Decarbonization of Municipal Buildings in Williamstown

Gracie Guidotti, Maria Avrantini, Alana Lopez Barro Rivera

Williams College, Fall 2022

Professor Sarah Gardner

Envi 402

Abstract

In June 2021, the Town of Williamstown passed a resolution in which they resolved to be Net Zero by the year 2050. In order to achieve this goal, the Town is striving to develop a comprehensive action plan by the end of 2023. In this paper we outline a clear roadmap for the decarbonization of Williamstown Municipal buildings and fleet to contribute to the Net Zero Carbon Emissions Action Plan. We present an inventory of all the municipal buildings alongside a report of their existing conditions. We then give building by building energy efficiency recommendations and present energy efficiency and decarbonization technology that could be implemented in the municipal buildings. Finally, we give general recommendations for the Town consisting of implementing a Sustainability Manager position, instituting a building efficiency rating system, and implementing annual check-ins with each of the building systems. This is only the first step in Williamstown reaching Net Zero Carbon Emissions by 2050, but we hope it will outline the necessary steps in order to reach the Town's goal.

Acknowledgements

Our team would like to express gratitude to Professor Gardner, who provided us with the opportunity to work on a real-life project and advised us throughout the research process. We are incredibly grateful to our clients, Nancy Nylen and Wendy Penner, for their guidance and precise demands. We acknowledge how significant the role of the broader COOL Committee is for Williamtown's future, and we appreciate the trust that our clients put in us. Finally, we are thankful to the interviewees and municipal building managers who put effort and time into helping us create this project.

Abbreviations

AHU - Air Handling Unit
BAU - Business As Usual
BTU - British Thermal Unit
CBECS - Commercial Buildings Energy Consumption Survey
CFL - Compact fluorescent lamp
DOER - Department of Energy Resources
DPW - Department of Public Works
ECM - Energy Conservation Measure
EIA - Energy Information Administration
EMS - Energy Management Services
ERV - Energy Recovery Unit
EUI - Energy Use Intensity
GHG - Greenhouse Gas
HTHW - High Temperature Hot Water System
hp - Horsepower
HVAC - Heating, Ventilation and Air Conditioning
ISO - Independent System Operator
kWh - Kilowatt hour
LED - Light-Emitting Diode
LTHW - Low Temperature Hot Water System
MassEVIP - Massachusetts Energy Vehicle Incentive Program
MCAN - The Massachusetts Climate Action Network
META - Municipal Energy Technical Assistance
MMA - Massachusetts Municipal Association
MTCO2e - Metric Tons of Carbon Dioxide equivalent
MW - Megawatts
RTO - Regional Transmission Organization
WEC - Williamstown Elementary School
WPD - Williams Police Department

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Introduction

In this project, our team is working with the Williamstown COOL Committee and the Williamstown Town staff to outline the path to decarbonization for the municipal buildings and Williamstown fleet. The municipal buildings include the Town Hall, Harper Center, Department of Public Works, Milne Library, Parks & Cemetery Buildings (Office/Shop & Sherman Chapel), Police Department, and Williamstown Elementary School. The Williamstown fleet consists of inspection services, road maintenance, and police vehicles. Our report determines the appropriate pathway to decarbonization for Williamstown by analyzing the current energy sources and systems of the municipal buildings and fleet. Our analysis includes examining energy efficiency measures, emissions comparisons, technology analysis, and an exploration of additional energy sources.

By decarbonizing the Williamstown municipal buildings, the Town will play an important role in taking action to reduce the impacts of climate change locally. Our goal for this project was to create a clear roadmap for the decarbonization of Williamstown Municipal buildings and fleet to contribute to the Net Zero Carbon Emissions Action Plan. Our process to create this roadmap consisted of undertaking thorough energy audits of all the municipal buildings, understanding their existing conditions, examining opportunities for decarbonization, and performing a rough economic analysis of the plan.

Background

a. **Electricity in Williamstown**

As a town in Massachusetts, Williamstown functions as part of the ISO New England Grid. ISO New England is a Regional Transmission Organization (RTO), serving Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. Figure 1 shows the 2021 energy mix for the RTO, with Natural Gas making up 53% of energy and renewables making up about 12%.[1]

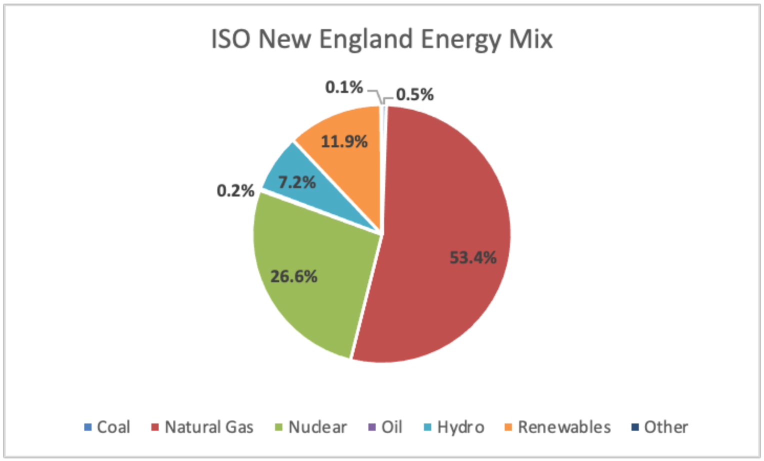

Figure 1: ISO New England Energy Resource Mix

According to the EIA, currently for the New England Region the emissions factor for electricity from the grid is 528.2 lbs CO2/MwH. In comparison, the emissions factor for natural gas is 898 lbs CO2/MwH.[2] Therefore, even though the grid is not fully green at this time, electricity from the Massachusetts grid has lower carbon emissions per megawatt-hour than natural gas energy. This means that electrifying building heating systems would already be beneficial, even if no changes were to be made. However, the grid is projected to become increasingly green in the coming years, with more than 7,000 MW of coal, oil, and nuclear plants being retired since 2013.[3] Additionally, there are many proposals and wind and solar projects in progress in the New England region. ISO New England has 18,000 MW of wind interconnections under study and "behind the meter" solar, connected to local utilities, is projected to grow significantly in the region. On a broader scale, Massachusetts' Clean Energy and Climate Plan for 2025 and 2030 aims to

[1] ISO New England."Energy Resource Mix."
[2] U.S. Energy Information Administration. "Carbon Dioxide Emissions Coefficients."
[3] Bethany-Sales. "Just How Green Is New England? A Lot More than You Probably Think."

modernize the grid.[4] Meanwhile, President Biden's Executive Order "Catalyzing America's Clean Energy Economy Through Federal Sustainability" targets on a federal level a carbon-free electric grid by 2035.[5]

In order to reduce the greenhouse gas emissions of Williamstown municipal buildings, the electrification of their heating systems will be necessary. Nevertheless, the Town must take into account the limits of the electric grid when making decisions. More precisely, Figure 2 shows the substation "Williamstown 3," which connects the two distribution lines of Williamstown, one on the south and the other on the north of the town. The limits of the 3-phase electric grid in Williamstown arise from the fact that both distribution lines have no available hosting capacity when taking into account the pending distributed generation. Therefore, no additional distributed generation can be supported in Williamstown without any upgrades or changes to the electrical grid ("Advanced hosting capacity analysis").

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[4] Executive Office of Energy and Environmental Affairs. "Massachusetts Clean Energy and Climate Plan for 2025 and 2030."

[5] The White House."Fact sheet: President Biden signs executive order catalyzing America's clean energy economy through Federal Sustainability."

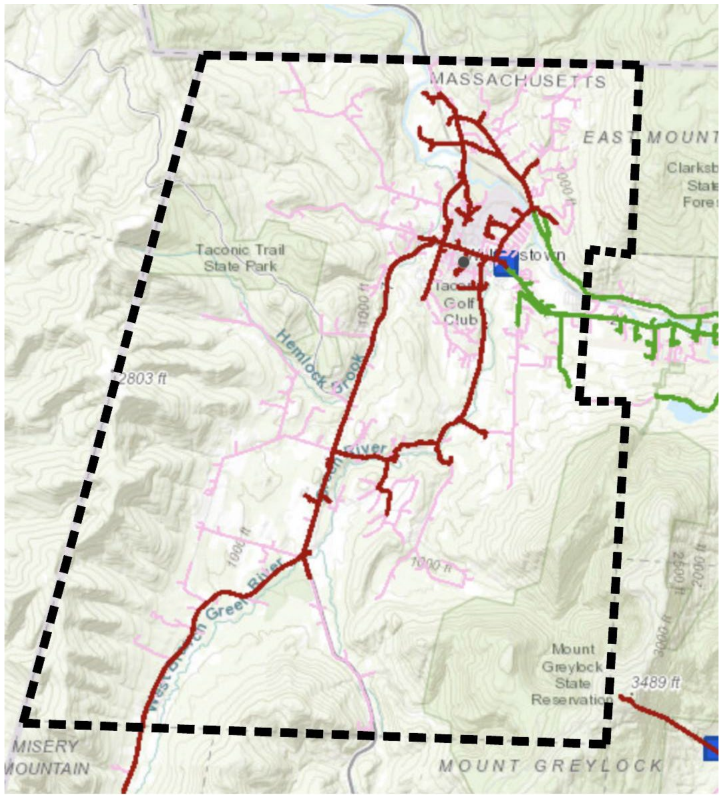

Figure 2: Borders and National Grid of Williamstown [6]

b. **COOL Committee**

The Williamstown CO2 Lowering (COOL) Committee was founded in 2001 and is a citizens committee of Williamstown Residents consisting of Wendy Penner, Susan Abrams, Alex Bryan, Betsy Kolbert, Nancy Nylen, Anne O'Conner, Stephanie Boyd, Hank Art, Mike Evans, Sarah Gardner, Jason Moran, and Tanja Srebotnjak. The COOL Committee has led many initiatives in Williamstown such as helping the Town become a certified Green Community in 2010 and most notably helping to pass the 2050 Net Zero Resolution in 2021. The COOL Committee has played an integral role in helping make Williamstown a more sustainable community.[7]

[6] National Grid. "Massachusetts System Data Portal."

[7] Williamstown COOL Co."Net Zero Emissions: Williamstown Cool Committee."

c. **Net Zero Resolution**

In 2021, the town of Williamstown passed a resolution with the goal of becoming net zero by 2050. This project is one aspect of the Williamston Net Zero Emissions Resolution and Action Plan. Its Action Plan's goal is to "support clean, efficient, affordable, renewable technologies and approaches to heating, cooling and powering our homes and businesses; fueling our vehicles; minimizing and disposing of waste; and other activities to achieve a Net Zero GHG emissions goal."[8]

The term "Net Zero" means that, on average, a building, town, country or other type of entity, is balancing their greenhouse gas emissions with the amount removed and stored by carbon sinks. This reduces their emissions to zero when accounting for offsetting activities. The first step towards decarbonization is creating a roadmap, a pathway of sorts, which outlines the steps the town needs to take in order to achieve their goal. This roadmap aims to create a local pathway towards decarbonization in line with the Massachusetts statewide goal of reaching net zero by 2050. This goal was set by the Commonwealth in December of 2020 in the *Massachusetts 2050 Decarbonization Roadmap Report*. This goal is also coupled with a statewide goal to reach 45% of 1990 emissions by 2030. The four key pillars of decarbonization for the Commonwealth guide our Net Zero Action Plan. First, the goal includes ending buildings' and vehicles' dependence on fossil fuels. Second, Williamtown will work to increase energy efficiency in cost-effective ways. Third, the Town will assess ways and technologies, such as solar panels, to produce low-carbon energy. Finally, part of the goal is to maintain and maximize the carbon removal storage capacity of Williamstown and its surroundings.[9]

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[8] Williamstown COOL Co

[9] Commonwealth of Massachusetts. "Massachusetts 2050 Decarbonization Roadmap."

Many other towns in Massachusetts are taking similar measures to reach net zero by 2050 such as Ashland, Westford, and many others.[10] In fact, the Climate Action Network (MCAN), a network of around fifty towns that take local climate action, provides examples of change at the municipal level to reach net zero.[11] As a member of the Massachusetts Municipal Association (MMA), Williamstown is able to get information as well as obtain referrals allowing it to benefit from the efforts of other Towns.[12]

d. **Experts' Input**

The team interviewed three experts in the field of decarbonization in order to get acquainted with the process of conducting an energy audit and to learn how to analyze our findings. The experts we met with are Tanja Srebotnjak, director of the Zilkha Center, Jason Moran, Assistant Director for Energy and Utilities at Williams College and Todd Holland, University of Massachusetts Energy Manager.

