BUILDING
DECARBONIZATION GUIDE



WORSHIP FACILITY

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HOW TO USE THIS GUIDE

WHAT IS BERDO?

Boston's Building Emissions Reduction and Disclosure Ordinance (BERDO) is a local law that aims to reduce air pollution and greenhouse gas emissions (GHG) from Boston's largest buildings, which account for 40% of the city's carbon emissions. Building owners subject to BERDO are required to report their buildings' annual energy and water consumption as well as comply with building emissions standards. These emissions standards decrease over time, with all BERDO buildings expected to reach net-zero emissions by 2050.

Reducing carbon emissions means cleaner air, improved public health, and fighting the climate crisis, but also makes our buildings healthier and more comfortable.

HOW TO USE THIS GUIDE

The City of Boston's Building Decarbonization Guides are a resource for building owners and property managers to get to know their buildings, understand how their buildings use energy, and identify the most impactful building upgrades that can improve energy efficiency, reduce emissions, and help with BERDO compliance.

In this guide, we model a sample **worship facility** to help you navigate the typical characteristics and energy systems found in these buildings. While your building may look a bit different from the sample model, the takeaways from this guide are relevant for any worship facility.

In this guide you will learn:

- Typical characteristics and energy systems in your building,
- How your building uses energy and produces emissions,
- Steps you can take to reduce your building's energy use and emissions, and
- Technical and financial resources available for building upgrades.

This guide can be a starting point to familiarize yourself with key aspects of building decarbonization, but all buildings will require their own assessment to select the right equipment, repairs, or electrical service that may be needed for specific upgrades. Always consult a qualified service provider before undertaking any building upgrades.

Is this not your building?

Explore other Building Decarbonization Guides we prepared for typical Boston buildings at **boston.gov/berdo**.

SAMPLE BUILDING:

WORSHIP FACILITY

In this guide, we will walk you through the types of energy upgrades and decarbonization measures you can make in a typical worship facility.

A worship facility has many ways to save energy and lower emissions over time. The first step is to understand the building's current systems and the challenges they face. Below are size characteristics of the building we modeled, as well as some of the common challenges found in each major building element.

33,000

SQUARE FOOTAGE

EXTERIOR WALLS

Steel framed construction with masonry façade.

Challenges:

- Air leakage
- Minimal to no insulation
- Thermal bridging/ heat loss at roofs and floorplates

WINDOWS

Double-hung framing made from different materials with single or double panes in mixed setups and no thermal break.

Challenges:

- Air leakage and drafts
- Poor insulative performance

HEATING

Hydronic hot water heating with baseboard convectors. Heating hot water supplied by gas boiler.

Challenges:

- Little to no temperature control or monitoring
- Uneven heating
- Varying occupancy schedules

COOLING

Ductless mini-split systems.

Challenges:

- Decentralized cooling, equipment operated based on individual settings

DOMESTIC HOT WATER

Dedicated gas-fired hot water heater.

Challenges:

- Low DHW use, hot water production relies on fossil fuel systems
- High water flow rates at plumbing fixtures

VENTILATION

Mixture of partial mechanical exhaust and natural ventilation through windows.

Challenges:

- No fresh air supply
- May have low ventilation or high ventilation which can cause poor indoor air quality and unnecessary energy use

ELECTRIC CAPACITY

Likely existing in-unit electrical capacity of 110/120 volt present.

Challenges:

- A study of current capacity and future needs may be required to see if upgrades are needed
- Switchgear and feeder cables at the building level, and panel and wiring upgrades likely needed to provide 220/240 volt service—dependent on the electrification upgrade

