Building Electrification Institute

CITIES DRIVING CHANGE

Burlington New Construction Customer Economics Analysis

Completed December 2021

Table of Contents

Customer Economics Analysis | Overview

Background and Summary of Project

Burlington, VT has been working on its building electrification efforts since 2016. Between 2020 and 2021, BEI worked with Burlington's municipal utility, the Burlington Electric Department (BED), to help assess the opportunities for electrification in new buildings.

As part of this work, BEI and its consultants at Steven Winter Associates (SWA) conducted this Customer Economics Analysis for all-electric or nearly all-electric new construction in Burlington. The goal of this analysis is to understand the expected installation and operating costs of new, all-electric buildings for several common building typologies, and to compare these costs to standard mixed fuel new construction in the city. This assessment also identifies potential opportunities to help improve the economics of all-electric new construction for building owners, developers, and residents in Burlington.

Customer Economics Analysis | Objectives

The purpose of the Customer Economics Analysis is to:

- Understand the expected installation and operating costs of all-electric new construction for multifamily and office buildings in Burlington in comparison to a standard mixed fuel construction baseline.
- Identify opportunities to improve the customer economics for all-electric new construction for building owners, developers, and tenants.

The intended outcomes of the analysis are to:

- Provide information to Burlington's building stakeholders on true costs of all-electric new construction.
- Support BED's development of a policy to encourage or require all-electric construction.
- Identify policy or program interventions that Burlington could develop to improve the local customer economics of all-electric new construction.

Customer Economics Analysis | Approach

1) Gather building models from recently constructed buildings

BED provided building models from recently constructed multifamily and office buildings in Burlington that provide baseline building inputs and gas equipment counterfactuals. The BEI project team adjusted inputs where needed to reflect typical elements of new construction.

2) Develop all-electric scenarios for Burlington's climate

The project team identified and sized the potential all-electric technologies to meet heating and hot water loads, as required by the original building models in Burlington's climate.

3) Research local installation costs

The project team used cost estimates for similar all-electric and gas systems, supplied by SWA based on their past projects, and vetted these inputs with knowledgeable local contractors to develop local cost estimates for each system.

4) Use spreadsheet model to estimate economics

Using a spreadsheet model with local gas and electricity rates, the project team produced economic outputs including installation costs, operational costs, and lifecycle costs for each building typology.

5) Evaluate impacts to building decision-makers and residents

The project team completed an analysis of costs and other impacts to different types of building decision-makers and residents as a result of the economics of all-electric buildings.

Customer Economics Analysis | Assumptions

Additional Assumptions

- The foundation of this analysis is based on newly constructed buildings that have participated in BED's energy efficiency programs for new construction.
  - BED provided models of recently constructed buildings, which are submitted before construction to receive incentives. These models are also re-calibrated after the building is in operation to reflect real-world performance.
  - The BEI project team used the re-calibrated heating energy use from these models as the required heating load for the all-electric building models.
  - The baseline buildings exceed Burlington's code minimum efficiency requirements for new construction. This is because BED works closely with builders to ensure a high level of energy efficiency is included for almost all new construction in the city.
- Because new construction is predominately infill in Burlington, the avoided gas infrastructure costs are assumed only to include in-building components, which include gas lines to heating and hot water systems behind the utility meter. The project team did not assume any reduction in the gas infrastructure costs at the utility level.
- In-building electrical panel and wiring costs for all-electric equipment are included in the installed costs, however utility-side costs for bringing electrical service to the building are not.

Customer Economics Analysis | Assumptions

Local Energy Rate Assumptions

- **Electricity Rates**
  - In most cases, this analysis assumes a blended average from BED:
    - Multifamily Buildings: $0.19/kWh
    - Office Buildings: $0.15/kWh
  - For scenarios with electric resistance heating, this analysis combines BED's large commercial rate for:
    - Demand rate: $20/kW
    - Consumption rate: $0.083/kWh
- **Gas Rates**
  - This analysis assumes a blended average from VGS:
    - $0.80/therm using rate G3

Notes: Analysis does not assume an escalation of gas or electricity costs. Central electric resistance backup is assumed to be on the owner meter and therefore would be subject to demand charges.
Sources: Cost assumptions are from the Burlington Electric Department and Vermont Gas

Table of Contents

Multifamily New Construction | Assumptions

Baseline Building Assumptions

- Based on a recently constructed dorm in Burlington:
  - 153,000 square feet (150 units)
  - Completed in 2018

Building System	Equipment
Heating	Gas boiler hot water baseboards (94% efficiency)
Cooling	Rooftop split units (15 SEER) for each apartment
Ventilation	Energy recovery ventilation (ERV) system with gas boiler supplement
Domestic Hot Water (DHW)	Central gas-fired plant (94% efficiency)
Envelope	Tight envelope (0.01 natural air changes per hour)*
Cooking	Electric stoves
Laundry	Central electric laundry system

Note: The Burlington Electric Department works closely with builders to ensure highly efficient building components. In this case, the baseline building had an envelope with 0.01 natural air changes per hour (nACH). This is just one-twentieth of the Vermont Commercial Building Energy Standards (CBES2015) code of 0.22 nACH. If instead the baseline building had a poorer performing envelope, there would be greater operational savings when compared to an all-electric scenario, improving overall economics of the electrification scenarios modeled in this analysis.

Multifamily New Construction | Scenarios

All-electric scenarios were developed to meet the baseline building heating, cooling and hot water load.

		All-electric Scenarios			
Building System	**Mixed Fuel Baseline**	**Air to Water Heat Pump with Water Loop Heat Pump** (Air-water HP w/ WLHP)	**Air Source Heat Pump Only** (ASHP Only)	**Air Source Heat Pump with Electric Resistance Backup** (ASHP + Elec Resistance)	**Ground Source to Water Loop Heat Pump** (Ground Source to WLHP)
Heating	**Gas Boiler** with hot water baseboards (94% efficiency)	**Central air to water heat pumps** with condenser loop and WLHPs	**Central ccASHPs** for 100% of load (overall COP 2.6)	**ccASHP w/Electric backup** - backup electric resistance that comes on at <5F (Overall heating COP of 2.55)	**Ground source to WLHP** Assumes ideal ground conditions, which is very site-specific
Cooling	**Rooftop split units** (15 SEER) per apartment	**Same as heating** (20 SEER, boost from summer DHW)	**Same as heating** (Central A/C via rooftop split units – 15 SEER)	**Same as heating** (15 SEER)	**Same as heating** (15 SEER)
Ventilation	**ERV system**, gas post-heat for ventilation	**ERV system**, heat pump post-heat	**ERV system**, heat pump post-heat	**ERV system**, heat pump post-heat	**ERV system**, heat pump post-heat
DHW	**Central gas-fired plant** (94% efficiency)	**Water-water heat pump for DHW** (overall DHW COP of 3.1)	**DHW central heat pump** – ccASHP for DHW (two-stage system)	**DHW central heat pump** with electric resistance supplement	**Ground source to WLHP**
Appliances	**Electric stove & laundry**	**Electric stove & laundry**	**Electric stove & laundry**	**Electric stove & laundry**	**Electric stove & laundry**
Envelope	**Very Tight as-built** (0.01nACH)*	**Very Tight as-built** (0.01nACH)	**Very Tight as-built** (0.01nACH)	**Very Tight as-built** (0.01nACH)	**Very Tight as-built** (0.01nACH)

*Natural air changes per hour

Multifamily New Construction | Scenarios

The all-electric scenarios were selected based on available technologies and projected costs.

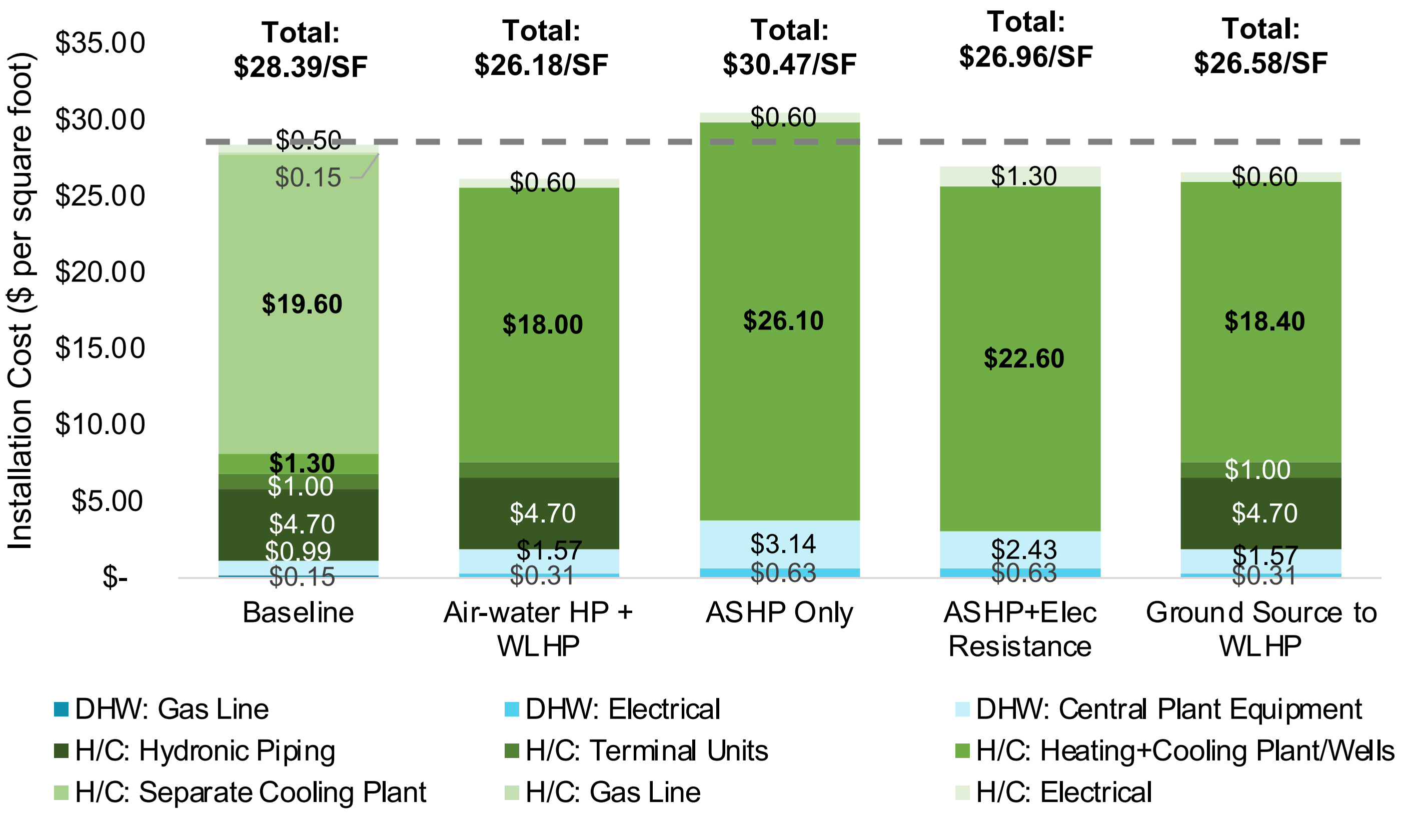
	Air to Water Heat Pump with Water Loop Heat Pump (Air-water HP w/ WLHP)	**Air Source Heat Pump Only** (ASHP Only)	**Air Source Heat Pump with Electric Resistance Backup** (ASHP + Elec Resistance)	**Ground Source to Water Loop Heat Pump** (Ground Source to WLHP)
General Benefits/ Rationale for Selection	Future-proof, regardless of site conditions.	Simple construction and operations.	Lowest construction costs with some redundancy.	Future proof, highly efficient, but subject to site conditions.
Benefits and Drawbacks of Heating and Cooling Technologies*	**+** Distribution system uses water instead of refrigerant, allowing longer life for piping **+** Simultaneous heating and cooling with heat recovery **+** Unified heat recovery system for space heating, cooling, and DHW **+** Summer cooling is more efficient because of DHW reciprocity	**+** Mature technology is well-known in the industry **+** Highly-efficient operation under part load conditions **+** Occupants can choose heating and cooling for each space	**+** ASHPs can be smaller in capacity and lower installed costs, using electric resistance to supplement on the coldest days. **–** Electric resistance requires higher electrical capacity and will result in slightly higher operating costs compared to ASHP only.	**+** Ground source technologies can be highly efficient to operate **+** Distribution system uses water instead of refrigerant, allowing longer life for piping **–** Installed costs range greatly depending on site conditions.
Benefits and Drawbacks of DHW Technologies*	**+** Space efficient water-water heat pumps don't need a dedicated outdoor unit. **+** DHW heat extraction in the summer boosts cooling efficiency	**–** Dedicated DHW heat pumps are oversized to meet winter load **+** Very efficient in the summer	**+** Electric resistance backup reduces installation cost without significantly affecting annual efficiency	**+** Highest efficiency DHW **+** DHW heat extraction in the summer boosts building cooling efficiency

*Note: (+) indicates a benefit and (–) indicates a drawback.