Tanja Srebotnjak has a PhD in environmental statistics and policy, and has been one of the people spearheading the Williams College Net Zero initiative. Tanja was able to share valuable information regarding the process of evaluating a building's energy efficiency. Tanja also informed us about metrics used to measure energy efficiency, such as Energy Use Intensity (EUI). This is a metric used to depict the amount of energy a building is using per square foot.[13]

Jason Moran has a background in engineering and was able to provide us with a lot of valuable information regarding the process of undertaking an energy audit of a building. Williams College dedicated 8 months to the building auditing process. Jason stressed the importance of

[10] Westford Clean Energy and Sustainability Committee. "Westford Climate Roadmap"
[11] Mass Climate Action Network. "Net-Zero Planning Communities."
[12] Massachusetts Municipal Association. "Resources."
[13] Brian Uhlrich."Net Zero Energy: Understanding EUI."

having a comprehensive audit to be able to move forward with accurate recommendations regarding energy efficiency and clean energy alternatives. Jason recommended we get in touch not only with the building managers, but also the head of facilities or the custodians of the buildings. It will most likely be them that have the best understanding of the areas of opportunity for the building. He also recommended we interview building occupants and inquire about the conditions of the building during different times of the year. Jason shared important aspects to take note of when visiting a building space: type of window panes, type of lightbulbs, space heaters, space coolers and areas of the building that feel drafty. Depending on what the conditions of the building are, there could be some easily addressed areas of opportunity that will make the building more energy efficient: double paned windows, LED lights, insulation and air sealing. Improving the building's energy efficiency will prepare it to receive a new, greener, heating and cooling system, which is the long term goal. Finally, Jason explained the green heating and cooling options that the college has been considering. First, the College is planning on moving away from steam as a source of heating, given that it is highly energy inefficient. The College is planning to transition to hot water alternatives, and considering water source heat pumps. These have the capacity of both heating and cooling, and use geothermal energy to do so.

Todd Holland currently works at UMass in energy management. UMass has set themselves a goal to be carbon neutral by 2032, and Todd is heavily involved in that process. He has a lot of experience working in energy management in a college setting. He has worked for the Amherst Consortium and also for Williams College. Even though our team is not focusing on creating a net zero roadmap for an academic institution, Holland had a lot of insightful information regarding the decarbonization process that was helpful to our investigation. He walked us through a recommended process for an energy audit:

1. Calculate the building's EUI (Energy Use Index) and compare the EUI to that of similar buildings. He recommended the CBECS index, which is managed by the Department of Energy, as a source in which we can find the EUI for other buildings.
2. Find areas through which the building could become more energy efficient.
3. Implement changes to get the building's EUI down to 20% less than the median. This means the building is ready to become carbon neutral, with the correct technology.

Methodology

a. Primary Research

Our team conducted twelve interviews and seven site visits in order to gather data about the municipal buildings that had not been collected prior to the project. We interviewed important stakeholders and people knowledgeable in the topic of decarbonization as outlined above.

We also visited all of Williamstown's municipal buildings and during our site visits, we interviewed the building managers. They provided us with their insights regarding the buildings that the town aims to decarbonize, such as information regarding future renovations or areas of opportunity that they see. We also conducted basic energy audits and assessed the energy efficiency of the buildings by looking at the cooling and heating systems and other building characteristics.

b. Secondary Research

We conducted secondary research using both internal and external sources in order first to understand what the decarbonization process of a community such as Williamstown should look like. In our research we determined tools and technology options for improving buildings' energy efficiency and decarbonizing them, along with learning about the various funding opportunities that the Town could benefit from. More precisely, the Acton Electrification Roadmap provided a strong example of the steps our team and Williamstown should follow.[14] Acton is a small town in Massachusetts that has already begun going down the road of decarbonization, and the Acton Electrification Roadmap worked as an aspirational document for our report. In addition, websites such as that of EPA and EnergyStar provided us with knowledge regarding energy efficiency measures, such as lighting upgrades, exhaust control systems, facade air sealing, as well as decarbonization options, such as air source heat pumps and onsite solar thermal.

c. **Data Analysis**

i. Dataset

Our team collected the data on the historical energy performance of each building either from MassEnergyInsight and from energy bills. The Town Hall provided the COOL committee with access to MassEnergyInsight, a free web-based tool provided by the MA state to cities and towns to track their energy use. All the municipal buildings except for the Police Department had filed their data in the MassEnergyInsight system. Our team collected data regarding the Police Department and solar production for the cemetery and department of public works buildings through the building managers. Additionally, for the buildings using delivered fuels such as wood or oil, we used information provided directly from the building managers on yearly consumption. Finally, our team collected data on the national and state greenhouse gas emission factors from the Environmental Protection Agency (EPA) Emissions Factors Hub.

[14]Acton, MA "Climate Action Plan: Acton, MA - Official Website."

ii. Analysis

The team used Google sheets to perform the data analysis. We calculated the BAU cooling and heating profiles, which are necessary to predict the HVAC system energy consumption, the HVAC system utility costs, and GHG emissions. Furthermore, we calculated the EUIs of each building and compared it to the median EUI provided by Energy Star based on building classification. EUIs result from dividing the building's annual total energy consumption by its total floor area in square feet.

Building Inventory

The inventory of each building below includes an explanation of the existing electrical, heating, and cooling systems in addition to important information on the use of each of the buildings. The building inventory is the foundation of our project because it will help inform us of the current state of the buildings we are looking to decarbonize. While our inventory includes the 7 buildings listed below, we chose to exclude the Hoosac River Water Quality District, Youth Center, Regional High School, and Fire Station. With the exclusion of the Elementary School, all of the buildings included in our analysis are owned and managed by the town. In comparison, all of the buildings listed as excluded are either regional facilities or are managed by other entities.

In addition to building use information we have also included calculations of the estimated GHG emissions, energy consumption, and energy utility costs for each of the Williamstown municipal buildings. These profiles assume that the energy use of each of the buildings will not differ significantly from 2021. The data from 2020 was not included due to the disruption of normal operations due to the COVID-19 pandemic.

The natural gas and electricity emissions factors are included below in Table 1. The emissions factor is a metric used to calculate the amount of carbon dioxide emitted per energy unit used. The natural gas emissions factor was obtained from the EIA emissions factors report for 2022 and the electricity emissions factors come from the EPA emissions factor hub.

Table 1: Greenhouse Gas Emissions Factors

Electricity (lb CO2e/MWh)	Natural Gas (lb CO2e/therm)	Distillate Oil No. 1 (lb CO2/gallon)
528.2[15]	11.665[16]	4.62

Because the town landfill solar field is distributed between all buildings, we did not take into account the greenhouse gas emissions or cost offsets for the electricity usage in our calculations. For the year 2021, the Town landfill solar site produced a total of 2,046 MWH of electricity. Additionally, we did not take into account machinery emissions from machines such as lawnmowers or trimmers.

a. **Existing Building Systems**

1. Town Hall

[15] United States Environmental Protection Agency "GHG Emission Factors Hub."
[16] U.S. Energy Information Administration. "Carbon Dioxide Emissions Coefficients."

The Town Hall is a 14,222 square feet building built in 1927 and located at 31 North Street Williamstown, MA. This was the first building the team visited. We met Ken McAlpine, the Head of Facilities at Williamstown Town Hall. The building has no central cooling system. Around 13 window AC units are used for cooling between late May and September. Window units run on electricity. The average EER rating for the AC units is 10.6, an above-average performance rating. However, window AC units are generally an inefficient method for cooling large spaces, like the Town Hall building. The building does have a central heating system which is powered by a natural gas steam boiler. Ken informed us that this boiler is old and should likely be replaced soon, however the burner on the boiler was replaced last year (2021). The building appears to be well insulated. All of the windows are double glazed, except for the town manager's office, which is single glazed with storm windows. Almost none of the building occupants reported feeling cold in the winter. Only one building occupant, whose office is at the end of the heating system circuit, reported using a space heater in the colder months.

We asked Ken whether there had been any recent changes implemented on Town Hall, and whether he foresaw any future changes occurring soon. He told us that most of the building's lights had changed to T8 fluorescent light bulbs a few years ago, after the building underwent an electricity audit. Another recent change that Town Hall underwent is that it no longer houses the Williamstown Police Department, as it used to for several decades. Now there are around three unused rooms in the building. They are still heated, but they are maintained at a lower temperature (52 F). There are currently no planned renovations for Town Hall, however, many are hoping to get a new Town Hall building altogether. Table 2 below shows the energy consumption, costs, and emissions per year for the energy systems in Town Hall and Figure 3 shows the estimated thermal load profile for the heating and cooling systems for the Town Hall.

Table 2: Williamstown Town Hall Energy Use Profile

	Energy Consumption (per year)	Utility Costs ($/yr)	GHG Emissions (MTCO2e/yr)
Natural Gas Heating	4,908 therms	3,166.95	25.97
Electricity	56.25 mwh	596.95	13.47

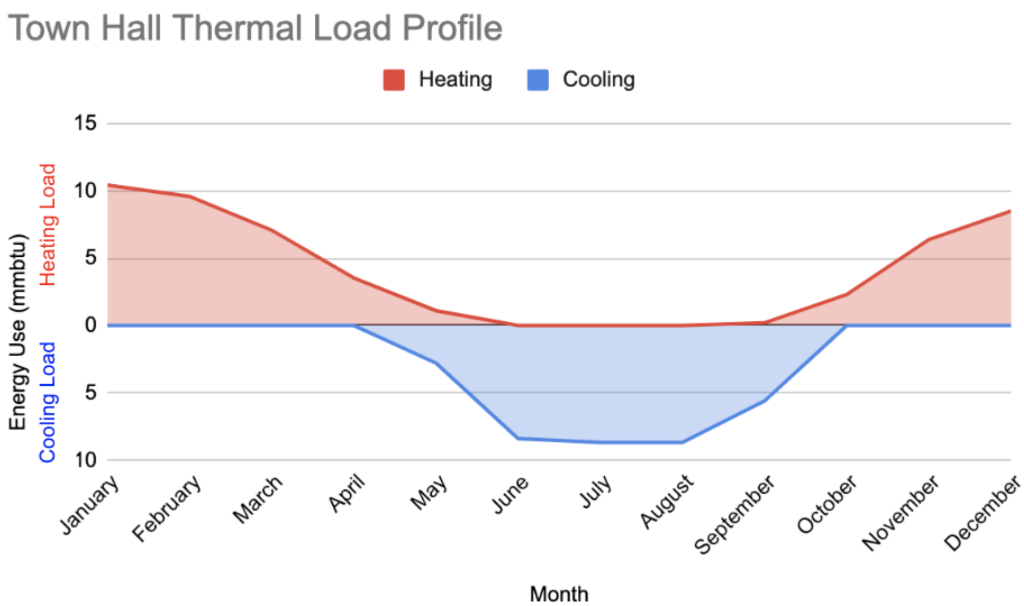

Figure 3: Williamstown Town Hall Thermal Load Profile

2. Harper Center

The Harper Center is part of the Williamstown Council on Aging, located at 106 Church Street, Williamstown, MA. The Harper Center provides services ranging from oil painting classes to seasonal tax assistance for the citizens of Williamstown that are 50 years and older. It is an important space in the community, given the high average age of the population of the town. The building is 4,298 square feet and was built in 1985. The team met with with Brian O'Grady, director of the Harper Center, who gave us information regarding the current conditions of the space. The building was renovated approximately 10 years ago (2012). The renovations were aesthetic and also improved the central heating and cooling infrastructure, which now runs only on electricity. There are two mini splits in the building, for smaller side rooms that do not get air from the central system delivered to them. These both heat and cool, and run on electricity as well. Natural gas is primarily used for heating water and cooking. The electrical system is a 225 A, 3 Phase, 4 Wire System.

When the building was renovated, all the walls were insulated and double paned windows were installed. Brian told us that the building stays cool in the summer and warm in the winter, and reported improvement in conditions from before the renovation. The roofs were replaced last year (2021). When asked about the installation of rooftop solar panels, Brian expressed interest but had run into permitting issues during the renovation surrounding the installation.[17] Brian does not foresee any large scale renovations for the Center in the near future, other than some cosmetic improvements. Regarding the use of the building, Brian shared that the hours of operation are usually longer than the ones stated on the Harper Center website (8:30 am - 4:30 pm). People tend to come in a bit earlier and leave a bit later, particularly in the summer when the days are longer. He does not foresee any changes to the hours of operation in the future, and told us that they have been constant over the past 10 years.

Table 3 below shows the consumption, costs, and emissions produced by energy use in the Harper Center building per year.

Table 3: Harper Center Energy Use Profile

	Energy Consumption (per year)	Utility Costs ($/yr)	GHG Emissions (MTCO2e/yr)
Natural Gas Heating	1,972 therms	1,373.27	10.43
Electricity	8.574 mwh	2,071.3	2.05

[17] We were unable to find specific information regarding these issues.

3. Highway Department / Department of Public Works

The Highway Department and Department of Public Works (DPW) building is located at 675 Simons Road, Williamstown, MA, and was built in 1998. This building is 25,800 square feet, and is composed of office space and a large garage. The building's electrical system is a 400 A, 3 Phase, 4 Wire System, and it also utilizes a 16.56 KW rooftop solar array (72 solar panels).