HOW THIS BUILDING USES ENERGY

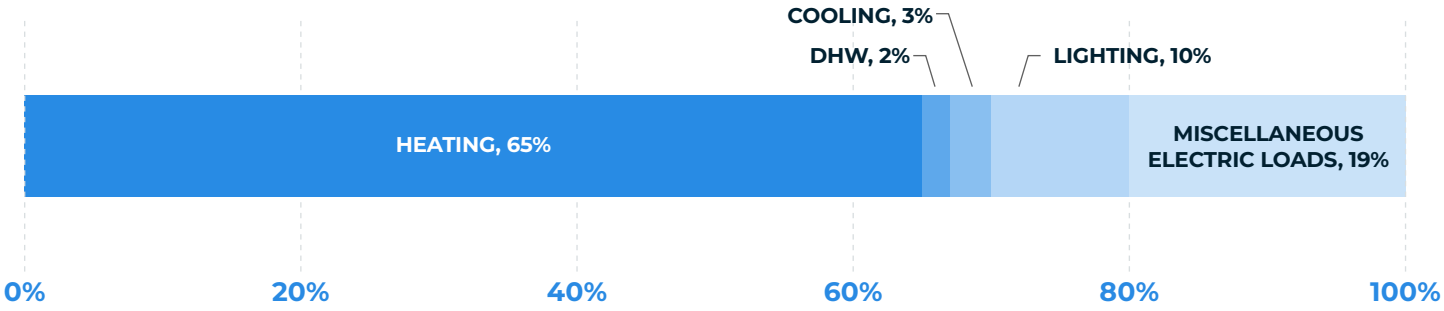
Heating with natural gas is the largest energy use in this building.

Upgrading the building's heating system is the biggest opportunity to reduce emissions.

Most of the **electricity** in this building is used for **lighting and miscellaneous electric loads.**

Miscellaneous electric loads can vary across buildings, but can generally be managed with efficient appliances, smart controls, and other strategies.

END USE BREAKDOWN ($kgCO_2e/sf$)



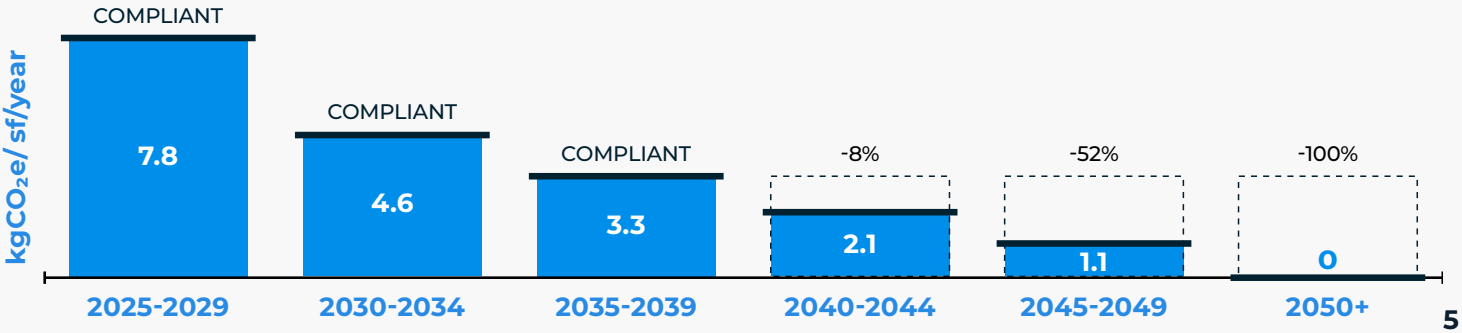
BERDO COMPLIANCE

BERDO requires the amount of kilograms of carbon dioxide a building releases per square foot every year (kgCO2e/sf/yr) to stay under the limit set for its building type. Houses of Worship fall under the Assembly building use type. This modeled building has an emissions intensity of 2.3 kgCO2e/sf/yr. This means our sample worship facility is already compliant with its emissions standards from 2025 to 2039. However, to comply with BERDO in the long-term, the house of worship will have to reduce its energy usage in order to lower its emissions by the percentages shown in the figure below for each period of time.

