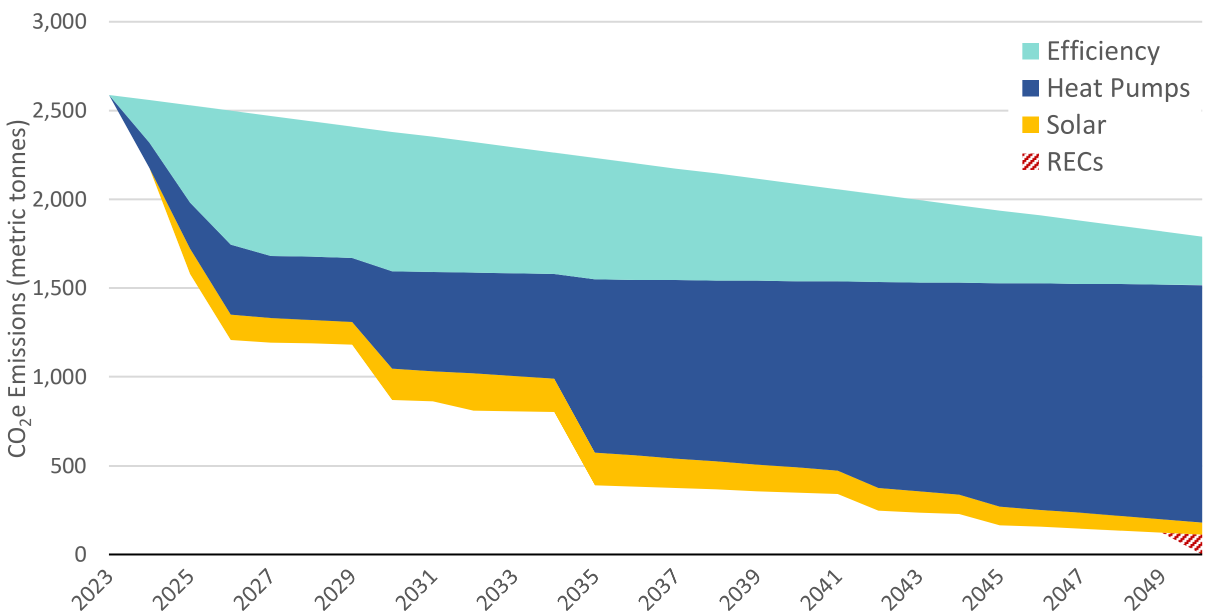
Figure 4. Locations of on-site solar system at the (from left) Franklin, Roosevelt, and Winthrop Schools, developed with HelioScope.



Getting to Net Zero

After completing all energy efficiency projects and installing heat pumps, the City of Melrose will be using about 2,400 MWh per year on average. It is possible the New England electric grid will be powered by 100% renewable energy, in which case the City of Melrose could get to net zero as early as 2045, but there is a chance that will not happen before 2050. In that case, the City of Melrose's load may equate to about 112 metric tons of CO_2e emissions remaining in 2050. To get to net zero, the City of Melrose will need to purchase Renewable Energy Certificates (RECs) to offset the emissions associated with the electricity purchased from the grid or purchase 100% clean energy through a supplier.

