



Multifamily Building Electrification

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Benefits of Electrification

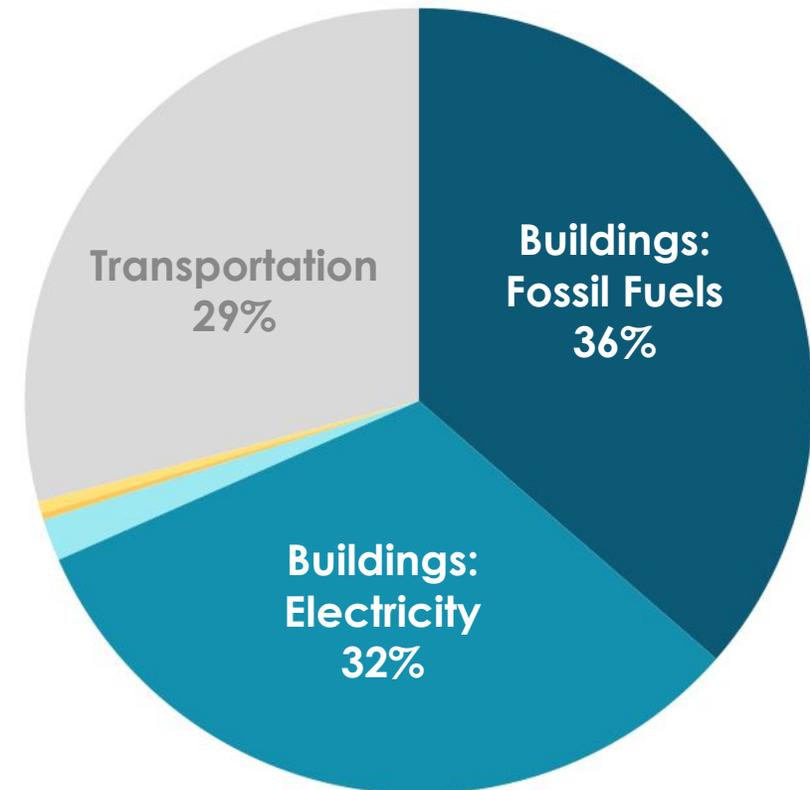


Building Electrification | Climate Change

- On-site fossil fuels in buildings account for 10% of GHG emissions in the U.S. Within cities, this proportion is much higher.
- In Boston, on-site fossil fuels in buildings account for 36% of community-wide emissions

Multifamily and residential emissions are primarily driven by their **space heating and domestic hot water**.

Boston Community-wide GHG Emissions (2018)

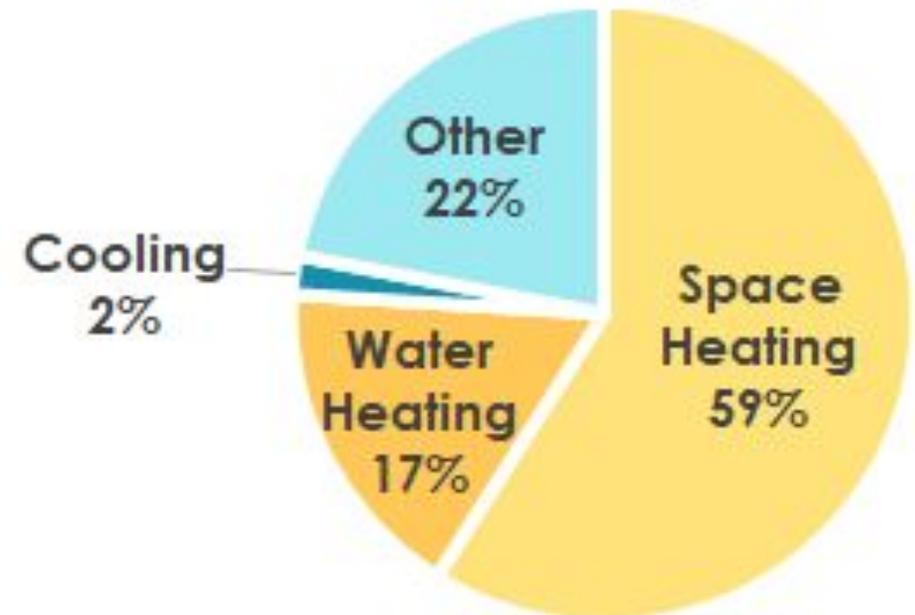


Benefits of Electrification

- **Clean Heating**
- Cooling
- Health & Safety
- Methane Leakage
- Economy Wide Energy Efficiency
- Potential to Reduce Costs

High-efficiency electric heat pumps source clean electricity to provide space and water heating (78% of average New England household energy use).