BERDO EMISSIONS STANDARDS (LIMITS) IN $kgCO_2e/sf/yr$

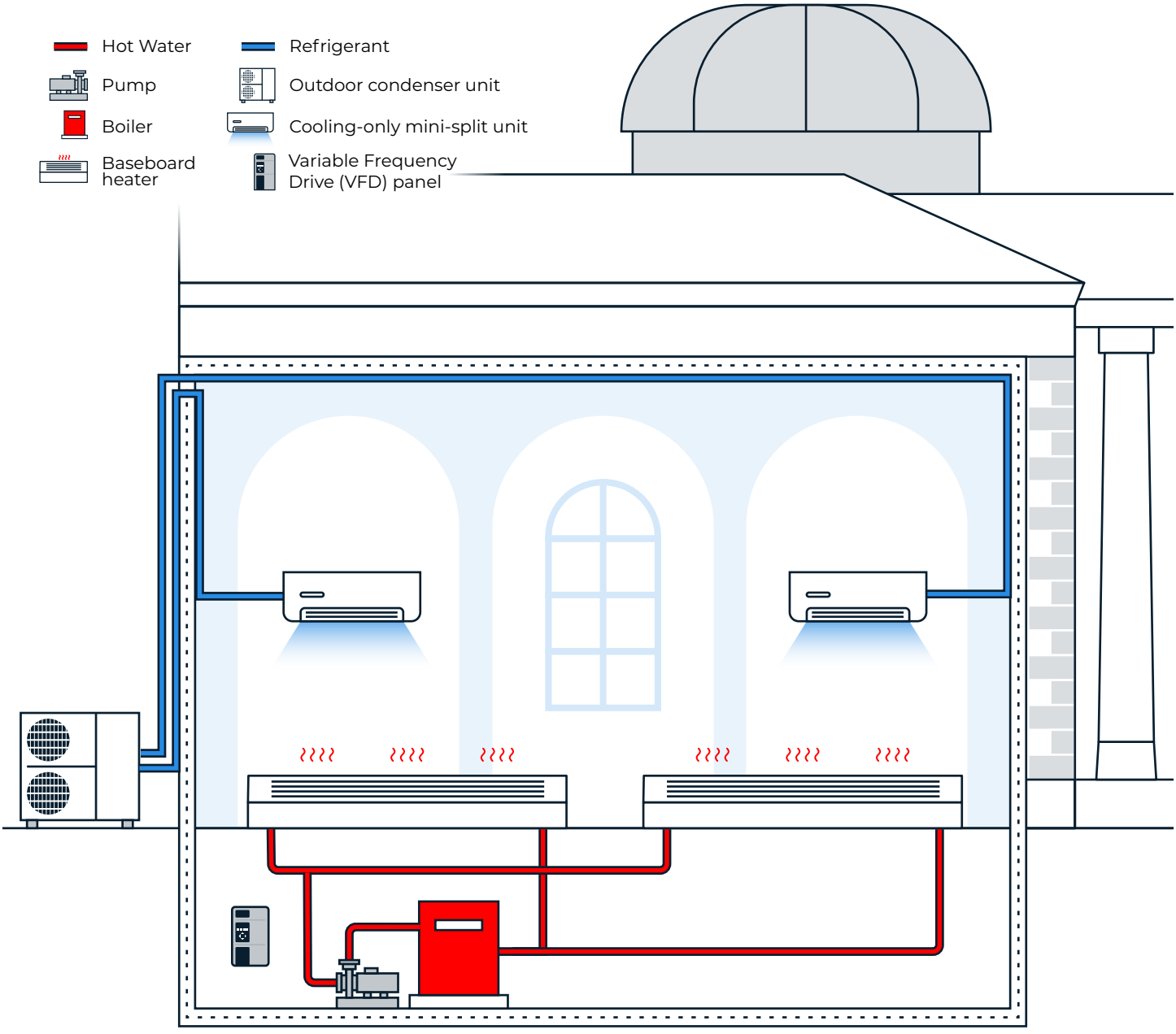
- *$kgCO_2e$/ sf/year*
- *% emissions reduction needed to comply with each period*
- *Emissions limit*

These estimates are based on a typical building of this size. Emissions reductions can change from building to building and should be calculated for each one separately.