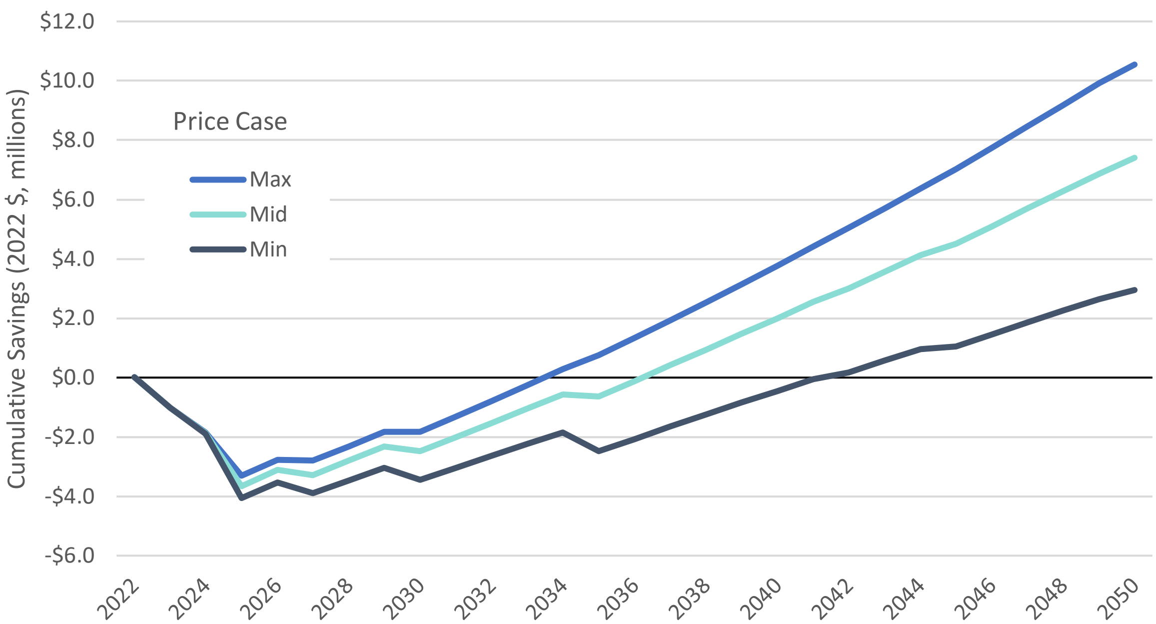
Figure 5. Impact of carbon dioxide reduction by type of project, 2023-2050.



Financial Impact

After incentives, the total investment required to execute this roadmap is estimated at $9 million. Of the possible ways to decarbonize the City of Melrose's buildings, we believe this is the most cost-effective way. Depending on future energy prices, **the City of Melrose is expected to save between $3 and $10 million by 2050** (Figure 6).

Figure 6. Cumulative savings from Decarbonization Scenario, by price case.



Implementation and Next Steps

This roadmap illustrates that the City of Melrose can cost-effectively reach net zero GHG emissions by 2050. To achieve that goal, we recommend setting interim targets of 50% by 2030 and 75% by 2040.

PowerOptions' assistance is available to put this roadmap into action. The first step to embarking on your building electrification roadmap is to receive a no-cost energy efficiency audit for your buildings. PowerOptions has an energy efficiency program to help you get started on this path. We have two utility-approved vendors on hand to conduct **free energy audits and implement turnkey efficiency solutions**. PowerOptions has been working with members to help streamline the process and ensure they are receiving maximum possible incentives, lowest costs on equipment through our competitive procurements, financing opportunities, and guidance and assistance through every step of the process. To get started, please contact **Erin Camp,** PowerOptions' Energy Sustainability and Analytics Program Manager at ecamp@poweroptions.org.

Appendix

Building	Energy Efficiency (EE) Measures	EE Year	Heat Pump Type	Heat Pump Year & Reason	Solar PV PPA (kW)	Solar PV Year	Investment Cost ($ million)	Incentives Available ($ million)	Net Investment ($ million)
Beebe Elementary School	• Recommission existing Building Automation System and review HVAC equipment schedules • Upgrade windows • Convert to a heat pump water heater	2023-2030 (HP Water Heater 2030)	Variable Refrigerant Flow Heat Pump	2045, End of Life of existing heating system	136 kW	2025	$1	$0.4	$0.6
Franklin Early Childhood Center	• Recommission existing Building Automation System and review HVAC equipment schedules • Reassess building envelopes and improve air sealing • Reduce lighting and plug loads • Upgrade windows • Convert to a heat pump water heater	2023-2030 (HP Water Heater 2030)	Variable Refrigerant Flow Heat Pump	2025, End of Life of existing heating system	103 kW	2025	$1.2	$0.45	$0.75