Average Household Energy Use in New England

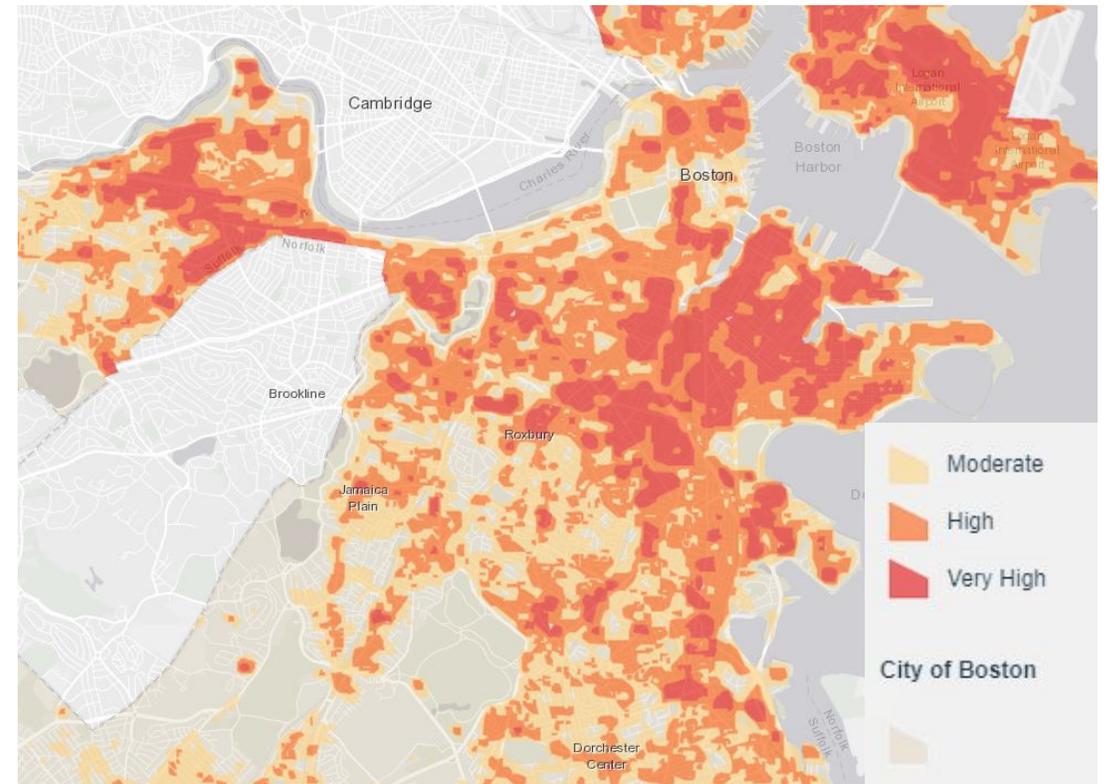


Benefits of Electrification

- Clean Heating
- **Cooling**
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Climate change is causing longer, more severe, and more frequent heat waves, particularly in cities. **Air source heat pumps can provide high efficiency cooling** alongside heating, all in one system.

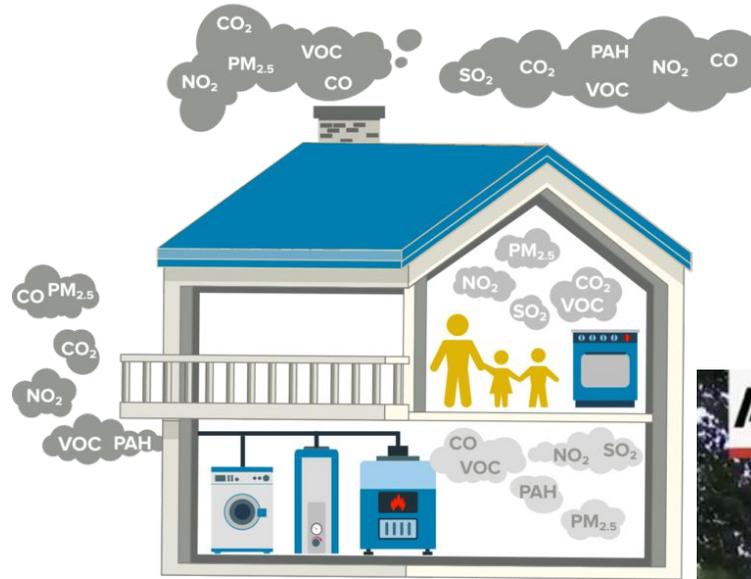
Extreme Heat: Land Surface Temperatures in City of Boston



Benefits of Electrification

- Clean Heating
- Cooling
- **Health & Safety**
- Methane Leakage
- Economy Wide Energy Efficiency
- Potential to Reduce Costs

In addition to risk of fire, explosion and carbon monoxide poisoning, gas appliances are linked to poor indoor air quality. In homes with gas stoves, children have a 42% increased risk of developing asthma.

