BUILDING
DECARBONIZATION GUIDE



COMMERCIAL OFFICE

Class B

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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 **Class B commercial office building** to illustrate the typical characteristics and energy systems found in these properties. While your building may differ somewhat from this model, the key takeaways apply to most office buildings with similar features.

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**.

CHARACTERISTICS OF CLASS B OFFICE BUILDINGS

Commercial office real estate is often grouped into different classes. These classes help describe a building's features, location, rent, age, and overall condition. In the City of Boston's Decarbonization Guides, we modeled two types of office buildings: Class A and Class B. **This guide will cover Class B buildings, you can find our Class A Commercial Office Buildings guide at boston.gov/berdo.**

CLASS A
BUILDINGS

Class A buildings usually have central systems that provide heating and cooling for the whole building. For these Building Decarbonization Guides, we assume Class A buildings were built more recently, any time between 1970 and today.

CLASS B
BUILDINGS

Class B buildings usually have central **heating** systems, but **cooling** is handled independently by each tenant. This means cooling systems vary from space to space.

For these Building Decarbonization Guides, we assume Class B buildings were built between 1900 and 1930. Our sample Class B commercial office building uses a **central heating and Domestic Hot Water (DHW) system** that relies on a natural gas boiler. **Cooling** is provided by decentralized air-cooled Direct Expansion units, also known as DX units. These air conditioning systems are directly operated by tenants. **Ventilation** is managed by opening windows and decentralized systems such as exhaust fans in bathrooms, and the DX units themselves.

Since electricity is already used for air conditioning, the building's electrical service may already be strong enough to upgrade to electric heating.

BUILDING FEATURES AND RELATED CHALLENGES

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

A Class B office building 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.

65,000

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 aluminum or fiberglass framing, double pane glass with thermal breaks.

Challenges:

- Air leakage and drafts
- Poor insulative performance

HEATING



Two-pipe steam system with a gas-fired boiler.

Challenges:

- Little to no temperature control or monitoring
- Uneven heating

COOLING



DX units, usually owned and operated by tenants.

Challenges:

- Decentralized cooling, equipment operated based on tenant individual settings

DOMESTIC HOT WATER (DHW)



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 risers and windows.

Challenges:

- No fresh air supply
- Both low ventilation and high ventilation in the building can cause poor indoor air quality and unnecessary energy use

ELECTRIC CAPACITY



Potentially has in-unit electrical capacity of 220 volts.

Challenges:

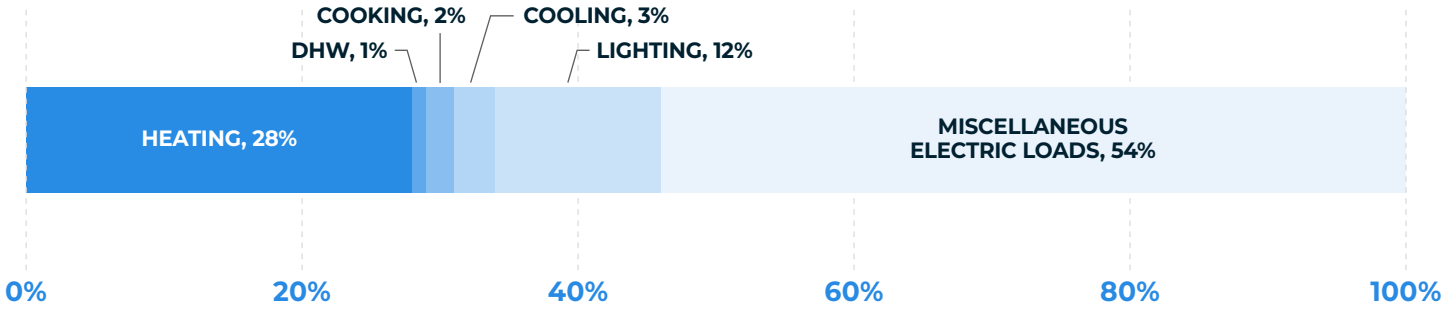
- A study of current capacity and future needs may be required to see if upgrades are needed

HOW THIS BUILDING USES ENERGY

Electricity is the main energy use and source of emissions in this building. Most electricity use is driven by tenant meters, which includes **miscellaneous electric loads** such as computers and lighting, and air conditioning in tenant spaces. Tenants are generally responsible for and pay for their own electricity use, which cannot be controlled by the building owner. A smaller amount of electricity is used for common area lighting, central cooling, and other small needs.