UNDERSTANDING YOUR HEATING SYSTEM

HYDRONIC LOOP WITH BASEBOARD HEATERS



Optimized hydronic loop heats the building through baseboard heaters. Ductless mini-splits provide cooling.

A hydronic loop with heat exchanger system is a common heating set up in worship facilities. In this example, a central boiler located in the basement of the building is used to heat water.

Large pumps move this hot water through a hydronic loop (a closed-piped water loop) connected to baseboard heaters.

Baseboard heaters located in the nave of the church work as heat exchangers that release heat from the hot water into the room. After transferring heat, the cooled water returns to the boiler to be reheated and sent out back to the baseboards again.

Hydronic systems need certain parts to help hot water move through the pipes properly:

- **Expansion tanks**: When water is heated, it expands and can't be compressed. Expansion tanks give the water extra space so the pipes and valves don't burst.
- **Air separators and air vents**: These parts remove air from the pipes. Getting rid of trapped air helps the water flow more smoothly through the system.

Cooling is provided by ductless mini-split units. In this example, the system consists of two mini-split units connected to an outdoor condenser unit via refrigerant lines. Unlike modern mini-split heat pumps, this mini-split system only provides cooling and cannot be used for heating.

NEAR TERM OPPORTUNITIES FOR IMPROVEMENT

There are cost-effective, proven improvements for hydronic systems to increase efficiency and comfort that should always be considered as part of any improvement plan. Further detail on these steps are provided in the last section of this guide:



RETRO-COMMISSIONING (*P. 13*)

A central heating plant and controls need regular tuning and adjustments for optimal performance.



INSTALL VARIABLE FREQUENCY DRIVES (VFDS) (*P. 14*)

VFDs allow pumps to speed up and slow down based on heating demand, reducing electricity usage and better responding to temperature needs in the building.



INSTALL SMART THERMOSTATIC RADIATOR VALVES (TRVS) (*P. 14*)

Install at each baseboard heater to regulate the flow of hot water and help maintain a desired temperature.

ELECTRICAL SERVICE CONSIDERATIONS FOR BUILDING ELECTRIFICATION

Switching to electric heating, hot water, and cooking systems is one of the main ways to reduce emissions, and it can be a big project. For example, **heat pump systems** need enough electrical power to work. Older buildings may need **electrical upgrades** to increase their electrical capacity. The cost of these upgrades depends on the building's current capacity and power use, so they should be carefully reviewed.

Electrical service upgrades can be broken down into these basic components:



ELECTRIC SERVICE FROM THE LOCAL GRID

First, the utility company must supply enough power to the building. Building owners need to work with the utility and review the building's current and future power needs to confirm there is enough capacity or to request an upgrade.

- An analysis is needed to figure out how much electricity a building will need from the utility.
- A mechanical engineer designs the heating and cooling systems and chooses the size of the equipment, which affects how much electricity the building will use.
- An electrical engineer then looks at the building's current electricity use and estimates how much more will be needed. This helps determine if the building has enough electrical capacity.

If the current supply is enough, the upgrades can move forward. If not, the utility will need to add more capacity. The utility decides what work is required and whether the building owner will need to pay for any of it. This can take anywhere from months to years, however, the timing and process can vary for each building.



BUILDING CENTRAL INFRASTRUCTURE

Electricity enters the building through a main connection and goes to a switchgear. The switchgear can turn the power on or off for the whole building when needed. This helps isolate the building from the main electrical supply. The switchgear must be large enough to handle all incoming electricity. Some equipment, such as large chillers, might also need a special transformer to provide extra voltage to operate.



DISTRIBUTION AND METERS

Next, electricity goes to the building's main meter or a group of meters for apartments or businesses. The cables that bring electricity must be the right size. Large equipment like a heat pump water heater usually connects at this point.