Building Electrification Institute

Multifamily New Construction | Installation Costs

Installation Costs for Heating, Cooling and DHW Systems

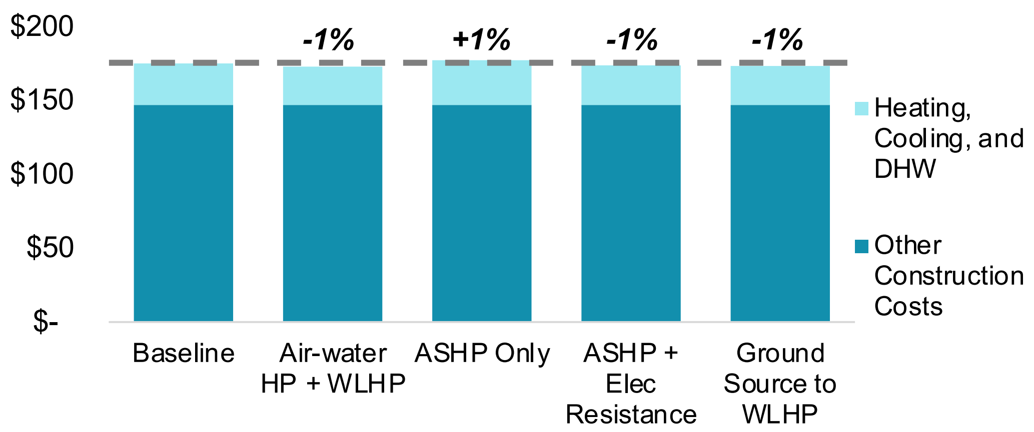


Takeaways:

- **Installation costs are lower, or close to breaking even, in every all-electric scenario** compared to the gas baseline, and total construction costs do not change significantly.
- All-electric heating and cooling equipment costs tend to be similar or lower than the mixed fuel baseline, while all-electric DHW costs tend to be higher.

Installation Cost by Total Construction Cost*

% Change from Baseline

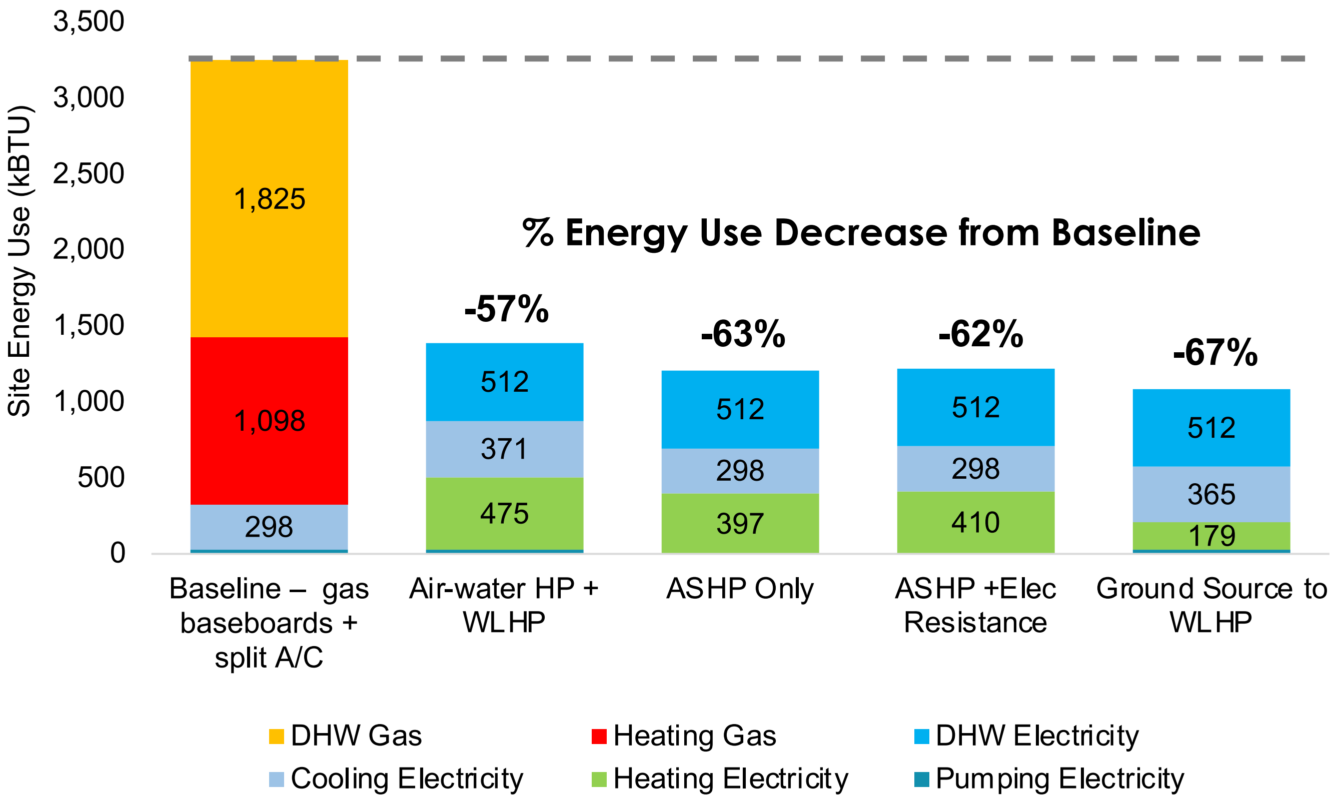


*Assumes Construction Cost of $175/SF. Source in Appendix.

Building Electrification Institute

Multifamily New Construction | Energy Use

Energy Use for Heating, Cooling, and DHW Systems



Takeaways:

- **The all-electric scenarios significantly reduce energy use compared to a mixed fuel building.** Site energy use decreases in all-electric buildings by between 57-67%.
- In Burlington, 100% of electricity is sourced from renewable sources, which means that all-electric buildings are Net Zero Carbon.
- In comparison, a mixed fuel building will always emit carbon because it uses gas, which can never be made 100% emission-free.

Multifamily New Construction | Energy Costs

Scenario Comparisons for Energy Costs

Mixed fuel new construction baseline scenarios:

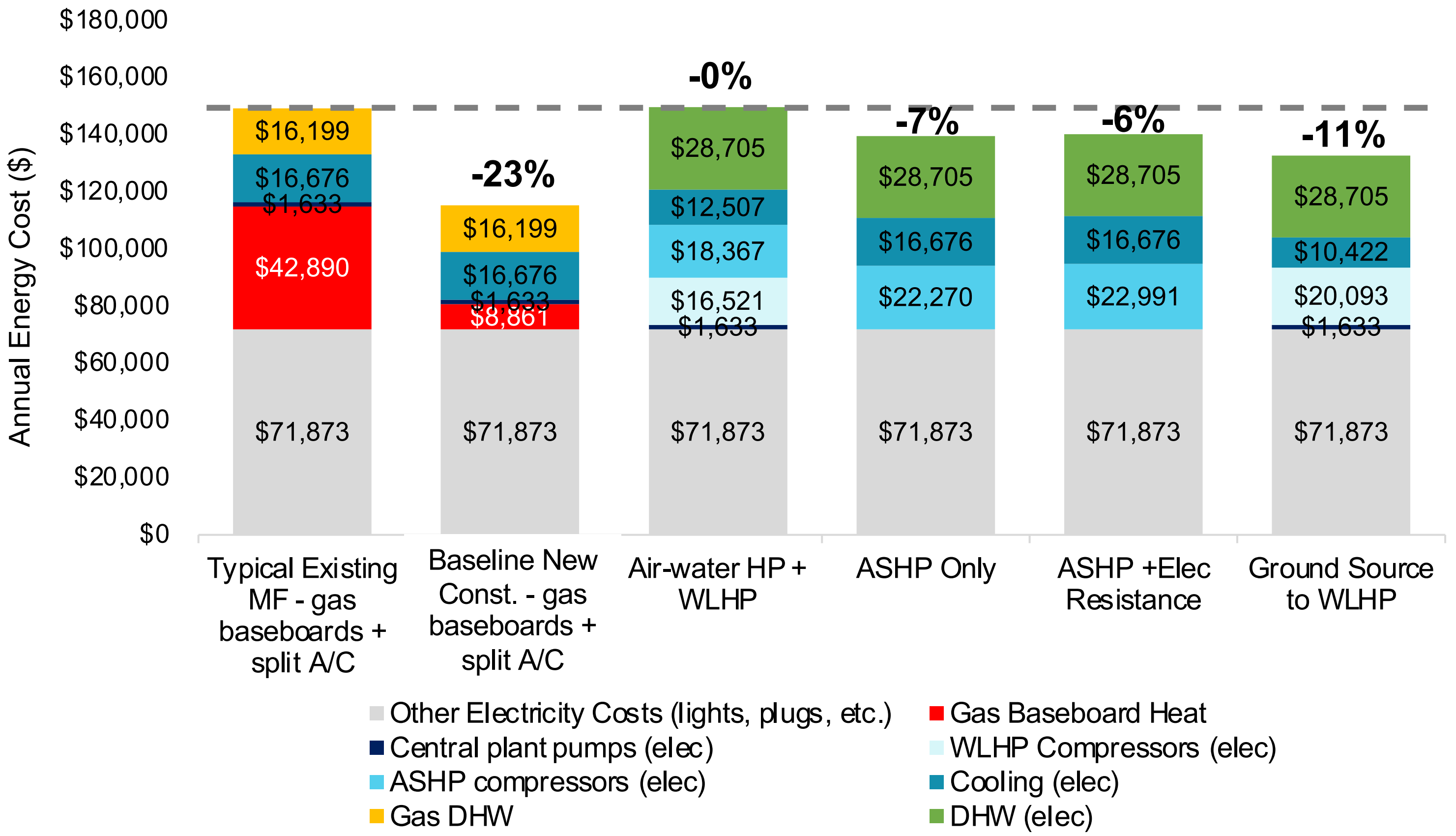
- **Master-metered Building:** This scenario assumes the building does not have any individual natural gas meters for tenant units. The owner pays for all in-unit gas heat and hot water, as well as gas used for cooking.
- **Tenant-metered for Cooking:** This scenario also assumes that the owner pays for all in-unit gas heat and hot water in the building, however it assumes that each tenant has an individual meter for gas cooking, and therefore pays the fixed costs associated with this gas meter, as well as gas used for cooking.