Heating with natural gas is the second largest energy use and source of emissions. The central heating system can be managed and upgraded by the building owner.

END USE BREAKDOWN ($kgCO_2e/sf$)

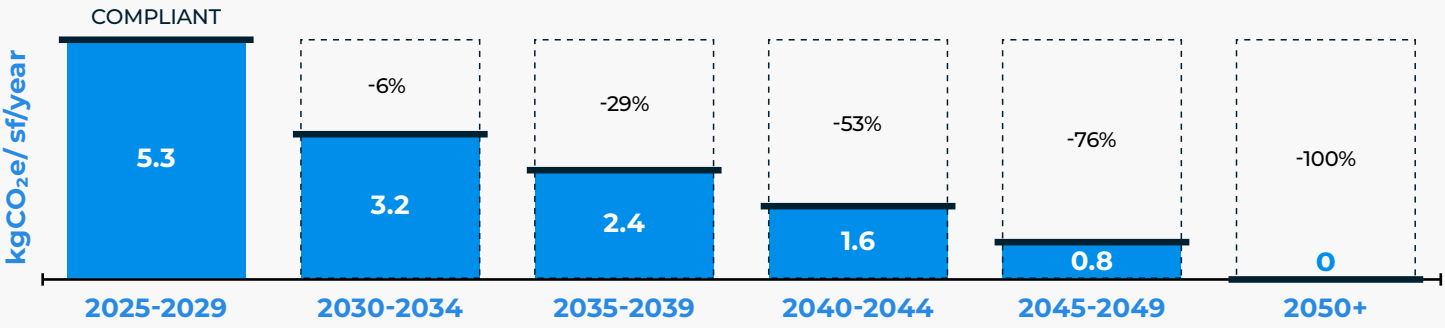


BERDO COMPLIANCE

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. From 2025 to 2029, an office building has an emissions limit of 5.3 kgCO2e/sf/yr. This modeled Class B commercial building is under the emissions limit for 2025-2029 but will need to lower its emissions by the percentages shown in the figure below for each period of time to remain compliant with BERDO.