The team met with Chris Lemoine, the director of the DPW, to understand the current conditions of the building. The building has a central heating and cooling system, which uses a duct system to diffuse cooled/heated air throughout the space. The DPW uses electricity to cool the building. For heating, they primarily use oil and wood as fuel. The wood boiler is around 20 years old and runs exclusively on waste wood that the DPW gathers through their daily work. All of the trees that fall during storms or that need to be brought down because they are a fall risk are used in the DPW boiler. This method has significant cost benefits given that they do not need to pay for the fuel. The boiler however is outdated and has had to be renovated by the DPW themselves multiple times. It cannot be replaced due to EPA regulations.[18] This is due to the large amounts of particulate matter pollution resulting from the use of a wood boiler. Research has found

[18] United States Environmental Protection Agency, "Ordinances and Regulations for Wood-Burning Appliances"

that outdoor hydronic heaters (wood-fired boilers) when used on a residential scale can emit as much particulate matter as 1,800 homes with natural gas heat.[19]

The building also has a backup generator, which runs on distillate. The oil heating system is a 570,000 BTU/hour system. To run the oil boilers, the DPW receives 3600 gallons of heating oil annually and uses waste oil from all of their vehicles. According to Chris, these boilers are common in car dealerships.

The building is kept at 69°F in the office space and at 62°F in the garage. Both the office and the garage are insulated. The office windows are double paned, but they are around 20 years old and no longer well sealed. Chris mentioned his office, which has two large windows, feeling colder than the rest of the office space in the colder months. He sometimes uses a space heater in the winter months, but not regularly. The DPW also houses 52 vehicles of different sizes (from trucks to snowplows and cranes). They run on gasoline and diesel.

We spoke with Chris about the possibility of transitioning to cleaner energy sources in the building. Chris seemed enthusiastic about some prospects, but voiced concerns about others. He told us that he has done research regarding the possibility of getting electric vehicles for the DPW. Currently, the only option available would be to get an electric truck, however, supply is very limited and there are extensive wait times. Similarly for many larger vehicles the technology for electrification has not been fully developed. Given that vehicles such as snow plows must run for 30 consecutive hours in winter storms, it would be difficult to find an electric vehicle to meet that demand.

[19] Commonwealth of Massachusetts, "Heating your home with a wood-burning appliance"

We also spoke to Chris about the idea of using heat pumps for heating and cooling, and he was wary of the concept. He mentioned heat pumps having been installed in Stockbridge, and it going poorly,[20] and also expressed concerns for the ground water of Williamstown getting polluted from the drilling for geothermal heat pumps. Aside from that, Chris seemed very open to transition to cleaner energy for the DPW. Table 4 below shows the consumption, costs, and emissions produced by energy use in the Department of Public Works building per year.

Table 4: Department of Public Works Energy Use Profile

	Energy Consumption (MMbtu/yr)	Costs ($/yr)	GHG Emissions (MTCO2e/yr)
Wood Boiler	1,383.6	0	129.78
Oil Boiler	494.57	unknown	36.65
Electricity	534.47 mwh	8,942.57	103.57

The calculations for the electricity greenhouse gas emissions take into account the amount of electricity produced by the rooftop solar array on the premise. In 2021 the solar array produced 10.22 mwh of electricity for the building, reducing the building's GHG emissions by 24.48 MTCO2.

Table 5 shows the fuel consumption, costs, and emissions for the Williamstown on-road fleet in 2021. The remaining 16 vehicles are off-road vehicles such as tractors and backhoes that do not have available emissions data.

Table 5: Department of Public Works 2021 On-Road Fleet Emissions[21]

Number of Vehicles	Average Fuel Consumption per Car (Gallons/yr)	Average Fuel Costs per Car ($/yr)	Total Fleet Emissions (MTCO2e/yr)

[20] The team was not able to find information to corroborate this statement

[21] National Grid Fleet Advisory Services Program Report

36	547.9	1,471.06	185.13

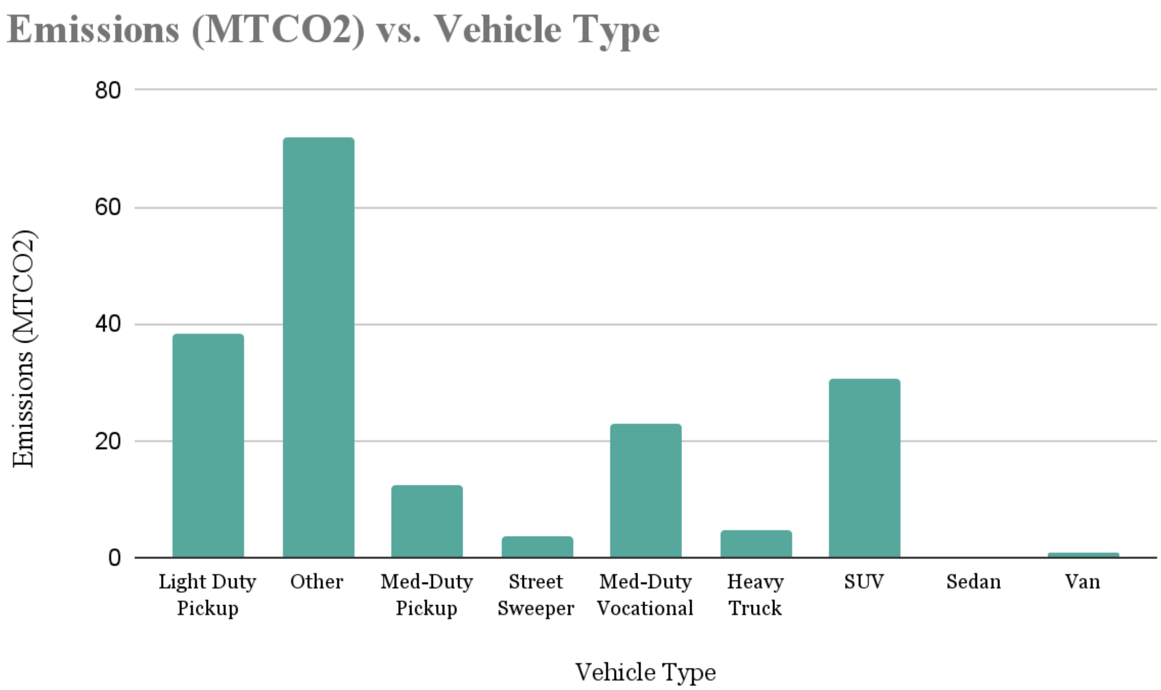

Figure 4: Fleet Emissions by Vehicle Type

4. Milne Library

The Milne Library is 18,843 square feet and was built in 1967 at 1095 Main Street. The building used to be a school, and was acquired by the town and turned into the Library. Currently, it houses a large selection of books and other media for groups of all ages, and also hosts events. The electric system of the building is a 120/240V AC, 1 Phase 3 Wire system. The library also has a 2.4 KW roof solar array which was installed in 2007. Pat expressed interest in expanding the solar array and having the library get more electricity from that source. The building does not have central cooling. The main area of the building gets its cooling from two mini split units, which are powered by electric heat pumps. Some of the offices and rooms on the side, which are separated from the main space, have AC window units installed for the warmer months of the year. This last year four window units were used. These are also powered by electricity, but are less efficient than the mini split units.

For heating, the building uses a hot water radiant heating system, which extends around the inside of the perimeter of the building. It uses a gas powered boiler to heat the water which heats the building. The water temperature is set to around 120 degrees fahrenheit, which is standard practice. The heating system begins in the boiler room, which is located in the basement. The hot water then moves through pipes that surround the perimeter of the basement rooms before they reach the ground floor of the building. Currently, all of the basement space works as either storage or is unoccupied. While the unoccupied rooms are not expressly heated, the water in the pipes loses heat as it goes through them, making it more difficult to heat the main used area of the building. The heat can be controlled remotely, which allows Pat to lower the temperature of the building during days off, or days when the building is unexpectedly closed. She shared that no one uses space heaters in the library, but that the building can get really cold in the winter. They close the library if the building ever gets to be below 60 degrees fahrenheit.

The building is composed of uninsulated cinderblock, which is the reason why it gets really cold in the winter. Before AC units were installed, they also had to close down on particularly hot summer days. The windows are double paned, but they are very old and have lost their seal, meaning they are not helping insulate the building. Pat mentioned that in the basement of the building, doors rattle when it gets really windy outside, from which we can infer that the building has poor air sealing. This also lowers the energy efficiency of the building. Pat informed us that she does not foresee any changes in usage of the building. There have been discussions of occupying the basement rooms, and using them for something other than storage, however Pat sees many challenges that prevent the basement from being used. Firstly, the ceilings are really low. They would have to be covered, as all of the cables and piping is currently exposed, lowering them further. Second, it is not handicap accessible. For this to be the case, an elevator would have to be installed, and this is out of the library's budget. Finally, the basement lacks emergency exits. There are many areas of opportunity for the Williamstown Public Library to become more energy efficient. Pat was excited about the prospect of insulating the building, and expanding the solar array on the roof. Pat also expressed some concerns. The building is really old, and they have been facing some flooding issues in the basement. She is aware that making this building Net Zero would be a large investment, and would not want to invest in a building that is reaching the end of its lifespan.

Table 6 shows the energy consumption, costs, and emissions from the library per year, excluding the solar energy produced from the rooftop solar array.

Table 6: Milne Library Energy Use Profile

	Energy Consumption (per year)	Utility Costs ($/yr)	GHG Emissions (MTCO2e/yr)
Natural Gas Heating	10,830 therms	5,434.77	57.304

Electricity	61.28 mwh	11,781.88	14.68

5. Parks & Cemetery

   i. *Office & Shop*

The Office and Shop located at the cemetery is 2,042 square feet, was built in 1966, and utilizes a 9.75 kW solar array. The primary heating fuel for this building is oil utilizing a 115 V, 15.2 A, 60 Hertz oil boiler installed in 2005. The building is separated into two main areas of a small office and larger shop area for the vehicles. The larger shop area is used for maintenance on the cemetery maintenance machines and is typically kept at a cooler temperature than the office area. In the small office, there is one window AC unit, which is used for cooling around five times a year. They currently own 10 fossil fuel powered mowers, and two fossil fuel powered trimmers. They have started transitioning to electric, but the process has been slow. The plan is to buy two electric machines yearly to replace non-electric ones. They currently only own one electric trimmer and one electric mower.

Table 7 below shows the energy consumption, costs, and emissions for the parks and cemetery office and shop. Although the office and shop building at the town cemetery consumes

8.88 mwh of electricity per year, the rooftop solar field offsets energy usage almost entirely, resulting in only 0.144 mwh consumed in 2021.

Table 7: Parks & Cemetery Office Energy Use Profile

	Energy Consumption per year	Utility Costs ($/yr)	GHG Emissions (MTCO2e/yr)
Oil	931 gallons	*unknown*	9.48
Electricity	8.88 mwh	135.49	0.03

ii. Sherman Burbank Memorial Chapel

The Sherman Chapel is located at 605 Main Street. The Chapel is 1100 square feet and was built in 1936. The primary heating fuel of this building is natural gas with oil heating used as a backup. The natural gas boiler was installed in 2010 and the oil boiler in 2005. The Chapel is kept at 50-55° F unless there are services. There are a couple services during winter and a few during summer. The energy usage for the building is low given the infrequent usage. Due to the infrequent usage, the building is heated very intermittently requiring the heating system to heat the building quickly for services.

Table 8 shows the energy consumption, costs, and greenhouse gas emissions per year for the Sherman Burbank Memorial Chapel.

Table 8: Sherman Burbank Memorial Chapel

	Energy Consumption per year	Utility Costs ($/yr)	GHG Emissions (MTCO2e/yr)
Oil	321.9 gallons	*unknown*	3.28
Natural Gas	970 therms	744.27	5.13
Electricity	1.919 mwh	516.9	0.46

6. Williamstown Police Department

The Williamstown Police Department has been located at 825 Simonds Road since 2019, and it is 12,000 square feet. Built in 2019, this is the newest municipal building. The building was previously a home. The main structure was kept and renovated and an annex was added. The occupants of the new building, including Chief Michael Ziemba who gave the team a tour, reported being satisfied with the new space. The electrical system is a 225 A, 120/208 V, 3 Phase 4 wire system. The building has central cooling and heating, both of which run on electricity. Michael told us that the building is usually kept cool in both the summer and winter (between 68-70 degrees Fahrenheit). The Police station operates 24/7, thus the building is heated or cooled 24/7. The station only uses natural gas to heat water, and has a backup diesel generator that is used only in blackouts. The natural gas water heater is highly rated by Energy Star, with an efficiency rating of 95 out of 96.3. The diesel generator runs for 10 minutes once a week, to ensure it is still operational. It was manufactured in 2018 and has a capacity of 1,161 gallons. Although the building has central heating and cooling, four rooms had mini splits for heating and cooling in them. These also run on electricity.