Additionally, the energy costs of all-electric new construction are compared to a **typical existing multifamily building in Burlington** with the same metering configurations. This allows for the comparison of energy costs for a tenant who moves from an existing building to a new building in Burlington.

Multifamily New Construction | Energy Costs

Energy Costs Compared to Typical Mixed Fuel Buildings*

***Master-metered existing building and baseline building** (no fixed gas charges for tenants)*



Takeaways:

- **Energy costs for new all-electric multifamily buildings are breakeven or lower than in a typical existing multifamily building that is master-metered.** Tenants moving from a typical existing building into a new all-electric building may see their energy costs go down.
- **Compared to mixed fuel construction that is master-metered, energy costs for new all-electric multifamily buildings are higher.** The energy cost increase ranges from 15% to 30%.
- In the all-electric scenarios, the metering configuration will determine the final distribution of the energy costs between the tenants and the owner.

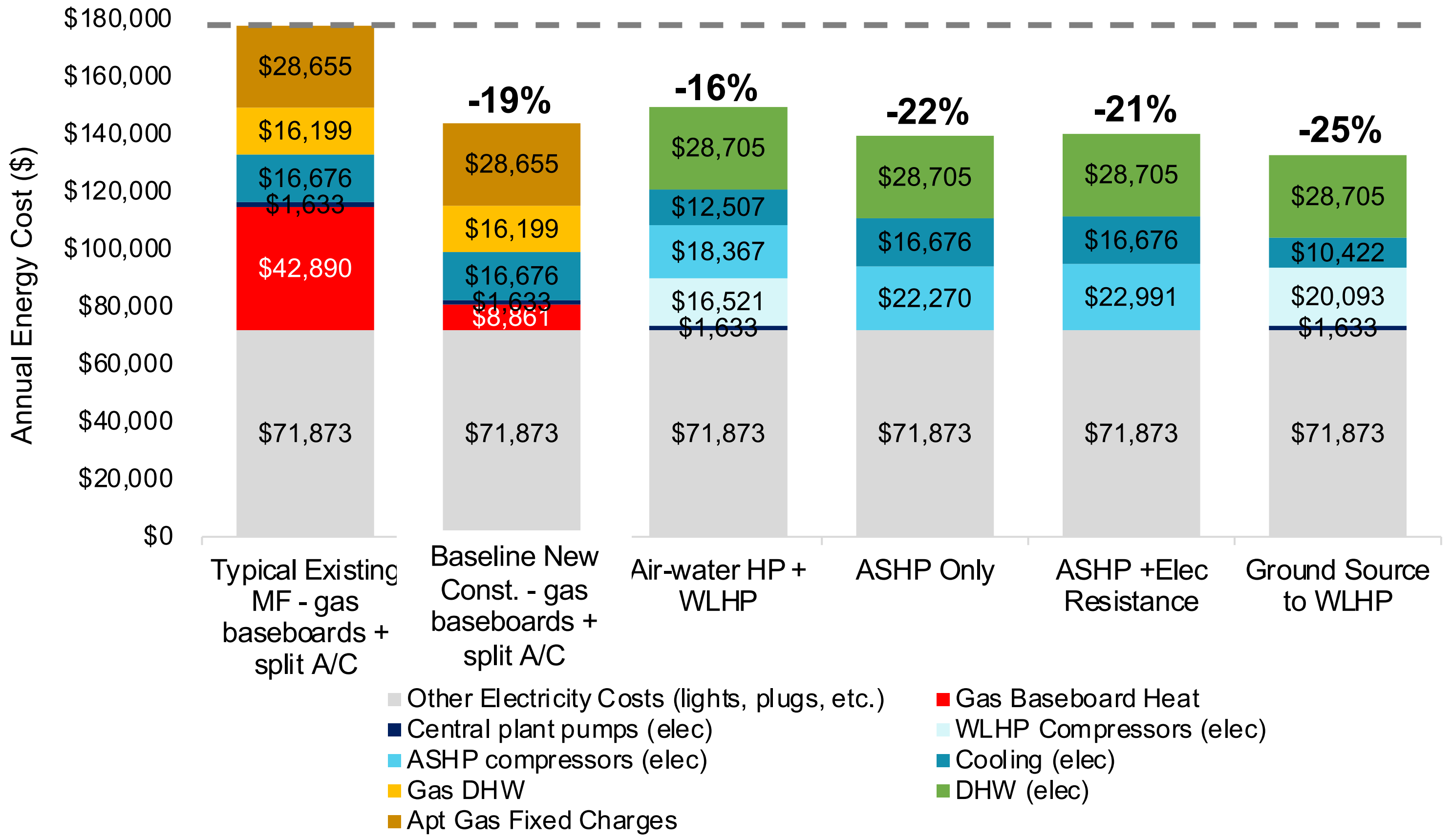
Building Electrification Institute

*Based on data provided by BED, the average heating energy use in existing multifamily buildings is 516 CCF / apt / year, while the high performance all-electric new building is just 107 CCF / apt / year. The costs assume that all scenarios are master metered for gas and electricity, and all use electric stoves.

Multifamily New Construction | Energy Costs

Energy Costs Compared to Typical Mixed Fuel Buildings*

Tenant-metered existing building and baseline building *(includes fixed charges for tenants)*



Takeaways:

- **Energy costs for new all-electric multifamily buildings are significantly lower than in a typical mixed fuel existing multifamily building that is tenant-metered.** Tenants moving from a typical mixed fuel existing building into a new all-electric building may see their energy costs go down.
- **Compared to mixed fuel construction that is tenant-metered, energy costs for new all-electric multifamily buildings are roughly breakeven or slightly lower**. The energy cost comparison can range from a 4% increase to an 8% decrease.
- In this case, **the addition of gas fixed charges for tenants overcomes the difference in electric and gas rates** in Burlington.

Building Electrification Institute

*Based on data provided by BED, the average heating energy use in existing multifamily buildings is 516 CCF / apt / year, while the high performance all-electric new building is just 107 CCF / apt / year. The costs assume that tenants pay for gas cooking in the mixed fuel baselines and have electric stoves in the all-electric scenarios. Smaller multifamily homes are more likely to fall into this scenario and have fixed gas charges.

Multifamily New Construction | Lifecycle Costs

Scenario Comparisons for Lifecycle Costs

Lifecycle costs include the combination of installation costs and energy costs to determine the total cost over the lifetime of the equipment.

The lifecycle costs of all-electric new construction are compared to mixed fuel new construction under the following scenarios:

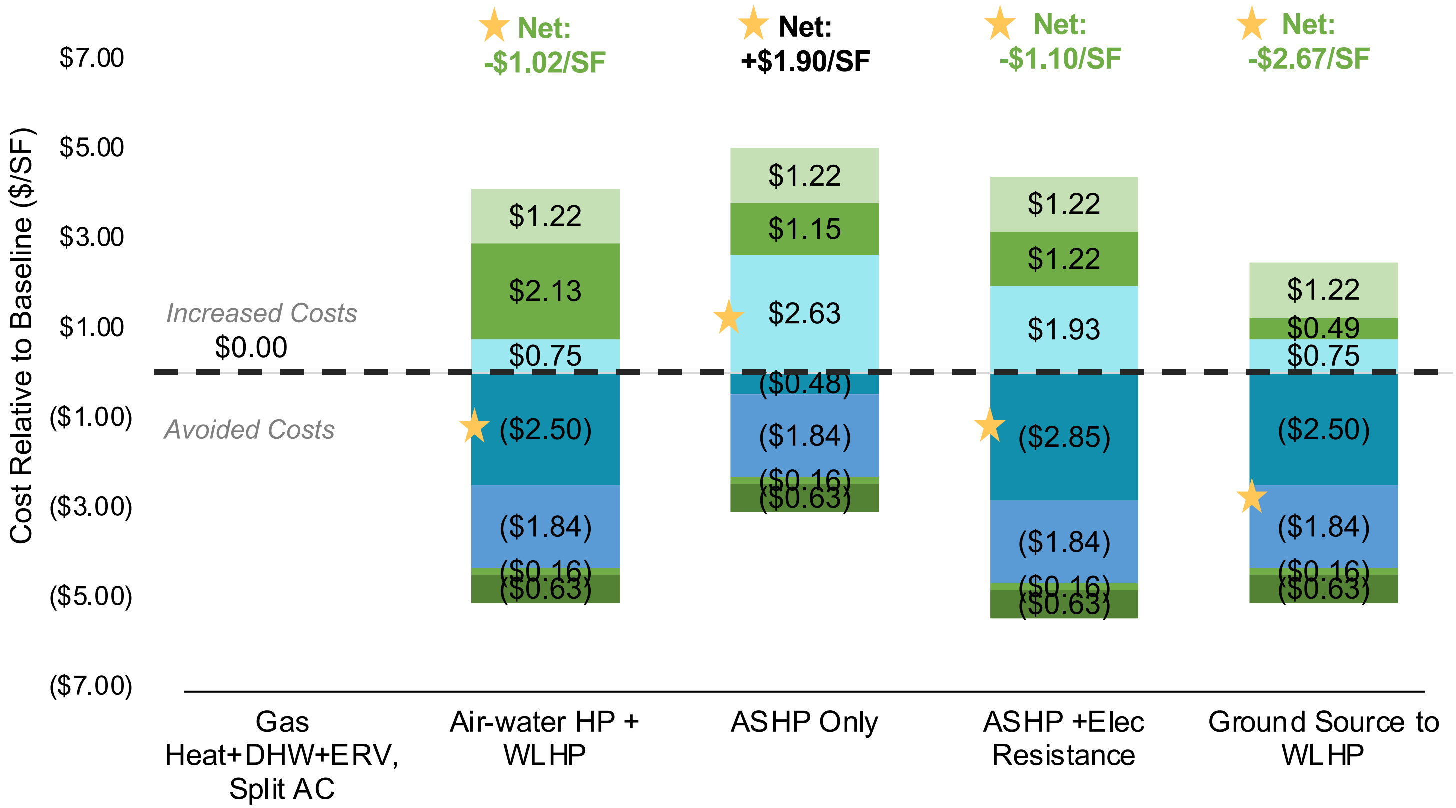
- **Master-metered:** This scenario assumes the building does not have any individual natural gas meters for tenant units. The owner pays for all in-unit gas heat and hot water, as well as gas used for cooking.
- **Tenant-metered for Cooking:** This scenario also assumes that the owner pays for all in-unit gas heat and hot water in the building, however it assumes that each tenant has an individual meter for gas cooking, and therefore pays the fixed costs associated with this gas meter, as well as gas used for cooking.
- **An Electrification-friendly Policy:** A potential policy that puts a price of $100 / mtonCO2e* for fossil fuel use and adds requirements for mixed fuel buildings to be built "electric-ready."**

*mtonCO2e: metric tons of carbon dioxide equivalent
** "Electric-ready" requires wiring and panel space for future electric appliances.

Multifamily New Construction | Lifecycle Costs

15-year Lifecycle Comparison with a Potential Policy

Cost relative to baseline ($/SF), including all tenant and owner costs
Master-metered baseline (no tenant gas meter charges)



Takeaways:

- **There are lifecycle savings in nearly all scenarios** compared to a master-metered baseline under the proposed policy.
- **An additional opportunity could come from increasing rentable space** by placing all-electric equipment on the roof rather than basements or mechanical closets. Increased rental space could be worth up to $0.30/SF.