INDIVIDUAL UNIT SERVICE

Electrical risers carry power to each unit's electrical panel. The panel controls electricity for the unit and provides safety shut-offs. Power flows from the panel to outlets and equipment. For equipment such as heat pumps, condenser units, water heaters, dryers, and refrigerators, the wiring and panel must provide enough amperage, usually 220 or 240 volts. This is often where electrical capacity is too low and a load study is needed to understand what upgrades are required. In some cases, new wiring can run directly from the equipment to a central location, bypassing panels, either through chases within or exterior to the building without going through the unit's panel.

The electrical infrastructure in your building should be evaluated to see if upgrades are needed to support new equipment installation. Evaluating your electrical infrastructure can sometimes be as simple as having an electrician inspect your panels, but more complex cases may require a full electrical feasibility study by a qualified firm or contractor.

TIMING YOUR BUILDING UPGRADES

Building systems impact each other. For example, better insulation can reduce heating and cooling loads. The timing of construction projects can impact installation costs and disruption. Using incentives or rebates that may be available in the short term frees up capital to invest in incremental improvements further into the future.

Poor sequencing can lead to missed chances to combine work or to retrofit building systems that work with each other and improve your building's performance in the long run. A long-term plan helps organize building upgrades so that a deep energy retrofit can be done more efficiently.

TIMING CONSIDERATIONS

EXISTING BUILDING SYSTEM OPTIMIZATION



Prioritize carrying out measures that reduce heating and cooling loads, such as air sealing, heating system controls, and distribution repairs, lighting and appliance upgrades as soon as feasible. These measures reduce heating and cooling needs, allowing for purchase of smaller and less expensive equipment when the time comes for future system upgrades. These measures also tend to improve comfort and health for occupants through improved air quality, temperature control, and safety.

The energy cost savings from reduced heating and cooling loads in the short term can also be applied toward capital expenses for future, larger-scale measures.

PROGRAMMING CHANGES



Building owners have the opportunity to make energy efficiency improvements in addition to repairs or aesthetic upgrades when spaces are not being used or when other changes are already planned for a space. This includes air sealing in places that may be hard to reach when spaces are occupied and replacing or upgrading equipment such as air conditioners or boilers when they are not being used. For a house of worship, this may mean timing upgrades with seasons, less busy times, and/or changes to community spaces like daycares.

EXISTING BUILDING SYSTEM END OF LIFE



Upgrades to building systems are often most cost-effective at the time when major equipment is at the end of its useful life and due for replacement. Capitalize on these times where investments are already required to upgrade key systems, or choose additional systems that can easily be completed at the same time. While the exact time for replacement may not be known, it is good practice to plan around the equipment's expected useful life. This also helps minimize the risk of expensive emergency repairs or replacements.

Between now and 2050, there may be only one chance to replace major systems like heating and cooling. It's important to plan ahead so you can make upgrades that save the most energy and money.

RESOURCES FOR BUILDING UPGRADES

There are many resources available to you to help you decarbonize your building:

Retrofit Resource Hub ↗

The City of Boston maintains a resource with the most up-to-date incentives, rebates, tax credits, and loans that can help you throughout your decarbonization journey.

Mass Save Non-Profit Program ↗

If you are ready to begin exploring decarbonization options for your building, start by identifying what upgrades your building needs. You can contact Mass Save for a no-cost energy assessment and to explore possible incentives and financing options.

Hire a Building Science Firm ↗

The City of Boston maintains a list of Building Science Firms that have responded to a request for information for BERDO-related services. This can serve as a helpful starting point for finding a vendor, but is not an exhaustive list of companies that offer these services. These firms can:

- Assess your building
- Recommend energy improvements
- Obtain incentives on your behalf, and
- Find the right contractors for the job.

TIP: ***It is best practice to request quotes from multiple providers to make sure that you are getting the right services for your situation at the best price.***

BUILDING UPGRADES TO LOWER GREENHOUSE GAS EMISSIONS

This section guides you through the measures you can take to upgrade your building systems, organized by system type. Each upgrade overview includes cost ranges, estimated energy savings, key considerations, and other helpful information. Depending on your building's condition, the age of your systems, and your available budget, you can decide which energy-saving measures can be made right away and which should be planned over time.