The building is insulated and all of the windows are double paned. Michael reported not having difficulties keeping the building warm in the winter or cooler in the summer. All of the lightbulbs are LEDs and the hallway lights are on sensors. Michael was excited about the prospect of making the building carbon neutral, and would like to cooperate with the initiative. He expressed interest in adding solar panels to the roof of the building and the roof of the car canopy outside. Both roofs are only four years old. However, he told us that solar panels were not added when the building was built, although interest was expressed at the time. He also does not foresee any changes in the use of the space, or any renovations in the near future. Table 9 below shows the energy consumption, costs, and emissions per year for the Williamstown Police Department.

Table 9: Williamstown Police Department Energy Use Profile

	Energy Consumption (per yr)	Utility Costs ($/yr)	GHG Emissions (MTCO2e/yr)
Natural Gas Heating	3,774 therms	343.85	19.97
Electricity	113.7 mwh	23,705.32	27.24

7. Williamstown Elementary School

The Elementary School is located at 115 Church Street, Williamstown, MA, and is 89,000 square feet built around 2003. The primary heating fuel of this school is natural gas, utilizing 3 Lochinvar high-efficiency natural gas boilers. Two of these are used for heating the building, and the third one is used for heating water. The school is cooled in the late summer and early fall months using three recently updated outdoor, electric 208/230V 3 Phase 60 Hertz cooling systems. Schools are required by law to have a certain amount of air exchange in order to maintain ventilated rooms. Since the Covid-19 pandemic, regulations increased the amount of times air had to be exchanged an hour from 4 times to 12 times. Generally, a lot of energy is lost as air from the outside is brought in, as it is much colder and needs to be heated. Luckily, the Elementary School already had an air handling unit installed in the attic since before the pandemic. This air recovery system draws air in from the outside, and begins raising its temperature. This eases the load on the boilers, making the heating and cooling systems of the building much more energy efficient. The temperature ranges from 68-72°F during the day. The temperature drops to 65°F at 4:30 pm, when the building is unoccupied, and it starts getting heated at 5 am in preparation for the school day. The building is insulated and the windows are double paned.

The existing electrical system for the building is a 208Y/120V 3-phase 4-wire system. The roof of the school also contains a 20 kW solar array. While the solar array has a large amount of potential to produce electricity to offset building use, the inverter has been out of order for the past 7+ years and has not been transmitting electricity to the building. All of the lights in the building are LEDs and they are all on sensors, meaning that if a space is not in use for 15 minutes, they automatically turn off.

Table 10 below shows the energy consumption, costs, and emissions per year for the Williamstown Elementary School.

Table 10: Williamstown Elementary Energy Use Profile

	Energy Consumption (per yr)	Utility Costs ($/yr)	GHG Emissions (MTCO2e/yr)
Natural Gas Heating	34,040 therms	16,288.67	180.11
Electricity	295.84 mwh	60,638.15	70.88

Energy Efficiency and Conservation Measures

a. Energy Efficiency Analysis

Figures 5 and 6 below show a comparison between the greenhouse gas emissions for each building. Figure 6 takes into account the square footage of each building, comparing emissions per square foot per building. Buildings that score high on both charts should be of the first priority for addressing energy efficiency and electrification options.

Both figures show that the DPW is the highest carbon emitter in total and per square foot. Given that the DPW is a building used frequently by maintenance vehicles in all hours of the day and heavily during winter months, this is to be expected. However, we aim to identify ways to reduce the carbon emissions and energy usage for this building through electrification and energy efficiency upgrades.

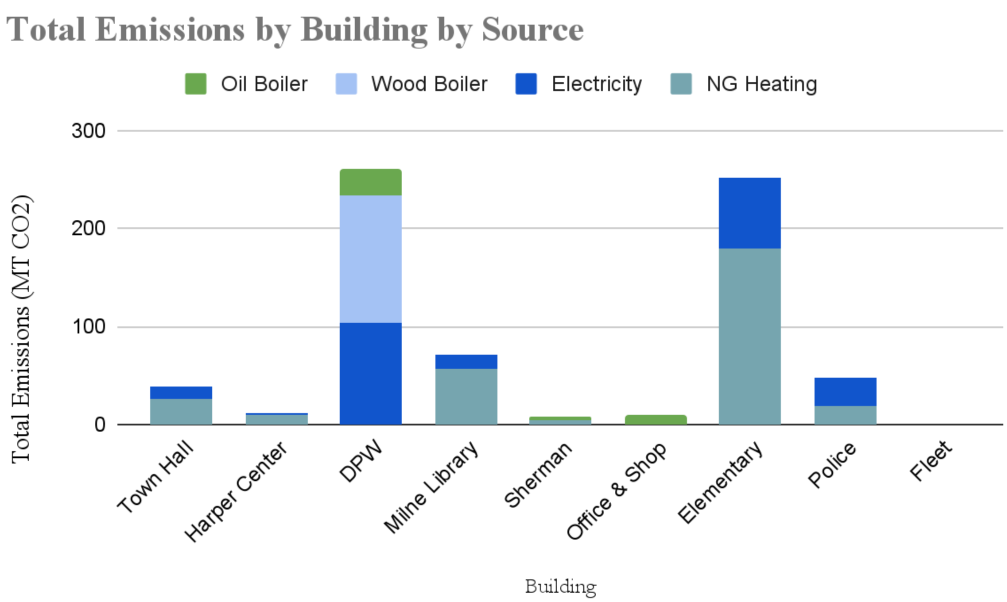

Figure 5: Total Emissions per Year by Building by Source

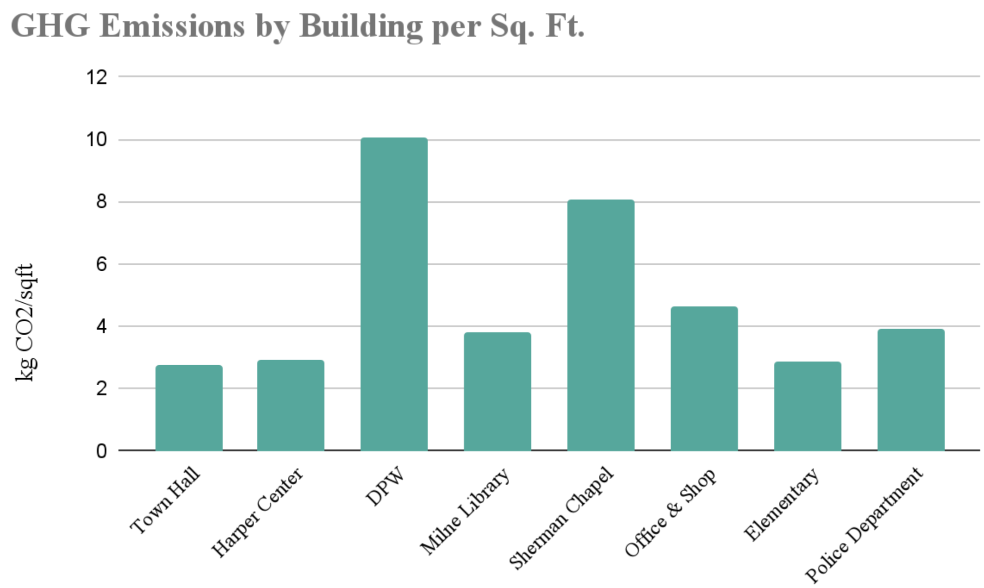

Figure 6: Total GHG Emissions by Building per square foot

In order to measure the efficiency of each building, we calculated each building's Energy Use Intensity (EUI), shown in Figure 7. This measure allows us to benchmark each building's energy use per square foot compared to the average building of its type. This means that this metric does not rely on the size of the building. A very large space can emit a lot overall, given its size, and also have a low EUI. Various factors affect a building's EUI rating such as the climatic conditions of the area, type of occupancy, and hours of operation. A lower value of EUI signifies a more energy-efficient building. In order for the buildings in our portfolio to be "net-zero ready" we must work to lower the EUIs for each building to at least 20% below the median EUI for each building type.

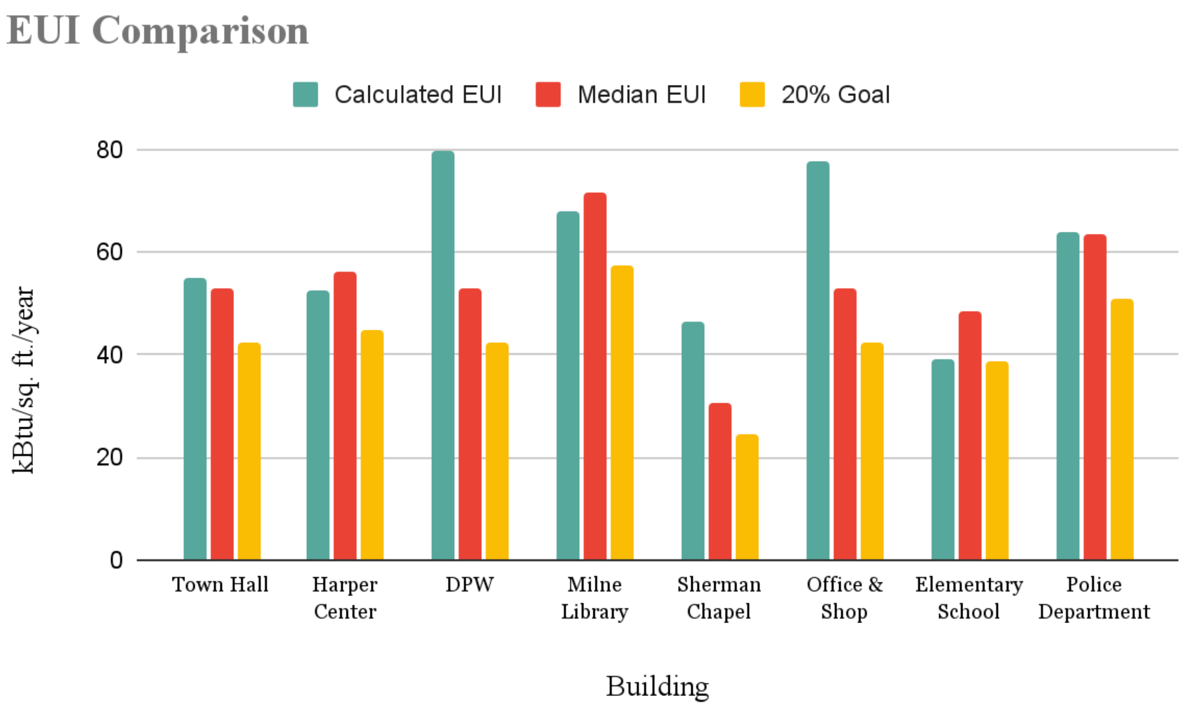

Figure 7: EUI Comparisons by Building

Figure 7 shows the EUI of each building compared to the median EUI for the associated building type, and the reduction goal of 20% lower than the median EUI. The Department of Public Works, the Cemetery Office & Shop, and the Police Department are the only municipal buildings that have an EUI that is above the median for their building type. The Town Hall, Harper Center and Milne Library are below the median EUI, but still above the target EUI. Interestingly, the Williamstown Elementary School is already operating at the 20% reduction target. However, the EUIs for the Department of Public Works and the Cemetery Office & Shop are significantly greater than the median EUI for their building type. This could be attributed to the multi-use properties of the space, given that both the buildings are used both as a shop for machine repair and as an office, making it difficult to classify the building.

Table 11 shows the characteristics of each municipal building to assess energy efficiency. The green signifies more energy efficient characteristics while orange and red identify less energy efficiency characteristics.