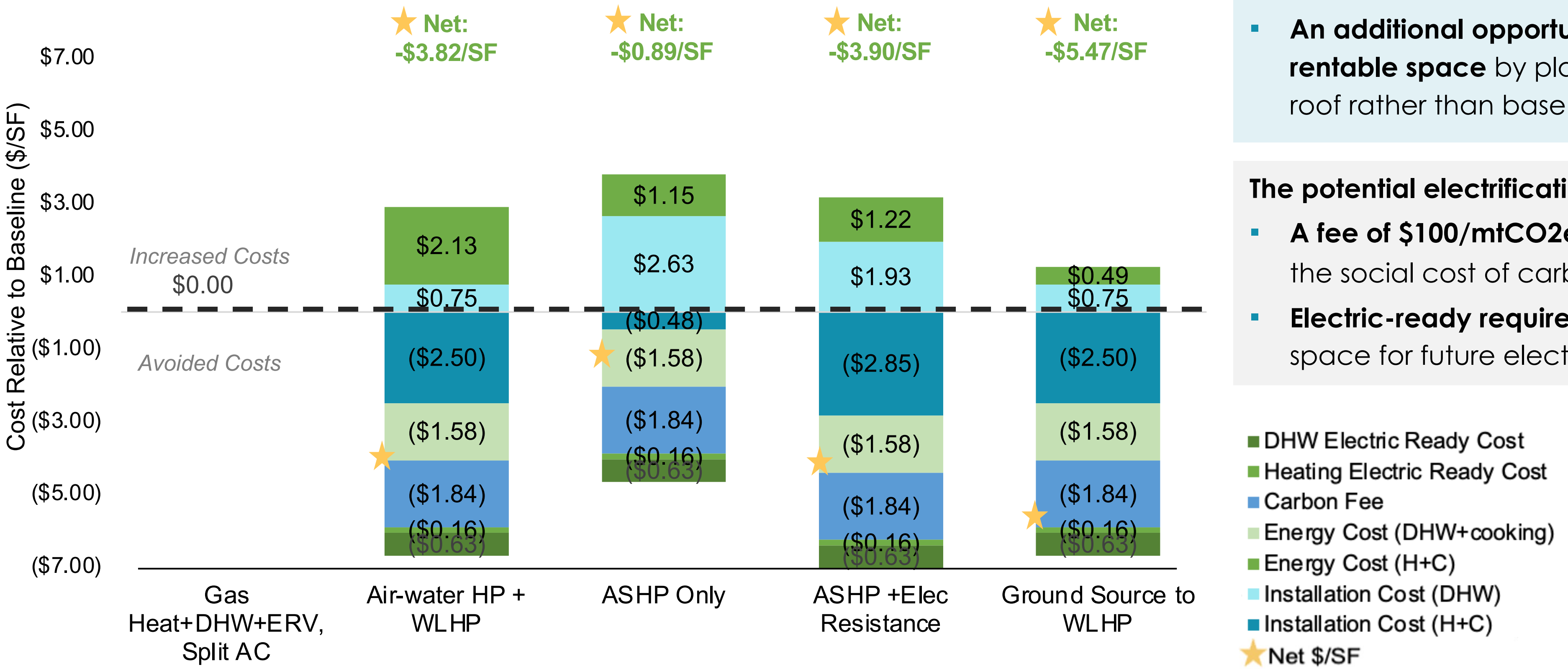
The potential electrification-friendly policy includes:

- **A fee of $100/mtCO2e for fossil fuel use**, which is based on the social cost of carbon
- **Electric-ready requirements**, including wiring and panel space for future electric appliances.

Multifamily New Construction | Lifecycle Costs

15-year Lifecycle Comparison with a Potential Policy

Cost relative to baseline ($/SF), including all tenant and owner costs
Tenant-metered baseline (includes fixed charges for tenants)



Takeaways:

- **There are lifecycle savings in every scenario** compared to a tenant-metered baseline under the proposed policy.
- **An additional opportunity could come from increasing rentable space** by placing all-electric equipment on the roof rather than basements or mechanical closets.

The potential electrification-friendly policy includes:

- **A fee of $100/mtCO2e for fossil fuel use**, which is based on the social cost of carbon
- **Electric-ready requirements**, including wiring and panel space for future electric appliances.

Building Electrification Institute

Multifamily New Construction | Findings

1. **Building all-electric multifamily buildings in Burlington is technologically possible, even with its cold climate.** This analysis identified four technology combinations that would meet the heating demand in multifamily buildings.
2. **All-electric multifamily new construction can significantly reduce energy use relative to mixed fuel construction, and this can lead to dramatic carbon reductions** due to Burlington's clean electric grid.
3. **All-electric and mixed fuel multifamily new construction have similar construction costs,** and in some cases all-electric construction is less expensive.
4. **All-electric buildings may have higher energy costs than some types of <u>newly constructed</u> mixed fuel buildings**. This is particularly true when compared to master-metered buildings, although all-electric construction is more likely to reduce costs compared to tenant-metered buildings because of the removal of the gas fixed charges.
5. **All-electric multifamily construction will result in energy cost savings relative to a typical mixed fuel <u>existing</u> multifamily building** in Burlington. This means that many existing residents who move to a new all-electric building will see lower energy costs.
6. **The impacts of a proposed policy in Burlington that includes a carbon fee and electric-ready requirements will result in lifecycle savings** for a new all-electric multifamily building compared to a new mixed fuel building.

Multifamily New Construction | Impacts

The economics of all-electric buildings will impact different building decision-makers and residents differently. The project team analyzed the potential impacts for four different stakeholder groups.

- **Tenant:** Individuals that rent out a space or unit of a building.
- **Developer:** An organization that designs and builds a building and then sells it to a separate owner for operation.
- **Owner:** An organization that purchases a building from a developer or a previous owner and rents the space to tenants.
- **Institutional Owner:** An organization that builds, owns, and operates the building (such as a university dormitory).

Metering Configuration Assumptions

Assumes owner pays for central systems and tenants pay for all other energy use.

End Use	Baseline Assumption	All-Electric Assumption
Space Heating	Owner pays for gas *(assumes central system)*	Tenant pays for electricity *(assumes distributed system in most cases)*
Space Cooling	Tenant pays for electricity *(assumes distributed system)*	Tenant pays for electricity *(assumes distributed system in most cases)*
Domestic Hot Water	Owner pays for gas *(assumes central system)*	Owner pays for electricity *(assumes central system)*

Note: A table summarizing all impacts is included in the appendix.

Multifamily New Construction | Impacts

Impacts to Tenants

While there is already a growing trend toward all-electric multifamily buildings in Burlington, tenants of new all-electric buildings could see an increase in their energy costs compared to new mixed fuel buildings, depending on the metering structure. It may be helpful to pursue policies that decrease operating costs in all-electric buildings, particularly for low-income households, to ensure there are no harmful impacts to these residents.

Installed Costs	***Energy Costs***	***Non-Energy Cost Benefits***

• **No direct impact** – tenants do not pay for these costs.
• **No expected indirect impact** – while installed costs could be passed through to tenants in the form of rent increases, because all-electric new construction tends to cost the same or less than mixed fuel construction, this is not expected to occur.
	• **Potential energy cost change** compared to mixed fuel new buildings.
	  • **Could increase $100-$150/year** (~20%) if tenants start paying for heat and if they previously had no fixed gas charges.
	  • **Could decrease $100-$175/year** (~20%) if tenants can eliminate their gas fixed charges in the all-electric building.
		• **Better indoor and outdoor air quality** due to elimination of carbon monoxide and NOx emissions.
		• **Increased safety** due to lower risks of fires and carbon monoxide poisoning.
		• **Less potential for future disruption** due to future retrofits that would be required to achieve Burlington's goal of net zero emissions.

Options for Reducing Energy Costs:

- **Lower electricity rates.** Could be across the board, for high efficiency electric heating, and/or for low-income customers. New rate design could also include time-of-use rates that reward heat pumps.
- **Incorporate solar.** On-site solar PV and/or community solar can help reduce electric rates for customers.
- **Update utility allowances** for regulated affordable housing and ensure that allowances are reflective of heat pump operations for low-income customers.
- **Weatherization** can reduce thermal load and therefore operating cost while improving thermal comfort.

Multifamily New Construction | Impacts

Impacts to Developers

All-electric multifamily buildings are often lower cost to build than mixed fuel construction and offer multiple non-energy benefits, making them a compelling option for developers. Still, there may be a need for technical assistance and design support to ensure developers are comfortable with all-electric construction.

Installed Cost	*Energy Costs*	*Non-Energy Cost Benefits*
• **Potential installed cost decrease**, depending on the technologies used. • **Could decrease by up to $2/SF** for lowest cost scenarios (although some scenarios saw a cost increase of up to $2/SF). • **This decrease is equivalent to a 1% reduction** in total construction costs.	• **No direct impact** – developers do not pay for these costs.	• **Reduced construction time** by eliminating gas pipe installation and infrastructure needs. • **Increased rentable space** by avoiding larger gas HVAC systems. • **New marketing opportunities** as "Net Zero Carbon" buildings with better indoor air quality and increased health and safety benefits.

Options for Reducing Installed Costs:

- **Invest in education and training for architects, engineers, and building trades.** This can help reduce soft costs associated with new all-electric design strategies.
- **Develop opportunities for peer learning, recognition, and/or data sharing.** This will further reduce soft costs for developers.
- **Enact a carbon fee or electric-ready requirements on mixed-fuel new construction.** This will further improve all-electric economics to motivate developers.

Multifamily New Construction | Impacts

Impacts to Owners

While there is already a growing trend toward all-electric multifamily buildings in Burlington, owners may see a relatively small increase in the energy costs that they are responsible for paying compared to similar mixed fuel new construction (although energy costs decrease compared to existing multifamily buildings). It may be helpful to pursue policies that decrease energy costs in all-electric buildings to help mitigate these increases.

Installed Cost	*Energy Costs*	*Non-Energy Benefits*

• **No direct impact** – owners who are not developers do not pay for these costs.
• **No expected indirect impact** – while installed costs could be passed through as higher purchase prices, because all-electric new construction tends to cost the same or less than mixed fuel construction, this is not expected to occur.
	• **Potential energy cost increase** compared to other new buildings.
	  ◦ **Could increase by $0.03-$0.04/SF annually** (16%) compared to a new mixed fuel building.
	  ◦ However, these costs are still **25% less than they would be for owners of a typical existing multifamily building** in Burlington.
		• **Improved ease of system maintenance** due to a single heating and cooling system.
		• **Increased rentable space** by avoiding larger gas HVAC systems.
		• **New marketing opportunities** as "Net Zero Carbon" buildings with better indoor air quality and increased health and safety benefits.

Options for Reducing Energy Costs:

- **Lower electricity rates.** Could be across the board, for high efficiency electric heating, and/or for low-income customers. New rate design could also include time-of-use rates that reward heat pumps.
- **Incorporate solar.** On-site solar PV and/or community solar can help reduce electric rates for customers.

Options for Reducing Installed Costs:

- **Enact an energy or carbon performance policy for existing buildings.** This will further increase the motivation for owners to buy or demand new all-electric buildings.

Multifamily New Construction | Impacts

Impacts to Institutional Owners

While there is already a growing trend toward all-electric multifamily buildings, institutional owners may see an increase in their operating costs (although costs may still be lower than the energy costs of existing multifamily buildings). It would be helpful to pursue policies that decrease operating costs in all-electric buildings, particularly for low-income households.