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

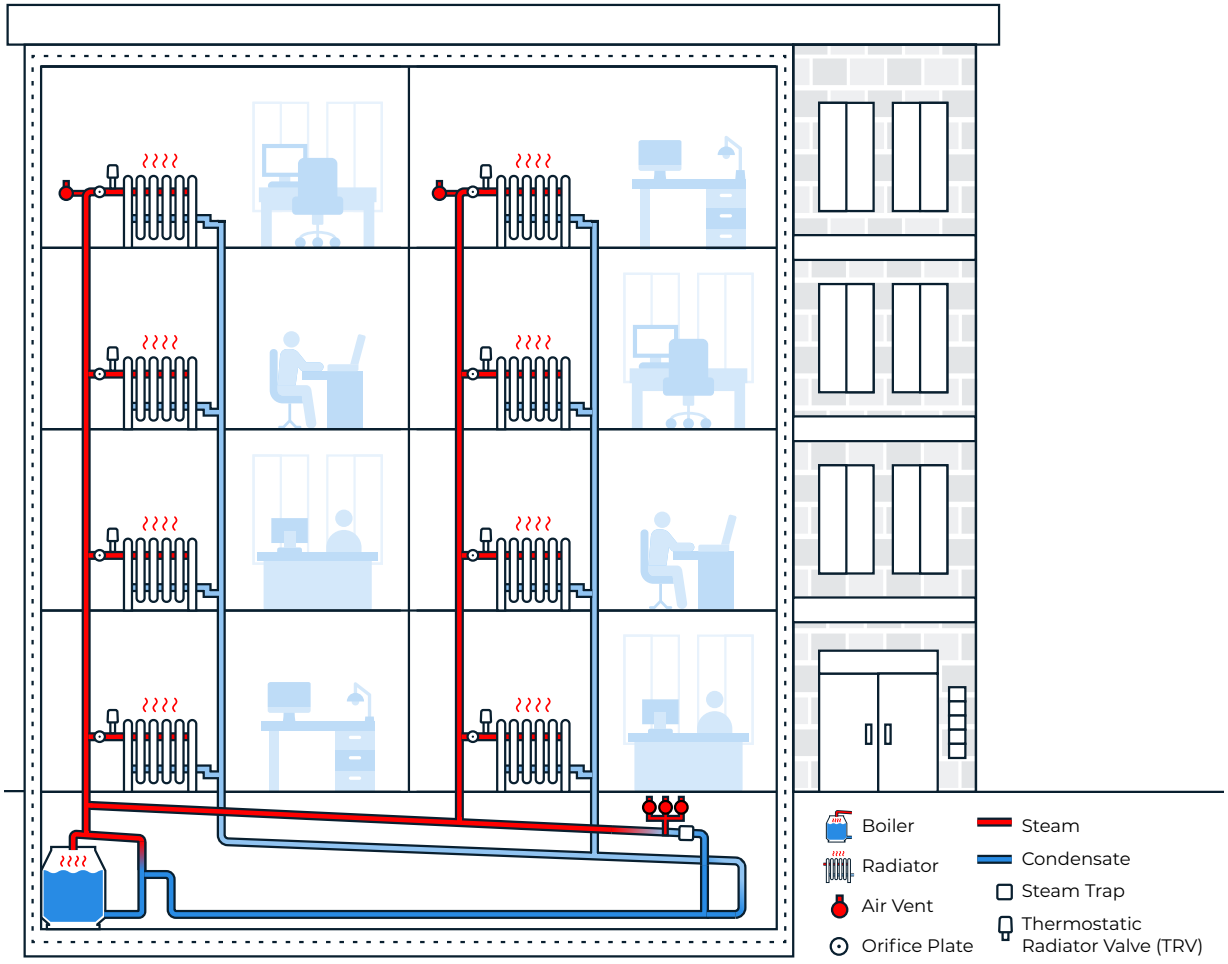
- *$kgCO_2e/sf/year$*
- *% emissions reduction needed to comply with each period*
- *Emissions limit*



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

TWO-PIPE STEAM SYSTEMS



Optimized two-pipe steam system in a Class B office building.

Two-pipe steam systems are a common heating setup found in older large commercial buildings. These systems consist of a central boiler that relies on fossil fuels, a steam supply pipe, a condensate pipe, and steam traps.

In this example, a boiler located in the basement heats water and converts it into steam. This steam travels through the supply pipe into individual radiators located inside individual rooms. After transferring heat to the radiators, the steam cools down and turns into condensated water. This water travels through the condensate pipe back into the boiler, where it is turned into steam again.

Steam traps are a very important part of a two-pipe steam system. When properly maintained, steam traps ensure steam stays in the radiators while letting air and water escape through the condensate pipe. Without working traps, steam would move through the radiators too quickly, leading to heat losses and higher operating costs.

Steam traps have a useful life of five to eight years. Frequently testing and replacing your building's steam traps is important to keep your two-pipe steam system operating efficiently.

FUEL OIL VERSUS NATURAL GAS IN TWO-PIPE STEAM SYSTEMS

If the equipment and setup are similar, two-pipe steam systems that use natural gas are usually more efficient than those that rely on fuel oil. However, **fuel oil generates around 40% more greenhouse emissions than natural gas.**

Fuel oil systems also need more regular maintenance. For example, you must ensure that the equipment used to check oil levels and the pumps used to move the fuel oil through the heating system are functioning at all times. Filters and strainers in the pipes must also be cleaned from time to time. Finally, some systems may also need pre-heaters to keep the fuel oil at the right temperature.