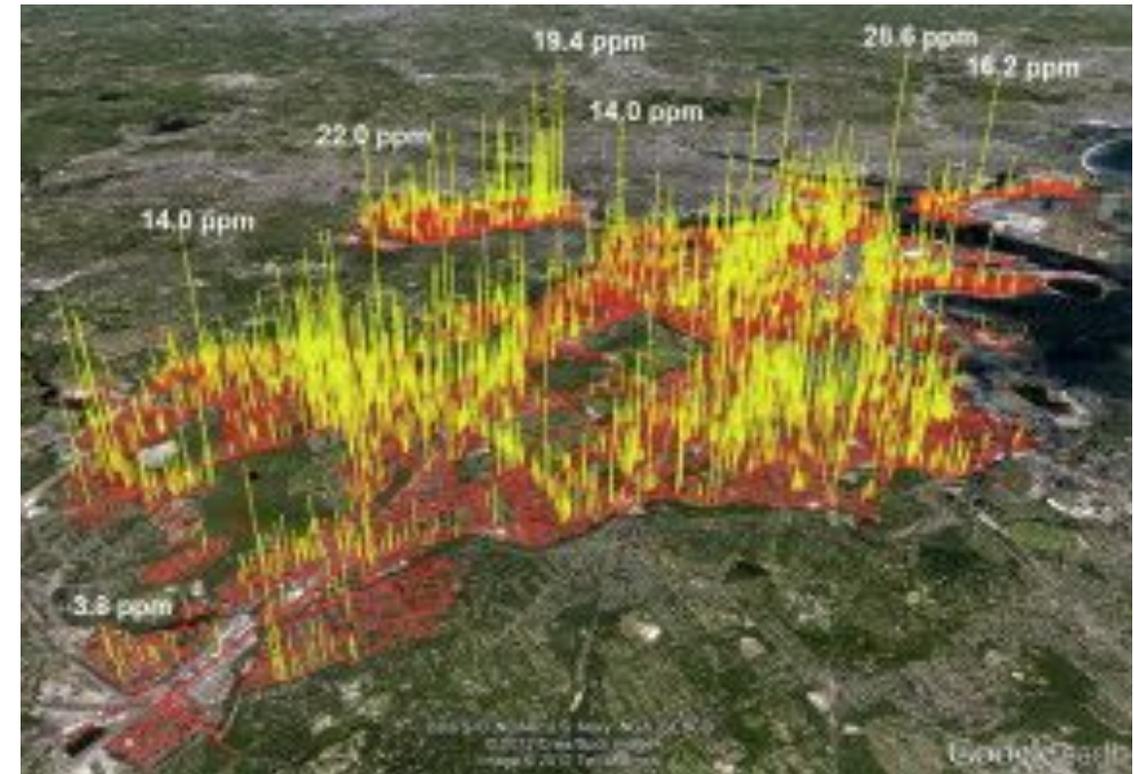


Benefits of Electrification

- Clean Heating
- Cooling
- Health & Safety
- **Methane Leakage**
- Economy Wide Energy Efficiency
- Potential to Reduce Costs

Recent studies are showing **much higher rates of methane leakage from the natural gas system** than previously estimated. Methane has a warming potential of 80x that of CO₂.

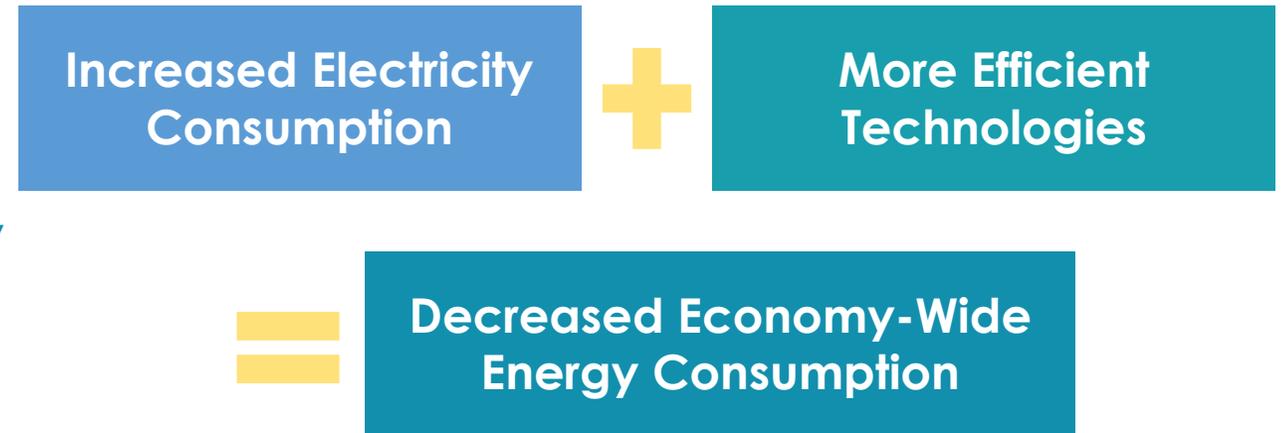
Methane Leaks in Boston



Total leaks in Boston in 2013: 3,356

Benefits of Electrification

- Clean Heating
- Cooling
- Health & Safety
- Methane Leakage
- **Economy Wide Energy Efficiency**
- Potential to Reduce Costs



Widescale deployment of heat pumps may increase total electricity use but **decrease economy-wide energy use, because heat pump technologies are so efficient.**

Benefits of Electrification

- Clean Heating
- Cooling
- Health & Safety
- Methane Leakage
- Economy Wide Energy Efficiency
- **Potential to Reduce Costs**

There are opportunities for installation and operational cost savings in many scenarios:

- Oil, propane, or electric resistance systems
- When paired with weatherization & on-site solar
- New construction



Benefits of Electrification | Compliance with BERDO

BUILDING EMISSIONS REDUCTION AND DISCLOSURE ORDINANCE (BERDO)

Boston's updated Building Emissions Reduction and Disclosure Ordinance (BERDO) sets requirements for large buildings. The goal is to reduce their emissions gradually to net zero by 2050. They also need to report their energy and water use data to the City annually.

What is Building Electrification?