Installed Cost	*Energy Costs**	*Non-Energy Benefits*

• **Potential installed cost decrease**, depending on the technologies used.
  • **Up to $2/SF decrease** for lowest cost scenarios (although some scenarios saw a cost increase of up to $2/SF).
  • **This decrease is equivalent to a 1% reduction** in total construction costs.
	• **Potential energy cost increase** compared to other new buildings
	  • **Could increase by $0.11-$0.22/SF (15-30%) annually** compared to a new mixed fuel building.*
	  • However, institutional owners will still save on energy costs compared to typical existing building.
		• **Reduced construction time** by eliminating gas pipe and infrastructure installation needs.
		• **Improved ease of system maintenance** due to a single heating and cooling system.
		• **Better air quality and safety** due to lower risks of fire and eliminating carbon monoxide and NOx emissions.
		• **Less potential for future disruption** due to future retrofits that may be required.

Options for Reducing Energy Costs:

- **Lower electricity rates.** Could be across the board, for high efficiency electric heating, and/or for low-income customers. New rate design could also include time-of-use rates that reward heat pumps.
- **Incorporate solar.** On-site solar PV and/or community solar can help reduce electric rates for customers.

Options for Reducing Installed Costs:

- **Enact an energy or carbon performance policy for existing buildings.** This will further increase the motivation for owners to buy or demand new all-electric buildings.
- **Invest in education and training for architects, engineers, and building trades.** This can help reduce soft costs associated with new all-electric design strategies.
- **Develop opportunities for peer learning, recognition, and/or data sharing.** This will further reduce soft costs for developers.

Building Electrification Institute

*Institutional owners are assumed to pay the entire energy cost of the building, including the in-apartment heating and cooling costs (costs that were assumed to be tenant-paid on previous slides). Cost ranges depend in part on metering configuration of the building.

Multifamily New Construction | Impacts

Key Findings

Developers and institutional owners will benefit from lower or breakeven construction costs from all-electric multifamily new construction and would also receive many non-energy benefits. To help ensure these benefits are realized, Burlington can:

- **Increase awareness of all-electric construction** for developers and owners through educational sessions, case studies, and peer-to-peer sharing on all-electric construction.
- **Invest in education and training** for architects, engineers, building trades, and building department inspectors on all-electric equipment.
- **Update utility allowances** for regulated affordable housing to encourage all-electric system installations.
- **Develop an electrification-friendly policy** that charges a fee based on the social cost of carbon and requires mixed fuel buildings to be "electric ready."

Owners, and in some cases, tenants may see slightly higher energy costs compared to new multifamily mixed fuel construction—although these will not be higher than energy costs in a typical existing multifamily building. Burlington can consider policies to reduce the potential energy cost increases, particularly for low-income tenants. This could include:

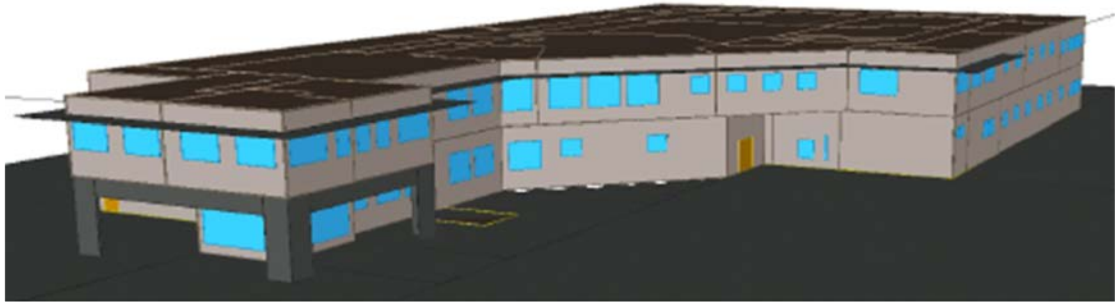
- **Encourage the inclusion of other efficiency measures and solar PV** to further reduce energy operating costs.
- **Lower or change electricity rates** to reduce the operating costs of electric systems.

Table of Contents

Office New Construction | Assumptions

Baseline Building Assumptions

- Based on a recently constructed Health Center in Burlington:
  - 60,000 square feet
  - Completed in 2011



Building System	Equipment
Heating	Gas boiler (94% efficient) feeding condenser water and a water loop heat pump (4.5 COP)
Cooling	Evaporative cooling tower connected to water loop heat pump (11 to 14 EER)
Ventilation	Energy Recovery Ventilation (ERV) system
DHW*	Indirect gas storage tanks (no DHW load was modeled for this building)
Envelope	Typical envelope slightly exceeding code requirements at the time
Cooking	Not included
Laundry	Not included

*BED's commercial building model did not include DHW energy use, and therefore DHW was not included in BEI analysis.

Office New Construction | All-Electric Scenarios

All-electric scenarios developed to meet baseline building heating and cooling load.

		All-electric Scenarios		
Building System	**Mixed Fuel Baseline**	**Air-water Heat Pump w/ Water Loop Heat Pump** (Air-Water HP + WLHP)	**Variable Refrigerant Flow Air Source Heat Pump** (VRF ASHP)	**Ground Source to Water Loop Heat Pump** (Ground Source to WLHP)
Heating	**Gas boiler** feeding condenser water and a water loop heat pump *(94% efficiency and COP 4.5)*	**Central air to water heat pumps** with condenser loop and water loop heat pump for heating and cooling *Heating COP 3.23 - average of VRF and ground source heat pumps assuming air is above -4F Cooling overall 13 kBTU/kWh*	**Central VRF plant** located outside with refrigerant piping to all spaces for heating and cooling *Heating COP 2.76- Study of cold climate heat pumps in Vermont** Cooling overall 15 kBTU/kWh*	**Ground source to WLHP** Assumes ideal ground conditions, which is very site-specific. *COP 3.7- Study of ground source heat pumps in Sweden*** Cooling overall 18 kBTU/kWh
Cooling	**Evaporative cooling tower** connected to water loop heat pump *(11 to 14 EER, overall 13 kBTU/kWh)*			
Ventilation	**ERV** with demand controlled ventilation rates	**ERV system**, heat pump post-heat	**ERV system**, heat pump post-heat	**ERV system**, heat pump post-heat
DHW *(not modeled)*	**Indirect gas storage tanks**	**Point-of-use electric water heaters**	**Point-of-use electric water heaters**	**Point-of-use electric water heaters**
Envelope	**Typical**	**Typical** (assumes no change from baseline)	**Typical** (assumes no change from baseline)	**Typical** (assumes no change from baseline)

*Source: The Cadmus Group, Evaluation of Cold Climate Heat Pumps in Vermont
**Source: Spitler and Gehlin, Measured Performance of a Mixed-Use Commercial-Building Ground Source Heat Pump System in Sweden

Office New Construction | All-Electric Scenarios

The all-electric scenarios were selected based on available technologies and projected costs.

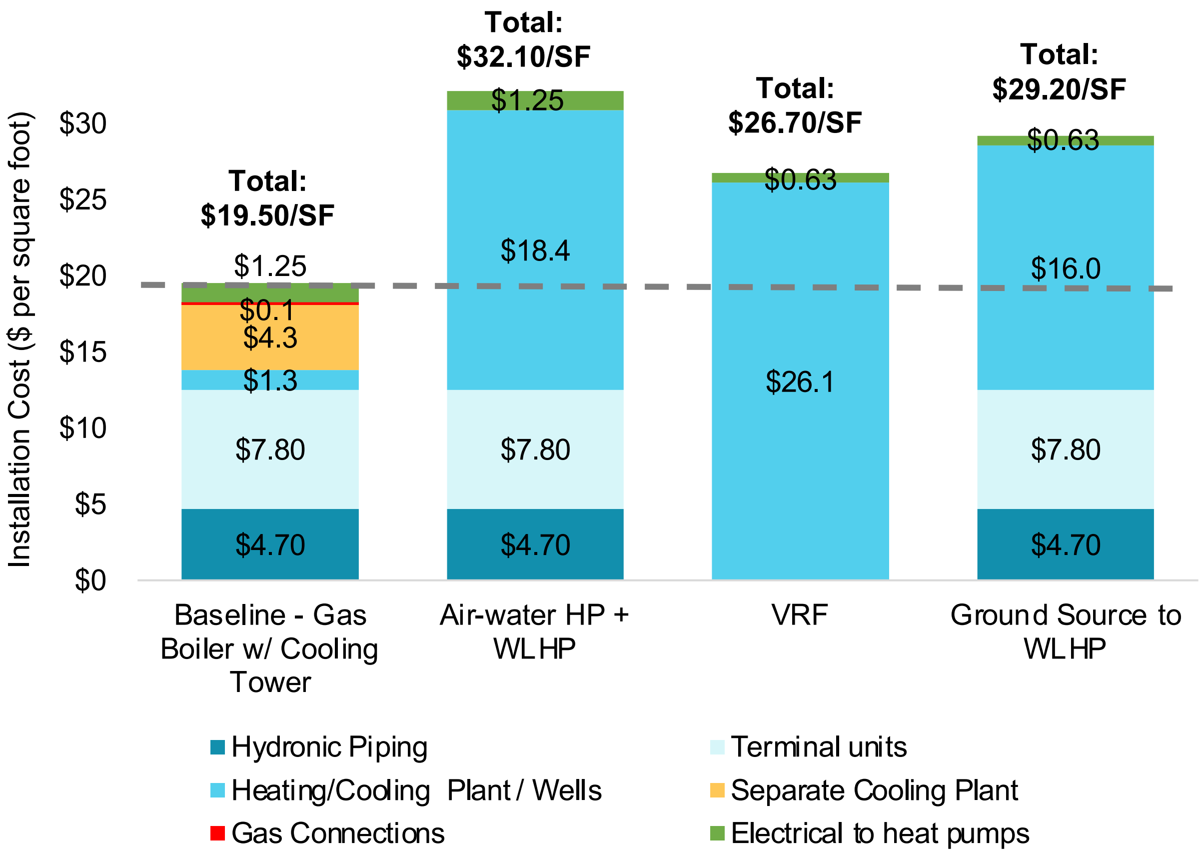
Rationale for Selection

	Air-Water HP + WLHP	VRF ASHP	Ground Source to WLHP
Benefits and Drawbacks of Heating and Cooling Technologies*	**+** Most similar to baseline building technology and therefore potentially most familiar to contractors and developers. **+** Can provide simultaneous heating and cooling throughout the building **+** Packaged equipment is easier to install and replace.	**+** Single system for heating and cooling (unlike boiler + cooling tower). **+** Highly-efficient operations and increasingly common. **+** Considered a "newer" technology for contractors and developers. **–** Extensive refrigerant distribution system not easily replaced.	**+** Ground source technologies can be highly efficient to operate, although the installed costs range greatly depending on site conditions.

*Note: (+) indicates a benefit and (–) indicates a drawback.