Key: Dark green = best, Light green = good, Orange = bad, Red = worst

Table 11: Energy Efficiency Matrix

Building	Lighting	Window Type	Insulated?	Heating/Cooling System
Town Hall	T8 FL[22] Bulbs	Double Paned (Town Manager Office Single Glazed Window with Storm Panels)	Yes	Window AC Units Natural Gas Boiler Heating
Department of Public Works	T5 FL Bulbs	Double Paned (Installed in 1999)	Yes	Wood / Oil Boiler Heating and Cooling
Milne Library	T8 Bulbs	Double Paned (Outdated)	No	Mini Split Cooling Hot Water Radiant Heat
Police Department	LED	Double Paned	Yes	Heat Pump Cooling and Heating
Harper Center	T8 FL Bulbs	Double Paned	Yes	Central Electric Cooling and Heating, Mini Split Cooling and Heating
Elementary School	LED	Double Paned	Yes	Natural Gas Boiler Heating, Electric Cooling
Cemetery Shop	T8 Bulbs	Double Paned (Installed in 2021)	Yes (Two walls not insulated)	Oil boiler Window Unit Cooling Natural Gas for for heating water and cooking
Sherman	LED	Single Paned	No	Oil Boiler and

[22] FL = Fluorescent

Burbank Memorial Chapel				Backup Natural Gas Boiler

Table 12: Bulb Comparison

Bulb Type	Watts Used	Efficiency (lumens per watt)	Cost	Lifespan	Color Rating Index (CRI)
CFL	13W	50-70	$1.57/year	6-10 years	80
LED	9W	75-110	$1.08/year	15-20 years	80-90

b. Mechanical Ventilation Systems

All buildings need to be ventilated. This can be done naturally, by not being well air sealed, or by installing mechanical ventilation. For energy efficiency purposes, having an air sealed building is very efficient. Air sealing helps not overwhelm heating and cooling systems. Outlined below are types of mechanical ventilation that both promote air circulation and help regulate and reduce energy usage.

i. Heat Recovery Ventilation (HRV)

Heat Recovery Ventilation (HRV) is a system that uses the heat in stale exhaust air to preheat incoming fresh air. This reduces the energy required to heat incoming air. HRV units require a fan to be operating on a continual basis, however, the energy recovered due to not having to heat incoming air as much is many times that of the energy required for the fan. Typical efficiencies range from 55% to 75%.[23]

[23] Boyer, Dennis. "Choosing Between an HRV and an ERV"

ii. Energy Recovery Ventilation

Energy Recovery Ventilation (ERV) units work differently than HRV units. This type of system captures some of the humidity in the air to keep it on the same side of the thermal envelope that it came from. In cold weather, an ERV system transfers the humidity from the air being extracted to the incoming fresh (and dry) air to help keep the ambient internal humidity level at a value between 40% and 60% at all times. In warm weather, the humidity transfer in an ERV reverses and the humidity in outside air is removed before it is injected into the home. This saves energy by reducing the load on air conditioning systems.[24]

Decarbonization Options

a. Electrification Options

In order to electrify each building, we aim to replace existing fossil-fuel-based heating and cooling systems with electricity-powered systems such as heat pumps. In order to evaluate the potential electrification options for heating and cooling systems in each building, we created a general evaluation matrix comparing the oil boiler, natural gas boiler, ground source (geothermal), and air source heat pumps. To evaluate the options, we considered 13 factors divided into technical, economic, and environmental categories. The two electric heating and cooling technologies considered were air source and ground source heat pumps.

[24] Boyer, Dennis. "Choosing Between an HRV and an ERV"

i. Air Source Heat Pumps

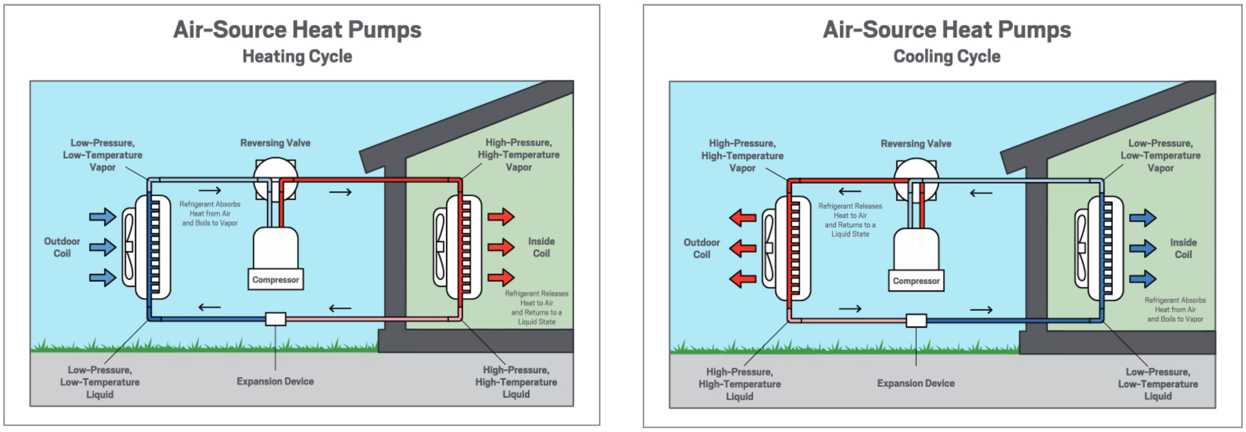

Figure 9: Air Source Heat Pumps[25]

An Air Source Heat Pump (ASHP) is a heating and cooling system that transfers heat to and from the outdoor air. An ASHP system can be used as part of both forced air and radiant HVAC systems but are recommended to be paired with low-temperature hot water systems (LTHW) given that ASHPs can generate LTHW more efficiently than HTHW. Although ASHP systems have a poor reputation for working under freezing conditions, ASHPs have proven to be efficient and effective in below freezing temperatures and the harsh winters of Maine. This system has a much lower upfront cost than ground source heat pumps and are very efficient.

ii. Ground Source Heat Pumps

A Geothermal Heat Pump or Ground-Source Heat Pump (GSHP) system is a heating and cooling system that transfers heat to and from the ground. The image below shows how GSHPs function for heating and cooling.

[25]Ameren. "Is an Air-Source Heat Pump Right for Your Home?"

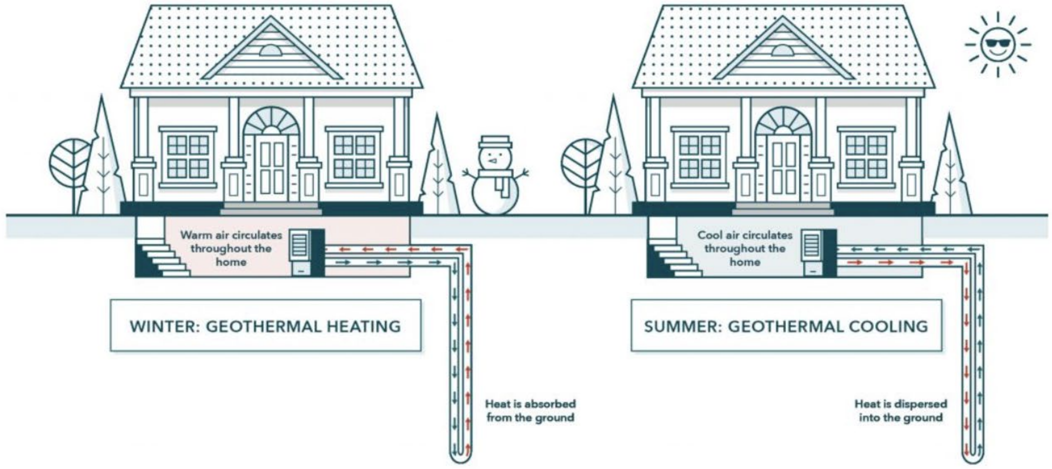

Figure 8: Geothermal Heat Pump Diagram

A ground source heating and cooling system includes a water source heat pump and heat recovery chillers combined with a geothermal bore field heat exchanger used for heating and cooling. This technology works best with LTHW systems rather than HTHW systems given that LTHW is more efficiently produced with this product. GSHP systems can be used in central plant or standalone, individual building applications. GSHP systems have a much higher upfront cost however are extremely reliable and efficient in cold conditions and have an extremely long lifetime.

The matrix below shows the rating system for each of the technologies to identify the best technology for buildings in general. A higher scoring value is optimal for each rating and the overall technology ratings. The explanations of each criteria and rating scale can be found in Appendix 7.

Table 13: Evaluation Matrix When Technology is not at its End of Life

Indicator	Criteria	Gas Boiler Heating System	ASHP	Ground Source Heat Pumps	Wood Boiler	Oil Boiler
Technical	Efficiency Score (under ideal conditions)	2	5	5	2	2
	Reliability (in cold climates)	2	2[26]	3	2	2
	Explosion Risk	1	3	3	1	1
	CO Risk	2	0	0	0	0
	Total (/14)	0.5	0.71	0.78	0.35	0.35
Economical	Investment Cost (per ton)	5	3[27]	1[28]	5	5
	Maintenance and Operation Cost ($100/yr)	2	2	3	2	2
	Fuel Cost ($/MMBtu)	5	1	1	5	2
	Service Life	3	3	5	3	3
	Predicted Cost of Fuel	1	3	3	2	1
	Payback Period (years)	3	2	1	3	3
	Total (/24)	0.75	0.58	0.58	0.83	0.67
Environmental	Ecosystem Disruption	3	3	2	1	3
	Noisiness	3	3	3	1	3
	Emissions	1	3	3	2	3

[26] Schoenbauer, Ben. "Case Study: Field Test of Cold Climate Air Source Heat Pumps (Single Family)"
[27] This Old House. "How Much Does a Heat Pump Cost?"
[28] This Old House. "How Much Does a Heat Pump Cost?"

	Factor					
	Total (/9)	0.89	1	0.89	0.55	1
Overall Score		2.14	2.29	2.25	1.73	2.02

The matrix presented in Table 13 shows that when using our defined scales, the recommended heating and cooling technology is the air source heat pump when the existing cooling systems are not near their end of life. For the existing systems not near their end of life we assume the investment cost is zero.

However, when we adjust for a being near its end of life, the investment cost values and the score are adjusted to values shown in Table 14. The results remain the same under both conditions, with air source heat pumps being the primary recommendation. The full matrix can be found in Appendix 2.

Table 14: Investment Costs for technology at end of life

Technology	Gas Boiler	ASHP	GSHP	Wood Boiler	Oil Boiler
Investment Cost (per ton)	3	3[29]	1[30]	1	3
Total Score	2.1	2.29	2.26	1.46	1.93

b. Other Options

i. Solar Hot Water Thermal

Solar hot water thermal systems provide heating and hot water to a building.[31] They can partially replace existing electric and natural gas heating systems, so they are not a complete replacement solution. A hot water thermal system includes panel collectors that can get installed

29 This Old House. "How Much Does a Heat Pump Cost?"
30 ibid.
31 Energy Saver. "Solar Water Heaters."

on 20-50 degree south-facing roofs, on the ground or on parking canopies. The system also requires new pumps and piping so that the panels are connected to the hot water distribution system of the building.[32] In order for a solar hot water thermal system to be effective, the building should have a high heating load, and preferably require heating the entire year. Therefore, this electrification option is on the list of considerations for first the Elementary School and second the Milne Library.

According to the Action Electrification Roadmap, the installation of a solar thermal collector system would be around $240,000 with a cost of a distribution 3hp pump being around $5,600. The annual maintenance cost would be approximately $250 per 1,500 sq. ft. collector. In terms of practicality, maintenance would be required every 3 to 5 years by a solar contractor while the system would probably need one or two replacement parts every 10 years.[33]

Recommendations

a. Building Recommendations

1. Town Hall

Town Hall has an EUI of 54.2 a value slightly above the median of 52.9. Regarding energy efficiency, the main areas of opportunity that the team found were the lightbulbs and the building envelope improvement. We recommend changing light bulbs from T8 fluorescent bulbs to LEDs, which are significantly more efficient. This change would be high on the priority list, given that it requires minimal intervention. Additionally, by engaging in an energy audit the Town Hall can identify areas where we can improve air sealing or insulation levels at low cost.

Next we recommend changing the building's cooling system. Currently, window AC units are used to cool Town Hall during the summer months. Replacing these with either mini split units

[32] Massachusetts Department of Energy Sources. "Solar Thermal."
[33] Andres, Becerra. "Electrification Roadmap: Town of Acton."

or central cooling, depending on the building's infrastructure, would improve energy efficiency during the warmer months. Once the building's EUI is lowered to the target level, the team recommends looking into electric heating options. The Town Hall's boiler is approaching the end of its lifespan. Because replacing it will be a large investment, this would be a good time for the building to transition into electric heating sources.

2. Harper Center

The Harper Center has an EUI of 52.69. It is already below the median of 56.1, but still above the target EUI of 44.88. The Harper Center recently underwent renovations, and the only area the team found lacking was the lighting. The team recommends changing the T8 fluorescent lights with LEDs, which are more energy efficient. If after this change, the EUI drops to the target value, then the Harper Center would be "net-zero ready." If not, the team recommends having the Harper Center undergo a professional energy audit to further investigate areas of opportunity.

3. Highway Department / Department of Public Works

The Department of Public Works has an EUI of 79.87, which is 26.97 units above the median (52.9) and 37.55 units above the target EUI (42.32). The two main areas of opportunity the team identified regarding energy efficiency were lighting and windows.

We recommend replacing the T5 fluorescent lights with LEDs, as they are more energy efficient. Next, we recommend replacing the old double paned windows with new ones, as they have lost their seal and are no longer effective at supporting temperature regulation. However, given that this is a significant investment we recommend, in the short term, adding storm panels to the windows to improve insulation. If with these changes the DPW still has a high EUI, we recommend a professional energy audit to identify more areas of opportunity.

The DPW is currently heated mainly using a wood boiler, also known as a Hydronic Heater. This boiler is over 20 years old and will need to be replaced soon. Replacing a boiler is always an investment. The team recommends looking into electric heating options for the office space in preparation for the boiler's replacement. However, given the characteristics of the garage space, we do not believe it would be feasible to replace the wood boiler with an electric heating system at this time. Given the fact that the wood boiler operates on the *free* fuel source of wood obtained from road-maintenance, we recommend adding particulate matter pollution controls until the system reaches its end of life.