1.4X MORE EMISSIONS

CREATED BY FUEL OIL THAN NATURAL GAS

FUEL / ENERGY SOURCE	EMISSIONS FACTOR (KG/MMBTU)
NATURAL GAS	53.11
PROPANE	64.25
FUEL OIL (NO. 1)	73.50
FUEL OIL (NO. 2)	74.21
FUEL OIL (NO. 4)	75.29
FUEL OIL (NO. 5, 6)	75.35

2025 Emissions Factors from ENERGY STAR Portfolio Manager

UPGRADING TWO-PIPE STEAM SYSTEMS

Your two-pipe steam system will eventually need to be replaced when it reaches the end of its useful life or fails. When this happens, you typically have three options:

- **Like-for-like replacements:** Replace your system with similar **fuel oil equipment**, which keeps your building's emissions high.
- **Fuel conversion:** Switch to **natural gas**, which has slightly lower emissions than fuel oil.
- **Electrification:** Switch to **electric systems**, such as heat pumps, which eliminate emissions from fossil fuels.

While replacing your existing equipment with the same type of fuel oil equipment may be cheaper or easier in the short term, **upgrading to energy-efficient electric systems can pay off in the long run.**

Upgrading to a more efficient heating system could save you more energy and reduce long-term BERDO compliance costs.

The timing of a replacement might not always match BERDO compliance deadlines. If that is the case, you can start with other energy efficiency measures in your building that can help you comply with BERDO in the short-term.

FUEL CONVERSIONS

Many buildings that use steam heating can switch from fuel oil to natural gas. This can help reduce (but will not eliminate) emissions from fossil fuels in your building. Usually, the same boiler and two-pipe system can stay in place, but the fuel and exhaust system need to change.

Before making this switch, building owners should think about long-term goals like:

- Reducing emissions to meet BERDO emissions standards in the long-term
- Planning for future equipment upgrades
- How much energy will cost over time
- Whether making Alternative Compliance Payments is more cost effective than improving your building's energy performance

COSTS AND WORK INVOLVED

Switching to natural gas usually involves:

- Shutting down the old fuel oil system, including removing tanks and pipes
- Changing the boiler to one that works with gas
- Updating exhaust systems to handle gas emissions
- Paying for the gas hookup to connect the building to the gas utility

While natural gas produces less emissions than fuel oil, long-term natural gas use will likely result in the need to pay Alternative Compliance Payments for BERDO in later years.

ELECTRIFICATION

Having an energy-efficient electric heating system will release the least amount of greenhouse gas emissions.

When deciding what kind of system to install, it's important to compare long-term costs. This means looking at how much it will cost to run the system over time and whether it will help you stay in compliance with BERDO.

Electric systems usually cost more to install than just replacing an existing fuel oil or natural gas system, but they can save money and reduce emissions in the long run. The best choice may be different for each building and it usually requires an electrification study done by an engineer.

NEAR TERM OPPORTUNITIES FOR IMPROVEMENT

There are cost-effective, proven improvements for two-pipe steam 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. 20*)

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

ADD MASTER VENTS TO PIPES (*P. 21*)

High-capacity air vents at the ends of steam mains and on the tops of riser lines should be installed to flush trapped air quickly and ensure that steam reaches all apartments evenly.

UPGRADE BOILER CONTROLS (*P. 21*)

Typical boiler controls rely only on outdoor temperature readings to turn the boiler on or off (regardless of how hot or cold apartments are), resulting in uncomfortable overheating. Upgrading to multi-sensor controls that monitor both indoor and outdoor temperatures makes a steam system more responsive to actual heating needs. This allows the boiler to run only as often as needed to maintain comfort, saving fuel and money.