Office New Construction | Installation Costs

Installation Costs for Heating and Cooling Systems

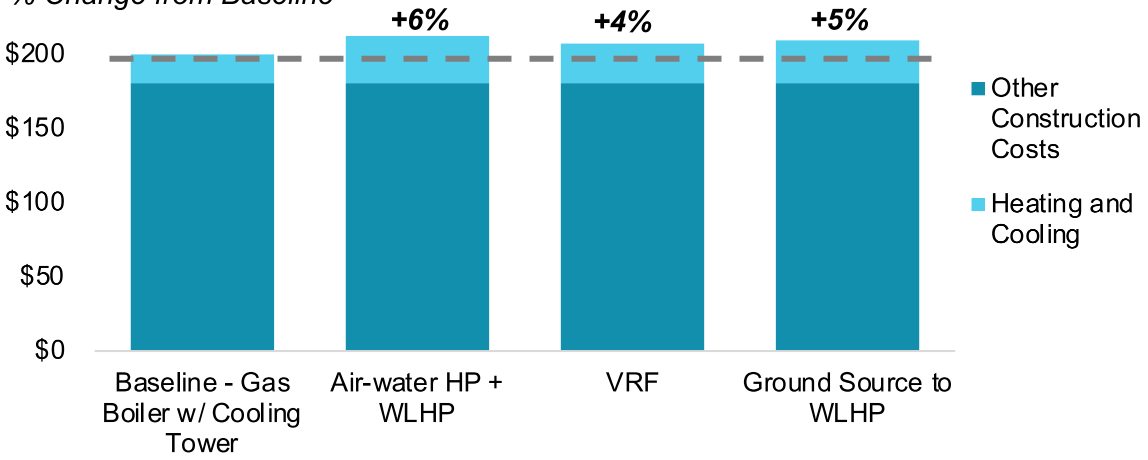


Takeaways:

- **All-electric commercial construction has higher installed costs** compared to the mixed fuel baseline, which is driven by the cost of the heating and cooling plant.
- When compared to total construction costs, **these increases would raise total commercial construction costs by about 4-6%.**

Installation Cost by Total Construction Cost*

% Change from Baseline

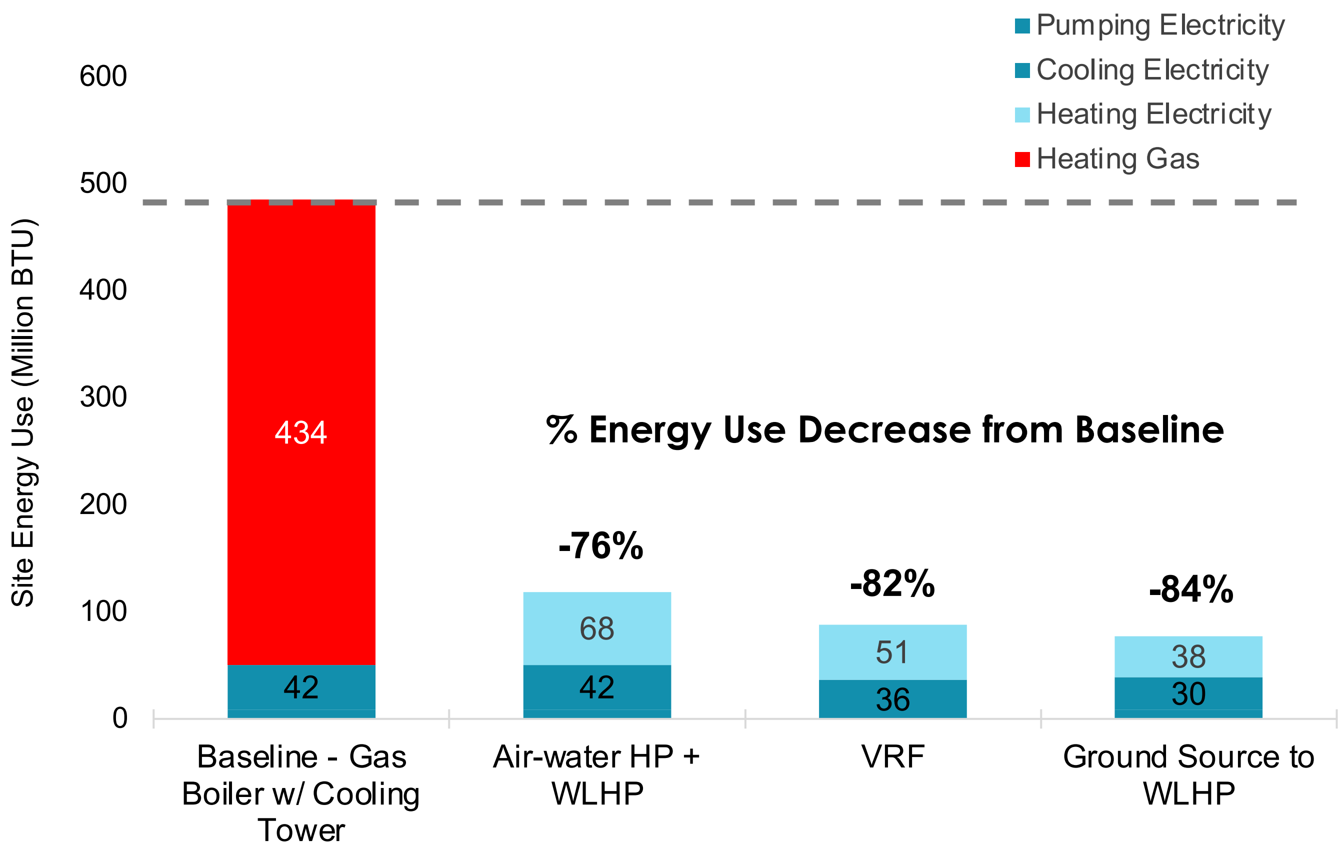


*Assumes construction costs of $200/SF. Source in Appendix.

Building Electrification Institute

Office New Construction | Energy Use

Energy Use for Heating and Cooling Systems

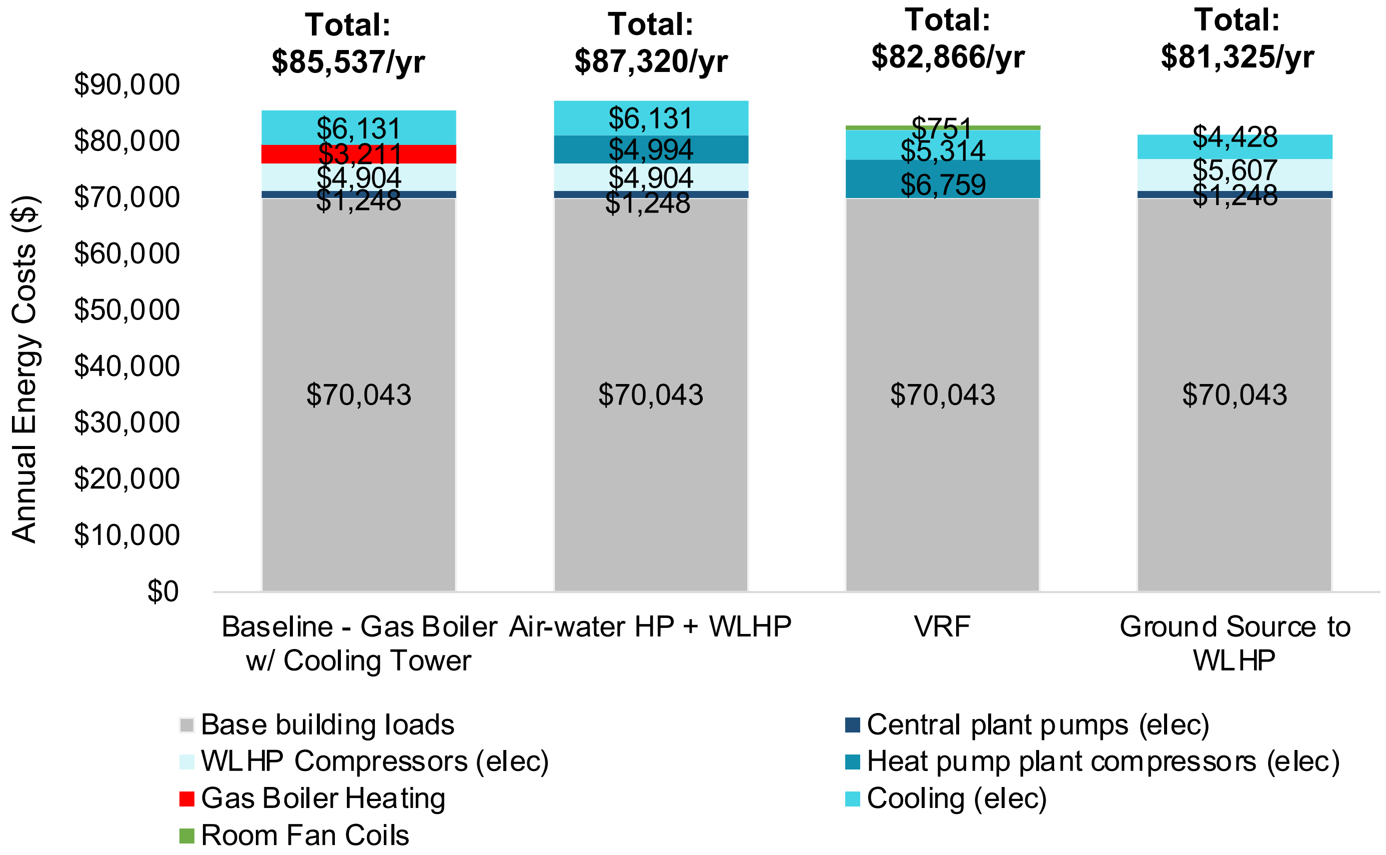


Takeaways:

- **All-electric office construction significantly reduces energy use compared to the mixed fuel baseline**, with site energy use decreases ranging from 76-84%.
- In Burlington, 100% of electricity is sourced from renewable sources, which means that all-electric buildings are Net Zero Carbon.
- In comparison, a mixed fuel building will always emit carbon because it uses gas, which can never be made 100% emission-free.

Office New Construction | Energy Costs

Energy Costs Compared to Mixed Fuel New Construction



Takeaways:

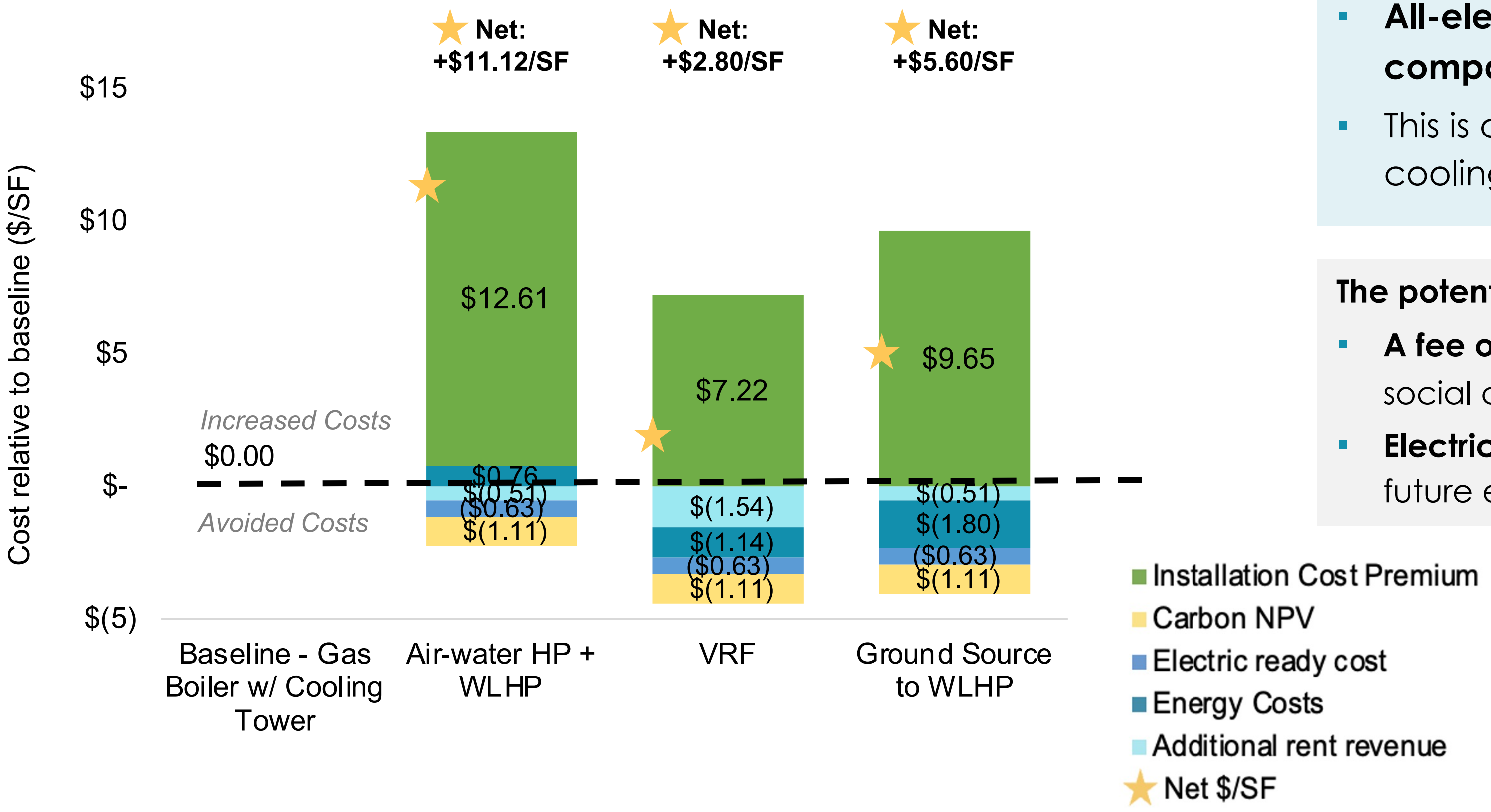
- **The total energy costs for a new, all-electric office building are roughly breakeven or lower** than the energy costs for a mixed fuel new office building.
- VRF systems and ground source heat pumps to a water loop heat pump systems are about 25% less expensive to operate compared to the baseline gas systems.
- The building's metering configuration will determine who will see energy cost increases/decreases between the owner and tenants.

Building Electrification Institute

Office New Construction | Total Costs with Policy

15-year Lifecycle Comparison of Installation and Energy Costs with a Potential Policy

Cost relative to baseline ($/SF)



Takeaways:

- **All-electric new construction may have higher lifecycle cost compared to a mixed fuel baseline.**
- This is due to the higher installation cost of the heating and cooling plant in all-electric construction.

The potential policy includes:

- **A fee of $100/mtCO2e for fossil fuel use**, which is based on the social cost of carbon
- **Electric-ready requirements**, including wiring and panel space for future electric appliances.

Building Electrification Institute

Office New Construction | Findings

1. **Building all-electric office buildings in Burlington is technologically possible, even with its cold climate.** This analysis identified three technology combinations that would meet the heating demand in typical office buildings.

2. **All-electric office new construction can significantly reduce energy use relative to mixed fuel construction, and this can lead to dramatic carbon reductions** due to Burlington's clean electric grid.

3. **All-electric office new construction will have higher costs for heating and cooling systems than mixed fuel office buildings,** although these costs do not dramatically increase the total construction costs for a typical office building.

4. **All-electric office buildings have break-even or lower operating costs than new mixed fuel office buildings,** although the reduction of these costs are not sufficient to create positive lifecycle economics for all-electric office construction compared to mixed fuel office construction.

5. **The impacts of a proposed policy that includes a carbon fee and electric-ready requirements improves the economics** for new all-electric office buildings, although do not achieve lifecycle savings compared to mixed fuel office construction.

Office New Construction | Impacts

The economics of all-electric buildings will impact different building decision-makers and residents differently. The project team analyzed the potential impacts to four different stakeholder groups.

- **Tenant:** Individuals that rent out a space or unit of a building.
- **Developer:** An organization that designs and builds a building and then sells it to a separate owner for operation.
- **Owner:** An organization that purchases a building from a developer or a previous owner and rents the space to tenants.
- **Institutional Owner:** An organization that builds, owns, and operates the building (such as a university dormitory).

Metering Configuration Assumptions can be:

- **Tenant Paid Energy**: Tenants pay for all energy use.
- **Tenant/Owner Paid Energy**: Tenants and owner splits the cost of energy use (see table below)

End Use	Baseline Assumption	All-Electric Assumption
Space Heating	Owner pays for gas for central system. Tenants pay for electricity within tenant space.	Tenant pays for electricity *(assumes distributed system in most cases)*
Space Cooling	Owner pays for electricity for central system. Tenants pay for electricity within tenant space.	Tenant pays for electricity *(assumes distributed system in most cases)*
Domestic Hot Water	Owner pays for gas *(assumes central system)*	Owner pays for electricity *(assumes central system)*

Note: A table summarizing all impacts is included in the appendix.

Office New Construction | Impacts

Impacts to Tenants

While tenants are not directly impacted to changes in construction costs, these costs are higher in all-electric new construction compared to baseline buildings. It is possible that there could be an increase in rents as a result of these higher construction costs. In either metering configuration, tenants would expect to see savings or break even in energy costs.

Metering	*Installation Costs*	*Energy Costs**	*Non-Energy Cost Benefits*
Tenant Paid Energy*	• **No direct impact** – tenants do not pay for these costs • **Potential indirect impact** –because all-electric commercial construction has higher installed costs compared to the mixed fuel baseline, installed costs could be passed through to tenants in the form of rent increases.	**Tenant energy cost change** compared to mixed fuel buildings. **Energy costs could:** • **Decrease by $0.12/SF** (~5%), or • **Increase $0.05/SF** (~2%)	• **Better indoor and outdoor air quality** due to elimination of carbon monoxide and NOx emissions. • **Increased safety** due to lower risks of fires and carbon monoxide poisoning. • **Less potential for future disruption** due to future retrofits that may be required.
Tenant/ Owner Paid Energy**		**Energy costs could:** • **Decrease by $0.02-$0.12/SF** (up to 1.5%).	

Options for Reducing Operating Costs:

- **Lower electricity rates.** Could be across the board, for high efficiency electric heating, and/or for low-income customers. New rate design could also include time-of-use rates that reward heat pumps.
- **Incorporate solar.** On-site solar PV and/or community solar can help reduce electric costs for customers.
- **Weatherization** can reduce thermal load and therefore operating cost while improving thermal comfort.
- **Encourage higher efficiency VRF or ground source heat pump (GSHP) systems** to maximize operational savings.

*Assumes $2.40/SF/year of energy costs for typical office building, based on this building's calibrated energy model. See Appendix for more details.
**In this scenario, the tenant pays for all energy costs including the central heating and cooling plant.
***In this scenario, the owner pays for the central heating and cooling plant, and the tenant pays for all other loads including distributed equipment.

Office New Construction | Impacts

Impacts to Developers

The trend of electric heating and cooling already exists in Burlington, but even when compared to a mixed fuel baseline building, an all-electric building would have a minimal increase in total construction costs. Technical assistance and design support would be helpful to ensure developers are comfortable with all-electric construction.

*Installation Costs**	*Energy Costs*	*Non-Energy Cost Benefits*
• **Potential installed cost increase**, depending on the technologies used. • **Could increase by $7-$13/SF**, which is equivalent to roughly a 4-6% increase in total construction costs.	• **No direct impact** – developers do not pay for these costs.	• **Reduced construction time** by eliminating gas pipe and infrastructure installation needs. • **Increased rentable space** by avoiding larger gas HVAC systems. • **New marketing opportunities** as "Net Zero Carbon" buildings with better indoor air quality and increased health and safety benefits.

Options for Reducing Installed Costs:

- **Invest in education and training for architects, engineers, and building trades.** This can help reduce soft costs associated with new all-electric design strategies.
- **Develop opportunities for peer learning, recognition, and/or data sharing.** This will further reduce soft costs for developers.
- **Enact a carbon fee on mixed-fuel new construction.** This will further improve all-electric economics to motivate developers.
- **Incentives to cover the incremental cost** increase for non-profit or community buildings.

*Assumes $200 per SF for construction costs based on studies in Boston and Denver. See Appendix for more details.

Office New Construction | Impacts

Impacts to Owners

While there is already a growing trend toward all-electric buildings, owners may see an increase in the energy costs that they are responsible for paying (although these costs may still be lower than in existing commercial buildings). It would be helpful to pursue policies that decrease operating costs in all-electric buildings to help mitigate these increases.

Metering	*Installation Costs*	*Energy Costs*	*Non-Energy Benefits*
Tenant Paid Energy	• **No direct impact** – owners who are not also developers do not pay for these costs. • **Potential indirect impact** – because all-electric commercial construction has higher installed costs compared to the mixed fuel baseline, installed costs could be passed through to owners in the form of higher purchase prices.	**None** – owners would not pay for energy costs in this metering configuration.	• **Improved ease of system maintenance** due to a single heating and cooling system. • **Increased rentable space** by avoiding larger gas HVAC systems. • **New marketing opportunities** as "Net Zero Carbon" buildings with better indoor air quality and increased health and safety benefits.
Tenant/ Owner Paid Energy		**Potential energy cost change** compared to new mixed fuel buildings. **Energy costs could:** • **Decrease by $0.14/SF** (~6%), or • **Increase by $0.05/SF** (~2%)	

Options for Reducing Operating Costs:

- **Lower electricity rates.** Could be across the board, for high efficiency electric heating, and/or for low-income customers. New rate design could also include time-of-use rates that reward heat pumps.
- **Incorporate solar.** On-site solar PV and/or community solar can help reduce electric costs for customers.

Options for Reducing Installed Costs:

- **Enact an energy or carbon performance policy for existing buildings.** This will further increase the motivation for owners to buy or demand new all-electric buildings.

Building Electrification Institute

Office New Construction | Impacts

Impacts to Institutional Owners

While there is already a growing trend toward all-electric buildings, institutional owners may see an increase in their energy costs (although these costs may still be lower than in existing commercial buildings) and in their construction costs. It would be helpful to pursue policies that decrease energy costs in all-electric buildings, and technical assistance would be helpful to support owners with all-electric construction.

Installation Costs	*Energy Costs*	*Non-Energy Benefits*
Potential installed cost increase, depending on the technologies used. • **Could increase by $7-$13/SF,** which is a 3.5-6.5% increase in total construction costs.	**Potential energy cost change** compared to new mixed fuel buildings, depending on the technologies used. **Energy costs could:** • **Decrease by $0.14/SF** (~6%), or • **Increase by $0.05/SF** (~2%)	• **Reduced construction time** by eliminating gas pipe and infrastructure installation needs. • **Improved ease of system maintenance** due to a single heating and cooling system. • **Better air quality and safety** due to lower risks of fire and eliminating carbon monoxide and NOx emissions. • **Less potential for future disruption** due to future retrofits that may be required. • **Increased available space** by avoiding larger gas HVAC systems.

Options for Reducing Operating Costs:

- **Lower electricity rates.** Could be across the board, for high efficiency electric heating, and/or for low-income customers. New rate design could also include time-of-use rates that reward heat pumps.
- **Incorporate solar.** On-site solar PV and/or community solar can help reduce electric costs for customers.