Building Electrification Technologies

Primary building electrification technologies

Space heating and cooling



Air source heat pumps

Hot water heating



Heat pump water heater

Cooking



Induction cooktops

Other complementary technologies



Energy efficiency



On-site Solar PV



Smart controls

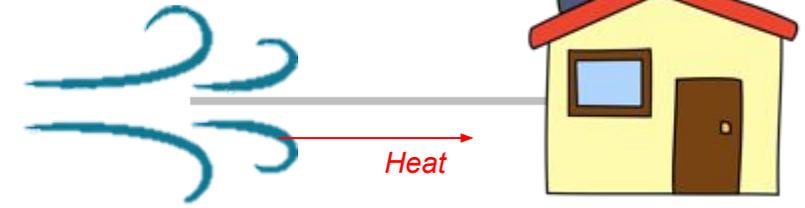


Ground source heat pumps

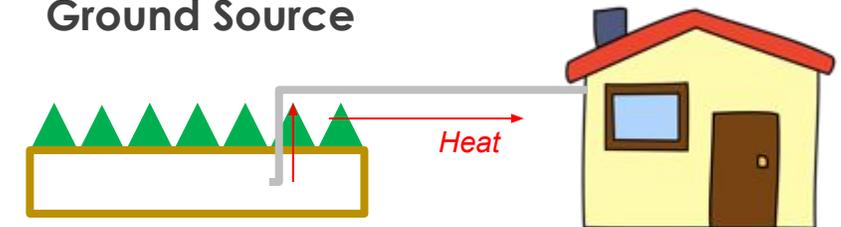
What is a “Heat Pump”?

- Heat pumps use electricity to “pump” heat from outside into an indoor space.
- **Not a new technology!**
 - Refrigerators use a similar process
 - Nearly 12 million heat pumps are installed in U.S. homes.
 - Heat pumps have 80%+ HVAC market share in Asia.
 - Not electric resistance heating

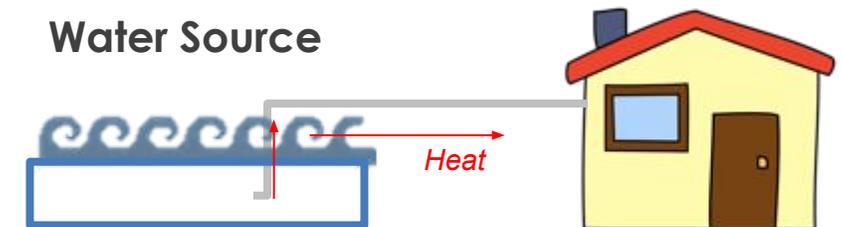
Air Source



Ground Source



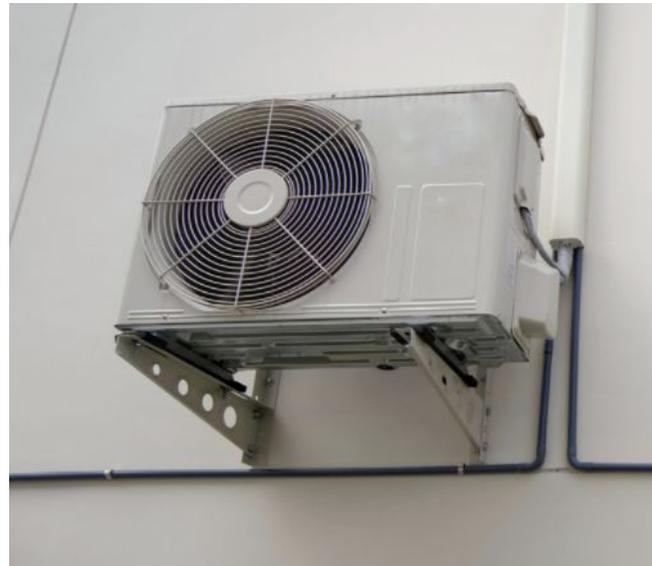
Water Source



Air Source Heat Pumps

- **Air source heat pumps transfer heat from the outside air into a building to provide heating and do the reverse to provide cooling.**
- Compared to ground and water source heat pumps, air source heat pumps are:
 - Less expensive
 - Often more appropriate in dense urban environments

Outdoor Unit (Condenser)



Indoor Unit (Head)



Air Source Heat Pumps | Available Options

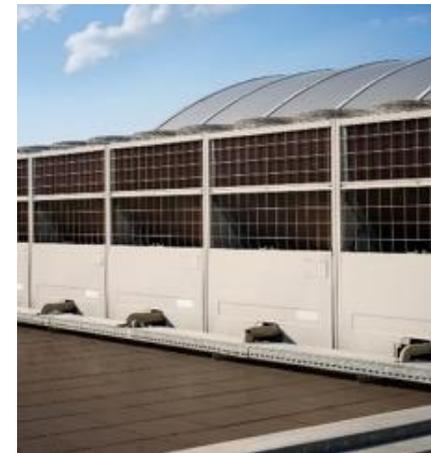
- **Centrally Ducted Heat Pumps:** Outdoor unit connects to a building's existing ductwork, similar to a furnace or central air conditioner.
- **Ductless Heat Pumps:** Outdoor unit connects to individual indoor units; sometimes also referred to as a ductless "mini-split."
- **Variable Refrigerant Flow (VRF):** Large systems that can provide simultaneous heating and cooling; sometimes also referred to as Variable Refrigerant Volume (VRV).
- **Packaged Terminal Heat Pumps:** Outdoor and indoor units that are installed together; applications generally found in multifamily buildings and hotels.