The City of Boston's BERDO team is here to help you. Visit boston.gov/berdo to learn about our program offerings, get in touch, and access our latest resources and guides.

GREENHOUSE GAS EMISSIONS REDUCTIONS AND COSTS

All emissions reductions and cost numbers in this document are estimates for the example building presented in this guide. Actual results may be different based on your building and its systems, market costs for equipment and labor, and the work that is needed.

COMPONENT	TERM	MEASURE	% REDUCTIONS	COST LOW	COST HIGH
LIGHTING & LOADS	Immediate	LED Upgrades + Controls	1.4%	$12,800	$16,600
HEATING & COOLING	Immediate	Retro-commissioning	5.1%	$11,600	$16,600
	Immediate	Controls + Distribution Improvements	3.5%	$33,100	$66,200
	Long	Heating Electrification	41.2%	$1,158,900	$2,483,300

EMISSIONS REDUCTION MEASURES BY SYSTEM TYPE

IMMEDIATE TERM

LIGHTING & LOADS

LED UPGRADES + CONTROLS

LED light bulbs use 90% less energy than traditional lighting options and have the longest lifespan of all bulb options. Automatic lighting controls such as motion sensors can reduce lighting energy use even further.

CONSIDERATIONS

- LED equivalents exist for all fixture and lamp types, which can be installed in main congregation areas as well as back of house and ancillary spaces.

ACCESS NEEDED TO MAKE IMPROVEMENTS

Access to lighting fixtures, minimal disruption.

ADDITIONAL RESOURCES

- LED lighting retrofits
- ENERGY STAR Energy Efficiency Toolkit for Worship Facilities
- ASHRAE Communities of Faith Technical Resources

RECOMMENDED SPECIFICATIONS

- Target 50% reduction in watts per square foot in common areas to reduce wasted energy use.
- ENERGY STAR labeled fixtures and lamps.

ENERGY SAVINGS

About 14% of the building's lighting load

CAPITAL COST

Estimated to be between $0.37–$0.50 / SF

EMISSIONS REDUCTION MEASURES BY SYSTEM TYPE

IMMEDIATE TERM

HEATING & COOLING

RETRO-COMMISSIONING

Retro-commissioning (RCx) is a crucial process for maintaining existing building performance and is generally recognized as the first stage in the building upgrade process. RCx focuses on optimizing and improving the performance of existing building systems.

RCx starts with an assessment from an energy engineer and/or commissioning agent to evaluate if the building's systems are designed, installed, functionally tested, and capable of being operated and maintained according to the owner's operational needs. Following the assessment, the owner must complete the study's recommendations to achieve energy savings. This can range from simple setpoint adjustments and scheduling improvements, to repairing or replacing sensors, dampers, or other non-functioning components of an HVAC system.

RCx can be done for any building, but is particularly useful for older buildings where systems may have changed from their original design specifications. RCx covers the performance of HVAC equipment, distribution efficiency, controls settings, and any operational settings that affect the system's energy efficiency.

CONSIDERATIONS

- Have equipment documentation available for consultant review and inventory all systems before assessment.

ACCESS NEEDED TO MAKE IMPROVEMENTS

- Access to mechanical systems and building automation system (if installed).

ADDITIONAL RESOURCES

- Operations & Maintenance Guide
- Hydronic Heat Upgrade
- ENERGY STAR Energy Efficiency Toolkit for Worship Facilities
- ASHRAE Communities of Faith Technical Resources

RECOMMENDED SPECIFICATIONS

- Follow best practices set by manufacturer or designer.

ENERGY SAVINGS

About 5% of the building's usage (conservative estimate based on federal research indicating up to 30%)

CAPITAL COST

Estimated to be between $0.39–$0.50 / SF

EMISSIONS REDUCTION MEASURES BY SYSTEM TYPE

IMMEDIATE TERM

HEATING & COOLING

CONTROLS + DISTRIBUTION IMPROVEMENTS

Hydronic systems can be optimized by better managing flow of the heating hot water through the system.