INSTALL SMART THERMOSTATIC RADIATOR VALVES (TRVS) (*P. 21*)

Install TRVs at each radiator to regulate the flow of steam into radiators 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.

TENANT TURNOVER



Building owners and landlords have the opportunity to make energy efficiency improvements in addition to repairs or aesthetic upgrades when tenants vacate spaces. This includes air sealing in places that may be hard to reach when spaces are occupied, standardizing equipment, and replacing or upgrading equipment such as air conditioners or packaged terminal units.

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 Commercial and Industrial 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.***

PERFORMANCE-BASED LEASES: ENCOURAGING ENERGY EFFICIENCY

The way most commercial leases are set up can make it difficult to invest in projects that lower emissions. Building owners are usually responsible for central HVAC systems and the building envelope, while tenants often handle the interior build-out and upgrades of their office spaces. Because of this, tenants and owners don't always have shared goals around energy efficiency. This creates what's called a **split incentive**, where the owner pays for new equipment, but the tenant benefits from lower energy bills.

One way to approach this is by using **Performance-Based Leases.** These leases include terms that support carbon reduction efforts. They set clear building performance targets, outline which party is responsible for costs and performance, and require regular tracking of energy use. They also include steps for ongoing monitoring and retrocommissioning (making sure building systems are working efficiently) and describe what happens if either the owner or tenant doesn't meet their goals.

For additional details on green leasing practices, visit greenleaseleaders.com.

GREEN LEASE LEADERS

BUILDING UPGRADES TO LOWER GREENHOUSE GAS EMISSIONS

This section guides you through the measures you can take to upgrade your building systems. Each upgrade overview is based on the modeled building and 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	% REDUCTION	COST LOW	COST HIGH
LIGHTING & LOADS	Immediate	LED Upgrades + Controls	1.7%	$25,100	$32,000
ENVELOPE	Immediate	Air Sealing	0.7%	$16,200	$32,000
	Immediate	Roof Insulation	0.6%	$198,400	$226,800
	Long	Recladding/Wall Insulation	7.2%	$885,500	$1,138,500
	Long	Window Replacement	1.9%	$759,000	-
VENTILATION	Long	Energy Recovery Ventilation (ERV) System	1.1%	$290,000	$340,000
HEATING & COOLING	Immediate	Retro-commissioning	5.0%	$22,600	$32,300
	Immediate	Controls + Distribution Improvements	3.9%	$64,650	$129,290
	Long	Heating Electrification	17.5%	$2,262,600	$4,848,400

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

- Beyond common areas (stairwells, corridors, back of house), address tenant spaces where possible, and all exterior fixtures.
- Tenant hard-wired fixtures can be upgraded to LED but requires coordination with tenants.

ACCESS NEEDED TO MAKE IMPROVEMENTS

Common Areas: Access to lighting fixtures, minimal tenant disruption.

Tenant Spaces: Access to hard-wired fixtures, minimal disruption.

ADDITIONAL RESOURCES

- LED lighting retrofits
- Chapter 5 of the ASHRAE Energy Efficiency Guides for Commercial Office Buildings
- US Department of Energy Advanced Energy Retrofit Guide for Office Buildings

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

ENVELOPE

AIR SEALING

Making a building airtight can lower energy use and improve indoor air quality. It also helps ventilation systems work more efficiently. You should consider airtightness in any building upgrade. All parts of the building envelope, including windows, walls, insulation, and doors, contribute to air tightness.

CONSIDERATIONS

- It's also important to seal up areas like stairwells, elevator shafts, duct risers, and roof bulkheads to stop air from leaking out.
- Different parts of the building need different materials to seal properly. For example, caulk works well for small cracks, while spray foam or weatherstripping may be better for larger gaps.
- Fresh air systems should be added or upgraded to keep the indoor air clean and healthy.

ACCESS NEEDED TO MAKE IMPROVEMENTS

- **Common Areas:** Not applicable.
- **Tenant Spaces:** Minimal. Access to air conditioners, window frames, and exterior facing walls may be required. Most in-unit air sealing is done with conducted caulk, weather stripping, or dedicated covers and gaskets.