Centrally Ducted Heat Pump



Ductless Mini-split



Variable Refrigerant Flow (VRF)



Packaged Terminal Heat Pump

Air Source Heat Pumps | Installation

Installation Best Practices

- Work with installers and experts that have certification from manufacturers or other third-parties.
- Consider weatherization and on-site renewable energy to reduce energy costs (and GHG emissions)
- Use cold climate certified heat pumps
- Evaluate replacement vs. displacement options

Replacement	Displacement
Serves as the sole source of heating and cooling	Supplements existing system, displacing fossil fuel heating
Costs more to install	Lower first cost
May not be suitable in particularly cold areas	Requires maintaining a backup heating system

neep Getting The Most Out of Your Heat Pump

Your cold-climate heat pump can save a lot on heating and cooling costs. Whether your heat pump is ductless or centrally ducted, this new technology is different than the conventional heating and air conditioning systems that you're probably used to. These tips will help you get the best comfort and the most savings for years to come.

Ductless Users! Maximize the use of your heat pump
If you have ductless indoor units, use them to heat as much of your house as possible in order to increase your savings!

Set the ductless heat pump thermostat for comfort

- Don't worry too much about the specific numbers.
- You may find it comfortable to set it higher in colder weather; that's OK!
- It's also OK to overheat one room a bit, to help heat more of the house.

If you are keeping your existing heating system as a backup, use it only when needed:

- Turn the thermostat for your existing heating system down 5-10 degrees lower than the usual setting to make the ductless heat pump your primary heating source.
- When the weather is very cold, you may need to turn up your backup slightly.
- Try to keep the doors open to rooms without the ductless unit, allowing the heat pump's heat to circulate as much as possible.

Settings are the Key to Great Heat Pump Performance
Use these settings, whether your heat pump is ducted or ductless, to maximize savings and improve your comfort:

Pre Tip! If your central heat is oil or propane, you can expect your electric bill to increase significantly in cold weather. But you will save more in the long run with reduced fuel costs. Keep running the heat pump as much as possible to minimize your backup system operation.

Set it and Forget it

- Avoid frequently adjusting the thermostat; try to keep indoor settings steady.
- It's fine to adjust temperatures up and down as needed for comfort (e.g. turn it down at night if you like it a bit cooler).
- However, unlike conventional heating systems, deep setbacks of cold-climate heat pumps may cost you energy and money!
- Avoid turning heat pump unit(s) "on" and "off" to control the temperature.
- "Set it and forget it" is effective when air conditioning, too.

Pre Tip! In humid summer climates, the "dry" setting (when available), may provide better comfort at less cost than "cool". You may need to set the temperature higher to avoid over-cooling.

Use the "heat" or "cool" setting on the thermostat or control, rather than "auto"

- Set the unit to "off" when outside temperature is mild and no heat or air conditioning is needed.

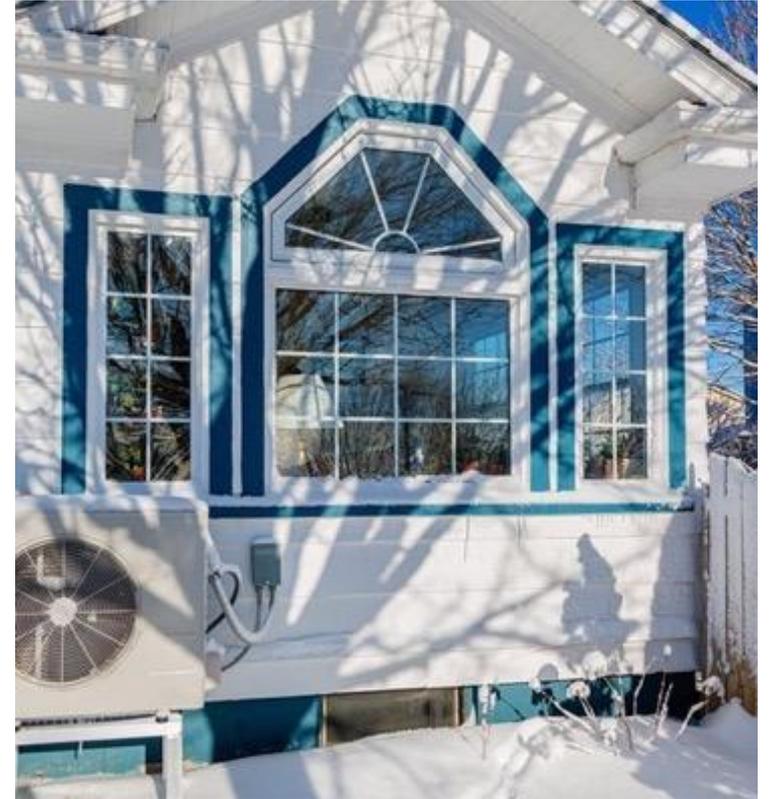
Set the indoor fan speed to "auto" or automatic, so the fan runs only as needed. Avoid settings that run the fan constantly.

For ductless heat pumps, keep the air vanes open to allow air to flow freely through the unit.

Air Source Heat Pumps | Common Concerns

System Performance

- Heating output and efficiency drop in very cold temperatures.
 - New models provide heat at high efficiencies down to -13°F.
- Integration with existing heating system to provide backup heat may be needed in very cold climates.
- Heat pumps should be run continuously to achieve high efficiencies (unlike furnaces).
- Contractors must be trained to perform high quality installations.