Given that the boiler is near its end of life and the building manager has expressed difficulty in obtaining a replacement, we recommend that following its retirement that the DPW transitions to emerging technologies. In the event that the wood boiler is no longer in use, the wood previously used for heating the building can be used in chip form to restore areas that are not intended to be loamed and seeded throughout Williamstown.

b. Fleet Recommendations

Although there are many barriers to the acquisition of electric vehicles for the Department of Public Works, we recommend continuing to prioritize the replacement of any vehicles that reach their end of life with electric alternatives. As more companies develop electric vehicle alternatives and the technology becomes developed, wait times will decrease and the DPW will be able to make purchases.

Similarly, given that electricity-powered snow plows are not an option. There are many alternative fuel sources available that reduce emissions for larger vehicles such as snow plows. For example, since 2020 the Iowa Department of Transportation has transitioned 10 of their larger snow removal and maintenance trucks to a 100% biodiesel fuel source reducing emissions drastically and maintaining reliability. Biodiesel is suitable for use in any diesel engine, and it can be adopted by fleets in varying blends from 5 percent biodiesel, or B5, all the way up to 100 percent (B100). Any blends above 20% biodiesel (B20) require upgrades in some diesel equipment. However, biodiesel can reduce carbon emissions by more than 50 percent and B100 will reduce Scope 1 carbon emissions by over 95 percent compared to traditional petroleum-based diesel fuel.[34]

4. Milne Library

The Milne Library has an EUI of 68. It is already below the median of 71.6, but still above the target EUI of 57.28. The team was surprised that the library's EUI was below the median, given that we found many areas of opportunity.

First, we recommend insulating the building where possible. The building's occupants reported feeling cold during the winter months and hot during the summer months. The building gets to temperatures so extreme, that the library has to be forced to close sometimes. Insulating would improve conditions for the occupants and help regulate the temperature of the building. Next, we recommend replacing the windows with new double pane windows. The current windows have lost their seal to the point that they are now not fully transparent. Building occupants reported being able to feel the cold coming in through the windows during cold months. Replacing them would help regulate temperature.

Next, the team recommends replacing the current T8 fluorescent light bulbs with LEDs, as they are more energy efficient. With these changes, the library's EUI could potentially reach the target value. If the target value is reached, the team recommends looking into changing the

[34] Optimus Technologies. "Iowa DOT's snow-removal operations achieve near-zero carbon emissions with 100% biodiesel trucks"

building's heating source into an electric one. In the meantime, the team recommends insulating the pipes in the basement that transport heat into the upper level of the building. Heat is being lost while the steam is transported from the boiler room to the main area of the library.

Because the library is outdated, we recognize that at a certain point the investments and benefits for efficiency upgrades on the building may not outweigh the benefits of investing in construction of a new building. Therefore, we do not recommend transitions to an electric heat pump heating and cooling system given the payback period and the estimated remaining time for the building.

Lastly, we were unable to find any tracking information for the production of the rooftop solar panels. The DPW tracking system found no recent data for the solar panels, causing concern for the state of functionality of the panels. We recommend contacting the installation company immediately to ensure that the panels are still functioning and updating the tracking information. Following this check-in, we also recommend exploring potential for adding additional solar panels to the array to offset more electricity use.

5. Parks and Cemetery

Office and Shop

The Office & Shop is not energy efficient, but it has the potential to achieve the net-zero goal. With an EUI of 77.65, it is 24.75 units above the median (52.9) and 35.33 units above the target EUI (42.32). In terms of energy efficiency measures, we recommend that the two walls that are currently not insulated get insulated. In addition, we would recommend replacing all T8 fluorescent light bulbs with LEDs. The Office & Shop's heating source is oil. Therefore, electric heating options should be explored for this municipal building as well given that it is within

Williamtown's Capital Plans to redo the wiring and lighting of the building.Because the oil boiler was installed in 2005, it is nearing its end of life (estimated lifetime 20-25 years). Therefore, we recommend replacing the existing boiler heating system with an air source heat pump system in the next few years when it reaches its end of life.

The Office and Shop currently owns 10 fossil fuel powered mowers and 2 fossil fuel powered trimmers, which are extremely polluting. They are a source of "...high levels of localized emissions that include hazardous air pollutants, criteria pollutants, and carbon dioxide … Extensive evidence exists on the adverse health effects of exhaust emissions and other fine particulates which include cardiovascular disease, stroke, respiratory disease, cancer, neurological conditions…"[35] The Office & Shop has initiated an effort to electrify their trimmers and mowers. Nevertheless, they may need external funding and ways to overcome the fact that the electric mowers market is order-based, while municipalities must first possess the mower to be able to get a rebate for it. Another alternative to electric mowers is checking whether the current mowers are compatible with biodiesel.[36] This fuel is significantly less polluting than gasoline or diesel. The mower manufacturers can be contacted to determine whether this is a viable option.

Sherman Burbank Memorial Chapel

The Shermal Chapel is the second oldest municipal building to which the Town has yet to give attention to energy efficiency. The building is generally kept at 50-55°F unless there are services, which are a couple during the winter and a few during the summer. With an EUI of 46.34, it is 15.84 units above the median (30.5) and 22 units above the target EUI (24.4). Our recommendations for the Chapel are to improve insulation wherever possible and to further

[35] Banks, Jamie. "National Emissions from Lawn and Garden Equipment"
[36] U.S. Department of Energy. "Alternative Fuel Commercial Lawn Equipment"

insulate the single-paned windows. Although the windows are a unique shape and offer aesthetic benefits, there are ways to improve the insulation level of more decorative windows. Storm windows can be added, however they have significant negative aesthetic impacts. Instead, Bowdoin College recently improved the insulation on their single paned-windows through Indow Window Inserts that fit any shape of window and are difficult to see once installed.[37] Adding these window inserts can have significant energy saving impacts.

The Chapel is currently heated using an oil boiler while having a natural gas boiler as a backup, the heat is dispersed through a radiator system. Due to the extremely energy inefficient nature of churches and the use of more intermittent heating in the space, heat pumps are not commonly recommended for Chapels. We recommend that the town explores the installment of air source heat pumps for the space while also remaining vigilant about emerging technologies that may replace the existing fossil fuel-based heating system.

6. Williamstown Police Department

The Police Department still has an EUI of 63.8, it is 0.3 units above the median (63.5) and 13 units above the target EUI (50.8). Given that this is a very new building, we would have expected better energy efficiency performance. However, given that it is nearly at the median level, it has far better performance than many other municipal buildings.

The only energy efficiency recommendation that the team has for the Police Department is to install more temperature controls, to ensure that rooms that are not in use are not heated/cooled, and that all rooms can be at an appropriate temperature (i.e. not having rooms get too warm/cold depending on their location in the building.) We also strongly encourage the Police

[37] Indow Windows. "Losing Church Heating Through the Windows"

Department to undergo an energy audit. All of the PD's heating and cooling is reliant on electricity, making it easier for them to receive clean energy coming in the shape of electricity. In order to fully transition to net-zero the PD will need to replace their existing natural gas water heating system with an electrified option.

In order to reduce building emissions, we recommend exploring the potential for the installation of rooftop solar on the building's roof and on the parking canopy. This could help to offset the electricity usage from the building considerably. Lastly, we recommend that the Police Station upload its current electricity and natural gas accounts to MassEnergyInsights.com. While this process is tedious, it allows for the energy-use data to be easily tracked for future projects.

7. Williamstown Elementary School

The Williamstown Elementary School is already doing a fantastic job regarding energy efficiency: they have already reached the target EUI for their building type. The team did not identify areas of opportunity in this building when it comes to energy efficiency. The Elementary School is ready to take the next step to becoming Net-Zero, which is electrification. The first step the team recommends taking is fixing their onsite solar. The Elementary School's solar panels still work. It is the inverter that needs to be fixed. Fixing the solar panels would help to considerably offset the School's GHG emissions.Additionally, we recommend exploring a potential expansion of the rooftop solar array or exploring parking canopy expansions.

In addition to expanding and fixing solar, we recommend replacing the heating system with heat pumps when it reaches the end of life. Currently, all of their heating comes from natural gas. Given that the Massachusetts Grid's emission factor is lower than that of natural gas, electrifying heating would get the building closer to net zero. Having electric heating and cooling systems would make the elementary school be ready to accept the energy from the Massachusetts grid, which the state of Massachusetts has committed to decarbonizing.[38] However, because the natural gas boiler system was just recently replaced, this replacement will not be cost effective for a number of years. There are successful case studies that Williamstown should draw lessons from. For instance, four elementary schools in Lincoln, Nebraska, installed geothermal heat pumps in 1998, when the performance of the GHP was to be determined. The performance results were positive."On average, the GHP schools [used] 26% less source energy per square foot per year than the non-GHP new schools" within the same district. At the same time, the GHP's "life cycle cost [was] some 15% lower than the life cycle costs of the next most economical option, the WCC/GHWB combination with variable-air-volume air handlers." [39]

c. General Recommendations

One of the main issues the team encountered as we undertook this project was the lack of centralized information. Each building manager is aware of their own building, but there is little town-wide knowledge about the state of the town buildings when it comes to energy usage and energy efficiency. Other similar towns, such as the town of Acton, have addressed this issue by having a Sustainability Coordinator. We recommend that Williamstown consider adding that position to their town management. Having a person in charge of overseeing the process of making the town net-zero will make the process move ahead more smoothly. We also propose having annual check-ins with all building managers to be able to keep updated knowledge regarding the state of all buildings, within the context of sustainability.

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[38] Commonwealth of Massachusetts. "Clean Energy and Climate Plan for 2025"
[39] Oak Ridge National Laboratory."Geothermal Heat Pumps in K–12 Schools."

Furthermore, we encourage implementing a building energy efficiency rating system. The New York City Department of Buildings announced a rating system that will "require all New York City buildings 25,000 square feet or larger to post an energy-efficient letter grade sign at their entrances" in 2024.[40] Inspired by the letter grade rating system of New York City, we recommend a similar system which would use the median EUI as a benchmark (see Appendix 6). Implementing a rating system will benefit the Net Zero effort in that it will allow for the comparison of municipal buildings in terms of energy efficiency. The recommended rating scale is subjective but also based on benchmarks, such as the median EUI provided by Energy Star and the input of experts. Even if subjective, the rating system will still be a tool for transparency as well as for reminding Williamstown's commitment to reaching NetZero. By reminding building managers, employees, and residents about building efficiency or inefficiency, the program will aim to foster a climate of pride for buildings that gradually improve their energy efficiency rating. However, such a rating system must be distinct from the goal of the Net Zero Resolution. Reaching an A or A* will not mean that the goal has been achieved but rather that Williamstown is on the right track.

Finally, achieving Net Zero will require educating Williamstown's older and younger generations. Therefore, an educational component in the broader effort for decarbonization could be fruitful. Interesting projects could educate K-12 students about energy use, efficiency, and decarbonization technologies. For instance, Acton came up with a project called "Power Down." The project includes actions such as the creation of artwork and the hanging of green door tags around the school by students to remind teachers and staff about energy conservation before the

[40] Sembros, Tom. "Understanding New York City's Building Energy Efficiency Rating System"

end of the week or holiday breaks.[41] In brief, students can learn about energy sustainability but can also be messengers in their households of Williamstown's or MA's climate action efforts. During a presentation of the Net Zero project to Mount Greylock High School students in December 2022, our team realized how interested the high school students were in learning about climate issues, which reinforces the recommendation to include students in the effort to achieve a carbon-free town.

Funding Prospects

In Massachusetts, the Green Communities division of the Department of Energy Resources (DOER) is the main provider of funding opportunities for municipalities with 20% or higher energy reduction goals.[42] More precisely, the division offers competitive grants twice a year, with applications usually due in early April and October. The funds can cover a variety of projects, such as energy conservation measures, the purchase of electric vehicles, the replacement of heating systems, etc. Williamstown, being a green community since 2010, and having received two of those grants in April and December 2021, could keep applying for funds assuming that the Green Communities division keeps providing them.[43] In addition, Williamstown could benefit from Municipal Energy Technical Assistance (META) grants that the Green Communities Division provides regardless of Green Communities status.[44] These grants are provided once a year. META aims to support the involvement of third parties in municipalities so that they can develop energy projects or conduct feasibility studies of such. For

[41] Massachusetts Department of Energy Sources. "Acton Public Schools/Acton- Boxborough Regional School District."
[42] Massachusetts Department of Energy Sources. "Being a Green Community."
[43] Massachusetts Department of Energy Sources. "Green Communities Designations Reach Two Hundred Eighty-Six."
[44] Massachusetts Department of Energy Sources. "Municipal Technical Assistance Grants Available"

example, Williamstown could use META grants to conduct engineering studies and identify the most feasible heating and cooling technologies for each building.