ADDITIONAL RESOURCES

Air Sealing for Room Air Conditioners

RECOMMENDED SPECIFICATIONS

- Reduce Air Leakage: Recommended airtightness = 1.0 ACH.

ENERGY SAVINGS

Estimated 2.5% of heating load

CAPITAL COST

Estimated $0.25–$0.50 / SF

EMISSIONS REDUCTION MEASURES BY SYSTEM TYPE

IMMEDIATE TERM

ENVELOPE

ROOF INSULATION

Upgrading roof insulation helps extend the building's lifespan and lowers energy costs by reducing the load on heating and cooling systems.

If your building has a flat roof with some or no existing insulation, consider installing insulation above the existing roof deck. This should include solid insulation boards such as polyisocyanurate (Polyiso), extruded polystyrene (XPS), or expanded polystyrene (EPS), covered by a protective layer. This type of installation provides more continuous insulation and often delivers better thermal performance.

CONSIDERATIONS

- Any plan to add insulation to the exterior of a building must be carefully coordinated with any zoning or lot line restrictions, as well as any potential oversight by local authorities such as historic preservation ordinances.
- Roof insulation is governed by minimum code requirements; adding insulation must comply with other regulations such as roof height, parapet height, etc.
- Insulation improvements are most cost effective at the time of roof replacement.
- Consider light and reflective cool roof materials when resurfacing.
- Consider improvements alongside rooftop equipment installation to phase work appropriately.
- Blown-in cellulose or mineral wool are preferred for their reduced health risks. Fiberglass is also used but should be properly sealed to limit exposure.

ACCESS NEEDED TO MAKE IMPROVEMENTS

- **Common Areas:** Roof access only.
- **Tenant Spaces:** Not applicable.

ADDITIONAL RESOURCES

- Roof Insulation
- Chapter 5 of the ASHRAE Energy Efficiency Guides for Commercial Office Buildings
- US Department of Energy Advanced Energy Retrofit Guide for Office Buildings

RECOMMENDED SPECIFICATIONS

- Minimum of R-30, or local code minimum (higher R-value is better)

ENERGY SAVINGS

2% of heating load

CAPITAL COST

$35–$40 / SF of roof area

EMISSIONS REDUCTION MEASURES BY SYSTEM TYPE

LONG TERM

ENVELOPE

RECLADDING/WALL INSULATION

Upgrading exterior insulation is one of the most effective ways to reduce energy use and maintain a comfortable indoor temperature. Products like External Insulation and Finishing Systems (EIFS) can be added to the outside of a building and include all parts of the exterior wall system in one product.

CONSIDERATIONS

- Unlike masonry and glass façades, products like EIFS do not have ongoing maintenance costs. Buildings that already budget for façade maintenance can repurpose this money to install EIFS. Well-made products are designed to handle weather better than older materials and often include a drainage layer to reduce moisture damage. Brick facades, for example, need regular maintenance and re-pointing bricks to stay in good shape and remain structurally safe.
- Before upgrading your façade, make sure a structural engineer reviews whether your building's structure can support the changes, especially if your building is an older masonry building.
- EIFS may not be allowed in certain landmark districts or on buildings with historic designation.

ACCESS NEEDED TO MAKE IMPROVEMENTS

- **Common Areas:** Common area windows may need exterior protection or scaffolding.
- **Tenant Spaces:** Interior insulation requires access to tenant spaces. Tenants need to temporarily relocate for a limited amount of time. Thoughtful planning is important to minimize disruption and keep things comfortable for tenants.