Heat Pump Water Heaters

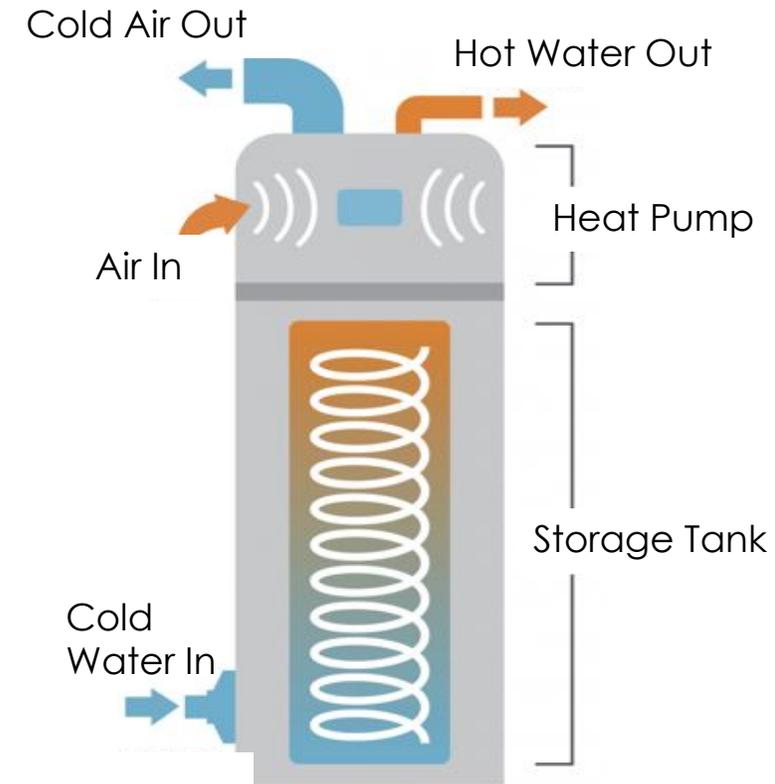
Heat pump water heaters are similar to air source heat pumps but **transfer heat from indoor or outdoor air into a storage tank to heat water.**

- Uses backup electric resistance heating for periods of high demand
- May have higher upfront costs than gas alternatives
- **Benefits**
 - Energy savings
 - GHG emissions reduction
 - Dehumidification
 - Grid reliability benefits



Hybrid Heat Pump Water Heater

How it works:



Heat Pump Water Heaters | Available Options

- **Integrated heat pump water heater:** Most heat pump water heaters have all components in a single tank, and typically transfer indoor heat into the tank.
- **Split heat pump water heater:** A limited number of models use an outdoor unit to absorb heat from the air and transfer it into an indoor storage tank.
- **Commercial-scale:** Larger scale systems are typically split systems that use outdoor air to serve large commercial and multifamily buildings.
 - Most current models are not well-suited for cold climates, requiring extra engineering to provide hot water year-round.



Hybrid Heat Pump Water Heater



Split Heat Pump Water Heater



Commercial Scale Heat Pump Water Heater

Heat Pump Water Heaters | Installation

Installation Best Practices

- **Spacing matters**
 - Hybrid heat pump water heaters need space for airflow to maximize efficiency, and can be taller than other water heaters
 - Must be located in an area where the intake and exhaust air from the unit does not blow onto the living space and cause discomfort
 - Requires a drain for condensation generated by the unit
- **Insulate piping and improve installation first**
 - Hot water taking a long time to reach the faucet is likely an issue with distribution rather than the heating source

Induction Stovetops

- **What is it?**

- Stove tops that use electricity to directly heat pots and pans through a magnetic current

- **Benefits**

- Heats quickly; precise temperature control; easier to clean; lower energy usage
- Reduces risk from fires, burns and indoor air pollution

- **Drawbacks**

- Higher first costs than conventional stovetops
- Some pots and pans do not work on induction stoves, although adapter plates are available



How to Electrify Multifamily Buildings

Highlights from *Multifamily Playbooks*



City Playbooks | Background

USDN Innovation Fund Project

Cities: Boston, Somerville, NYC

- Supported by BEI and Steven Winter Associates
- Advisors: Emerald City Collaborative, NYSERDA, MassCEC, NYC Housing Preservation and Development, heat pump manufacturers

Access here:

<https://www.beicities.org/city-playbooks>



City Playbooks | Existing Buildings

While there have been many examples of all-electric new construction, there are very **limited examples of retrofitting** existing multifamily buildings to all-electric end points.

Retrofitting multifamily buildings pose additional challenges such as:

- *Split incentives/metering arrangements*
- *Coordination accessing tenant spaces*
- *Age of building and infrastructure*

New Construction Guide Example



Multifamily Typologies

Four common multifamily typologies were selected for research based on data analysis and stakeholder input.