Options for Reducing Installed Costs:

- **Enact an energy or carbon performance policy for existing buildings.** This will further increase the motivation for owners to buy or demand new all-electric buildings.
- **Invest in education and training for architects, engineers, and building trades.** This can help reduce soft costs associated with new all-electric design strategies.
- **Develop opportunities for peer learning, recognition, and/or data sharing.** This will further reduce soft costs for developers.

Office New Construction | Impacts

Key Findings

All-electric office new construction in Burlington is slightly higher cost to build than mixed fuel office construction, although it will provide many non-energy benefits. To reduce construction costs, Burlington can:

- **Provide incentives** to lower the equipment costs of all-electric new construction.
- **Invest in education and training** for architects, engineers, building trades, and building department inspectors on all-electric equipment.
- **Develop an electrification-friendly policy** that charges a fee based on the social cost of carbon and requires mixed fuel buildings to be "electric ready."

Energy costs are breakeven or lower than new mixed fuel office construction, although these cost savings are not sufficient to result in lifecycle savings for all-electric commercial buildings. Burlington can consider policies to further reduce energy costs, which could include:

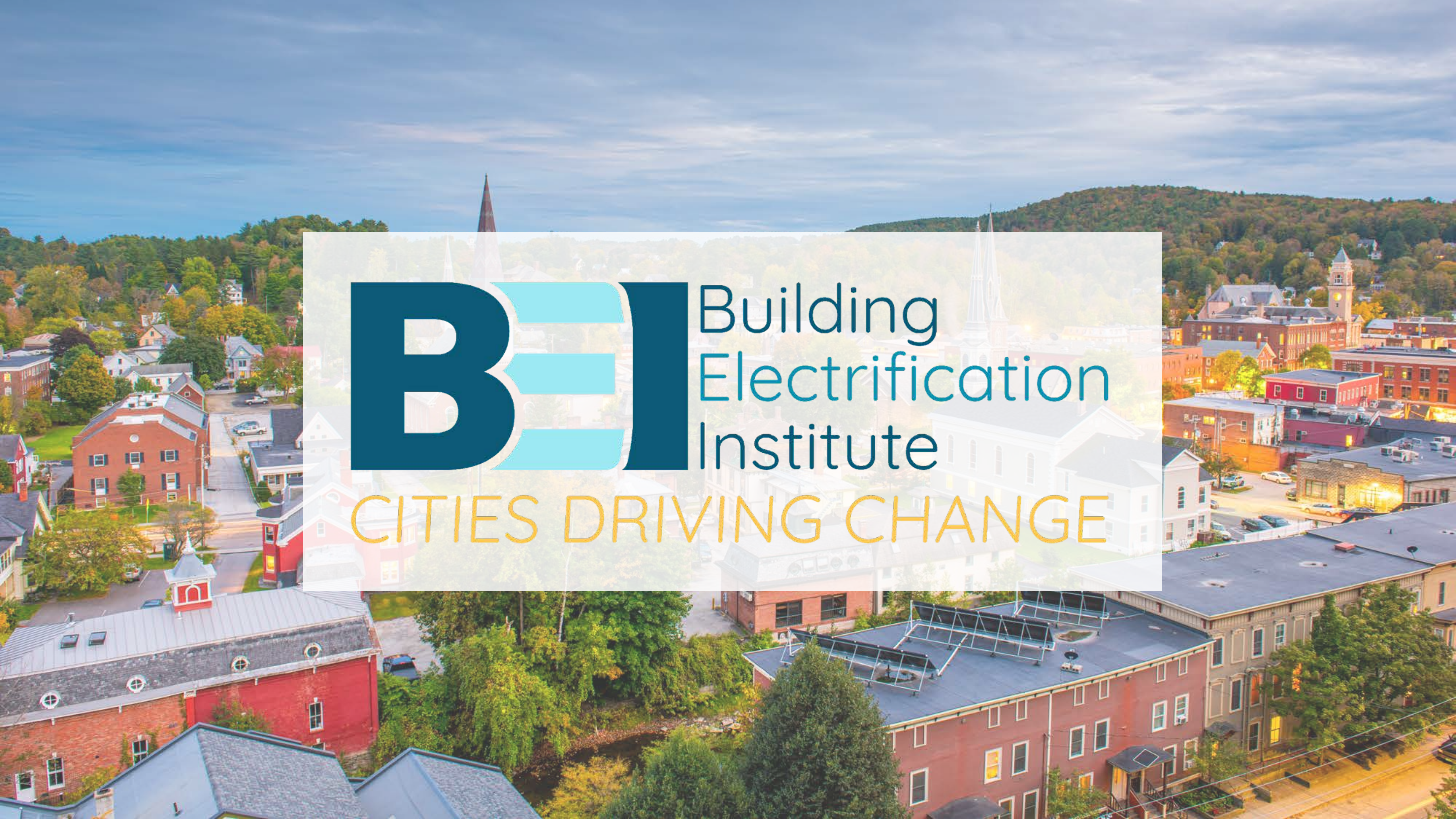
- **Encourage building with VRF or GSHP systems** through incentives and training to maximize operational savings.
- **Encourage the inclusion of other efficiency measures and solar PV** to further reduce energy operating costs.
- **Lower or change electricity rates** to reduce the operating costs of electric systems.

Table of Contents

Recommendations

BEI's Recommendations for Burlington

- **Invest in education and training for architects, engineers, building trades, and building department staff** to increase knowledge of and confidence in all-electric new construction in Burlington's cold climate.
- **Continue to provide incentives for efficient electric technologies to cover incremental installation costs.** Although all-electric multifamily buildings have similar construction costs to mixed fuel multifamily buildings, the installation costs are higher for office buildings.
- **Consider lowering or changing electricity rates,** which could be applied for all buildings, for certain systems, and/or for income-qualified customers, to bring down operating costs of all-electric construction compared to new mixed fuel construction.
- **Encourage the incorporation of energy efficiency measures and high efficiency equipment** in all-electric construction, including solar PV, community solar, and weatherization to maximize operational energy savings.
- **Enact a policy to charge a carbon fee and/or require "electric ready" measures to improve the economics and accelerate the development** of new all-electric commercial and multifamily buildings in Burlington.


BEI
Building
Electrification
Institute
CITIES DRIVING CHANGE

Appendix

Multifamily New Construction | Energy Metering Assumptions

Energy Metering Configuration *Owner pays for energy use of central HVAC and DHW systems*	**Gas Baseline**	**All-Electric Alternatives**
Space Heating	Owner pays for gas	Tenant pays for electricity
Central Heating Circulation Pumps (not present in all scenarios)	Owner pays for electricity	Owner pays for electricity
Ventilation ERV post-heating and cooling (assumed to be 10% of space conditioning energy consumption)	Owner pays for gas and electricity	Owner pays for electricity
Space Cooling	Tenant pays for electricity	Tenant pays for electricity
Domestic Hot Water	Owner pays for gas	Owner pays for electricity

Assumptions:

- Metering:
  - Owner pays for central HVAC and DHW energy use
  - Tenant pays for all other energy use
- Typical Electricity Costs per Apartment: $0.60/SF
  - Assumes 3kWh/SF/year
- Typical Multifamily Construction Cost: $175/SF
  - NYSERDA's Building of Excellence has new building development costs between $100-$300/SF for a typical building built to code.
  - CHFA had Connecticut constructions costs of $212/SF for a new construction steel frame multifamily building.
  - Burlington net zero homes range from $200-$300/SF.

Multifamily New Construction | Summary of Costs and Benefits

New Construction	Upfront Costs	Operating Costs	Non-Energy Benefits
Developer	**$2/SF increase to $2/SF savings on construction costs** *1% savings to 1% increase*	None	• No need to build chimneys • More rentable space by avoiding larger gas HVAC systems • GHG reductions
Owner	None	**$0.03 to $0.04/SF increase in annual energy costs** *16% increase*	• Maintenance of one system instead of two • More rentable space by avoiding larger gas HVAC systems • Reduce the need for future retrofits • GHG reductions
Developer/ Owner	**$2/SF increase to $2/SF savings on construction costs** *1% savings to 1% increase*	**$0.03 to $0.04/SF increase in annual energy costs** *16% increase*	• Increased focus working with electrification trades • No need to build chimneys • More rentable space by avoiding larger gas HVAC systems • GHG reductions • Maintenance of one system instead of two • Future proofing if/when retrofits are required
Institutional Owner	**$2/SF increase to $2/SF savings on construction costs** *1% savings to 1% increase*	**$0.11 to $0.22/SF increase in annual energy costs** *15-30% increase*	• Increased focus working with electrification trades • No need to build chimneys • More rentable space by avoiding larger gas HVAC systems • GHG reductions • Maintenance of one system instead of two • Reduce the need for future retrofits • Improved air quality
Tenant	None	**$100-$150/year** (~20%) **increase to $100-$175/year** (~20%) **decrease in annual energy costs**	• Improved air quality • Reduce the need for future retrofits • GHG reductions

Office New Construction | Energy Metering Assumptions

Energy Metering Configuration *Owner pays for energy use of central HVAC equipment*	**Gas Baseline**	**All-Electric Alternatives**
Space Heating	Owner pays for gas	Tenant pays for electricity
Central Heating Circulation Pumps (not present in all scenarios)	Owner pays for electricity	Owner pays for electricity
Ventilation ERV post-heating and cooling (assumed to be 10% of space conditioning energy consumption)	Owner pays for gas and electricity	Tenant pays for electricity
Space Cooling	Owner pays for electricity	Tenant pays for electricity
Room-located WLHPs or fan coils (not present in all scenarios)	Tenant pays for electricity	Tenant pays for electricity

Assumptions:

- Metering:
  - Owner pays for central HVAC energy use
  - Tenant pays for all other energy use
- Typical Electricity Costs: $3/SF
  - Assumes 15kWh/SF/year
- Typical Office Construction Cost: $200/SF
  - Offices in Boston $225-325/SF
  - Offices in Denver $165-200/SF

Office New Construction | Summary of Costs and Benefits

New Construction	Upfront Costs	Operating Costs	Non-Energy Benefits
Developer	**$7 to $13/SF increased construction cost** 4-6% increase in construction costs	None	• Increased focus working with electrification trades • No need to build chimneys • More rentable space • GHG reductions
Owner	Possibly higher cost of purchasing the building	**$0.14/SF savings to $0.05/SF increase in annual energy costs** *6% savings to 2% increase*	• Maintenance of one system instead of two • More rentable space • Reduce the need for future retrofits • GHG reductions
Developer/ Owner	**$7 to $13/SF increased construction cost** 3.5-6.5% increase in total construction costs	**$0.14/SF savings to $0.05/SF increase in annual energy costs** *6% savings to 2% increase*	• Increased focus working with electrification trades • No need to build chimneys • More rentable space • GHG reductions • Maintenance of one system instead of two • Future proofing if/when retrofits are required
Institutional Owners	**$7 to $13/SF increased construction cost** 3.5-6.5% increase in total construction costs	**$0.14/SF savings to $0.05/SF increase in annual energy costs** *6% savings to 2% increase*	• Increased focus working with electrification trades • No need to build chimneys • More rentable space • GHG reductions • Maintenance of one system instead of two • Future proofing if/when retrofits are required • Improved air quality
Tenant	None	**If tenant and owner split electric costs, tenants could see $0.02 - $0.12/SF savings in annual energy costs** (up to 1.5% savings) **If the tenant pays for all energy costs energy costs could decrease by $0.12/SF** (~5%), or **increase $0.05/SF** (~2%) in annual energy costs	• Improved air quality • Less disruption as fewer retrofits will be needed in the future • GHG reductions