ADDITIONAL RESOURCES

- Wall Insulation
- Chapter 5 of the ASHRAE Energy Efficiency Guides for Commercial Office Buildings
- US Department of Energy Advanced Energy Retrofit Guide for Office Buildings

RECOMMENDED SPECIFICATIONS

- R value = Minimum R-22

ENERGY SAVINGS

26% heating energy savings

CAPITAL COST

$35–$45 / SF of wall area

EMISSIONS REDUCTION MEASURES BY SYSTEM TYPE

LONG TERM

ENVELOPE

WINDOW REPLACEMENT

Choosing the right windows is important to keep indoor spaces comfortable and reduce heating and cooling needs. Triple-pane windows are often recommended for better comfort. Passive House certified windows are a great choice because they are well-sealed and energy efficient.

Window styles like awning, tilt-turn, and casement are better than double-hung or sliding windows because they let in less air and last longer thanks to stronger locks and seals.

CONSIDERATIONS

- Start by identifying windows that are old or damaged, since replacing them at the right time can save money.
- How the windows are installed matters just as much as the kind of window you choose. Make sure you hire a reputable contractor who's familiar with proper window sealing during installation to avoid air leaks.

ACCESS NEEDED TO MAKE IMPROVEMENTS

- **Common Areas:** Access to common area windows may need exterior protection and scaffolding.
- **Tenant Spaces:** Full access is needed to make improvements and replace windows. Thoughtful planning is recommended to minimize tenant disruption during this time.

ADDITIONAL RESOURCES

- High Performance Windows
- Chapter 5 of the ASHRAE Energy Efficiency Guides for Commercial Office Buildings
- US Department of Energy Advanced Energy Retrofit Guide for Office Buildings

RECOMMENDED SPECIFICATIONS

- U value = 0.167 Btu/hr.ft2.F (lower U-value is better)

ENERGY SAVINGS

Estimated 7% of heating load

CAPITAL COST

Estimated $70 / SF of window area

EMISSIONS REDUCTION MEASURES BY SYSTEM TYPE

LONG TERM

VENTILATION

ENERGY RECOVERY VENTILATION (ERV) SYSTEM

An Energy Recovery Ventilator (ERV) is a type of ventilation system that brings fresh air into a building while using less energy. It helps improve indoor air quality and keeps people healthy.

An ERV works by using the air that's leaving the building to warm or cool the fresh air coming in. This means your heating and cooling systems don't have to work as hard, which saves energy and reduces pollution.

CONSIDERATIONS

- **Mechanical Exhaust System:** If there is space available, ERVs can work with existing mechanical exhaust systems.
- **Ductwork Modifications:** Some buildings may need added or modified ductwork to distribute fresh air effectively.
- **Exhaust Riser Condition:** Cleaning and sealing of exhaust risers is important for the best performance. Exhaust risers help remove stale, or contaminated air from different parts of the building and push it up to the roof or an upper-level vent where it's released outside.
- **Fan Replacement:** Existing exhaust fans in common areas, bathrooms, and other spaces may need to be replaced.
- **Electrical Capacity:** Installing an ERV may require increased electrical capacity both at the unit level and in the building's main electrical panel.

ACCESS NEEDED TO MAKE IMPROVEMENTS

- **Common Areas:** Access to exhaust risers and rooftop.
- **Tenant Spaces:** Access needed to make improvements to clean and seal ductwork. Some through all access may be necessary to repair damaged risers.

ADDITIONAL RESOURCES

- Enhanced Ventilation with Energy Recovery Ventilators (ERV)

RECOMMENDED SPECIFICATIONS

- Sensible Heat Factor: 80%
- Max fan power: 0.76 W/cfm

ENERGY SAVINGS

4% of heating usage

CAPITAL COST

Costs vary depending on the type of mechanical ventilation risers currently installed in the building, as well as the materials and labor used to install new ERV equipment. There are additional costs for cleaning, sealing, and balancing risers.

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

- **Common Areas:** Access to mechanical systems and building automation system (if installed).
- **Tenant Spaces:** Not applicable.

ADDITIONAL RESOURCES

- Operations and Maintenance Guide
- Chapter 5 of the ASHRAE Energy Efficiency Guides for Commercial Office Buildings
- US Department of Energy Advanced Energy Retrofit Guide for Office Buildings

RECOMMENDED SPECIFICATIONS

- Follow best practices set by manufacturer or designer.