Typology	Assumptions			
	Building Size	Heating/Cooling Type	Domestic Hot Water	Electrical Service (Typically per apt)
Low-Rise with Furnace	2-10 units 1-3 stories	Heat: Furnace, ducted Cool: Central cooling, ducted	Per apartment or in basement	120/240V and 60-100 amps
Low-Rise with Boiler	2-10 units 1-3 stories	Heat: Boiler, hot water (hydronic) Cool: Unitary Cooling	Per apartment or in basement	120/240V and 40-80 amps
Mid-Rise with Boiler	5-200 units 4-7 stories	Heat: Boiler, steam or hydric Cool: Unitary cooling	Centralized	208/240V and <80 amps
High-Rise with Boiler	8+ stories	Heat/cool: Boiler, Steam PTACS OR Heat: Boiler, Steam; Radiators / Baseboard Cool: Unitary Cooling	Centralized	208/240V and 40-125+ amps

Multifamily Typologies | Mid-rise with Steam Boiler



	Starting Point	Ending Point	Considerations
Space Heating	Boiler with steam distribution to radiators or convectors with window A/C units	Ductless heat pumps in each apartment	Existing boiler, distribution and end units can be removed or abandoned in place. Roof must be structurally sound to support outdoor mini-split units. Retrofits can occur at tenant turn over.
Water Heating	Central water heating plant	Central split heat pump water heater (HPWH)	Storage must be sized larger to account for longer recovery time. Outdoor unit must be protected with sufficient air flow.
Cooking	Gas cooktops and stoves	Electric cooktop and stoves	Retrofits can occur at tenant turnover.

Why Ductless Heat Pumps for each apartment instead of central VRF or unitized PTHPs?

- High efficiency
- Each resident controls heating and cooling as desired
- Lower upfront cost than more centralized systems
- Electrical and plumbing scope is easier to keep on the roof rather than to each apartment.

Multifamily Typologies | Mid-rise with Steam Boiler



	Starting Point	Ending Point	Considerations
Space Heating	Boiler with steam distribution to radiators or convectors with window A/C units	Ductless heat pumps in each apartment	Existing boiler, distribution and end units can be removed or abandoned in place. Roof must be structurally sound to support outdoor mini-split units. Retrofits can occur at tenant turn over.
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Why Central HPWHs over an apartment-by-apartment equipment approach?

- If the existing water heating system is centralized, a central piece of equipment can replace it without apartment access
- Avoid tenant complaints of putting new equipment in apartments
- Electrical and plumbing scope is easier to keep in a central location rather than to each apartment.

Multifamily Typologies | Mid-rise with Steam Boiler



	Starting Point	Ending Point	Considerations
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Electrical Upgrades:

- Upgrade to **unit panels** for cooking and indoor mini-split units. Upgrade common area panel for central water heating and outdoor mini-split units.
- Install **conduits** from panels to stoves and indoor mini-split units in apartments.
- Likely upgrade to the **whole building electrical service**

Consider all electric upgrades, including EV and solar, at once to minimize disruptions and cost

Multifamily Typologies | High-rise with Boiler



	Starting Point	Ending Point	Considerations
Space Heating	Boiler with steam distribution to radiators or convectors with window A/C units or through wall A/C units	PTHPs or a central VRF system	Existing boiler, distribution and end units can be removed or abandoned in place. Roof must be structurally sound to support outdoor units. Retrofits can occur at tenant turn over.
Water Heating	Central water heating plant	Central split heat pump water heater (HPWH)	Storage must be sized larger to account for longer recovery time. Outdoor unit must be protected with sufficient air flow.
Cooking	Gas cooktops and stoves	Electric cooktop and stoves	Retrofits can occur at tenant turnover.

Why PTHPs instead of mini-splits for each apartment?

- Ductless heat pumps have limits on refrigerant line lengths; the distance from the roof may be too long for >6 story buildings
- Each resident controls heating and cooling as desired
- Lower upfront cost than more centralized systems

Why Central VRFs instead of any other space heating option?

- While more expensive and lower performance, central VRFs can be used if PTHPs or mini-splits can't be installed

Multifamily Typologies | Low-rise with Furnace



	Starting Point	Ending Point	Considerations
Space Heating	Furnace with ducted system, heated by gas, and central cooling	Ducted or ductless heat pumps in each apartment	Ductwork may or may not be compatible with a heat pump – an evaluation is necessary. Otherwise, switch to ductless Can be done per apartment unit
Water Heating	Each apartment has a gas fired storage water heater	Use integrated or split HPWHs per apartment	The new equipment should be in about the same location as the existing equipment (i.e., in the basement, or in apartments)
Cooking	Gas cooktops and stoves	Electric cooktop and stoves	Retrofits can occur at tenant turnover.

What about air sealing and insulation?

- Sealing up the envelope will reduce drafts, keeping residents comfortable and lowering energy bills.
- Heat pumps for space heating will still work in leaky homes, but because the fossil fuel systems likely had a higher capacity, the drafts and cold spots in a home will become more apparent with a heat pump system, so air sealing and insulation should be assessed.

Multifamily Typologies | Low-Rise with Boiler



	Starting Point	Ending Point	Considerations
Space Heating	Boiler with steam distribution to radiators or convectors with window A/C units	Ductless heat pumps in each apartment	Existing boiler, distribution and end units can be removed or abandoned in place. Roof must be structurally sound to support outdoor mini-split units. Retrofits can occur at tenant turn over.
Water Heating	Each apartment has a gas fired storage water heater	Use integrated or split HPWHs per apartment	The new equipment should be in about the same location as the existing equipment (i.e., in the basement, or in apartments)
Cooking	Gas cooktops and stoves	Electric cooktop and stoves	Retrofits can occur at tenant turnover.

What about air sealing and insulation?

- Same as the previous typology - beneficial to be sure, but not necessary for electrification

What to do with the radiators?