Install Variable Frequency Drives (VFDs): VFDs can be installed at the main distribution pumps to reduce electricity usage. Distribution pumps without VFDs run at a constant speed when operating, regardless of heating demand in the building. VFDs can speed up and slow down pumps as needed to maintain temperatures to a desired level and reduce electricity consumption. New distribution pumps may be needed that are compatible with VFD controls.

Install Smart Thermostatic Radiator Valves (TRVs): TRVs and control systems can be installed at the baseboard convectors to regulate temperatures across rooms. Control systems can also address varying occupancy schedules by adapting to periods of low and high occupancy and accounting for varying spaces within the building.

CONSIDERATIONS

- Pumps must feature the appropriate insulation class in order to accommodate VFDs. Existing pumps must be surveyed for suitability, or replaced.
- The heating supply must be shut off to implement this work. This is best completed in the summer or well-scheduled to minimize heating disruptions during the winter.

ACCESS NEEDED TO MAKE IMPROVEMENTS

- Access to basement piping and pumps.
- Plumber/technician access at all terminal units.

ADDITIONAL RESOURCES

- ENERGY STAR Energy Efficiency Toolkit for Worship Facilities
- ASHRAE Communities of Faith Technical Resource
- Hydronic Heat Upgrade

RECOMMENDED SPECIFICATIONS

- Specifications must be designed by engineers.

ENERGY SAVINGS

Estimated 4% of heating load

CAPITAL COST

Estimated $1.00–$2.00 / building SF

EMISSIONS REDUCTION MEASURES BY SYSTEM TYPE

LONG TERM

HEATING & COOLING

HEATING ELECTRIFICATION

Heating electrification is a major project that involves completely replacing the heating system and its related equipment and connections. Switching to electric heating is one of the best ways to lower emissions because it replaces one of the biggest sources of fossil fuel use in buildings. There are two main types of efficient, electric heating systems:

Mini-Split Heat Pumps



These are small systems with one outdoor unit (compressor) connected to the indoor unit (mini- split) that condition the air in the room. They don't use ducts and are good for heating and cooling single rooms.



Central Air to Water Heat Pump (AWHP) Plant

A bank of AWHPs can replace a fossil fuel boiler and heat the hot water loop for the building.

CONSIDERATIONS

- **Mini-Split Heat Pumps:** This is a well-established technology you can trust. Space is needed for exterior condensing units – usually roofs or ground level space. You should consider your building's structural integrity, your roof's replacement schedule, and placement of refrigerant lines.
  - Best suited for smaller buildings—refrigerant lines connecting condensing units to the mini-splits within the building have maximum length limitations and must be placed appropriately.
  - Installation requires penetrations for refrigerant lines between condensers and the in-unit mini-splits.
- **Central Air to Water Heat Pump (AWHP) Plant:** This is a technology already available in the market.
  - The number of heat pumps you need depends on your heating load.
  - Space is needed for equipment and adequate venting.
  - Replacing your building's heating source for AWHP may require little to no adjustment to the existing distribution system or terminal units.
- Your building and local utility must have enough electrical capacity to support heat pump systems. Always check electrical loads first, as electric service upgrades can have high costs depending on your building's existing capacity.
- Regulations for refrigerants can change over time. You should always confirm that the equipment you are installing is permissible under upcoming code requirements.

ADDITIONAL RESOURCES

- Mini-Splits

RECOMMENDED SPECIFICATIONS

- Heating: 3.3 COP @ 47°F Cooling: 4.4 COP
- Cold climate certified equipment

ENERGY SAVINGS

Estimated 73% reduction in heating loads

CAPITAL COST

Cost can range from $35 / SF to over $100 / SF, depending on the system type and capital constraints.

Electric service upgrades can have high costs depending on your building's existing conditions, but they are not always necessary. Electric service upgrades must be identified on a site-by-site basis.