Building	Energy Efficiency (EE) Measures	EE Year	Heat Pump Type	Heat Pump Year & Reason	Solar PV PPA (kW)	Solar PV Year	Investment Cost ($ million)	Incentives Available ($ million)	Net Investment ($ million)
Hoover Elementary School	• Recommission existing Building Automation System and review HVAC equipment schedules • Reassess building envelopes and improve air sealing • Convert to a heat pump water heater	2023-2030 (HP Water Heater 2030)	Variable Refrigerant Flow Heat Pump	2025, End of Life of existing heating system	67 kW	Existing install 2023	$0.9	$0.3	$0.6
Horace Mann Elementary School	• Recommission existing Building Automation System and review HVAC equipment schedules • Reassess building envelopes and improve air sealing • Upgrade windows	2023-2030	Variable Refrigerant Flow Heat Pump	2042, End of Life of existing heating system	50 kW	Existing install 2023	$0.6	$0.22	$0.38
Lincoln Elementary School	• Recommission existing Building Automation System and review HVAC equipment schedules • Reassess building envelopes and improve air sealing	2023-2030 (HP Water Heater 2025)	Variable Refrigerant Flow Heat Pump	2025, End of Life of existing heating system	223 kW	2030	$1.8	$0.66	$1.1

Building	Energy Efficiency (EE) Measures	EE Year	Heat Pump Type	Heat Pump Year & Reason	Solar PV PPA (kW)	Solar PV Year	Investment Cost ($ million)	Incentives Available ($ million)	Net Investment ($ million)
	• Complete LED lighting project to reduce lighting load • Upgrade windows • Convert to a heat pump water heater								
Melrose High School	• Recommission existing Building Automation System and review HVAC equipment schedules • Reassess building envelopes and improve air sealing • Complete LED lighting project to reduce lighting load • Upgrade windows	2023-2030	Ground-Source Heat Pump	2035, End of Life of existing heating system	301 kW	Existing	$5.7	$3.4	$2.3
Melrose Veterans Memorial Middle School	• Recommission existing Building Automation System and review HVAC equipment schedules • Complete LED lighting project to reduce lighting load • Convert to a heat pump water heater	2023-2030 (HP Water Heater 2027)	Ground-Source Heat Pump	2035, End of Life of existing heating system	50 kW	Existing	$4.9	$2.8	$2.1

Building	Energy Efficiency (EE) Measures	EE Year	Heat Pump Type	Heat Pump Year & Reason	Solar PV PPA (kW)	Solar PV Year	Investment Cost ($ million)	Incentives Available ($ million)	Net Investment ($ million)
Ripley Elementary School	• Recommission existing Building Automation System and review HVAC equipment schedules • Reassess building envelopes and improve air sealing • Upgrade windows • Convert to a heat pump water heater	2023-2030 (HP Water Heater 2030)	Variable Refrigerant Flow Heat Pump	2030, End of Life of existing heating system (estimate)	125 kW	2025	$0.6	$0.2	$0.4
Roosevelt Elementary School	• Recommission existing Building Automation System and review HVAC equipment schedules • Reassess building envelopes and improve air sealing • Complete LED lighting project to reduce lighting load • Upgrade windows • Convert to a heat pump water heater	2023-2030 (HP Water Heater 2025)	Variable Refrigerant Flow Heat Pump	2027, End of Life of existing heating system	210 kW	2032	$1.8	$0.67	$1.1

Building	Energy Efficiency (EE) Measures	EE Year	Heat Pump Type	Heat Pump Year & Reason	Solar PV PPA (kW)	Solar PV Year	Investment Cost ($ million)	Incentives Available ($ million)	Net Investment ($ million)
Winthrop Elementary School	• Recommission existing Building Automation System and review HVAC equipment schedules • Reassess building envelopes and improve air sealing • Complete LED lighting project to reduce lighting load • Upgrade windows • Convert to a heat pump water heater	2023-2030 (HP Water Heater 2030)	Variable Refrigerant Flow Heat Pump	2030, End of Life of existing heating system (estimate)	100 kW	2025	$1.1	$0.4	$0.7