ENERGY SAVINGS

Estimated 5% of whole building usage (conservative estimate based on federal research indicating up to 30%)

CAPITAL COST

$0.39–$0.50 / SF

EMISSIONS REDUCTION MEASURES BY SYSTEM TYPE

IMMEDIATE TERM

HEATING & COOLING

CONTROLS + DISTRIBUTION IMPROVEMENTS

Add Master Vents to Pipes: Improve master venting on steam mains to reduce overheating and improve heating system performance. Correctly sized vents must also be installed on all radiators.

Upgrade Boiler Controls: Improved heating system controls can monitor indoor and outdoor temperatures and better regulate heating production on top of the above distribution improvements.

Install Smart Thermostatic Radiator Valves (TRVs): Adding TRVs to radiators provide residents more control over the heating system and balances heat distribution.

Add Orifice Plates: Orifice plates are small metal plates that are installed in the steam supply pipe by the radiators. These plates restrict the flow of steam into radiators and reduce their heat output by about 20%. This decreases heat losses because most steam radiators were deliberately oversized to heat apartments even with windows open. With reduced steam flow, steam condenses before it reaches the end of the radiator, eliminating the need for steam traps (**see page 7**). This means that adding orifice plates can reduce overheating and eliminate costly steam trap maintenance every 5 to 8 years.

CONSIDERATIONS

- The heating supply must be shut off to complete these upgrades. It is best to do this work in the summer when residents will not be affected, or have a well-scheduled plan to minimize heating disruptions during the winter.

ACCESS NEEDED TO MAKE IMPROVEMENTS

- **Common Areas:** Access to steam distribution piping.
- **Tenant Spaces:** Plumber/technician access at all terminal units.

ADDITIONAL RESOURCES

- Two-Pipe Steam Systems
- Chapter 5 of the ASHRAE Energy Efficiency Guides for Commercial Office Buildings
- US Department of Energy Advanced Energy Retrofit Guide for Office Buildings

RECOMMENDED SPECIFICATIONS

- Your building needs custom specifications designed by engineers. For example, the amount of venting needed by your heating system will depend on the length of your building's steam pipes. Vents must be installed in appropriate locations to function well and not be damaged.

ENERGY SAVINGS

Estimated 14% of heating load

Savings are based on the ideal scenario where all measures are installed together. Actual savings may be lower if measures are done individually or over time.

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 a few main types of 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.



Package Terminal Heat Pumps (PTHPs)

These are single units usually found under windows in through-wall penetrations in bedrooms or living rooms. They heat and cool one room at a time and can be plugged in or hard wired.

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 apartments have maximum length limitations and must be placed appropriately.
  - Installation requires penetrations for refrigerant lines between condensers and the in-unit mini-splits. Connection is somewhat straight forward once equipment location is identified.
- **Package Terminal Heat Pumps (PTHP):** This is a well-established technology you can trust. PTHP requires through-wall penetrations. This can result in increased air movement, unless properly gasketed and installed.
  - Good for buildings of any size, especially where through-wall penetrations for package terminal air conditioners (PTACs) already exist.
  - Installation is low maintenance where penetrations already exist. PTHPs will likely need power supply in the unit. PTHPs require moisture drainage which may be difficult if an existing pathway isn't already present.
- 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.
- A new technology uses window-based air-source heat pumps that can be placed directly in a window opening, similar to a standard air conditioner. This option doesn't require special installation, just enough electrical power for the wall outlet. Pilot projects in New York City are currently testing this technology.

ACCESS NEEDED TO MAKE IMPROVEMENTS

- **Common Areas:** Required.
- **Tenant Spaces:** Required, except in the case of PTHP installation in existing, appropriately sized sleeves. Window Heat Pump technology is also a simple installation option.

ADDITIONAL RESOURCES

- Mini-Splits
- Packaged Terminal Heat Pumps

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.