In addition, MassSave, an initiative sponsored by Massachusetts electric utilities, natural gas, and energy efficiency service providers, offers electrification, workforce development, and equity incentives for climate action. The municipality of Williamstown or the COOL Committee could be eligible for grants, such as the Mass Save Workforce Partnership Grant or the Community First Partnership program. MassSave also offers rebate incentives. For instance, it currently offers $2,500/ton for air-source heat pumps and $4,500/ton for ground-source heat pumps.[45]

Regarding municipal vehicles, Massachusetts currently has an Energy Vehicle Incentive Program (MassEVIP).[46] The two programs that Williamstown is an eligible applicant for are the MassEVIP Fleets Program and the MassEVIP Workplace and Fleet Charging Program. The first provides funding for municipalities to buy or lease EVs, while the second provides funding for the municipality's electric fleet vehicle charging stations.

Although not a funding source, Energy Management Services (EMS) can also benefit Williamstown's larger energy projects. EMS is an option for energy-saving performance contracting.[47] It guarantees that the contractor executing the project and installing equipment will also ensure a certain level of energy project performance. Unless the targeted energy savings are achieved, EMS will pay for the lack of performance.

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45 Mass Save. "Air Source Heat Pumps"
46 Massachusetts Department of Environmental Protection. "Apply for MassEVIP Fleets Incentives."
47 Massachusetts Department of Energy Sources. "EMS Procurement Assistance and Enforcement."

Final Recommendations

In summary, we recommend that prior to implementing any of the decarbonization technologies, the town must make significant investments in improving the energy efficiency of each of the buildings so that they become "net zero ready" as defined by the 20% EUI reduction goal. The roadmap below outlines the appropriate steps needed to be taken by the town in order to reach its overall Net Zero by 2050 goal. Within the energy efficiency measures, stage 3, we have outlined the building priorities based on the total greenhouse gas emissions produced and EUI performance. The process of this ranking can be explored further in Appendix 1.

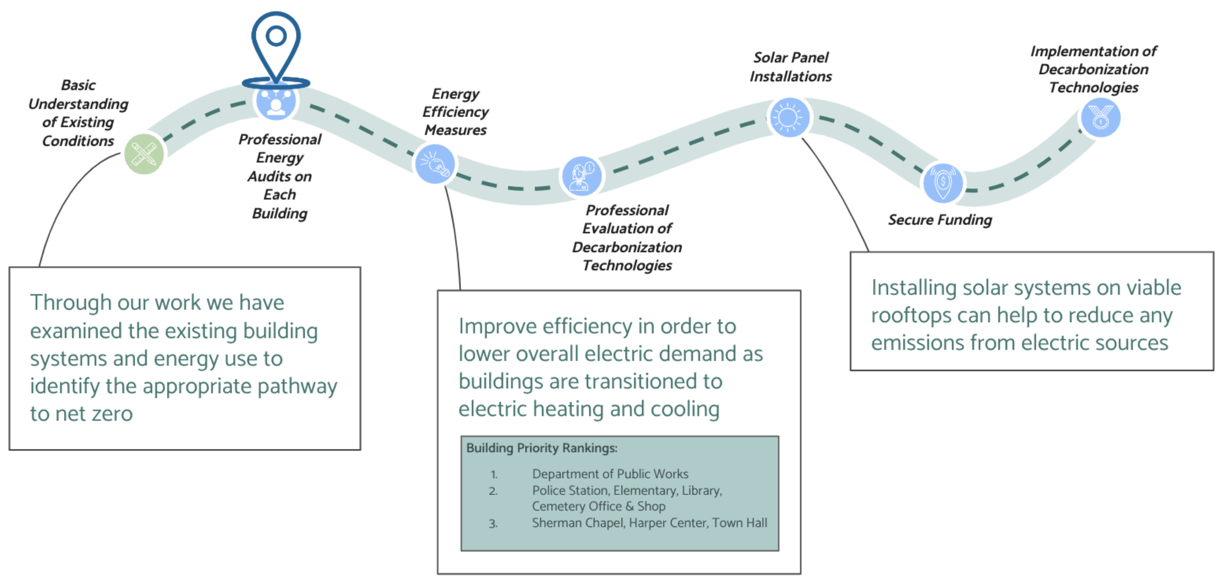


Figure 9: Williamstown Roadmap To Net Zero by 2050

Additionally, we have outlined 4 immediate action items for the town to begin with in their path to net zero. These items are based on ease of completion and importance of action.

Immediate Action Items:

- Fix the Elementary School Solar Inverter
- Check in on Milne Library solar Array tracking system

- DPW Storm Window Addition and Library Window Replacement
- Evaluate replacement and upgrade options for DPW heating system

Conclusion

The roadmap we have generated creates a loose pathway for the Williamstown municipal buildings to reach their net zero goals by 2050. This report signifies a very important step in reaching the Town's decarbonization goals; however it is just the first of many. Although we have done important work in collecting building data and analyzing the state of the municipal buildings, it is important to employ professionals to provide more accurate and specific energy efficiency recommendations and to assess the viability of many recommended technologies within each building space.

While at the time of the presentation of this report the viability or cost-competitiveness of some technologies may not be at the standard needed by the Town, by taking action on the recommended energy conservation measures, the Town can prepare the buildings for when the technologies become available.

Additionally, in order to reach these net zero goals, the Town must incorporate the environmental benefits of energy efficiency and decarbonization measures into their cost-benefit analyses. We hope that by taking our recommendations outlined in this plan into consideration in addition to placing a priority on town sustainability, Williamstown will be able to achieve its net zero goal by 2050.

Appendix

Appendix 1: EUI Calculations

Building	Calculated EUI	Median EUI	20% Goal	Building Classification
Town Hall	54.86	52.9	42.32	Office
Harper Center	52.69	56.1	44.88	Social/Meeting Hall
DPW	79.87	52.9	42.32	Office
Milne Library	68.00	71.6	57.28	Library
Sherman Chapel	46.34	30.5	24.4	Church
Office & Shop	77.65	52.9	42.32	Office + repair services
Elementary School	39.22	48.5	38.8	School
Police Department	63.78	63.5	50.8	Police Station

Appendix 2: Heat Pump Matrices

For Technology Far From End of Life:

Scoring Matrix

Indicator	Criteria	Gas Boiler Heating System	ASHP	Ground Source Heat Pumps	Wood Boiler	Oil Boiler
Technical	Efficiency Score (under ideal conditions)	2	5	5	2	2
	Reliability (in cold climates)	2	2[48]	3	2	2
	Explosion Risk	1	3	3	1	1
	CO Risk	2	0	0	0	0
	Total (14)	0.5	0.71	0.78	0.35	0.35
Economical	Investment Cost (per ton)	5	3[49]	1[50]	5	5
	Maintenance and Operation Cost ($100/yr)	2	2	3	2	2
	Fuel Cost ($/MMBtu)	5	1	1	5	2
	Service Life	3	3	5	3	3
	Predicted Cost of Fuel	1	3	3	2	1
	Payback Period (years)	3	2	1	3	3
	Total (24)	0.75	0.58	0.58	0.83	0.67

[48] Schoenbauer, Ben. “Case Study: Field Test of Cold Climate Air Source Heat Pumps (Single Family)”
[49] This Old House. “How Much Does a Heat Pump Cost?”
[50] This Old House. “How Much Does a Heat Pump Cost?”

Environmental	Ecosystem Disruption	3	3	2	1	3
	Noisiness	3	3	3	1	3
	Emissions Factor	1	3	3	2	3
	Total (9)	0.89	1	0.89	0.55	1
Overall Score		2.14	2.29	2.25	1.73	2.02

Qualitative Matrix

Indicator	**Criteria**	**Gas Boiler Heating System**	**ASHP**	**Ground Source Heat Pumps**	**Wood Boiler**	**Oil Boiler**
Technical	Efficiency Score (under ideal conditions	50%-90%	300%-600%	300%-600%[51]	40%-90%	56%-85%[52]
Economical	Investment Cost ($)	3,760-6,730[53]	3,300-7,500[54]	13,000-36,000[55]	$6,000-$14,00[56]0	$3,800-$7,500
	Maintenance and Operation Cost ($/yr)	350	350	225	125	135[57]
	Fuel Cost ($/MMBtu)	6.12	28.61	28.61	0	22.69
	Service Life (years)	15-20	10-20	-20+ for the heat pump itself -25 to 50 years for the underground infrastructure.	15-20	15-20[58]

51 U.S. Department of Energy. "Guide to Geothermal Heat Pumps"
52 Holden. "AFUE Furnace Ratings: What is Considered "Good"?"
53 Bonner, Catie. "How Much Does a New Gas Boiler Cost to Install?"
54 This Old House. "How Much Does a Heat Pump Cost?"
55 This Old House. "How Much Does a Heat Pump Cost?"
56 Graham, Adam. "How Much Does It Cost to Install a Wood Boiler?"
57 Massachusetts Department of Energy Resources. "Oil Heat Maintenance"
58 Miller, Rene. "The Life Span of an Oil Furnace"

	Predicted Cost of Fuel	increase	decrease	decrease	same	increase
	Payback Period (years)	0	4.7	5-10 years	0	0
Environmental	Ecosystem Disruption	none	none	Drilling for geothermal space	none	Particulate matter emissions, noise pollution
	Noisiness	low	50 to 60 decibels	42 decibels	Loud	53 decibels[59]
	CO2 Emissions Factor	898	528.2	528.2	723	556.9
	Total	8.98	5.282	6.282	7.23	
Overall Score						

For Technology Near End of Life:

Scoring Matrix

Indicator	Criteria	Gas Boiler Heating System	ASHP	Ground Source Heat Pumps	Wood Boiler	Oil Boiler
Technical	Efficiency Score (under ideal conditions)	2	5	5	2	2
	Reliability (in cold climates)	2	2[60]	3	2	2
	Explosion Risk	1	3	3	1	1
	CO Risk	2	0	0	0	0
	Score (14)	0.5	0.71	0.79	0.35	0.35

59 D.R. Plumbing & Heating. "How Noisy is an Oil Boiler?"
60 Schoenbauer, Ben. "Case Study: Field Test of Cold Climate Air Source Heat Pumps (Single Family)"

Economical	Investment Cost (per ton)	3	3[61]	1[62]	1	3
	Maintenance and Operation Cost ($100/yr)	2	2	3	2	2
	Cost of Fuel ($/MMBTU)	5	1	1	5	2
	Service Life	3	3	5	3	3
	Predicted Cost of Fuel	1	3	3	2	1
	Payback Period (years)	3	2	1	3	3
	Score (17)	0.71	0.58	0.58	0.67	0.58
Environmental	Ecosystem Disruption	3	3	2	1	3
	Noisiness	3	3	3	1	3
	Emissions Factor	1	3	3	2	3
	Score (9)	0.89	1	0.89	0.44	1
Overall Score		2.1	2.29	2.26	1.46	1.93

Qualitative Matrix

Indicator	**Criteria**	**Gas Boiler Heating System**	**ASHP**	**Ground Source Heat Pumps**	**Wood Boiler**	**Oil Boiler**
Technical	Efficiency Score (under ideal conditions	50%-90%	300%-600%	300%-600%[63]	40%-90%	56%-85%[64]

61 This Old House. "How Much Does a Heat Pump Cost?"
62 This Old House. "How Much Does a Heat Pump Cost?"
63 U.S. Department of Energy. "Guide to Geothermal Heat Pumps"
64 Holden. "AFUE Furnace Ratings: What is Considered "Good"?"

Economical	Investment Cost ($)	3,760-6,730[65]	3,300-7,500[66]	13,000-36,000[67]	$6,000-$14,00[68]0	$3,800-$7,500
	Maintenance and Operation Cost ($/yr)	350	350	225	125	135[69]
	Fuel Cost ($/MMBtu)	6.12	28.61	28.61	0	22.69
	Service Life (years)	15-20	10-20	-20+ for the heat pump itself -25 to 50 years for the underground infrastructure.	15-20	15-20[70]
	Predicted Cost of Fuel	increase	decrease	decrease	same	increase
	Payback Period (years)	0	4.7	5-10 years	0	0
Environmental	Ecosystem Disruption	none	none	Drilling for geothermal space	none	Particulate matter emissions, noise pollution
	Noisiness	low	50 to 60 decibels	42 decibels	Loud	53 decibels[71]
	CO2 Emissions Factor	898	528.2	528.2	723	556.9
	Total	8.98	5.282	6.282	7.23	
Overall Score						

[65] Bonner, Catie. "How Much Does a New Gas Boiler Cost to Install?"
[66] This Old House. "How Much Does a Heat Pump Cost?"
[67] This Old House. "How Much Does a Heat Pump Cost?"
[68] Graham, Adam. "How Much Does It Cost to Install a Wood Boiler?"
[69] Massachusetts Department of Energy Resources. "Oil Heat Maintenance"
[70] Miller, Rene. "The Life Span of an Oil Furnace"
[71] D.R. Plumbing & Heating. "How Noisy is an Oil Boiler?"

Appendix 3: Building Prioritization Matrix

The following matrix calculates a total ranking of priority for each building. A higher total score indicates a higher priority. The greenhouse gas ranking ranks each building based on total greenhouse gas emissions (excluding any emitted from the electric grid) and the EUI ranking ranks each building based on the difference between its calculated EUI and the median building EUI.