- The lowest cost option is to leave them in place (which could also provide some emergency back up heating if the boiler and gas line remain), but residents may appreciate freeing up that space, so some budget should be allowed for removal and finishes

Considerations | Cost

Upfront Costs

- Heat Pump Water Heaters and stoves are often more expensive than their gas counterparts, but incentives can help with this
- Space heating heat pump systems can be comparable or more expensive upfront compared to replacement of existing systems
- Panel costs may vary

Operating Costs

- Total energy usage will likely go down for all scenarios, but bills may increase.
 - Weatherization and solar PV helps address this
 - Lower cooling costs may offset higher heating costs.
- Metering configuration and who pays utilities may influence who sees savings from upgrades

Considerations | Contractors & Maintenance

Contractor Coordination

- Upgrades can be complex and will involve multiple trades
 - Clearly articulate holistic goals and plans for electrification across all contractors
 - For larger buildings, work with a trusted engineer or energy consultant to coordinate across trades and other parties
- Consider requiring fair wages, benefits, and women- and -minority-owned business status of contractors or subcontractors

Ongoing Maintenance

- Annual servicing is recommended, similar to typical heating systems
- Consider and clearly communicate who is responsible for these ongoing needs

Takeaways & Recommendations

Mitigating Negative Tenant Impacts

Physical disruptions during retrofit

Installing refrigerant lines and electrical conduits may require access to interior walls, and therefore cause disruption in apartment units. Distributed heating or hot water will also require some work within tenant spaces.

Note: If any disruptions risk the health and safety of residents or extend over multiple days, residents should be offered a stay at a local hotel for no cost.

Recommendations for aligning with other touchpoints:

- At tenant turnover: Mini-splits, PTHPs, electric stoves and integrated HPWHs (if in tenant space)
- During kitchen renovations: install conduit and electric stoves
- During wall insulation install: run refrigerant lines and conduits to mini-splits

Mitigating Negative Tenant Impacts

Changes to energy bills:

Electrification will inevitably lower or eliminate fossil fuel bills and likely increase electricity bills.

The overall savings is dependent on the chosen retrofits, as well as local energy prices.

To ensure savings, the highest efficiency equipment should be paired with weatherization to reduce heating loads, and solar PV systems to reduce electricity costs.

Recommendations:

- Calculate energy and rent impact considering building's metering configuration
- Include combination of measures that will guarantee bill savings
- Consider new leasing agreements to offer shared savings with tenants
- Provide educational materials about electric equipment to ensure it runs efficiently

Boston's Retrofit Resource Hub

Acts as a single entry point for owners, contractors, and renters to access resources for building retrofits.

Phase 1 - Informational website for building owners and tenants

boston.gov/departments/environment/retrofit-resource-hub

- BERDO
- How to decarbonize
- Available funding options
- Tenant protections
- Green leasing
- Workforce training



Phase 2 - Technical Support

- Webinars
- Office hours
- One-on-one consultations

Resources

Supportive Programs:

- [Mass Save](#)
- [MA Clean Energy Center](#)

Reports:

- [City Playbooks](#)
 - Includes [Journey Pages](#) 
- [Heat Pump Strategies for Multifamily Buildings](#) (NRDC, Steven Winter Associates)
- [2020 Air-Source Heat Pump Program Incentive Summary](#)

Building Typology 1: Low-Rise, Furnace and Central Cooling



EXAMPLES OF TYPOLOGY 1

Existing Technical Building Conditions

Building System	Existing Condition	Applicability of Upgrades to Other Buildings
Size	2-10 Units, 1-3 Stories	These low-rise buildings are similar in physical characteristics and equipment types to single-family homes of the same vintage. These retrofits are also compatible with low-rise garden style apartments with ducted systems.
Heating	Furnace, gas with ducted distribution	Applicable to any system with ducted distribution that supplies both heating and cooling.
Cooling	Central cooling, electric with ducted distribution	
Water Heating	Each apartment has a gas-fired storage water heater	Applicable if heaters are located in basement or in apartments and each apartment has its own water heater.
Electrical Service	Single-phase electricity from the utility, 120/240V distribution; 60-100 amp service per apartment	If existing electricity service is higher than 100 amps capacity per apartment, then electricity service upgrades may not be necessary.
Cooking	Gas cooktop and stove	Cooking upgrades are not required if building already has electric cooktops and stoves.

Retrofit Path Summary

Costs and Benefits Legend

-  indicates the measure's capital cost for installation including labor. Measures with high costs may need capital planning and/or outside financing/funding.
-  indicates on-site time required for installation. Those retrofits that require longer time on-site may require greater coordination with the tenants. All retrofits are assumed not to displace tenants or require temporary housing.
-  indicates the measure's impact on reducing carbon emissions. The report assumes an electricity grid that is less GHG-intensive than the on-site gas system being replaced.
-  indicates the measure's impact on health including improvements in air quality, cooling, and safety.

Building System	Upgrade	Cost/Benefits
Electrical Service	Upgrades to unit panels for cooking and hot water. Add additional conduit to appliances. Possible whole building electrical service upgrade needed.	
Water Heating	If existing water heaters are in apartments, upgrade to integrated HPWHs with sufficient air flow.	
	If existing water heaters are in basements, upgrade to split HPWHs.	
Space Heating and Cooling	If ductwork can be reused, replace furnace with ducted ASHP tied into existing ductwork.	
	If ductwork cannot be reused, install mini-splits or mini-ducted units using ducts for refrigerant lines.	
Cooking	Replace gas stoves and cooktops with electric.	



Questions?

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