Building	**GHG Ranking**	**EUI Ranking**	**Total Score**
DPW	7	8	15
Elementary School	8	1	9
Office and Shop	2	7	9
Sherman Chapel	1	6	7
Harper Center	3	4	7
Library	6	3	9
Police Station	4	5	9
Town Hall	5	2	7

Appendix 4: Total Emissions Calculations

	Total Emissions (MT CO2)	kg CO2	Square Footage	kg CO2/sqft
Town Hall	39.44	39440	14,222	2.773168331
Harper Center	12.48	12480	4298	2.903676128
DPW	260	260000	25,800	10.07751938
Milne Library	72.164	72164	18,843	3.829751101
Sherman	8.87	8870	1100	8.063636364

Chapel				
Office & Shop	9.51	9510	2042	4.657198825
Elementary	250.99	250990	88,000	2.852159091
Police Department	47.21	47210	12000	3.934166667
Town Fleet	185.13	185130	-	-

Appendix 5: 2021 Energy Usage by Building

Electricity Usage (kwh)								
	Town Hall	**Harper Center**	**DPW**	**Police Station**	**Elementary School**	**Library**	**Office & Shop**	**Sherman Chapel**
January	8,061.0	668.0	7,408.3	6,960.0	23,680.0	5,200.0	365.5	170.0
February	6,739.0	604.0	7,544.0	6,800.0	21,760.0	4,880.0	184.9	209.0
March	7,075.0	690.0	7,711.7	10,800.0	24,640.0	-	202.1	201.0
April	6,763.0	633.0	4,552.8	11,760.0	25,440.0	13,600.0	1,040.5	140.0
May	6,478.0	570.0	3,540.1	13,920.0	22,400.0	4,160.0	1,079.3	78.0
June	6,285.0	642.0	2,736.1	13,600.0	31,040.0	4,160.0	1,165.6	71.0
July	7,358.0	749.0	2,807.7	10,240.0	23,360.0	4,320.0	1,201.3	205.0
August	5,465.0	825.0	3,077.9	8,080.0	22,080.0	4,400.0	1,097.3	176.0
September	5,701.0	927.0	3,106.0	8,000.0	24,640.0	5,440.0	772.1	190.0
October	4,745.0	707.0	2,584.2	8,040.0	26,560.0	3,760.0	970.2	148.0
November	4,574.0	643.0	3,011.3	8,040.0	24,160.0	4,960.0	445.3	136.0
December	4,821.0	807.0	5,367.3	7,460.0	26,080.0	6,400.0	359.8	195.0

Natural Gas Heating (therms)								
	Town Hall	**Harper Center**	**DPW**	**Police Station**	**Elementary School**	**Library**	**Office & Shop**	**Sherman Chapel**
January	1,241.0	267.0		370.0	6,780.0	2,290.0		61.0
February	886.0	267.0		288.3	6,184.0	2,152.0		293.0

March	708.0	258.0		250.3	4,782.0	1,712.0		172.0
April	346.0	199.0		161.1	2,666.0	719.0		40.0
May	158.0	77.0		75.5	1,116.0	332.0		0.0
June	66.0	63.0		65.1	298.0	1.0		0.0
July	2.0	73.0		4.1	238.0	0.0		0.0
August	2.0	65.0		36.0	212.0	0.0		0.0
September	14.0	81.0		76.8	401.0	0.0		0.0
October	269.0	105.0		94.5	1,567.0	386.0		0.0
November	700.0	235.0		198.7	4,430.0	1,456.0		163.0
December	883.0	282.0		264.0	5,366.0	1,782.0		241.0

Appendix 6: Energy Efficiency Rating System

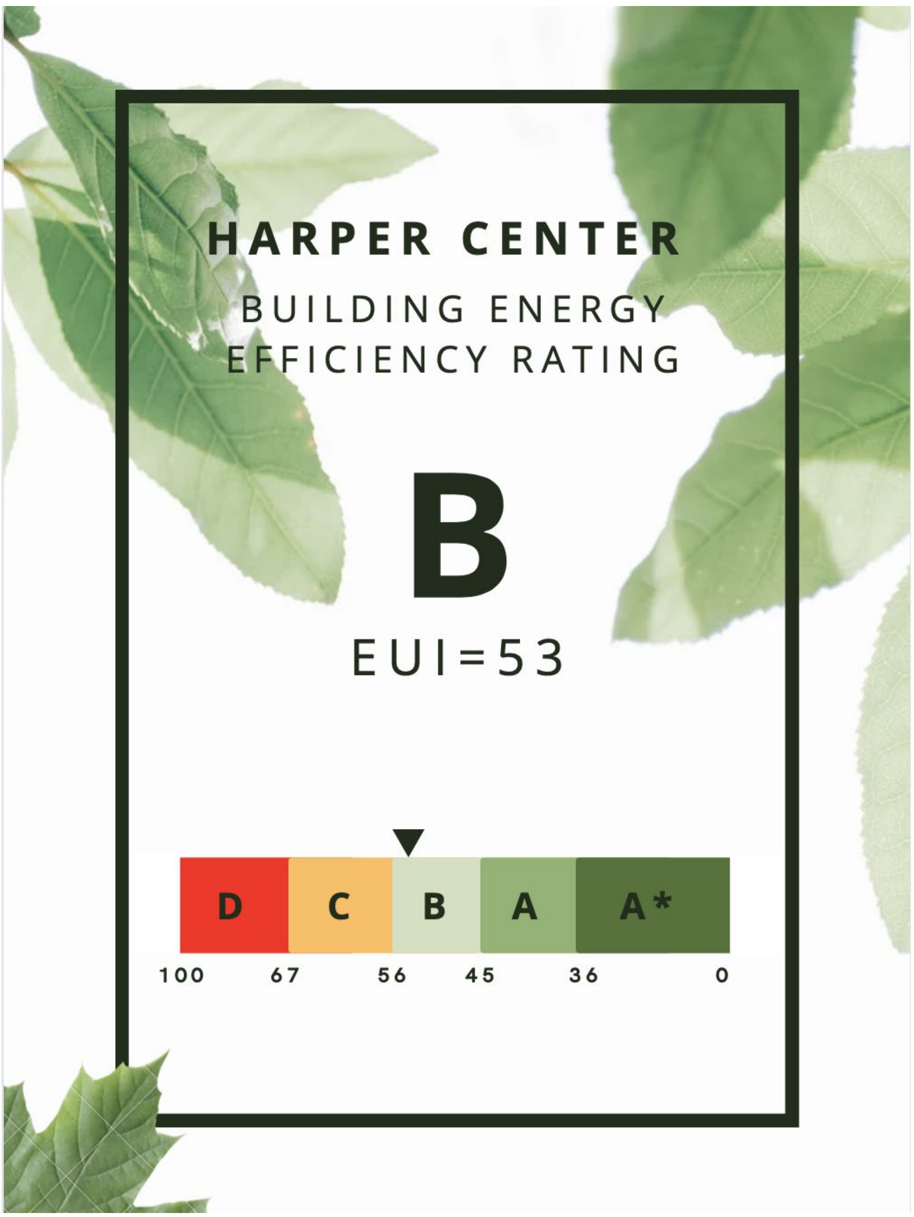
The recommended letter grading assignment is the following:

- A* - when EUI >35% lower than the median EUI
- A - when EUI at least 20% lower than the median EUI
- B - when EUI = median EUI or 1-19% lower than the median EUI
- C - when EUI max 20% higher than the median EUI
- D - when EUI >20% higher than the median EUI

Building	**Calculated EUI**	**Median EUI**	**20% Goal**	**Building Classification**	**% difference from median EUI**	**Recommended System Ratings**
Town Hall	54.86	52.9	42.32	Office	+3.7%	**C**
Harper Center	52.69	56.1	44.88	Social/Meeting Hall	-6%	**B**
Department of Public Works	79.87	52.9	42.32	Office	+50%	**D**
Milne Library	68.00	71.6	57.28	Library	-5%	**B**
Sherman Chapel	46.34	30.5	24.4	Church	+52%	**D**

Office & Shop	77.65	52.9	42.32	Office + repair services	+47%	**D**
Elementary School	39.22	48.5	38.8	School	-19.13%	**B/A**
Police Department	63.78	63.5	50.8	Police Station	0.4%	**B**

Example of Building Energy Efficiency Rating Poster



Appendix 7: Rating Systems for the Electrification Matrix

Below are the scales for each of the factors used to rank the technologies. Each factor was rated on either a 3- or 5-point scale outlined below.

Technical Factors:

Energy efficiency under ideal conditions: based on each technology's Annual Fuel Utilization Efficiency[72], which measures the percentage of heat produced for every volume of fuel consumed per year. When technologies have an AFUE that is above 100%, that means that they produce more energy than they consume. When their AFUE is lower than 100%, it means that there are energy leakages during the energy production process. We will use the median of the range of efficiencies for each technology.

1. 0%-50%
2. 50%-100%
3. 100%-200%
4. 200%-300%
5. 300% - 400%

Efficiency in cold climates: sometimes the AFUE of heating technologies changes when they are exposed to very cold temperatures. Because Williamstown reaches really low temperatures in the winter, we took into account how these technologies function in these conditions.

1. 0%-50%
2. 50%-100%
3. 100%-200%
4. 200%-300%

[72] Boyer, Dennis. "Choosing Between an HRV and an ERV"

5. 300% - 400%

Reliability in cold climates: Performance of the heating system in cold weather below freezing temperatures. Is there any research that warns against this technology failing in the winter?

1. Frequent failure in below freezing conditions
2. Occasional failure in below freezing conditions
3. No recorded failure in below freezing conditions

Explosion Risk: some heating technologies that use gas or oil have the potential to explode if not working properly. We ranked technologies based on this safety risk.

1. High Risk of explosion
2. Medium risk of explosion
3. Low Risk

Carbon Monoxide Risk: Carbon monoxide is a colorless, odorless, tasteless gas. It is a by-product of combustion, created by the incomplete burning of any material containing carbon, such as gasoline, natural gas, oil, kerosene, propane, charcoal, or wood. Carbon monoxide poisoning can occur when there are high amounts of the gas in an enclosed space[73].

1. High Risk of CO Poisoning
2. Medium risk of CO Poisoning
3. Low Risk of CO poisoning

Economic Factors:

Investment Cost: Measured as the estimated average cost for both the unit and installment costs for each technology type. For units already present in the buildings (boilers) the estimated investment cost is zero.

[73] Mississippi State Department of Health. "Fact Sheet: Carbon Monoxide in the Home"

1. $8,000+
2. $6,000-$7,999
3. $4,000-$5,999
4. $2,000-$3,999
5. $0-$1,999

Maintenance Cost: The estimated average cost in dollars for yearly maintenance performed on the heating and cooling system.

1. $500+
2. $300-$499
3. $200-$299
4. $100-$199
5. $0-$99

Service Life: The expected lifetime of the heating system.

1. 5-10 years
2. 10-15 years
3. 15-20 years
4. 20-25 years
5. 25+ years

Predicted Cost of Fuel: Simple qualitative scale of the predicted rise or fall of energy sources into the future. Given that the price of fossil fuel resources is expected to rise and electricity is expected to fall, we will take into account the predicted direction of fuel costs.

1. Predicted Increase
2. No Change
3. Predicted Decline

Payback period: The average time to payback the cost of investment taking into account savings earned from technology upgrades

1. 6-8 years
2. 3-6 years
3. 0-3 years

Environmental Factors:

Emissions Factor: The emissions factor is a calculation of the pounds of carbon dioxide produced per megawatt hour of energy produced.

1. 8-10
2. 6-7.99
3. 4-5.99

Noisiness: Qualitative scale of the amount of noise produced from the use of the energy system.

1. Notable noise production
2. Some noise production
3. No noise disruption

Ecosystem Disruption: Qualitative scale of the physical impact on the surrounding environment resulting from the installation process. This may include noise pollution, particulate matter pollution, or physical destruction of ecosystems.

1. Large amount of disruption
2. Some ecosystem disruption
3. No Disruption of Ecosystem

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Expert Interviews

- Tanja Srebotnjak, Director of the Zilkha Center at Williams College. Oct 19, 2022.
- Jason Moran, Assistant Director for Energy and Utilities at Williams College. Oct 20, 2022.
- Robert Menicocci, Williamstown Town Manager. Oct 21, 2022.
- Todd Holland, University of Massachusetts Energy Management. Nov 2, 2022.

Site Visit Interviews

- Ken McAlpine, Head of Facilities at Williamstown Town Hall. Oct 26, 2022.
- Chris Lemoine, Director of the Department of Public Works. Oct 27, 2022.
- Pat McLeod, Director of the Milne Library. Oct 31, 2022.
- Michael Ziemba, Williamstown Chief of Police. Nov 3, 2022.
- Brian O'Grady, Director of the Harper Center. Nov 4, 2022.
- Jim O'brien, Williamstown Elementary School Head of Facilities. Nov 15, 2022.
- Justin Olansky, Cemetery Office and Shop. Nov 15, 2022.